Coordinated phalarope surveys at western North American staging sites, 2019-2021

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Cover photo: Wilson's Phalaropes at Mono Lake, July 2021, by Samuel Rapp

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Summary

Wilson's and red-necked phalaropes (*Phalaropus tricolor and P. lobatus*, respectively), have poorly understood conservation statuses. These species breed in mid- to northerly latitudes of North America and migrate to saline lakes in western North America, where Wilson's phalaropes double their fat reserves and molt before migrating to South America, and red-necked phalaropes stop for an unknown amount of time to feed and continue on their southward migration. Saline lake habitat is threatened worldwide by water diversion and climate change, so there is an urgent need to better understand the populations trends and flexibility of staging site selection of the phalaropes that rely on them. We conducted coordinated monitoring of western North American staging areas of historical importance to phalaropes: Great Salt Lake (Utah), Mono Lake (California), Lake Abert (Oregon), Owens Lake (California), south San Francisco Bay (California), and Chaplin Lake (Saskatchewan). We conducted surveys at each site during week-long "survey windows," from mid-July to mid-September, 2019-2021, with the goal of at least one survey per site per window. Methods were standardized within sites but varied across sites because of different conditions at each lake. Methods included plane-based, boat-based, and land-based surveys. We report results from Great Salt Lake, Mono Lake, and Lake Abert in 2019 and for all surveyed sites in 2020 and 2021. We report totals of unidentified phalaropes along with the species-specific totals counted for the same window, to account for the impact of unidentified birds on interpretation of results.

The maximum annual counts in a single survey window for Wilson's/unidentified phalaropes was 370,770 in 2019 (Great Salt Lake, Mono Lake, Lake Abert only), 236,452 in 2020, and 295,902 in 2021. Notable results for Wilson's phalaropes were the decrease in overall numbers in 2020, and an increase in 2021 at Mono Lake of approximately 30,000 birds compared to the previous two years. It is unclear why this increase at Mono Lake occurred, but it was concurrent with the virtual drying up of Lake Abert, suggesting a potential movement between sites based on environmental conditions. The maximum annual counts in a single survey window for red-necked/unidentified phalaropes was 296,731 in 2019 (Great Salt Lake, Mono Lake, Lake Abert only), 124,048 in 2020, and 161,804 in 2021. Similar to Wilson's phalaropes, red-necked phalarope numbers were lower in 2020 than in the other two years, and during 2021 more red-necked phalaropes were recorded at Mono Lake than previously in the study. There is a need for continuing standardization of survey methods across sites, research on phalarope movements among sites and residence times at sites, and attention toward the issue of interpretation of unidentified phalarope counts. Continued monitoring will help us understand phalarope population trends, migratory patterns and timing, and response to climate and environmental factors, and will provide a valuable indicator of the health of saline lake ecosystems.

Introduction

Wilson's and red-necked phalaropes (*Phalaropus tricolor and P. lobatus*, respectively) are iconic species of saline lakes in the interior west of North America, where hundreds of thousands of individual phalaropes stop each year. The conservation statuses of these phalaropes, however, are poorly understood (Lesterhuis and Clay 2009, Rubega et al. 2020). This data gap is largely due to the difficulty of counting these unusual shorebirds that spend much of their time swimming far from shore on large lakes. Many saline lakes are existentially threatened by water diversion and climate change (Larson et al. 2016, Moore et al. 2016, Wurtsbaugh et al. 2017), so there is an urgent need to better understand the population trends of the phalaropes that rely on them. Indeed, the National Audubon Society considers the Wilson's phalarope "climate endangered" (Langham et al. 2015) and the red-necked phalarope "highly vulnerable" (Wilsey et al. 2019) to climate change related habitat loss.

Phalaropes breed in mid- to northerly latitudes of North America, and during southward migration hundreds of thousands of Wilson's and red-necked phalaropes stop at hyper-saline lakes in western North America (Jehl 1986, 1988). Smaller numbers of phalaropes are also seen at wetlands across a broad geographic front in western North America, and whether and how either species' movements vary seasonally or annually is unknown. The majority of the world population of Wilson's phalaropes is believed to stop over at North American saline lake staging sites (Jehl 1999). The North American red-necked phalarope population uses a greater diversity of habitat, including the Atlantic and Pacific coasts, and it is unclear what proportion of their overall population relies on saline lakes for staging (Rubega et al. 2020). Wilson's phalaropes spend boreal winter in interior saline wetlands in South America (Hurlbert et al. 1984, Lesterhuis & Clay 2009), and red-necked phalaropes spend it at sea off the western coast of South America (Rubega et al. 2020).

Among the most important North American phalarope staging sites historically are Great Salt Lake (Utah), Mono Lake (California), Lake Abert (Oregon), San Francisco Bay (California), and Chaplin Lake (Saskatchewan; Jehl 1988). With major phalarope population concentrations occurring during a relatively short time period at these staging sites, coordination of surveys across sites offers an opportunity to understand population trends of the species overall (Jehl 1986, 1999). To understand the population trends of phalaropes, these major staging sites must be surveyed in a narrow time range, so that movement of the birds between sites does not confound results. Although ongoing shorebird or waterbird monitoring has been conducted at some staging sites, there have not been consistent phalarope censuses at most sites since the 1990s (Jehl 1999). With respect to phalarope populations there been no coordination of survey effort, and there is a need for a standardized, repeatable survey method to allow for annual comparisons of survey data within and across sites.

In 2019, we founded the International Phalarope Working Group with partners from around the western hemisphere, and identified coordination of surveys in western North America as a top priority for phalarope conservation research (Carle and Rubega 2019). Objectives of coordinated surveys is to create an annual index of phalarope numbers at major staging sites for the evaluation of population trends, and to better understand if phalaropes can flexibly choose which site to use based on environmental conditions. In 2019 and 2020, we initiated a program of

coordinated annual phalarope-specific surveys at Great Salt Lake, Mono Lake, south San Francisco Bay, Lake Abert, Owens Lake (California), and Chaplin Lake.

At many of these sites, annual waterbird or shorebird surveys were already in place, but we made efforts to coordinate the timing of these with phalarope-focused surveys at multiple sites. In 2019 we formed connections and organized new survey efforts; however, we only achieved full coordination of counts at Great Salt Lake, Lake Abert, and Mono Lake that year. During 2020, we added coordinated counts at Owens Lake, south San Francisco Bay, and Lake Chaplin. In this report we present results from our coordinated surveys from 2019-2021, with emphasis on 2021. More detailed results of 2020 and 2021 are available in Appendix 1 Tables 1 and 2, and in Carle et al. (2020).

Methods

Study sites

In 2019-2021, we coordinated surveys across six phalarope staging sites in western North America: Great Salt Lake (Utah, U.S.A.), Mono Lake (California, U.S.A.), Lake Abert (Oregon, U.S.A.), Owens Lake (California, U.S.A.), the south San Francisco Bay (California, U.S.A.), and Chaplin Lake (Saskatchewan, Canada; Fig. 1). These sites were chosen because they historically hosted consistent large aggregations of Wilson's and red-necked phalaropes (Jehl 1986, Jehl 1988, Rubega et al. 2020). Owen's Lake currently hosts phalaropes (Carle et al. 2020), but was dry during historic surveys in the 1980s and 1990s.

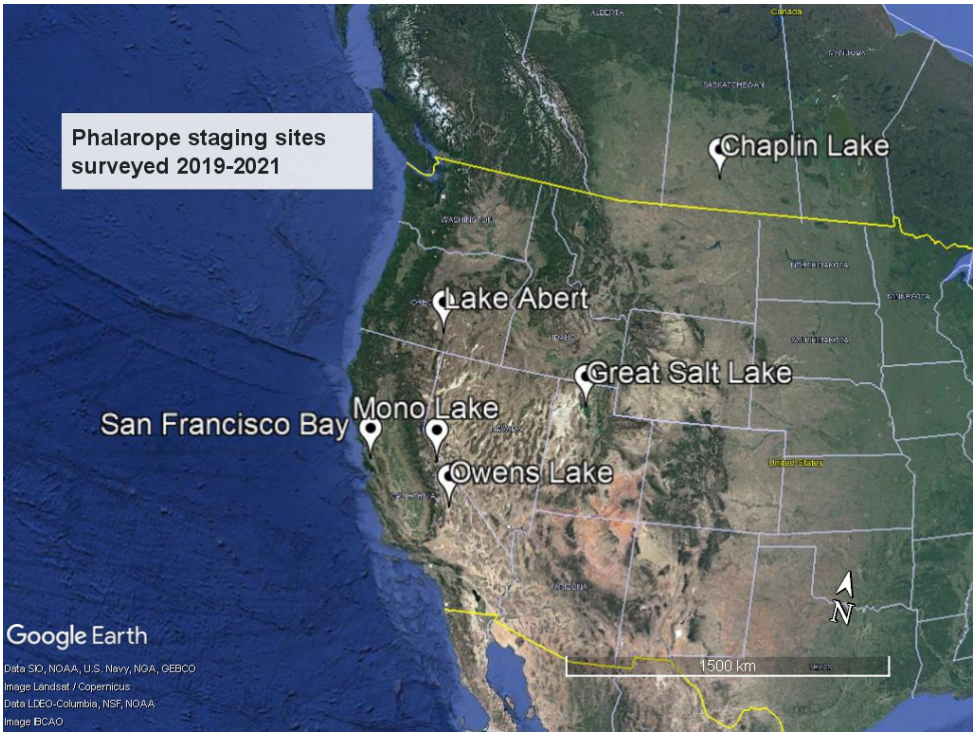

Figure 1. Western North American phalarope staging site surveys locations, 2019-2021.

We conducted surveys at each site during week-long "survey windows," in which the goal was to conduct at least one survey per site (Table 1; 2019 and 2020 suvey window dates are in Appendix 1, Tables A1 and A2). By surveying all sites during each survey window, we reduced the chance of double-counting birds moving between sites. Survey window dates differed slightly in each year but targeted the same time periods: late June-early July (2021 only), mid-July, late July-early August, mid-August, late August-early September, and mid-September.

Survey methods were tailored to the specific terrain, resources, and staffing available at each site, and are detailed below. We attempted to keep methods and survey coverage standardized within sites, so that each survey window's data could be directly compared. We present results from 2019 for Great Salt Lake, Mono Lake, and Lake Abert, because those sites had consistent surveys with coordinated timing that year (Appendix 1, Table A1). We report results from all six monitored sites for 2020 and 2021 (Appendix 1, Tables A1, A2).

Table 1. Dates of 2021 phalarope surveys at western North American staging sites. Blank cells indicate no survey was conducted during that window. Asterisks indicate dates that were 1-2 days outside the week-long survey windows but were included in those survey windows for summary. Windows with no surveys at Lake Abert and Mono Lake were due to cancellation of surveys because of smoke from wildfires.

Site	Outside window - early	Jun 29-Jul 5	Jul 14-20	Jul 29-Aug 3	Aug 13-19	Aug 28-Sep 3	Sep 12-18
Great Salt Lake		6/29	7/19	7/29	8/20*	9/1	9/15
Mono Lake		6/30, 7/2	7/14, 7/16	8/1, 8/2	8/14	No survey	9/15, 9/16
Lake Abert		7/6*	No survey	7/27*	8/17	No survey	No survey
Owens Lake		6/30	7/19	8/2	8/17	9/3	9/15
Chaplin Lake	6/20	No survey	7/15	7/29	8/19	No survey	No Survey
SF Bay		7/6	7/20	8/3	8/17	8/31	9/14

Great Salt Lake

At Great Salt Lake (hereafter GSL), Utah (41.115 N°, -112.477 W°) aerial surveys were conducted by Utah Division of Wildlife Resources personnel from a small plane (Cessna 185 Skywagon) between 25-60 m above the surface of the water travelling at 130-160 km per hour. Phalarope counts by species, number, and general location were recorded by two separate observers, one looking out each side of the aircraft, using hand-held audio tape recorders during the flight and transcribed afterward. Flocks of >75,000 birds were counted several times by both surveyors, usually by groups of 5,000, and totals decided by consensus.

Each survey started around 7 a.m. and lasted about 3 hours traveling over the water about 800 m from the shoreline of GSL in a counter-clockwise direction (see Appendix 1, Fig. A1, for route map). Counting started on the shoreline along the north side of Ogden Bay north of Fremont Island and west to Promontory Point then north to Little Valley Harbor in Gunnison Bay. From there, the survey continued across the lake west-northwest to Gunnison Island and south along the western and southern shores to the southern tip of Antelope Island where the survey turned east over adjacent wetlands and then entered Farmington Bay. The northern shoreline of Antelope Island to White Rock Bay was then surveyed followed by the rest of Ogden Bay, the western shore of Bear River Bay, Bear River Migratory Bird Refuge and adjacent private wetlands, Willard Spur, Harold Crane Waterfowl Management Area and finished along the eastern shore of Bear River Bay if extensive water was present. If phalarope flocks were observed in the open water away from the shoreline, east-west transects spaced 1.9 kilometers apart were flown over the extent of these concentrations.

Mono Lake

At Mono Lake, California (38.028° N, -119.011° W) surveys were conducted by Oikonos Ecosystem Knowledge and the University of Connecticut, with staff and equipment support from California State Parks and the Mono Lake Committee. Two surveys were conducted during each survey window, either on consecutive days, or with one day between surveys. Surveys consisted of a combination of boat- and shore-based counts. The survey protocol was based on that of historical surveys conducted by Rubega and Keimel (2017) in 1990 and 1991, with modifications. Boat counts consisted of two surveyors visiting permanent boat survey points (56 in 2019, 59 in 2020 and 2021; Appendix 1, Fig. A2) and simultaneously counting phalaropes in a fixed-distance radius from the boat, using binoculars. The first three 2019 surveys (July 11, July 12, and August 1) used an unlimited boat survey radius; all subsequent 2019 and 2020 surveys used a standard 400 m radius. We used a rangefinder to determine that 400 m was a count radius likely to result in phalarope detections without being so large that accurate identifications became difficult. We calibrated observer estimates of the 400 m count radius during each survey by practicing with a range finder on static objects, and by referencing print outs of aerial images showing the 400 m radius for count points with landmarks. Shore surveyors counted from locations in discrete areas with limited overlap with the boat survey (there were 4 shore count locations in 2019, 5 in 2020; Appendix 1, Fig. A2). Shore surveyors used a combination of spotting scopes and binoculars. Each shore survey count area was standardized but total area covered varied by shore survey point (see Appendix 1, Table A3 for count areas). Shore surveys

were conducted by trained volunteers. On both boat and shore surveys, phalaropes were counted in 1s, 10s, 100s, or 1,000s, depending on flock size, with results reported in corresponding round numbers. In areas where boat and shore survey points overlapped, the proportion of overlap was multiplied by the number of birds counted in the boat count, and the result was subtracted from that boat point's count (these instances made up a small proportion of overall points and birds). For detailed methods see Carle and Rubega (2019, 2020).

The Mono Lake count is an index-count, to be compared to itself year to year, rather than an attempt to count of every bird on the lake. Count stations were spread across the full extent of the lake (Appendix 1, Fig. A2). Mono Lake had two surveys during each survey window; we report here the highest single-survey counts in each window.

Lake Abert

At Lake Abert, Oregon, (42.703° N, -120.221° W) shore-based surveys were conducted by volunteers from East Cascades Audubon Society. Observers arrived early in the morning to avoid heatwaves reducing visibility, and drove along highway 395 on the east side of the lake, stopping at approximately15 pullouts to make counts, with approximately 0.25 miles between pullouts. Observers used binoculars to identify and count nearby birds and used scopes for distant birds. Where birds were in flocks, numbers of birds in each field of view were estimated in multiples of 25, 50, 100, etc. and then the size of entire flock was estimated by multiplying the numbers of birds in each field times the numbers of scope fields the flock occupied.

Because Lake Abert is 3-5 miles across on average, about half or less of the lake could be adequately counted. Phalaropes usually appeared to be in relatively visible areas either at the narrow south end of the lake or near the eastside springs at the north end. Occasionally large flocks of shorebirds could be seen on the far shore, but could not be counted. Phalaropes were identified to species if they were close enough to the observers to make accurate identifications. In 2021, surveys were made difficult by wildfire smoke that filled the basin throughout most of the summer. Low water levels meant that birds were located far from the highway where observations were made.

Owens Lake

At Owens Lake, California (36.445 N°, -117.945 W°) surveys of the Owens Lake Dust Control Program Area were conducted by both Eastern Sierra Audubon (ESA) and the Los Angeles Department of Water and Power (LADWP). The Owens Lake Dust Control Program Area totals 48 square miles, of which 30 square miles is currently water-based. LADWP applies water to portions of Owens Lake from October through June to control dust. Some water is also released outside this period to maintain wildlife habitat. The Dust Control Program Area is divided into numerous discrete dust control management units referred to as Dust Control Areas or "cells" (Appendix 1, Fig. A3). Cells differ in size, depth, salinity and water persistence.

LADWP biologists conduct four surveys a year of the entire Owens Lake Dust Control Program Area: April, August, September and October. These "lakewide surveys" require 6-7 people 1-3 days to complete. One of these lakewide surveys overlapped the phalarope survey windows in

2021 (August). ESA conducted smaller-scale surveys during other survey windows to fill in these gaps. LADWP worked with ESA to determine the best subsample of DCAs to consistently survey during the other phalarope survey windows, as surveying all DCAs is not needed due to a lack of habitat, and personnel are not available. A total of 16 DCAs were subsampled, based on an analysis of phalarope abundance on lakewide surveys for the time period 2015-2020 (Appendix 1, Figure A3). These 16 DCAs accounted for 91% of all phalaropes based on past data (D. House, LADWP).

In 2021, ESA surveyed in all survey windows. The August 17, 2021 lakewide survey conducted by LADWP covered all Dust Control Areas; for that day, we report data only from the 16 areas covered by the other 2021 surveys. Starting time was near dawn each day. All surveys were conducted by driving along roads and berms surrounding cells, stopping periodically to survey using binoculars and spotting scopes.

South San Francisco Bay

At San Francisco Bay, California (37.444° N, -122.069° W) the San Francisco Bay Bird Observatory (SFBBO), with financial and logistical support from multiple agencies and landowners (see acknowledgements), surveyed at former salt evaporation ponds, managed ponds, and several other sites in southern San Francisco Bay (hereafter referred to as SFB). Thirty-one sites were selected, composed of a subset of ponds in the Alviso, Mowry, Newark, and Ravenswood complexes of the Don Edwards San Francisco Bay National Wildlife Refuge, a subset of ponds in Eden Landing Ecological Reserve, Alviso Marina County Park, Spreckles Marsh, New Chicago Marsh, Crittenden Marsh, Coyote Hills Regional Park, and the Sunnyvale Water Pollution Control Plant (Appendix 1, Fig. A4). Together these sites comprise 6,687 out of 20,357 acres of former commercial salt pond habitat (encompassing areas where 99% of historical SFBBO phalarope observations occurred), in addition to 378 acres of other diked wetlands and treatment ponds in SFB (where multiple observations of phalaropes have occurred on eBird; Tarjan 2020). Note that the scope of the surveys was south of the San Mateo Bridge and that additional managed ponds, diked or muted tidal marshes, and storage or treatment ponds exist in north San Francisco Bay. Coverage throughout the entire 54,732 acres of potential phalarope habitat in north and south San Francisco Bay is a goal of future surveys.

Surveys at the majority of SFB sites were synchronized with the coordinated survey windows of other North American staging sites. A few SFB sites were surveyed on alternative dates surrounding the primary survey dates due to staff availability and access limitations. One site could not be accessed for surveys during the mid-August window due to active construction. Surveys were conducted from shore using binoculars and 40x spotting scopes. Surveys were conducted between 8 a.m. and 12 p.m. by SFBBO staff and trained volunteers. Count boundaries were delineated by maps and instructions.

Chaplin Lake

At Chaplin Lake, Saskatchewan (50.411° N, -106.603° W), an established protocol developed by the Canadian Wildlife Service and University of Saskatchewan involved weekly fall shorebird surveys at 18 point count stations throughout the roads and dikes that surround and bisect the lake (Appendix 1, Fig. A5). Point count stations had a radius of either 200m or 500m depending

on topography and proximity of neighboring stations, and therefore these surveys did not cover the entire available habitat on the lake (Appendix 1, Fig. A5). However, in 2020 and 2021, all phalaropes seen while traveling in a vehicle between survey points were counted, essentially covering the entire road/dike system that is accessible by vehicle, and associated distance that is visible into the lake from shore.

Observers counted all shorebirds seen within the point count station radius during an unlimited time period, using binoculars and spotting scopes. Shorebirds were identified to species whenever possible, and surveys were conducted at any time of day provided weather conditions are appropriate (i.e., no heavy precipitation or strong winds). In 2021, surveys were conducted weekly from July 15 to August 26. Thus, surveys conducted on July 15, July 29, and August 19 fell within the windows defined in this report.

Caveats for comparisons between sites

The methods and coverage of surveys varied at each site. Reasons for differing survey methodologies were related to factors including the site topography and conditions, the level and training of staffing available, and the choices of those designing the surveys at each site. In comparing the results, it is important to keep in mind that the following factors varied across sites 1) survey effort; 2) observer training; 3) survey area; 4) estimation methods; 5) vantage/proximity to birds; 6) methods to control double-counting; 7) time of day/time distribution of effort; and 8) completeness of site coverage. Care was taken to keep methods consistent *within* sites, meaning that surveys carried out on different dates or years at a single site should be comparable, allowing for effects of varying environment conditions, such as smoke that hampered observations at Mono and Abert Lakes in 2021

Results and discussion

Peak counts: Wilson's phalaropes

The maximum 2021 count during a single survey window of Wilson's phalaropes and unidentified phalaropes combined was 295,902 birds during July 19-August 3 (Table 3, Fig. 2). Of that count, 95,140 birds were identified as Wilson's phalaropes and the remainder were unidentified phalaropes. 2021's maximum Wilson's/unidentified count was 59,450 birds greater than 2020's (236,452 birds) and 74,868 fewer than 2019's (370,770 birds; Fig. 2). The peak count survey window in 2020 (July 19-Aug 3) was later than the previous two years (mid-July).

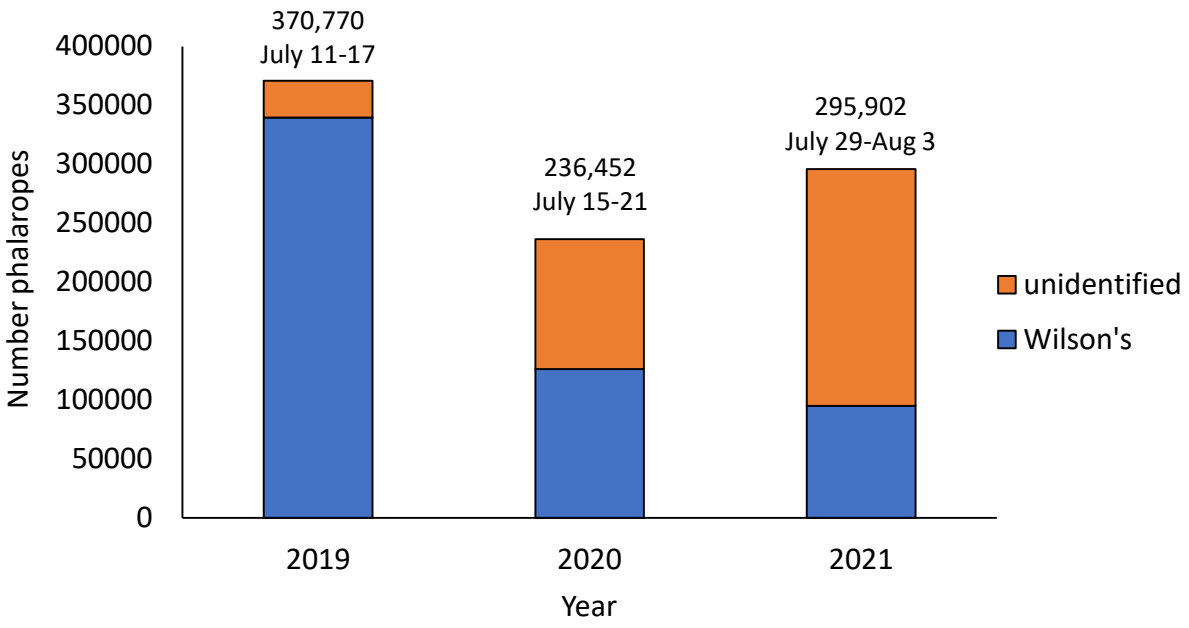

Figure 2. Peak single-window counts of Wilson's/unidentified phalaropes across all sites 2019-2021. Peaks of combined counts of Wilson's and unidentified phalaropes were the same as peaks of just Wilson's in all years. 2019 total is Great Salt Lake, Mono Lake, and Lake Abert only; 2020-2021 counts are all 6 monitored sites. The sum of Wilson's and unidentified phalaropes of each count, and the count date, is shown above the bar.

Peak counts Red-necked Phalaropes

The maximum 2021 count during a single survey window of of red-necked phalaropes and unidentified phalaropes was 161,804 birds during the August 13-19 window (Fig. 3). Of that count, 35,854 birds were red-necked phalaropes and the remainder were unidentified phalaropes (Fig. 3). The maximum red-necked/unidentified count was 37,756 birds greater than in 2020 and 134,927 fewer than in 2019 (for which the count was from GSL, Mono Lake and Lake Abert only; Fig. 3). Historically, most Wilson's phalaropes depart staging sites by mid-August (Jehl 1988, Rubega and Keimel 2017). Thus, it is probable that many of the unidentified birds during the red-necked phalarope peak count were red-necked phalaropes.

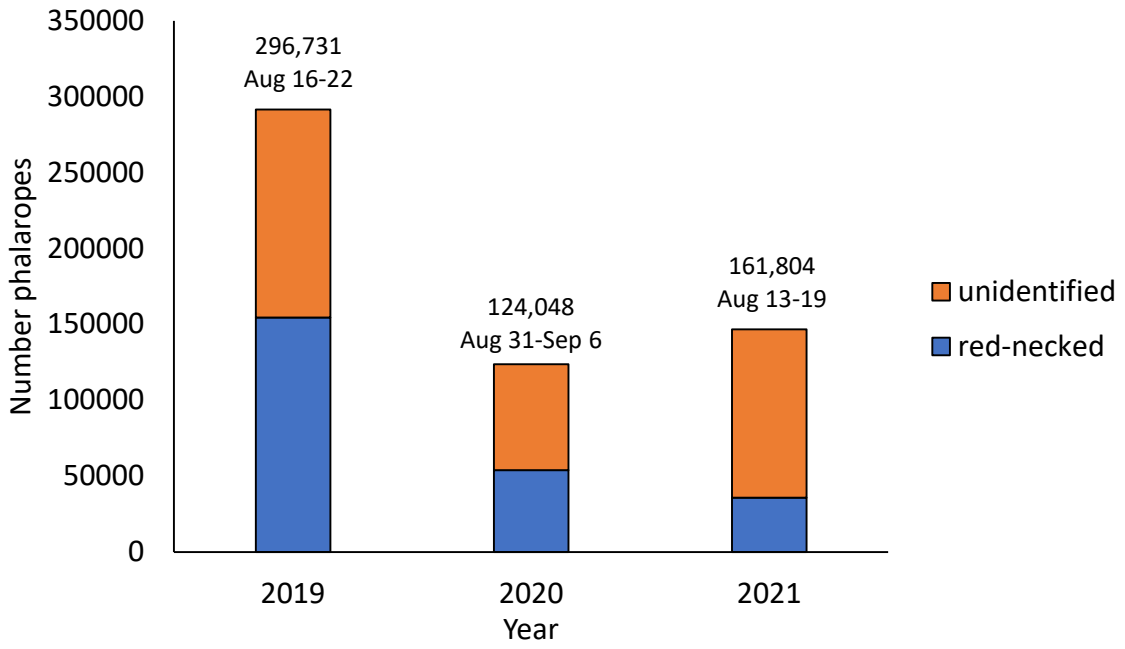

Figure 3. Peak single-window counts of red-necked/unidentified phalaropes across all sites 2019-2021. Peaks of combined counts of red-necked and unidentified phalaropes differed in all years from the peak of just red-necked phalaropes; shown here are the windows of the red-necked phalarope peaks and the unidentified totals from that window. 2019 total is Great Salt Lake, Mono Lake, and Lake Abert only; 2020-2021 counts are all 6 monitored sites. The sum of red-necked phalaropes and unidentified phalaropes of each count, and the count date, is shown above the bar.

Timing of Wilson's and red-necked phalaropes

Overall, the timing of both phalarope species during 2021 was similar to recent years (Carle et al. 2020) and historical patterns (Jehl 1986, Jehl 1988). The late July-early August Wilson's phalarope peak in 2021 was driven by a high count at GSL during that window. However, peak counts for Wilson's phalaropes at Mono (45,143 birds) and Owen's Lakes (1,987 birds) occurred earlier, during the July 14-20 window. In 2021, we added a new June 29-July 5 survey window. Wilson's phalarope were present during this earlier window in large numbers at some sites, with counts of 35,750 at GSL (plus 81,977 unidentified birds), 22,440 at Mono, and 9,855 at Lake Abert. During 2020, we were concerned that the first survey window in mid-July was also the Wilson's phalarope peak, and that we may have been missing early Wilson's phalaropes (Carle et al. 2020). By adding the additional window in late June-early July 2021, we captured the build up of numbers before the peak of Wilson's phalaropes.

Red-necked phalarope numbers peaked during August 13-19, but individuals were present in relativley large numbers over a protracted period from early August to mid-September (totals ranging from 15,826–5,854 per window; Fig. 4). This pattern was consistent with previous years (Carle et al. 2020) and historical patterns red-necked phalarope timing (Jehl 1986).

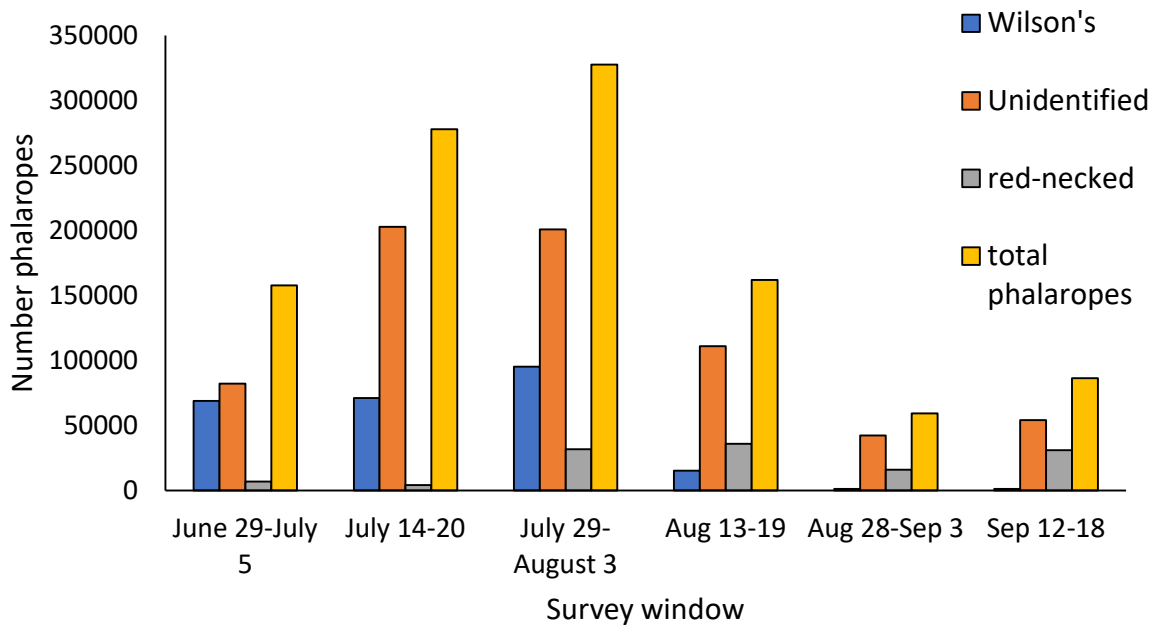

Figure 4. Numbers of Wilson's, red-necked, unidentified phalaropes counted per survey window at 6 monitored sites, 2021. All sites were surveyed in each survey window, with the following exceptions of sites that were not surveyed during the survey windows listed: Jun 29-Jul 5 (Chaplin Lake), Jul 14-20 (Lake Abert), Aug 28-Sep (Mono lake, Lake Abert, Chaplin Lake), Sep 12-18 (Lake Abert, Chaplin Lake).

Comparisons across sites

Wilson's phalaropes

Similar to previous years, GSL had the largest aggregations of Wilson's phalaropes of any site (Fig. 5). During 2021, 95% and 72% of the peak counts of Wilson's/unidentified phalaropes and red-necked/unidentified phalaropes, respectively, was from GSL. Mono Lake had its highest Wilsons' phalarope count in the three years of surveying, with 45,143 birds during mid-July (Fig. 5). Lake Abert's peak of 9,855 Wilson's phalaropes on July 7 was lower than peaks in 2019 and 2020, however Lake Abert was not surveyed in mid-July 2021. Other sites' peak Wilson's phalarope counts were 1,986 at Owens Lake (July 19), 738 at SFB on July 6, and 780 at Chaplin Lake on July 15 (plus an additional 500 unidentified phalaropes; Fig. 5).

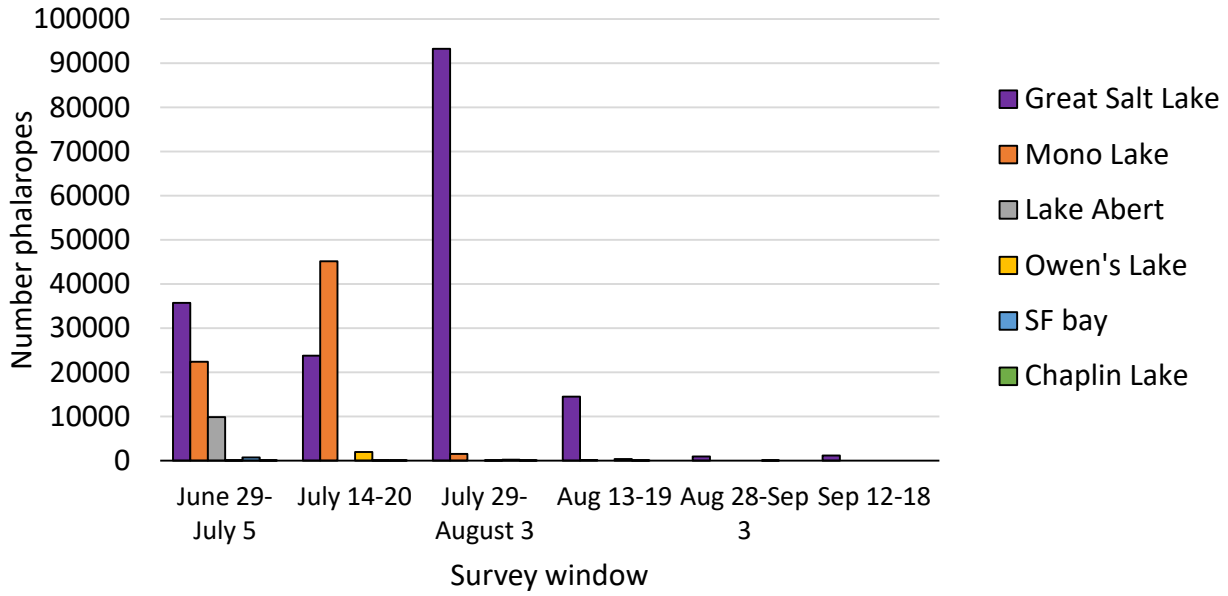

Figure 5. Peak Wilson's phalarope counts during survey windows at western North American staging sites, 2021. At Mono Lake, two surveys were conducted in each survey window, and the single survey with the highest count is shown for each survey window. See Appendix 1, Table A1 and A2 for exact numbers from each site for 2021.

Red-necked phalaropes

GSL historically has had the greatest aggregations of red-necked phalaropes of western North American staging sites, and this held true in 2021 (Fig. 6). The peak red-necked phalarope count at GSL was 29,255 on July 29 (Fig. 6). However, on the same day GSL had 186,420 unidentified birds. It is difficult to know if the unidentified phalaropes were Wilson's or red-necked on that day because July 29 was also the peak Wilson's phalarope count at GSL. Similar to 2019-2020, Mono Lake had the next highest red-necked phalarope counts during 2021 (Fig. 6). Mono's peak 2021 red-necked phalarope count of 12,647 on September 16 (with no unidentified phalaropes) was much later than GSL's on July 29 (Fig. 6). Mono's count was also the highest red-necked phalarope count recorded there during 2019-2021. Other notable red-necked phalarope site counts were 6,767 at SFB on September 13-14, and 2,719 at Owens Lake on September 3 (Fig. 6), and 407 at Chaplin Lake on July 15.

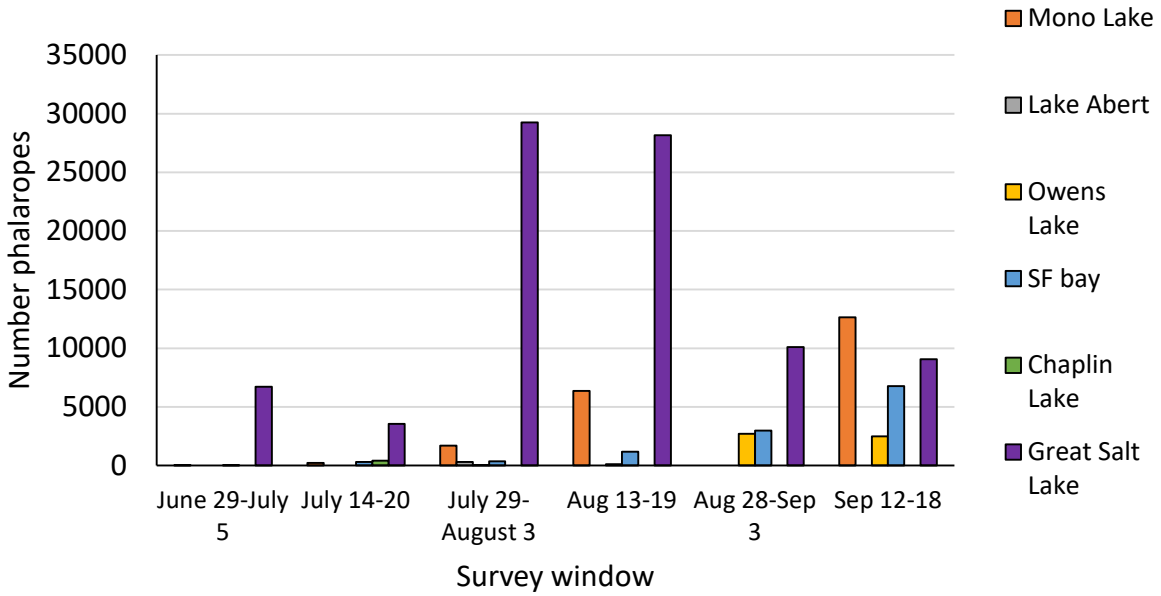

Figure 6: Peak counts of red-necked phalaropes during each survey window at western North American staging sites, 2021. All sites were surveyed in each survey window, with the exceptions of Mono Lake in the Sep 14-22 window, Lake Abert in the Aug 13-19 window, and Chaplin Lake in Sep 13-22 window. See Appendix 1, Table A1 and A2 for exact numbers from each site.

Possible effects of environmental change on phalarope movement between sites

During our monitoring in 2019-2021, we witnessed environmental change at saline lakes in real-time. Lake Abert virtually dried up during 2021 (Figs. 7, 8), and GSL reached its lowest level in recorded history (since 1847). A critical question for phalaropes is whether they can adapt to major environmental perturbations at staging sites; i.e., are they flexible enough to move from one site to another if they find a major staging site, such as Lake Abert, has dried up?

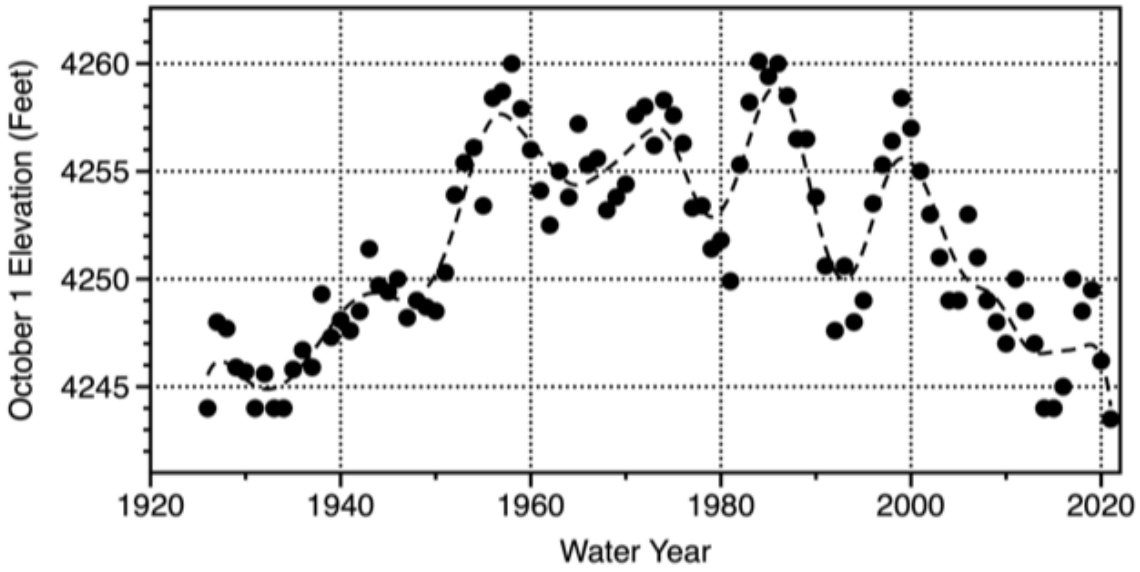

Figure 7. October lake elevation (feet above sea level) of Lake Abert, Oregon, 1926-2021. The 2021 elevation of 4,244 is the lowest on record and represents a virtually dry lake. Lake Abert hit the same low elevation mark during the dust bowl drought of the 1930s and during drought in 2014 and 2015. Data from Philips and Van Denburgh (1971), Keister (1992), Larson et al. (2016), and Kreuz, Larson, and Mayer unpublished data.

Without tracking of individual phalaropes, we cannot directly answer these questions, but survey results can point to clues. For example, the approximately 30,000-bird increase in numbers of Wilson's phalaropes at Mono Lake in 2021 (Fig. 9) suggests that those individuals visited other sites in previous years. This large flock at Mono Lake occurred in late June through mid-July, and was composed of a mix of adult males and females (Fig. 10). Wilson's phalarope numbers did not increase proportionally elsewhere and actually were lower, when totaled across all sites, than in 2019 (Fig. 2). This suggests that this increase at Mono Lake was due to site selection by migrating birds, rather than an increase in the whole population or high reproductive success in one year. The high proportion of male birds in late June (Fig. 10), also suggested that birds may have come early from the breeding ground, perhaps due to poor reproduction conditions, though this is also speculative.

Figure 8. Shallow, hyper-saline water conditions at Lake Abert on July 7th, 2021. No birds used this extremely saline area that is dominated by hyper-saline bacteria. Photo by Ron Larson.

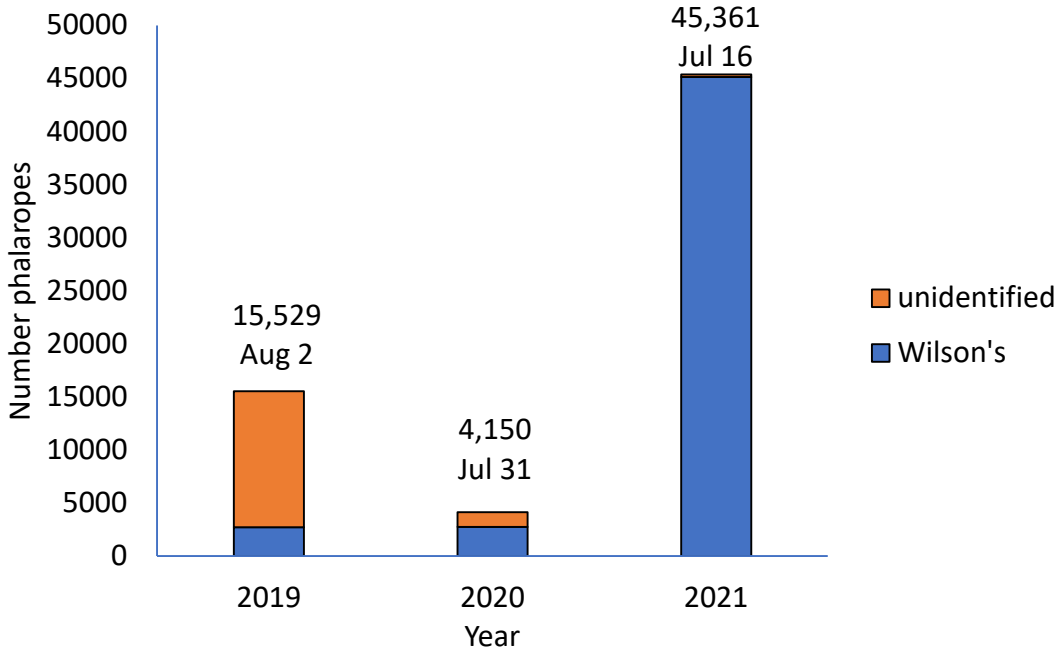

Figure 9. Maximum Wilson's and unidentified phalarope counts at Mono Lake 2019-2021. The combined total of Wilson's and unidentified phalaropes and date of the count are shown above the bars.

Figure 10. Phalarope flock at Mono Lake on June 29, 2021. This flock grew to approximately 45,000 birds by mid-July. The flock was composed of a mixture of adult females (darker, reddish necks) and males (lighter, brownish necks). Photo by Ryan Carle.

Numbers of Wilson's phalaropes at Lake Abert appear to have declined substantially from 2019-2021 (i.e., a 2019 peak of 89,000 unidentified phalaropes, and a 2021 peak of 9,855 Wilson's phalaropes; Fig. 11). A caveat is that there was no survey during mid-July at Lake Abert in 2021, so it is possible that a high count was missed. At GSL, numbers of Wilson's phalaropes were higher than in 2020 and lower than in 2019. Thus, the increase at Mono Lake in 2021 may have been driven by birds choosing to come there instead of Lake Abert or GSL, perhaps due to poorer habitat quality at those sites.

Notably, there were also incidental reports of aggregations of an estimated 10,000-20,000 Wilson's phalaropes at Tule Lake National Wildlife Refuge, California, during several weeks in July 2021 (Kahle 2021a, Kahle 2021b). The presence of large numbers of Wilson's phalaropes at Tule Lake was corroborated by multiple observers (R. Larson pers. obs.), and video. These numbers suggested the potential that birds may have visited Tule Lake instead of Lake Abert during July 2021. Tule Lake is located approximately 80 air miles from Lake Abert. The dominant invertebrate prey present at Tule Lake during July 2021 was *Daphnia* spp. (R. Larson, pers. obs.), rather than alkali flies (*Ephydra hians*), which are typically available at Lake Abert (Larson et al. 2016). Wilson's phalaropes prey on *Daphnia* spp. at Great Salt Lake and elsewhere (Frank and Conover 2021), but it is unknown how a shift from an alkali fly-dominated prey base to a *Daphnia* dominated one might affect phalarope energetics as they prepare for their migration. Based on conversation with refuge managers and eBird data, such large aggregations of Wilson's phalaropes at Tule Lake had not been observed there previously (at least in recent

memory; eBird 2022, R. Larson, pers. comm.). Overall, the large numbers of Wilson's phalaropes at both Mono Lake and Tule Lake during July 2021 suggests selection of sites based on environmental conditions and prey availability.

Red-necked phalarope numbers at Lake Abert and Mono Lake in 2021 showed a similar pattern to that of Wilson's phalaropes. Lake Abert's 2020 and 2021 red-necked phalarope peak counts (635 and 4,315, respectively) were much lower than its 2019 peak count (22,000). Mono Lake's 2021 red-necked phalarope peak count (12,674) was the highest recorded during 2019-2021. 1,500 red-necked phalaropes were also observed at Tule Lake on September 1, 2021 (K. Spencer, pers. comm. with R. Larson). The speculative theory that more phalaropes came to Mono Lake and Tule Lake in 2021 because they did not go to Lake Abert, is supported by quantitative analyses showing that, across 25 years, fewer phalaropes used Lake Abert during periods of high salinity and low water levels (Larson et al. 2016, Senner et al. 2018). The 2021 pattern, with fewer birds overall but more birds at Mono Lake, differed from 2020, in which numbers were down across all sites.

The patterns we have observed over three years of monitoring show that our coordinated surveys are valuable for helping understand phalarope responses to rapid environmental change at saline lakes. Planned efforts to track phalaropes at saline lake staging sites will further help with understanding how birds will respond to climate- and water diversion-induced change to saline lake water levels.

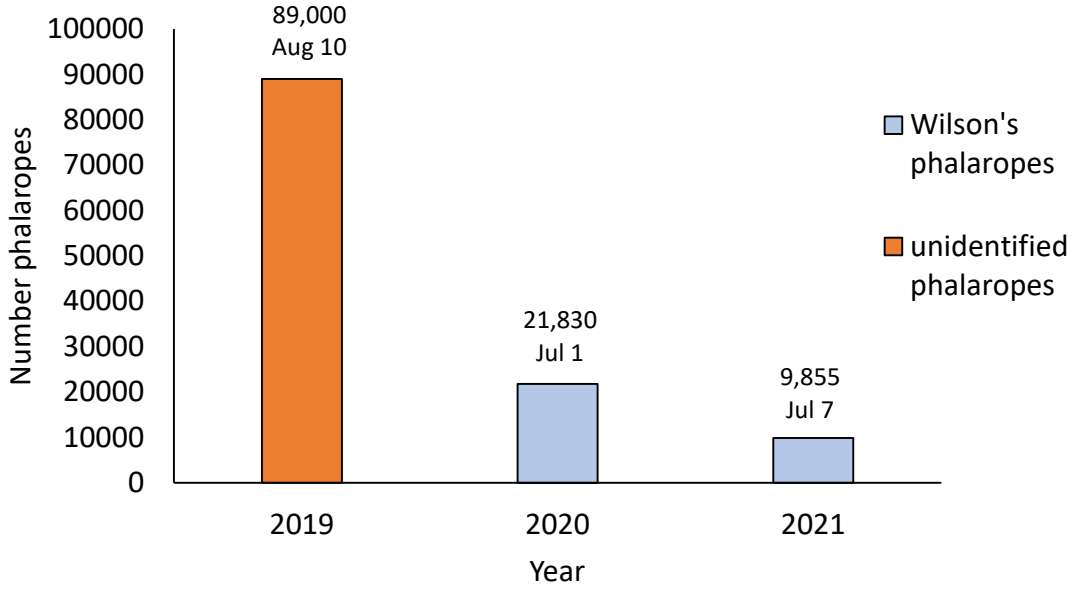

Figure 11. Maximum Wilson's and unidentified phalarope counts at Lake Abert during 2019-2021. Note that no Wilson's phalaropes were identified on the peak 2019 count, and no unidentified phalaropes were recorded on the peak 2020 count.

Conclusions

Our results underscore the usefulness of coordinated surveys across major staging sites for interpreting population trends, migratory timing, and habitat use of phalaropes. The value of these coordinated surveys will compound as they continue over more years. Importantly, the surveys also highlight what we *do not* know about phalaropes, and what major gaps and challenges there are for surveying them. Below we briefly elaborate on a few methodological challenges and major takeaways.

Methodological challenges

Unidentified phalarope counts remain a challenge for interpretation. Often the numbers of unidentified phalaropes exceed those of phalaropes identified to species. For very early summer counts (e.g., late June-early July), it may be accurate to assume unidentified birds are Wilson's and for later fall counts that they are red-necked phalaropes (e.g., late August onward). However, during mid-July to mid-August, including periods with peak counts, the two species may be intermixed (for example, July 29, 2021 was the high count at GSL for the year for Wilson's, red-necked, and unidentified categories). Recent discussion among the collaborative group working on surveys has identified the goal of developing methods to sub-sample species composition of flocks to create site- and day-specific species ratios that can be applied to unidentified counts.

Standardization of census methods: We have achieved coordination of timing across sites, but each site continues to be monitored differently, with varying levels of standardization across years at each site. A continuing goal to strive for is greater standardization of methods at each site, so that trends can be interpreted without being confounded by methodological issues. Notably, despite challenges of standardization at various sites, the quality of the surveys carried out for this study is more replicable than any previous effort (i.e., Jehl 1988), or and more rigorous and reliable than data from eBird (eBird 2022). eBird data is useful for describing incidental observations such as the Tule Lake reports described in this report, but is inconsistent in timing, locations, area coverage, observer skill, and precision of estimates. For example, the maximum number of Wilson's phalaropes recorded in a single day at Mono Lake on eBird during 2021 was 12,000 on June 22 (Escruceria 2021), whereas our standardized surveys recorded 45,143 on July 16. That eBird sighting was valuable in recording a large number of Wilson's phalaropes at Mono Lake in June before our surveys began, but no eBird reports in 2021 accurately covered the entire flock of Wilson's phalaropes at Mono Lake at its mid-July peak.

Cancellation of surveys from wildfire smoke: During 2019-2021, events of extremely poor air quality occurred regularly in California and Oregon, due to mega-wildfires. We had to cancel surveys in each year to protect the health of surveyors. Sites with cancelled surveys were Lake Abert, Mono Lake, and SFB. These smoke events happened most frequently in August and September, thus most affecting counts relevant to interpretation of red-necked phalarope numbers. However, at Lake Abert in 2021, a mid-July survey was cancelled from smoke, during the window that is often the timing of peak Wilson's phalarope counts. Wildfire smoke events are becoming predictably unpredictable; it is uncertain which locations and dates will have

smoke issues, but it appears likely to happen during the course of the survey season. At Mono Lake, we developed an Air Quality Index protocol in which surveys were automatically cancelled, for observer health, at an AQI exceeding 150 ppm.

Conservation implications

Worldwide, saline lakes are in danger of ecosystem collapse as water levels fall due to water diversion and climate change (Moore et al. 2016, Wurtsbaugh et al. 2017). The sites we monitored are no exception; Lake Abert and GSL are at the forefront of the list of endangered saline lakes (Larson 2016, Moore 2016, Null & Wurtsbaugh 2020). Phalaropes are an excellent indicator of the overall health of the network of saline lakes. Phalaropes' ability to adapt is key to the question of how much the saline lake network can be damaged without losing the migratory wildlife that depends on it. Over three years of monitoring, we have observed trends in annual total numbers of phalaropes at the staging sites, and indications that phalarope numbers may increase at one site in response to environmental conditions at another.

We need more years of monitoring to interpret trends from our coordinated efforts at staging sites. However, the overall totals from our surveys are lower than those of the one similar effort that occurred for Wilson's phalaropes in 1986 (Jehl 1988). At the same six sites that we monitored, Jehl (1988) recorded 495,145 Wilson's phalaropes in 1986, whereas we recorded fewer than 300,000 at those sites in 2020 and 2021. In 2019, we recorded 370,770 at only GSL, Mono Lake and Lake Abert. Because of methodological and coverage differences, the large errors associated with counting big flocks of phalaropes, and the existence of only one year of historical data, it is uncertain whether this represents a real decline.

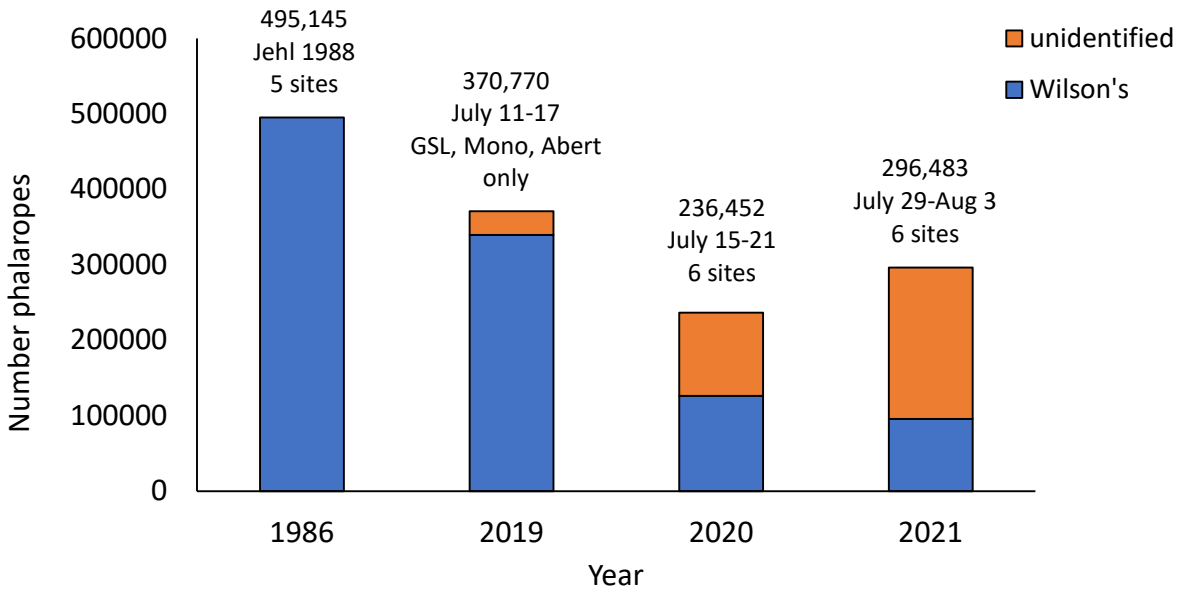

Figure 12. Peak single-day counts of Wilson's and unidentified phalaropes at six sites during 1986, and 2019-2021. 1986 data are from Jehl (1988); all the same sites were surveyed in that study as in ours, with the exception of Owens Lake, which was dry at

the time. Note that there were substantial differences in methods and site coverage between the Jehl (1988) study and ours.

The only other data available on phalarope trends are Breeding Bird Survey analysis for Wilson's phalaropes (Sauer et al. 2019). The Breeding Bird Survey (BBS) is based on standardized surveys in breeding habitat, rather than the staging habitat we monitored. BBS results from 1966–2019 indicate a slightly declining trend overall for Wilson's phalaropes, with steeper declines in specific conservation regions of the Great Basin, Northern Rockies, and Southern Rockies/Colorado Plateau (Sauer et al. 2019). All conservation regions showed declines except the Badlands and Prairies region, which showed a slight increasing trend (Sauer et al. 2019). BBS trends cannot be calculated for red-necked phalaropes due to their arctic breeding habit not being surveyed. In historical analyses, trends from BBS and staging sites have not matched up well. Such comparisons have not been completed for contemporary data, but would be useful.

Given the mosaic of threats and variable levels of protection of North American phalarope staging sites, and climate change impacts are happening in real time, it is imperative for phalarope conservation to continue coordinated monitoring across the region rather than disjointed surveys at single sites, or no surveys at all.

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Appendix 1

Table A1. Maximum 2019 phalarope counts in survey windows at Great Salt Lake, Mono Lake, and Lake Abert.

Wilson's phalarope

Survey window	Great Salt Lake	Mono Lake	Lake Abert	Total
July 11-July 17	337,698	2,017	0	339,715
July 30-Aug 5	231,920	2,712	1,084	235,716
Aug 16-22	4,895	312	0	5,207
Aug 31-Sep 6	No data	4	0	4
Sep 11-Sep 17	2	0	No data	2

Red-necked phalarope

Survey window	Great Salt Lake	Mono Lake	Lake Abert	Total
July 11-July 17	33,030	83	0	33,113
July 30-Aug 5	81,330	2,612	5	83,947
Aug 16-22	149,660	4,921	0	154,581
Aug 31-Sep 6	No data	5,573	0	5,573
Sep 11-Sep 17	35,100	4,707	No data	39,807

Unidentified phalarope

Survey window	Great Salt Lake	Mono Lake	Lake Abert	Total
July 11-July 17	2,386	4,408	24,261	31,055
July 30-Aug 5	12,735	12,817	0	25,552
Aug 16-22	114,770	173	22,000	136,943
Aug 31-Sep 6	No data	8	1,050	1,058
Sep 11-Sep 17	3,640	0	No data	3,640

Table A2. Maximum 2020 phalarope counts in survey windows at all sites surveyed. SF Bay is south San Francisco Bay.

Wilson's phalarope

Survey window	Great Salt Lake	Mono Lake	Lake Abert	Owens Lake	SF Bay	Chaplin Lake	Total
July 15-21	122,850	2,475	80	90	767	26	126,288
July 29-Aug 4	74,045	2,765	450	670	446	120	78,496
Aug 13-19	10,530	637	No data	1,144	162	5	12,478
Aug 31-Sep 6	145	15	6	81	110	No data	357
Sep 14-21	100	No data	25	0	0	No data	125

Red-necked phalarope

Survey window	Great Salt Lake	Mono Lake	Lake Abert	Owens Lake	SF Bay	Chaplin Lake	Total
July 15-21	0	129	8	5	182	50	374
July 29-Aug 4	2,505	8,220	300	0	758	0	11,783
Aug 13-19	28,235	10,891	No data	280	904	0	40,310
Aug 31-Sep 6	43,725	8251	267	86	1,700	No data	54,029
Sep 14-21	6,570	No data	675	1,550	935	No data	9,730

Unidentified phalarope

Survey window	Great Salt Lake	Mono Lake	Lake Abert	Owens Lake	SF Bay	Chaplin Lake	Total
July 15-21	107,990	1	2,000	33	140	0	110,164
July 29-Aug 4	119,335	1,385	0	0	5	0	120,725
Aug 13-19	62,270	241	No data	76	0	30	62,617
Aug 31-Sep 6	69,620	0	0	42	0	No data	69,662
Sep 14-21	36,975	No data	0	No data	32	No data	37,007

Table A3. Maximum 2021 phalarope counts in survey windows at all sites surveyed. SF Bay is south San Francisco Bay.

Wilson's phalarope

Survey window	Great Salt Lake	Mono Lake	Lake Abert	Owens Lake	SF Bay	Chaplin Lake	Total
June 29-July 5	35,750	22,440	9,855	19	738	NA	68,802
July 14-20	23,825	45,143	No data	1,987	12	780	71,747
July 29-August 3	93,310	1,579	0	11	240	580	95,720
Aug 13-19	14,490	158	0	425	24	0	15,097
Aug 28-Sep 3	975	NA	No data	0	33	No data	1,008
Sep 12-18	1,185	0	No data	0	0	No data	1,185

Red-necked phalarope

Survey window	Great Salt Lake	Mono Lake	Lake Abert	Owens Lake	SF Bay	Chaplin Lake	Total
June 29-July 5	6,710	5	0	0	35	No data	6,750
July 14-20	3,570	218	No data	0	313	407	4,508
July 29-August 3	29,255	1,694	300	3	370	0	31,622
Aug 13-19	28,170	6,378	0	110	1,196	0	35,854
Aug 28-Sep 3	10,115	NA	No data	2,719	2,992	No data	15,826
Sep 12-18	9,065	12,647	No data	2,489	6,767	No data	30,968

Unidentified phalarope

Survey window	Great Salt Lake	Mono Lake	Lake Abert	Owens Lake	SF Bay	Chaplin Lake	Total
June 29-July 5	81,977	60	0	0	16	No data	82,053
July 14-20	202,125	245	No data	0	414	500	203,284
July 29-August 3	186,420	10,253	3,930	76	84	1	200,764
Aug 13-19	102,675	5,105	3,070	0	3	0	110,853
Aug 28-Sep 3	36,700	No data	4,315	522	792	No data	42,329
Sep 12-18	53,545	0	No data	515	0	No data	54,060

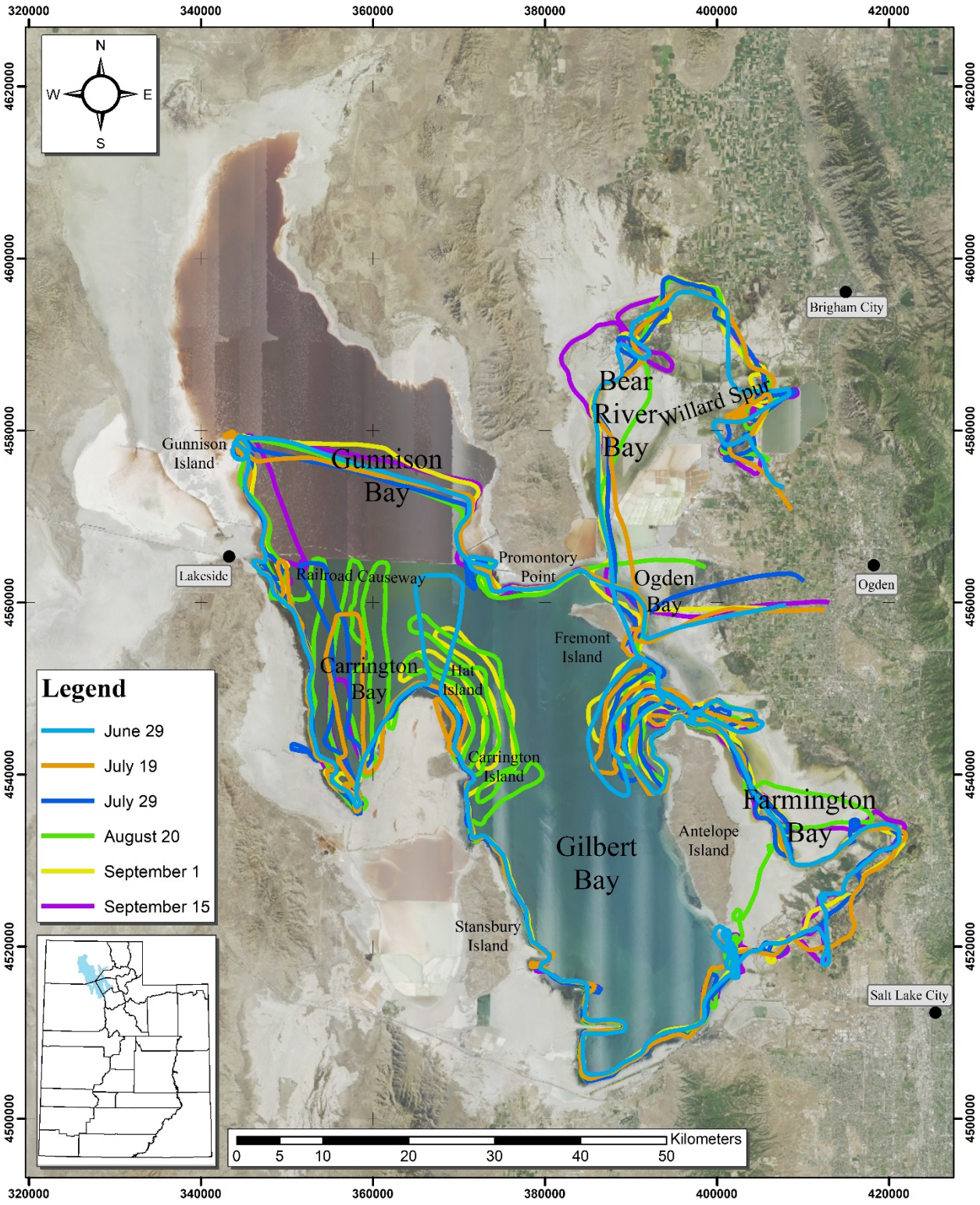

Figure A1. Phalarope survey flight paths in 2021 at Great Salt Lake, Utah. All flights originated and ended at the Ogden Airport and generally traveled in a counterclockwise direction.

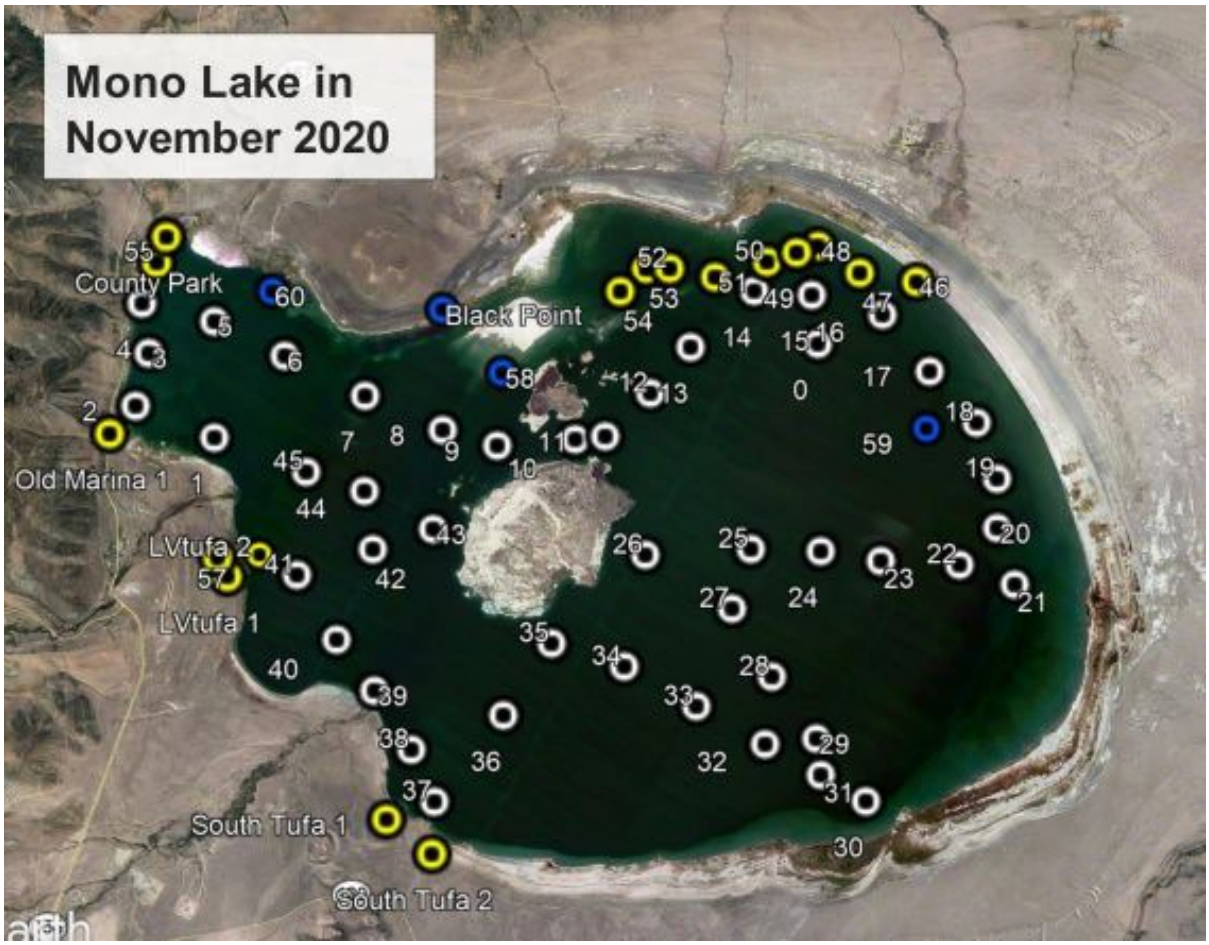

Figure A2. Mono Lake phalarope survey points. White dots are original 1990-1991 phalarope boat survey points, yellow dots are points added in 2017 and 2019, and blue dots are points added in 2020. Numbered dots are boat survey points, named dots are shore survey points. Note that areas in the north and east of the lake that were dry in 1990-1991 were flooded in 2019-2021.

Table A3. Total estimated lake surface areas (km^2) of phalarope survey points at Mono Lake (using 2019 satellite imagery of lake level). See Carle and Rubega 2020 for full methodological details of Mono Lake surveys.

Phalarope Survey Point	Total Count Area (km^2) Nov 2019 photo
Boat point – 400 m radius	0.50
County Park shore survey	0.20
Lee Vining Tufa shore survey point 1	0.13
Lee Vining Tufa shore survey point 2	0.16
Old Marina shore survey	0.47
South Tufa shore survey point 1	0.22
South Tufa shore survey point 2	0.25
Black Point shore survey	0.66

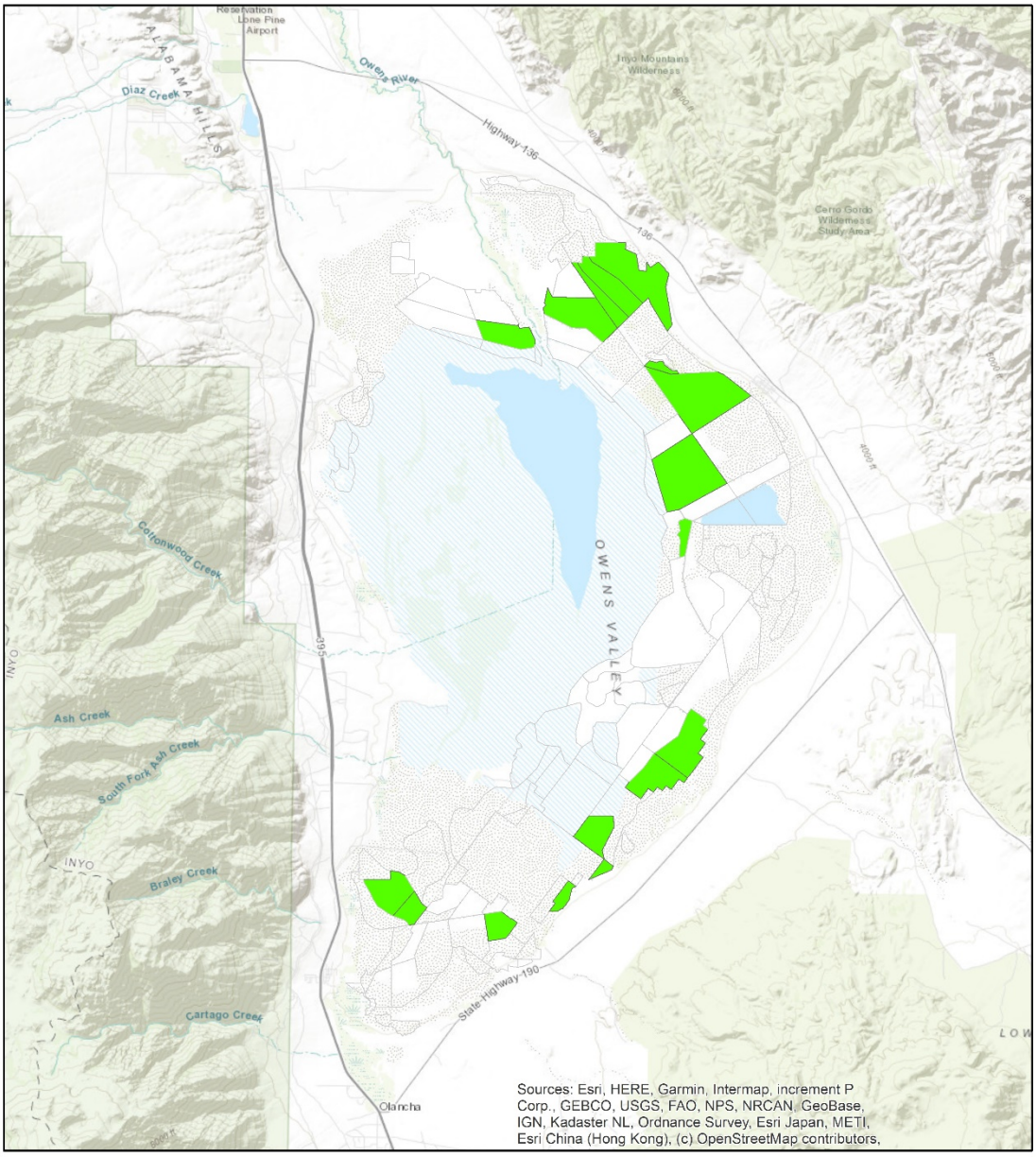

Figure A3. Owens Lake dust control area "cells." Sixteen Dust Control Areas (DCAs) were surveyed by Los Angeles Department of Water and Power and Eastern Sierra Audubon in 2021.

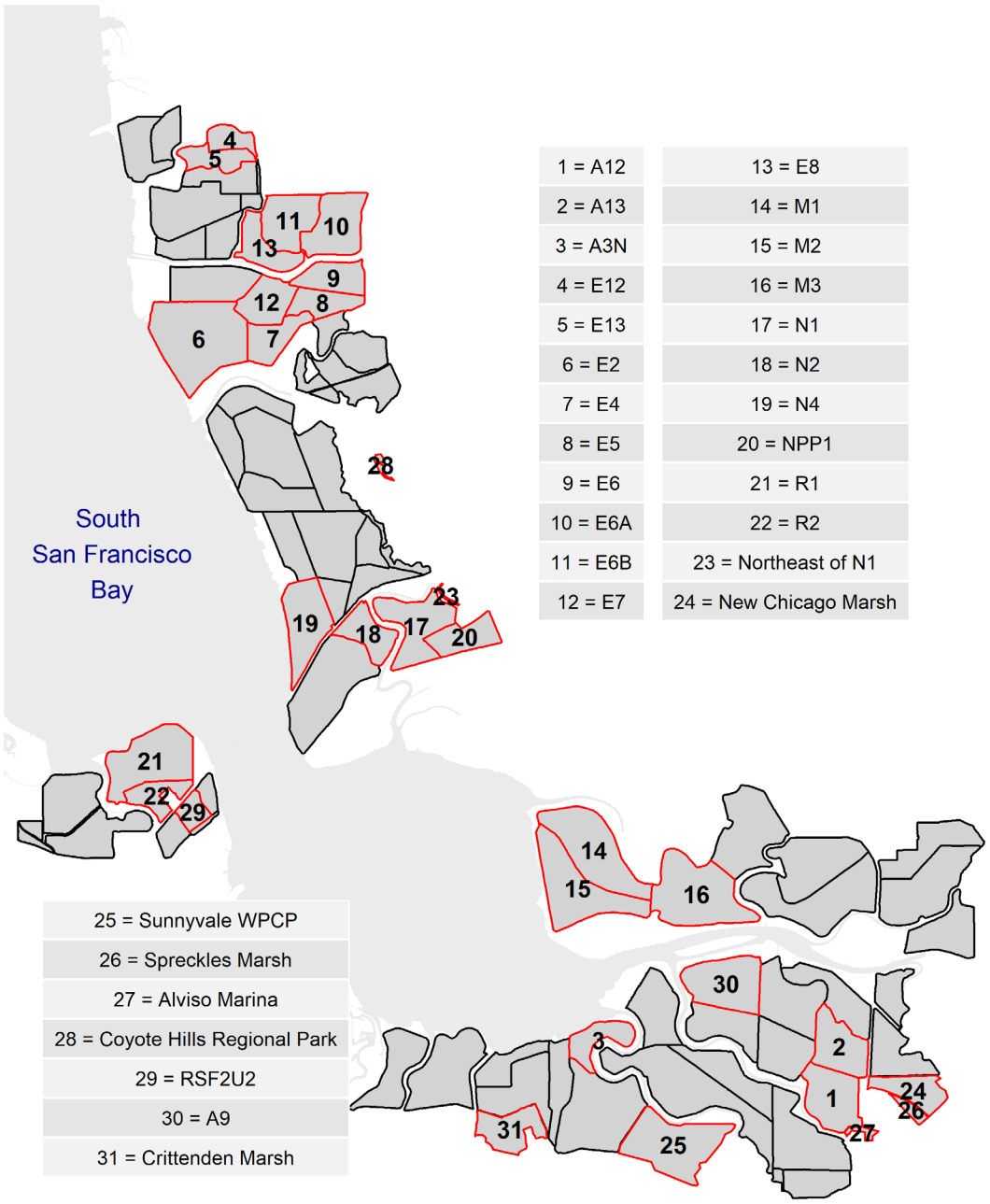

Figure A4. Map of 2021 phalarope survey sites in south San Francisco Bay. San Francisco Bay Bird Obsevatory used an area search approach to survey for phalaropes at sites outlined in red. Sites 1-22 and 29-30 are former salt production ponds. Other former and current salt production ponds are outlined in black. Sites 23-27 and 31 include water treatment ponds and diked wetlands.

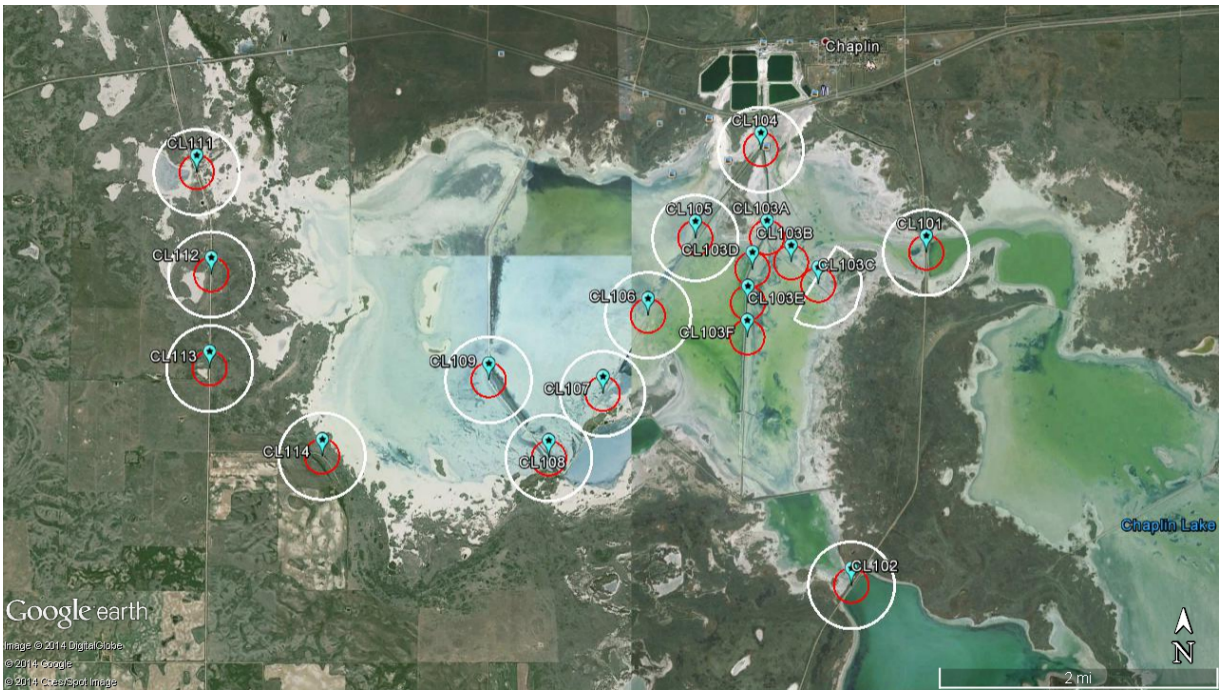

Figure A5. Point count stations at Chaplin Lake, Saskatchewan. Red circles indicate the 0-200 m buffers and the white circles indicate the 200-500 m buffers.