Preface

When thinking about Great Salt Lake, it is easy to think in superlatives, after all it is the largest saline lake in North America. Great Salt Lake's immense size leads to other superlatives. The largest concentration of wetlands in the state (75% of the total) provides an incredible abundance of habitat and food resources and that draws 10 million birds from 338 species. It hosts the most breeding California gulls and snowy plovers in the world, the most American avocets and black-necked stilts across their range during the fall staging period, and, some years in the fall, nearly the whole North American population of eared grebes. The lake also supplies most of the magnesium produced in North America, produces the most sulfate of potash in North American, and provides most (40%) of the world's supply of brine shrimp eggs.

Without the foresight of managers and biologists, we wouldn't know much about the bird life at Great Salt Lake. Its size presents a challenge to study and monitor over the long-term. The Utah Division of Wildlife Resources created the Great Salt Lake Ecosystem Program in order to study aquatic and terrestrial life at Great Salt Lake and its relationship to the commercial harvest of brine shrimp cysts. Studying the ecosystem as a whole allows informed and adaptive management of the brine shrimp harvest.

Starting in the summer of 1997, one year after the creation of the Great Salt Lake Ecosystem Program, an ambitious five-year survey of all waterbirds began on the lake. More than 150 volunteers, staff, and other agency personnel, surveyed 51 sites 17 times from April through September each year. Surveyors collected information on the waterbird species present on the landscape including their numbers and distribution, timing of arrival and departure in the spring and fall, and habitat preferences, all in relation to the annual rise and fall of Great Salt Lake. The results and a report of the Great Salt Lake Waterbird Survey are found on the Great Salt Lake Ecosystem Program's website.

Being a terminal lake, the elevation of Great Salt Lake historically has risen two feet in the spring from precipitation and runoff and falls two feet during the summer and fall from evaporation. Drought conditions following the five-year survey spurred additional waterbird surveys starting in 2004 to capture the effects of lower lake levels on waterbird populations and establish a sustainable, long-term monitoring of waterbirds at Great Salt Lake, which still continues today.

In collaboration with National Audubon Society's Saline Lakes Program, 21 years of waterbird survey data from 1997-2017 have been standardized and summarized to provide a long-term perspective on the timing and distribution of bird communities at Great Salt Lake. These 21-year summaries are presented in six new appendices formatted similar to the appendices from the original five-year report. The appendices are accompanied by this preface, an introduction, and study objectives.

In addition to the six new appendices, GSLEP and National Audubon analyzed the 21-year dataset to examine bird trends and to quantify relationships between bird counts and hydrology conditions. These analyses are summarized in two manuscripts. The first manuscript, titled "Twenty-one Year Trends for Shorebirds, Waterfowl, and Other Waterbirds at Great Salt Lake, Utah," was published in the journal Waterbirds in February 2023. It describes spring and fall population trends of 35 migratory waterbird species or taxonomic groups for 24 survey areas considered as a whole and

individually. The second manuscript, "Hydrology Affects Shorebirds, Waterfowl, and Other Waterbirds at Bear River Bay, a Globally Important Bird Area," was published in November 2021 with open access in the Journal of Field Ornithology. It models and details the importance of both spring and fall surface water flows in Bear River Bay to 35 migratory waterbird species or taxonomic groups.

Audubon's Marcelle Shoop, Brian Tavernia, and Tim Meehan were critical in initiating and developing a new analysis of the Great Salt Lake Waterbird Survey dataset. Without the vision and implementation of the first Great Salt Waterbird Survey by Don Paul, Ann Manning, and Clay Perschon, this long-term dataset and analysis would not have been possible.

Introduction

Some of the first lake-wide surveys of waterbird species at Great Salt Lake began in 1982 with separate fall migration studies of phalaropes and eared grebes. A comprehensive survey of breeding California gulls followed in 1984, and, interestingly, the Los Angeles Department of Water and Power contracted these studies to get a better understanding of how water diversions from the creeks entering Mono Lake in California can have range-wide effects on certain bird species that rely on saline lakes.

These early studies showcase the unrivaled importance of Great Salt Lake and Mono Lake to migrating and breeding waterbirds. Over 90% of the eared grebe population in North America stages at only these two saline lakes during one of the latest fall migrations for birds (Jehl 1988; Jehl et al. 2002). Beginning in August, grebes stage and feed almost solely on brine shrimp to fatten up, molt, and then continue their migration south in December. Wilson's phalaropes visit both lakes as well, feeding on abundant brine flies. Numbers of Wilson's phalaropes exceed half a million at Great Salt Lake and dwarf the numbers seen at any other location in the United States, even the tens of thousands at Mono Lake. Wilson's phalarope numbers alone qualified and led to the designation of Great Salt Lake as a site of "Hemispheric Importance" within the Western Hemisphere Shorebird Reserve Network in 1991. For California gulls, Mono Lake hosts the second largest breeding concentration in the world eclipsed only by Great Salt Lake.

Avian connections between Great Salt Lake and Mono Lake do not stop with only these three species, nor do they stop at only two saline lakes in the West. With the ability of flight, birds travel throughout the West to migratory stopover locations and breeding sites with some traveling thousands of miles each year and tens of thousands of miles over a lifetime from as far as the Arctic to the southern tip of South America. Connections, like Great Salt Lake, between breeding and wintering grounds are vital for birds and act as an expansive rest area, gas station, and restaurant all rolled into one. Forty-two species of shorebirds, 38 species of waterfowl, and 58 other waterbird species, all rely on Great Salt Lake.

These lake-wide studies of individual waterbird species led, in part, to the creation of the Great Salt Lake Waterbird Survey as a means to measure the significance of all waterbird species that rely on Great Salt Lake. The Waterbird Survey continues to quantify the importance of habitats at Great Salt Lake to individual migratory bird species that would otherwise be unknown. The new information summarized in this report and the new appendices expands on the first five years of data and bolsters our knowledge with an additional 16 years of data. Great Salt Lake water levels fluctuate over time and the habits of birds changed in response. The new analysis provides a more complete and

comprehensive picture of the spatial and temporal patterns of waterbirds over time particularly in a period of extended drought and lower lake levels as compared to the original five-year survey.

Study Objectives

A concern with many scientific studies is the lack of annual monitoring data needed for undertaking the development of a long-term trends analysis with the requisite statistical analyses to provide meaningful understanding of trends. Long-term trend studies are rare due to available long-term funding sources, as well as staff limitation and institutional commitment and knowledge to maintain a long-term study. At Great Salt Lake, many of those limitations have been overcome. Since the initial study from 1997-2001, the Great Salt Lake Waterbird Survey developed into a long-term monitoring effort for studying the waterbird populations of Great Salt Lake following two, stepped reductions in survey effort and coverage. The study's objective remains unchanged:

> Determine for the migratory waterbird species using the Great Salt Lake Ecosystem, an estimate of the population during the migration period, their periods of use, location, and habitat characteristics plotted against GSL elevation.

The five-year waterbird survey used detailed point sample counts to characterize which suites of waterbird species use which habitat at Great Salt Lake. Since these data likely do not change much over time, point sample counts were discontinued after 2001 once the habitat preferences of these waterbirds were determined. These data are found in Appendix 3 of the five-year report.

The target species are the same for each of the three phases of the Great Salt Lake Waterbird Survey. They include all waterbird species from the taxonomic families *Anatidae*, *Podicipedidae*, *Rallidae*, *Gruidae*, *Recurvirostridae*, *Charadriidae*, *Scolopacidae*, *Laridae*, *Gaviidae*, *Phalacrocoracidae*, *Pelecanidae*, *Ardeidae*, and *Threskiornithidae* (see Appendix 1B for a complete list of all detected species throughout the 21-year data set). Five other appendices are included in the new 2022 report and attempt to mirror the appendices from the original *Great Salt Lake Waterbird Survey Five-Year Report (1997-2001)* in appearance and function but use 21 years of data instead of five. Appendix 2B documents the details on the Waterbird Survey's background, harmonization of the 21-year data set for the 24 selected survey areas, production of the new appendices (additionally 4B, 5B, 6B, and 8B), and a caution regarding the comparison of the two sets of appendices.

Development of the harmonized dataset for the 21 years of survey data provides a more complete and robust picture of the waterbird populations and their spatial patterns at Great Salt Lake as compared to the original five-year survey. However, bird survey data from 2018 through 2021 have not yet been analyzed and at least two of the years during this period experienced some of the lowest water levels seen at Great Salt Lake, particularly in 2021 when the lake reached its lowest level in recorded history. Future analyses of the additional data may give us further insight in to the relationship of water flows and bird usage around areas of the lake.