Phalarope Migration Surveys
June – September 2022

Prepared By:

Gabbie Burns, Associate Senior Scientist
Katie LaBarbera, Landbird Program Science Director
Nathan D. Van Schmidt, Waterbird Program Science Director

San Francisco Bay Bird Observatory
524 Valley Way, Milpitas CA 95035

Prepared For:

Dave Halsing, Executive Project Manager, and Donna Ball, Lead Scientist
South Bay Salt Pond Restoration Project
State Coastal Conservancy

Rachel Tertes, Wildlife Biologist
Don Edwards San Francisco Bay National Wildlife Refuge
U.S. Fish & Wildlife Service

John Krause
California Department of Fish and Wildlife

Amy Larson
California Wildlife Foundation

Laura Cholodenko
California State Coastal Conservancy

FINAL REPORT
April 21, 2023

Suggested citation: Burns, G., K. LaBarbera, and N. D. Van Schmidt. 2023. Phalarope Migration Survey: June – September 2022. San Francisco Bay Bird Observatory. Report prepared for the South Bay Salt Pond Restoration Project.

EXECUTIVE SUMMARY

The South Bay Salt Pond Restoration Project (SBSPRP) is restoring over 15,000 acres of former salt evaporation ponds to a mix of tidal marsh and ponded wetland habitats. These wetlands provide habitat for many waterbirds, including migrating red-necked phalarope (*Phalaropus lobatus*) and Wilson's phalarope (*P. tricolor*). Sustaining baseline population goals for wildlife populations requires understanding how species are responding to restoration actions over time. While many waterbird guilds have increased in abundance from pre-restoration baselines, surveys in 2017 showed phalarope numbers declined by 78% compared to pre-restoration baseline monthly summer average of 3225 birds has warranted ongoing phalarope studies. The purpose of this ongoing study is to understand observed declines in phalarope numbers within the SBSPRP area and their relationship with broader population trends and phalarope movements. This report serves as a data summary and coarse-scale assessment of phalarope monitoring efforts in the South San Francisco Bay during the 2022 migration.

From June 21, 2022 to September 27, 2022, we conducted phalarope migration surveys at 31 sites (17 SBSPRP-managed former salt ponds, 7 Cargill-managed salt production ponds, and 7 additional non-salt pond sites). The surveys found that counts of Wilson's phalaropes peaked at 735 phalaropes on 07/19/22 and counts of red-necked phalaropes peaked at 4357 phalaropes on 08/30/22. Across all sites, a total of 13039 phalaropes were counted throughout the summer (1100 Wilson's, 11032 red-necked, and 907 that could not be identified to species). Looking only at the 24 current and former salt pond sites within the study area, a total of 8698 phalaropes were counted throughout the survey season (2 Wilson's, 7896 red-necked, and 755 that could not be identified to species). The total and peak counts for Wilson's phalarope were similar to 2021 data while the total and peak counts for red-necked phalaropes were both somewhat lower. The proportion of unidentified phalaropes relative to total observations decreased slightly from 2021 and continues to be a complicating factor in species-level analysis, but taking the measure of assigning them to the most likely based on survey date does not change the peak counts/dates or the direction of the trends for season totals for either species. Calculations to compare these survey data against the NEPA/CEQA baseline show that phalarope abundance continues to be below the management trigger of more than 50% below baseline values.

At the pond-level, phalarope abundance did not align with expectations around their preference for high-salinity ponds. The majority of phalaropes (96%) were found in medium- and low-salinity sites, suggesting that they may be using different selection criteria. As the SBSPRP progresses, we recommend a precautionary approach to waterbird habitat management and tidal marsh restoration. To the extent feasible, ponds within the project area should be maintained to provide a variety of salinity and water levels suitable for different guilds. Given the limited number of ponds that can be maintained under sea level rise, studies are needed to identify the specific salinity and water level characteristics that cannot be provided by restored tidal marsh for habitat specialist species. Special consideration should be given to understanding what influences phalarope site selection and preserving ponds with those characteristics.

Continued dedicated monitoring of phalaropes and analysis with habitat and external regional datasets will be valuable in assessing the decline in survey counts since pre-restoration baselines. Future phalarope migration surveys are needed to estimate inter-year changes in abundance that could be used to assess the relative importance of broader-scale climatic drivers (or breeding ground conditions) versus local

management and habitat characteristics on the observed declines. Few phalaropes were observed during the new June survey date, but these surveys allowed us to definitively identify the peak of migration, which was not possible in 2021 because the highest counts that year were in early July (the previous first survey date). Future study of Motus data when it is available will aid in estimating population sizes and understanding phalarope migration between stopover sites.

INTRODUCTION

In 2003, the U.S. Fish and Wildlife Service (USFWS) and California Department of Fish and Wildlife (CDFW, formerly California Department of Fish and Game) entered into an historic agreement with Cargill Salt to acquire 15,100 acres of salt evaporator ponds in the South San Francisco Bay. The South Bay Salt Pond Restoration Project (SBSPRP) has begun to restore the area to a mix of tidal and ponded habitats while continuing to provide flood protection and improved public access.

Salt ponds have been present in the San Francisco Bay for over 150 years (Ver Planck 1958) and have significant wildlife value (Anderson 1970, Accurso 1992, Takekawa et al. 2001, Warnock et al. 2002). Due to the loss of wetlands elsewhere (e.g., in California's Central Valley), the ponds now provide important foraging and roosting areas for many waterbirds. As a major migratory and wintering location along the Pacific Flyway, the San Francisco Bay supports more than a million birds throughout the year (Page et al. 1999, Warnock et al. 2002). The SBSPRP has committed to restoring some ponds to tidal marsh, while retaining some pond habitat as managed ponds within the project area for waterbirds. Today, the South Bay is a mix of these managed ponds and restored tidal marsh within the SBSPRP area, ponds still operated for salt production by Cargill Salt, and additional wetlands of different types outside of the SBSPRP footprint (hereafter "sites").

More than a decade of waterbird counts show that many waterbird guilds increased in abundance by 2017 relative to SBSPRP baselines, which were established prior to implementation of project restoration and enhancement actions. Most migratory waterbird guilds use the now managed ponds at higher rates than commercial ponds. The waterbird abundance and food productivity of ponds varies significantly as a result of pond topography, salinity, and restoration status, but some ponds are able to meet the energetic requirements to maintain waterbird abundance along the Pacific Flyway (Athearn et al. 2012, Brand et al. 2014).

However, combined counts of two phalarope species, red-necked phalarope (*Phalaropus lobatus*) and Wilson's phalarope (*P. tricolor*) showed a decline of 78% from prior to the start of restoration project activities by 2017 (Tarjan 2019a). This decline was the impetus for more intensive surveys focused on better understanding phalarope population dynamics in the South Bay. Previously, less frequent summer salt pond surveys during phalarope migration impeded our ability to capture phalarope use of the SBSPRP area. NEPA/CEQA significance thresholds require that a decline is attributed to restoration activities (South Bay Salt Pond Restoration Project, 2007). Understanding phalarope trends within the SBSPRP and how they relate to broader population trends requires targeted surveys during the peak phalarope season. Such high-quality datasets could be compared to enable broader regional trends and explanatory factors such as habitat quality and SBSPRP management changes.

Through an analysis of the existing dataset and eBird observations (Tarjan 2019b), we found that Wilson's phalarope exhibited one peak that clustered in late summer, whereas red-necked phalarope showed one peak in spring and were present for a more prolonged period in late summer to early fall. Both species showed similar preferences for select sites, suggesting that surveys could target specific areas. Based on these results, SFBBO made the following recommendations: 1) Capturing the peak migration for the two common phalarope species in San Francisco Bay requires conducting two sets of surveys, one set centered around July 17 for Wilson's phalarope and one set centered around August 24 for red-necked phalarope; and 2) Surveys of 24 SBSPRP- and Cargill-managed sites are likely to capture >99% of phalaropes on current and former salt ponds; eBird sightings suggest adding 7 additional sites outside the salt pond area to surveys.

In accordance with these recommendations, SFBBO piloted two surveys during peak phalarope migration in 2019. In 2020, due Covid-19 safety requirements, we conducted surveys across the full range of seven dates at only a subset of sites. We conducted surveys at all sites on all dates in 2021 and 2022. This report summarizes the results of SFBBO's phalarope surveys in the South San Francisco Bay from 2019 through 2022 (Table 1).

METHODS

Study Area

The study area for SFBBO's annual waterbird monitoring for SBSPRP includes 82 current and former salt ponds in the Santa Clara, Alameda and San Mateo counties of California. Alviso and Ravenswood complexes are owned and managed by Don Edwards San Francisco Bay National Wildlife Refuge. Eden Landing Ecological Reserve (Eden Landing) ponds are owned and managed by California Department of Fish and Wildlife (CDFW). Coyote Hills, Dumbarton, and Mowry salt ponds are owned by Don Edwards San Francisco Bay National Wildlife Refuge, but managed for salt production by Cargill Salt and not part of the SBSPRP footprint. Additional wetland sites in the South Bay are owned by various other entities, including City of Sunnyvale (Sunnyvale Water Pollution Control Plant ponds) and East Bay Regional Parks District (Coyote Hills Park).

Phalarope migration surveys were conducted at 31 sites in the South Bay (Figure 1). These included 24 of the 82 sites historically included in SBSPRP monitoring: 17 SBSPRP-managed ponds (4 in the Alviso complex, 10 in the Eden Landing complex, and 3 in the Ravenswood complex), and 7 ponds managed by Cargill for salt production (1 in the Coyote Hills complex, 3 in the Dumbarton complex, and 3 in the Mowry complex. An additional 7 sites outside of the current and former salt ponds were also surveyed: Coyote Hills Regional Park, Crittenden Marsh, Northeast of N1, New Chicago Marsh, Spreckles Marsh, Alviso Marina, and the Sunnyvale Water Pollution Control Plant.

Phalarope Migration Surveys

We conducted 8 surveys in 2022 during the season of peak phalarope migration. Surveys occurred every two weeks with the following target dates: 06/21, 07/05, 07/19, 08/02, 08/16, 08/30, 09/13, 09/27 (Table 1). Counts were collected by a combination of SFBBO staff and trained community scientist volunteers to allow all sites to be surveyed synchronously or near synchronously. Surveyors were trained to identify red-necked phalaropes, Wilson's phalaropes, and red phalaropes (*P. fulicarius*). However, the red phalaropes are rare in South San Francisco Bay and were not observed, and therefore are not covered by this report.

During each survey period, all sites were surveyed as close in time as possible, with most being surveyed simultaneously. Surveyors identified and counted phalaropes at each site from the nearest drivable levee using spotting scopes. Data collected included species counts, date, survey start time, survey end time, an estimate of the percent of the site that was visible to the observer, and an estimate of the percent of the site that was covered in water.

Water Quality Sampling

We sampled water quality at 30 of the survey sites (Crittenden Marsh was dry) on at least two dates during the phalarope migration. The water sampling did not necessarily occur on the same day as the phalarope counts and we do not expect pond salinity to vary widely over a matter of a few days or weeks. We recorded dissolved oxygen, salinity, conductivity, pH, and temperature at one sampling location at each site using a Hydrolab Minisonde (Hydrolab-Hach Company, Loveland, CO). When salinities exceeded approximately 72 ppt (the maximum value registered by the Hydrolab Minisonde), we calculated salinity using a hydrometer (Ertco, West Paterson, NJ) to measure specific gravity in combination with a temperature reading from the water sample. We calibrated all Hydrolab Minisonde sensors before the start of each sampling day. We followed water quality monitoring methods outlined by Murphy et al. (2007). Sites were classified as low (0-60 ppt), moderate (61-120 ppt), or high (>120 ppt) salinity.

Data Summary

We calculated the total counts and peak counts for each species, and both combined. We visualized phalarope trends using the ggplot2 package (Wickham 2016) in R version 3.5.3 (R Development Core Team 2018).

The adaptive management plan for the SBSPRP calls for assessing trends at multiple scales, including at the community scale (ponds or pond types), across the entire South Bay, and for the entire BayArea and beyond (South Bay Salt Pond Restoration Project 2007). Counts were therefore summarized across the entire South Bay study area, the current and former salt ponds only, site-specific, and in each of the three salinity bins. See LaBarbera et al. (2023) for comparisons to trends in the entire Bay Area and all of California.

RESULTS & DISCUSSION

Total Counts

Across all 31 targeted sites and 8 surveys in 2022 we counted a total of 11032 red-necked phalarope, 1100 Wilson's phalarope, and 907 phalarope of unidentified species, for a grand total of 13039 birds (Figure 2). Red-necked phalarope were most abundant at E6, A3N, M2, while Wilson's phalarope were most abundant at New Chicago Marsh, Spreckles Marsh, Sunnyvale WPCP (Figure 3). In just the area used to set the SBSPRP monitoring baseline (i.e., excluding the 7 non-salt pond sites), we observed a total of 7896 red-necked phalarope, 2 Wilson's phalarope, and 755 phalarope of unidentified species, for a grand total of 8698 birds. Among these sites, Wilson's phalarope were only found in E13. Figure 4 shows the pattern of habitat use from 2021, for reference.

Peak Counts

Across all sites, counts of Wilson's phalaropes peaked at 735 birds during the survey centered on 07/19 and counts of red-necked phalaropes peaked at 4357 birds during the survey centered on 08/30 (Figures 2, 5). In just the area used to set the SBSPRP monitoring baseline, counts of Wilson's phalaropes peaked at 2 birds during the survey centered on 8/16 and counts of red-necked phalaropes peaked at 3686 birds during the survey centered on 8/30. These peaks indicate that the current survey schedule largely spans the period when phalaropes are present in the area (Figure 2).

Unidentified Phalaropes

Observations of unidentified phalarope present a particular challenge when analyzing data to understand species-specific trends. In 2022, unidentified species represented 7.0% of the total observations, versus 8.8% in 2021 and 2.6% in 2020. Handling of unidentified observations is a challenge for phalarope studies across their migration range and there is no agreed upon best practice for whether or how to include them in analysis (Carle et al. 2023). One estimation method is to assign all unidentified individuals to species based on which migration peak they were observed in (e.g., unidentified phalarope in July would be cast as Wilson's). Doing this with 2022 numbers does not change the peak count or date for either species. The majority (875 of 907) of unidentified phalaropes were observed during the red-necked phalarope migration window.

Salinity and Site Preference

Phalaropes traditionally exhibit preference for high-salinity environments, such as saline lakes (Jehl 1988, Jehl 1999, Frank and Conover 2021, Carle et al. 2023). As such, we would expect them to be more abundant in the remaining medium to high-salinity salt ponds surveyed compared to low-salinity ponds. This assumption is not strongly supported by the data from 2021 and 2022. The most abundant sites during 2021 surveys were ones that are predominantly low-salinity, with the exception of A13, which was classified as medium-salinity. In 2022, 96% of phalarope observations were in low- or medium-salinity ponds. Red-necked phalaropes may have more plasticity in foraging habitats, as they also use coastal habitats during migration and the proportion of the population that relies on saline lakes is not known (Rubega et al. 2020). However, previous studies of Wilson's phalaropes have established that the species almost exclusively utilizes high-salinity lakes and ponds during migration (Carle et al. 2023).

One point of note is that in 2021, E6 was classified as a high-salinity pond and had no reported phalaropes. In 2022, the water quality readings made it a medium-salinity pond and it had the greatest total abundance for the season. Other changes between those two years make it impossible to draw conclusions from this data point. As additional years of data are collected, statistical tests for changes in abundance at ponds with variable salinity across years could provide new insights.

Trends Across Years

The total counts for phalaropes were slightly lower in 2022 than in 2021, which is the only other year with a complete set of survey data. Counts of Wilson's phalarope were similar across both years (1100 in

2022 versus 1047 in 2021). These numbers are lower than 2020 counts, during which *fewer* sites were surveyed due to Covid-19 restrictions. Red-necked phalarope and unidentified phalarope counts were both slightly lower compared to 2021 counts, but still higher than 2020 numbers.

Going into the season, we were concerned that red-necked phalarope counts may be especially low this year because their most abundant pond by far in 2021 was A13 (Figure 4), which was largely drained and the site of major levee maintenance work as part of the Shoreline Project. Correspondingly, the local counts this year in A13 were low (only 17 birds; Figure 3). That the 2022 total counts were similar to last year suggests that phalaropes are willing to move between local sites to find more favorable conditions. With additional years of both local and regional surveys it may be possible to determine if local annual changes in populations are simply tracking broader declines, or are more severe, indicating a problem with local management.

In 2019, coordinated monitoring of phalarope staging sites in western North America began (Carle et al. 2023). The 2022 report shows a decrease in the range-wide peak counts for both Wilson's and (to a lesser extent) red-necked phalarope (Carle et al. 2023). An index of annual relative change in abundance from year to year (i.e., lambda) can be compared from these regions to our results because our surveys were coordinated to match the timing and number of surveys in other regions (however, raw abundance estimates are not comparable because survey methods differed from region to region, i.e., ground vs. boat vs. aerial; Carle et al. 2023). After an initial high during the first year of surveys in 2019, researchers observed a substantial decline in the peak counts for each species in 2020. Regional numbers in 2021 were slightly higher, but were reduced again in and 2022 have fluctuated up and down, and but remain well below 2019 counts. Our observed decline from 2021 to 2022 qualitatively aligns with these species-wide trends for both Mono Lake and Great Salt Lake; however, the three other staging areas do not show synchrony with these trends, so it is unclear if this is statistically significant. In 2019 SFBBO conducted pilot surveys at only a subset of dates and sites, so we do not know whether there was a similar high peak in the Bay Area, and 2020 surveys were limited by Covid-19 restrictions, so we currently only have a single reliable data point for inter-year comparisons With additional years of data collection, we will be able to directly compare regional annual change inside and outside of the South Bay to determine if local trends are tracking or diverging from broader population trends.

Management Recommendations for the South Bay

We make our recommendations for next steps based on the Project's Adaptive Management Plan, which describes a set of *a priori* population threshold triggers and a process to "Correct current actions if triggers are tripped", "Update key uncertainties and hypotheses for testing", and "Revise/design plans for large-scale restoration and design applied studies", noting that this is a "risk-averse approach [designed] to prevent the Project from harming the South Bay system" (Figure 6; South Bay Salt Pond Restoration Project 2007). We herein "synthesize and interpret data for use by managers and stakeholders."

After controlling for protocol differences between these surveys and those used to compute the NEPA/CEQA baseline, the 2022 counts are >50% below the revised baseline regardless of conversion factor method used to calculate it, surpassing the management trigger (Burns & Van Schmidt 2023). A link between SBSPRP management actions and ongoing declines has not been scientifically proven, but the precautionary principle suggests conservative management to prevent further declines until such a statistical test has been conducted. The original crossing of the trigger resulted in the current study design, resulting in this report, as part of the Adaptive Management Plan's "synthesize and interpret data" stage (Figure 6, left column).

We acknowledge the work of the South Bay Salt Pond Restoration's Pond Management Working Group in recommending and implementing changes at the pond systems since the initiation of the project. In order for the South Bay to retain its current bird numbers, we recommend that the SBSPRP's Project Management Team, the Refuge, and Eden Landing Ecological Reserve consider managing ponds to support use by phalaropes to address declines at SBSPRP sites. Unfortunately, given the surprising results indicating low-salinity selection, it is not clear what best management for phalaropes should be. Until future studies can identify the factors causing phalaropes to select these ponds, special consideration should be given to retaining current management of ponds that have hosted large numbers of phalaropes in recent years and managers should conservatively try to maintain current water management strategies. Examining trends across both years of full surveys (2021 and 2022), several sites merit special consideration and conservation. A3N supported a large number of phalaropes, especially in 2022. Many of the Eden Landing ponds supported high counts consistently across both years. Notably, in both years Eden Landing ponds were not used until midway through the summer once red-necked phalaropes arrived.

Drying of A13 in preparation for the Shoreline Project and its eventual restoration to tidal action appears to have negatively impacted its ability to support phalaropes. After extremely high use observed in that pond in 2021 (Figure 4), use was minimal in 2022 (Figure 3). E2 and E4 also supported substantial numbers of phalaropes and are slated to be restored as part of Phase 2, as did R1 which is under consideration for restoration under the SAFER Bay Project. This is not unexpected as >99% of phalarope observations are outside of restored tidal wetlands (Tarjan et al. 2019b). Available evidence therefore unfortunately indicates that proceeding with these plans does pose a non-negligible risk of harming the South Bay system as defined in the Adaptive Management Plan (South Bay Salt Pond Restoration Project 2007). There may have been movement to nearby ponds in 2022, which could suggest the population may not be at carrying capacity and may be able to adapt their habitat use. Nearby New Chicago Marsh and Spreckles Marsh saw correspondingly large increases in 2022. Whether these sites can support this many phalaropes, or are potentially beyond their carrying capacity as a result of displacement from A13 following its drying, is not clear. Phalarope population sizes are known to respond with a one-year lag to habitat changes on breeding grounds (described in the next section; Jehl et al. 1999), so it is likely that we will may not see the true impact of such changes on abundance until summer 2023 earliest.Given these significant unknowns in what is driving phalarope habitat use, much less changes in use across sites and years, proceeding with restoration of A13 does pose significant risks. If recent issues with the R1 water control structure could interfere with its ability to provide phalarope habitat in the coming season, repairing this structure could provide.

Given the observed negative impacts on habitat use within the SBSPRP footprint and significant uncertainties, our recommendation for management revisions (i.e., the top loop of Figure 6) is to develop options to pause the drying and/or restoration of ponds that are used by phalaropes in Phase 2 (E2 and E4) and other projects (A13 and R1) until such studies can be completed. We may then be able to determine the full scope of negative impacts of restoration and design management alternatives that can ameliorate these impacts. If restoration actions do proceed on these ponds in Phase 2, managers should establish more detailed thresholds for detecting future impacts of *specific actions* in addition to the 50% population-wide threshold that was already passed. In the Adaptive Management Plan, once thresholds are reached they “signal the Project Managers will take steps to understand what is happening and, if necessary, take action to put the system back on track” which includes plans to "regularly update the restoration targets and management triggers with new information” (South Bay Salt Pond Restoration Project 2007). No *a priori* threshold for determining when new restoration actions have negatively impacted phalarope populations has been set. Thresholds of detecting not just Bay-wide population impacts but also local-scale and complex-scale impacts should be clearly defined before further actions occur to ensure that the impacts of actions can be scientifically tested, effectively creating large-scale experimental information that can provide valuable guidance for future phases of restoration. For each restoration action, a decline in the South San Francisco Bay population equivalent to the previous long-term average population within that site could be used as a threshold for determining a significant impact from that action. Furthermore, now that the 50% decline in the guild has been detected, we suggest that Wilson’s and red-necked phalaropes should have separate thresholds set because the species may have differing habitat needs and responses to changes.

Beyond pausing restoration of ponds used by phalaropes, it is premature to provide habitat management recommendations that might recover the population because phalaropes, as summer migrants, have not been included in past habitat analyses that focused on either fall, winter, or spring migrants (Brand et al. 2014, De La Cruz et al. 2018) or breeding birds (Ackerman et al. 2014, Hartman et al. 2016a, Hartman et al. 2016b). Improved data collection has revealed important gaps in our understanding of phalarope habitat selection–most notably, that phalaropes are not using high-salinity sites to the degree expected–which we are now well positioned to address. We are thus once again at the stage of “Update key uncertainties and hypotheses for testing” (Figure 6, right column). The next stage should be once again designing applied studies, for which we propose several avenues in the following sections.

Considerations for Future Study

Continued Monitoring Needs

Without monitoring, the impact of ongoing management changes cannot be assessed, and recovery can never be detected. Therefore at the most fundamental level it is key that Phalarope Migration Surveys continue in 2023 and future years at intervals of no less than every two weeks during the peak migration period for each phalarope species. For guilds that migrate through the area over a short timespan, such as phalaropes, frequent sampling is required during phalarope migration to understand their use of the SBSPRP area and surrounding areas in south SF Bay. Robinson-Nilsen and Demers (2012) suggested intervals of 2–3 days during the latter part of summer, so a two-week window is likely already liberal. The cessation of summer salt pond surveys in 2019 makes alternative approaches to monitoring for these declining species particularly important. Though we observed few birds in the new mid-June survey, inter-annual variability in migration timing is high and we recommend continuing it for the time being to ensure we are capturing the full range of migration of the rarer Wilson’s phalarope.

Maintaining annual surveys will greatly increase our ability to detect drivers of declines. By tracking year-to-year changes, we can assess the impact of climate on population dynamics, which is otherwise not possible because of the high annual variability in California's mediterranean climate. Annual surveys also allow for estimation of year-to-year changes in phalarope abundance that can be compared to changes in other regions (i.e., from Carle et al. 2023) to test whether declines are driven by broad-scale annual climatic conditions or local-scale habitat conditions (Coates et al. 2020). Comparisons could also be made between rates within salt ponds and non-salt pond sites. This can provide a robust approach to determining whether management actions within the SBSPRP are a significant factor in the observed ongoing declines, but requires an annual estimate of lambda to account for the high inter-annual variability in population counts. We now have two complete years of data (2021 and 2022), and one partial year (2020). One additional year of study will give us two robust estimates of lambda, which can begin to be compared to annual weather patterns to look for climatic drivers in changes in abundance. Tarjan (2019a) explored power analyses with Salt Pond Survey data and found >50% declines could be detected with confidence for most guilds after three years of data had been collected, while more subtle changes (10–20%) could require up to ten years. While Salt Pond Surveys performed poorly for phalaropes, this is our best estimate for the statistical power the new surveys will have over a given number of years.

Critically, monitoring of impacts from management changes also will likely require multi-year annual datasets. Changes occur on the landscape each year, and their impacts may take several years to be fully realized. At Mono Lake, nesting habitats strongly correlate with abundance a year later (i.e., a one-year time lag), because staging phalaropes are mostly adults and changes in recruitment therefore do not show up until a year later when the adults from this age class migrates through this area (Jehl et al. 1999). If changes to migratory habitats impact survival and recruitment of juveniles the following summer, it is plausible that the full impact on migratory population sizes will not be seen until up to two summers later. Notably, reducing salinity in hypersaline ponds to transition them out of salt production began in summer 2004 and included most ponds by fall 2005 (South Bay Salt Pond Restoration Project 2007), and a decline in abundance below the management trigger threshold occurred two years later, in summer 2007. This would be consistent with a hypothesis that impacts on population sizes are lagged two years.

Testing Species-Habitat Relationships

We suggest six hypotheses that could be tested. The first three could examine potential causes of the historical decline through re-analysis of historical Salt Pond Survey data possessed by SFBBO, without any additional data collection:

1) Phalaropes declined locally more quickly at sites following changes in salinity management than at sites without changes, immediately following management actions.
2) Phalarope declines in total abundance at the pond cluster or South Bay scale have correlated with major management changes lagged by 1- or 2-years.
3) The decline in total phalarope abundance is largely due to loss of Wilson's phalaropes from managed ponds, while the more generalist red-necked phalaropes have remained more stable.

These hypotheses could be tested using a first-order Markov model of population change; covariates would be fit to rates of change, rather than overall abundance. Because the historical Salt Pond Survey data has low statistical power for phalaropes (Tarjan et al. 2019c), it remains a possibility that re-analysis of historical data could fail to identify meaningful relationships. However, statistical power may be able to be improved by replacing the previously used summer or fall windows with the new Jul–Sept window (Burns & Van Schmidt 2023). If an analysis workflow is developed for Salt Pond Data, it could subsequently be applied to Phalarope Migration Surveys, which are better suited to such an analysis.

Species-habitat relationships for phalaropes are unknown because they have been excluded from previous habitat selection and carrying capacity studies (Brand et al. 2014, Ackerman et al. 2014, Hartman et al. 2016a, Hartman et al. 2016b, De La Cruz et al. 2018). In this initial analysis, phalarope abundance at the site level in 2021 and 2022 did not support our assumptions that numbers would be greater in ponds with higher salinity. This observation has significant management implications, complicates the process of making recommendations, and merits further investigation. Statistical habitat modeling could be used to identify statistically significant correlates of habitat selection by migrating phalaropes, and examine potential drivers of variability both within and across years. Looking specifically at ponds whose salinity has changed across years (as E6 did between 2021 and 2022 surveys) could be a way to control for other confounding habitat characteristics. Preliminary efforts are already underway to analyze habitat and climate relationships driving variability in the long-term historical Salt Pond Survey dataset, however, the higher temporal resolution, synchronicity, and improved coverage of the Phalarope Migration Surveys dataset should make it more fruitful for analysis. Such an analysis could be incorporated into future reports with a modest increase in effort to measure additional habitat characteristics (bathymetry, water quality) at higher temporal frequency for all surveyed sites.

Investigation into other factors such as prey abundance across different sites would also be informative as they may more directly correlate with phalarope site selection than salinity. Collection of invertebrates was previously done for baseline monitoring (South Bay Salt Pond Restoration Project 2007, Brand et al. 2014). We suggest three more hypotheses about prey-driven habitat suitability that could guide future management of ponds to improve habitat quality for phalaropes, which would depend on obtaining additional data from new fieldwork and/or collaborators. Efforts should be made to understand what factors influence phalarope site preference within the salt pond project area in order to inform management decisions.

4) Phalarope habitat selection in the early years of the study was driven by macroinvertebrate prey density rather than salinity or other habitat characteristics.
5) Currently selected phalarope habitat is driven by macroinvertebrate prey density.
6) Phalarope populations are not at carrying capacity in the Bay Area. (assess with macroinvertebrate data).

Hypothesis (4) would be easiest to explore, if the macroinvertebrate data from U.S. Geological Survey collected during baseline monitoring period could be obtained. Assessing hypotheses (5) would require new macroinvertebrate sampling during summer 2023 in Phalarope Migration Survey ponds and modeling of prey abundance, which could follow methods for the salt ponds established by Brand et al. (2014). Estimated prey abundance could subsequently be used as a covariate for phalarope habitat selection. A future study could then test Hypothesis (6) by then applying Brand et al (2014)'s carrying capacity modeling approach to Wilson's and red-necked phalaropes, which could be parameterized with existing bathymetry elevation data gathered during fieldwork and accessible LiDAR. In lieu of funding for invertebrate sampling, it would still be possible to analyze whether other habitat characteristics such as bathymetry might better predict selection by phalaropes.

Movement Ecology Studies

Lastly, data from Motus towers that have recently been or are currently being installed around the Bay Area could potentially detect movement rates between the South Bay and the broader populations and determine the stopover time of phalaropes in the Bay Area during migration. Stopover time estimates would make it possible to estimate the likelihood of counting the same individuals across multiple surveys, enabling the instantaneous counts produced by the surveys to be better converted to true population size estimates. Researchers at other migration sites are looking into tagging phalaropes beginning in 2023, and SFBBO has installed one Motus tower near the Alviso ponds and is currently working to install two others at sites in the South Bay. If some of the tagged birds migrate through the Bay Area and are detected by one of the new Motus towers, it will give us insight into their stopover time. Motus data from tagged phalaropes may also provide insight into how phalaropes move between migration stopover sites (e.g. Mono Lake, Great Salt Lake) within and between migrations. There is some evidence that suggests birds may switch from using one site to another during years when conditions are less favorable (Carle et al. 2023), but research has yet to confirm the frequency or scope of this behavior.

ACKNOWLEDGEMENTS

Thank you to the California Wildlife Foundation, the U.S. Fish & Wildlife Service, the California State Coastal Conservancy, and the Santa Clara Valley Water District (Valley Water) for coordinating and funding this work. We would like to thank Rachel Tertes at the Refuge for help with coordinating site access. We would like to acknowledge the South Bay Salt Pond Restoration's Pond Management Working Group that has recommended and implemented many management changes over the years as they relate to specific pond systems. Thank you to Dave Halsing of the South Bay Salt Pond Restoration Project and John Krause with the CDFW Eden Landing Ecological Reserve. We could not have done this work without our dedicated field crew of SFBBO staff and volunteers: Ben Pearl, Byron Ryono, Chris Wilson, Cole Jower, Dan Wenny, Eric Lynch, Howard Higley, Jeff Englander, Jeremy Reinhard, Joan Mancini, Josh Scullen, Kaili Hovind, Maureen Lahiff, Michael Mammoser, Neela Srinivasan, Parker Kaye, Pete Dunten, Phil Cotty, Rasia Holzman Smith, Sasha Nouri, Sirena Lao, and Tomas McKay. Thank you also to SFBBO staff Rasia Holzman Smith for their logistical support on these surveys.

LITERATURE CITED

Accurso, L. M. 1992. Distribution and abundance of wintering waterfowl on San Francisco Bay 1988-1990. Master's Thesis. Humboldt State University, Arcata, CA.

Ackerman, J. T., C. A. Hartman, M. P. Herzog, L. M. Smith, S. M. Moskal, S. E. De La Cruz, J. L. Yee, and J. Y. Takekawa. 2014. The critical role of islands for waterbird breeding and foraging habitat in managed ponds of the South Bay Salt Pond Restoration Project, South San Francisco Bay, California. Page 108. Open-File Report, US Department of the Interior, US Geological Survey, Sacramento, CA.

Anderson, W. 1970. A preliminary study of the relationship of salt ponds and wildlife – South San Francisco Bay. California Fish and Game 56: 240–252.

Brand, L. A., J. Y. Takekawa, J. Shinn, T. Graham, K. Buffington, K. B. Gustafson, L. M. Smith, S. E. Spring, and A. K. Miles. 2014. Effects of Wetland Management on Carrying Capacity of Diving Ducks and Shorebirds in a Coastal Estuary. Waterbirds 37:52–67.

Burns, G. 2022. South Bay Salt Pond Waterbird Surveys: September – November 2021. Report prepared for the South Bay Salt Pond Restoration Project.

Burns, G., and N.D. Van Schmidt. 2023. Bridging the gap between disparate phalarope survey methodologies to evaluate population status. San Francisco Bay Bird Observatory. Report prepared for the South Bay Salt Pond Restoration Project.

Carle, R.D., G. Burns, K. Caruso, D. House, R. Larson, A. Lewis, A. E. McKellar, J. Neill, M. Prather, J. Reuland, M. Rubega, and K. Tarr. 2023. Coordinated phalarope surveys at western North American staging sites, 2019-2022. Report of the International Phalarope Working Group.

Coates, P. S., B. G. Prochazka, M. S. O'Donnell, C. L. Aldridge, D. R. Edmunds, A. P. Monroe, M. A. Ricca, G. T. Wann, S. E. Hanser, L. A. Wiechman, and M.P. Chenaille. 2021. Range-wide greater sage-grouse hierarchical monitoring framework—Implications for defining population boundaries, trend estimation, and a targeted annual warning system: U.S. Geological Survey Open-File Report 2020–1154, 243 p., https://doi.org/10.3133/ofr20201154.

De La Cruz, S. E. W., L. M. Smith, S. M. Moskal, C. Strong, J. Krause, Y. Wang, and J. Y. Takekawa. 2018. Trends and habitat associations of waterbirds using the South Bay Salt Pond Restoration Project, San Francisco Bay, California. Page 148. Report, Reston, VA.

Hartman, C. A., J. T. Ackerman, J. Y. Takekawa, and M. P. Herzog. 2016. Waterbird nest-site selection is influenced by neighboring nests and island topography. The Journal of Wildlife Management 80:1267–1279.

Hartman, C. A., J. T. Ackerman, and M. P. Herzog. 2016. Island characteristics within wetlands influence waterbird nest success and abundance. The Journal of Wildlife Management 80:1177–1188.

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.

Murphy, A., C. Strong, D. Le Fer, and S. Hudson. 2007. Interim Cargill salt pond report. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

R Development Core Team. 2018. R: A language and environment for statistical computing. version 3.5.3. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.r-project.org

Robinson-Nilsen, C. and J. Bluso-Demers. 2012. Salt pond waterbird surveys report, October 2010-September 2011. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

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

South Bay Salt Pond Restoration Project. 2007. Final Environmental Impact Statement/Report. Appendix D: Adaptive Management Plan. http://www.southbayrestoration.org/pdf_files/SBSP_EIR_Final/Appendix%20D%20Final%20AMP.pdf

Takekawa, J. Y., C. T. Lu, and R. T. Pratt. 2001. Bird communities in salt evaporation ponds and baylands of the northern San Francisco Bay estuary. Hydrobiologia 466: 317–328.

Tarjan, L.M. 2019a. Trends in waterbird counts in south San Francisco Bay. Report prepared for the South Bay Salt Pond Restoration Project Management Team.

Tarjan, L.M. 2019b. Migration timing and spatial distribution of phalaropes in San Francisco Bay. Report prepared for the South Bay Salt Pond Restoration Project Management Team. Revised April 2020.

Tarjan, L.M. 2019c. South Bay Waterbird Surveys: Evaluation of Monitoring Protocols. Report prepared for the South Bay Salt Pond Restoration Project Management Team.

Tarjan, L.M. and G. Burns. 2020. South Bay Salt Pond waterbird surveys, September 2019-February 2021. Report prepared for the South Bay Salt Pond Restoration Project Management Team.

Ver Planck, W. E. 1958. Salt in California. California Division of Mines Bulletin, No. 175.

Warnock, N., G. W. Page, T. D. Ruhlen, N. Nur, J. Y. Takekawa, and J. T. Hanson. 2002. Management and conservation of San Francisco Bay salt ponds: effects of pond salinity, area, tide, and season on Pacific Flyway waterbirds. Waterbirds 25: 79–92.

Wickham, H. 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

TABLES

Table 1. Schedule for phalarope migration surveys. Sites = the number of sites visited during each survey, where each site was visited once between the start and end dates. RNPH = number of red-necked phalaropes; WIPH = number of Wilson's phalaropes; PHAL = number of phalaropes that could not be identified to species. No red phalaropes were observed.

Survey.ID	Survey.block	Year	Start	End	Sites	RNPH	WIPH	PHAL	Total
1	Mid Aug.	2019	08/15	08/20	30	1447	284	10	1741
2	Late Aug.	2019	08/26	09/01	34	1068	114	1	1183
3	Early July	2020	07/06	07/09	15	1	548	0	549
4	Mid July	2020	07/20	07/23	17	182	767	140	1089
5	Early Aug.	2020	08/04	08/06	15	758	446	5	1209
6	Mid Aug.	2020	08/18	08/20	15	904	162	0	1066
7	Late Aug.	2020	08/31	09/01	14	1700	110	0	1810
8	Mid Sept.	2020	09/15	09/16	13	935	0	32	967
9	Late Sept.	2020	09/29	09/29	14	40	1	0	41
10	Early July	2021	07/06	07/07	31	35	738	16	789
11	Mid July	2021	07/19	07/20	31	313	12	414	739
12	Early Aug.	2021	08/02	08/03	31	370	240	84	694
13	Mid Aug.	2021	08/16	08/17	30	1196	24	3	1223
14	Late Aug.	2021	08/30	08/31	31	2992	33	792	3817
15	Mid Sept.	2021	09/13	09/14	31	6767	0	0	6767
16	Late Sept.	2021	09/28	09/30	30	811	0	0	811
17	Late June	2022	06/20	06/21	29	0	18	0	18
18	Early July	2022	07/05	07/06	29	0	83	2	85
19	Mid July	2022	07/18	07/19	29	186	735	0	921
20	Early Aug.	2022	08/01	08/02	29	87	10	0	97
21	Mid Aug.	2022	08/15	08/16	31	1557	19	30	1606
22	Late Aug.	2022	08/29	08/30	31	4357	220	0	4577
23	Mid Sept.	2022	09/12	09/13	31	2882	15	875	3772
24	Late Sept.	2022	09/27	09/27	30	1963	0	0	1963

FIGURES

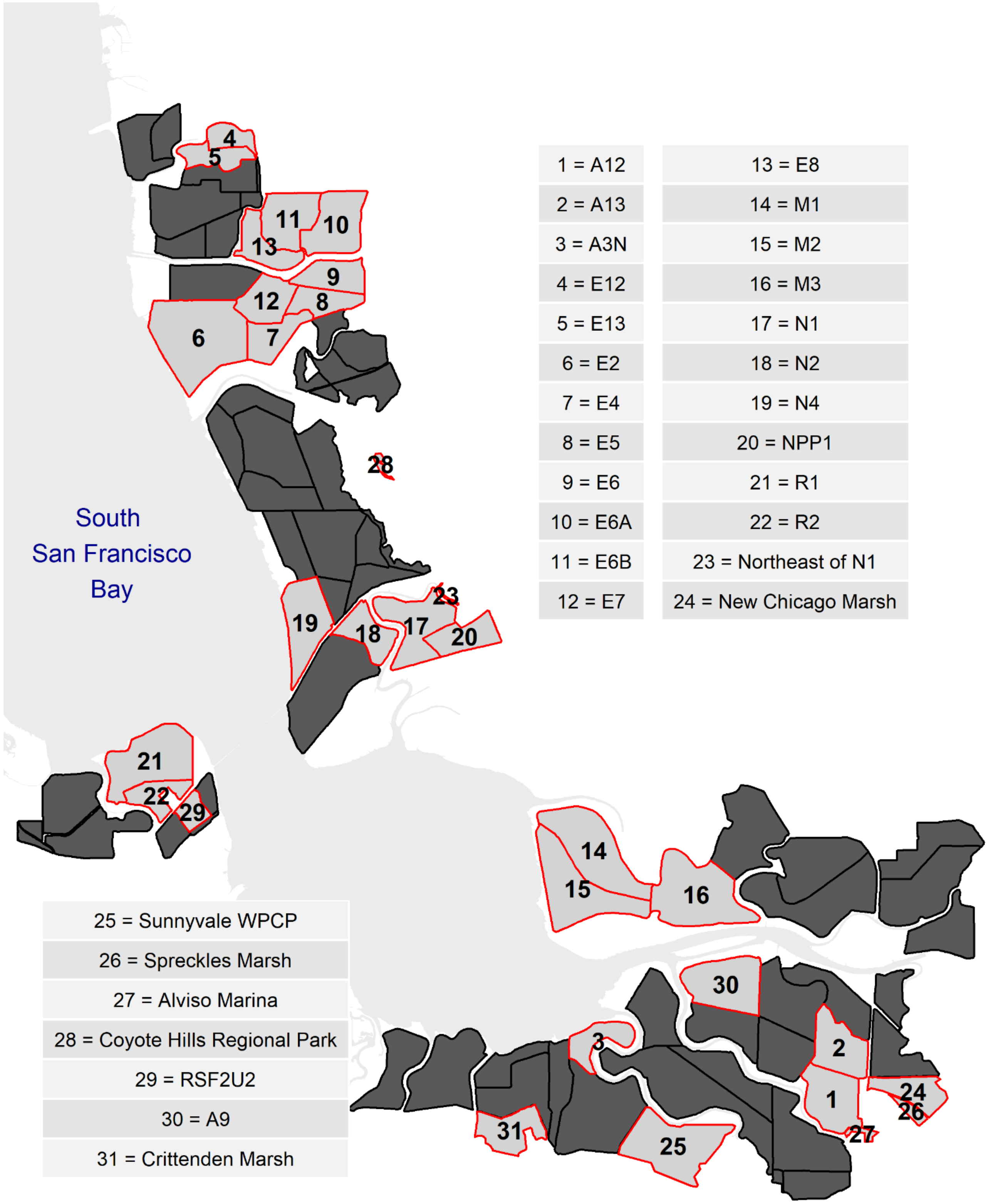

Figure 1. Map of target sites for Phalarope Migration Surveys.

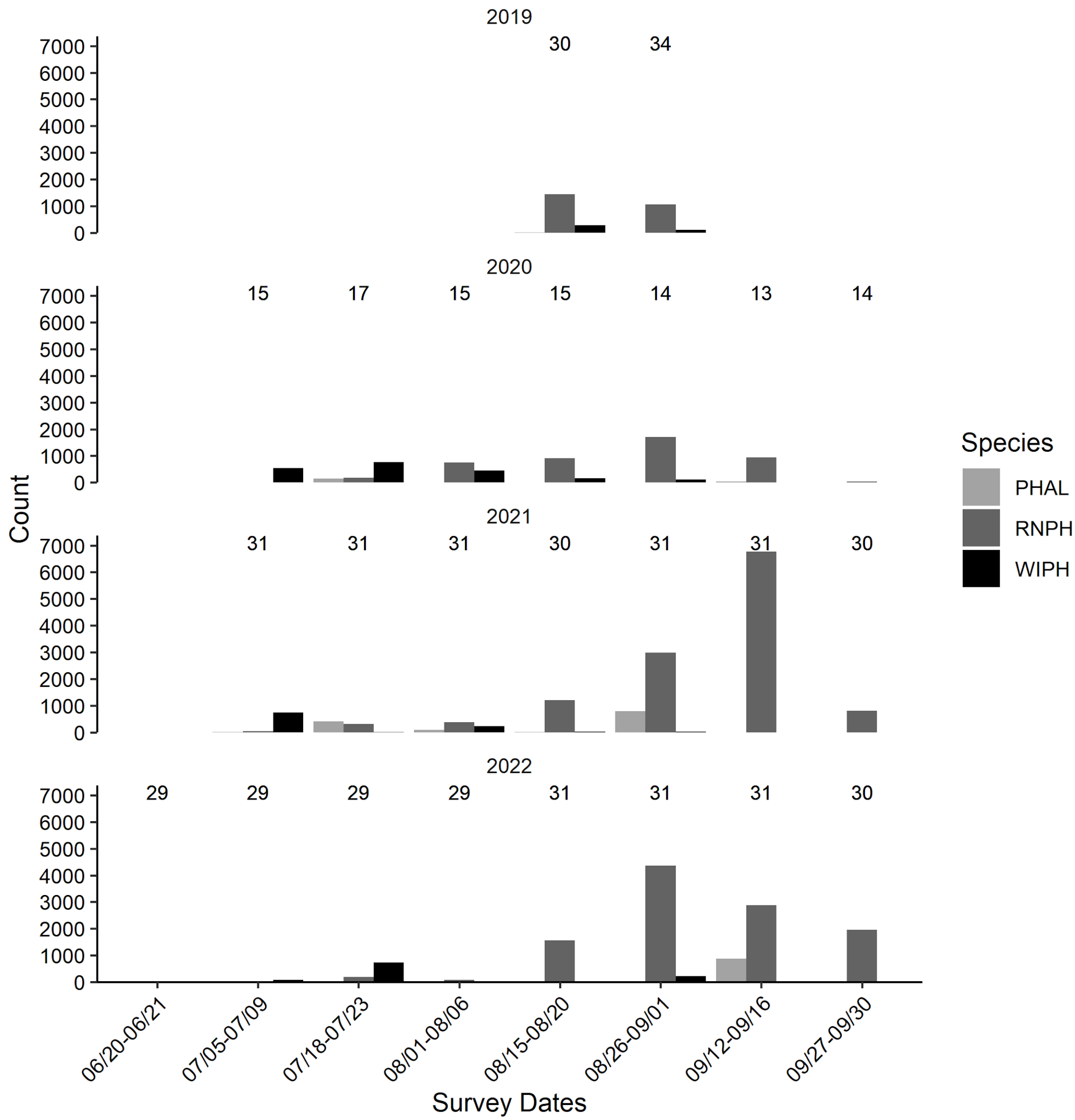

Figure 2. Counts of phalarope species observed during the phalarope migration surveys in 2019- 2022. PHAL = phalaropes of unidentified species; RNPH = red-necked phalarope; WIPH = Wilson's phalarope. No red phalaropes were observed. Counts are summed across all sites visited during each survey. Number above each date is the number of sites surveyed during that round.

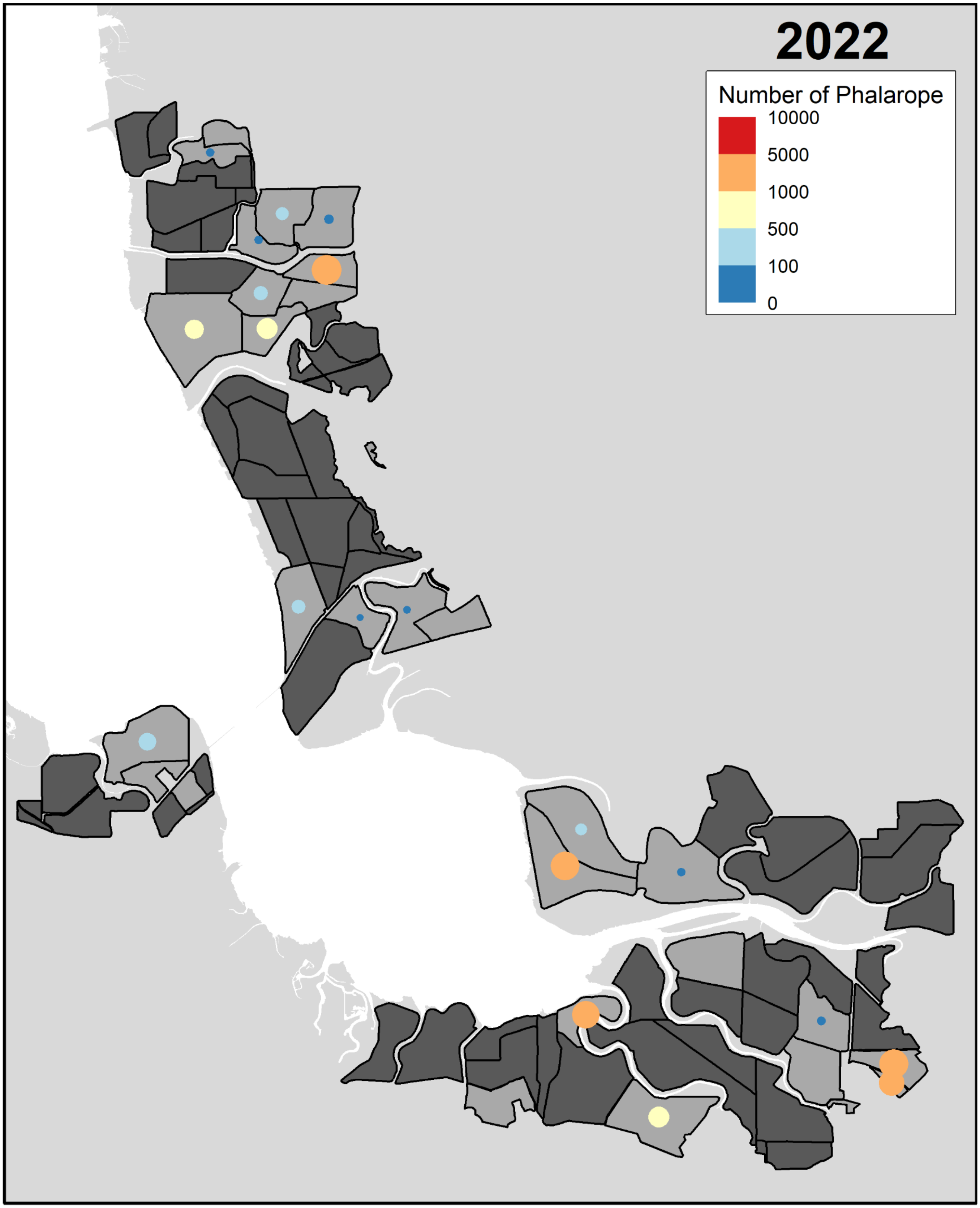

Figure 3. Map with counts of the total number of phalaropes observed during the phalarope migration surveys in 2022. Dots are scaled and colored to represent the number of phalaropes observed; ponds with no dot had zero phalarope observations. Dark gray ponds were not surveyed for Phalarope Migration Surveys in 2022.

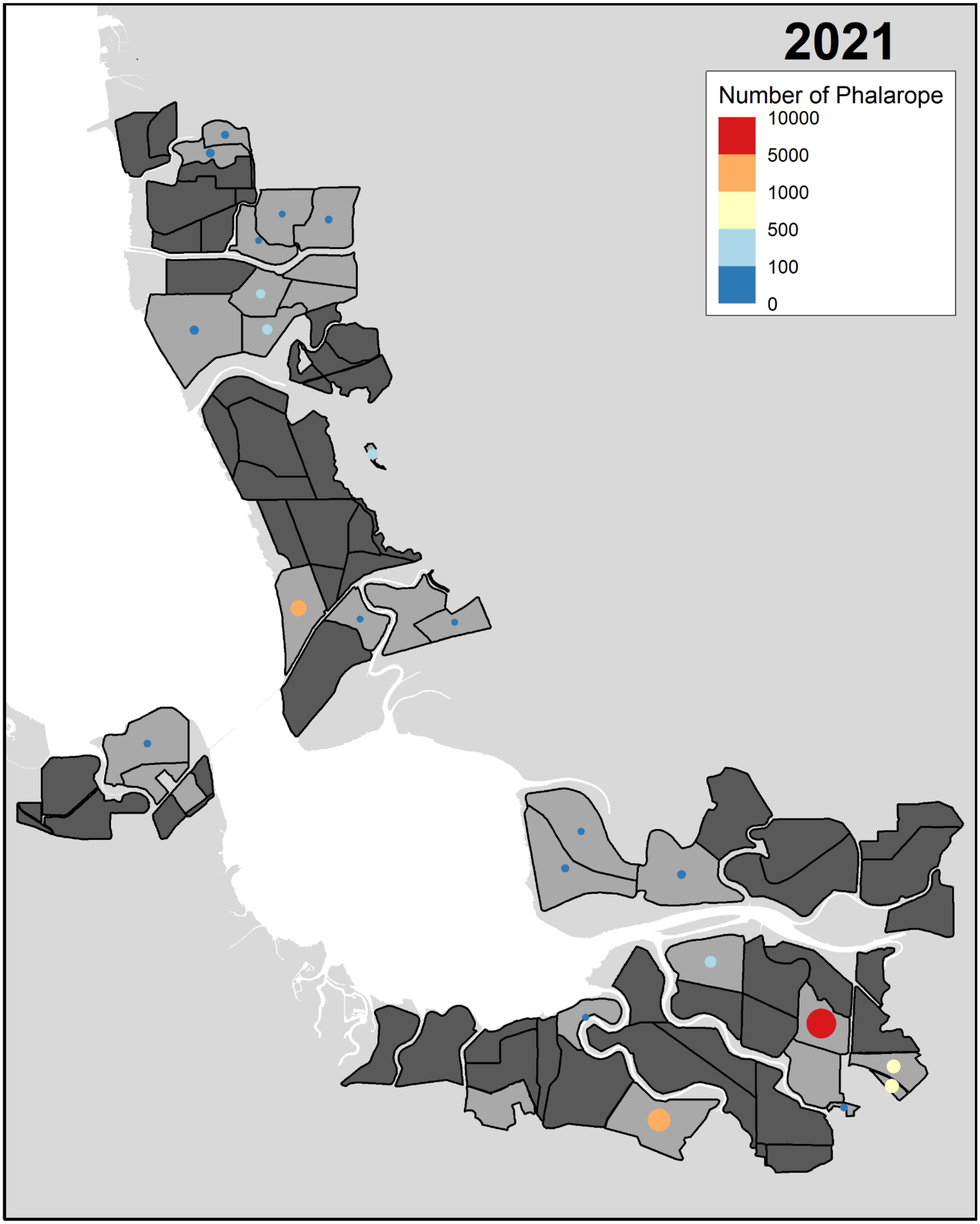

Figure 4. Map with counts of the total number of phalaropes observed during the phalarope migration surveys in the previous year (2021), for comparison. Dots are scaled and colored to represent the number of phalaropes observed; ponds with no dot had zero phalarope observations. Dark gray ponds were not surveyed for Phalarope Migration Surveys in 2021.

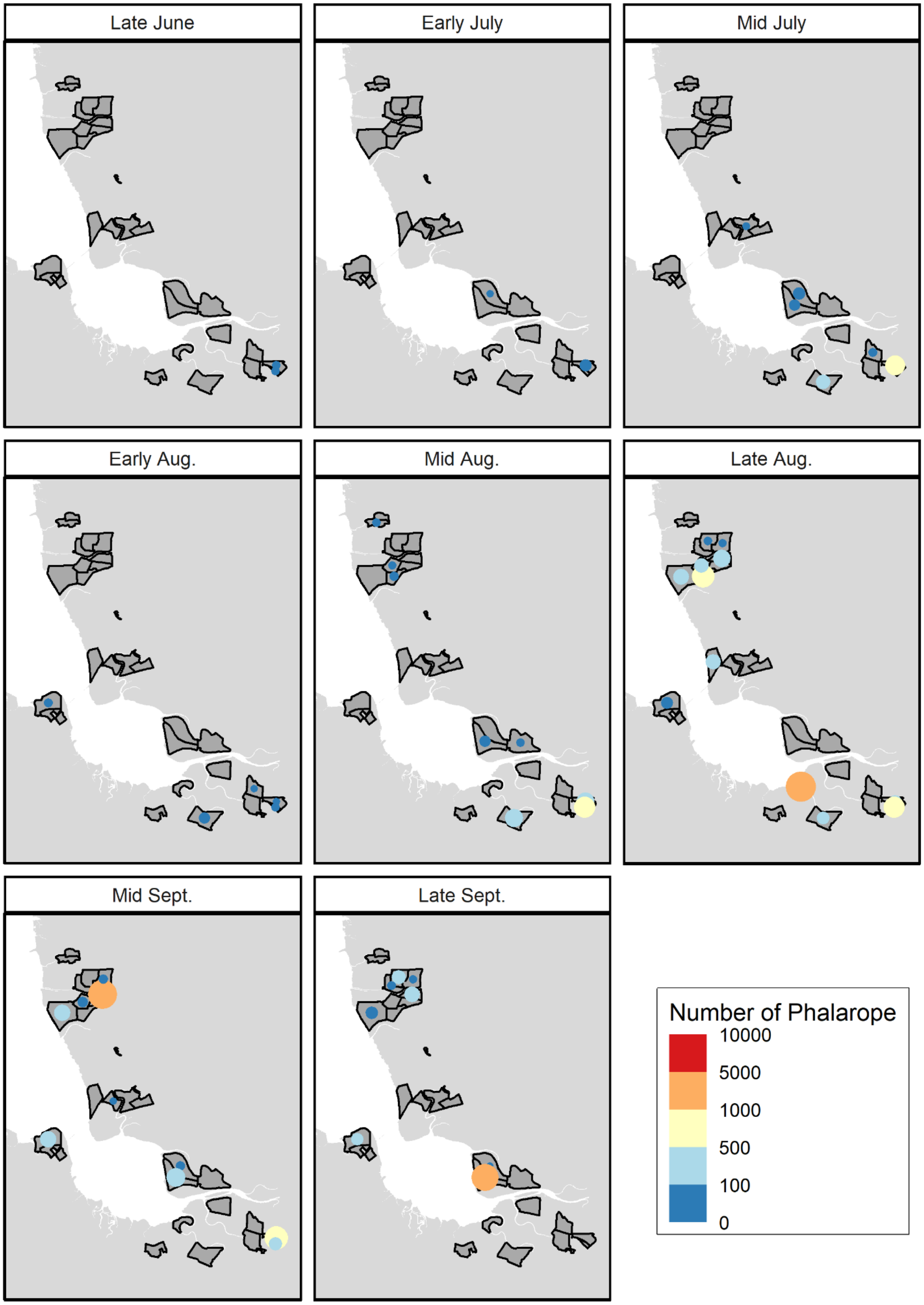

Figure 5. Map with counts of the total number of phalaropes observed during each phalarope migration survey in 2022. Survey block is indicated at the top of each map. Dots are colored and scaled to represent the number of phalaropes observed;pPonds with no dot had zero phalarope observations.

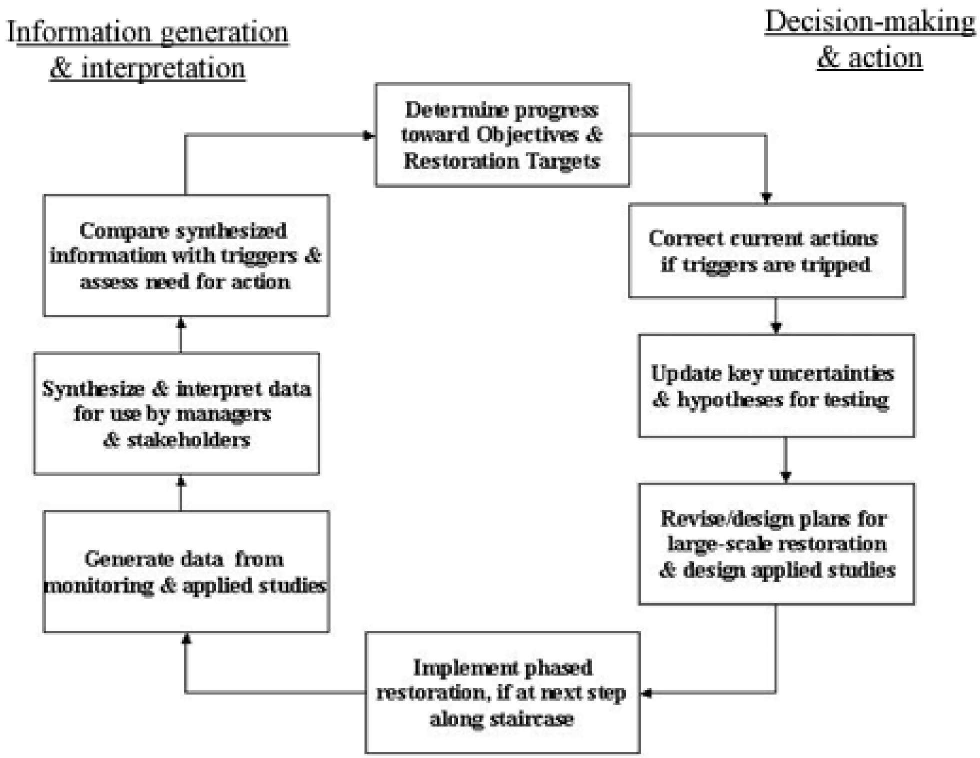

Figure 6. Adaptive management process as described in the Adaptive Management Plan (South Bay Salt Pond Restoration Project 2007).