

Mono Lake Phalarope Surveys 2020 Report



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Summary

Population trends of Wilson's and red-necked phalaropes are poorly understood, though their habitat at saline lake migratory staging areas is threatened by water diversion and climate change. We conducted a second consecutive year of phalarope monitoring at Mono Lake in 2020, with the goal of better understand timing, habitat use, and population trends of Wilson's and red-necked phalaropes at Mono Lake. We conducted eight boat- and shore-based whole-lake surveys during 2020, with pairs of surveys 1-2 days apart every two weeks from mid-June to early September. Maximum counts during 2020 were $2,765 \pm 96$ Wilson's phalaropes and $10,891 \pm 581$ red-necked phalaropes. Timing of phalaropes was consistent with past years, with Wilson's phalarope numbers peaking in late July, and red-necked phalarope numbers staying relatively high from late July through early September. In 2020, both Wilson's and red-necked phalaropes used habitat in the remote north-northeast quadrant of Mono Lake, and Wilson's also concentrated at South Tufa. Wilson's phalarope peak numbers were similar in 2019 and 2020. However, there were >10,000 thousands fewer unidentified phalaropes during peak Wilson's phalarope surveys in 2020 than in 2019, suggesting thousands fewer Wilson's phalaropes were present in 2020. Red-necked phalarope numbers were greater in 2020 than in 2019, with the 2020 peak nearly double the 2019 peak. Both species' numbers in 2019 and 2020 were lower by multiple thousands of birds than results from surveys in 1990-1991 conducted with a similar methodology to ours, but trends remain uncertain without more survey years with comparable data. Our results underscore the need for rigorous annual surveys with a stable, standardized methodology at Mono Lake and other major staging sites, as well as the need for tracking studies to understand phalarope residence times at staging sites and movement patterns between sites.

Introduction

Wilson's and red-necked phalaropes are banner species of saline lakes in the interior west of North America, where they stop in flocks of up to hundreds of thousands. Although the saline lake and wetland habitats that phalaropes rely on are globally threatened, the conservation status of each species of phalaropes is 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. Given their reliance on saline lakes, many of which are existentially threatened by water diversion and climate change (Moore et al. 2016, Wurtsbaugh et al. 2017), there is an urgent need to better understand the phalarope population trends. Indeed, the National Audubon Society considers Wilson's phalaropes "climate endangered" (Langham et al. 2015) and red-necked phalaropes "highly vulnerable" (Wilsey et al. 2019) to climate change based on modeled loss of wetland habitats predicted with climate change.

Phalaropes breed in northerly latitudes of North America, and during southward migration significant numbers of Wilson's and red-necked phalaropes stop at just a few hyper-saline lakes (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. Both species spend boreal winters in the southern hemisphere—Wilson's phalaropes in hyper-saline interior wetlands in South America, and red-necked phalaropes on the ocean off the western coast of South America. Historically, Great Salt Lake, Utah, Mono Lake, California, and Lake Abert, Oregon, have hosted large concentrations of phalaropes, and surveys at these sites offer a good opportunity to understand population trends of the species overall (Jehl 1986, 1999). Phalarope-focused surveys have not been conducted at regular intervals over the duration of the staging period at Mono Lake since the 1990s (Jehl 1999), though annual aerial surveys have occurred in September during the 2000s (LADWP unpublished data). There is a need for a standardized, repeatable annual survey method that can be compared year to year, and across major staging sites.

In 2019, we began annual surveys of phalaropes at Mono Lake in order to create a standardized time-series to evaluate population trends in Wilson's and red-necked phalaropes, and to better understand the current timing and spatial use of phalaropes at Mono Lake. Also in 2019, we founded the International Phalarope Working Group with partners from around the western hemisphere. The working group has worked to coordinate phalarope censuses at Mono Lake with other Great Basin sites, and to survey Wilson's phalaropes in South America, with the goal to update the world population estimate for the species (Castellino and Lesterhuis 2020). 2020 was our second consecutive year of surveys at Mono Lake, using a methodology based on surveys by Rubega and Keimel in 1990, 1991, and 2017. The timing of our Mono Lake surveys was coordinated with phalarope surveys at five other western North American staging sites during 2020. Results across all sites will be described in an upcoming report.

Methods

During 2020, we conducted eight full-lake censuses of Mono Lake from July 16th to September 5th, with two surveys in a 2-3 day window roughly every two weeks. Two planned mid-September surveys were cancelled because of heavy smoke in the Mono Basin from wildfires

during September. We did one shore survey on September 20th without a boat survey. Boat surveyors were Ryan Carle, Ashli Lewis, and Sarah Hecocks, the same boat survey team that conducted 2019 surveys. Shore surveyors were Nora Livingston, Dave Marquart, Bartshe Miller, David Carle, Janet Carle, and Catherine Jones.

Our 2020 protocol followed methods developed during the 1990s by Rubega and Keimel (2017), that we modified during 2017 and 2019. The 1990s protocol calls for surveying phalaropes by boat at defined survey points (Fig. 1A), where two observers in the same boat count phalaropes in a 360° span within a fixed-distance radius. Any single point set of counts differing by more than 10% is repeated. Depending on flock size, flocks are counted in groups of 1s, 10s, 100s, or 1,000s and reported in corresponding round numbers. Count times are held to under 5 minutes to minimize recounting birds. Boat survey directions are alternated on sequential survey days, in order to minimize time-of-day effects on detection, starting either at point 1 and ending at point 45, or vice versa.



Figure 1A. Mono Lake in 1991. Numbered points are the original 45 phalarope boat survey points. The lake's elevation was approximately 6,375 feet above sea level in 1990-1991. Note the dry areas in the north and east of the lake, which were flooded during 2019-2020 surveys.

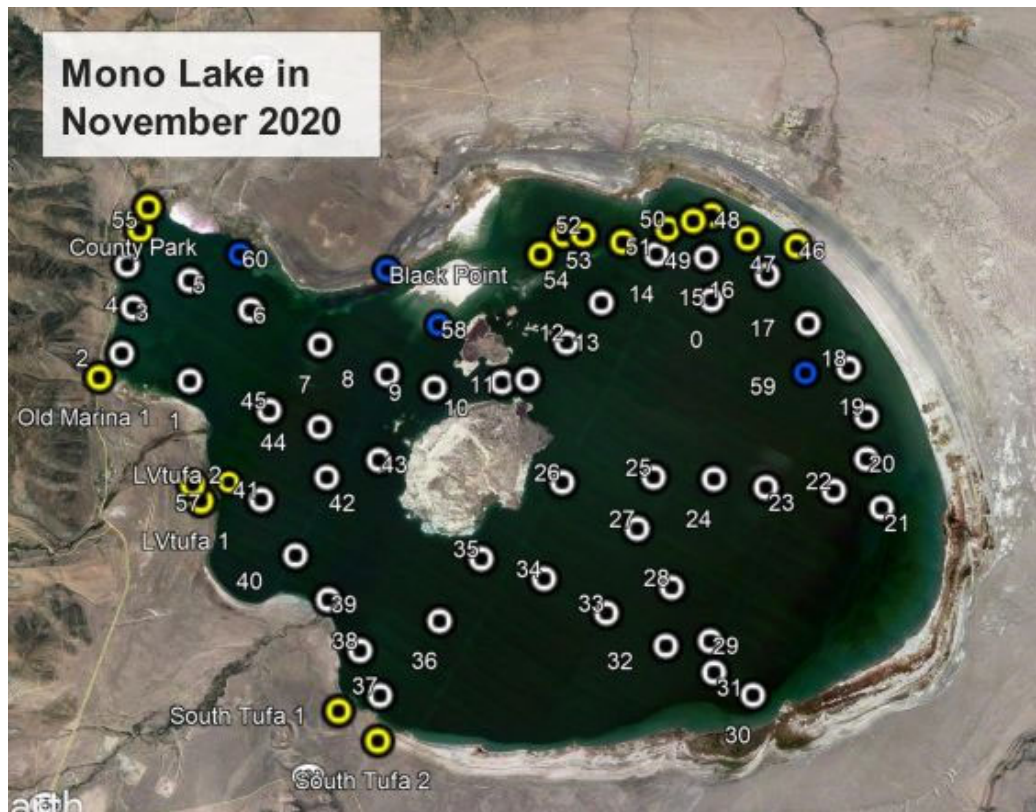


Figure 1B. Mono Lake in 2020. The 2019-2020 elevation of the lake was 6,381-6,382 feet above sea level– 6-7 vertical feet higher than in 1990-1991. White dots are original 1990-1991 phalarope boat survey points, yellow dots are points added in 2017 and 2019, and blue dots are points added in 2020. Numbered 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 (Fig. 1A) were flooded in 2019-2020.

During 2019, we updated the survey methods because Mono Lake's water level had risen six vertical feet since 1990-1991. The lake's surface area in 2019-2020 was much larger than in 1990-1991 (Fig. 1A, 1B), meaning nearshore points in 1990-1991 were now farther offshore, and some large areas were flooded that were once dry, especially the north and east parts of the lake (Figs. 1A, 1B).

A detailed description of modifications to the protocol during 2019 are described in our 2019 report (Carle and Rubega 2019). Major modifications were:

- The addition of nine boat survey points in 2017, and two in 2019. The number of boat survey points was 45 in 1990-1991, 54 in 2017, and 56 in 2019.
- The modification of the 1990-1991 boat count radius from 75m (17,671 m² total count area per point) to 400m (503,000 m² total count area per point), starting in 2019. During 1990-1991, a 75m radius was guessed at without measuring tools. In 2019, few birds were recorded within 75m, so we used a rangefinder to determine that 400m was a count radius more likely to result in detections without being so large that accurate identifications became difficult. 400m radius counts began on August 2nd, 2019.

Comparison of count numbers suggest that the 75m count radius during 1990-1991 was likely overestimated. We again used a 400m count radius in 2020.

- The addition of shore survey points at County Park, Old Marina, Lee Vining Tufa, and South Tufa in 2019. Boat survey points established in the 1990s near shore in these areas historically known to host phalaropes (Jehl 1986, 1988), were no longer near shore in 2019. These areas also could not be fully covered by new boat points because of shallow water, views blocked by tufas, and nesting osprey disturbance.

The shore survey protocol, added in 2019, consisted of one observer counting with a spotting scope at standardized GPS points at shore locations. At each shore survey point, count area and distance were standardized using fixed landmarks and maps (see Appendix 2). We estimated the total lake area surveyed at each shore point by measuring the areas of polygons of survey coverage created in Google Earth Pro (Table A2.1, Appendix 2), using a satellite image from November 2019. Lake area covered varied by shore survey site (Table 1), based on the specific views afforded by each site. The estimated survey area for each shore survey location was less than the 0.5 km² area of each boat point (Table 1).

Table 1. Total estimated lake surface areas (km²) of phalarope survey points at Mono Lake during 2019. See Appendix 2 for maps of shore survey areas.

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

During 2020, we made the following additional modifications to the protocol:

- The addition of three more boat survey points to provide greater overall coverage of the lake. These were located on the west side of Negit Island near the Black Point Shoals (Point 58; added August 13th), near the Mill/Wilson Creek deltas (Point 60; added August 15th), and in a part of northwest of the lake that was previously without any points (Point 59; added August 15th; blue dots in Fig. 1B). The Mill/Wilson Creek delta and Negit Island points were in near-shore, shallow areas with submerged tufa, characteristics which appear to attract phalaropes. These areas were dry when the survey protocol was created in the 1990s. The point in the middle of the lake was in an area that was previously not well covered by the survey, which we had observed was often used by phalaropes. The addition of these points complicates year to year comparisons, so we excluded them in direct comparisons of 2019 and 2020 results. However, the addition of

these points gives a more complete account of the total number of phalaropes on the lake during a survey, though it is important to note that the result is still an index, not a comprehensive count of every bird on the lake.

- The addition of a shore survey point at Black Point. This area was dry during the 1990-1991 surveys, but in 2020 had a shallow inlet of water between shore and the land bridge island (also known as Gaines Island). This inlet was invisible from the boat points and was too shallow to boat into. Similar to the additional boat points added in 2020, we dropped this point for direct comparisons with 2019, but used it to report maximum 2020 counts.
- Refinement of shore survey boundaries and observer training (see Appendix 2), and the addition of a second observer during shore surveys for better error estimation.
- Change of the error threshold for repeating counts from 10% difference between observers to 15%. We decided to do this because of the tradeoff between making time-consuming repeat counts of large flocks until we were within 10% observer error, and finishing the survey without frequent large-flock recounts, and within the limited daily window when counting is possible. Moreover, recount results often differed from original counts because of movement of birds during the time-consuming counts of large flocks. Observer error was often within 15%, but not 10%, in original counts, so we chose the 15% threshold.

To create single-day totals for each species, we combined each day's boat and shore survey results. First, we adjusted boat survey totals in places with overlapping shore and boat points by estimating the percentage of overlap area between the boat and shore points, and subtracting that proportion from the boat point's count (see Appendix 2). We used this method for boat points that overlapped with shore counts at South Tufa, Lee Vining Tufa, Old Marina, and County Park. To quantify the total number of phalaropes observed per species on each survey, we used the equation

$$\bar{x}_{boat} + \bar{x}_{shore} = total\ phalaropes$$

where $\bar{x}$ is the mean of the two observers' totals from each survey type.

We calculated a standard deviation for the combined total using the equation:

$$\sqrt{(SD_{boat}^2 + SD_{shore}^2)} = SD_{total\ survey}$$

We report errors throughout as ± 1 standard deviation.

Results and discussion

Maximum numbers of phalaropes

The season maximums for phalaropes on Mono Lake during 2020 were $2,765 \pm 96$ Wilson's phalaropes on July 31st, $10,891 \pm 581$ red-necked phalaropes on August 15th, and $1,385 \pm 25$ unidentified phalaropes on July 31st (Fig. 2). The greatest combined count of phalaropes of all species during 2020 was 11,130 birds on August 15th.

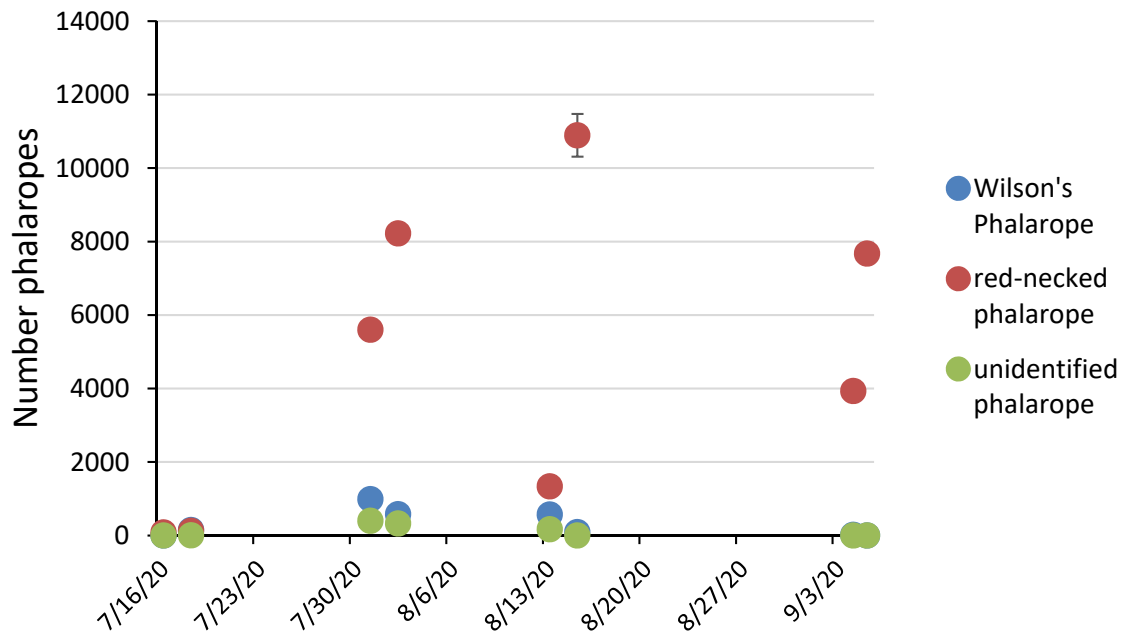


Figure 2: Total number of Wilson's, red-necked, and unidentified phalaropes recorded on Mono Lake from combined boat and shore surveys during 2020. Data includes all points counted in 2020, including points not counted in 2019. Totals shown for each date are the sum of the averages of the two boat surveyors' totals and the averages of the two shore surveyors' totals. Error bars are the combined standard deviation of these two averages (see equation in text). With the exception of August 15th, SDs were too small to be visible on the scale of the graph. For four points with overlapping shore and boat surveys, we adjusted boat survey totals to account for the percent of overlap (see text, Appendix 2). Points close together are from surveys within 1-3 days of each other. Raw data from all dates and surveyors, as well as overall whole-lake totals are in Appendix 1.

To compare 2020 counts with 2019, we dropped the counts from the three boat points (58, 59 and 60) and one shore point (Black Point) added in 2020. Excluding those points did not change high count dates, but changed maximum count totals of red-necked phalaropes to $10,597 \pm 567$, and unidentified phalaropes to 400 ± 14 . Exclusion of those points did not change the Wilson's phalarope high count. The remainder of the results reported in the results section exclude the points added in 2020 unless otherwise noted. We compare 2020 counts only to 2019 counts with 400m boat count radii (August 2nd 2019 and on).

The July 31st high count of $2,765 \pm 96$ Wilson's phalaropes was similar to 2019's August 2nd high count of $2,712 \pm 75$ (Fig. 3). These numbers remarkably are similar; however, there were

far more additional unidentified phalaropes on the peak Wilson's phalarope count day in 2019 (12,817 unidentified phalaropes) than in 2020 (400 unidentified phalaropes; Fig. 4). If unidentified phalaropes counted on July 31st, 2020 at Black Point (which was not surveyed in 2019) were included, the maximum combined Wilson's and unidentified count would be 4,150 for 2020, vs. a combined unidentified and Wilson's high count of 15,582 in 2019. A portion of the "unidentified" birds in 2019 were a flock of 8,000-9,000 phalaropes at South Tufa that were repeatedly identified as Wilson's during late July-early August 2019, but were recorded as unidentified on the official August 2nd, 2019 shore survey. Including these birds in the 2019 high count results in an estimate of approximately 11,200 Wilson's phalaropes. Thus, it appears that the number of Wilson's Phalaropes at Mono Lake was many thousands of birds lower in 2020 compared with 2019.

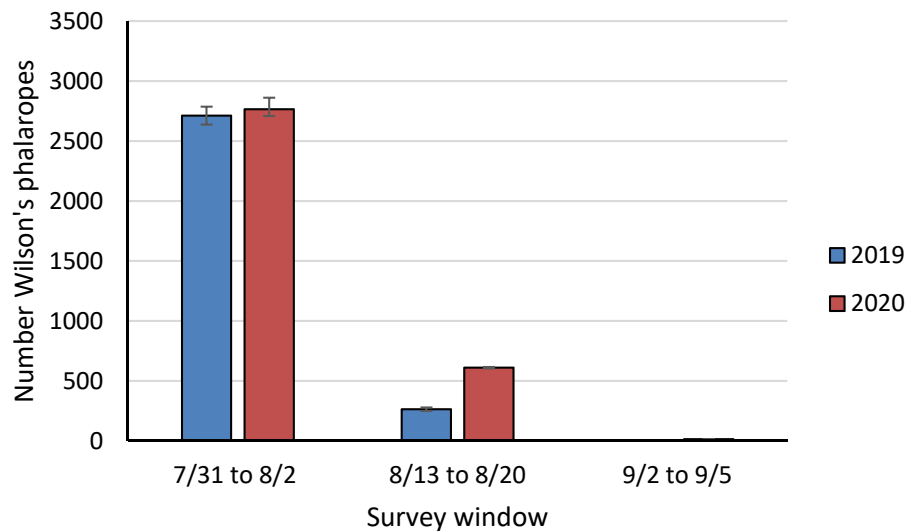


Figure 3. Comparison of Wilson's phalarope high counts during survey windows in 2019 and 2020. For each survey window, the highest single-day total is shown. There were two surveys in each window in each year. Mid-July surveys are not shown because the mid-July 2019 surveys used a different boat count radius than was used on subsequent surveys. Differences in annual Wilson's phalaropes are best interpreted along with unidentified phalarope counts on the same dates (Fig. 4).

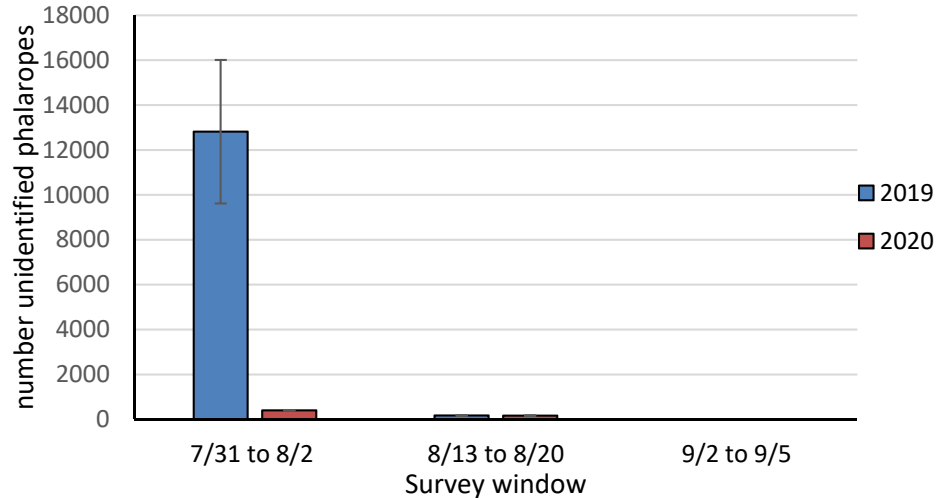


Figure 4. Comparison of unidentified phalarope high counts during survey windows in 2019 and 2020. For each survey window, the highest single-day total is shown. There were two surveys in each window in each year. Mid-July surveys are not shown because the mid-July 2019 surveys used a different boat count radius than was used on all subsequent surveys.

The maximum count of red-necked phalaropes in 2020 was on August 15th ($10,597 \pm 567$), and was nearly double the 2019 maximum ($5,573 \pm 177$, September 2nd, 2019; Fig. 5). Indeed, counts on four of the 2020 dates exceeded the maximum 2019 count. Red-necked phalarope numbers historically remained near peak-levels into mid-September (Jehl 1986), so it is possible that we missed a peak of red-necked phalaropes because we could not survey in mid-September 2020.

The maximum count of unidentified phalaropes in 2020 was 400 ± 14 on July 31st, much less than the $12,817 \pm 3,197$ maximum on August 2nd 2019 (Fig. 4). Far fewer birds were unidentified in 2020, mainly because shore survey observers had greater identification skills and regularly identified birds to species at Lee Vining Tufa and South Tufa shore survey points. The exception was the Black Point shore point, which was too distant from the water to tell species apart during most surveys. Black Point was excluded for comparison with 2019, but the highest overall 2020 counts of unidentified birds (985 ± 21 on July 31st, 418 (one observer, no SD) on August 2nd) were from Black Point.

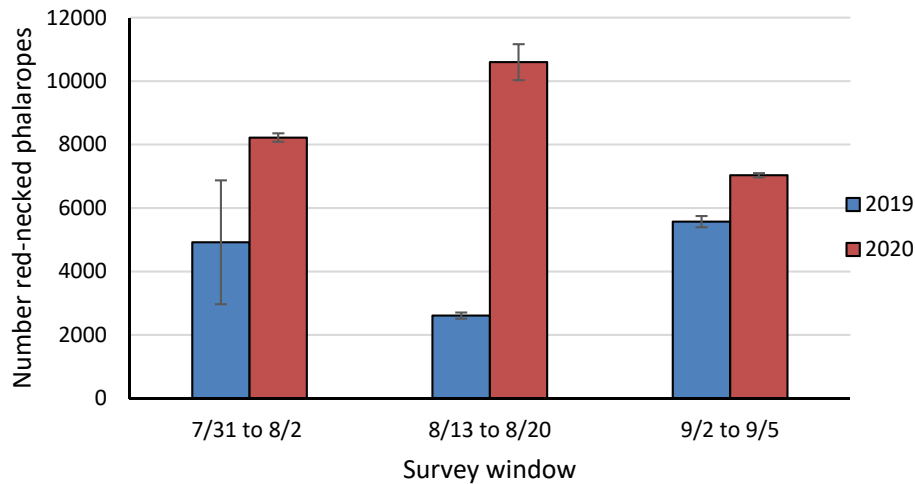


Figure 5. Comparison of red-necked phalarope high counts during survey windows in 2019 and 2020. For each survey window, the highest single-day total is shown. There were two surveys in each window in each year. Mid-July surveys are not shown because the mid-July 2019 surveys used a different boat count radius than was used on all subsequent surveys.

Timing and spatial use of phalaropes

Wilson's phalaropes

Wilson's phalarope numbers increased from 658 ± 18 on July 16th to $2,475 \pm 535$ on July 18th, peaking on July 31st at $2,765 \pm 96$ (Fig. 2 for trends, exact values in Table A1.2 Appendix 1). Numbers dropped to $1,128 \pm 57$ by August 2nd, and declined through mid-August (totals in the hundreds) and early September (totals of 15 and zero birds). The attendance pattern and timing of Wilson's Phalaropes in 2020 was similar to 2019 and to patterns during 1980-1986 (Jehl 1988) and 1990-1991 (Rubega and Keimel 2017). The pattern in all survey years was that numbers rapidly grew to a peak from mid-July to early August, followed by a rapid drop in the numbers by mid-August, with most birds departed by September (Fig. 2).

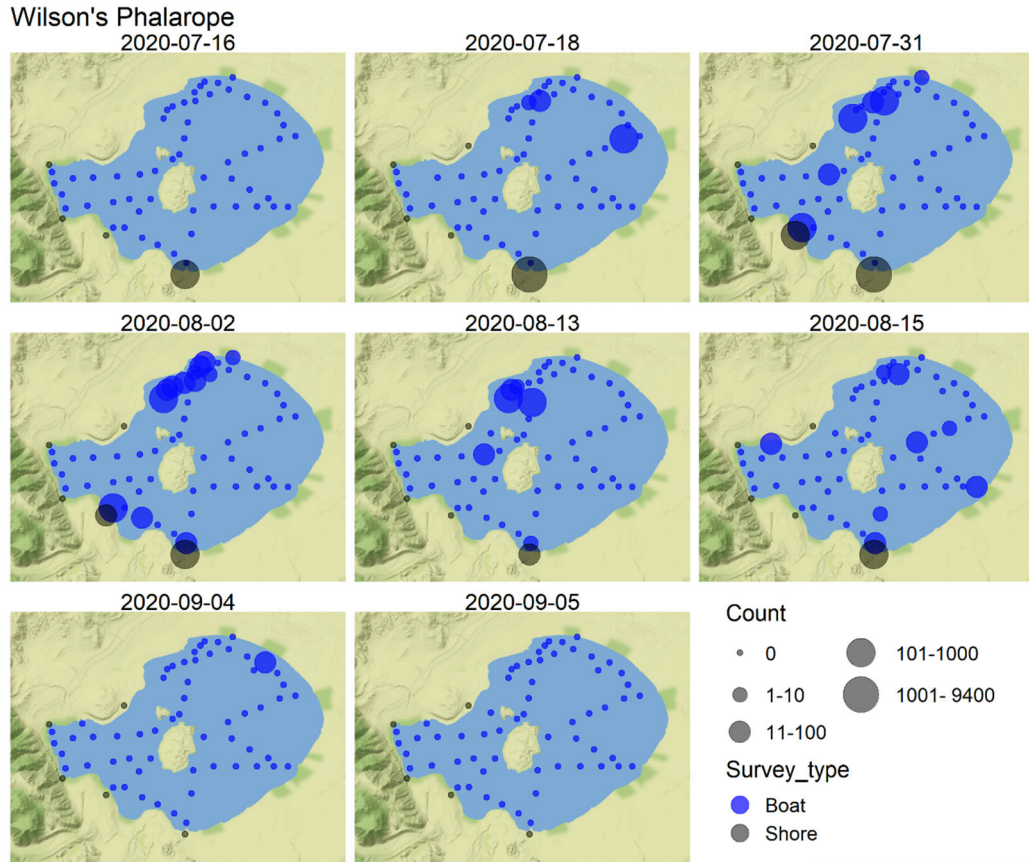


Figure 6. Distribution and magnitude of Wilson’s phalaropes on Mono Lake across the 2020 season, from boat and shore surveys. Circle size indicates the magnitude of counts at a given location on each date. Blue dots are boat surveys and gray dots are shore surveys. Note that all boat survey points are directly comparable, with a standardized count radius, whereas shore survey count areas are variable. See Table 1 for count areas of each shore survey point. The peak Wilson’s phalarope count was July 31st.

Spatial use of Mono Lake by Wilson’s phalaropes in 2020 was generally similar to 2019, with the largest flocks near shore at South Tufa and smaller flocks at Lee Vining Tufa and in the north-northwest part of the lake (Fig. 6). In 2020, Wilson’s phalaropes were often in mixed flocks with red-necked phalaropes (see cover photo of this report) in the north-northwest part of the lake, whereas in 2019 the two species were often more segregated by species. In 2019, some Wilson’s phalaropes moved to the west shore of the lake in mid-August, which did not occur in 2020. The use of both the south shore tufa areas and the north-northwest shore of the lake by Wilson’s phalaropes was consistent with patterns in 1980-1986, though Wilson’s phalaropes also used the west shore more during those years than during 2019-2020 (Jehl 1988). In 2017, Wilson’s phalaropes were concentrated in the north-northwest shore and were not observed at South Tufa or Lee Vining Tufa during several partial surveys over three days in mid-July (Rubega and Keimel 2017).

Red-necked phalaropes

Small flocks of red-necked phalaropes were present during the mid-July surveys (≤ 120 birds total). Numbers increased to $5,597 \pm 122$ on July 31st and $8,220 \pm 134$ on August 2nd, and peaked at $10,597 \pm 567$ on August 15th (see Fig. 2 for trends, exact values in Table A1.2 Appendix 1). Red-necked phalarope abundance did not follow a consistent trajectory; counts on back to back days sometimes differed by thousands (Fig. 2). A count of $1,337 \pm 18$ on August 13th was followed by a count of $10,587 \pm 567$ on August 15th, and a September 4th count of $3,428 \pm 17$ was followed by a September 5th count of $7,023 \pm 70$. These results showed the importance of the back to back counts for capturing the daily variability of results and increasing the likelihood of capturing peaks. Whether day-to-day variability is related to birds being present at points during some survey days and not others, and/or to arrivals and departures of birds from Mono Lake, is unknown. Day-to-day numbers of red-necked phalaropes also varied in 2019, but by a lesser magnitude. Residence time of red-necked phalaropes at Mono Lake and other staging sites is unknown, though it has been suggested that it is shorter than that of Wilson's phalaropes (Jehl 1988). Our results on back to back days are suggestive of birds leaving and arriving, though we cannot be certain it is not a survey effect without direct measurement of residence time. Generally, the arrival of major numbers of red-necked phalaropes to Mono Lake in late July/early August, followed by a protracted peak throughout August and September, was consistent with both our 2019 results and those of surveys from 1981-1984 (Jehl 1986).

During the July 31st and August 2nd 2020 surveys, red-necked phalaropes were concentrated in the north-northwest of the lake in shallow nearshore areas (Fig. 7). During mid-August and early September surveys, red-necked phalaropes remained in that north-northwest part of the lake, but also spread southwest into a greater swath of the eastern lake (Fig. 7). Small numbers (< 300 birds) appeared at County Park on the northwest shore in September (Fig. 7). This movement pattern was remarkably consistent in 2019 and 2020, and was relatively similar to movements during 1981 and 1982 (Jehl 1986), when the lake's elevation was ~ 10 vertical feet lower. In those years, red-necked phalaropes concentrated in the north part of the lake in late July-early August, and then spread out to more locations by mid-August, though they used the west and south shores more often than in 2019 and 2020.

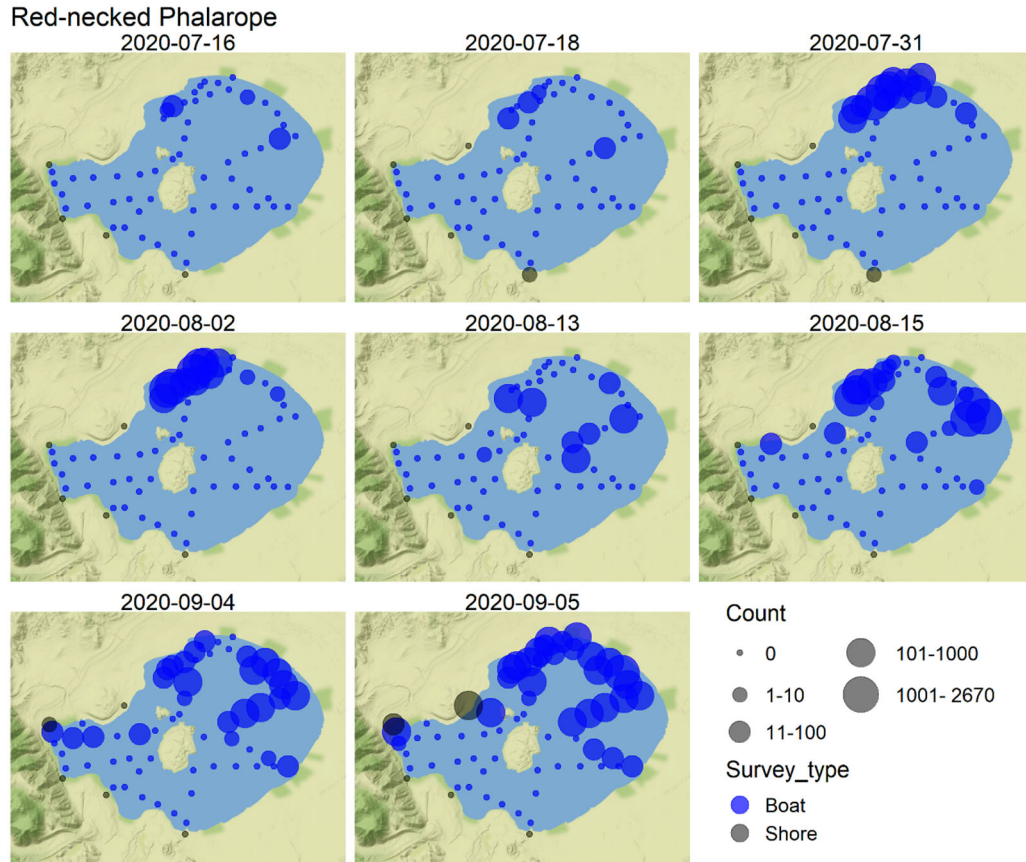


Figure 7: Distribution and magnitude of red-necked phalaropes at Mono Lake across the 2020 season, from boat and shore surveys. Circle size indicates the magnitude of counts at a given location on each date. Blue dots are boat surveys and gray dots are shore surveys. Note that all boat survey points all directly comparable, with a standardized count radius, whereas shore survey count areas are variable in area. See Table 1 for count areas of each site. The peak red-necked phalarope count was August 15th.

Unidentified phalaropes

Unidentified phalaropes were located only in the northern part of Mono Lake in 2020 (Fig. 8). This was because it was usually not possible to differentiate phalarope species at the Black Point shore survey point because of its distance from the lake, and because often the light was often challenging looking straight east. Likewise, it was not always possible on the boat survey to identify every bird in large flocks at points in the north of the lake. Unlike 2019, birds at South and Lee Vining Tufas were regularly identified to species, due mainly to better observer identification skills in 2020.

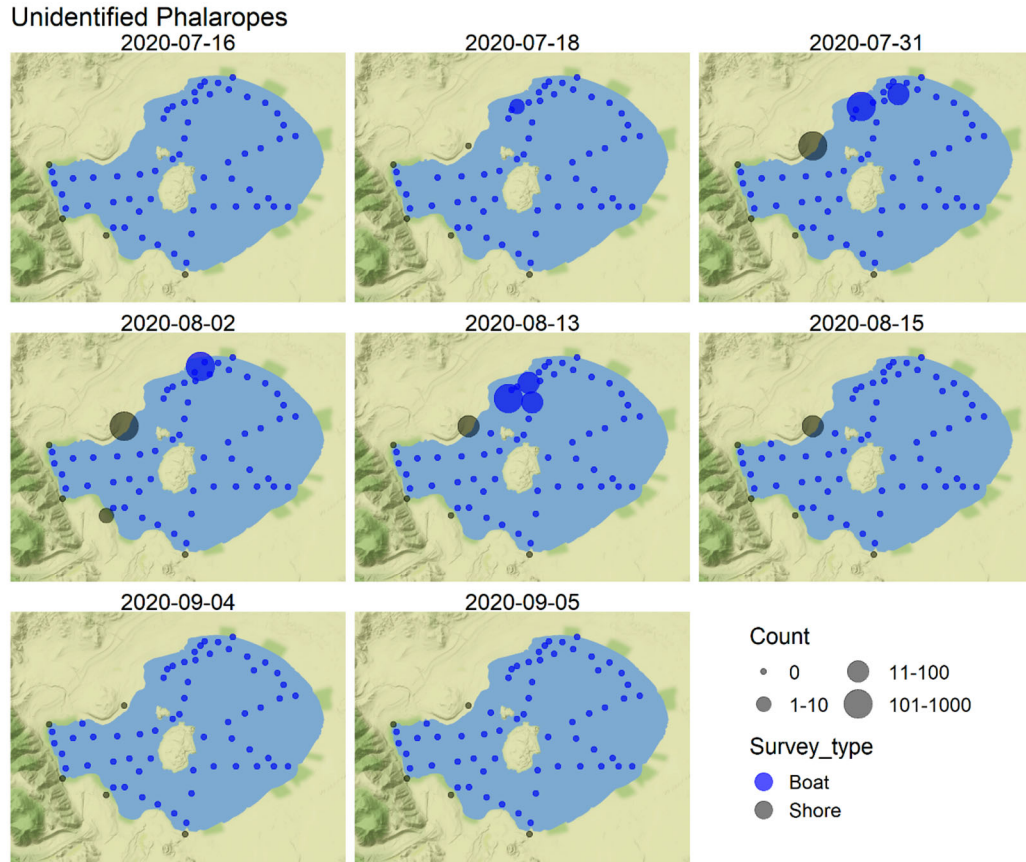


Figure 8: Distribution and magnitude of unidentified phalaropes at Mono Lake across the 2020 season, from boat and shore surveys. Circle size indicates magnitude of counts at a given location on each date. Blue dots are boat surveys and gray dots are shore surveys. Note that all boat surveys are directly comparable, with a standardized count radius, whereas shore survey count areas are variable. See Table 1 for count areas of each site. The peak unidentified phalarope count was July 31st.

Comparison of survey results on consecutive days

Phalaropes move around Mono Lake on a scale from hours to days (Jehl 1988), and individuals may arrive or depart from staging sites from one day to the next. Daily movements affect count totals as they relate to the “true” total number of birds present. To compare counts during our paired surveys (within 1-2 days of each other), we divided the absolute difference of the two counts by the total from the highest count (Table 2). Daily counts differed by 59-100% in Wilson’s phalaropes, with absolute differences sometimes over a thousand, and 32-87% in red-necked phalaropes, with absolute differences of up to 9,260 (Table 2). This highlights the importance of doing multiple surveys during survey windows at regular intervals throughout the summer. For example, a single survey in a given year would be unlikely to accurately capture a peak total of either species given day to day variability. This variability may be related to birds moving around the lake and being visible at the fixed survey points one day and not the next, or to birds arriving and departing the lake, or both. Moreover, we lack information about whether birds move between Mono Lake and nearby wetlands, such as Owens Lake. The striking difference in red-necked phalarope totals between August 13th and 15th (>9,000 more on the 15th) was noticed during the survey; our sense was that there were many more birds on the lake overall on the 15th than on the 13th, and it was not entirely a survey-effect. Better understanding of

residence time of phalaropes, especially of red-necked phalaropes, would help us interpret day to day variability in count numbers.

Spatially, locations of phalaropes were fairly similar during each survey window (Figs. 6, 7, 8), though there were enough differences to illustrate the importance of whole lake surveys. The differing locations of Wilson's phalaropes on August 13th and 15th (Fig. 6) was a good illustration of how birds can be concentrated in one area (the north-northwest shore near the land bridge island) one day, and mostly absent from that area two days later.

Table 2. Day to day differences in total counts of Wilson's, red-necked, and unidentified phalaropes during 2020. All counts shown were either on back to back days or were two days apart. Percent differences were calculated by dividing the absolute difference between the consecutive daily counts by the higher of the two count totals. Totals used for each day were the combined average counts of the two boat observers and two shore observers, excluding four points added in 2020 that were not counted on all 2020 dates.

Survey dates	WIPH totals (first survey, second survey)	WIPH Absolute difference	WIPH % difference	RNPH totals (first survey, second survey)	RNPH absolute difference	RNPH % difference
7/16 and 7/18	658 ± 18, 2,475 ± 535	1,817	73%	82 ± 0, 129 ± 7	47	36%
7/31 and 8/2	2,765 ± 96, 1,128 ± 57	1,638	59%	5,597 ± 122, 8,220 ± 134	2,623	32%
8/13 and 8/15	637 ± 8, 203 ± 12	408	67%	1,337 ± 18, 10,891 ± 581	9,260	87%
9/4 and 9/5	15 ± 0, 0 ± 0	15	100%	3,938 ± 11, 8,251 ± 15	3,604	51%

Comparison of counts between boat observers: A key factor in bird surveys is error associated with differences among individual surveyors. Table 3 shows absolute and percent differences between observers on boat surveys. During most dates, the two observers' results were within 10% of each other. Exceptions (e.g., Wilson's phalaropes on August 15th; Table 3) were usually driven by one observer seeing a flock of birds fly by that the other observer did not see. These instances are methodologically important, but occurred most often with small groups of birds, so they did not affect overall interpretation of results greatly. Though observers' overall survey sums were usually within 10% of each other, at individual points with large groups of birds it was often difficult to efficiently achieve counts within 10% of each other. Indeed, trying to hit the 10% threshold often felt like it biased the results by extending the count time as observers attempted to get similar counts. This was why we changed the threshold to 15% in 2020, which was an easier threshold to achieve.

Table 3. Absolute and percent differences between boat observers total survey counts. Percent difference is the absolute difference divided by the highest count on each date.

Date	WIPH totals (obs. 1, obs. 2)	Absolute difference WIPH	% difference WIPH	RNPH totals (obs. 1, obs. 2)	Absolute difference RNPH	% difference RNPH
7/16	0, 0	0	0%	82, 82	0	0%
7/18	152, 141	11	7%	122, 132	10	8%
7/31	1037, 1061	24	2%	5683, 5511	172	3%
8/2	641, 581	60	9%	8314, 8125	189	2%
8/13	573, 564	9	2%	1350, 1324	26	2%
8/15	96, 83	13	14%	11301, 10480	821	7%
9/4	15, 15	0	0%	3949, 3921	28	1%
9/5	0, 0	0	0%	7715, 7681	34	0%

Shore surveys vs. boat surveys: As in 2019, shore surveys were an important complement to boat surveys. Though few or no phalaropes were registered at County Park, Old Marina, or Lee Vining Tufa during 2020, shore surveys registered flocks of >1,000 Wilson’s phalaropes at South Tufa in July, which were not recorded by the boat survey points (Table 4). Phalaropes at South Tufa were located close to shore and often blocked from the view of boat points by tufa towers. The additional shore point at Black Point, added in 2020, also registered groups of hundreds to a thousand phalaropes. 2020 results also underscored the fact that both boat and shore points are crucial for getting a complete picture of phalarope numbers at Mono Lake. In both 2019 and 2020, the vast majority of phalaropes were located on the north and eastern parts of the lake, often far out on the water in areas accessible and visible only by boat. With Mono Lake’s dynamically fluctuating lake elevations, it is clear that survey protocols must balance flexibility to adapt to the changing conditions (e.g. the addition of new shore and boat points in previously dry areas) with maintaining standardization for time-series comparisons (e.g. keeping historical boat points in the same places).

Table 4. Total counts of Wilson's and red-necked phalaropes from overlapping both boat and shore survey points at Mono Lake, 2020. Boat survey numbers shown are raw, unadjusted counts. Note that boat and shore points shown were adjacent to each other, with varying degrees of overlap. See Appendix 2. for overlap proportions in each area. Areas with shore and boat counts that registered no birds are not shown (e.g. zero birds the whole season at Old Marina, and zero Wilson's phalaropes at County Park). Red-necked phalaropes were seen at South Tufa only once (2 birds on the July 18th shore survey, zero on the boat survey). Black Point is not shown because it did not overlap with a boat survey point.

Date	Wilson's Phalarope				Red-necked phalarope	
	South Tufa Boat	South Tufa shore	Lee Vining Tufa boat	Lee Vining Tufa shore	County Park boat	County Park shore
7/16/20	0 ± 0	658 ± 18	0 ± 0	0 ± 0	0 ± 0	0 ± 0
7/18/20	0 ± 0	2328 ± 535	0 ± 0	0 ± 0	0 ± 0	0 ± 0
7/31/20	10 ± 0	1447 ± 90	291 ± 13	333 ± 4	0 ± 0	0 ± 0
8/2/20	12 ± 1	502 ± 33	158 ± 8	49 ± 2	0 ± 0	0 ± 0
8/13/20	7 ± 3	69 ± 6	0 ± 0	0 ± 0	0 ± 0	0 ± 0
8/15/20	11 ± 1	114 ± 7	0 ± 0	0 ± 0	0 ± 0	0 ± 0
9/4/20	0 ± 0	0 ± 0	0 ± 0	0 ± 0	51 ± 3	9 ± 0
9/5/20	0 ± 0	0 ± 0	0 ± 0	0 ± 0	215 ± 7	91 ± 0

Phalarope trends at Mono Lake

There have been phalarope surveys at Mono Lake since the 1970s (e.g., Winkler et al. 1977, Jehl 1986, Jehl 1999), but it is difficult to directly compare these surveys to our own, or to each other, due to important differences in methodologies and coverage. We are working on a separate report examining the details of how to best interpret historic data from Mono Lake, Great Salt Lake, and Lake Abert. Here, we focus on comparing our 2019 and 2020 Mono Lake surveys with each other, and to Rubega and Keimel (2017)'s surveys in 1990, 1991, and 2017, which established the protocol ours is a refinement and extension of.

When comparing contemporary results with Rubega and Keimel's 1990 and 1991 surveys, it is noteworthy that the lake's elevation was 6-7 vertical feet lower in 1990-1991 than in 2017, 2019, or 2020 (Figs. 1A, 1B). The 1990-1991, 2017, and 2019-2020 surveys followed similar protocols, but modifications were made as the lake level changed (see details in Methods). Given the addition of more boat survey points, shore survey points, and a greater boat count radius during 2019-2020 it might be expected that, all things equal, the 2019-2020 surveys would register more birds than the 1990-1991 surveys did. However, it is also possible that phalaropes were more concentrated in a smaller area in 1990-1991, and it may be easier to miss them on the survey under current conditions, despite the additional survey points.

Wilson's phalarope trends

2019 and 2020 surveys registered far fewer Wilson's phalaropes than the 1991 peak of 35,225 birds on July 18th (Rubega and Keimel 2017; Fig. 9). Rubega and Keimel's 1990 survey was not timed to capture Wilson's phalarope peak numbers, though they registered 9,037 on August 7th. Contemporary surveys (2017, 2019, 2020) have recorded no more than 16,000 birds even when

combining confirmed Wilson's phalaropes with unidentified birds seen on the peak Wilson's phalarope count date (Fig. 9).

Trends of peak Wilson's phalaropes are best examined along with the totals of unidentified birds on the same dates (Fig. 6), because in some years there were many more unidentified birds than confirmed Wilson's phalaropes. In 2017, surveys were conducted only on July 17th-19th, and none was a complete survey (Rubega and Keimel 2017). However, the July 19th survey registered 1,168 Wilson's phalaropes and 14,096 unidentified phalaropes (no error rates reported; Rubega and Keimel 2017; Fig. 6). Given this timing, it seems likely that many of the unidentified birds were Wilson's phalaropes in 2017 because mid-July surveys in 2019 and 2020 registered few red-necked phalaropes (i.e., <150 birds).

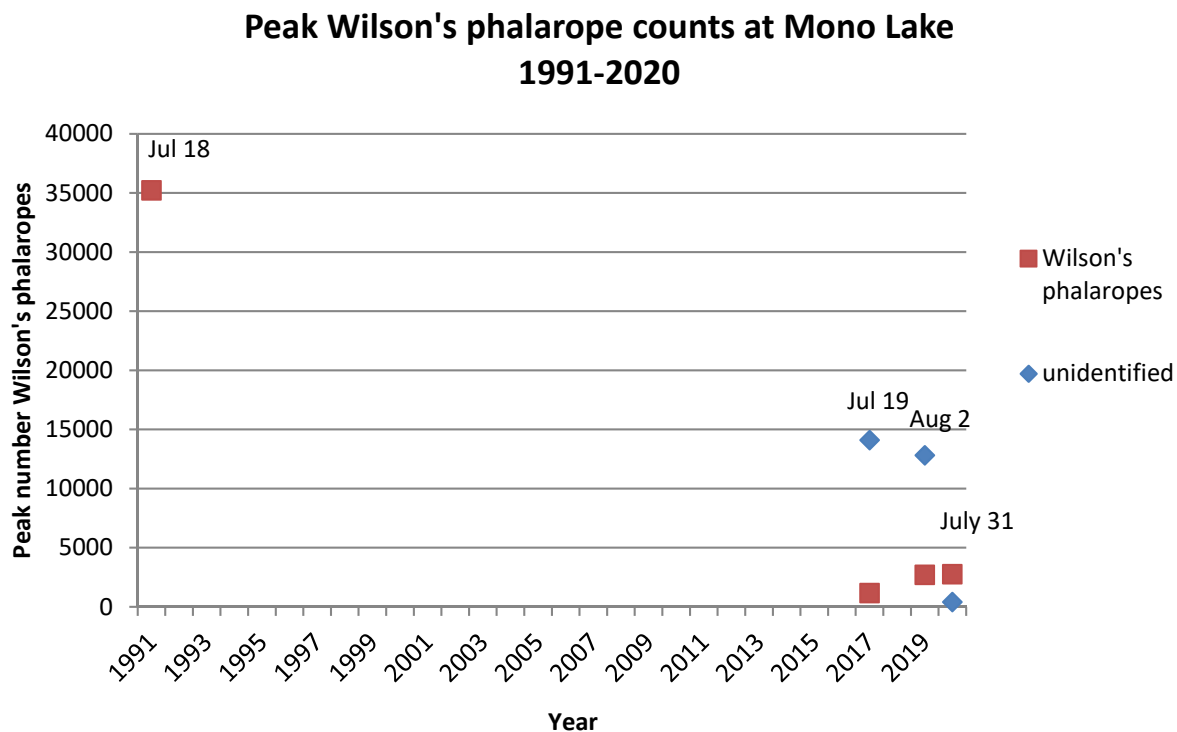


Figure 9. Peak annual numbers of Wilson's phalaropes, and unidentified phalarope totals on the same day, at Mono Lake, 1991-2020. Red squares are Wilson's phalaropes and blue diamonds are unidentified phalaropes. Survey date is shown above the data points for each year. 1991 and 2017 data are from Rubega and Keimel (2017). All surveys shown were based on the same protocol, but 2019-2020 surveys had additional boat and shore surveys and a greater count radius than 1991 or 2017 (see text).

During 2019, the peak confirmed Wilson's phalarope count was $2,712 \pm 75$ on August 2nd, but there were also $12,817 \pm 3,197$ unidentified birds on the lake that day (Fig. 6). A flock of 9,457 confirmed Wilson's phalaropes were counted from shore a few days prior at South Tufa. 8,500 unidentified phalaropes were at South Tufa on July 31st, and were almost certainly Wilson's. There were also substantial numbers of red-necked phalaropes at the lake on August 2nd 2019 (2,612 identified as red-necked). Thus, the true number of Wilson's in 2019 was likely somewhere in the range of 11,000-14,000 birds.

In 2020, the peak count of Wilson's phalaropes was $2,765 \pm 96$ on July 31st. An additional 400 ± 14 unidentified birds could have been Wilson's, but even with these unidentified birds, the total count would only be $3,165 \pm 97$. Despite the difficulties of modified methodologies and the uncertainty of Wilson's vs. unidentified phalaropes in some years, the differences between the 1991 and contemporary counts are striking, and cause for concern. There were half as many or fewer Wilson's phalaropes at Mono Lake in 2017, 2019, and 2020 than there were in 1991, and 2020 counts were especially low (Fig. 9).

Red-necked phalarope trends

Our 2019 and 2020 surveys registered lower peak red-necked phalarope totals than 1990 and 1991 surveys, though the magnitude of the difference was not as great as the difference in Wilson's phalarope numbers between those years. The 1990 and 1991 surveys recorded peaks of 17,000-18,000 red-necked phalaropes (Rubega and Keimel 2017), whereas the 2019 survey had $5,573 \pm 177$ and the 2020 survey had $10,597 \pm 567$. A better understanding of red-necked phalarope movements among lakes and residence times at Mono Lake, both of which are unknown, is needed for both an accurate estimate of the total number of birds using Mono Lake, and overall species population trends.

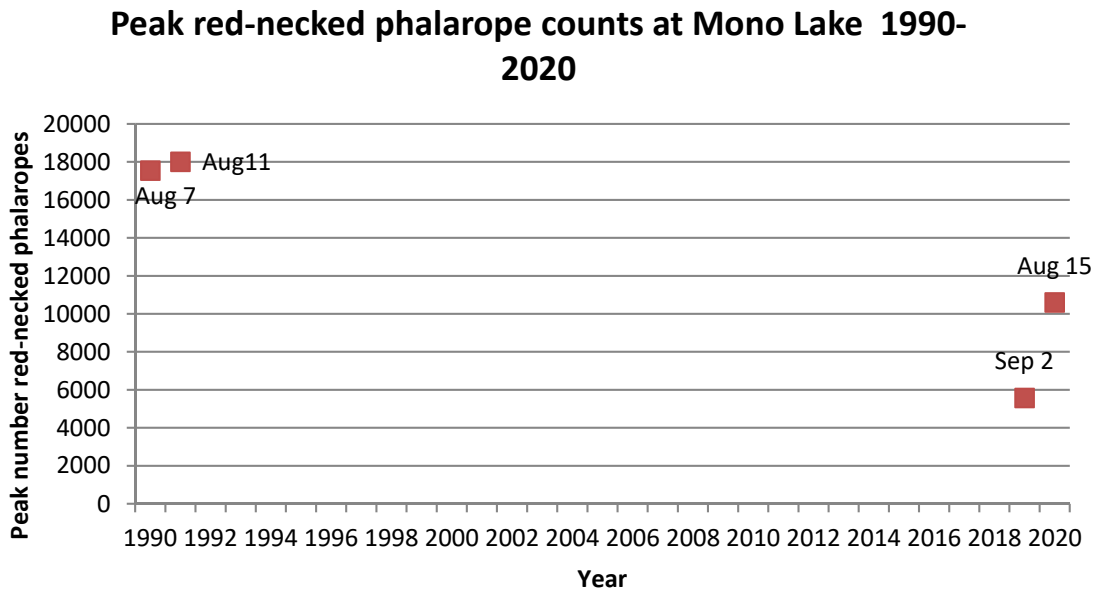


Figure 7. Peak annual numbers of red-necked phalaropes at Mono Lake, 1990-2020. Survey date is shown above the data points for each year. 1990, 1991, and 2017 surveys were carried out by Rubega and Keimel (2017). All surveys shown were based on the same protocol, but 2019-2020 surveys had additional boat and shore survey points and a greater count radius than 1990, 1991, and 2017 (see text).

Conclusions

One take-away from the 2020 surveys at Mono Lake is the continued importance of rigorous annual surveys with a stable, standardized methodology. With 2019 and 2020 data, we now have two years that are fully comparable. These surveys are comparable enough to the 1990, 1991, and 2017 surveys to be of some use for comparisons over time. Each additional year of surveys using the current method will add value to the time-series and bring us a better understanding of phalarope trends at Mono Lake.

Another take-away is that the timing of phalaropes at Mono Lake appears unchanged since surveys in the 1980s and 1990s. This is important as it suggests that climate change has not altered the timing of migration of phalaropes at Mono Lake; whether phalarope arrival or departure from staging sites will begin to lag annual peaks in prey abundance remains to be seen. This information is also helpful for planning dates of future surveys and interpreting data from years like 2017, when there was only a mid-July survey.

We have learned a great deal about the current spatial use of phalaropes at Mono Lake, partially answering an original question of this project—why do people have a general impression that there are few phalaropes at Mono Lake in recent years? One answer is that many of the phalaropes at Mono Lake in 2019 and 2020 were simply in places where it is difficult for casual observers to see them. The vast majority of red-necked phalaropes, and many Wilson's phalaropes, were located in the north-northwest quadrant of Mono Lake in 2019 and 2020, where shore access is difficult. Furthermore, birds were often located far out on the water, not visible from any point from shore (Fig. 8). This underscores the need for the full-lake surveys that include boat points, and that casual surveys such as eBird, which are biased toward accessible shore sites like South Tufa and County Park, will never tell a complete story about Mono Lake phalaropes.



Figure. 8. Red-necked phalaropes far out on the water in the eastern part of Mono Lake, which is accessible only by boat.

Comparison of 2019-2020 and 1990-1991 data suggests declines in both phalarope species using Mono Lake, and especially of Wilson's. However, more data are needed to evaluate if these are real population trends and how much inter-annual variability and/or movement among lakes is influencing count numbers. Combining Mono Lake data with results from other locations is vital for understanding species-level trends. We are continuing to work with partners at Great Salt Lake (Utah), Lake Abert (Oregon), Owens Lake (California), Lake Chaplin (Saskatchewan), San Francisco Bay (California), and elsewhere to collate data from coordinated surveys in 2020. Finally, efforts facilitated by the International Phalarope Working Group to survey Wilson's phalaropes in South America and to install Motus towers for phalarope tracking at multiple sites will help us contextualize and understand results from Mono Lake, and lead us toward a better understanding of how to conserve phalaropes across the hemisphere.

Funding

Funding for this project came from California State Parks, The Tracy Aviary Conservation Fund, the Jeff Maurer Chautauqua Research Grant, Friends of Mono Lake Tufa State Reserve, and private donations.

Acknowledgements

Many thanks to the multitude of partners that contributed to the success of this project, including California State Parks for funding and staff and logistical support, and the Mono Lake Committee for use of the research boat, and staff and logistical support. Thanks especially to Bartshe Miller and Claire Landowski for help with boat coordination. Thanks to phalarope boat surveyors Sarah Hecocks and Ashli Lewis, and shore surveyors David Carle, Janet Carle, Catherine Jones, Nora Livingston, Dave Marquart, and Bartshe Miller. Thanks to Jonathan Felis for making beautiful visualizations of the data. Thanks to Jessica Espinosa for comments that improved the draft report.

Literature Cited

Carle, R. & M. Rubega. Phalarope surveys at Mono Lake 2019 report. Unpublished report to California State Parks. Available at: https://oikonos.org/wp-content/uploads/2020/03/Phalarope-Surveys-at-Mono-Lake-2019-Report.final_.pdf

Castellino, M. & A. Lesterhuis. 2020. Wilson's phalarope simultaneous census 2020. Unpublished report by Manomet, Plymouth, Massachusetts, USA.

Jehl, J.R. 1986. Biology of Red-necked Phalaropes (*Phalaropus lobatus*) at the western edge of the Great Basin in fall migration. Great Basin Naturalist 46: 185-197.

Jehl, J. R. 1988. Biology of the Eared Grebe and Wilson's Phalarope in the nonbreeding season: a study of adaptations to saline lakes. Studies in Avian Biology 12.

Jehl, J. R. 1999. Population studies of Wilson's Phalaropes at fall staging areas, 1980-1997: A challenge for monitoring. Waterbirds 22: 37-46.

Langham, G. M., Schuetz, J. G., Distler, T., Soykan, C. U., & C. Wilsey (2015). Conservation status of North American birds in the face of future climate change. PloS one, 10(9).

Lesterhuis, A. J., & R.P. Clay. 2009. Conservation plan for Wilson's phalarope (*Phalaropus tricolor*). Manomet Center for Conservation Sciences, Manomet.

Moore, J.N. 2016. Recent desiccation of western Great Basin saline lakes: lessons from Lake Abert, Oregon, USA. Science of the Total Environment 554: 142-154.

Rubega, M. A., D. Schamel, and D. M. Tracy. 2020. Red-necked Phalarope (*Phalaropus lobatus*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. <https://doi.org/10.2173/bow.renpha.01>

Rubega, M. and B. Keimel. 2017. Final report on a 2017 census of phalaropes at Mono Lake, California. Unpublished report to California State Parks.

Wilsey, C, B Bateman, L Taylor, JX Wu, G LeBaron, R Shepherd, C Koseff, S Friedman, & R. Stone. 2019. Survival by Degrees: 389 Bird Species on the Brink. Report by the National Audubon Society: New York.

Wurtsbaugh, W.A., Miller, C., Null, S.E., DeRose, R.J., Wilcock, P., Hahnenberger, M., Howe, F. and Moore, J. 2017. Decline of the world's saline lakes. Nature Geoscience 11: 816-821.

Winkler, D.W., Weigen, C.P., Engstrom, F.B., Burch, S.E. 1977. Ornithology in An Ecological Study of Mono Lake (D. Winkler, Ed.). Institute of Ecology Publication No. 12. University of California, Davis.

Appendix 1.

Table A1.1. Mono Lake 2020 shore survey totals. Results shown are averages of the two shore survey observers $\pm$ combined SD. Counts without an SD reported were made by a single observer.

Wilson's phalarope					
Date	South Tufa	Lee Vining Tufa	Old Marina	County Park	Black Point
7/16/20	658 $\pm$ 18	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	No survey
7/18/20	2328 $\pm$ 535	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
7/31/20	1447 $\pm$ 90	333 $\pm$ 4	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
8/2/20	502 $\pm$ 33	49 $\pm$ 2	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
8/13/20	69 $\pm$ 6	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
8/15/20	114 $\pm$ 7	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
9/4/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
9/5/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
9/20/2020	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	No survey
Red-necked phalarope					
	South Tufa	Lee Vining Tufa	Old Marina	County Park	Black Point
7/16/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	No survey
7/18/20	2 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
7/31/20	1 $\pm$ 1	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
8/2/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
8/13/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
8/15/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
9/4/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
9/5/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	91 $\pm$ 0	490
9/20/2020	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	No survey
Unidentified phalarope					
	South Tufa	Lee Vining Tufa	Old Marina	County Park	Black Point
7/16/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	No survey
7/18/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
7/31/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	985 $\pm$ 21
8/2/20	8 $\pm$ 0	8 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	418 $\pm$ 32
8/13/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	73 $\pm$ 4
8/15/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	37 $\pm$ 2
9/4/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
9/5/20	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
9/20/2020	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	No survey

Table A1.2. Mono Lake 2020 boat survey totals from both observers. Totals shown are unadjusted for overlap with shore points.

Date	WIPH Observer 1	WIPH Observer 2	RNPH Observer 1	RNPH Observer 2	Unidentified phalarope Observer 1	Unidentified phalarope Observer 2
7/16/20	0	0	82	82	0	0
7/18/20	152	141	122	132	2	0
7/31/20	1037	1061	5683	5511	390	410
8/2/20	641	581	8314	8125	310	340
8/13/20	573	564	1350	1324	158	178
8/15/20	96	83	11301	10480	0	0
9/4/20	15	15	3949	3921	0	0
9/5/20	0	0	7715	7681	0	0

Table A1.3. Mono Lake 2020 combined totals of boat and shore surveys. Totals are shown for all points that were surveyed in 2020 (left), and for only points that were also surveyed in 2019 (right). Points surveyed only in 2020 were Black Point (added July 18th) and three boat survey points added August 13th (1 point) and 15th (2 points).

2020 totals--all points surveyed in 2020				2020 totals--only points also surveyed in 2019		
Date	WIPH	RNPH	Unidentified phalarope	WIPH	RNPH	Unidentified phalarope
7/16/20	658 ± 18	82 ± 0	0 ± 0	658 ± 18	82 ± 0	0 ± 0
7/18/20	2475 ± 535	129 ± 7	1 ± 1	2475 ± 535	129 ± 7	1 ± 1
7/31/20	2765 ± 96	5597 ± 122	1385 ± 25	2765 ± 96	5597 ± 122	400 ± 14
8/2/20	1128 ± 57	8220 ± 134	743 ± 38	1128 ± 57	8220 ± 134	325 ± 21
8/13/20	637 ± 8	1337 ± 18	241 ± 15	611 ± 6	1337 ± 18	168 ± 14
8/15/20	203 ± 12	10891 ± 581	37 ± 2	203 ± 12	10597 ± 567	0 ± 0
9/4/20	15 ± 0	3938 ± 11	0 ± 0	15 ± 0	3428 ± 17	0 ± 0
9/5/20	0 ± 0	8251 ± 15	0 ± 0	0 ± 0	7032 ± 70	0 ± 0

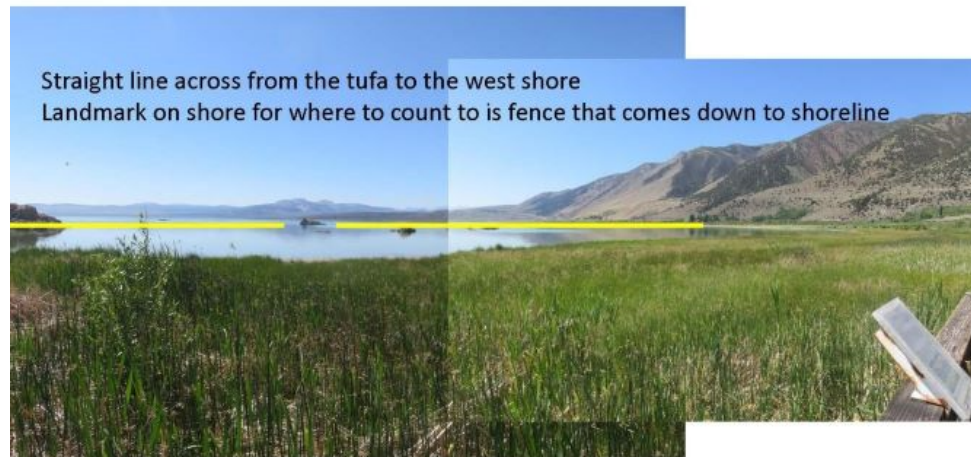
Appendix 2: Shore survey methods

Standardized shore surveys were carried out on the same day as boat surveys. Shore surveys were always in the morning. Two observers conducted the shore survey, driving between GPS-marked points. Observers used a combination of spotting scopes and binoculars, but were instructed to scan with spotting scopes on all surveys. See Figure 1 in the main text for shore survey locations relative to the whole lake. At each site, observers used the maps below to identify survey area boundaries (Fig A2.1, A, B, C, D, E). The County Park-Old Marina-Lee Vining Tufa-South Tufa circuit was completed by one set of observers each survey day, and the Black Point point was completed by a different pair of observers. All shore observers were trained in-person in the field by project manager Ryan Carle.

Figure A2.1. Survey boundary maps used by shore observers during 2019.

- A. County Park. County Park surveys were conducted at the viewing platform at the end of the County Park boardwalk.

County Park



- B. Lee Vining Tufa. Lee Vining Tufa surveys were conducted from Test Station Road.

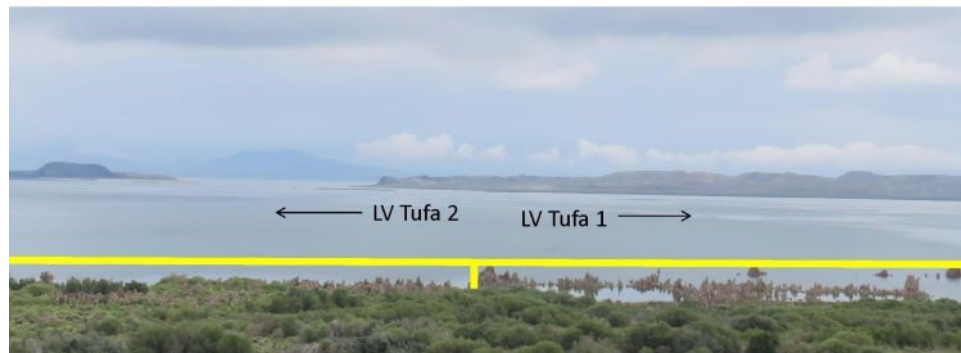
LV Tufa 1 –east side



LV Tufa 1 west side



Lee Vining Tufa 1 & 2

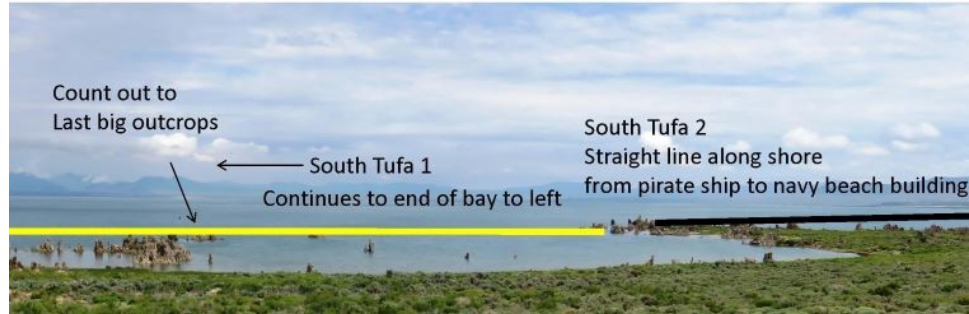


LV Tufa 2 west side



- C. South Tufa. Note the "pirate ship" is a cluster of tufa that is currently an island but used to be an isthmus near the "grotto" on the South Tufa interpretive trail. Shore survey observers were familiar with this name for the geographical landmark. South Tufa surveys were conducted from Test Station Road and the connector road between South Tufa and Navy Beach.

South Tufa



ST 1 west



- D. Old Marina. Old Marina survey was conducted from the top of the paved road into Old Marina off highway 395.

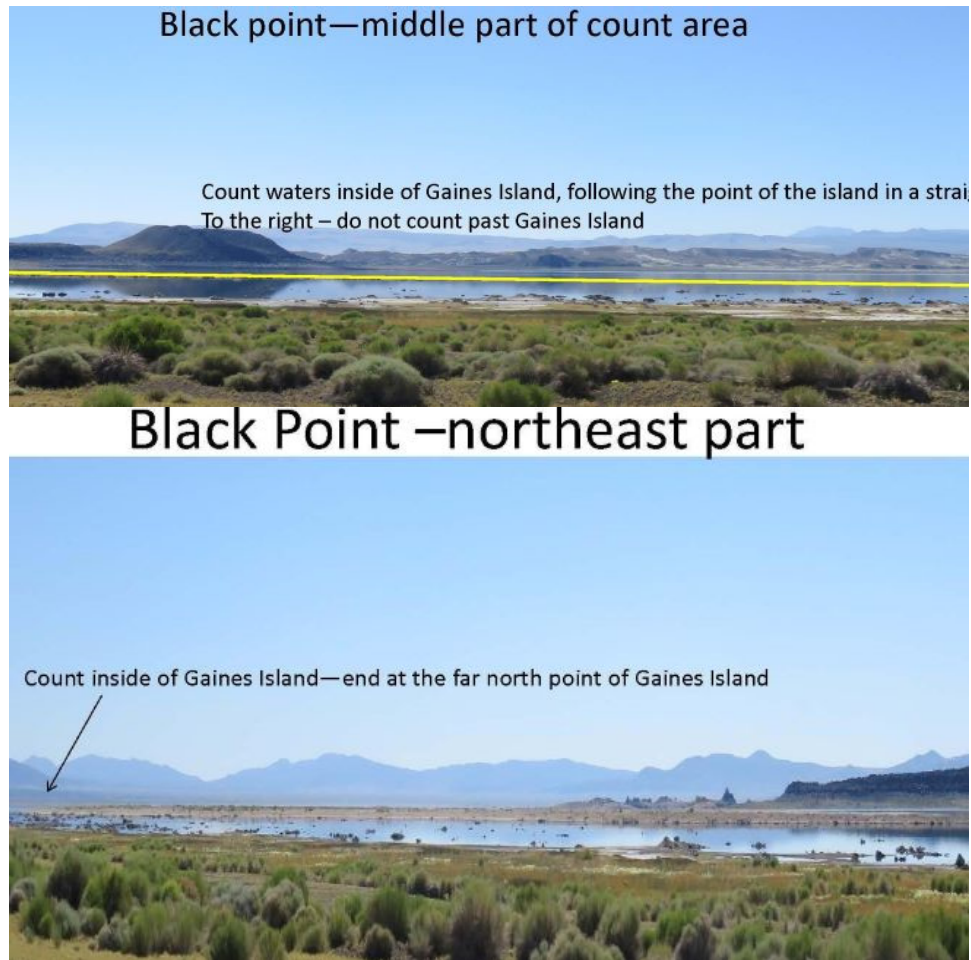
Old Marina



- E. Black Point. The Black Point survey was conducted from a GPS point a short walk east from the Black Point parking lot.

Black point—west side of count area





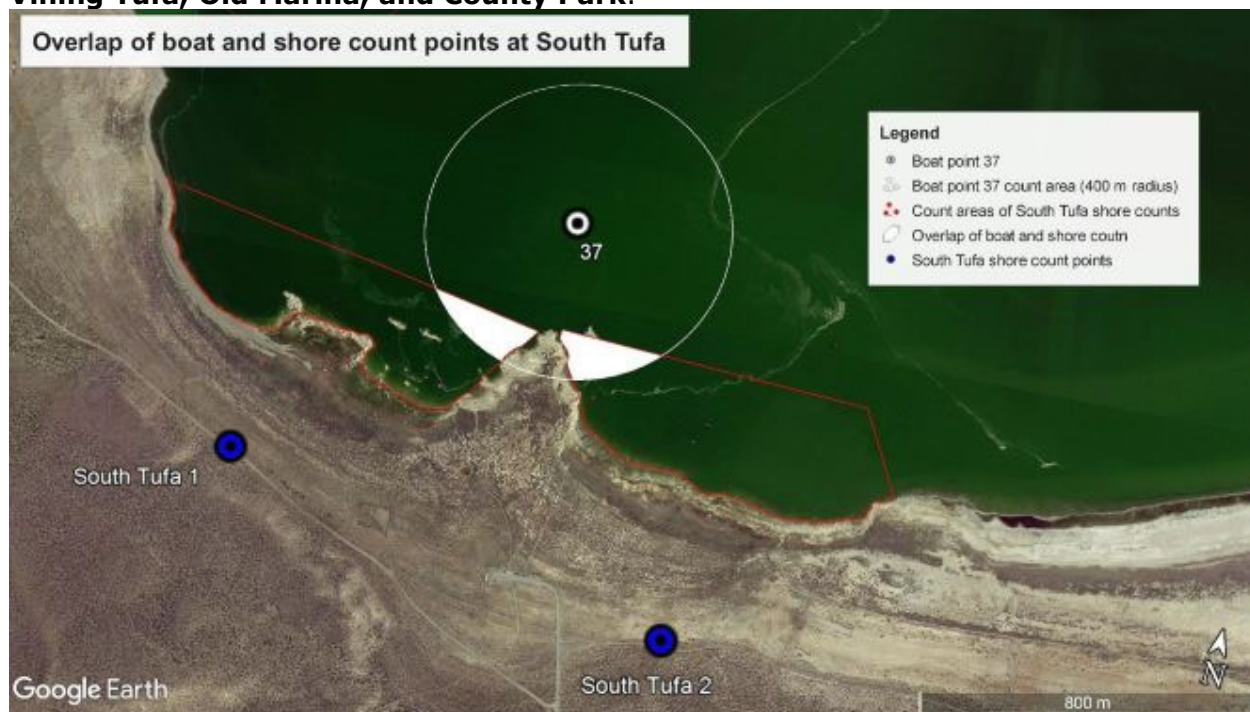
Calculation of shore survey areas and overlap with boat surveys

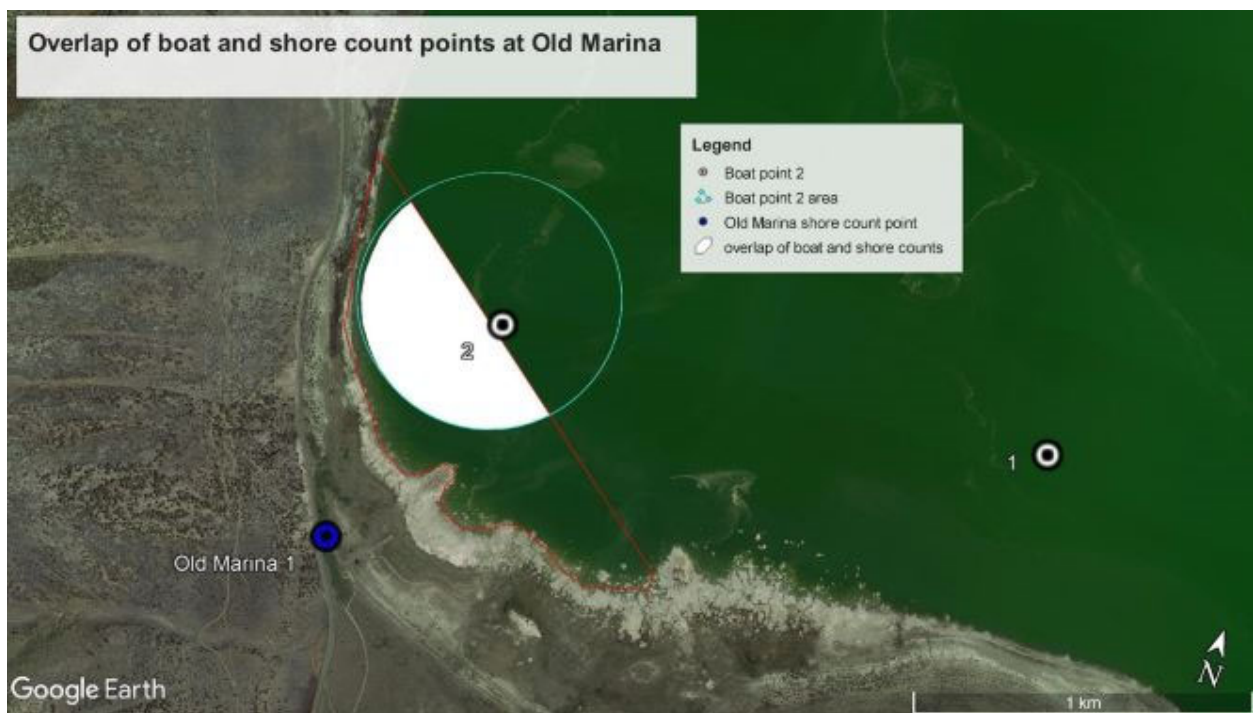
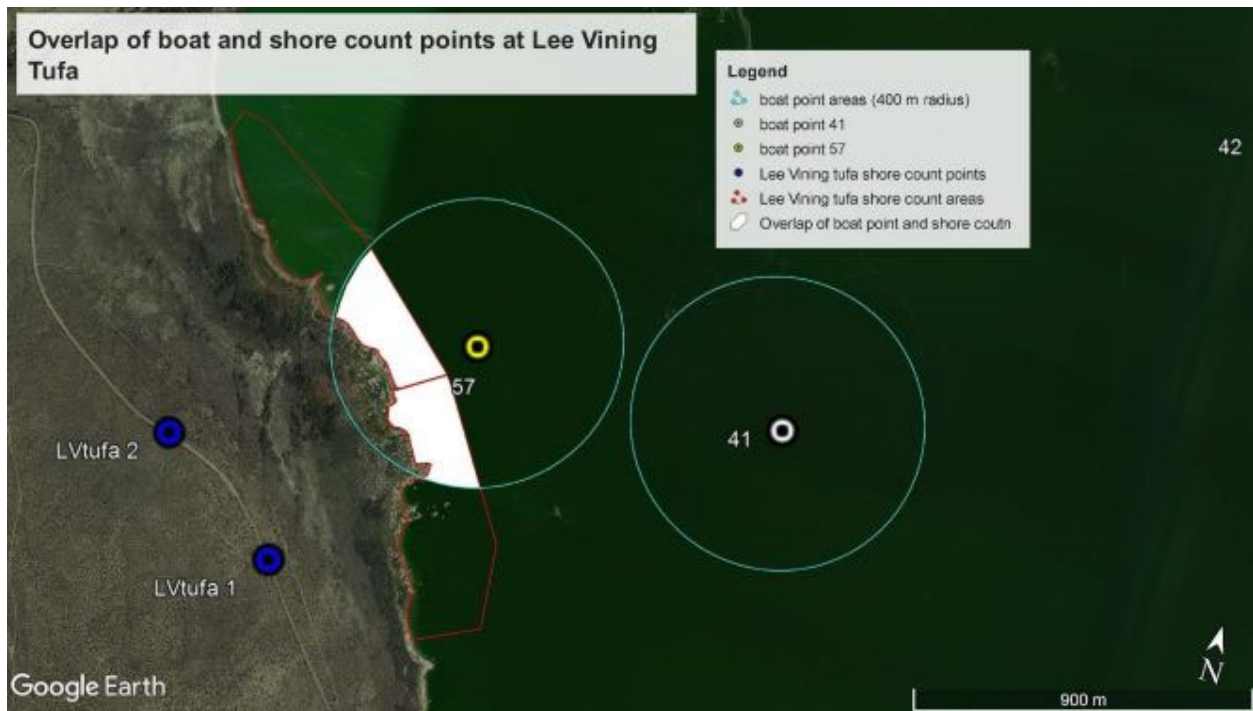
To calculate the area of shore surveys we used Google Earth Pro to draw polygons based on the field maps of shore survey boundary areas (Fig. A2.2). We used the “measure” tool to calculate the total area of each shore survey area polygon, based on a November, 2019 satellite photo of Mono Lake. To calculate the area of overlap with boat points, we projected a 400 m radius circle around the closest boat point to each shore point, then made polygons of the overlapping area with the shore survey (Fig. A2.2). We used the “measure” tool to calculate the total area of overlap at each shore survey/boat survey location (Fig. A2.2, Table A2.1). We also drew polygons around the land area covered by each boat point that overlapped with a shore survey, and subtracted land area from the total survey area to determine “total water survey area” (Table A2.1). We divided the total overlap area with the shore survey by the total water area of each boat survey point to determine the percentage of the boat survey area that overlapped with the shore survey (Table A2.1). Finally, we subtracted the percentage of overlap between the shore and boat survey from the boat survey total of each category of phalaropes (Wilson’s, red-necked, and unidentified) for that point (Table A2.1). The entire shore survey result was included in the whole-lake totals, as well as the adjusted boat survey sums.

Table A2.1. Calculations of area of overlap of shore surveys and nearby boat survey points. To determine total proportion of overlap, the area of water overlap between the shore and boat points was divided by the total water area of each boat point.

Boat Point	Shore point	Area of overlap between boat and shore point (m ²)	Area of boat point	Land area in boat point	Water area of boat point (total area minus land)	Proportion of boat point water overlapping with shore point
Point 38	South Tufa (points 1 and 2 combined)	37,316	503,000	12,344	490,656	0.076
point 57	Lee Vining Tufa (points 1 and 2 combined)	97,261	503,000	44,163	458,837	0.212
Point 2	Old Marina	215,119	503,000	0	503,000	0.428
Point 55	County Park	113,563	503,000	46,283	456,717	0.249

Figure A.2.2. Maps of overlap between boat and shore points at South Tufa, Lee Vining Tufa, Old Marina, and County Park.





Overlap of boat and shore count points at County Park

