State of Utah
Department of Natural Resources
Division of Wildlife Resources
Great Salt Lake Ecosystem Program

Great Salt Lake Waterbird Survey

Five-Year Report (1997-2001)

Publication Number 08-38

Great Salt Lake Ecosystem Program
Utah Division of Wildlife Resources
1594 West North Temple
Salt Lake City, Utah 84114

James F. Karpowitz, Director

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Five-Year Report (1997-2001)

by

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December 2002

Publication Number 08-38

Utah Division of Wildlife Resources
1594 West North Temple
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Preface

The Great Salt Lake Ecosystem Program was instituted by the Utah Division of Wildlife Resources (UDWR) in July of 1996. Our goal was to study Great Salt Lake (GSL) and its biota. An important part of this objective was understanding the biology of brine shrimp and how it relates to three important questions. How many brine shrimp cysts should remain in the lake after their commercial, fall harvest in order to sustain shrimp populations the following spring? What are the food needs of the birds? What is the remaining cyst availability for the subsequent harvest?

We determined that for a survey of the birds associated with the lake, it would be necessary to quantify what species utilized the lake, how many, and where they occurred throughout the year. Habitat conditions were also of interest. As the levels of the lake fluctuate, so do the habitats and bird use. A five year study helped to account for this critical influence along with normal bird population fluctuations. For that period of time, over 150 personnel, many of them volunteers, conducted surveys of 53 sites up to 17 times per year. The five year survey resulted in an enormous data set.

After the five years of surveys, two years were spent assembling, analyzing, editing, and presenting the data. After preparing a preliminary report, we decided color graphics best represented the data, however, the size of the report (313 pages) made comparisons between species, sites, and times of the year cumbersome. We discovered a similar representation of data done by the Oregon Department of Fish and Wildlife in an interactive CD. That format presented the data and allowed comparisons much better than the written report and permitted an easier and more cost effective method to distribute and share the information. At that time, the popularity of the internet was growing quickly, and we saw the opportunity for presenting the information on the UDWR website as well on CD.

A tremendous amount of work was done by UDWR staff and Matt Cole to construct the interactive CD. The result of all these efforts culminated in the end product you are viewing now. We believe this presentation of the data is in a form that is most user friendly and easy to understand. Studying bird use at the lake for five years gave us tremendous resolution on what species, and their populations, use specific places around the lake over time. With this information, biologists are able to offer the best advice about habitat conservation and continue monitoring populations in an effort to realize our goal of understanding GSL biota.

We gratefully acknowledge the help and assistance that many offered to achieve this goal. First and foremost, we recognize all of those that trudged through mud, bugs, and salt for many survey periods over the five years of the project. Matt Cole worked for a long time to develop the CD and suffered through many edits and changes until we had the best possible product. Suzanne Fellows, of the U. S. Fish and Wildlife Service, provided funding to cover a portion of the costs to develop the CD. Jon Bart, of the USGS Snake River Field Station, provided technical interpretation of the data. All of the Great Salt Lake Ecosystem Program staff over the years have developed and contributed, especially Don Paul, Ann Manning, John Luft, John Neill, and Clay Perschon. With an effort this size, there are undoubtedly others that lent a hand. To all of you, a very sincere thank you. Your efforts have resulted in the conclusive success of the project.

--Clay Perschon, Fmr. Great Salt Lake Ecosystem Program Manager

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Glossary

anthropogenic Caused by or relating to human intervention.
antithetical Of, relating to, or marked by the direct or exact opposite.
arid Lacking moisture, especially having insufficient rainfall to support trees or woody plants.
aridity The state or quality of being arid or without moisture; dryness.
avifauna The birds of a specific region or period.
biomass The total mass of living matter within a given unit of environmental area.
cryptic Tending to conceal or camouflage.
ephemeral Existing or lasting only a short time; short-lived or temporary.
filamentous algae Algae suspended in water with a thread-like root system.
fledgling A young bird that has recently acquired its flight feathers.
foraging To wander in search of food or provisions.
geo- Of or relating to the earth.
geomorphic Of or relating to changes in the earth.
halophile An organism that requires a salty environment.
halophyte Any terrestrial plant that is adapted to grow in high concentrations of salt, such as in salt marshes.
hydrology The scientific study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.
inorganic Involving neither organic life nor the products of organic life.
invertebrate An animal, such as an insect or mollusk, that lacks a backbone or spinal column.
leeward On or toward the side to which the wind is blowing.
limnology The scientific study of bodies of water for their biological and physical and geological properties.
molt To shed periodically part or all of a coat or an outer covering, such as feathers, cuticle, or skin, which is then replaced by a new growth.
obligate Able to exist or survive only in a particular environment or by assuming a particular role.
organic Of, relating to, or derived from living organisms.
paleoclimatic Of or relating to ancient or prehistoric climate.
passerine Of or relating to birds of the order Passeriformes, which includes perching birds and songbirds such as the jays, blackbirds, finches, warblers, and sparrows.
phylogenetic Of or pertaining to the evolutionary relationships among species.
piscivorous Habitually feeding on fish; fish-eating.
playa A nearly level area at the bottom of an undrained desert basin, sometimes temporarily covered with water.
pupae The nonfeeding stage between the larva and adult in the metamorphosis of holometabolous insects, during which the larva typically undergoes complete transformation within a protective cocoon or hardened case.
recurvirostrid Any shorebird species within the family Recurvirostridae (i.e., stilts and avocets). Bills are recurved or bend up.
saline Of, relating to, or containing salt; salty.

topography Graphic representation of the surface features of a place or region on a map, indicating their relative positions and elevations.

transitory Existing or lasting only a short time; short-lived or temporary.

ubiquitous Being or seeming to be everywhere at the same time; omnipresent.

vagrant Moving in a random fashion; not fixed in place.

xeric Of, characterized by, or adapted to an extremely dry habitat; being deficient in moisture.

List of Abbreviations

AC	Area Count
AR	Aerial Survey
ASL	Above Sea Level
ATV	All-terrain Vehicle
BCR	Bird Conservation Region
BLM	Bureau of Land Management
DNR	Department of Natural Resources
GIS	Geographic Information System
GPS	Global Positioning System
GSL	Great Salt Lake
GSLEP	Great Salt Lake Ecosystem Program
ha	Hectare
ISSR	Inland Sea Shorebird Reserve
MBR	Migratory Bird Refuge
ppt	Parts per Thousand
PS	Point Sample
TC	Total Count
UDWR	Utah Division of Wildlife Resources
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
WBS	Waterbird Survey
WHA	Wildlife Habitat Area
WMA	Waterfowl/Wildlife Management Area
YBP	Years Before Present

See Appendix 1 for four- and six-letter avian species codes.

Suggested Citation: Paul, D.S., and A.E. Manning. 2002. Great Salt Lake Waterbird Survey Five-Year Report (1997-2001). Publication Number 08-38. Great Salt Lake Ecosystem Program, Utah Division of Wildlife Resources, Salt Lake City.

Abstract

The Great Salt Lake (GSL) Waterbird Survey (WBS) is a five-year study (1997-2001) that examines the relationships of migratory waterbirds with the GSL ecosystem through the spring, summer and fall seasons, between years, and across a variety of habitats. An important part of this ecosystem is the dynamic lake elevation, which during the study period ranged from 4199.3’ to 4204.6’ above sea level (ASL). This shift in water level causes dramatic changes in the availability and quality of habitat used by more than 55 species of waterbirds. During the study the high lake elevation was in 1999. As a result, many stands of emergent vegetation were inundated with lake water, and became salt burned. As the lake receded to its lowest point during the study period in 2001, extensive mud bars void of vegetation were exposed. For five years researchers completed counts of waterbirds at GSL every ten days from April through September. The counts included the following families: *Gaviidae, Podicipedidae, Pelecanidae, Phalacrocoracidae, Ardeidae, Threskiornithidae, Anatidae, Rallidae, Gruidae, Charadriidae, Recurvirostridae, Scolopacidae, Laridae*. Avian use of the GSL ecosystem was measured by bird use days (one bird use day equals one bird spending 24 hours within the study area during the study period). The five-year mean bird use days is 86,752,258. Bird use days for all GSL survey areas combined were lowest during the high water year (1999).

Introduction

The discovery of the GSL by Jim Bridger in 1824, as he explored the Bear River Delta, introduced European man to the lake’s abundant waterbird resources (Miller 1980). Since that time, valley residence interests in GSL bird life changed from the eclectic practices of egg collection, guano harvest and market shooting to contemporary scientific investigation. With increasing human populations in the GSL valley came an elevated awareness in GSL bird life. It was difficult to ignore the extent and richness of waterbird presence. The establishment of numerous duck clubs within the delta complexes of the Jordan, Weber, and Bear River systems is evidence of the abundant migratory waterfowl moving through the lake’s wetlands. The creation of State and Federal wildlife management areas followed on the heels of duck club development. These areas were originally established to enhance, protect, and manage waterfowl habitat. Currently, there are nine wildlife management areas including eight State areas and one, large Federal wildlife area. Over time each management system has carried out a variety of primarily independent bird surveys to assess use at individual complexes.

In addition to curiosity in migratory birds, some valley resident academics, visiting scientists, and hobbyists have developed an interest in GSL breeding bird populations, especially colonial species. The most prominent figure emerging from a colorful history of GSL bird study is William H. Behle, who over the course of several decades studied California gulls, American white pelicans and other breeding colonial species (Behle 1958).

Behle’s systematic survey of some colonial nesting populations, the State of Utah’s fall waterfowl aerial surveys, and some limited but intensive species and suite population surveys have contributed to the collective avian knowledge. Many of these early surveys have made significant contributions to the present knowledge of the GSL’s importance to continental migratory bird populations. These include American white pelican (Behle 1958, Knopf 1975, Paul et al 2000a), tundra swan, cinnamon teal, ruddy duck, redhead, pintail ducks (UDWR unpublished reports), white-faced ibis (Paul and Manning 2000, 2001a; Ivey 2001), snowy plover, American avocet and black-necked stilt (Shuford et al. 1995, Paton 1994), Wilson's and red-necked phalaropes and eared grebes (Jehl 1988, Paul et al. 1999, 2000c). Even so, until now there has not been a comprehensive survey of all waterbird use in all habitat types conducted within the GSL ecosystem during the same time frame.

Study Objectives

It became evident to those working with GSL avian resources that to more fully understand how birds distribute across the landscape and how each habitat complex contributes to occurrence and abundance of waterbirds through time, a comprehensive study was in order. In 1996, wildlife biologists and managers met on several occasions to develop plans for an ecosystem-based waterbird survey. The Great Salt Lake Ecosystem Program (GSLEP) of the Utah Division of Wildlife Resources (UDWR) managed the project. The GSLEP terrestrial Wildlife Biologist was assigned to oversee the project, but the project was founded in the community with community participants sharing ownership. Several decisions were made at the beginning to assist in narrowing the focus including setting the survey period, and limiting the target species to waterbirds of the families: *Gaviidae, Podicipedidae, Pelecanidae, Phalacrocoracidae, Ardeidae, Threskiornithidae, Anatidae, Rallidae, Gruidae, Charadriidae, Recurvirostridae, Scolopacidae, Laridae*. A detailed list is included as Appendix 1. Passerine marsh birds were excluded. Except for a few small sections associated with wetland surveys, uplands were excluded from the inventoried habitat types.

A primary objective was established and inventory protocols were developed to address it. The primary project objective as stated in the Great Salt Lake Waterbird Survey Narrative is:

> For migratory waterbird species using the Great Salt Lake Ecosystem, we hope to estimate individual species populations during the migration period, their periods of use, location, and habitat characteristics of use areas plotted against Great Salt Lake elevation (1997-2001).

The collection of data for use in conservation planning for the GSL was a secondary objective that evolved through the development of the protocol and which was of particular interest to the drafters of GSL avian plans, especially the Draft Shorebird Management Plan, and to habitat managers. The protocols developed to address these objectives will be discussed in the methods section of this report.

Community-Based Participation

Community participation in this project was essential and desired. A large number of surveyors were required because of the enormity of the task and the desire to build ownership in the conservation of this unique ecosystem. Salt water covers 3,885 km^2 of lake bottom and the wetlands occupy 1,600 km^2. In order to conduct extensive surveys within all waterbird habitats some 40-50 survey teams would need to be enlisted.

There were not enough professional biologists in the area to staff the effort. Surveyors representing Federal and State agencies, several non-profit organizations, GSL associated industries, and a significant number of Salt Lake valley citizens assisted through the five-year study period.

Regional, Physical and Ecological Setting

The GSL is located at the lowest point of a 35,000 km^2 drainage basin (between 40º and 41º N, 113º and 112º W). This places the lake on the eastern edge of the Great Basin embracing the west escarpment of the Wasatch Range. One of the four largest terminal lakes in the world, the GSL varies in size as it expands and contracts in cadence to changing moisture patterns.

The GSL sits in a high elevation, cold desert region modified by arid mountain-framed basins. Temperatures range from 38º C in summer to -18º C in winter. Great Salt Lake's west side habitats are xeric, receiving less than 25 cm of annual moisture. In contrast, the east side receives 38 cm. The east margins of the lake fall under the influence of the "Lake Effect:" as warmer air lifts off the GSL, it condenses at higher elevations of the Wasatch Mountains.

The GSL ecosystem is an extensive complex of salt water, wetlands, uplands and drainage systems occupying roughly 7,800 km^2; it becomes more impressive as one considers its regional and hemispheric setting. Except for the moister mountain ranges and high elevation valleys, the GSL sits in an expansive dry sweep of land in Western North America. This region extends from the Canadian Prairies to the Tropic of Cancer and receives less than 50 cm of precipitation annually. Because of the surrounding desert, the GSL acts as an oasis for waterbirds as they explore breeding habitats and establish migratory pathways within and across this arid expanse. For many species the lake is their migratory "halfway point" between northern breeding grounds and southern wintering locations. In this case, the lake is an important refueling site with seasonally abundant invertebrate resources.

GSL habitats are varied and in some cases unique among salt lakes of Western North America. The following is a description of GSL habitat types (Aldrich and Paul 2002).

> The terminal nature of the lake with its various saline systems and associated halophiles contribute greatly to the uniqueness of the natural wonders that happen there. The Great Salt Lake is a playa lake with an extremely low-gradient bottom. When the surface elevation is 4202 feet above sea level, the average depth of the lake is four meters. With the seasonal recharge of water from rivers and other drainages and subsequent evaporation, the effect of this shallow flat bottom is most apparent in the highly transitory shoreline. The result is ephemeral pools, expansive mud flats and sand bars that warm quickly in spring and easily reach temperatures around 29º C in summer. Some parts of the lake shoreline migrate more than 800 m from spring to fall depending on the levels of water recharge and evaporation that year. These water depth and shoreline fluctuations are fundamental ingredients in the creation of highly productive habitats for wading waterbirds.

Lake Elevation Fluctuation

When considering the history of bird use within the GSL region, it is important to consider its climate and geomorphic history. The GSL is a recent lake, dating approximately 10,000 years before present (YBP). Its Pleistocene predecessor, Lake Bonneville, with its enormous size, abundant fresh water, and cool climate, was significantly different from today's GSL. Avian paleontological evidence indicates that Bonneville supported, in part, a different avifauna complex than what currently persists in this more arid climate (Miller 2002).

Between 19,000-10,000 YBP the climate changed and a catastrophic hydraulic breaching of weaker geologic substrate at Red Rock Pass spilled 105 vertical meters of water from Lake Bonneville into the Columbia River Basin. These events soon led to a salt lake environment. Much paleoclimatic evidence indicates two periods of aridity occurred during the mid-Holocene Epoch. These periods were between 7,500 and 5,000 years ago (Street and Grover, 1979). Evidence suggests that the GSL was a playa landscape, at least briefly, during mid-Holocene time (Currey 1980). Even in the absence of a salt water body, salt marshes and saline ponds would have existed especially along the near-mountain, east margins of the lake basin. This is important when considering the potential history of long-term waterbird presence in the area during profound periods of dryness.

Records of lake elevations have been kept since 1847. In this period the lake has fluctuated within a range of six meters (20 feet), reaching a high of 4212 feet in the mid 1980s and a low of 4191.35 in 1963. Under present climatic conditions, the GSL tends to fluctuate in dynamic equilibrium between water recharge and evaporation. Studies of water consumption within the GSL drainage basin indicate that without human water use, the lake would have an additional 1.5 m (five feet) of elevation (Arnow 1980). However, climatic trends in the GSL area still are the main driving force in lake elevation and volume.

Physical and Biological Relationships

The limnology of the GSL, and its subsequent effect on birds using the system, is in large part a consequence of physical and chemical conditions. Many of the current physical features of the lake that pose major influences upon lake biology are human-produced. Among these are trans-lake causeways, solar pond impoundments for mineral extraction, and the dikes, levees, roadways, and impoundments constructed for wildlife habitat management. Each of the three major river deltas, as well as other significant wetland complexes, have been modified significantly through water diversion, distribution, and impoundment. The GSL offers a unique relationship between fresh and salt water habitats that is particularly attractive to birds. In some areas this relationship is compromised through development and in others it is enhanced. This salt water/fresh water interface is often allied with the GSL shoreline. The degree of salt and fresh water association is mostly dependant on lake elevation. At any one point in time, parts of the GSL can be removed from fresh water by hundreds of meters of exposed mud or sand bars, while at other elevations, salt and fresh water may be continually mixing along the lake. Additionally, flooding by the GSL during periods of high water elevation can cause salt water intrusion into fresh water impoundments.

Lake volume and elevation affect brine concentrations. In recent years brine concentrations are also a product of intra-lake diking. These dikes, in conjunction with lake volume, have essentially created four distinct limnological units. Each of these lake units harbors its own halophyte and halophile community. Some of these lake complexes are important as waterbird foraging sites. These conditions within the Great Salt Lake Ecosystem provide for diverse habitat conditions that are dynamic through climatic cycles. There are four and one half billion tons of salt in the GSL system, distributed throughout the lake in solution or as bottom precipitants.

There is also an important relationship between shoreline conditions and brine fly production. When brines exceed 60 ppt at the shoreline and there is an appropriate substrate, impressive populations of brine flies are produced in the warm seasons. Thousands of brine fly adults can occur per square meter. A recent survey of brine fly pupae casings estimated nine billion casings washed up on shore along a six-mile stretch of the Antelope Island State Park Causeway (Paul et al. 2001c). Hundreds of waterbirds may be found when these brine conditions and associated brine fly populations are located in close proximity with the distinct emergent vegetation and abundant macroinvertebrate populations of fresh water wetlands or drainages.

When brine concentrations and other factors are appropriate, populations of brine shrimp persist throughout the water column and occupy open water environments. These conditions are most often located within the South Arm portion of the GSL. Where healthy populations of brine shrimp occur, so do foraging waterbird populations, often in significant numbers. Eared grebes, phalaropes, gulls, and wintering ducks are especially attracted to this condition.

The Great Salt Lake's Importance to Birds

Before this study, data had been collected for individual species that brought to light the local, regional, continental, hemispheric, and world importance of GSL to the species occurring here. For some species, the GSL ecosystem is important for breeding, for others the area is important during migration, and for still others, the lake provides important wintering habitat (Table 1). Some species use the lake for combinations of these reasons. Implicit in these uses of lake environments, depending on the species, is the need for a place to molt, fatten, court, and stage for migration. Significant numbers of American bald eagles and peregrine falcons forage at the lake on its concentration of waterbirds. Several species of swallows and other passerines exploit the robust populations of brine flies and midges at the lake.

The importance of the GSL to birds is underscored by the levels of local, regional, and national planners that have included the GSL in their scope of concern and conservation action. The GSL is prominently featured in the U.S. Shorebird Conservation Plan and the Intermountain West Regional Shorebird Plan. The GSL ecosystem is also featured in the Intermountain West regional and Continental Waterbird Conservation Plans. The GSL and associated wetlands have long been recognized by the North American Waterfowl Management Plan as key to the habitat integrity of the Pacific Flyway. The GSL is one of the few ecosystems in western North America that is recognized as a site of hemispheric importance within the Western Hemisphere Shorebird Reserve Network.

Recently, avian values of the GSL were recognized by the GSL Comprehensive Management Plan developed under the auspices of the Utah Department of Natural Resources. Currently, a GSL Shorebird Plan is being developed as a tool in lake wide conservation planning for use by the various GSL resource users.

Table 1. Noteworthy avian resources of the Great Salt Lake.

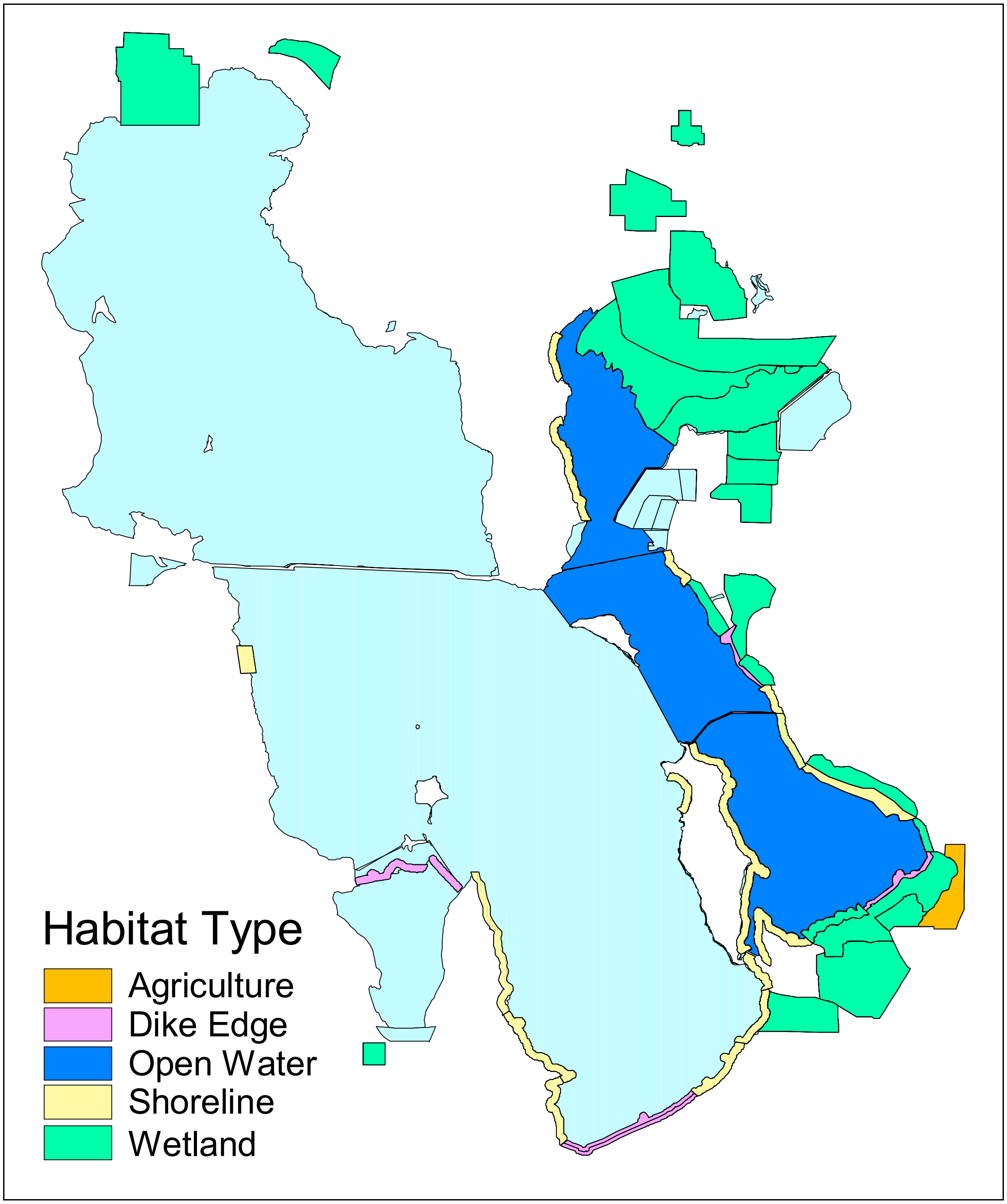
Species	**Population and Status Values**
Wilson's Phalarope	500,000: largest staging concentration in the world (Jehl 1988)
Red-necked Phalarope	240,000: single day estimate (Paul 1982)
American Avocet	250,000: many times higher than any other wetland in the Pacific Flyway (Shuford et al 1995)
Black-necked Stilt	65,000: many times higher than any other wetland in the Pacific Flyway (Shuford et al 1995)
Marbled Godwit	30,000: the only staging area in the interior United States (Shuford et al 1995); 43,000 peak period count (this report)
Snowy Plover	10,000: the world's largest assemblage, representing 55% of the entire breeding population west of the Rocky Mountains (Paton 1994)
Western Sandpiper	150,000: single day count (this report)
Long-billed Dowitcher	32,000: single day count (Shuford et al 1995)
American White Pelican	20,000 breeding adults: one of the three largest colonies in the western United States (Paul et al 2000a)
White-faced Ibis	21,600 breeding adults: world's largest breeding population (Paul et al 2000b)
California Gull	160,000 breeding adults: world's largest breeding population in North America (Robinette et al 1993)
Eared Grebe	2,200,000: one of two of the largest staging populations in North America (Neill et al 2006)

Methods

Study Area

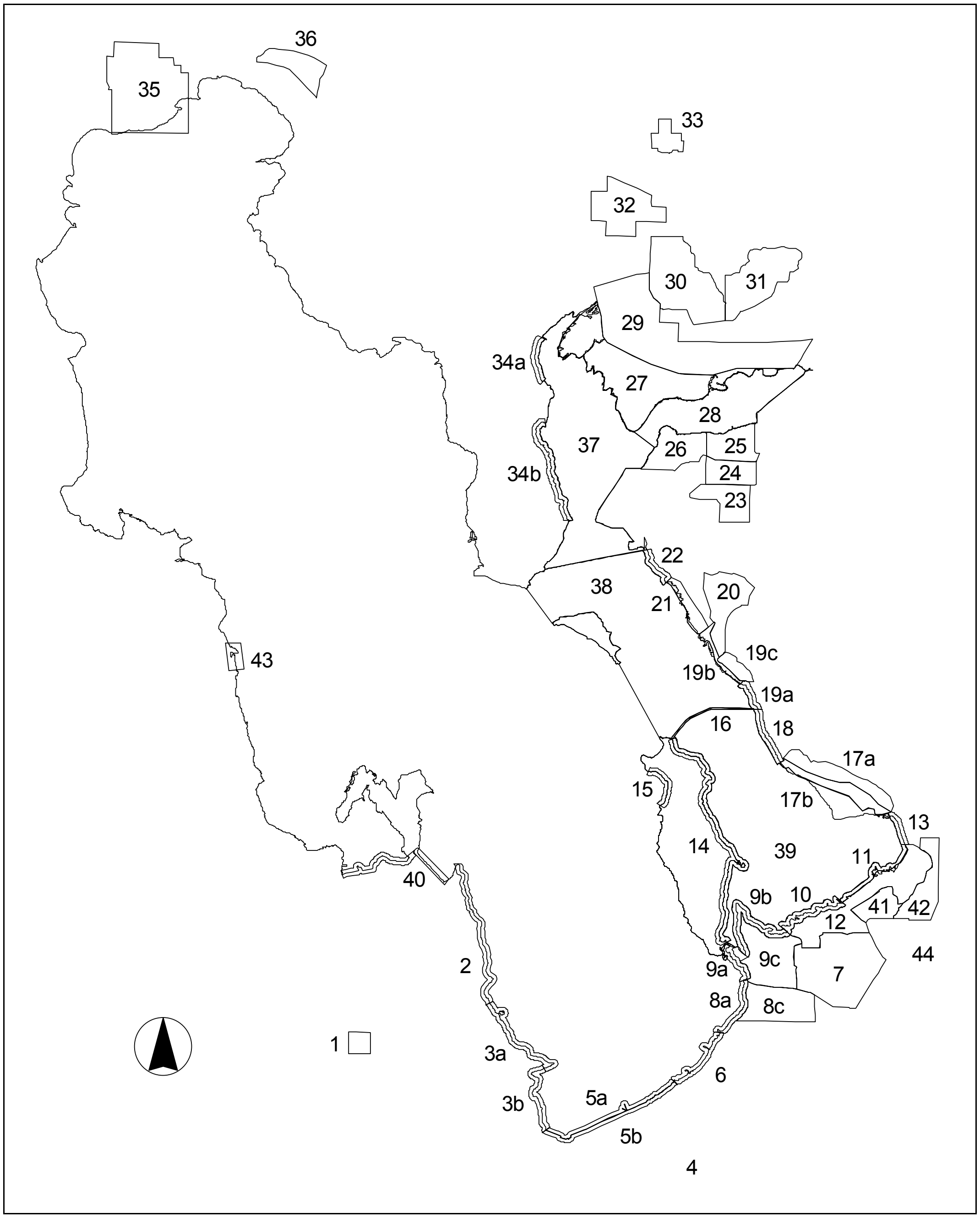
Because of the size of the GSL ecosystem, the original organizing group of the GSL Waterbird Survey decided to concentrate the survey efforts for the five-year study on the known areas of waterbird concentration within the GSL ecosystem. In general, this area included the GSL surface, shoreline, and associated wetlands, including the three major delta regions and nearby wetland complexes that drain into the GSL. Within this focus area, we identified sites to be surveyed in all the primary habitats, which included open water, shoreline, managed and unmanaged wetlands, and points of fresh/salt water interface (Figure 1). Most of the survey areas occurred near the east side, and north and south ends of the lake. There were a few survey areas that were placed on the west side and at the extreme north and south ends of the lake to cover more xeric environments. Of the four regions of the lake proper, only the North Arm (Gunnison Bay) was left unsurveyed.

Figure 1. Great Salt Lake Waterbird Survey areas classified by habitat type.



Actual survey sites included all the primary wetlands, and all of the shoreline on the east side of the lake from Stansbury Island on the south to and including the east side of Promontory Point on the north end (Figure 2, Table 2). Open water was surveyed at Farmington Bay, Bear River Bay, and Ogden Bay west to a georeferenced line between Antelope and Fremont islands. An estimated 73% of important wetlands, largely within duck clubs, was not covered by this effort because of limited access and man power.

Figure 2. Great Salt Lake Waterbird Survey areas. See Table 2 for names and specific descriptions.



Organizers of actual survey sites took into consideration land ownership, potential access, proximity to other survey areas, habitat type(s), the ability to recruit surveyors, specialized equipment needs and other logistical factors. The selection of actual survey routes and area sizes was largely predicated on the capacity to survey the area in four-hours or less. Survey areas were mapped and assigned a survey area name and number. Eventually, each survey was developed into a survey polygon and georeferenced for purposes of assessing relative avian population. Over the five-year study period, five new survey areas were included into the project.

Table 2. Summary of GSL Waterbird Survey areas.

Area Number	Area Name	Years Surveyed	Survey Technique*	Mode of Travel	Site Description
1	Timpie Springs WMA	1997-2001	TC	Driving	State managed wetland
2	Stansbury Island North	1999-2001	AR	Airplane	Private Shoreline
3a	Stansbury Island South- N	1997-2001	TC w/ PS	ATV/walking	Shoreline
3b	Stansbury Island South- S	1997-2001	TC w/ PS	ATV/walking	Shoreline
4	Interstate 80 South	Not surveyed			
5a	I-80 North-N	1997-2001	TC w/ PS (semi-circular plots)	Driving	Shoreline
5b	I-80 North- S	1997-2001	TC	Driving	Wetland-flooded area
6	Saltair	1997-2001	TC w/ PS	Walking	Shoreline
7	Associated Duck Club	1997-2001	TC	Driving/walking	Private duck club
8a	Kennecott- Lakeside	1997-2001	TC w/ PS	Walking	Shoreline
8c	Kennecott- ISSR	1997-2001	TC	Walking	Privately managed wetland
9a	Audubon Lakeside	1997-2001	TC w/ PS	ATV/walking	Shoreline
9b	Audubon North	1997-2001	TC w/ PS	ATV/walking	Shoreline
9c	Audubon Interior	2001	TC w/ AC	ATV/walking	Privately managed wetland
10	Crystal Lakeside	1997-2001	TC	Airboat	Marsh
11	Farmington Bay Lakeside	1997-2001	TC w/ PS	Driving	Shoreline
12	Farmington Bay WMA	1997-2001	TC w/ AC	Driving	State managed wetland
13	West Farmington	1997-2001	TC w/ PS	Walking	Shoreline
14	Antelope Island East	1997-2001	TC	Driving	Island shoreline
15	Antelope Island West	1997-2001	TC w/ PS	Walking	Island shoreline
16	Antelope Island Causeway	1997-2001	TC	Driving	Road to island
17a	West Kaysville- Interior	1997-2001	TC	Airboat	Marsh
17b	West Kaysville- Shore	1997-2001	TC w/ PS (1997), TC (1998-2001)	ATV/walking/airboat	Shoreline
18	West Layton	1997-2001	TC w/ PS	Walking	Shoreline
19a	Howard Slough WMA- Shore	1997-2001	TC w/ PS	Walking	Shoreline
19b	Howard Slough WMA- Dike	1997-2001	TC	Driving	Diked shoreline
19c	Howard Slough WMA- Pond	1997-2001	TC w/ AC (1997), TC (1998-2001)	Driving/walking	State managed wetland
20	Ogden Bay WMA	1997-2001	TC w/ AC	Driving	State managed wetland
21	Ogden Bay Lakeside	1997-2001	TC	Airboat	Marsh
22	Ogden Bay North	1998-2001	TC	Airboat	Shoreline
23	Rainbow	1998-2001	TC	Driving	Private duck club
24	South Harold Crane	1998-2001	TC	Driving	State managed wetland
25	Harold Crane WMA	1997-2001	TC w/ AC	Driving	State managed wetland
26	West Harold Crane Mud Bar	Not surveyed			
27	South Bear River	1997-2001	TC	Airboat	Federal managed wetland
28	Willard Spur	1997-2001	TC (1997), AR (1997-2001)	Airboat/airplane	Federal managed wetland
29	Bear River Refuge	1997-2001	TC	Driving	Federal managed wetland
30	Bear River Club	1997-2001	TC	Driving/walking	Private duck club
31	Chesapeake	Not surveyed			
32	Public Shooting Grounds WMA	1997-2001	TC w/ AC	Driving	State managed wetland
33	Salt Creek WMA	1997-2001	TC w/ AC	Driving	State managed wetland
34a	East Promontory- N	1997-2001	TC w/ PS	Walking	Shoreline
34b	East Promontory- S	1997-2001	TC	Driving	Shoreline
35	Locomotive Springs WMA	1997, 2001	TC w/ AC	Driving	State managed wetland
36	Salt Wells Flat WHA	1997-2001	TC w/ PS and AC	ATV/walking	Federal shoreline, wetland, and mudflat
37	Bear River Bay	1997-2001	AR	Airplane	Open water
38	Ogden Bay	1997-2001	AR	Airplane	Open water
39	Farmington Bay	1997-2001	AR	Airplane	Open water
40	Magcorp	1998-2001	AC	Driving	Two lakeside ponds
41	New State Duck Club	1999, 2001	TC	Motorized boat	Private duck club
42	East Farmington Bay	1999-2001	TC	Driving	Agricultural, urban, and industrial lands
43	Deardens Knoll	1999-2001	TC w/ PS	Driving	US Airforce/BLM public land
44	Jordan River	1999-2000	AR	Airplane	Private agricultural land

* Survey techniques: TC=Total count, TC w/ PS=Walking transect comprised of a total count combined with point sample(s), AC=Area count, AR=Aerial survey

Survey Protocol

Surveys were conducted every 10 days falling on or close to a designated target date (usually a Friday). The first survey season in 1997 started in late June and continued until mid-September with a total of 9 survey periods. Seasons in 1998-2001 had 17 survey periods from April through September. Four survey techniques were used based upon the area type. All data were collected in a format appropriate for analysis at the conclusion of the study.

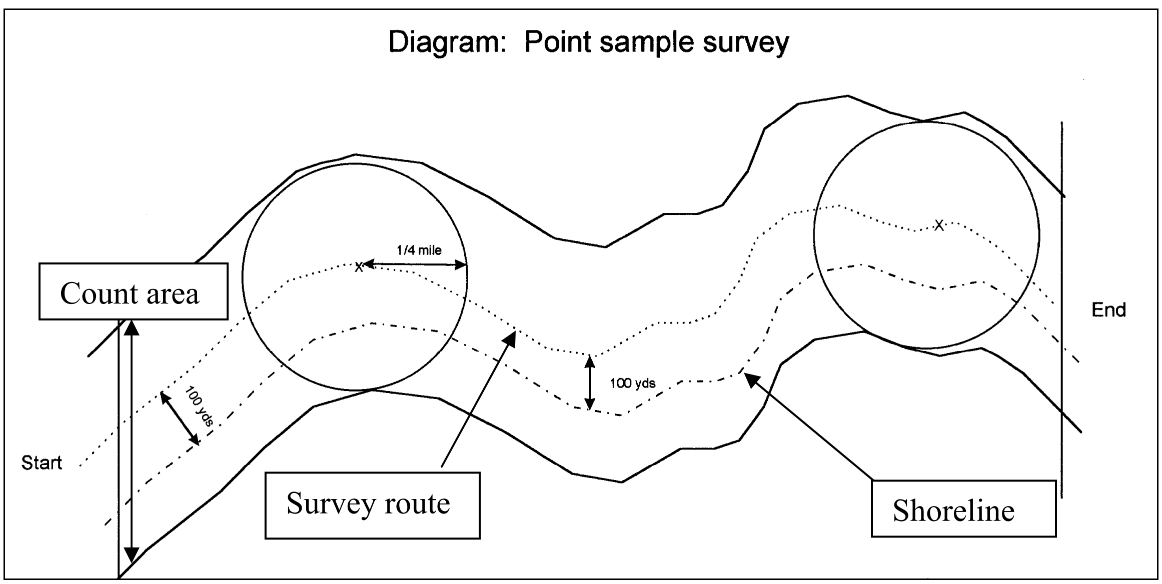
Total Count (TC)

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). Often TC sites 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 dikes, and in some areas transects were established. Many of these sites were located in State and Federal wildlife management areas or within the confines of private duck clubs or wildlife preserves.

Walking Transect and Point Sample (TC w/ PS)

Surveys along the shoreline of the lake were comprised of a walking transect with at least one point sample (Figure 3). Several shoreline areas were surveyed using all-terrain vehicles (ATV) due to their length.

Figure 3. Diagram of shoreline survey protocol. A typical route of a shoreline survey transect with a point sample parallels the shoreline at a distance of 100 yards. Point samples are centered on the survey route and encompass a circular area of ¼ mile radius.



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; point counts were recorded separately.

All point sample locations were chosen in one of two random manners: numbers generated from a random numbers table determined the distance of random point count locations from the designated starting point of the transect; ten percent of all drainage points on the south, east, and north shorelines of the lake were also selected randomly for a point count. Due to the dynamic nature of GSL shorelines, it was determined that point samples should always be centered 100 yards from the shoreline through time. 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 may be isolated some distance from the shoreline on land, or be surrounded by water during high lake periods. Many of the shoreline areas in the South Arm and Farmington Bay were mapped with Global Positioning System (GPS) equipment.

Area Count (AC)

One or more area counts were conducted at each of the large State waterfowl management areas (WMA) and the Federal wildlife habitat area (WHA). Survey sites were selected by the area managers based on their management needs. Counts were conducted along manmade impoundments or naturally occurring ponds with an identifiable boundary. The boundary enclosed a measured area from which bird density estimates could be derived. 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 (AR)

Surveys were conducted from the air to count birds occupying open water in the large bays, and 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 4201.10’ 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. An in-plane, GPS was used to locate the predetermined start and finish points of transects. Georeferenced transects established in 1997 were used throughout the remainder of the five year survey period. To ensure plenty of light flights began around 7:30 am. According to the variety and abundance of waterbirds viewed below, speed of the plane varied but 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. At the Stansbury Island North site, the airplane followed the shoreline for the length of the transect, and waterbirds were identified and counted out to 0.125 miles on each side of the plane.

Transect counts from the three open water bays were extrapolated to the entire bay area in two ways: a general extrapolation was calculated by multiplying counts by four for each survey; a more seasonal specific extrapolation was achieved by calculating an average species density and multiplying it by the surface area of the bay specific to lake elevation at the time of the survey.

Surveyors

Because there was not enough professional staff to conduct the surveys, we recruited the assistance of citizen-scientists and avid birders from Audubon chapters, Friends of Great Salt Lake, universities, birding groups, duck clubs, allied State and Federal agencies, and the public at large. Eighty percent of the volunteers had birding and other natural resource field experience. Internal funds of the GSL Ecosystem Program supported three WMAs with a month each of technician time for each of the five years. In addition, the full-time staff from four WMAs carried out surveys on their respective sites or sites nearby. The Bear River Migratory Bird Refuge (MBR) biologists surveyed the 80,000 acre refuge. Other Utah Division of Wildlife Resources biologists from the Northern Region and the Salt Lake office, and biologists from the United States Fish and Wildlife Service (USFWS) and Bureau of Land Management (BLM) offices cooperated in surveying sites.

Often volunteers from other organizations brought field and bird identification skills to the study that were equal to, or exceeded some full-time professionals. There were some volunteers who had some or little skill in bird identification or in estimating large numbers of waterbirds. Often these people gained experience through on the job training, by acting as data scribes, and an extra pair of eyes for survey teams. Project managers organized teams, designating a leader. The team leader was selected based on past years experience, birding skill, and interest in the project or survey area. These people were critical in maintaining consistency in the data collection and in many cases were with the study for the entire five years. Team leaders were responsible for scheduling survey dates among the team and sending in the appropriate data forms.

Training was provided for participants prior to the start of the field season each year. A review of the study objectives and methods was discussed in a classroom session, and bird identification was practiced with a slide show presentation. Periodically, participants were asked to take a short bird identification quiz after the review to be used to ascertain skill levels. Data forms, return envelopes, survey protocol, area maps, and official letters of participation were distributed to each team. A second training session in the field focused on survey methodology for a point sample, distance estimation, bird identification, and flock size estimation.

During the field season, monthly newsletters were sent out to all participants with announcements, reminders, short data reports, and educational articles. The main objective for the newsletter was to maintain adherence to protocol standards, provide an efficient means of communication from the project coordinators to participants, as well as to create a sense of teamwork and community. As often as possible, articles were included that indicated how the Waterbird Survey (WBS) data were being used on the local and national levels. Participants were encouraged to send in descriptions of interesting survey experiences to share with the others.

Data Compilation

Weather information was collected by surveyors and from local climatological data reports from the National Oceanic and Atmospheric Administration. Lake elevation data measured by a gauge at Boat Harbor, South Arm was provided by Wallace Gwynn, Utah Geological Survey.

The project coordinators designed a data form suitable for all survey types. Participants recorded weather information and bird counts by species. Additionally, habitat evaluations, and species use and behavior data were recorded in survey sites that included point samples. Project coordinators encouraged team leaders to send in data forms at the end of every month. Data were then entered into a Paradox software database. Yearly Paradox data sets were sent to Jonathan Bart, United States Geological Survey (USGS), to be organized and transformed into Excel software tables that were more easily used by project data managers. The modified tables filled in missing data points by calculating an average of existing values on either side of a missed survey. Also, survey areas that were extremely incomplete were not included in lake-wide calculations (Appendix 2). Annual summary reports were written and distributed to all participants.

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. For example, counts of Wilson's phalaropes from all survey sites were totaled for each survey period for each of the five years. Yearly totals for survey period 1 were averaged. This was repeated for the remaining 16 survey periods resulting in average numbers of phalaropes by survey period through the season. To calculate an overall average of Wilson's phalaropes, the 17 survey period means were averaged together. Also, selected periods of phalarope presence were averaged to get an estimate of the species' peak occurrence at GSL. Species distribution maps illustrate mean counts over survey periods when the species are present at Great Salt Lake. Means for suites of species were also calculated. Suites included unidentified groups that were not assigned to any species totals. For example, the DUCKSX suite includes all duck species and the "unidentified duck" (DUCK) category that cannot be assigned to any one species. Unidentified numbers are considerable in many cases and should not be overlooked. Peak numbers reported are the largest 5-year period mean for a particular species or suite.

An important consideration during the five-year survey was the fluctuation of lake elevation and its affect on habitat. For analytical purposes we determined to evaluate habitat changes and their subsequent species use for the years of lowest and highest lake elevation during the years of the study. The highest lake elevation year was 1999. Two years, 1997 and 2001, were both years of low lake elevation. The 2001 survey season was chosen to be the representative low lake year because the data set was more complete than that of 1997. 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 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%. For a more accurate comparison of bird use days between years, data from 1997 were omitted.

Results

Great Salt Lake Climate and Elevation

Historical Perspective

The long-term (1847-2001) GSL mean elevation is 4200.4' ASL. These data were collected from the South Shore Boat Harbor. The range between record low and high lake elevations is 20.5'. The low occurred on November 1, 1963 at 4191.35' and the high on June 3, 1986 at 4211.85' (Table 3).

The rate of change in elevation varies with climatic patterns and especially with variation in periodic weather patterns. Hydrologic data indicate the lake will be equal to or exceed 4204' ASL ten percent of the time, and conversely, the lake will be equal to or less than 4193.5' ASL ten percent of the time (Austin 1980). This implies that the predicted change in GSL elevation will fall within a 10.5' pattern 80% of the time. From the same hydrology data set, which has 125 years of GSL elevation records modified by the 1980 rate of upstream water consumption, it is predicted that GSL will exceed 4210' ASL approximately once every 200 years (Austin 1980).

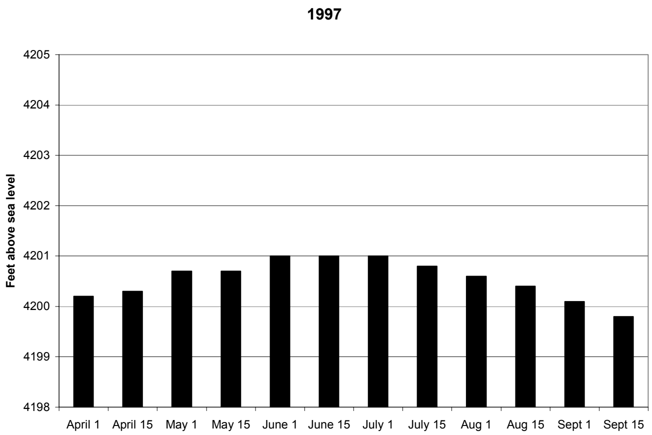
1997-2001

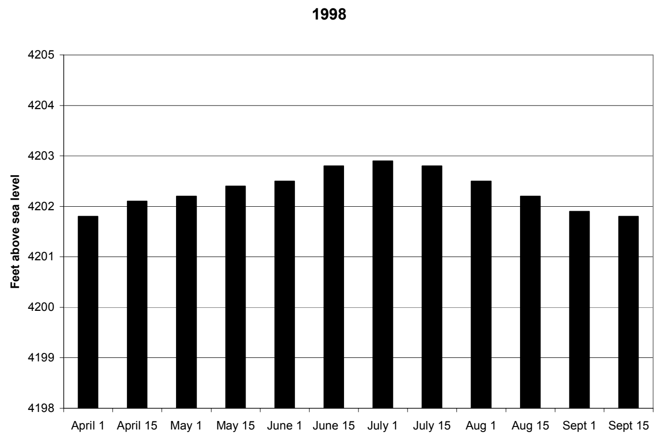
The GSL mean elevation was 4201.9' during the five-year study period. The range was 5.3' with a low lake elevation of 4199.3' and a high of 4204.6' occurring on June 15, 1999 and September 15, 2001 respectively. The most notable rate of change occurred between 1999 and 2001 at 5.3', and the greatest rate of change within one year was 2.4' in 2000 (Figure 4).

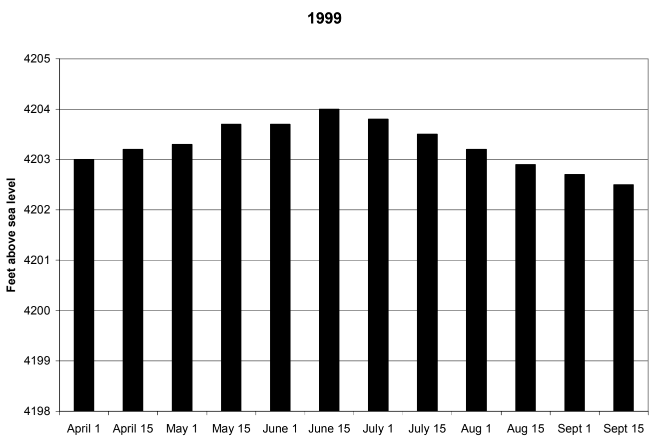
Table 3. Notable weather periods and lake elevations at Great Salt Lake.

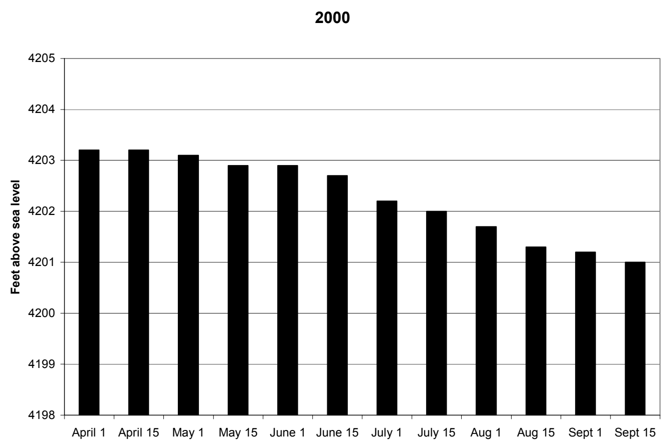
Time period	Average elevation	Std. Dev.	Range (feet)	Note
1847-2001	4200.4	4.5	20.5	154 years of elevation records.
1910-1930	4202.4	1.1	5.4	A 20-year weather cycle from 4201' to 4205' and back to 4200'.
1960-1990	4199.7	5.6	20.5	30 years that include the historic low (1963) and high (1987).
1982-1987	4208.1	3.2	11.8	Historic flood years with elevation ranging from 4200' to 4211.9'.
1997-2001	**4201.9**	**1.4**	**5.3**	**Waterbird Survey.**

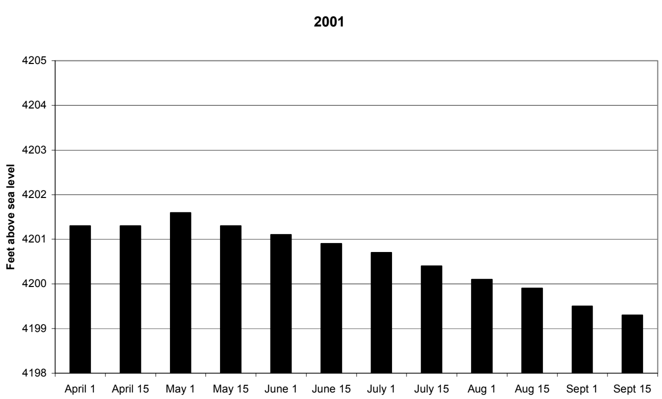
Figure 4. Great Salt Lake elevation at two-week intervals during the Waterbird Survey, 1997-2001.





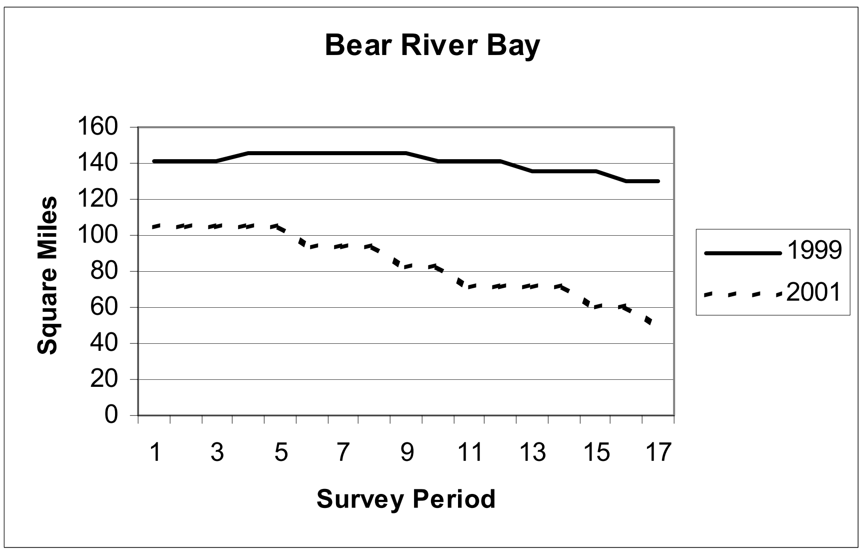


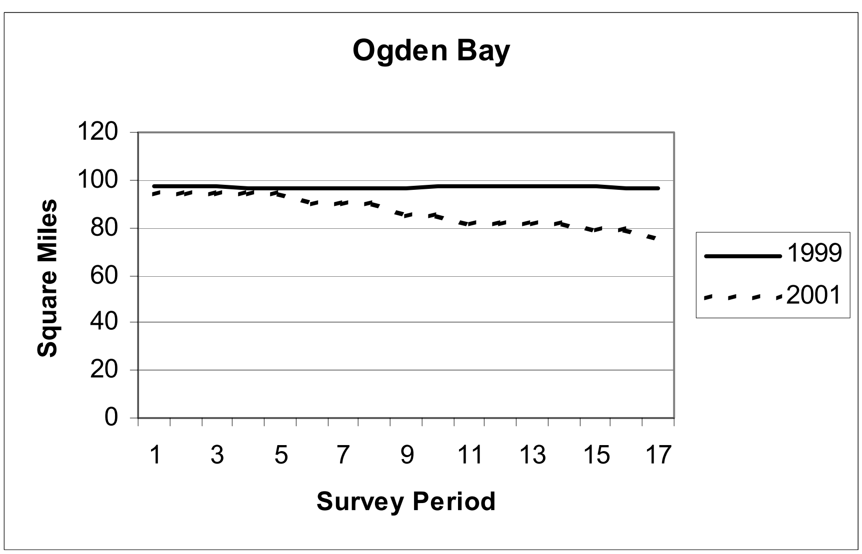


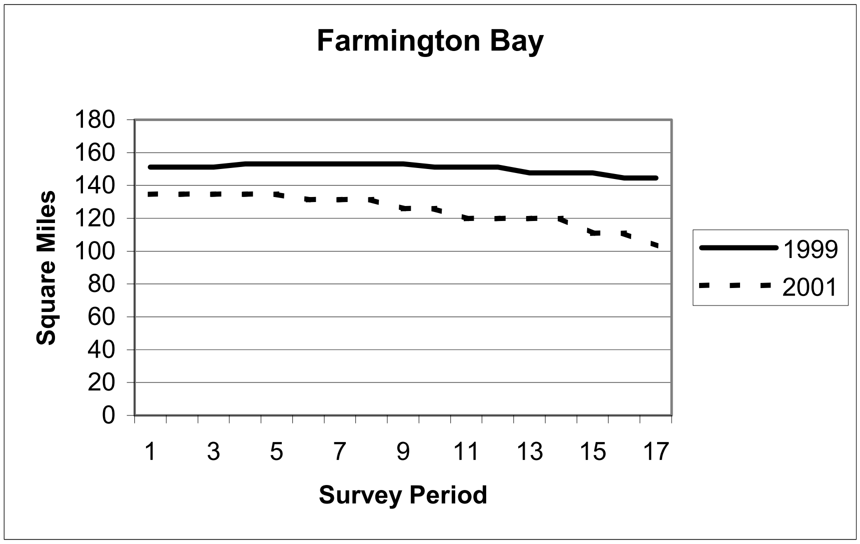


Fluctuations in the lake elevation throughout seasons and between years correlated directly with changes in the surface area of the open water bays (Figure 5). As the lake level dropped in 2001, the area size of all bays also decreased. As a result, the quantity and quality of available habitat for species that use open water spaces was 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 80 square miles smaller than the same time during the high lake year of 1999.

Figure 5. Changes in bay area sizes with fluctuations in lake elevation. For three open water bays at Great Salt Lake (Bear River Bay, Ogden Bay, and Farmington Bay), each chart shows variation throughout the survey season (survey periods 1-17) and compares a year of high lake elevation (1999) to a year of low lake elevation (2001).



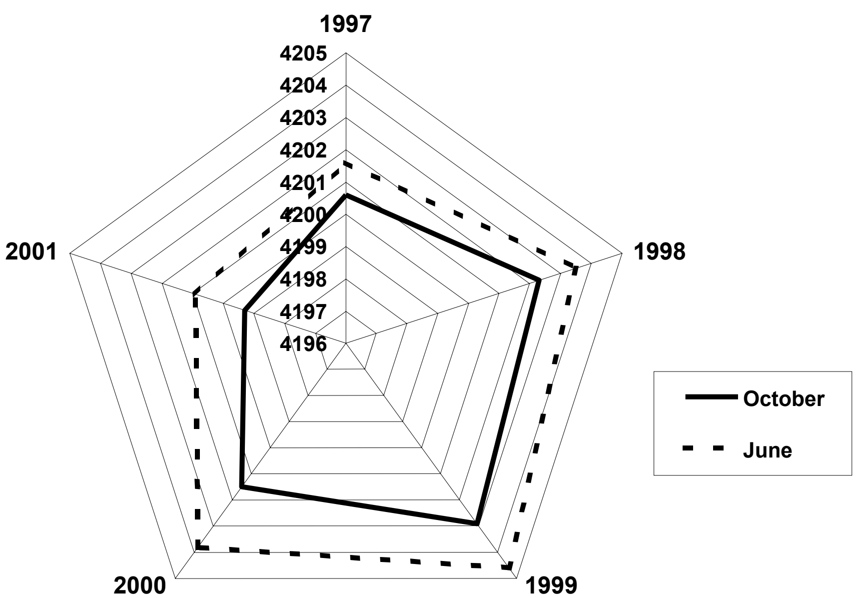




Within Season Changes

The changes of GSL elevation within survey seasons varied from 0.3 m (1 ft) in 1997 to 0.7 m (2.25 ft) in 2000 (Figure 6). These conditions reflect the vagrant conditions 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.

Figure 6. Comparison of GSL high (June) and low (October) elevations, 1997-2001. Lake elevation values are listed in the column (4196 – 4205) and represent feet above sea level.



The effects of wind on shoreline varied with shoreline type. Winds in excess of 30 mph were experienced each survey season. Where causeways were encountered by wind, the force often caused mixing on the leeward side of culverts. During strong winds, the Antelope Island State Park causeway culverts experienced focused, driving water on the windward side that ballooned through culverts often in excess of 1 km. These conditions were visible because of surface watercolor contrasts. Farmington Bay water is often less green or blue than the denser brines of Gilbert Bay. Vertical mixing of salinities at these culvert sites is unlikely due to the difference in brine densities.

Wind effect on low gradient mudflats and sandbars was noted to spread surface water over extensive areas, sometimes for several hundred meters. This phenomenon affected habitat and bird use in several ways. The substrate became moistened, and seemed to increase foraging activity in some cases (Appendix 3). At times invertebrate activity on wet shorelines also increased. Wind tides also drove masses of filamentous algae on to otherwise relatively sterile beaches (e.g., Ogden Bay North; Appendix 4). After these algal biomasses were stranded, they attracted brine flies, and subsequently, birds that foraged on the flies. This condition was noted most often later in the season, after filamentous algal blooms were well developed. Flies and birds used these same algae mats as they floated about the lake. Wind tides caused brine fly pupal chamber residue from hatches to windrow along the shoreline. These windrows offer a nutrient rich mix of algae and adult brine flies on which gulls and other shorebirds concentrate.

Wind also distributes organic and inorganic debris along the shoreline. Snowy plovers, stilts and avocets often nest next to wind placed debris. Western sandpipers also roost next to these debris at times in excess of 200 m from the current shoreline. Near shorelines on various islands and elevated bars, gulls use large isolated debris (logs, planks and uprooted brush). Water evacuated from beaches on the leeward side of wind events exposes wet mudflats used by foraging shorebirds and gulls. At other times wind tides inundate nests, causing egg loss or nest desertion.

Wind may or may not change the condition of large and small WMA impoundments. In general, the wind effect on managed sites is not as eventful because of their smaller size and emergent vegetation, which act as a buffer. Often, birds use managed sites for shelter during wind events.

Survey Coverage

Percent of GSL ecosystem covered by Waterbird Survey

For this report the GSL ecosystem is represented by the GSL and its associated delta-formed wetlands. When the lake is at its long-term historic elevation of 1,281 m (4202’ ASL), the lake surface area is 3,885 km^2, and the associated emergent marshes and non-vegetated mud flats and salt flats encompass 2,065 km^2 (Fretwell et al. 1996). The GSL Waterbird Survey covered approximately 21% of the total area, and approximately 28% of important waterbird habitat (i.e., Gilbert, Ogden, Farmington and Bear River bays, Willard Spur and wetlands; see Table 4).

Table 4. Summary of area sizes of Great Salt Lake bays and wetlands, and the portions covered by the Waterbird Survey.

Area name	Area size (ha)	Portion surveyed (ha)	Percent coverage
Gilbert Bay	187,962	3,426	2
Ogden Bay*	21,148	21,148	100
Farmington Bay*	31,102	31,102	100
Bear River Bay/Willard Spur*	23,708	23,708	100
Total	**263,920**	**79,384**	**30**
North Arm	156,667	0	0
Willard Bay	3,821	0	0
MagCorp Pond 1N	13,857	376	3
Total	**174,345**	**376**	**0**
Total wetlands	**161,874**	**43,984**	**27**
Grand total	**600,140**	**123,744**	**21**

*One quarter of area surveyed via plane and results extrapolated for 100% coverage.

Coverage within survey areas

The GSL Waterbird Survey covered most of the known waterbird habitat (Figure 2). All of the shoreline from the Bear River Delta south to the Jordan River Delta and west to Stansbury Island was surveyed. Along that same section much of the lake's associated wetlands was included in survey areas, and a good proportion had survey coverage. Some wetlands known to have waterbird use that were not covered in this study are: Blue Creek complex south of Lampo Junction, Chesapeake Duck Club, Black Marsh, Reeder Overflow, the east extension of Ogden Bay WMA, Sulphur Creek, several clubs within the Associated Duck Clubs region, and ponds cut off from the south end of the lake by Interstate 80. These areas were not surveyed because of limited volunteer numbers or restricted access, but in the future should be investigated to determine the extent of waterbird use. Open water areas of Bear River, Ogden and Farmington Bays were surveyed by transects representing approximately ¼ of the total lake surface.

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 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.

On the north end of the lake, the managed wetland areas had some survey coverage, and the shoreline and open water were determined unsuitable for waterbird use because of the extreme saline conditions. A portion of the western shoreline south of the railroad causeway was covered by some survey efforts. The land on this side of the lake is used by the US Air Force munitions testing and has highly restricted access. Stansbury Bay has been converted into commercial evaporation ponds, but surveys were conducted between Lakepoint, Badger Island, and Stansbury Island from a dike road. This survey has been important in detecting the presence of large flocks of Wilson's and red-necked phalaropes on the west side of the lake.

Large wetland complexes were not surveyed in their entirety (Table 5). Coverage was limited for many reasons including: difficult access, limited viewing, and large area size. These complexes have been evaluated separately to describe survey coverage. The Waterbird Survey project managers met with site managers and/or survey participants to determine the approximate percent coverage of these areas. The size of the survey area, percent of appropriate waterbird habitat within the area, percent visibility, and the percent of the area actually surveyed were discussed. These coverage estimates were used in calculating densities of waterbird species in the respective area.

Between Year Changes in Survey Coverage

Survey coverage did alter between years, usually due to limited numbers of volunteers or restricted access at certain locations. Stansbury Island North (2) had restricted ground access, and was added to the aerial survey route in 1999 but was skipped every third period. Concurrently, the Farmington Bay lake portion coverage was reduced to the alternate flights when Stansbury Island North was not flown; this decision was made due to the low bird counts during parts of the survey season in this large area. Coverage continued through 2001. Audubon Interior (9c) had restricted access until the 2001 season. Locomotive Springs WMA (35) was surveyed in 1997 but not again until 2001 because of limited surveyors and the remote location. Magcorp (40; currently called US Magnesium Corporation of Salt Lake City) was added to the Waterbird Survey in 1998 and efforts continued through 2001. New State Duck Club (41) has limited access and difficult travel conditions. The area was added to the Survey in 1999 and covered by UDWR personnel. In 2000 the area was dropped because of limited UDWR staff, and in 2001, surveyed by a member of the duck club. East Farmington Bay (42) and Deardens Knoll (43) were added to the survey in 1999 and covered through 2001. Jordan River (44) was added to the aerial survey route in 1999 and counted every third period. The survey was dropped in 2001 because low lake elevation left this area dry and unused by waterbirds.

Survey coverage within years also had some variation. Most areas were surveyed on a regular basis; counts before and after the gap were averaged to fill in the missing point in cases where a survey period was missed. 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.

Migration Chronology

The five year study of species use at the Great Salt Lake allows for a break out of five significant categories of use as birds move through the season (Table 6). These classifications are based on data displayed in the species count charts (see Species Accounts). 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. A weighted line through the appropriate time periods shows species presence. Line designations are a subjective measurement of the portion of a species population known to be at Great Salt Lake at its peak time. Relative numbers of species by survey period are charted in the Species Accounts.

Table 5. Summary of survey coverage of large wetland complexes associated with GSL.

Name	**Area size (ha)**	**Percent covered by WBS**	**Percent good waterbird habitat**	**Comment**
Associated Duck Clubs	5910.5	15	90	Visibility is uninhibited, but in some cases viewing distances are too great for 100% detection.
Bear River Club	5183.8	40	95	Extensive open ponds, edge and emergent wetlands that support breeding populations of shorebirds and colonial nesting species.
Bear River Migratory Bird Refuge	10449.4	30	60	South Bear River (an adjacent 8272.3 ha survey area) has 80% good waterbird habitat and 50% was covered by WBS.
Farmington Bay WMA	4544.5	65	90	To get full coverage the best view would be from the air. It is difficult to travel on foot and in some places vegetation compromises great viewing distances.
Harold Crane WMA	5012.9	33	50	West Harold Crane mud bar was not surveyed. Areas not covered by survey could be accessed on foot. Some colonial nesting occurs in wetlands.
Howard Slough WMA	1263.9	85	95	Since 1997 the outer dikes have been washed out. The south impoundment has visibility difficulties because of large distances.
Locomotive Springs WMA	7607.9	4	17	Most mudflats were not surveyed. Other studies have observed snowy plovers in large numbers in these areas. Areas of emergents that are not viewed easily can be accessed on foot.
New State Duck Club	1200.2	50	100	
Ogden Bay WMA	2495.6	60	80	Areas not visible are likely not good for shorebirds. Near Unit 1 there is viewing difficulty near the grass island. Viewing could be enhanced from a boat for closer access.
Public Shooting Grounds WMA	3248.7	20	70	There is a large expanse of potholes that is not visible from the dike roads but would be visible from a plane.
Salt Creek WMA	863.4	35	55	Very few shorebirds. Tall vegetation is a barrier. Viewing could be enhanced from an observation tower.
Salt Wells Flat WHA	1659.8	40	40	Access is good and visibility could be improved from an observation tower. Mud is very soft and difficult to walk on, ATV needed for travel.
Timpie Springs WMA	556.7	80	90	

Table 6. Migration chronology of waterbirds at Great Salt Lake.

━━━ 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 (Apr.)	Migrants to Breeding Grounds (Apr.–May)	Local Breeders (Apr. – Sept.)	Early Migrants to Wintering Grounds (July – Aug.)	Later Migrants to Wintering Grounds (Aug.-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				━━━		
WFIB		───	━━━	━━━		
WILL		━━━	━━━			
WIPH		───		━━━		

Breeding Species

This study did not directly assess the breeding status of waterbirds within the boundaries of the study area. However, counts did include breeding waterbird species as they occurred within each survey site. From this data set it is possible to assess potential breeding adults through the assumption that adults observed at known breeding periods are potential breeders. For this report, breeding period is defined as the period of time that encompasses pair bonding, nest building, and egg laying. These conditions can vary within and between species at the GSL. A conservative assessment was made to determine potential breeding adults by examining the five-year survey period means at a time when the species was present within the defined breeding period. For example, the optimum breeding period for American avocets was judged to fall between May 21 and July 10. At this time, the highest five-year survey period mean was greater than 63,000 potential breeding adults (Appendix 5). The survey period distribution of these 63,000 potential breeding avocets is displayed in Appendix 6. The projected breeding period was determined to be during survey periods 5-10 for this species. Similar examinations can be made for the most common, if not all potential breeding species at the GSL by examining the potential breeding data (Table 7) and comparing them to the Species Distribution by Survey Period (Appendix 6).

Table 7. Potential breeding population estimates of some waterbird species at GSL.

Species	Number of potential breeding adults
California gull	95,183
American avocet	63,806
Franklin's gull	30,652
White-faced ibis	28,626
Black-necked stilt	20,502
American white pelican	9,898
Forster's tern	1,586
Snowy egret	1,353
Snowy plover	541
Great blue heron	460
Black-crowned night heron	342
Cattle egret	53

Great Salt Lake Waterbird Species Accounts

The five-year data set was used to describe GSL ecosystem use by individual species with local population sizes according to survey period. It was then used to map their distribution around the lake. These data have been compared to global and North American population estimates where available. Our analytical approach has allowed us to identify peak periods of species presence, expressed by five-year means. Data are also available to identify the mean peak survey period, as well as the highest count recorded for one survey period during the five years. Mean occurrence by survey period are charted and mapped by survey area (Appendix 6).

Species Distribution By Survey Period

To accomplish our objective of identifying important waterbird use areas at GSL, georeferenced data have been mapped for individual species by survey period. Five-year means were plotted by survey area to show lake-wide distribution. Bird density by area information is provided in the Survey Area Descriptions (Appendix 4).

High and Low Lake Elevation Species Distribution (1999 and 2001)

Two years were compared to assess the distribution of individual species relative to high and low lake elevation scenarios. Species counts by survey area and survey period for the high lake year of 1999 and the low lake year of 2001 were mapped for comparison. The general trend of bird distribution follows the presence of water as lake elevation changes (Appendix 3).

Bird Use Days

A bird day is defined as one bird spending 24 hours within the study area during the study period. The GSL bird use day five-year mean was 86,752,258 (Table 8). Data from 1997 were only used in the five-year mean calculations of selected suites of species in Table 10. The 1997 data were omitted from the other tables to minimize variation in individual year means, because the survey season in 1997 had eight fewer survey periods than the other four years.

Bird use days are noticeably smaller in 1999. Bird use days by avocets and stilts were greatest in 2000 and 2001, and for dowitchers and waterfowl in 1998. The years 2000 and 2001 showed greater 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 greatest year of peep sandpiper presence was 2000, while for phalaropes the highest use year was 2001 (Table 9).

An examination of the five-year mean bird use days by suite reflects the importance of the lake to avocets, phalaropes, waterfowl, and gulls--each present at GSL in the millions of bird days (Table 10).

Table 8. Mean bird use days at Great Salt Lake by year, 1998-2001.

Year	Mean Bird Use Days
1998	89,183,180
1999	77,469,285
2000	88,889,577
2001	85,349,660

Table 9. Annual bird use days at Great Salt Lake for selected suites of species.

	Bird Use Days by Suites						
Year	Avocets and Stilts	Dowitchers	Waterfowl	Gulls	Herons and Egrets	Small Sandpipers	Phalaropes
1998	8,815,020	1,669,340	38,070,840	16,164,400	227,635	1,434,150	4,630,780
1999	10,443,400	1,100,080	28,810,680	12,286,700	246,570	516,475	6,019,690
2000	15,776,080	792,975	23,412,310	19,671,630	238,620	3,198,305	9,135,470
2001	13,224,590	434,715	22,838,960	23,842,820	191,890	965,570	11,622,420

Table 10. Five-year mean bird use days at Great Salt Lake for selected suites of species.

Suite	Five-Year Mean Bird Use Days
Avocets and Stilts	14,696,844
Dowitchers	1,133,536
Waterfowl	32,563,640
Gulls	22,062,838
Herons and Egrets	262,739
Small Sandpipers	2,030,585
Phalaropes	7,044,632
All Waterbirds	86,752,258

Survey Area Descriptions

Each survey area is described and evaluated as to habitat type, accessibility, visibility, waterbird use, and actual survey coverage (Appendix 4). Five-year mean counts by species are displayed in a table for each area. These counts are the same values that are mapped by species in the Species Accounts. Species densities are also listed for each area. Calculated with ArcView software and georeferenced topographic maps, area sizes are a rough estimate. In general, shoreline areas had good visibility and virtually complete coverage. Large, wetland areas often were difficult to survey completely because of lack of surveyors, poor accessibility, or limited visibility. Species densities for these areas were figured with the area size actually surveyed, as estimated by the participants or area managers. This was done in an effort to make the density values more comparable between areas.

Habitat Use

All count data for the years representing high and low lake conditions (1999 and 2001, respectively) show patterns of abundance for the following suites of species (Appendix 3). Ducks and dowitchers that favor fresh water in association with emergent wetlands were more abundant in 1999. Gulls, avocets/stilts and small sandpipers were more abundant during the low lake year of 2001. These groups prefer exposed shoreline and mudflats for nesting and foraging. Phalaropes were also more abundant in 2001. Personal observations by the authors noted more abundant brine fly production during this low water year, which may have contributed to the larger numbers of phalaropes, gulls, and sandpipers. The survey year 2001 was also a better year for brine shrimp production than 1999. Counts at point samples did not always reflect these same patterns. Of 19 point samples, 74% had a greater ratio of species to habitat types in 1999 over the drier year of 2001 (Table 11 and Table 12).

Table 11. Comparison of species and habitat diversity at point samples in 1999 and 2001. The values listed are ratios of the number of species to number of habitat types.

Point	1999	2001
3a	2.3	1.7
3b	2.4	1.8
6.1	0.6	1.1
6.2	2.1	1.0
6.3	3.2	1.6
8a.1	4.0	3.7
8a.2	3.4	2.9
8a.3	4.5	5.8
9b	3.8	2.7
11.1	4.0	3.6
11.2	3.8	3.0
11.3	5.7	2.8
18.2	2.1	2.6
18.3	2.4	3.8
15.1	2.3	3.8
15.2	2.2	1.8
34a.1	3.8	1.1
34a.2	4.3	1.8
34a.3	4.1	2.0

Table 12. Comparison of waterbird density (birds/ha) by suite at point samples and corresponding shoreline areas. Point sample data were averaged through time and across samples. Data from the following shoreline areas were used to calculate mean birds per hectare for a point sample and the entire block of respective areas: 3a, 3b, 6, 8a, 9b, 11, 18, 34a.

Suite	Name	Mean density at a point sample	Mean density at GSL shoreline survey areas
1	Gulls	5.77	2.46
2	Terns	0.20	0.01
4	Dabbling ducks	0.94	0.19
5	Diving ducks	0.24	0.01
6	All ducks	7.07	0.20
7	Herons and egrets	0.08	0.00
8	Avocets and stilts	3.56	1.54
9	Small sandpipers	1.81	0.20
10	Dowitchers	0.30	0.00
11	Yellowlegs	0.07	0.00
13	Plovers	0.24	0.03
14	Phalaropes	1.29	0.41
15	Large sandpipers	0.13	0.02
16	Ibis	0.21	0.01
17	Pelicans	0.96	0.04
18	Eared grebes	1.62	0.14
19	Coots	0.90	0.05
20	Geese	0.73	0.05
21	Cormorants	0.09	0.00
22	Cranes	0.04	0.00
23	Medium sandpipers	0.49	0.01
24	Soras and rails	0.02	0.00
25	Other grebes	0.14	0.00
26	B.B. plovers and red knots	0.51	0.01
	All birds	27.42	5.40

Discussion

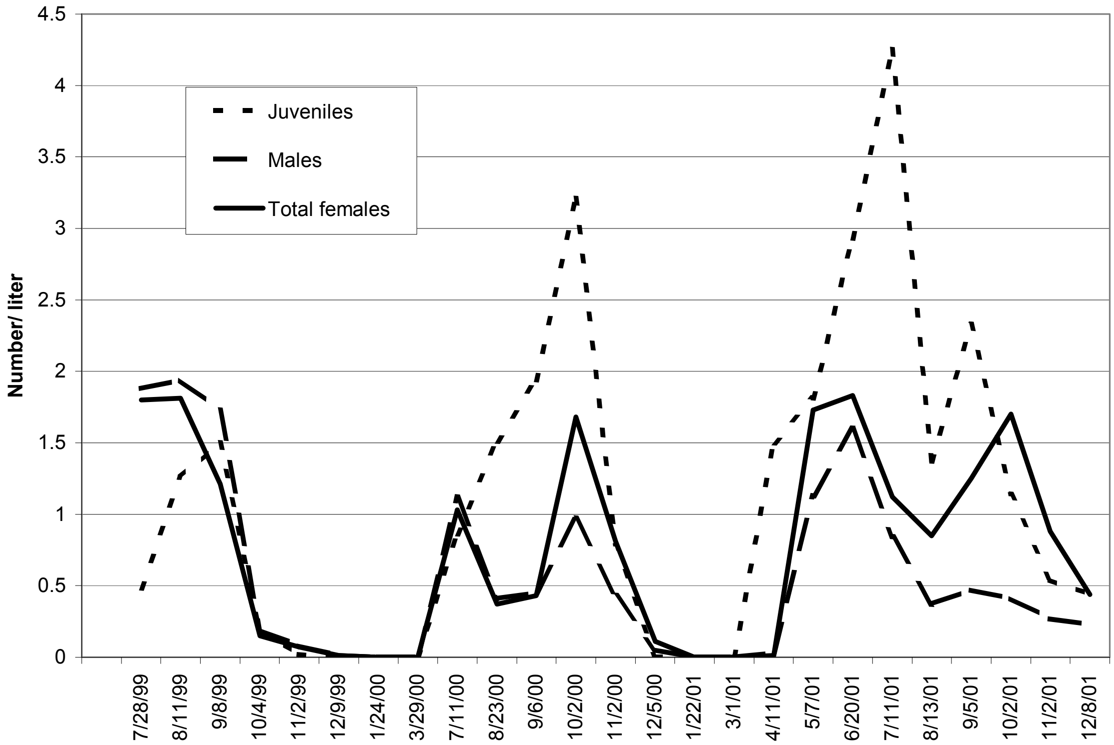
Habitat Changes with Lake Elevation Shift

It is important to consider the GSL elevation during the five-year study in context of 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% of the 20.5' range known to occur over the 154-year lake elevation record period (Table 3). The five-year elevation pattern mimicked a period spanning 20 years, from 1910-1930. We consider the study period of 1997-2001 to be a reasonable representation of typical water level patterns, though condensed into a shorter time frame. 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 4200' 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. Shoreline fluctuation during the five-year study affected lake habitats in ways similar to those observed in the past. When the lake was at 4204.6' ASL, it flooded emergent vegetation stands in the same locations and reduced the shoreline playa reach between the water edge and uplands at other locations. Species that use flooded emergents for nesting colonized in several locations around the lake. At this lake elevation, some mud bars were covered, including some that were used by colonial nesters at other times. 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 was salt water intrusion into WMA ponds. Of note was the flooding of substantial bars that, at lower elevations, extrude for miles into parts of the lake. This was especially true in Farmington Bay where the bar south of the Great Salt Lake Shorelands Preserve was inundated, as well as the bar at the northwest end of the Jordan River Delta complex.

An antithetical condition occurred in 2001 and also to some degree in 1997 when the lake dropped below 4200'. The shorelines were dominated by extensive open mud bars, which in some cases isolated emergent wetlands from the salt water. The interface between salt water and fresh water wetlands and uplands was widened in many places by hundreds of meters. Colonial nesting species, especially gulls, occupied low relief mud bars and other islands. Nesters abandoned these nesting sites as land bridges became exposed and accessible to predators. Emergent wetlands were salt burned and set back to early serial stages, and mosaic patterns of new emergents were established. Distance increased between shoreline foraging habitat and other lake habitats like fresh water inflows.

Changes in lake volume affect lake limnology, as an artifact of lake elevation. During low lake periods, the decreased volume increases brine concentration and subsequently influences obligate halophytes and halophiles occurring at GSL. In general, lower brine concentrations foster greater species diversity, but 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; in these years, the Gilbert Bay portion of the South Arm was below 4202' ASL during mid-summer and early fall (Figure 7).

Figure 7. Brine shrimp numbers per liter in the South Arm, Great Salt Lake, 1999-2001.



In addition to lake elevation, there are other factors that affect lake limnology. Seasonal ambient and water temperatures are important, and nutrient recharge may affect lake production and species compositions of algae and invertebrates. A major breach in the Union Pacific railroad causeway near Lakeside, between Gunnison and Gilbert Bays was improved between the 2000 and 2001 survey years and allows better water flow exchange.

Changes in limnology in turn affect fisheries at GSL. During 1997, 1998, and 1999 a fishery occurred in the Bear River Bay/Willard Spur region. This fishery spanned from approximately two miles north of the Great Salt Lake Minerals Company (formerly IMC Kalium) culvert to the Bear River National Wildlife Refuge, and east in Willard Spur to the Willard Bay dike. Large numbers of several species of piscivorous birds consumed carp and gizzard shad during these years. In mid-summer 2000 and extending through 2001 this fishery was lost due to reduced flows from the Bear River and falling lake elevations that left mud flats and very shallow water as this region dried up.

Weather Variances

On several occasions during the mid 1970s, extreme wind events over the GSL drove Wilson's and red-necked phalaropes off the lake. On one occasion, large flocks of phalaropes were carried over the UDWR Northern Region office by wind from the southwest. As the wind subsided these flocks were observed returning west to the lake from the Ogden area. On another occasion a person brought several Wilson's phalaropes into the UDWR Northern Region office that had been found dead on Willard Peak. After an interview, it was learned that the phalaropes had been picked up by a southwest wind and carried to the Willard Basin where a severe rainstorm changed to hail at higher elevations. This storm had killed large numbers of the species in the Willard Basin area. With this information, D. Paul drove to the basin where he observed several hundred dead Wilson's phalaropes in an area of several square kilometers.

Although extreme conditions similar to this unique event were not recorded, there were episodes of high wind, cold periods (Spring 1999), and long, dry periods (July 2000-2001). Each of these conditions had an effect on habitat, bird distribution and surveyor capacity.

Evaluation of Methods

Most missing data points were sporadic, and filled in by taking an average of the numbers on either side of the gap. However, when two or more consecutive missed points occurred, the gaps were not filled. These holes in the data set do affect total counts at the all-lake level, but especially at the level of survey area. In large part the data reported are in the format of a five-year mean, and the missed counts are tempered by averaging. Comparisons between years are not as reliable because of missed surveys in areas. In some cases areas were not surveyed at all for a particular year. To make direct year-to-year comparisons, it is necessary to select areas that are similar in the extent of their coverage and then draw conclusions for those areas only, not from the entire GSL ecosystem. The Survey Area Descriptions section (Appendix 4) details the degree of coverage by survey area for the study period.

Detection rates were variable across survey areas. Most often shoreline areas were classified as having 100% detection. The wetland complex areas with tall, emergent vegetation, long viewing distances or access difficulties did not always have good detection rates. These situations were fairly consistent throughout the five years, and therefore the counts were constant 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 the project managers 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 (Table 2). 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.

Most survey forms were complete when turned in, especially for total count data. When information was missing, contacts with the survey team leader or surveyor were generally sufficient to make the data complete. The most incomplete or confusing data from the field crews pertained to point sample data. The survey form was not user-friendly, and the complexity of recording habitat type estimates by percent within the point and bird use within the types was the most difficult task requested of surveyors. Even so, with some effort on the part of the data manager, most of the sample point data was entered and used.

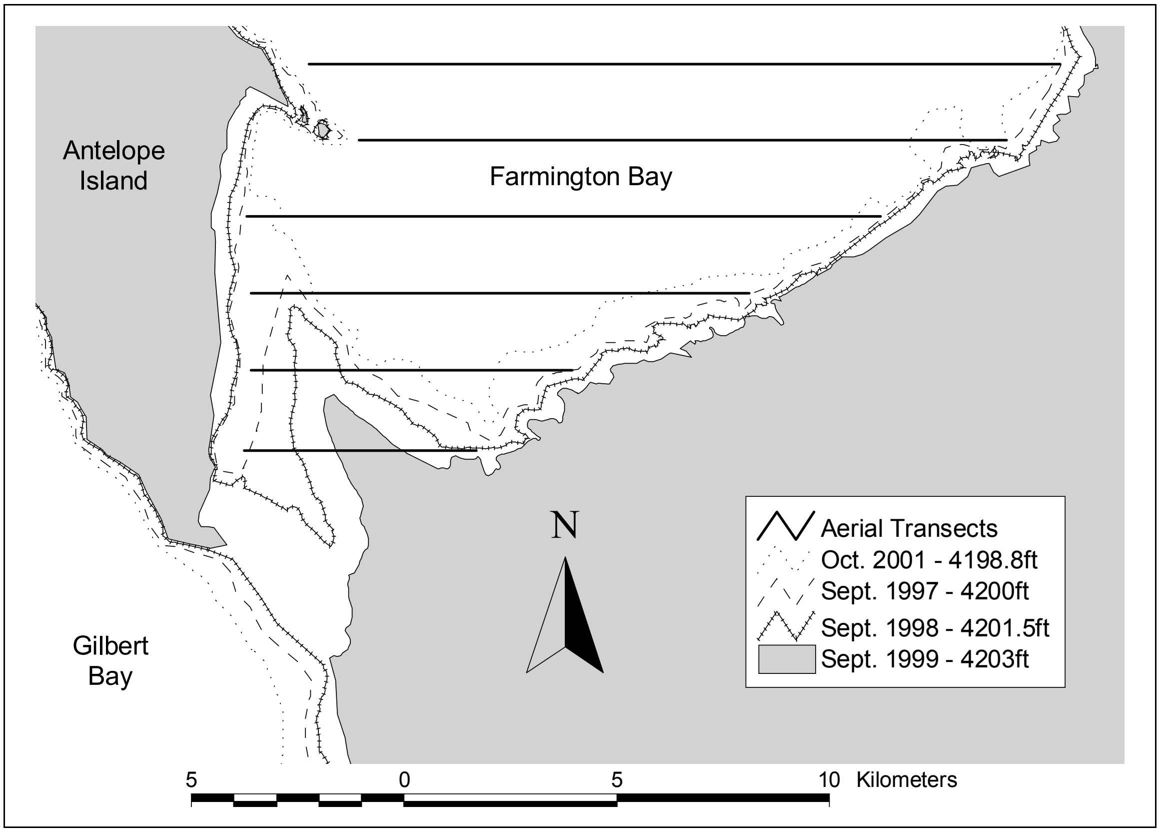
When GSL open water transects were developed in 1997, the GSL elevation was 4201.6' ASL (June 15, 1997). The transects for the open water in Farmington, Ogden, and Bear River bays were established so that the end points occurred one half mile off shoreline. Shoreline survey protocols required observers to count birds within a half-mile window, one-quarter mile on each side of the survey line, which paralleled the shoreline 91 meters (100 yards) from the water's edge. Thus, a surveyor counted birds out to 275 meters, or nearly ¼ mile, therefore reducing the bias of double counting birds observed in the aerial survey. However, because the shoreline fluctuated with changing lake elevations in neighboring survey areas there were potential overlaps between aerial and shoreline surveys. The 1997 aerial transect endpoints were used throughout the five years of study, but the potential overlaps occurred when the GSL elevation fell below 4201.6' ASL for two reasons. First, when the lake was down the aerial survey transect endpoints were within the adjacent shoreline survey areas as the surveyors on foot moved out with the GSL shoreline to maintain a 91 m travel lane from the water's edge. Second, when two sandbars extruded into the aerial transects, they dramatically re-configured the shoreline travel route (Figure 8). However, these overlap issues were addressed reducing the potential double count bias. The conflict with the dynamic shoreline was resolved in most cases through the aerial coverage. Bird counts were stopped short when the transect was within an estimated ½ mile of the shoreline. This was really only an issue in 2001 when the GSL was considerably lower than 4201' ASL, and in some late summer survey periods when the water level was down. Most of the extruding sandbar problems were resolved through communicating between aerial and ground surveyors.

As outlined in the Methods section of this report, a moving sample point was developed so that the inventory of birds using the shoreline was constant through the five-year study. This floating point occurred 91.44 m (100 yards) from the shoreline and at right angles between the original point sample marker and the GSL shoreline. This condition was largely achieved during the study. Exceptions occurred only if original point sample markers were lost during the winter or needed replacement. We used GPS references for replacement whenever possible, but the need to replace a marker was rare, because salt water retarded surface freezing during winter months.

We identified one set of circumstances that biased the comparison of bird use and habitat types at individual point sample sites. As surveyors moved out or back from point sample markers with shoreline fluctuations, they often moved into different habitat types or closer to or farther from specific habitats and landscape features. In some years, observers were hundreds of meters from the point sample marker of 1997. Therefore, perhaps the best comparison of data between years within point sample areas is for the data of birds directly associated with the actual shoreline.

The study managers did work to reduce bias from individual surveyor capacity to estimate distances accurately, especially at a quarter mile (440 yards or 402.3 m). We held an annual field day each spring for Waterbird Survey Team Members, and part of the training was spent helping surveyors develop distance estimation skills. Several tools were provided including the use of auxiliary posts placed at 440 yards on each side of a point sample marker to visually assess ½ mile diameter sampling areas. We know there will be variation by surveyor in estimating the boundaries of the sample point sites, however, the same surveyors made most of the counts throughout a season and from year to year. Therefore, bias should be consistent.

Figure 8. Aerial transects and GSL shoreline configuration at high and low lake elevations.



Data describing behavior of waterbird suites by habitat type were collected at point sample locations. Pre and post survey season meetings were held to assist survey team members in the use of the sample point and other survey protocols. This behavioral data was used mostly as an index to the reason for bird presence in this report. It was collected as a sample of one point in time (one observation / bird) and, therefore, is only a field note pertaining to habitat use within the point sample for each sample period.

From the five-year data set and other information and observations at the GSL, it is obvious that we have 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, western grebe, scaup, 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, some sea ducks, common merganser, Bonaparte's gull, and a few species of northern gulls are the majority of these birds missed by the survey. These are the primary components of frame bias associated with the data set. Beyond missing the peak period for some species, 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 not in a survey area. Other species such as bitterns and rails were secretive and often not detected. Species like long-billed curlews and willets use uplands for nesting and part of their populations were not successfully surveyed.

The database that was established at the beginning of the Waterbird Survey was not an effective tool for several reasons. First, the format of the database underwent some changes between 1997 and 1998 especially within the point sample section, making data from 1997 difficult to use and incomparable with the other years. Second, the data entry system was not user friendly. The screen for actual data input was different from the screen to view all data, and as a result quality control during the data entry process was cumbersome. The database was quite complicated with different people responsible for entering data during each of the five years of study. Data querying and extraction from the database were also difficult, as data managers were not trained in the use of the program. Third, the Waterbird Survey data set was meant to be shared with others within and without the Utah Division of Wildlife Resources, but because the selected program is not universally used, requested data had to be transferred to a spreadsheet to make it functional, therefore, the tables of GSL Waterbird Survey data produced by Jonathan Bart USGS were utilized almost exclusively in the analysis of this data set.

The GSL Waterbird Survey data set is extensive, and the contents of this report only begin to answer a few of the many questions that may be addressed. This report does, however, provide good descriptions of bird use at GSL by species, by time period, and by survey area. Only basic statistical analyses have been completed to this point; a more sophisticated statistical analysis may be appropriate in drawing out additional detailed patterns of habitat selection and population fluctuations that may exist. Project managers have made great efforts to produce a database that is solid and broad in its reach of area, time and species coverage. This has been achieved and is a good foundation for further investigations of waterbird use of the Great Salt Lake ecosystem.

Survey Coverage

It was difficult to maintain consistent coverage over the five years, as we were dependent upon volunteer help. Also, natural barriers to optimal viewing compromised the quality of coverage in some areas. In a separate document, the greater Great Salt Lake area is evaluated as to the extent of appropriate shorebird habitat, detection rates around the lake are described, and suggestions are given for methods to provide for complete coverage. This document is titled "A Plan for Monitoring Shorebirds During the Non-breeding Season in Shorebird Monitoring Region Utah-BCR 9 (Great Basin)" and focuses on shorebird species. However, similar principles apply to other waterbird species and the evaluation could be expanded to include other species as needed (Manning et al. 2002). It is included as Appendix 7 at the end of this report.

Migration Chronology

A primary target of the five-year study was to capture the pulse of waterbirds as they move into, out of, and within the GSL ecosystem. We know from the high lake years of the 1980s that species move between systems in the intermountain region and beyond as local conditions change. The white-faced ibis is an example. In the mid

1980s, the GSL inundated much of the historical nest site habitat and subsequently ibises exploited improving water conditions elsewhere in the west. Oregon, Idaho, Nevada and northern Utah wetlands experienced expanding breeding populations of ibises. After the flood years and as habitat conditions improved for ibises they again colonized re-established emergent wetland vegetation sites at GSL. This study refines the current understanding of how waterbirds like white-faced ibises use the GSL ecosystem through the season.

In the evaluation of methods, frame bias was discussed for species that are on the margins of time pertaining to the study period. These species fit within six categories that we identified as periods of use in the migration chronology of waterbirds claiming some time and space at GSL (Table 6). These six periods are (1) April, departing winter residents; (2) April-May, migrants to breeding grounds; (3) April-September, local breeders; (4) July-August, early migrants to wintering grounds; (5) August-September, late migrants to wintering grounds; and (6) September, arriving winter residents. These categories are not mutually exclusive, and there are many species that fall into several of the descriptions. The degree to which species are present at GSL is well documented by this study. A good example of species presence through several periods is the American avocet. Avocets arrive from their wintering grounds on the west coast of Mexico in late March and by late April, approximately half of the peak GSL population is present and begin to pair up and establish nesting colonies. Some 60,000 to 100,000 breeding adults are present into April. Their young and arriving migratory individuals begin to flock and gorge on September brine flies. At the peak population size of 200,000 to 300,000 avocets depart GSL in late September and October.

For most departing winter residents (Migration Chronology Period 1), April is the end of their winter residency at the GSL. Winter residents return near the end of the survey season (September/October). The migrants to breeding grounds in Period 2 will stay at GSL to breed or travel farther north. Some individuals of these species associated with nesting at GSL (e.g., willets, move through the lake to nest at the northern extension of their range. Others still have many hundreds or thousands of miles to travel (e.g., long-billed dowitcher, black-bellied plover, greater yellowlegs, red-necked phalarope). There are at least 28 species that utilize the GSL ecosystem for breeding. There are some species that leave for their wintering grounds from the GSL in July and August. These include most of the peeps, many black-necked stilts, California gulls, Franklin’s gulls, greater yellowlegs, lesser yellowlegs, marbled godwits, white-faced ibises, willets, and Wilson’s phalaropes. Some of these species have been at the GSL though most of the survey periods, but others are just coming through from sites further north. This is also the case for species in the late migrants (August-September) category. In this group, there are many waterfowl species that are just arriving to GSL. Some continue on, while some stay until ice-up. Others, like the eared grebe, use GSL as a molt migration site. The ring-billed gull sometimes stay the winter, and other times passes through. The GSL breeding populations and their offspring are augmented by migratory populations of the same species in later survey periods. This seems to be true of avocets and pelicans for example.

The assessment of bird use days at GSL indicates that the greatest period of use begins halfway into the survey season and lasts through the remainder. Because of the numerical make up of occurrence, the waterfowl category is of great magnitude. It is suspected that bird use days remain strong well into the fall, beyond our periods of survey. Another important period of use is concurrent with summer and late fall halophile production of brine flies and shrimp.

The migration chronology data also demonstrate the dynamics of spring as birds move 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 phalaropes, Wilson's phalaropes, and eared grebes are similar in this regard, as they pass through to breeding grounds.

Species Distribution

Shorebirds

The distribution of shorebirds at GSL varied by species. There were even some changes in habitat type use by the same species during different times of the survey season, and some that keyed on the same geographic locations despite changes in lake elevation. The magnitude of occurrence of some long-range migrants seemed to change between spring arrival and fall passage. These observations are made by examining five-year averages by survey period for each survey area. There is some variation to these mean numbers if each survey year is examined separately. However, these variations in distribution are more contingent on survey site than survey period. For some years the habitat type is different for the same survey area as a consequence of lake elevation and transitory shoreline, or the availability of water to manage wetland complexes. At other times wetland managers adjusted water levels as part of a prescribed application.

Following are some highlights of shorebird presence on the lake through the survey season. These comments are based on data presented in Appendix 6. For details of occurrence by location see Survey Area Descriptions (Appendix 4).

American avocets and black-necked stilts both seem to use managed wetland complexes extensively from April-July. Starting in August a preponderance of avocets disperse to GSL shorelines and congregate in large numbers in Farmington Bay. This is true too for black-necked stilts, but they also use east Gilbert Bay and Bear River Bay in large numbers.

Long-billed dowitchers and greater and lesser yellowlegs prefer to use wetlands with pools and ponds bordered with emergent vegetation. In April, and May, and July through September, dowitchers are found in large numbers at Bear River MBR and Farmington Bay WMA complexes, and can also be found in small concentrations throughout GSL wetland complexes. The two yellowlegs species are often observed together from April into early May, and again in late June through September. The largest numbers occur in Farmington Bay WMA, Ogden Bay WMA, and Bear River MBR.

Marbled godwits occur at the lake in mid April, on their return to the prairies for breeding. In the spring, the largest numbers were recorded at Bear River MBR and Ogden Bay WMA. Late June through September, they are present in the tens of thousands within the Bear River Bay complex, especially in the Willard Spur.

From April through mid September, snowy plovers are found in numerous playas and shoreline reaches. Large numbers were located in the Locomotive Springs WMA and Salt Wells Flat WHA. They were also present in good numbers at Stansbury beach and along the South Shore, within the Inland Sea Shorebird Reserve, along the Audubon beach, and in the Harold Crane WMA complex.

Wilson's phalaropes appear at the lake in open water and associated wetlands during two concentration periods. First, in late April and early May they locate at Bear River MBR, east Gilbert Bay and Farmington Bay for a stop along their spring migration northward. Second, they return from breeding grounds in the intermountain west and prairies in June, build into July when they congregate in large flocks around Bear River MBR, the shorelines of the lake, and especially on open water reaches of GSL. Large flocks were counted in Gilbert Bay both in and out of Waterbird Survey areas, and also in Farmington Bay, and the largest flocks occurred around Carrington Island, along the Magcorp dike, and on the west shore.

Black-bellied plovers arrive in spring and again in late summer when they are observed in small flocks. The largest groups are consistently observed along the southern end of Antelope Island and the shoreline south of the Crystal Marsh and west of the Audubon properties. In some years, other sites of concentration are the Howard Slough shoreline and Ogden Bay WMA.

Least sandpipers are present in April and May and most commonly observed on the South Shore, Stansbury beach, the Inland Sea Shorebird Reserve, Farmington Bay WMA, and Bear River MBR. They return in August, locating again at the south end of the lake, Farmington Bay WMA, Inland Sea Shorebird Reserve and the Magcorp dike.

Western sandpipers arrive in late June and are seen though August. Some counts exceeded 150,000 individuals at Bear River MBR. Large numbers were also observed at Ogden Bay WMA, Farmington Bay WMA, the South Shore including Stansbury beach and the southeast shore of Antelope Island.

Sanderlings often occupy strips of sandy beach around the South Shore and along gravel dikes and causeway road structures including the Antelope Island State Park causeway, Magcorp dike, and dikes at Locomotive Springs. They are present at GSL April through May.

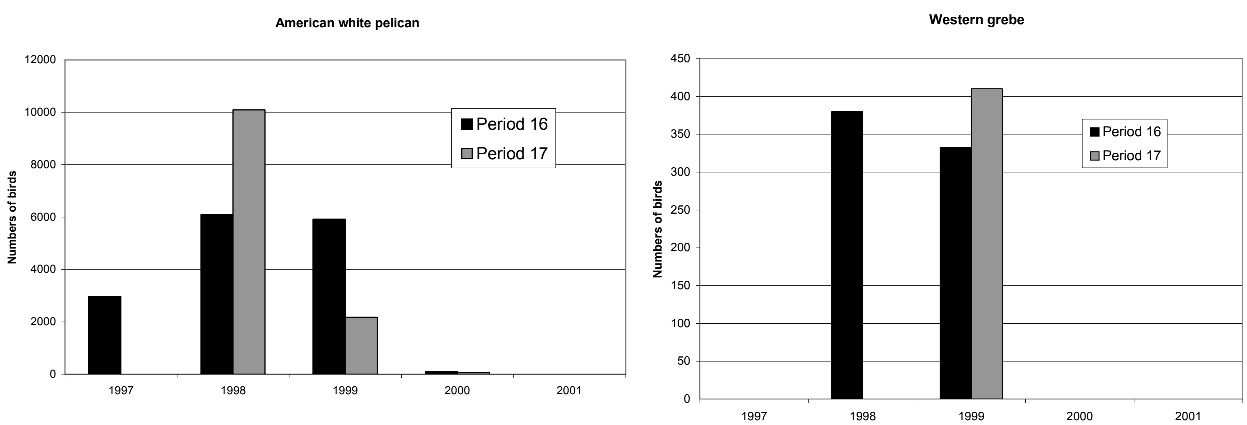
Colonial Waterbirds

Due to the close proximity of nesting colonies to some survey areas colonial waterbird distribution observations and population estimates within the ecosystem may be biased for some nesting species. In fact, several survey areas had colonies within their boundaries. This was true for California gulls, American avocets, black-crowned night herons, black-necked stilts, Caspian terns, eared grebes, Forster's terns, Franklin's gulls, western grebes, snowy egrets, and white-faced ibises. Some of these species do not always nest in dense colonies (e.g., American avocets and black-necked stilts), but most others do. The survey only required observers to report nesting activity during collection of point sample data. American white pelicans are an important species where no nesting activity took place in a survey area. The only nesting colony occurs on Gunnison Island, 35 miles from the nearest survey area.

Many waders are piscivorous species and were normally observed in parts of the ecosystem where fisheries occur. This was also the case for western grebes, Clark's grebes, double-crested cormorants, Forster's terns, Caspian terns, and black terns, all fish by diving into and under the water surface. These foraging conditions occurred at various locations around the lake and were largely associated with the three major river deltas of the Bear, Ogden/Weber, and Jordan. Occurrence was also noted at the mouths of smaller tributaries, canals and other artificial structures. Bear River Bay and Willard Spur portions of GSL held a fishery through the first three and a half survey seasons. The carp and gizzard shad fishery deteriorated with the hot, dry summer of 2000 continuing into 2001 when the Willard Spur was almost completely dry. Large carp carcasses were visible from the air in shallow water and on mudflats in the Bear River Bay region outside the D-line dike of Bear River MBR in mid summer 2000 and beyond. This affected fish-eating species distribution due to lack of a suitable fishery.

Observations of American white pelicans during the five-year study described how piscivorous species were influenced by variable conditions in GSL fisheries. Distributions of American white pelicans by survey period (Appendix 6) reflect specific site importance during an average year for pelicans. Areas of pelican concentration were the Bear River system and State WMAs on the east side of the lake. If the data are examined as annual means, counts of pelicans during late summer of 2000 and 2001 drop dramatically (Figure 9). These declines directly correlate with observed fishery loss in the Bear River system. Other fish eating waterbirds were also affected in a similar manner. However, the magnitude of effect depends on the species. Terns that forage on smaller fish, and grebes that dive, have some alternative fisheries in the area, such as Willard Bay Reservoir. Regardless, the quality of the fishery in the Bear River system has a profound affect on bird occurrence in the area.

Figure 9. Numbers of American white pelicans and western grebes at Willard Spur (28) during survey periods 16 and 17, 1997-2001. In 1997 survey work was not completed during period 17. No western grebes were recorded in the Willard Spur during survey periods 16 and 17 of 2000 and 2001 because the area was dry.



The California gull is an example of a ubiquitous, breeding, colonial species at the GSL, with a broad diet and exploitative foraging behavior. Five-year mean counts by survey period show this species' universal use of the GSL with some hot spots of occurrence near breeding colonies. These conditions are apparent in the months of June and July when the colonies are active with young (Appendix 6). In August and September, California gulls are found exploiting the large numbers of brine flies and brine shrimp in open water and shoreline areas.

White-faced ibises are a colonial species that establish colonies in emergent vegetation but spend much of their foraging in flood-irrigated agricultural lands feeding on earthworms and other invertebrates. Because the majority of their activity around the lake proper is associated with nesting, it is obvious where the nest sites occurred within wetland systems (see Appendix 6—White-faced Ibis Distribution by Survey Period, Periods 9 and 10).

Waterfowl

The distribution of waterfowl at GSL wetlands is well understood-data have been amassed for well over a half-century-and data from the five-year study show those same patterns (Appendix 6). Ducks occur in large numbers during April (survey periods 1 and 2) as they pass through the area en route to breeding grounds. Then they start to re-appear in late June when some molt migration takes place, and build in numbers through September when the largest numbers of all ducks materialize, especially at the managed systems, Bear River, and Farmington bays.

These are but a few examples of the distribution of different species across the GSL ecosystem through the 17 survey periods. Examination of individual Species Accounts (Appendix 5) and specific Survey Area Descriptions (Appendix 4) allows for a more detailed understanding of how each species uses the GSL landscape during the months of April through September. To better understand how lake elevation affects species distribution, see also Species Distribution at High and Low Lake Elevations (1999 and 2001, respectively) in Appendix 8.

Breeding Species

These data are taken from all-lake five-year means for survey period nine (end of June, beginning of July), and are assumed to be the peak breeding time (Table 7). However, Waterbird Survey areas did not cover all of the GSL breeding grounds, and some species have peak numbers later in the season. California gulls breed on many islands outside the GSL Waterbird Survey study area and therefore this potential breeding adult figure would underestimate their actual numbers. American white pelicans also breed outside the survey area but because of their use of fresh water fisheries within the survey area, the population estimate from survey data should be more realistic. The actual five-year average of American white pelicans from the Gunnison Island breeding adult survey is 13,338 for 1997-2001, a difference of 3,440 from the WBS estimate. If the high year (1999) is dropped the four-year average is 12,183 or a difference of 2,285. These estimates might also be useful in assessing the percentage of the breeding adult population that forages outside the survey area (i.e., American Falls Reservoir, Idaho).

Species Accounts

Data reported by species are valuable in drawing conclusions about GSL populations as they relate to populations of a larger geographical area. It is interesting to note what percentage of North American, or worldwide, populations are found at GSL. Equally important is a review of the scale of a particular population. All species do not occur at the same magnitude. For example, the estimated number of mallard ducks in North America is close to 7.5 million, and the high count recorded at GSL is137,468. The GSL population is 2% of the continental population. The highest count of marbled godwits at GSL during this study was 43,833, less than one-third the number of mallards. However, the estimated population size for marbled godwits in North America is 171,500, of which the GSL group represents 25%.

Three numbers for waterbird species present at GSL are reported in the Species Accounts: mean, peak and high count. All are useful in describing waterbird use of the GSL ecosystem. The mean is a stable and conservative figure that indicates likely population sizes during the respective time frame of presence for each species in any given year. The peak number is the highest count for one survey period. This is a mean over five years and is graphically displayed. The high count is the greatest number recorded in one survey during the study. This value may represent a time of optimal conditions at GSL for a particular species, or it may be an artifact of other circumstances that affect a species during other parts of its life cycle.

Bird Use Days

The bird use day calculation is useful in considering numbers of birds present at GSL in conjunction with their length of stay. A bird day is defined as one bird spending 24 hours within the study area during the study period. On average, between April and September (170 days) waterbirds spend 86,752,258 bird days at GSL. This number alone illustrates the importance of GSL and its allied wetlands to many waterbird species. This presence includes a range of activities: migratory stopovers, breeding cycles, molt migrations and a portion of year round residency. It is a way to combine observations of species that migrate through the area in large flock sizes (phalaropes) with species that spend much of the year at GSL (gulls), and species of which part of the population uses GSL habitats as a breeding site and part arrives later in the season to stage for fall migration (avocets).

Survey Area Descriptions

Not all survey areas contributed the same level of bird use to the total. Upon review of the Area Accounts it is possible to select areas that a related study could focus on to collect data that would provide very similar results to an all-lake survey, but require fewer resources to complete the task. One of the goals of this study was to develop a less intensive sampling plan that would maintain the same quality of information. This type of approach has been described in some detail in the document titled "A Plan for Monitoring Shorebirds During the Non-breeding Season in Shorebird Monitoring Region Utah-BCR 9 (Great Basin)", and can be found in Appendix 7 (Manning et al. 2002). In no way does this indicate that some of the outlined survey areas at GSL are not of importance to waterbirds. To date, the GSL ecosystem still has large tracts of contiguous wetland habitat, which varies with changes in lake elevation. This expanse of waterbird habitat is likely what attracts millions of migrating birds every year to feed on the abundant food source that inhabits these salt and fresh water systems. The whole is greater than the sum of its parts.

Identification of Important Sites

There were no sites surveyed that did not contribute 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 values depending on lake elevation or drainage flow patterns. There were many sites that had relatively constant high value for a variety of species through the five-year study, such as Bear River MBR. Other areas that consistently had high numbers of birds were Ogden Bay and Farmington Bay WMAs and the Layton Wetlands (West Layton 17 a and b). 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, and the state of emergent vegetation follows the type of available habitat changes. As a result the species present change, and total bird numbers can differ depending on the natural history of the species. North American population numbers are reported in the Species Accounts (Appendix 5). Therefore, total bird numbers are not the only way to judge the value of an area.

One tool that can be used to assess survey areas for important occurrences is the peak number category of Survey Area Descriptions (Appendix 4). For example, data from survey area 34b, East Promontory South, show a five-year mean number of Canada geese to be 1,897, and a peak number of 5,990. The data show high counts in the month of June. These geese appear at East Promontory South with their young in a molt migration and then they disperse. The ratio of peak to mean counts for Canada geese is 3.1 to 1, and for ring-billed gulls it is 1.1 to 1. High ratios seem to reflect high occurrence events or birds that are strongly migratory through the system. Birds that are breeders are more stable in numbers through time, and they generally appear to have smaller peak to mean ratios.

In summary, the best information for assessing areas of importance for waterbirds comes from the Survey Area Descriptions (Appendix 4). This information does not provide occurrence by date, but does provide some numeric values. The information by date is available in the GSL Waterbird Survey database that houses some nine million bird observations for each of the five years. For more detailed analysis, this database is the most comprehensive source for study information. Access to these data may be granted through the Great Salt Lake Ecosystem Program Manager.

Habitat Use

Generally, 1999 was wetter and cooler than 2001. Ducks were more prevalent in the wetter, high lake year, and gulls, phalaropes, recurvirostrids favored the drier, low lake year with its abundant macroinvertebrate halophiles. On a smaller scale, dowitchers favored wetter years with good stands of emergent vegetation surrounding open water, and peep sandpipers took advantage of dry year invertebrates and lots of mudflat habitat.

What we have learned about habitat change was perceived before the five-year study. We assumed that we would see significant variation in habitats and their use due to the terminal lake phenomenon that drives the GSL environments. This, we believed, would certainly be true as lake dynamics-affected shorelines. The 1980s high lake years provided a platform for this assumption as biologists and managers watched entire refuge systems go under water and then reappear as the lake receded. Bird populations reacted to these changes.

What was perhaps not as apparent or forecasted was exactly how individual species would react to change in their geographic and habitat use of the system. The temporal patterns were not well perceived either. This study has brought some of the answers to these questions into better focus and has allowed for a reaffirmation of lake dynamics (see Appendices 3 and 8). For example, Appendix 8 (avocets and stilts) shows avocet and stilt numbers at the end of the summer in 1999 (survey periods 13-17) were abundant in the Bear River MBR region. However in 2001 when that area dried up, avocets and stilts were absent from the MBR and moved to more favorable habitat at the peripheries of Farmington, Ogden, and Bear River Bays. Marbled godwit presence (as mapped in Appendix 8) shows a different response to the change in water level. In 1999, godwits were abundant at Bear River MBR during the mid and late summer survey periods. This is a typical pattern when water is present in the area providing appropriate habitat for godwits. During the last two survey periods of 2001, rather than shifting to another favorable place nearby, the area was dry and godwits left the GSL early.

The 2002 summer was even dryer than 2001. The lake continued to shrink with mid summer lake elevations at 4198' ASL. The landmass associated with south Farmington Bay migrated to Antelope Island near the Fielding Garr Ranch. The Willard Spur was dry again and certainly some bird populations adjusted accordingly. The most apparent habitat characteristic of the ecosystem is the dynamic condition that drives constant change in shorelines, serial stages in emergent vegetation, lake limnology, characteristics and location of colonial nesting substrate, and other habitat conditions.

Comparison of Other Great Salt Lake Surveys

William H. Behle conducted systematic colonial waterbird surveys in the 1930s and again in the 1940s with some follow up in the 1950s (Behle 1958). With the establishment of State and Federal wetland management projects (1930 to present), surveys have been conducted for waterbirds, primarily waterfowl. More recently, starting in 1980 surveys have been conducted at GSL for some migratory non-waterfowl species. The following is a list of key species suites and associate colonial nesting species for which five to 25 years of data are available: American white pelican, eared grebe, snowy plover, Wilson's phalarope, red-necked phalarope, white-faced ibis, California gull, Franklin's gull, black-crowned night-heron, snowy egret, and cattle egret. Of special interest are the survey data that overlap the GSL Waterbird Survey. Data comparisons are provided for five species: American white pelican, eared grebe, snowy plover, white-faced ibis and Wilson's phalarope.

American White Pelican

Each year since 1979 American white pelican breeding adult and projected fledgling data have been collected. These data are acquired by applying a photo survey protocol to the Gunnison Island breeding colony. The Gunnison colony is photographed from an airplane each May 20th, or the closest day to that date possible. Photographs are taken of each sub-colony from which count data are extrapolated to breeding adults. One nest-attending adult represents one pair.

There was a general downward trend in numbers of pelicans observed in the GSL Waterbird Survey through the five-year study. From a high of 85,000 to a low of 9,898; this trend generally reflects the collapse of the local non-game fishery associated with the drought conditions at the end of the study. Field surveyors often observed both fish mortality and loss of shallow water habitat during this time. The Bear River MBR operated at less than 27% of capacity during 2001 (Al Trout, personal communication), and the Willard Spur dried up completely. In 1999 cool, wet spring weather may have also been responsible for some declined use.

Gunnison Island breeding adult numbers have always shown considerable variability between years, but usually there are trends for different sets of years. An up and down cadence of year-to-year variation can be seen in the five-year data set. The year 2000 was interesting for pelican surveys, and illustrates the effect that changes in microclimate can have on the population. The spring of 2000 was ideal for the onset of breeding with reasonable moisture and lots of residual water from the wet 1999 year. However, conditions did not hold, and the summer turned dry and hot. When late summer arrived, the fishery habitats were poor, and pelican counts in August and September dropped as a result. The counts at Willard Spur for survey periods 16 and 17 in September 1999 were 5,921 and 2,176 respectively. During the same survey periods in 2000, the pelican counts at Willard Spur were 116 and 72 respectively. A dry winter, spring and summer followed with diminished numbers of pelicans in the 2001 count year (Figure 10 and Table 13). This figure also demonstrates a peculiar phenomenon; the breeding population of adults was higher than the Waterbird Survey count in 2001. From the conditions of the 1980s high lake years when WMAs were under a meter or two of water, we know that Gunnison Island breeding pelicans were making foraging sorties to American Falls Reservoir, Idaho and Utah Lake. With the numbers of Gunnison Island breeders higher than those at Waterbird Survey areas around the GSL ecosystem, there may have been some overflights of traditional fisheries from GSL to places beyond. For example, we know from satellite telemetry that pelicans fly from Pyramid Lake, Nevada to GSL in the course of a half-day (Fuller et al. 1998).

Figure 10. Graphical comparison of American white pelican data from the Waterbird Survey with the annual breeding population count at Gunnison Island using aerial photography.

Table 13. Comparison of American white pelican data from the Waterbird Survey with the annual breeding population count at Gunnison Island using aerial photography.

American White Pelicans	**1997**	**1998**	**1999**	**2000**	**2001**
Gunnison Island Survey[1]	12,516	14,014	11,702	17,958	12,010
Waterbird Survey period 5 count[2]	no count	1,756	3,224	3,785	1,457
Waterbird Survey peak count	85,834	68,187	51,114	20,404	9,898

[1]A photo survey of sub-colonies on Gunnison Island conducted in May of each year.
[2]Period 5 includes the date of the photo survey.

Snowy Plover

Peter Paton conducted an extensive ecological study of snowy plovers at GSL during the post-1980s high lake years and into the early 1990s (Paton 1994). This study followed Point Reyes Bird Observatory and the Utah Division of Wildlife Resources snowy plover inventories that suggested the snowy plover was prominent on the GSL landscape (Halpin and Paul 1989). Paton continued his snowy plover research in 1997 while under contract with the American Bird Conservatory. He carried out a replicate survey to those conducted in the early 1990s to see if the population had changed with any subsequent changes in the habitat. This survey overlapped the beginning year of the GSL Waterbird Survey. Paton's survey team assisted in collecting all waterbird data for the Waterbird Survey in conjunction with surveying snowy plovers at the Locomotive Springs WMA.

Over seven years of surveying snowy plovers, Paton's studies averaged 1121.8 plovers during peak periods. During the Waterbird Survey (1997-2001) peak counts for each year averaged 670.6. There were two exceptional count years in Paton's study, 1991 and 92. These were transition years when extensive flats occurred that had once been occupied by emergent wetlands but were barren of vegetation as the GSL receded increasing extensive snowy plover and other shorebird habitat. If these two high count years are eliminated from the Paton sample, the difference between averages of Paton's surveys and the Waterbird Survey is considerably less: 670 (Waterbird Survey) and 992 (Paton). The 1997 Paton and Waterbird Survey difference is very small, only nine percent, with numbers of 1,122 and 1,228 respectively (Table 14).

Beyond survey year differences, another influence in higher averages in the Paton sample is the conditions under which the information were collected. Paton et al developed a search gestalt only for snowy plovers. In contrast, Waterbird Survey volunteers were counting all waterbirds encountered. Under this system it becomes more difficult to pay the necessary attention to effectively search for the cryptic snowy plover. Given these conditions the peak counts are not out of line. Also, the survey routes for the Waterbird Survey stayed at 100 yard from the shoreline, and it is likely that in areas where the mudflats were extensive existing snowy plovers were too far from surveyors to be detected. The surveys in 1997 that overlapped may have been close in numbers because of the added emphasis on snowy plover detection by Paton's surveyors who were rolling up their plover observations into the Waterbird Survey.

Table 14. Comparison of snowy plover data from the Waterbird Survey with Peter Paton studies.

Snowy Plovers							
	Paton study						
Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1997**
Number of adults	478	845	769	1344	1501	1150	1122
		Waterbird Survey peak counts					
Year		**1997**	**1998**	**1999**	**2000**	**2001**	
Number of adults		1228	627	584	297	617	

Wilson's Phalarope

Wilson's phalaropes present a survey challenge due to their use patterns of the GSL ecosystem. Starting in June they occur at GSL in large numbers and numbers build until they peak in July (Appendix 5, Wilson's phalaropes). During this time, they aggregate into large flocks (tens to hundreds of thousands) that seem to develop patterns of occurrence that can change between years but remain somewhat constant within a year. These aggregations are usually birds standing on shorelines or in shallow water. During the day these large flocks break up into smaller foraging flocks (hundreds to thousands) that use the open water of GSL to forage brine shrimp and brine flies. They are often dynamic moving from one area of the lake to another. These conditions make surveying difficult from at least two perspectives. Sometimes the large flocks may be missed in aerial survey efforts to cover the 1,500 mi^2 lake and its vast associated shorelines. On the other hand small, mobile, open water foraging flocks are even more difficult to survey accurately because of their constant movements in and out of aerial survey transects. Wave action and cloud cover can exacerbate detection in open water environments.

Even so, there is a general trend shared by the two concurrent and independent surveys studying GSL Wilson's phalarope: the WBS and a one-day aerial survey (Figure 11 and Table 15). One exception to the similar counts found by both surveys is the 1999 annual aerial survey. Here, two possible conditions may have occurred: the aerial survey missed one or more large aggregate flocks, or it missed the peak of migration. The five-year mean peak from the Waterbird Survey occurs during the second week of July. The annual aerial survey occurred on or close to July 29th each year.

Phalaropes are dependent on the two major invertebrates that persist in the GSL when these birds are staging for migration to South America. Due to diluted brines at higher lake elevations and cool, wet weather 1998 and 1999 were years of low GSL macroinvertebrate production. Brine shrimp numbers were so low in Gilbert Bay that the brine shrimp harvest season was closed for that reach of the lake. The difference between the two surveys in 2001 is also interesting. During that year most of the Wilson's phalaropes were located on the west shore near Carrington Island, outside of most Waterbird Survey areas.

Figure 11. Graphical comparison of Wilson's phalarope data from the Waterbird Survey with the annual aerial, all-lake, population count.

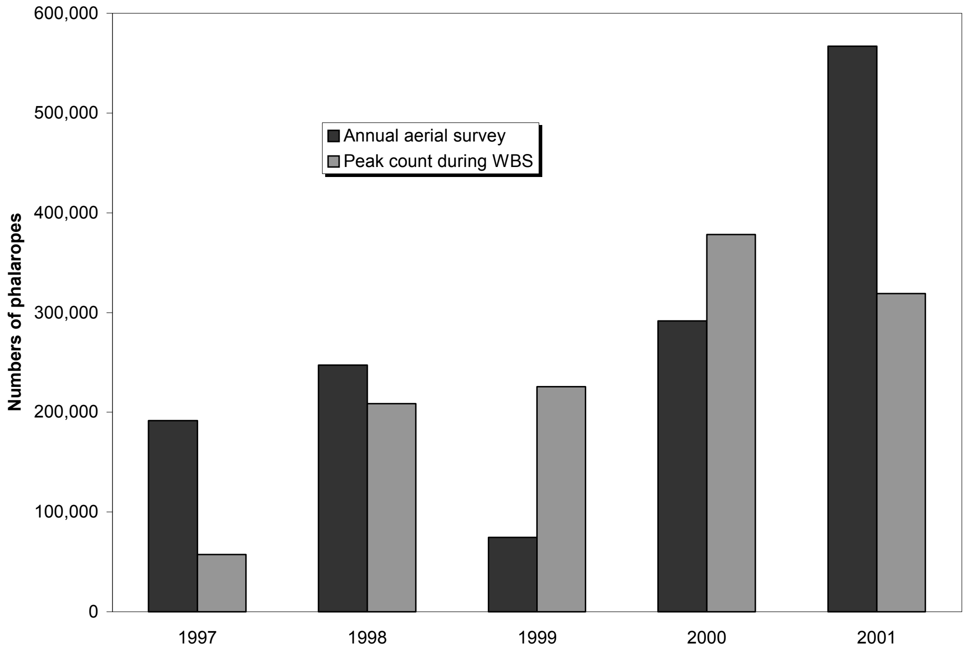


Table 15. Comparison of Wilson's phalarope data from the Waterbird Survey with the annual aerial, all-lake, population count.

Wilson's Phalaropes	**1997**	**1998**	**1999**	**2000**	**2001**
Annual aerial survey[1]	191,733	247,286	74,668	291,671	566,834
Waterbird Survey period 12 count[2]	57,328	17,431	81,478	25,021	242,344
Waterbird Survey peak count	57,328	208,461	225,488	378,292	318,974

[1]A one-day, all lake survey conducted in late July each year.
[2] Period 12 includes the date of the annual one-day survey.

Eared Grebe

For a number of years, an annual eared grebe survey has been conducted during the molting period in October. This is a stratified photo survey that has been developed in cooperation with Hubbs Sea World Research Institute and the Canadian Wildlife Service (Boyd and Jehl 1998). Survey areas are georeferenced, flown by a series of transects, and photographed at intervals. The mean number of birds counted per unit area is used to extrapolate to the GSL population size. A portion of the fall eared grebe population falls within the GSL Waterbird Survey boundaries of Ogden and Farmington Bays, with another small proportion inhabiting the Bear River Bay system. However, the majority of the fall population occurs outside the Waterbird Survey boundaries in open lake water between Antelope and Stansbury Islands, around the Carrington and Hat

Island complex, and extending up the west shore and north and west of Antelope and Fremont Islands. Because of this fact and the differences between survey techniques, comparisons between the two surveys are difficult (Figure 12 and Table 16). Also, the data from 1998 and 1999 reflect the absence of brine shrimp adults in the water column. This is important because when eared grebes are present at GSL, 99% of their diet is comprised of adult brine shrimp (UDWR unpublished data).

Figure 12. Graphical comparison of eared grebe data from the Waterbird Survey with the annual population estimate using aerial photography.

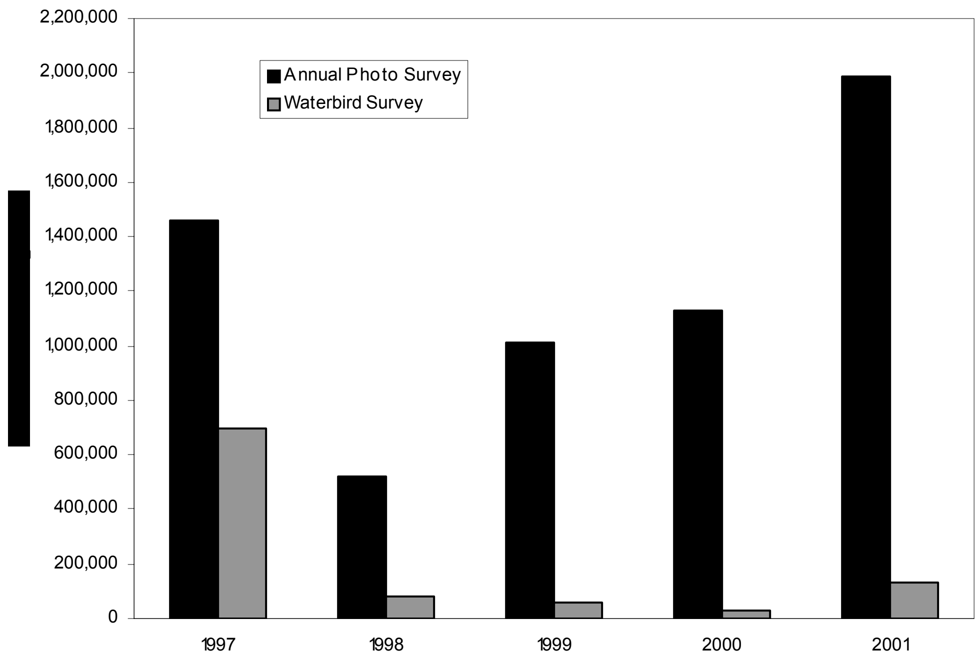


Table 16. Comparison of eared grebe data from the Waterbird Survey with the annual population estimate using aerial photography.

Eared Grebes	**1997**	**1998**	**1999**	**2000**	**2001**
Annual Photo Survey[1]	1,460,151	522,287	1,008,656	1,127,307	1,987,564
Waterbird Survey	698,793	80,541	60,499	28,893	130,473

[1]Adjusted estimate. Survey conducted in mid-October of each year.

White-faced Ibis

Concurrent with the Waterbird Survey, colonial waterbird surveys were conducted for known colonies of species using emergent wetlands (Paul et al 2000b). This included white-faced ibises that often nest in conjunction with several other species. Franklin's gulls, black-crowned night-herons, Forster's terns, snowy egrets, cattle egrets, and a few others were frequently located together. The target of the colonial waterbird survey was to assess the number of breeding adults in the colony. The comparative Waterbird Survey data for the same years are uniformly higher and should be, as they include non-breeding adults, sub-adults, and hatching year birds in the count. However, the trends are similar between the two data sets (Figure 13 and Table 17).

Figure 13. Graphical comparison of white-faced ibis data from the Waterbird Survey with the annual colonial waterbird breeding survey.

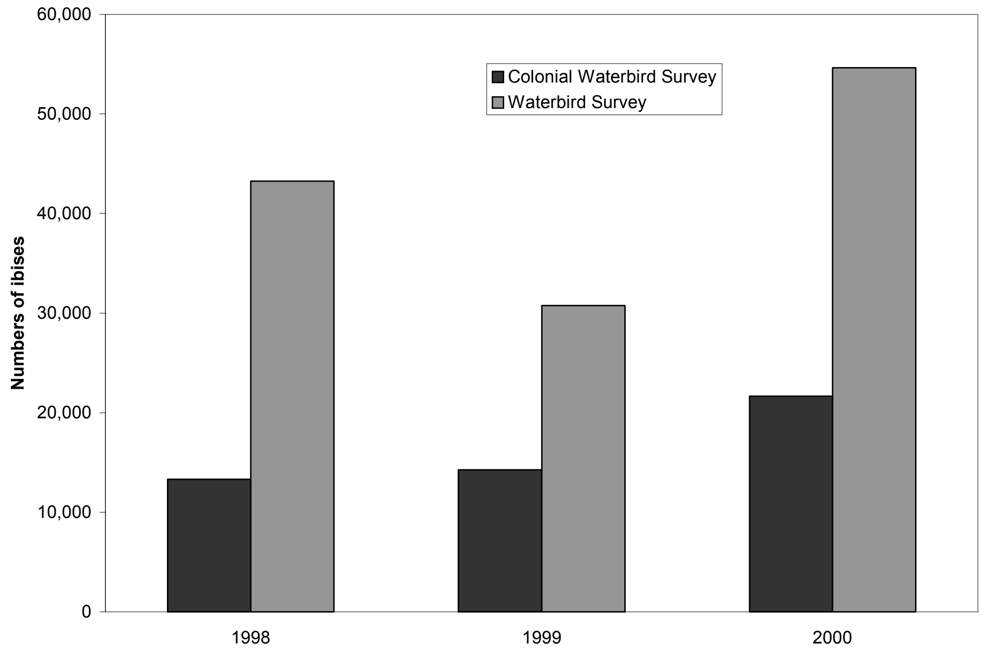


Table 17. Comparison of white-faced ibis data from the Waterbird Survey with the annual colonial waterbird breeding survey.

White-faced Ibises	1997	1998	1999	2000	2001
Colonial Waterbird Survey	no count	13,294	14,260	21,664	1,896
Waterbird Survey peak count	47,577	43,265	30,779	54,634	34,854

Management Implications

Implicit in the primary study objectives is the need to understand species habitat relationships for more effective management and stewardship. Many of the data analyses, if not all, were developed and executed to assist local resource managers in making wise and cogent decisions for a long term, sustainable GSL ecosystem. This study, basically a systematic inventory, and its database were used to gather and store data from which specific questions can be queried. Through some analyses, we have answered questions that will assist managers and decision makers as they seek to protect and conserve GSL resources. Some of these analyses follow.

Georeferenced Survey Areas

At the onset of the study, survey areas were delineated in discrete units with physical descriptions. These areas were placed into logical blocks that comprised similar resource areas (i.e., WMAs, stretches of shoreline, open water, islands, etc.). Later the database manger, with the assistance of Dave Mann and other UDWR GIS staff georeferenced each survey area. Then, survey areas where sampling was conducted were further refined to a percent of the area that was actually covered by survey effort. This process allowed for inter-area contrast through the application of population and species density comparisons (Appendix 4). Geographically referenced sites also allow resource managers to combine adjoining sites, or even similar habitat types that are not joined for evaluation. This can be either a quantitative or qualitative tool for comparative analyses on prioritizing conservation actions.

Survey Area Descriptions

Survey Area Descriptions may be the single most important source of information to evaluate on-the-ground bird presence in specific locations (Appendix 4). This is the density information by species. These data should be used with the knowledge that since it is an average of 77 surveys over five years, a five-year mean is a strong number with considerable comparative value. These years represent a good variation of wet and dry conditions, and reflect past times of lake fluctuation of five feet in elevation. On the other hand, the extreme situations are tempered in mean data, and therefore, it is of value to examine individual years and survey periods to get a clearer picture of what might happen under specific circumstances. There are times in a survey area when a species or suite is notably present, without an understanding of why that is the case.

Other information that may be of import to resource managers is species diversity. In this report, species diversity is defined as the number of species occurring in an area in high presence values. These individual area accounts will provide information on coverage by year and some comments on survey detection rates.

Species Accounts

This report presents Species Accounts for the majority of species identified during the Waterbird Survey (Appendix 5). Due to small data size or irregular occurrence, however, there are some species excluded. The information is presented in order to help resource managers grasp the importance of the GSL population compared to the North American and/or global populations where numbers were available. A graph of the mean five-year counts by survey period provides information on seasonal presence. Perhaps of greatest value in importance assessment for habitat use is in the species distribution plots georeferenced to a GSL map. This map reflects an over all area habitat use value of the five-year mean. This might be the answer to general questions like "which area(s) is most important for American white pelicans." The answer from the map is the Bear River Bay complex, and is true if you roll all survey periods into one mean; but without Gunnison Island (the breeding colony) for a substantial number of these pelicans using the Bear River system, this map would be altered significantly. To assist in the evaluation of areas important to species use at GSL, it will be important to inspect the specific Survey Area Descriptions (Appendix 4) and to consult the Species Distribution by Survey Period section (Appendix 6). These analyses and others in the report will help develop a more precise picture of bird use of the GSL.

The pelican example brings to light the observation that breeding populations in the area sometimes influence the Waterbird Survey data for specific areas, regions and populations of the lake. Breeding populations were not accounted for in this study. The only time breeding populations are considered is in some of the narrative of specific Survey Area Descriptions. Yet, colonial nesting populations and loosely associated nesters (i.e., American avocets were frequently associated with survey areas and routes) did influence counts in many areas. There was no attempt to avoid them; they were counted uniformly across the landscape along with non-breeding populations.

Species Distribution by Survey Period

Information important during different periods of the survey season is available here. This information represents a five-year mean for each survey period (1-17). These temporal data are important to evaluating seasonal use of each species. Cinnamon teal distributions through time is prominent in the Bear River Bay during the early to mid survey periods (April-July), and becomes equally or more important in the Ogden and Farmington Bay WMAs at the end of the season (August-September).

The vast majority of marbled godwits are located in the Bear River Bay system through both the spring and late summer use periods. Managers considering the GSL's role in godwit conservation need to pay close attention to the Bear River MBR and the Willard Spur systems. Why birds occur at certain times in specific places is a question not answered for most species in this study.

Migration Chronology

This report provides a migration chronology similar to the information on presence status in Birds of Utah (Behle and Perry 1975), but refined for GSL (Table 6). Habitat managers and biologists are often requested to provide recommended windows of time for development or potential disturbance activities. These "best time, worst time" requests are difficult without systematically collected temporal data. Therefore, this migration chronology should assist resource mangers in designing best-case scenarios.

Shoreline Conservation

The numerous shoreline survey area data sets confirm the critical role that GSL shorelines habitats play for a variety of species for most phylogenetic groups in the GSL ecosystem. Several of the analyses provided in the report can assist in the understanding of shoreline habitat characteristics and values.

Point sample data are the only information describing habitat use by waterbirds in the study. These data are summarized for the high lake study year, 1999, and the low lake year, 2001, only. Mean bird counts are compared by suite, habitat type, and year. Charts compare mean bird counts for all habitat types combined for 1999 and 2001. Due to the dynamic condition of the shoreline, which is an important value and phenomenon in lake avian ecology, this information should be used to predict bird use at different elevations and for developing shoreline management strategies. The data collected in this study makes clear the critical role shoreline fluctuations play in bird and wetland succession. For this reason, shorelines should be allowed to expand and contract through their full range with minimal anthropogenic developments.

When point samples were established at GSL in 1997, certain randomly selected points were put in place to compare with bird use data collected from non-drainage points. The comparison between these two point sample types is difficult because we do not have good flow rates at drainage points. Some were established where irrigation returns enter the GSL; flow regimes are difficult to measure at these sites due to the intermittent flows associated with agriculture water systems. In some cases drainages were discontinued altogether, and the drainage point sample became a non-drainage point in terms of presence of water and bird use.

Managed Wetlands

Until this study, there had not been an effort to collect coordinated data between wetland managers (State, Federal and non-profit). With this study, wetland managers will be able to determine which species and for which time of year their management areas are important. The data will also make coordinated conservation actions between management areas a more viable possibility. These data provide some information on species values by area that can assist managers in developing management practices that best suit their areas and intrinsic habitat values.

In addition to total count data, most State managers incorporated area counts into their sampling program during the study. These area counts were conducted in defined sites, bounded by dikes or other borders, that have or could be georeferenced to compute density data for comparison. The area counts assess the area in the same way that occurred in point samples. Area counts were suggested as a tool for managers to use in assessing treatment values to the area. These could include controlled burns, drawdowns and flooding, and chemical treatments. The study allowed the managers to choose area count sites within their sampling scheme. This approach was developed for managers to use as a tool and not as an element to be analyzed in this report. Data were provided annually to managers for their use. The use of this technique can be applied in time and is suggested as a possible evaluation tool for future treatments.

The data sets for managed areas are among the richest in species composition and numbers of birds that occurred in the five-year study. The individual and collective data sets for emergent vegetation survey areas, the species accounts, and chronological bird data are some useful tools to consider for managers.

The Great Salt Lake

Bird use of the GSL is substantial but varies by area, time of year, and lake elevation. The three open lake regions of the GSL that were surveyed, Farmington Bay, Ogden Bay, and Bear River Bay, each offer significant avian values. Managers can assess the values by examining the individual Survey Area Descriptions (Appendix 4).

Managers should carefully consider shoreline associations of each of these lake regions. Lake elevation should also be considered when evaluating annual data. Most of the data are represented as a five-year mean, but there is a sample of high and low lake elevation, 1999 and 2001 respectively, in the Appendix 8. There is also a high and low lake year data set for GSL shoreline use as described through point sample data (Appendix 3).

Important to the Farmington Bay region is the occurrence of large sandbars in the south part of the bay between the mainland and the southeastern portion of Antelope Island and south of the Great Salt Lake Shorelands Preserve. These formations are two of the most dynamic features at GSL. Carefully consider bird data in this area by lake elevation. An interesting pattern of bird use occurs at different lake elevations in the Layton Wetland complex as well.

Within the study area, East Gilbert Bay is the primary producer of brine shrimp and is an extension of the main Gilbert Bay where the vast majority of brine shrimp are produced. This area is also affected by lake elevation, but not in the same way as Farmington Bay. Here, WMA dikes at Howard Slough and Ogden Bay are submerged when GSL is above 4202' ASL. Managers should pay attention to lake elevation and brine shrimp and fly production when evaluating bird data in this area. These is no current brine fly monitoring at GSL, but the Great Salt Lake Ecosystem Program files have good brine shrimp harvest and density data since 1996. Great Salt Lake elevation records generally correlate to brine densities, and these data are available through Utah Geologic Survey, Utah Department of Natural Resources.

The Bear River Bay region is an intermittent fishery and the associated waterbird presence is profoundly influenced by the fishery condition. The most extensive wetlands occurring outside management areas occur here. When there are low flows in the Bear River and the GSL is at 4200' ASL or below, the fishery in the Bear River Bay and Willard Spur is dysfunctional. When flows are average or greater and elevations are at 4202' ASL or higher, there is a consequential fishery and piscivorous bird presence in the area. The difference can be tens of thousands of birds. During the dry climate condition, much of the outlying emergent wetlands are dry. During wet cycles robust emergent waterbird colonies are present; some colonies are the largest in western North America. These are especially important to white-faced ibises and Franklin's gulls. Here again five-year mean data are of value but particular attention should be paid to individual year records measured against Bear River flows and lake elevation.

Habitat and Population Modeling

Some modeling of habitat and potential species presence exists using the database and this report. Because this study was an ecosystem based systematic survey that covered all prominent habitats, modeling is a real possibility. This survey can be used to refine the model that is currently in place to assess brine shrimp harvest impacts on avian resources.

Conservation Planning

This data set and subsequent report provide a foundation of biological and habitat information for conservation planning within the ecosystem. The surveys took place over several years and during five feet of vertical lake elevation change, and provide a reasonable picture of how the lake is used by waterbirds under a variety conditions, and through much of recorded lake elevation history. However, it is important to remember that extreme events did not occur during this survey. Extreme events (i.e., historic lows and highs) can have dramatic effects on wildlife populations and their habitats.

This information will also be useful in evaluating existing plans such as the Utah Department of Natural Resource's GSL Comprehensive Management Plan, regional and national shorebird and waterbird plans, and Intermountain West Joint Venture Focus Area plans. The draft GSL Shorebird Plan will perhaps benefit the most from this data set as it validates assumptions and offers new information. The GSL Waterbird Survey Report will be helpful in defending the 23-21-5 designation authorized by the Utah state legislature that allows for wildlife management primacy in several sections of State land within Farmington, Bear River, Gilbert and Gunnison Bays.

The information collected in this study is already being utilized with the Western Shorebird Survey. This survey is a subset of data being collected to monitor national and continental shorebird populations. Utah was one of the first states to come on line in the Western Shorebird Survey with survey sites, surveyors and data sets already in place. This web-based approach to data collection is unique in the western shorebird monitoring community.

This study with its impressive bird numbers and demonstrative species value should be used to emphasize the importance of the system to communities and their leaders. Bird use days, peak populations and the strength of the five-year mean data are selling points from Syracuse, Utah to Washington D.C. These data validate the anecdotal observations and less robust data sets by describing in more detail, with greater accuracy and more reliable data, the value of the GSL in the Western Hemisphere setting. This story should be told.

Recommendations

The data reported in this document are valuable to many entities around GSL and other organizations nationwide, and have been already shared with such groups while the study was ongoing. But 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. As the GSL is a dynamic system, long-term data collection is even more important, to blend lake flooding and receding cycles into larger scale population trends (Table 18).

Now that a baseline inventory of waterbird species around GSL has been completed, it is recommended that future efforts reduce the scale of study and focus on areas of high waterbird use as outlined in the document, "A Plan for Monitoring Shorebirds During the Non-breeding Season in Shorebird Monitoring Region Utah-BCR 9 (Great Basin)" (Manning et al 2002). Intensive survey work at the species level would also be valuable for those species that may not have been well detected through the Waterbird Survey protocol. For example, snowy plovers are small and cryptic, and are not located near the shoreline all of the time. Because Waterbird surveyors stayed 100 yards from the shoreline they may have missed plovers distributed on an expansive mudflat. A more concentrated area search at all appropriate habitat types would yield a more accurate number of snowy plovers at GSL. The same applies for other species.

If a similar inventory using volunteer help is planned, we make the following recommendations. To minimize the variation in skill levels between surveyors, provide ample training for volunteers. This is 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 could not be used. Survey routes should be limited to that which can be covered in 2 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. The coordination of this effort should be an element of the Utah All Bird Committee and the Utah All Bird Plan.

The Western Shorebird Survey is already in place, and Utah is organized and cooperating in the 2002 season. This commitment should be considered in developing survey schedules. (Complete by February 2003.)

The GSL shorebird planning effort should be revisited using the GSL Waterbird Survey five-year data set as a conservation and implementation tool. This plan should be completed with the involvement of the primary land managers associated with the GSL shoreline and water bodies as proposed in the draft plan. (Complete by April 2004.)

Community based data collection and data use were sub-objectives of the Waterbird Survey, and given this element, the database should be provided to cooperators for their use in conservation actions. It is recommended that electronic copies of the database be provided to the sponsoring institutions of Waterbird Survey team members. In addition, this report should be made available in hard copy to each Waterbird Survey team member, each sponsoring institution, and the organizations listed in the Acknowledgements. This report should be for sale in hard copy format in the Utah state of Utah Department of Natural Resources bookstore. We also recommend that this report be produced in an interactive format on CD-ROM and made available through the bookstore and at the Northern and Central UDWR regional offices. This format should also be put on the UDWR website through the Great Salt Lake Ecosystem Program link.

The Paradox database should be appropriately archived in three or more locations to help insure its preservation through time. Copies should be housed in the Aquatic Section, GSLEP, the Wildlife Section, Habitat section, non-game bird coordinator's office, and the waterfowl management coordinator's office.

Table 18. Recommendations for further waterbird study at GSL and volunteer participation.

For continued study of waterbirds at Great Salt Lake:

- Continue to monitor migratory bird populations at GSL.
- Some species may require specialized survey methods (e.g., snowy plovers).
- Develop a schedule for survey work through time, coordinating monitoring protocols describe in bird management plans.
- Make data available to local and national managers, conservation planners and research biologists.

For volunteer participation in survey work:

- Provide ample training for volunteers.
- Keep survey protocol simple.
- Survey routes should be limited to that which can be covered in two hours.

Acknowledgements

This data set and report would not have been completed without the contributions of many people. We thank Clay Perschon, Great Salt Lake Ecosystem Program Leader, UDWR for enthusiastically supporting this project. Other UDWR personnel who contributed to the organization and analysis of data are Greg Evans, Paul Birdsey and Kirk Poulsen, database design; Frank Howe, Russell Norvell and Dave Mann, study design and data analyses; Mark Davidson, and Jim VanLeeuwan, equipment maintenance. Steve Biggs, Clair Schaffer and Craig Hunt piloted us safely back and forth across the lake for our aerial surveys. Seasonal employees were invaluable in their participation in survey work and data entry. Thanks to Joel Flory, Elizabeth Annand, Henry E. Ford, Shelly Kremer, Lindsey Dewey, and John Neill. John Neill also contributed to the compilation of several of the data tables found in this report.

Wallace Gwynn, Utah Geological Survey, provided important data regarding GSL elevation and salinity. Jonathan Bart, USGS, was helpful in providing data analysis consultation. Some financial support was received from USFWS, in addition to editorial comments from Suzanne Fellows and Karen Lindsey. Antelope Island state Park personnel were generous in their contributions of office space for project managers, equipment storage and survey participation. Farmington Bay WMA managers also kindly allowed us to store equipment at their facility and participated in the survey effort. We appreciate the enthusiasm and willingness to participate in this study of other state, Federal and private and corporate site managers. Many private landowners graciously allowed project volunteers access on their properties for surveys. We especially thank our cadre of volunteers who braved the sun, rain, wind and muck to count birds 17 times a year for five years (Table 19). Their effort was enormous and a project of this scope could not have been completed without their participation. We appreciate their support, friendship and respect for Great Salt Lake and her waterbirds.

Table 19. Great Salt Lake Waterbird Survey participants. This list is unfortunately not all-inclusive. There are several people not on this list that gave time and effort to contribute to this study and our records did not capture their names.

Albanese, Gene	Halliday, Karen	Neptune, Dawn
Anderson, Kathy	Harvey, Adrienne	Neville, Ann
Annand, Elizabeth	Hatch, Jolene	Norvell, Russell
Armantrout, Hank	Hayness, Michelle	O'Brien, Deedee
Bachman, Val	Henry, Adonia	O'Connell, Ann
Ballard, Leanna	Hill, Melissa	Oliver, George
Bates, Steve	Hillard, Ryan	Orton, Kay
Beeny, Lance	Hooker, Lori	Packer, Nate
Beeny, Tara	Howe, Frank	Parrish, Jim
Berger, Randy	Hudman, Chris	Paul, Don S.
Beyer, Senta	Huntington, Bob	Pearce, Ann
Birdsey, Paul	Jancart, Susan	Pearce, Maunsel
Bloch, Yvonne	Jochum-Natt, Stephanie	Perschon, Clay
Brown, Chris	Johnson, Bruce	Peterson, Cheryl
Bruner, Sue	Johnson, Richard	Peterson, Joel

Bryner, Yae
Butler-Curl, Jaimi
Cady, Candace
Caldes, Clair
Carpenter, Gordon
Case, Bill
Catchelin, Adrienne
Chase, Dan
Chelminski, Michael
Christiansen, Lynn
Ciak, Penny
Clapier, Dave
Clark, Alan
Cline, Chris
Collins, Dennis
Currie, Vera
Darnall, Nathan
Davidson, Jenny
Davidson, Mark
DeFreitas, Patrick
Dewey, Lindsey
Dick, Ann
Dolling, Justin
Douglass, Phil
Evans, James
Ewing, Louise
Fletcher, Bonnie
Flory, Joel
Ford, Henry
Freeman, Terry
Frokjer, Chris
Gardiner, Kirk
Goodell, John
Gray, Bill
Gray, Sylvia
Hall, Chauncey
Hall, Emily
Johnston, Dan
Johnston, Laura
Jorgensen, Ray
Kadesch, Margot
Kearl, Debbi
Kearl, Rick
Kelly, Patrick
Klein, Kimberly
Koch, Brandee
Kramer, Pam
Kremer, Shelly
Larsen, Elizabeth
Laurila, Pamela
LeBer, Jeanne
LeBlanc, Cecile
Lee, Dave
Light, Avis
Light, Jim
Lindsey, Karen
Loeffel, Leslie
Low, Blair
Luft, John
Magasich, Phil
Manes, Sam
Manning, Ann
Marden, Brad
Markin, Melanie
Martinson, Wayne
Martz, Maxine
Melcher, Jaye
Merola, Paul
Mills, Mike
Natt, Mark
Neff, Darcie
Neill, John
Nelson, Marie
Reed, Rick
Roletto, Jan
Roundy, Steve
Roy, Vickie
Rudman, Jill
Ryburn, June
Saenz, Joe
Saffle, Sue
Sherman, Kevin
Slaughter, Danielle
Smith, Bill
Smith, Harold
Smith, Margaret
Sorensen, Ella
Stafford, Cindy
Stauffer, Jim
Sterner, Shannon
Stroup, Yvonne
Swartzfager, Marsha
Szczypinsky, Mark
Torres, Maria
Torrey, Jack
Trimmer, Edie
Tripp, Tom
Tropea, Kim
Warchol, Glen
Warrick, Curtis
Watson, Alan
Watts, Ardean
Welty, Todd
Werner, Ron
White, Mel
Wood, Mike
Wyss, Larene
York, Elaine
Zuby, Kris

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