South Bay Waterbird Surveys:
Evaluation of Monitoring Protocols

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Executive Summary

The South Bay Salt Pond Restoration Project (SBSPRP) is restoring historic salt evaporation ponds to a mix of tidal marsh habitat and managed ponds to improve wildlife habitat, flood protection, and public access. Evaluating wildlife response to the actions of this multi-decade restoration project is essential for sustaining baseline populations. At the outset of the project, the SBSPRP and regulatory agencies defined targets (baseline waterbird counts), thresholds (percent declines below the baseline), and triggers (counts below baseline values over a given number of consecutive years) for waterbird populations in the project area and/or South San Francisco Bay (Appendix 1). With more than a decade of monitoring data available, it is possible to assess our ability to use current monitoring data to detect these trends, and the opportunity to decrease survey effort while maintaining our ability to address project objectives. To evaluate the effectiveness of decreased effort, we performed a power analysis, which defines the power to detect changes in waterbird counts over time. We used a simulation approach to calculate detection power given the variability in waterbird counts from between 30 and 100% of project sites. Analyses suggest that survey effort should remain at or above 60% of sites to maintain alignment of count trends between the subset and all sites. Although comparable trends can be obtained by surveying a subset of sites for some guilds, subsetting sites provides poor representations of trends for gulls and phalaropes, introduces the risk of biases in counts, and cost savings are minimal. Notably, current survey efforts at all sites do not confer sufficient power to detect 50% declines of phalaropes, Bonaparte's Gulls, and Western Sandpipers within five years of the decline, indicating that additional survey effort is required to address existing NEPA/CEQA significance thresholds, or the thresholds should be revised. Recommendations for monitoring (pg. 11) include careful consideration of biases associated with site subsets. Critical next steps (pg. 13) include aligning the geographic scope of data collection and project targets and/or evaluating available sources of supplementary data.

Introduction

The South Bay Salt Pond Restoration Project (SBSPRP) is the largest tidal wetland restoration project on the West Coast of the Americas. In 2002, 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 evaporation ponds in the South San Francisco Bay. The 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 to many sites.

Salt production 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, 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). One of the goals of the SBSPRP is to maintain migratory bird populations that currently use salt ponds while supporting increased populations of native species that use tidal marsh (Takekawa et al. 2005). 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. Information is needed to ensure that habitat requirements of large numbers of waterbirds can be met with reduced pond acreage, including both salt production ponds and wildlife managed ponds.

In order to gauge the impact of tidal marsh restoration project on bird populations of the region, the SBSPRP compiled targets (baseline waterbird counts), thresholds (percent declines below the baseline), and triggers (counts below baseline values over a given number of consecutive years) for species and/or guilds within South San Francisco Bay (Appendices 1-2). A selection of guilds/species are of particular concern because as tidal restoration continues, their preferred habitat type (managed ponds) will decrease. Species and guilds of particular concern include Ruddy Ducks, diving ducks, small shorebirds, phalaropes, and Eared Grebes. Targets (i.e. baseline counts) for these guilds were defined as part of the Adaptive Management Plan (South Bay Salt Pond Restoration Project 2007) along with NEPA/CEQA significance thresholds, which specify a given percent decrease below baseline values. The Plan also identifies triggers, observable downward trends in waterbird counts that warrant a pause and conversation with project stakeholders, which take the form of a decrease in counts over a given number of consecutive years (e.g., two or three). While not all guilds were prescribed NEPA/CEQA thresholds (e.g., dabbling ducks, medium shorebirds, fisheaters), some guilds have goals defined by the USFWS Don Edwards San Francisco Bay National Wildlife Refuge. In the absence of

NEPA/CEQA significance thresholds for the SBSPRP, the Refuge goals offer an alternative metric for assessing waterbird population trends in the SBSPRP area.

The objectives of this ongoing study are to document avian use of current and former salt evaporation ponds in the South San Francisco Bay and to use data collected on waterbird abundance, distribution, and habitat associations to inform regional conservation, management, and habitat restoration efforts. To meet these objectives, SFBBO and USGS have conducted regular waterbird surveys since 2003. Annual reports that summarize the data are prepared by SFBBO each year and shared with land managers and the SBSPRP. These reports inform restoration actions and pond management. As the SBSPRP proceeds, understanding how waterbirds use managed ponds, restoration sites, and salt production ponds, identifying key habitat associations, and incorporating features needed by marsh or pond-dependent species into restoration design plans will be increasingly important in maintaining numbers of waterbirds in the South Bay.

Now that over a decade of data are available, it is possible to evaluate our ability to detect trends in waterbird abundance using realistic variability in counts. Such an assessment is desirable because it will allow us to test whether other protocols could be more cost-effective while yielding a dataset of comparable capabilities. Securing funding for monitoring for a multi-decade project is challenging, so methods that maximize efficiency in resource use are desirable. To this end, we produced this report to meet the objectives described below.

Report Objectives

The primary objective of this report is to determine our ability to detect trends in waterbird abundance using proposed updates to survey methods. The results can be used to identify more efficient methods of monitoring waterbirds in the South Bay, with particular emphasis on monitoring within the footprint of the South Bay Salt Pond Restoration Project, to meet the goals of maintaining waterbird numbers throughout the SBSPRP area. Our task is to assess ongoing monitoring efforts to ensure that they are both effective for evaluating SBSPRP targets and efficient to ensure sustainability. Specifically, we aimed to determine an approach that (1) is more resource efficient than current survey protocols, and (2) can be used to answer the question of whether waterbird populations in the South Bay are above or below targets defined in the Adaptive Management Plan of the SBSPRP. We also sought protocols that generate data that are directly comparable to counts from previous years.

Methods

Data Collection

We conducted waterbird surveys at 82 ponds in the Alviso, Coyote Hills, Dumbarton, Eden Landing, Mowry, and Ravenswood complexes (Figure 1, Appendix 3). Survey frequency changed over the course of the study with the availability of resources. USGS conducted monthly waterbird surveys within the SBSPRP (Eden Landing, Alviso, and Ravenswood complexes) from October 2002 to April 2013, while SFBBO conducted monthly surveys in Cargill-managed ponds (Mowry, Coyote Hills, and Dumbarton) from October 2005 to April 2015 (De La Cruz et al. 2018). During this time, data from 2003-2005 were used to establish baseline conditions before restoration activities, but after the SBSPRP had started the Initial Stewardship Plan (2003) and salt was no longer being produced. SFBBO then conducted surveys at all 82 ponds during seven 6-week survey periods each year from January 2014 to January 2018. Surveys of all 82 ponds are conducted twice during the spring, fall, and winter seasons and once during the summer season.

We performed surveys exclusively at high tide, defined as a tide of 4.0 feet or greater at the Alameda Creek Tide Sub-Station (37° 35.70' N, 122° 08.70' W). During each survey, we observed birds from the nearest drivable road or levee using spotting scopes and binoculars. We counted the total number of individuals of all waterbird species present on each pond and recorded the location of each using aerial site photos superimposed with 250 m^2 individually labeled grids. For each grid-scale sighting of an individual bird or bird group of the same species, we recorded behavioral data (whether the bird or bird group was foraging or roosting). For roosting birds only, we recorded whether we observed the bird or bird group on a levee, an island, or a manmade/artificial structure (e.g., blind, fence post). Note that water quality data are also collected and important for inferring bird habitat associations, but analyzing our power to detect habitat associations is beyond the scope of this report (De La Cruz et al. 2018).

Subsetting Protocols

We used power analyses and simulations informed by our existing dataset to explore the feasibility of decreasing survey effort using a subsetting protocol. Previous analyses (Tarjan & Heyse 2018) revealed that survey frequency needs to remain at current levels (twice during the peak season for any given species) to detect SBSPRP targets for multiple species. These results are in agreement with Wood et al.'s (2010) findings that decreasing survey effort by 50% (from every one to every two years) dramatically decreases the power to detect trends in bird abundances. An alternative approach to decrease survey effort is to survey fewer locations, which we evaluate here.

The ideal subset of sites would yield counts that are representative of the population. Counts from a subset of sites can become biased if birds shift their locations over time. The potential for this “frame bias” (Bart et al. 2005) leaves researchers unsure of whether a decline occurred due to a decline in the larger population or due to movement away from the surveyed sites (i.e. the frame) over time. A second type of bias called selection bias arises when some sites cannot be surveyed due to access restrictions (Wood et al. 2010).

Earlier work by Wood et al. (2010) simulated shorebird counts from sites within the San Francisco Bay Area to evaluate the accuracy and precision of eight subsetting protocols. They tested variations of random sampling, stratification by region such that each region was equally represented in the subsample, and site selection weighted by the abundance of shorebirds in historical data. Based on their assessment of accuracy and precision, they recommended random selection of sites that are weighted using historical data for annual surveys, and stipulated that remaining sites are surveyed every ten years to check for frame bias (i.e. movement of birds between sites). They concluded that with this scheme, survey effort could be reduced by up to 75% and still deliver accurate (+/- 20%) estimates of 20-year population trends at 0.05 and/or 0.15 power.

We applied Wood et al.’s approach with modifications to the detection criteria to identify feasible reductions in survey effort for the SBSPRP. We evaluated our ability to detect trends under sampling schemes where we sample 100%, 70%, 60%, 50%, 40%, and 30% of the survey sites. Our goal was to identify a subset of sites that would yield a ten-year trend in waterbird counts within 15% of the estimate for the full dataset (Wood et al. 2010), which is the smallest NEPA/CEQA significance threshold for any non-breeding species/guild.

We assumed that one goal of subsetting sites is to have a collection of sites that is representative of all survey sites in terms of species composition and diversity. Upholding this assumption facilitates comparison of new data with historical data. We used a similarity index to evaluate how representative counts in a subset are to counts in the entire sample. This similarity assessment was implemented using the bioenv function in the Vegan package (Oksanen et al. 2019) in R. We selected a set of sites with a rho value of at least 0.95 when compared with the full set of sites in terms of species composition and relative abundance.

The community was represented by a small number of ponds (<10), so we added sites of interest as defined by the Project Management Team, which comprised: RSF2U1, RSF2U2, RSF2U3, RSF2U4, A16, A17, A19, A8, E12, E13, E9, E10, R3, R4, A1, E6, E6C, E4C, E5C. These sites were identified based on their past (Phase I) and planned (Phase II) status as a managed, breached, or reconfigured site. We added subsequent ponds using a weighted approach following

Wood et al. (2010), where the sites (which we define as ponds) were weighted by historical bird abundance. The birds within the SBSPRP represent diverse guilds (e.g. shorebirds, dabbling ducks, diving ducks) so their habitat preferences differ and high density areas are not necessarily representative of the preferred area for all species. To incorporate representative sites for all guilds and species of interest, we randomly selected sites weighted by density for each guild/species of interest, comprising small shorebirds, dabbling ducks, diving ducks, Eared Grebe, phalaropes, medium shorebirds, terns, and gulls. We then randomized the order of guilds/species and selected the top sites in sequential order for each guild/species. Note that Eared Grebe are a species of interest due to their reliance on high salinity ponds, so we included salt production ponds outside of the project footprint (i.e. ponds in the Mowry, Coyote Hills, and Dumbarton salt production pond complexes) in this part of the selection process to capture Eared Grebe trends in South San Francisco Bay.

To address the effects of restoration and management on waterbird abundance, the subset included representative sites of different restoration and management types. Pond types were defined as (a) salt pond, (b) managed pond, (c) reconfigured pond (Phase I or Phase II), and (d) breached pond (Initial Stewardship Plan & Phase I or Phase II) (see Appendix 3 for categorizations and definitions). We summarized the representation of each pond type at each subset level in Table 2.

Simulations

We used the simulation approach outlined in Tarjan & Heyse (2018), which followed that of Wood et al. (2017), to estimate our power to detect trends of various magnitudes with count data from each subset of sites. We analyzed our ability to detect a pulse decline in counts (i.e. an immediate decline that occurs across one time period of data collection), which is most similar to the current NEPA/CEQA significance threshold definitions (Table 1 in Tarjan & Heyse 2018). NEPA/CEQA significance thresholds are defined as a given percent decrease without an associated timeframe. For example, the threshold for Ruddy Ducks is a decline in South Bay numbers of 15% as a result of the SBSPRP. The threshold is relevant no matter the duration of the decline, but our ability to detect the decline will depend on how quickly the decline manifests. We tested the extreme case of a pulse decline in counts that occurred across one year, which may occur in the context of the restoration project if birds respond immediately to restoration activities. Declines over longer time periods are likely more difficult to detect, so this analysis provides the upper limit of our power to detect a decrease in population counts. For each species, we simulated 3 to 15 years of count data with error equal to the variability in our historical dataset. The initial simulated count (year 1) was equal to the mean historical count for each species. The mean simulated count then decreased by either -10, -15, -20, or -50% in year two, and was sustained at that size for the duration of the surveys.

To incorporate realistic variation into the count data, the simulated count for each biannual survey was randomly selected from a normal distribution of 10,000 values with the mean tracking the designated percent decrease and the error equal to variation in the historical dataset. This variation includes both the natural variation in the latent population size over time and also the variability in our monitoring protocols. To estimate the variation in historical data, we used historical counts that occurred within the peak season for each species, where peak season is the season during which the species is most abundant. We then estimated historical variation as the mean within-year variance in the (log-transformed) counts. An alternative approach may be to use the residual variance around a linear model of all log-transformed counts; for an existing dataset, the coefficient of variation (CV) can be estimated by residual variance about the regression line (Gerrodette 1987). However, estimating CV using this approach assumes that the population followed a single linear trend throughout our historical data. Given that many populations grow in a nonlinear fashion over decades, it is possible that some species are not best represented by a linear model, and that estimating CV using residual variance would inflate our estimates of variability in the count data. Instead, we use the within-year variability in counts to estimate variability in our simulated data. Since standard deviation scales to the mean in our dataset, we estimated the standard deviation for each mean using a linear model of standard deviation as a function of mean counts of historical data, with the intercept fixed at zero.

The simulated count was observed two times in the peak season (or once in summer) for the species, which reflects survey efforts from 2014-2019. For each simulated dataset, we performed a one-sample t-test comparing the baseline count to the counts in years following the decline and determined whether or not a change in counts was negative at the $p < 0.05$ significance level. We repeated this procedure 1,000 times for each combination of species, effect size, and survey period (from 3 to 15 years) and estimated power by the proportion of those 1,000 replicates that correctly detected a negative trend in bird counts over time. We then identified the minimum number of survey years required to detect the decline with a power of 0.8. All analyses were performed in R version 3.5.1 (R Development Core Team 2018).

Results & Discussion

Site Subsets

Based on the similarity index, the waterbird community in the SBSPRP footprint was well-represented by the following sites: A19, A3W, A8, A9, E6B, E8AE, E9. Average counts by guild for this subset of sites compared with the entire set of sites were very similar, with rho = 0.98. In addition to these seven sites, we manually added the following sites based on input from the SBSPRP Science Advisory Team: RSF2U1, RSF2U2, RSF2U3, RSF2U4, A16, A17, A19,

A8, E12, E13, E9, E10, R3, R4, A1, E6, E6C, E4C, E5C. Finally, we ranked additional sites using random weighted selection, where we selected guilds in random order and each site was weighted by the historical abundance of the guild of interest. The final pond rankings and subsets appear in Table 1 and Figure 1. To accommodate sites representative of the waterbird community and sites suggested by the Science Advisory Team, a minimum proportion of 0.3 of the sites should be included in the subset. Salt production ponds (i.e. sites at Mowry, Coyote Hills, and Dumbarton) were not included in the community assessment and did not appear in the suggested sites, so salt production ponds are not present at subset levels below 0.4 (Table 2).

Trend Alignment

Trends for multiple guilds were non-linear across the most recent ten years of data (2007-2017), so we fit LOESS curves to waterbird count data from each site subset to characterize the alignment between trends from the subsets and all sites combined (Table 3, Figure 2). The alignment of the subsets varied by guild. Each subset level showed good alignment with overall trends (i.e. the percent change across the ten-year period for the subset was within 15% of the percent change for all sites) for divers, small shorebirds, and terns. According to this metric, divers and small shorebirds require at least 40% of sites to be surveyed, while Eared Grebe and phalarope require at least 50% of sites to be surveyed. Trends in gull counts were poorly represented by all subset levels, indicating that spatial patterns of gull abundance are distinct from other species.

Power Analyses

By using the variance in counts from over a decade of historical waterbird monitoring data, we were able to run a realistic simulation of waterbird counts for populations experiencing various levels of decline. We found that our power to detect decreasing trends in waterbird counts was dependent on species, survey effort (i.e. the number of sites surveyed during the peak season for each species), and the effect size (i.e. the magnitude of the decreasing trend) (Figures 3-10). Nur et al. (1999) estimated that 10+ years of data are required to detect a trend using an area search protocol. Nur's estimated requirement of 10+ years of data generally coincides with our ability to detect between a -15% and -10% pulse decline in waterbird counts using the most recent survey effort of two surveys per season (Table 4).

NEPA/CEQA significance thresholds do not specify a sustained annual percent decline, but rather a pulse decline that occurs over any time period. Under current survey efforts with two surveys per season at 82 sites, we detect a -50% pulse decline in waterbird counts in 3-7 years for most species. NEPA/CEQA significance thresholds for some species specify a decline of -15%, with some as low as -10%. Tarjan and Heyse (2018) found that pulse declines are generally easy to detect when the magnitude is a -50% decline. For example, we can detect a

-50% pulse decline in 90% of cases within three years of data collection for Bufflehead, Canvasback, Eared Grebe, and many other species (Table 3 in Tarjan & Heyse 2018). However, declines of smaller magnitudes are very difficult to detect for some species. For example, our power to detect pulse declines in Bonaparte's Gulls, Western Sandpipers, and Least Sandpipers with current survey efforts remains below 0.8 power for over 15 years for pulse declines of -20, -15, and -10%. Our ability to detect pulse declines of these magnitudes for Red-necked Phalarope never exceeds 0.2, implying that we are functionally incapable of detecting pulse declines equal to or less than -20% for this species using current approaches. Based on these results, we recommended that survey frequency remain at or above two surveys per season.

Similar trends exist at the guild level (Figures 3-10). We are able to detect a decline of -50% within 3 years for nearly all guilds, with the exception of phalaropes, which requires 9 years of data collection. Declines of smaller magnitude are more difficult to detect. For example, we would require more than ten years of data collection to detect a -10% decline in terns, small shorebirds, medium shorebirds, and gulls.

The power to detect trends in waterbird abundance decreases as fewer sites are surveyed (Table 4). This result is a direct consequence of the higher variability in waterbird counts when counts are summed across fewer sites. This decrease in power supports using a relatively larger subset for waterbird counts. Surveying 70% of sites requires more than ten years of data collection to detect declines of -10 to -15% for five guilds. To detect changes of -20% in fewer than ten years for most guilds, 60% of sites should be surveyed. However, small shorebirds would require more than 15 years of data collection to reach 0.8 power at this subset level. Declines of diving ducks of multiple magnitudes are relatively easy to detect across multiple subset levels. Notably, the loss of power across subsets is less than the loss of power observed when survey frequency is decreased (Tarjan & Heyse 2018). This result is in agreement with Wood et al.'s (2010) finding that shorebird surveys should continue at a higher frequency, but could occur at fewer sites. However, subsetting the sites introduces multiple potential biases, such as frame bias. While periodic surveys of all sites can be used to detect frame bias, correcting for frame bias if it is detected is challenging. Furthermore, results from the power analysis must be considered in conjunction with results from the assessment of trend alignment.

Tarjan and Heyse (2018) found that detection of pulse declines of magnitudes less than -50% using current approaches may require too much time for enacting appropriate responses if we rely on targets as they are currently defined. We suggested that triggers (counts below baseline values over a given number of consecutive years) would be more sensitive to declines in waterbird numbers than existing NEPA/CEQA significance thresholds and therefore may be detected earlier; however, a formal analysis of the effectiveness of triggers was not performed in that report. This report illustrates that the probability of detecting triggers is a direct function of the variability in waterbird counts, and is not dependent on additional data collection after the decline has occurred and three years of data have been collected (Table 5). Fortunately, we are much more likely to detect a decline using triggers, which we defined as two out of three consecutive years where counts fall below the baseline, than by analyzing significance thresholds. After only three years of data collection at any subset level, we are confident (i.e. with a probability greater than 80%) that we can detect a trigger for all guilds for a -50% decline, and for all guilds except phalarope for a -20% decline. At a -15% decline, our detection probability for triggers drops for small shorebirds in addition to phalarope at all subset levels. Detecting -10% declines using triggers is likely insufficient for dabbling ducks, gulls, small shorebirds, and phalaropes, even if all ponds are surveyed. Subsetting sites has a relatively small effect on our ability to detect triggers, suggesting that triggers are relatively robust to a subset protocol. It is important to note that the usefulness of triggers for a subset of sites relies on the assumption that declines occur evenly across all sites. Triggers and targets cannot be meaningfully scaled up from the subset level to the project level unless this assumption is accurate.

Our ability to detect the NEPA/CEQA significance thresholds and triggers is unlikely to improve across a range of other realistic ecological situations using current approaches. We modeled the most extreme case of a pulse decline, where the population decreases immediately between years 1 and 2, and is then sustained at the lower size over time. Furthermore, we assumed that all years of data following year 1 were useful in estimating recent population status, thus increasing our sample size for the statistical analysis. In the event that the decline occurred over additional years, which is likely if birds respond to slow changes in restored habitats, the trend would be even more difficult to detect. In the case of a longer duration of decline, the power to detect the decline would increase if a subset of the most recent surveys were compared to the baseline. However, even this approach would yield power lower than our simulations due to the corresponding decrease in sample size.

Preliminary Updates to the Survey Protocol

The Science Advisory Team suggested that waterbird surveys could be made more efficient by eliminating the process of designating birds to 250x250m grids within each pond (Tarjan & Heyse 2018). Bird data have been collected using grids from 2002-2017. Assuming habitat preference does not change in the future, it is likely that sufficient data are already available to answer questions about habitat use within the ponds. SFBBO re-commenced surveys in January 2019 and removed the procedure of assigning birds to grids. Available data suggest that survey duration without the grid-assignment procedure (mean duration = 63 min) is lower than with grid-assignment (mean duration = 73 min) during the months of January-March ($t = -2.4659$, $df = 183.23$, p-value = 0.01459) (Figure 11). Removing grid assignment also simplifies data entry, but an analysis of increased efficiency associated with data entry hours was beyond the scope of this report.

Survey Schedule and Cost

The survey schedule for waterbird counts has changed over time to accommodate surveys of both SBSPRP sites and salt production ponds by one entity (Figure 12). SFBBO's survey periods are six-weeks in duration, which allows two staff and two interns (one in summer) to visit all sites within the survey period. Reducing the number of sites will allow for a shorter survey period, which is desirable because it decreases the likelihood that birds will move between sites or to/from the survey footprint during the survey period. If survey effort remains at two surveys per season (with one in summer) and the goal is to characterize bird abundance throughout the season, then survey periods should be evenly dispersed throughout each season, and the start dates for surveys should remain the same. Alternatives to this schedule include selecting particular periods of interest (e.g. the midpoint of each season) and concentrating surveys around those periods (Figure 12).

Survey cost will not align directly with reductions in sites. A large portion of the survey cost is travel time to the sites, and the best site subsets require continued visitation to each pond complex. Surveyors are generally limited to one pond complex per day by the restricted period during which the tide is above 4ft. Furthermore, the site subsets are biased to sites with higher bird density and diversity, so data collection and data entry will take longer than for a random subset of sites.

For a given subset level, the survey cost will lie between the corresponding proportion of the total cost (e.g. 30% of the cost for 0.3 of the ponds) and the total cost of surveying all sites. The relationship between the site subset level and cost is likely to be nonlinear with a decreasing slope, such that adding sites to the survey will cost relatively less per site at higher subset levels. A preliminary assessment indicates that the cost of surveying at the 60% subset level defined in this report would be 85-89% of the cost of surveying all 82 sites. As the bulk of the cost is staff hours, note that alternative schedules (e.g., Option 1 in Figure 12) may compromise the significant cost-savings associated with internships. Interns generally require one survey round for training, so internships would remain valuable if interns could be kept on retainer in between survey periods. One possible cost-saving measure would be to share an intern and field vehicle with a SBSPRP partner organization (e.g., US Fish and Wildlife Service).

Recommendations for Monitoring

Based on the current analysis in combination with previous results described in Tarjan and Heyse (2018), we make the following recommendations for waterbird monitoring for the SBSPRP.

1. Managers should carefully weigh the following risks with the cost savings associated with subsetting sites:
    a. There is a risk of “frame bias”, where birds shift their use of the sites over time and the subset becomes a poor representation of the overall area. This risk can be somewhat mitigated by scheduling a periodic (e.g. every 5-10 years) comprehensive survey of all sites to reevaluate the subset. However, managers should consider whether implementation of these comprehensive surveys will be difficult in the future.
    b. The conclusions in this report depend on the assumption that declines occur equally across all sites. If declines instead manifest in a biased manner (e.g., declines occur first at lower density sites), then our ability to detect changes may be compromised beyond the losses in power described in this report.
    c. Surveys to date provide an index of bird abundance because it is not possible to survey all sites simultaneously with current efforts. Any changes to the survey schedule or duration could bias future counts relative to historical data. The direction of such a bias will remain unknown without a targeted study comparing the two protocols.
2. If a subset of sites is used, it should comprise greater than 60% of sites to ensure alignment of trends in waterbird counts between the subset and all sites. Managers should create a plan for implementing periodic comprehensive surveys to check for frame bias and again consider that there may be minimal cost savings.
3. Some sites that ranked high in the subsetting procedure have limited access, either now or in the future (e.g. A6). The subset should be evaluated and updated if access poses too great a challenge. However, eliminating these sites will likely introduce selection bias, especially as these sites have similar habitats (i.e. the sites have been breached). See “Next Steps” #4 below for a discussion of eliminating selection bias.
4. Waterbird surveys should continue at a rate of 2-3 surveys per season during spring, fall, and winter. Goals require that surveys capture the peak numbers of multiple guilds, which occur during different seasons. Decreasing survey effort to one survey per season would require substantially more than 15 years of data to detect NEPA/CEQA significance thresholds for many species. Triggers may not be a sufficiently sensitive alternative.
5. Waterbird surveys could be made more efficient by eliminating summer surveys. Most guilds are not at their peak during this season. However, eliminating these surveys assumes that breeding birds are surveyed using another method (e.g., California Gull and Double-crested Cormorant walkthrough surveys). Collaborators discussed whether a loss of summer surveys would negatively impact our ability to detect phalaropes. The current analysis suggests that peak counts of Red-necked Phalarope and phalaropes as a guild occur during fall surveys. Also, current protocols are unable to detect pulse changes smaller than -50% without more than 15 years of survey effort for Red-necked Phalarope.

Alternative approaches to capture summer counts may be a citizen science count, potentially targeted on dates when phalaropes are reported on eBird. If this is pursued, we would suggest a cost analysis for organizing the count and compare it to the cost of summer surveys by researchers. Given the lack of comprehensive breeding waterbird surveys in South San Francisco Bay, the SBSPRP would benefit from re-allocating resources for summer surveys to targeted breeding bird surveys (see Next Steps #1).

6. Available data suggest that removing the procedure of assigning birds to grids within sites decreases survey effort during January-March. We suggest that this practice is continued, and that survey duration is reanalyzed after a full year of surveys to quantify improvements in survey efficiency due to this update in the survey protocols.

Next Steps

We suggest these next steps to improve alignment between project objectives and monitoring protocols and to further address the objective of increasing survey efficiency.

1. We recommend that project managers revisit the geographic scope of the project goals, targets, and triggers. Current surveys cover the project pond system and additional Cargill-managed ponds, whereas many of the goals are stated in terms of the number of birds within the South Bay. This analysis made the assumption that NEPA/CEQA significance thresholds could be evaluated within the project footprint and neighboring salt production ponds, but this may not be equivalent to evaluating the entirety of the South Bay. If goals remain defined within this larger geographic scope, then additional data would be required to evaluate project status. Furthermore, NEPA/CEQA significance thresholds require that researchers can demonstrate that declines are a result of the SBSPRP. Supporting this claim may require that trends within the project footprint can be compared to trends outside of the project footprint. If there is an intent to use external sources of data to address these deficiencies, then those external data sources should be identified and the dataset should be evaluated for comparability with the existing dataset for waterbirds in the SBSPRP. External sources of data would likely need to be reformatted for comparison with the existing dataset, if such a comparison is deemed possible. Other ongoing surveys in the region that could contribute to this effort include the Pacific Flyway Shorebird Survey (Point Blue Conservation Science) and the Midwinter Waterfowl Count (formerly U.S. Fish & Wildlife Service, currently U.S. Geological Survey). Surveys of breeding waterbirds in South San Francisco Bay are of limited geographic scope, with the exception of Rintoul et al. (2003), which is limited to American Avocets and Black-necked Stilts, and a planned breeding waterbird survey in May 2019 (J. Ackerman, personal communication). In the absence of ongoing studies for breeding waterbirds, resources for summer surveys in the SBSPRP area could be reallocated to targeted breeding bird surveys during peak breeding season (mid-May).

Available datasets of counts of Eared Grebe, phalaropes, Bonaparte's Gulls, and Least Terns during post-breeding dispersal at the scale of South San Francisco Bay remain to be identified.

2. Project management should explicitly define how targets, triggers, and significance thresholds should be evaluated. This topic warrants a discussion and consensus about the most appropriate method, as there are alternatives to the one suggested here.
3. Managers should discuss alternative or reinforced approaches for monitoring species for which we are unlikely to detect NEPA/CEQA significance thresholds using current approaches, notably Least Terns, Western Sandpipers, Least Sandpipers, and Red-necked Phalaropes.
4. Site access will continue to be a challenge as additional ponds are breached. Surveys of restored sites seem critical to addressing the effects of restoration on waterbirds, so alternative methods of surveying inaccessible sites (e.g., the use of Unmanned Aerial Systems) should be investigated.

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 Cheryl Strong at the Refuge for help with coordination and guidance for these surveys. Thank you to our partners at the South Bay Salt Pond Restoration Project; John Krause with the CDFW Eden Landing Ecological Reserve; and the U.S. Geological Survey. We could not have done this work without our dedicated field crew: Anjou Kato, Alicia Manfroy, Illianna Termuehlen, Victoria Heyse, Wray Gabel, Rock Delliquanti, Emma Stevens, Alex Rinkert, Anqi Chen, Dan Wenny, and Cole Jower. Thank you to SFBBO staff, Josh Scullen and Yiwei Wang, for their logistical support with surveys and feedback on this report. Thank you to Cheryl Strong, Laura Cholodenko, Jared Underwood, Julien Wood, Josh Ackerman, and Jennifer Watson for comments on an earlier draft of this report.

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Tables

Table 1. Sites included at each subset level. The subset level equals the proportion of sites included in the subset. The spatial layout of each subset is viewable in Figure 1.

Subset Level	Sites
0.3	A19, A3W, A8, A9, E6B, E8AE, E9, RSF2U1, RSF2U2, RSF2U3, RSF2U4, A16, A17, E12, E13, E10, R3, R4, A1, E6, E6C, E4C, E5C, N4, A7, R1
0.4	A19, A3W, A8, A9, E6B, E8AE, E9, RSF2U1, RSF2U2, RSF2U3, RSF2U4, A16, A17, E12, E13, E10, R3, R4, A1, E6, E6C, E4C, E5C, N4, A7, R1, A15, E10X, A14, N1A, A12, N3A, A23, NPP1
0.5	A19, A3W, A8, A9, E6B, E8AE, E9, RSF2U1, RSF2U2, RSF2U3, RSF2U4, A16, A17, E12, E13, E10, R3, R4, A1, E6, E6C, E4C, E5C, N4, A7, R1, A15, E10X, A14, N1A, A12, N3A, A23, NPP1, N2, E6A, M3, N4AB, E5, A10, A6N, A2E
0.6	"A19, A3W, A8, A9, E6B, E8AE, E9, RSF2U1, RSF2U2, RSF2U3, RSF2U4, A16, A17, E12, E13, E10, R3, R4, A1, E6, E6C, E4C, E5C, N4, A7, R1, A15, E10X, A14, N1A, A12, N3A, A23, NPP1, N2, E6A, M3, N4AB, E5, A10, A6N, A2E, M4, R2, AB1, A5, R5, N5, M6, E4, N4AA
0.7	A19, A3W, A8, A9, E6B, E8AE, E9, RSF2U1, RSF2U2, RSF2U3, RSF2U4, A16, A17, E12, E13, E10, R3, R4, A1, E6, E6C, E4C, E5C, N4, A7, R1, A15, E10X, A14, N1A, A12, N3A, A23, NPP1, N2, E6A, M3, N4AB, E5, A10, A6N, A2E, M4, R2, AB1, A5, R5, N5, M6, E4, N4AA, E8, E8AW, E14, A6S, E1C, M5, N2A, A8S
1	A19, A3W, A8, A9, E6B, E8AE, E9, RSF2U1, RSF2U2, RSF2U3, RSF2U4, A16, A17, E12, E13, E10, R3, R4, A1, E6, E6C, E4C, E5C, N4, A7, R1, A15, E10X, A14, N1A, A12, N3A, A23, NPP1, N2, E6A, M3, N4AB, E5, A10, A6N, A2E, M4, R2, AB1, A5, R5, N5, M6, E4, N4AA, E8, E8AW, E14, A6S, E1C, M5, N2A, A8S, M1, N1, A2W, N9, A20, E3C, N3, E1, AB2, E2C, N6, E7, N8, E2, A13, E11, A3N, M2, A11, E8X, N7, N4B, RS5, A21, A8W, A22

Table 2. The percent of sites of each type represented at each subset level. The subset level equals the proportion of sites included in the subset. Managed and breached ponds remain below 100% representation at subset level 1 because limited accessibility has already prohibited surveys of some sites. See Appendix 3 for site categorizations and category definitions.

Subset Level	**Managed**	**Breached**	**Breached Phase II**	**Reconfigured**	**Reconfigured Phase II**	**Salt Pond**
0.3	19%	33%	50%	100%	43%	0%
0.4	30%	50%	70%	100%	43%	5%
0.5	44%	50%	70%	100%	43%	23%
0.6	52%	58%	70%	100%	57%	41%
0.7	63%	58%	80%	100%	57%	59%
1	89%	83%	100%	100%	100%	100%

Table 3. Ten-year trend estimates (2007-2017) of waterbird counts in each subset and across all sites. Columns show the subset level (i.e. the proportion of sites included in the subset) and trends are represented by the percent change across the most recent ten-year period. * denotes trend estimates that are within 15% of the trend across all sites.

	0.3	**0.4**	**0.5**	**0.6**	**0.7**	**1**
SMSHORE	68%*	69%*	66%*	68%*	66%*	65%
DABBLER	60%	49%*	51%*	49%*	51%*	46%
DIVER	70%*	72%*	71%*	70%*	71%*	71%
EAREDGR	26%	50%	64%*	80%*	83%*	74%
PHAL	-191%	-219%	-75%*	-84%	-84%	-68%
MEDSHORE	72%	62%*	59%*	54%*	53%*	56%
TERN	74%*	71%*	75%*	75%*	73%*	66%
GULL	59%	61%	63%	65%	26%	40%

Table 4. The number of years of data required to detect a given percent pulse decrease (-10, -15, -20, or -50% decline across one year) with $p \leq 0.05$ and power > 0.8 in counts of each waterbird guilds for multiple subsets of sites. The site subset represents the proportion of sites included in the subset. Refer to Table 1 and Figure 1 for the composition of each subset. * indicates the "NEPA/CEQA significance threshold" trend for the species when one is defined.

			Subset Level					
Guild	**Peak survey season**	**Percent decrease**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**1**
Dabbling ducks	Winter	-50%	3	3	3	3	3	3
		-20%	7	8	6	6	6	5
		-15%	13	13	11	10	11	9
		-10%	>15	>15	>15	>15	>15	>15
Diving ducks	Winter	-50%	3	3	3	3	3	3
		-20%*	3	3	3	3	3	3
		-15%	4	3	3	4	4	3
		-10%	7	4	5	5	5	5
Eared Grebe	Winter	-50%*	3	3	3	3	3	3
		-20%	10	4	4	3	3	3
		-15%	>15	5	5	4	4	3
		-10%	>15	11	10	6	6	4
Gull	Summer	-50%*	5	4	4	4	4	4
		-20%	>15	>15	>15	13	7	8
		-15%	>15	>15	>15	>15	12	13
		-10%	>15	>15	>15	>15	>15	>15
Medium Shorebird	Winter	-50%	3	3	3	3	3	3
		-20%	5	6	5	5	6	4

		-15%	8	9	8	8	9	6
		-10%	>15	>15	>15	>15	>15	12
Small Shorebird	Winter	-50%	4	4	4	3	3	3
		-20%*	>15	>15	>15	>15	>15	11
		-15%	>15	>15	>15	>15	>15	>15
		-10%	>15	>15	>15	>15	>15	>15
Phalarope	Fall	-50%*	9	9	9	10	10	9
		-20%	>15	>15	>15	>15	>15	>15
		-15%	>15	>15	>15	>15	>15	>15
		-10%	>15	>15	>15	>15	>15	>15
Tern	Summer	-50%	4	4	4	4	4	4
		-20%	10	9	9	11	11	7
		-15%	>15	>15	>15	>15	>15	11
		-10%	>15	>15	>15	>15	>15	>15

Table 5. The probability of detecting a trigger at a given percent pulse decrease (-10, -15, -20, or -50% decline across one year) in counts of each waterbird guild for multiple subsets of sites. A trigger is defined as two out of three consecutive years where the mean annual count is below the baseline. The subset level represents the proportion of sites included in the subset. Refer to Table 1 and Figure 1 for the composition of each subset. * indicates the "NEPA/CEQA significance threshold" for the species when one is defined.

Guild	**Peak survey season**	**Percent decrease**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**1**
Dabbling ducks	Winter	-50%	1	1	1	1	1	1
		-20%	0.87	0.86	0.9	0.91	0.9	0.94
		-15%	0.79	0.78	0.81	0.82	0.81	0.86
		-10%	0.69	0.68	0.72	0.74	0.71	0.74
Diving ducks	Winter	-50%	1	1	1	1	1	1
		-20%*	1	1	1	1	1	1
		-15%	0.97	1	1	0.99	0.99	0.99
		-10%	0.9	0.98	0.95	0.93	0.94	0.94
Eared Grebe	Winter	-50%*	1	1	1	1	1	1
		-20%	0.82	0.98	0.98	1	1	1
		-15%	0.76	0.93	0.94	0.98	0.99	1
		-10%	0.66	0.82	0.84	0.92	0.93	0.98
Gull	Summer	-50%*	1	1	1	1	1	1
		-20%	0.79	0.83	0.84	0.88	0.96	0.96
		-15%	0.72	0.73	0.76	0.79	0.90	0.88
		-10%	0.64	0.67	0.67	0.7	0.77	0.78
Medium Shorebird	Winter	-50%	1	1	1	1	1	1

		-20%	0.94	0.93	0.93	0.94	0.93	0.97
		-15%	0.87	0.85	0.85	0.86	0.84	0.91
		-10%	0.75	0.74	0.74	0.76	0.73	0.8
Small Shorebird	Winter	-50%	0.85	0.84	0.85	0.84	0.85	0.86
		-20%*	0.6	0.61	0.6	0.6	0.6	0.61
		-15%	0.59	0.58	0.57	0.57	0.58	0.56
		-10%	0.55	0.54	0.55	0.55	0.54	0.55
Phalarope	Fall	-50%*	0.99	0.99	0.99	1	1	1
		-20%	0.71	0.72	0.72	0.73	0.76	0.81
		-15%	0.65	0.66	0.65	0.66	0.7	0.74
		-10%	0.6	0.6	0.61	0.61	0.63	0.66
Tern	Summer	-50%	1	1	1	1	1	1
		-20%	0.92	0.94	0.93	0.91	0.91	0.97
		-15%	0.83	0.87	0.86	0.82	0.83	0.91
		-10%	0.74	0.76	0.75	0.72	0.73	0.80

Figures

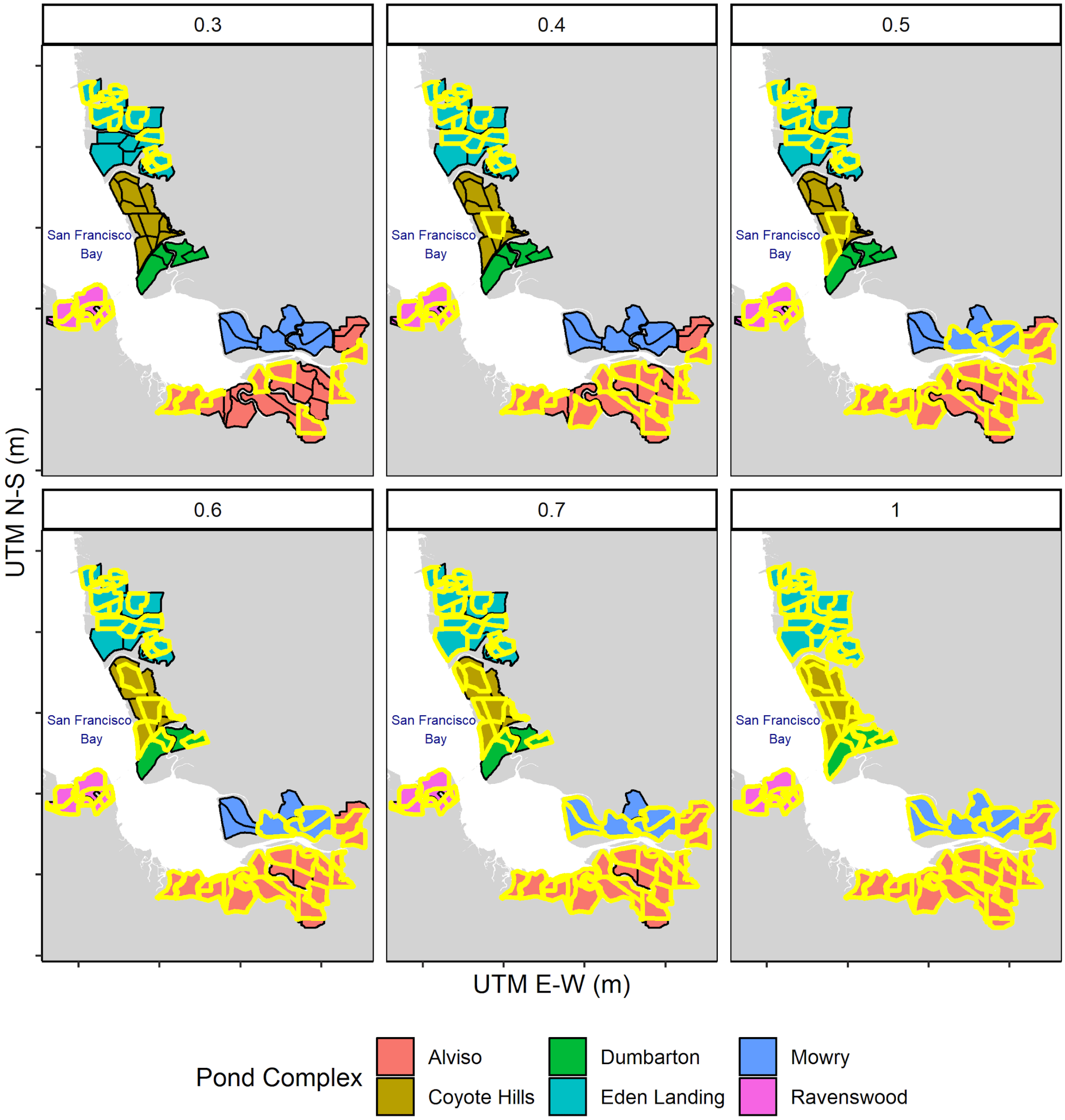


Figure 1. Maps of the project sites and salt production ponds included in each subset level. The number at the top of each panel indicates the proportion of sites represented in the subset. Sites included at each subset level are outlined in yellow.

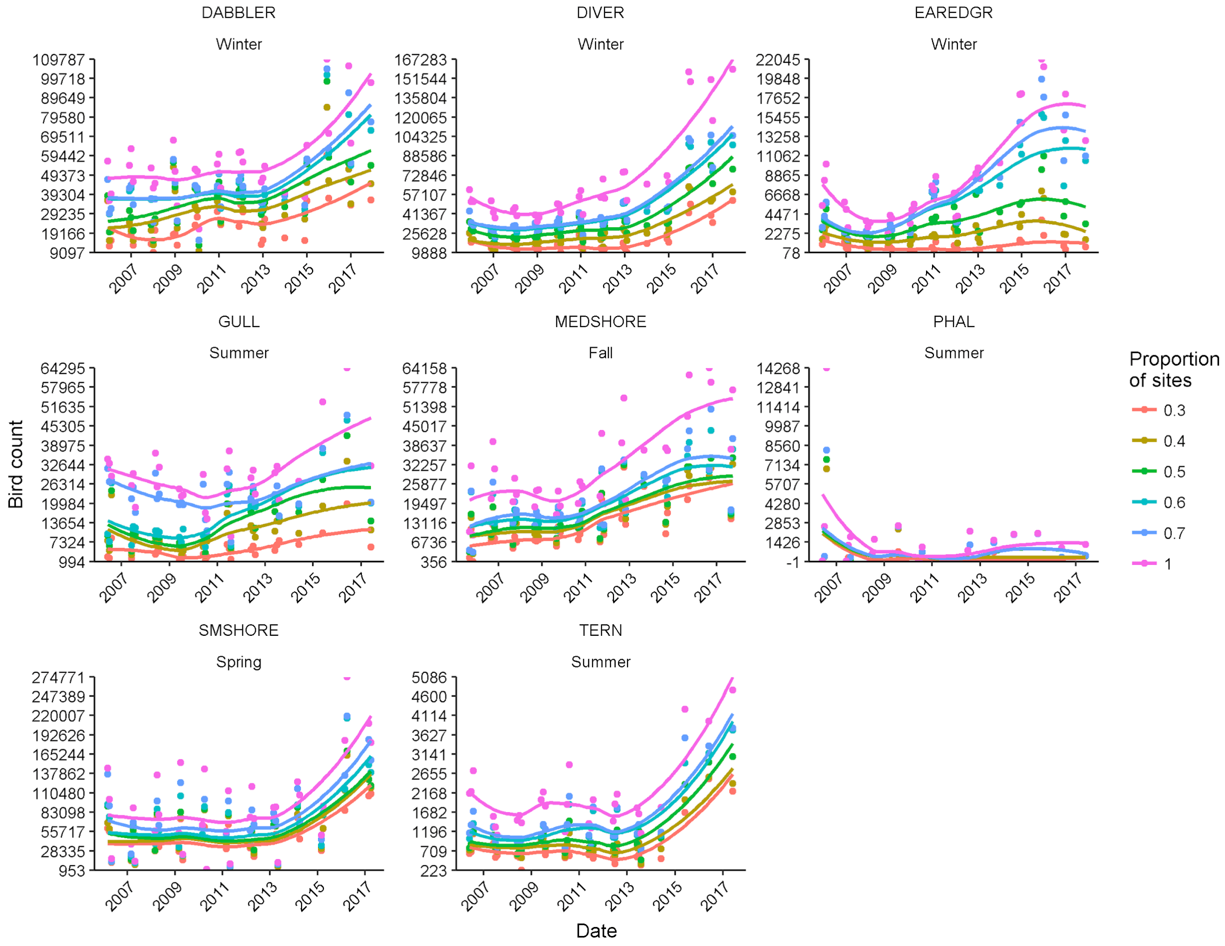


Figure 2. Temporal trends in winter waterbird counts for multiple subsets of sites. Waterbird counts are separated by guild. Color indicates the subset level, which is defined as the proportion of sites included in the subset. We fit lines to the point data using LOESS smoothing. Representative subsets should yield fit lines that are parallel to the line representing counts from all sites (pink).

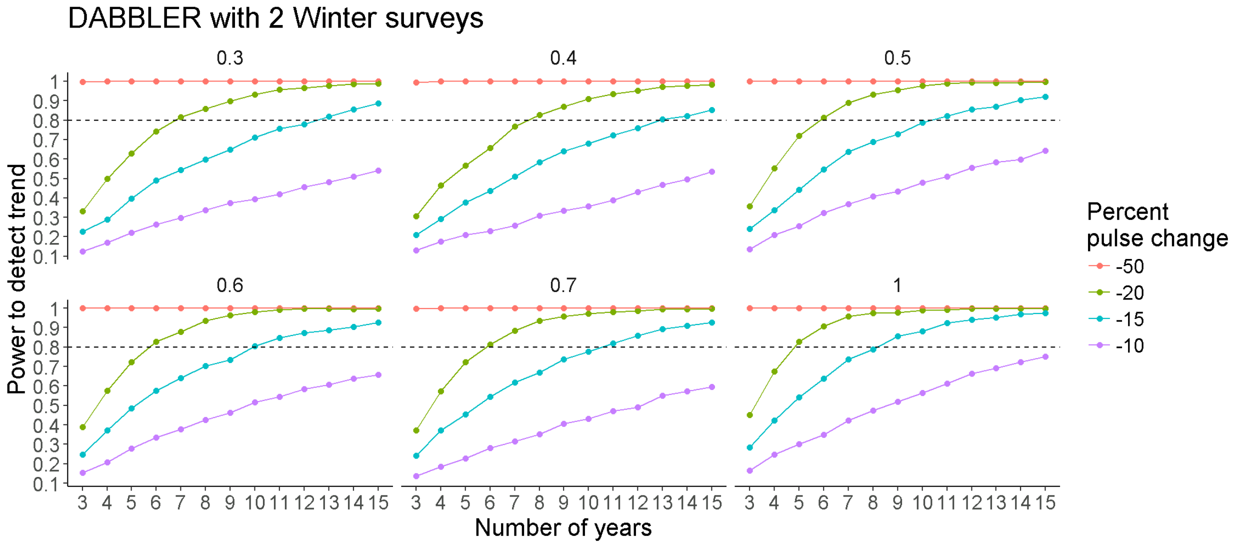


Figure 3. The power to detect a given percent pulse change in dabbling duck counts over time with two winter surveys using multiple site subsets. The dotted line denotes a threshold power of 0.8, which represents the point at which we have enough years of data to reach an 80% chance of detecting the trend.

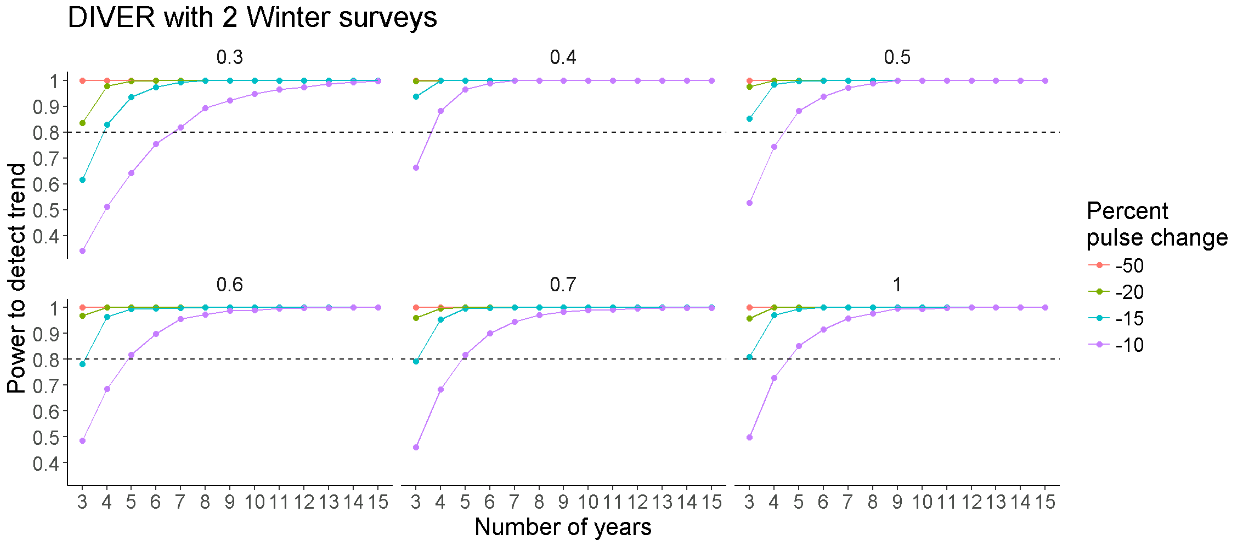


Figure 4. The power to detect a given percent pulse change in diving duck counts over time with two winter surveys using multiple site subsets. The dotted line denotes a threshold power of 0.8, which represents the point at which we have enough years of data to reach an 80% chance of detecting the trend.

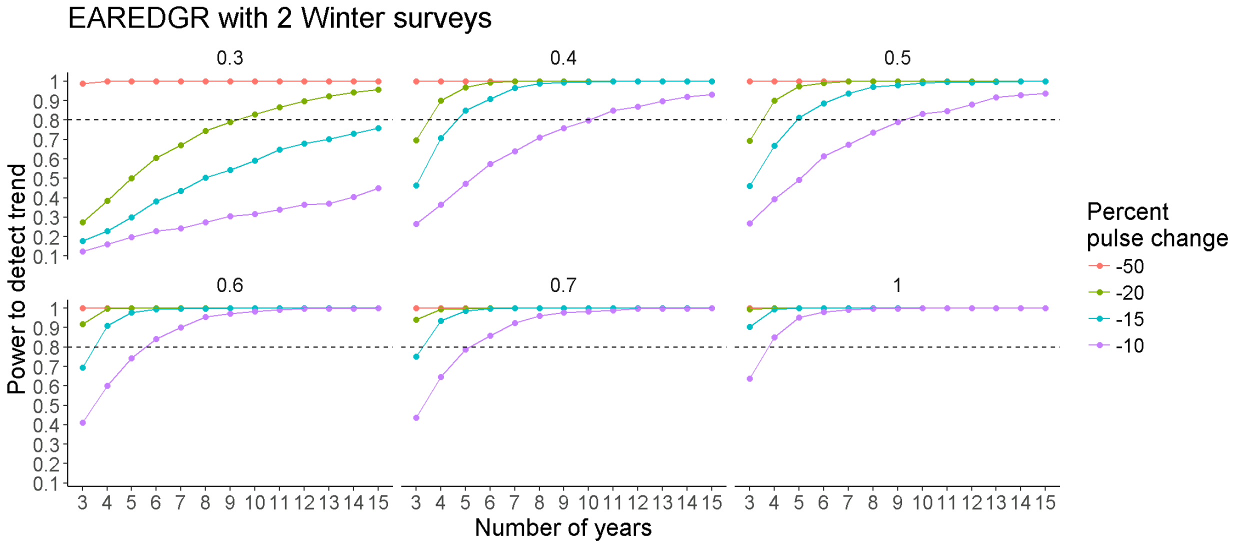


Figure 5. The power to detect a given percent pulse change in Eared Grebe counts over time with two winter surveys using multiple site subsets. The dotted line denotes a threshold power of 0.8, which represents the point at which we have enough years of data to reach an 80% chance of detecting the trend.

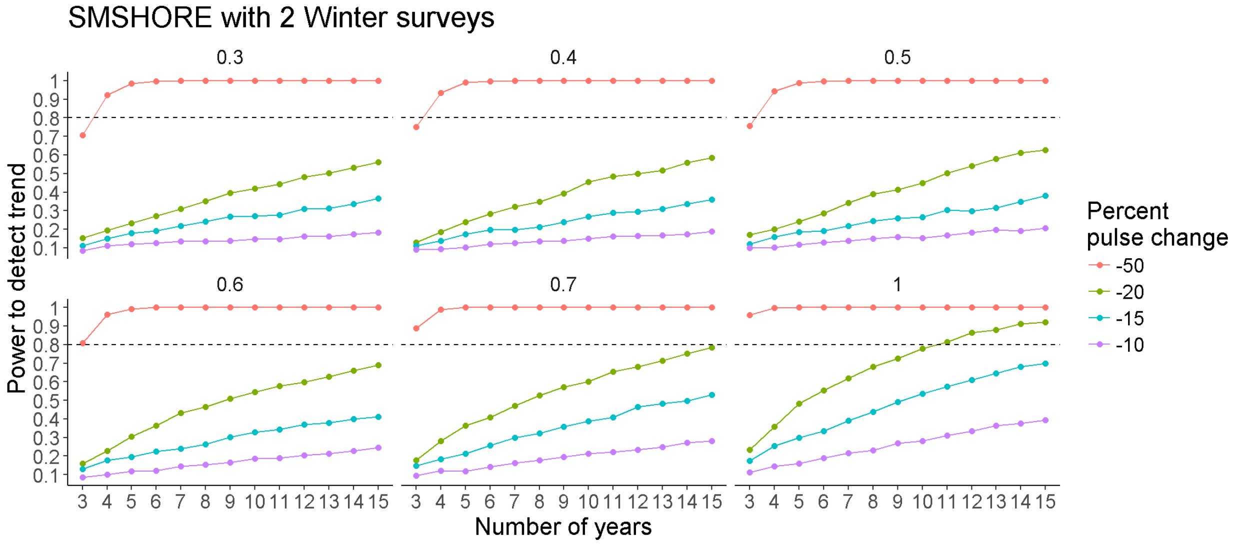


Figure 6. The power to detect a given percent pulse change in small shorebird counts over time with two winter surveys using multiple site subsets. The dotted line denotes a threshold power of 0.8, which represents the point at which we have enough years of data to reach an 80% chance of detecting the trend.

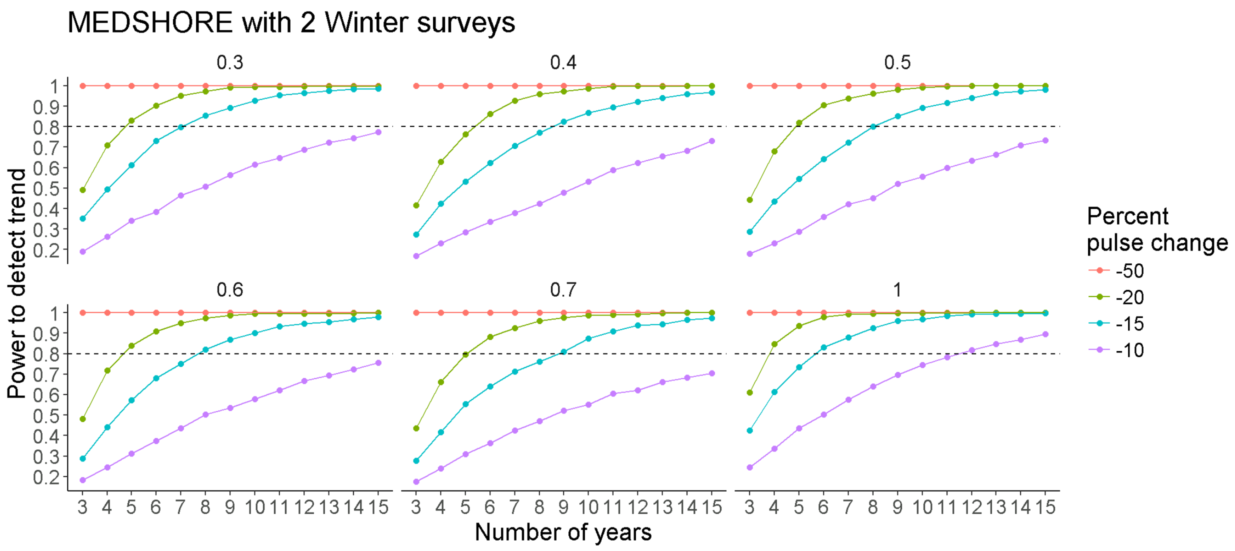


Figure 7. The power to detect a given percent pulse change in medium shorebird counts over time with two winter surveys using multiple site subsets. The dotted line denotes a threshold power of 0.8, which represents the point at which we have enough years of data to reach an 80% chance of detecting the trend.

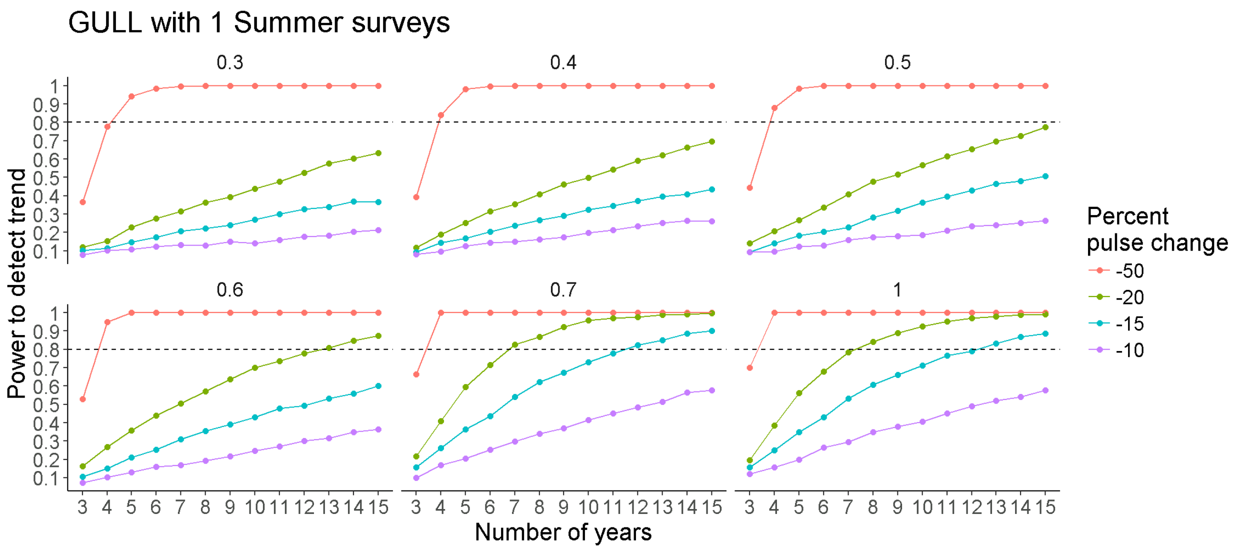


Figure 8. The power to detect a given percent pulse change in gull counts over time with one summer survey using multiple site subsets. The dotted line denotes a threshold power of 0.8, which represents the point at which we have enough years of data to reach an 80% chance of detecting the trend.

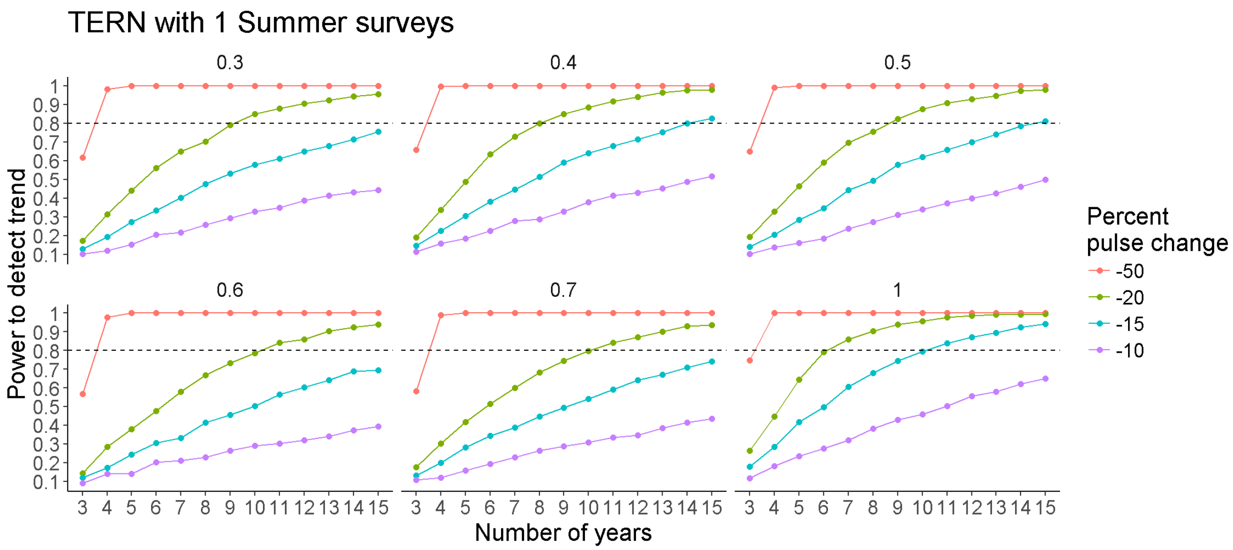


Figure 9. The power to detect a given percent pulse change in tern counts over time with one summer survey using multiple site subsets. The dotted line denotes a threshold power of 0.8, which represents the point at which we have enough years of data to reach an 80% chance of detecting the trend.

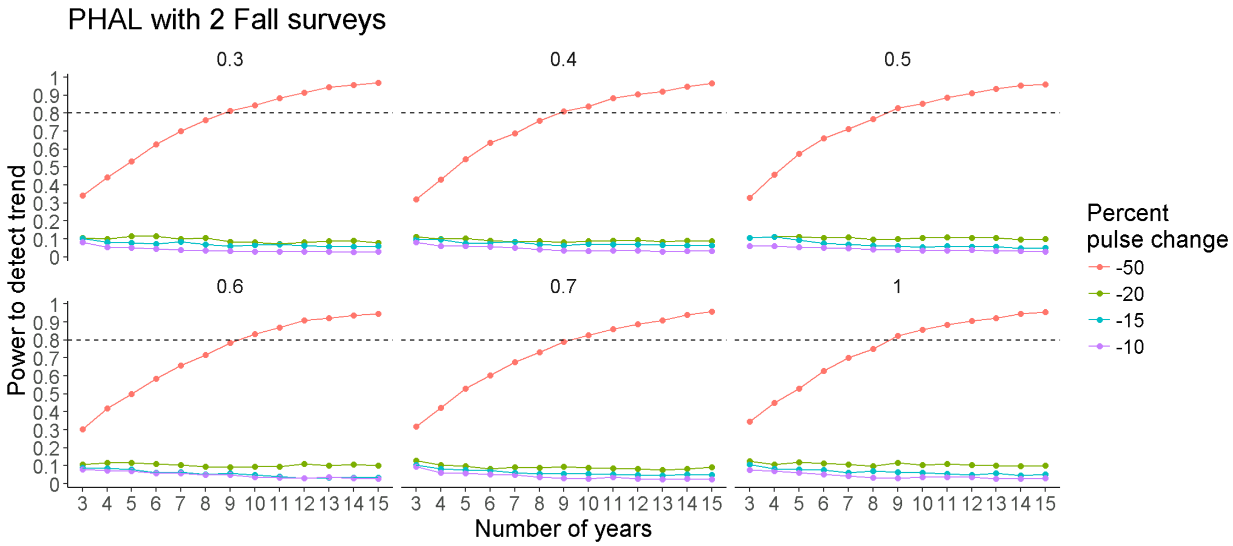


Figure 10. The power to detect a given percent pulse change in phalarope counts over time with two fall surveys using multiple site subsets. The dotted line denotes a threshold power of 0.8, which represents the point at which we have enough years of data to reach an 80% chance of detecting the trend.

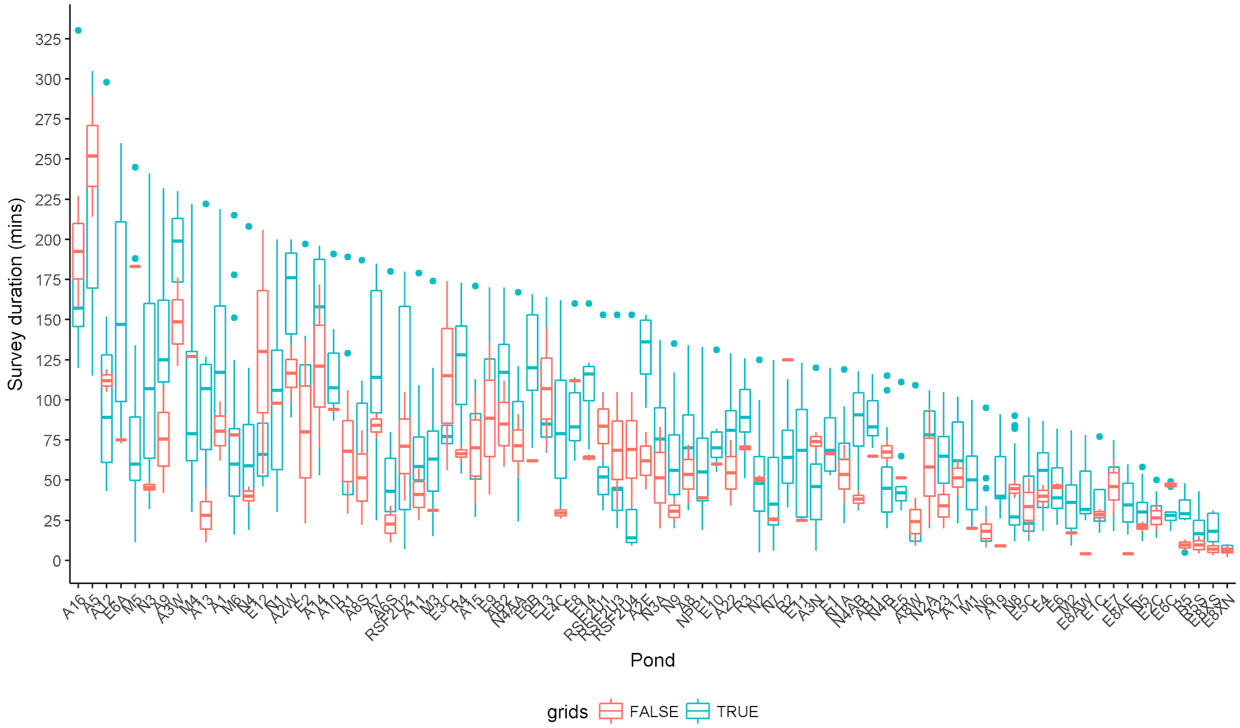
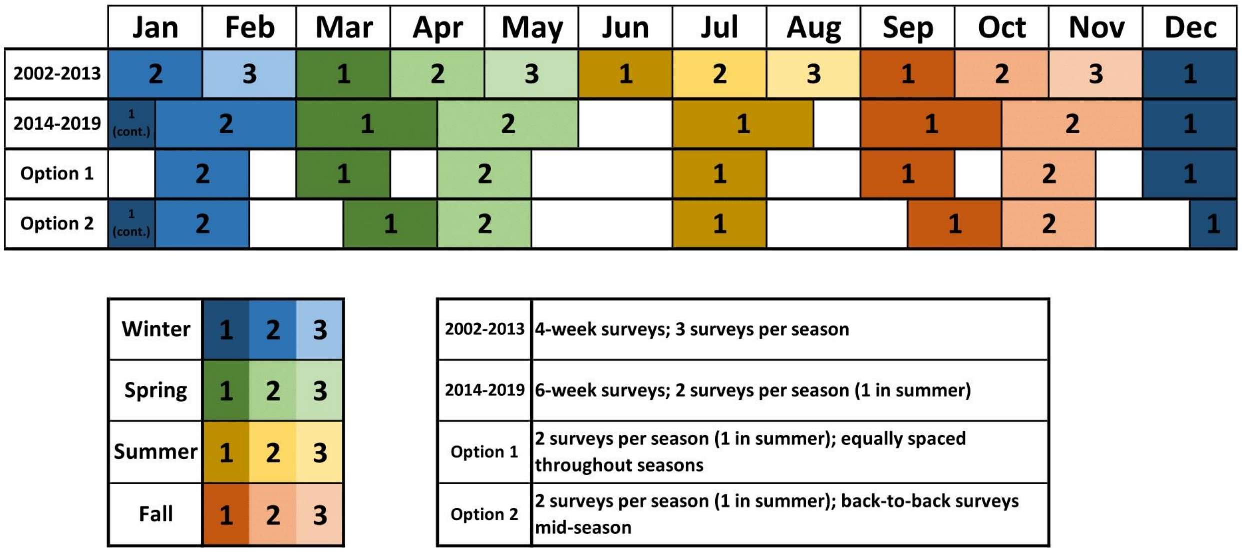


Figure 11. Survey duration at each site for surveys where field teams included (grids = True) or excluded (grids = False) the procedure of assigning birds to 250x250m grids. Birds were assigned to grids from 2003-2018. We have excluded the procedure of grid assignment since January 2019. Available data suggest that surveys are faster without gridding for the months of Jan-Mar.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002-2013	2	3	1	2	3	1	2	3	1	2	3	1
2014-2019	1 (cont.) 2		1	2			1		1	2		1
Option 1	2		1	2			1		1	2		1
Option 2	1 (cont.) 2		1	2			1		1	2		1

Winter	1	2	3
Spring	1	2	3
Summer	1	2	3
Fall	1	2	3

2002-2013	4-week surveys; 3 surveys per season
2014-2019	6-week surveys; 2 surveys per season (1 in summer)
Option 1	2 surveys per season (1 in summer); equally spaced throughout seasons
Option 2	2 surveys per season (1 in summer); back-to-back surveys mid-season

Figure 12. Past and proposed survey schedules. Color indicates season (blue = winter; green = spring; yellow = summer; orange = fall), and the numbers indicate the first, second, or third survey of the season. Survey durations for Options 1 and 2 are approximate and will depend on the number of sites visited.

Appendix 1

Table of targets, thresholds, and triggers for each waterbird species and guild of interest for monitoring in the South Bay Salt Pond Restoration Project area and South San Francisco Bay. Adapted from the SBSPRP Adaptive Management Plan: Adaptive Management Summary Table (Appendix 3) and restoration targets set by USFWS as part of the Recovery Plan for Tidal Marsh Ecosystems of Northern and Central California (2013). Originally compiled in Tarjan & Heyse (2018).

Species/ Guild	NEPA/CEQA Baseline (Target)	SBSPRP Adaptive Management Trigger	NEPA/CEQA Significance Threshold	DESFBNWR Targets
Ruddy Duck (RUDU)	12602 (2005-2007 mid-winter survey mean); range: 10722 (2007)-15575 (2005)	two years of decline in numbers below baseline conditions in South Bay as a whole out of any consecutive three years	decline in South Bay numbers of 15 percent as a result of the SBSP Restoration Project	
Diving Ducks (excludes RUDU)	27043 (mid-winter survey average 2005-2007); range: 19521 (2007)-40326 (2005)	two years of decline in numbers below baseline conditions in South Bay as a whole out of any consecutive three years	decline in South Bay numbers of 20 percent as a result of the SBSP Restoration Project	
Small Shorebirds - Winter/Fall	60623 (fall; 2005-2007 USGS/SFBBO mean); range 130662 (2005) to 241546 (2006)	two out of three consecutive years when the South Bay shorebird abundances fall below the baseline in any given season	decline in South Bay numbers of 20 percent as a result of the SBSP Restoration Project	

Small Shorebirds - Spring	73728 (2005-2007 USGS/SFBBO mean); range 140618 (2007) to 269331 (2006)	two out of three consecutive years when the South Bay shorebird abundances fall below the baseline in any given season	decline in South Bay numbers of 20 percent as a result of the SBSP Restoration Project	
Eared Grebe (EAGR)	5640 (winter; 2005-2007 USGS/SFBBO mean); range: 3826 (2007) to 8036 (2006)	AMP = three consecutive years more than 25% below NEPA/CEQA baseline, or any single year more than 50% below NEPA/CEQA baseline	decline in South Bay numbers of 50 percent as a result of the SBSP Restoration Project	
Phalaropes	3225 (summer; 2005-2007 USGS/SFBBO mean); range: 1013 (2007) to 5623 (2006)	AMP = three consecutive years more than 25% below NEPA/CEQA baseline, or any single year more than 50% below NEPA/CEQA baseline	decline in South Bay numbers of 50 percent as a result of the SBSP Restoration Project	
Bonaparte’s Gull (BOGU)	1270 (winter; 2005-2007 USGS/SFBBO mean); range: 896 (2005) to 1917 (2006)	AMP = two out of three consecutive years more than 25% below NEPA/CEQA baseline, or any single year more than 50% below NEPA/CEQA baseline	decline in South Bay numbers of 50 percent as a result of the SBSP Restoration Project	
Dabbling Ducks	n/a	n/a	n/a	Over the next 5 years (FY 2018-2022), wintering waterfowl species richness and abundance on the Don

				Edwards is maintained relative to the 2012 (Richmond et. al 2014) baseline (grebes=5,343, waterfowl=80,793,14 species waterfowl).
Medium Shorebirds	n/a	n/a	n/a	Over the next 5 years (FY 2018-2022), wintering shorebird species richness and abundance is increased at Don Edwards SF Bay NWR from fair to good relative to the 2015 baseline (56,147, 22 spp).
Least Tern (LETE) post-breeding dispersants in South Bay	63 (2005-2007 mean); range: 36 (2007)-112 (2006)	decline in total number of birds using South Bay as post-breeding foraging area in any two out of three consecutive years	decrease in foraging habitat or prey availability for post-breeding dispersants in the South Bay, leading to a decline in the Bay Area breeding population	

Appendix 2

Species assignments to foraging guilds. Guilds included dabblers, divers, Eared Grebes, fisheaters, gulls, herons, medium shorebirds, phalaropes, small shorebirds, and terns.

Common Name	Scientific Name	Guild
American Coot	*Fulica americana*	Dabbler
American Green-winged Teal	*Anas crecca*	Dabbler
American Wigeon	*Anas americana*	Dabbler
Blue-winged Teal	*Anas discors*	Dabbler
Cinnamon Teal	*Anas cyanoptera*	Dabbler
Common Moorhen	*Gallinula chloropus*	Dabbler
Domestic Mallard	*Anas spp*	Dabbler
Eurasian Wigeon	*Anas penelope*	Dabbler
Gadwall	*Anas strepera*	Dabbler
Green-winged Teal	*Anas crecca*	Dabbler
Long-tailed Duck	*Clangula hyemalis*	Dabbler
Mallard	*Anas platyrhynchos*	Dabbler
Northern Pintail	*Anas acuta*	Dabbler
Northern Shoveler	*Anas clypeata*	Dabbler
Unidentified dabbling duck	*dabbling duck spp.*	Dabbler
Barrow's Goldeneye	*Bucephala islandica*	Diver
Bufflehead	*Bucephala albeola*	Diver
Canvasback	*Aythya valisineria*	Diver
Common Goldeneye	*Bucephala clangula*	Diver
Greater Scaup	*Aythya marila*	Diver

Lesser Scaup	*Aythya affinis*	Diver
Redhead	*Aythya americana*	Diver
Ring-necked Duck	*Aythya collaris*	Diver
Ruddy Duck	*Oxyura jamaicensis*	Diver
Surf Scoter	*Melanitta perspicillata*	Diver
Tufted Duck	*Aythya fuligula*	Diver
Unidentified diving duck	*diving duck spp.*	Diver
Unidentified scaup	*Aythya spp.*	Diver
White-winged scoter	*Melanitta fusca*	Diver
Eared Grebe	*Podiceps nigricollis*	Eared Grebe
American White Pelican	*Pelecanus erythrorhynchos*	Fisheater
Belted Kingfisher	*Ceryle alcyon*	Fisheater
Black Skimmer	*Rhynchops niger*	Fisheater
Brown Booby	*Sula leucogaster*	Fisheater
Brown Pelican	*Pelecanus occidentalis*	Fisheater
Clark's Grebe	*Aechmophorus clarkii*	Fisheater
Common Loon	*Gavia immer*	Fisheater
Common Merganser	*Mergus merganser*	Fisheater
Double-crested Cormorant	*Phalacrocorax auritus*	Fisheater
Hooded Merganser	*Lophodytes cucullatus*	Fisheater
Horned Grebe	*Podiceps auritus*	Fisheater
Long-tailed Jaeger	*Stercorarius longicaudus*	Fisheater
Pacific Loon	*Gavia pacifica*	Fisheater
Pelagic Cormorant	*Phalacrocorax pelagicus*	Fisheater

Pied-billed Grebe	*Podilymbus podiceps*	Fisheater
Red-breasted Merganser	*Mergus serrator*	Fisheater
Red-necked Grebe	*Podiceps grisegena*	Fisheater
Red-throated Loon	*Gavia stellata*	Fisheater
Unidentified Cormorant	*Phalacrocorax spp*	Fisheater
Unidentified grebe		Fisheater
Western Grebe	*Aechmophorus occidentalis*	Fisheater
Western Grebe or Clark's Grebe	*Aechmophorus spp.*	Fisheater
Bonaparte's Gull	*Larus philadelphia*	Gull
California Gull	*Larus californicus*	Gull
California Gull or Ring-billed Gull	*Larus spp.*	Gull
Franklin's Gull	*Larus pipixcan*	Gull
Glaucous Gull	*Larus hyperboreus*	Gull
Glaucous-winged Gull	*Larus glaucescens*	Gull
Herring Gull	*Larus argentatus*	Gull
Mew Gull	*Larus canus*	Gull
Ring-billed Gull	*Larus delawarensis*	Gull
Sabine's Gull	*Xena sabini*	Gull
Slaty-backed Gull	*Larus schistisagus*	Gull
Thayer's Gull	*Larus thayeri*	Gull
Unidentified gull	*Larus spp.*	Gull
Western Gull	*Larus occidentalis*	Gull
American Bittern	*Botarus lentiginosus*	Heron
Black-crowned Night-Heron	*Nycticorax nycticorax*	Heron

Cattle Egret	*Bubulcus ibis*	Heron
Great Blue Heron	*Ardea herodias*	Heron
Great Egret	*Ardea alba*	Heron
Green Heron	*Butorides virescens*	Heron
Little Blue Heron	*Egretta caerulea*	Heron
Snowy Egret	*Egretta thula*	Heron
White-faced Ibis	*Plegadis chihi*	Heron
American Avocet	*Recurvirostra americana*	Medium shorebird
Black Oystercatcher	*Haematopus bachmani*	Medium shorebird
Black Turnstone	*Arenaria melanocephala*	Medium shorebird
Black-bellied Plover	*Pluvialis squatarola*	Medium shorebird
Black-necked Stilt	*Himantopus mexicanus*	Medium shorebird
Common Snipe	*Gallinago gallinago*	Medium shorebird
Golden Plover	*Pluvialis spp.*	Medium shorebird
Greater Yellowlegs	*Tringa melanoleuca*	Medium shorebird
Killdeer	*Charadrius vociferus*	Medium shorebird
Lesser Yellowlegs	*Tringa flavipes*	Medium shorebird
Long-billed Curlew	*Numenius americanus*	Medium shorebird
Marbled Godwit	*Limosa fedoa*	Medium shorebird
Pacific Golden-Plover	*Pluvialis fulva*	Medium shorebird
Red Knot	*Calidris canutus*	Medium shorebird
Ruddy Turnstone	*Arenaria interpres*	Medium shorebird
Ruff	*Philomachus pugnax*	Medium shorebird
Spotted Redshank	*Tringa erythropus*	Medium shorebird

Stilt Sandpiper	*Calidris himantopus*	Medium shorebird
Surfbird	*Aphriza virgata*	Medium shorebird
Unidentifed yellowlegs	*Tringa spp.*	Medium shorebird
Unidentified medium shorebird	*med shorebird spp.*	Medium shorebird
Wandering Tattler	*Tringa incana*	Medium shorebird
Whimbrel	*Numenius phaeopus*	Medium shorebird
Willet	*Catoptrophorus semipalmatus*	Medium shorebird
Red Phalarope	*Phalaropus fulicaria*	Phalarope
Red-necked Phalarope	*Phalaropus lobatus*	Phalarope
Unidentified phalarope	*Phalaropus spp.*	Phalarope
Wilson's Phalarope	*Phalaropus tricolor*	Phalarope
Baird's Sandpiper	*Calidris bairdii*	Small shorebird
Dunlin	*Calidris alpina*	Small shorebird
Least Sandpiper	*Calidris minutilla*	Small shorebird
Long-billed Dowitcher	*Limnodromus scolopaceus*	Small shorebird
Pectoral Sandpiper	*Calidris melanotos*	Small shorebird
Sanderling	*Calidris alba*	Small shorebird
Semipalmated Plover	*Charadrius semipalmatus*	Small shorebird
Semipalmated Sandpiper	*Calidris pusilla*	Small shorebird
Short-billed Dowitcher	*Limnodromus griseus*	Small shorebird
Snowy Plover	*Charadrius alexandrinus*	Small shorebird
Spotted Sandpiper	*Actitis macularia*	Small shorebird
Unidentified Dowitcher	*Limnodromus spp.*	Small shorebird
Unidentified peeps	*Calidris spp.*	Small shorebird

Western Sandpiper	*Calidris mauri*	Small shorebird
Western Sandpiper or Dunlin	*Calidris spp.*	Small shorebird
Western Sandpiper or Least Sandpiper	*Calidris spp.*	Small shorebird
Arctic Tern	*Sterna paradisaea*	Tern
Black Tern	*Chlidonias niger*	Tern
Caspian Tern	*Sterna caspia*	Tern
Common Tern	*Sterna hirundo*	Tern
Elegant Tern	*Sterna elegans*	Tern
Forster's Tern	*Sterna forsteri*	Tern
Least Tern	*Sterna antillarum browni*	Tern
Unidentified tern	*Sterna spp.*	Tern

Appendix 3

Sites with their associated complex, status, and timeframe. Site category has the following definitions: Breached = levees at the site are breached to open the site to tidal action; Managed = water levels are managed for wildlife; Reconfigured = site is enhanced for wildlife (e.g., islands are constructed); Salt pond = a salt production pond. Category status indicates if the category was obtained in the past or is planned for the future, with the following definitions: Initial Stewardship Plan = category was reached during the Initial Stewardship Plan of the SBSPRP; Phase 1 = category was reached during Phase 1 of the SBSPRP; Phase 2 = category is planned for Phase 2 of the SBSPRP; Indefinite = category is current and may remain the same indefinitely.

Site Name	Complex	Category	Category status
A1	Alviso	Breached	Phase 2
A10	Alviso	Managed	Indefinite
A11	Alviso	Managed	Indefinite
A12	Alviso	Managed	Indefinite
A13	Alviso	Managed	Indefinite
A14	Alviso	Managed	Indefinite
A15	Alviso	Managed	Indefinite
A16	Alviso	Reconfigured	Phase 1
A17	Alviso	Breached	Phase 1
A19	Alviso	Breached	Initial Stewardship Plan
A20	Alviso	Breached	Initial Stewardship Plan
A21	Alviso	Breached	Initial Stewardship Plan
A22	Alviso	Managed	Indefinite
A23	Alviso	Managed	Indefinite
A2E	Alviso	Managed	Indefinite
A2W	Alviso	Breached	Phase 2
A3N	Alviso	Managed	Indefinite
A3W	Alviso	Managed	Indefinite
A5	Alviso	Breached	Phase 1
A6	Alviso	Breached	Phase 1
A7	Alviso	Breached	Phase 1
A8	Alviso	Breached	Phase 1

A8S	Alviso	Breached	Phase 1
A9	Alviso	Managed	Indefinite
AB1	Alviso	Managed	Indefinite
AB2	Alviso	Managed	Indefinite
N1A	Coyote Hills	Salt pond	Indefinite
N2A	Coyote Hills	Salt pond	Indefinite
N3A	Coyote Hills	Salt pond	Indefinite
N4	Coyote Hills	Salt pond	Indefinite
N4AA	Coyote Hills	Salt pond	Indefinite
N4AB	Coyote Hills	Salt pond	Indefinite
N4B	Coyote Hills	Salt pond	Indefinite
N5	Coyote Hills	Salt pond	Indefinite
N6	Coyote Hills	Salt pond	Indefinite
N7	Coyote Hills	Salt pond	Indefinite
N8	Coyote Hills	Salt pond	Indefinite
N9	Coyote Hills	Salt pond	Indefinite
N1	Dumbarton	Salt pond	Indefinite
N2	Dumbarton	Salt pond	Indefinite
N3	Dumbarton	Salt pond	Indefinite
NPP1	Dumbarton	Salt pond	Indefinite
E1	Eden Landing	Breached	Phase 2
E10	Eden Landing	Managed	Indefinite
E10X	Eden Landing	Breached	breached
E11	Eden Landing	Managed	Indefinite
E12	Eden Landing	Reconfigured	Phase 1
E13	Eden Landing	Reconfigured	Phase 1
E14	Eden Landing	Managed	Indefinite
E14B	Eden Landing	Managed	Indefinite
E15B	Eden Landing	Managed	Indefinite
E16B	Eden Landing	Managed	Indefinite
E1C	Eden Landing	Reconfigured	Phase 2
E2	Eden Landing	Breached	Phase 2
E2C	Eden Landing	Breached	Phase 2

E3C	Eden Landing	Managed	Indefinite
E4	Eden Landing	Breached	Phase 2
E4C	Eden Landing	Breached	Phase 2
E5	Eden Landing	Reconfigured	Phase 2
E5C	Eden Landing	Breached	Phase 2
E6	Eden Landing	Reconfigured	Phase 2
E6A	Eden Landing	Managed	Indefinite
E6B	Eden Landing	Managed	Indefinite
E6C	Eden Landing	Reconfigured	Phase 2
E7	Eden Landing	Breached	Phase 2
E8	Eden Landing	Managed	Indefinite
E8A	Eden Landing	Breached	Phase 1
E8X	Eden Landing	Managed	Indefinite
E9	Eden Landing	Breached	Phase 1
M1	Mowry	Salt pond	Indefinite
M2	Mowry	Salt pond	Indefinite
M3	Mowry	Salt pond	Indefinite
M4	Mowry	Salt pond	Indefinite
M5	Mowry	Salt pond	Indefinite
M6	Mowry	Salt pond	Indefinite
R1	Ravenswood	Managed	Indefinite
R2	Ravenswood	Managed	Indefinite
R3	Ravenswood	Reconfigured	Phase 2
R4	Ravenswood	Breached	Phase 2
R5	Ravenswood	Reconfigured	Phase 2
RS5	Ravenswood	Reconfigured	Phase 2
RSF2U1	Ravenswood	Reconfigured	Phase 1
RSF2U2	Ravenswood	Reconfigured	Phase 1
RSF2U3	Ravenswood	Reconfigured	Phase 1
RSF2U4	Ravenswood	Reconfigured	Phase 1