A MONITORING PLAN FOR WINTERING SHOREBIRDS IN SAN FRANCISCO BAY

v.1.0

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Revision History Log

Although consistency of sampling design and survey methodology is an important component to any long-term monitoring program, this plan should be modified as needed to meet the monitoring objectives. All changes to the monitoring plan should be detailed in this "Revision History Log".

Prev. Version #	Revision Date	Author(s) (of changes)	Changes Made	Reason for Change	New Version #
1.0					

EXECUTIVE SUMMARY

The San Francisco Bay Estuary (SF Bay) provides habitat for more migrating and wintering shorebirds than any other coastal wetland on the U.S. Pacific coast south of Alaska and has been designated as a site of hemispheric importance by the Western Hemisphere Shorebird Reserve Network. Currently there is no annual effort to monitor shorebirds throughout SF Bay despite ongoing habitat changes in the estuary. Designing an efficient and effective annual shorebird monitoring program for SF Bay is an essential step towards the long-term conservation and management of shorebirds in the California Landscape Conservation Cooperative (CA LCC) and the Western Hemisphere. Based on simulation studies using historic monitoring data from SF Bay, we propose a monitoring plan with a standardized survey protocol that will provide robust estimates of spatial and temporal changes in shorebird populations in SF Bay. We also present an online data entry portal developed for the California Avian Data Center (CADC) to capture data and provide general summaries from annual monitoring data. We recommend an annual survey of a stratified random sample of locations to be conducted during high tide on a single day. We provide the analytical framework for population and trend estimates to be made annually as new data come in through the online data portal in CADC. Overall, the new survey design is a 66% reduction in effort from previous comprehensive surveys yet will achieve accurate estimates of trend. We also recommend that a comprehensive survey be completed 2 consecutive years every 10 years to determine if the distribution of shorebirds or shorebird habitat has shifted significantly within SF Bay. Large distributional changes could bias inference about trend and habitat associations. We present approaches to modifying the sampling design and analytical approaches to accommodate observed changes. Lastly, we recommend a series of needed pilot studies including evaluating methods for estimating error rates in shorebird counts and determining the appropriate scale to measure habitat and the need for habitat tracking. The new monitoring strategy was launched on November 19, 2010, with more than 100 citizen scientists and professional biologists conducting surveys

and entering their data through the new online data portal. We will use the first 2-years of data from this renewed effort to critically evaluate this monitoring plan.

Background

The San Francisco Bay Estuary (SF Bay) provides habitat for more migrating and wintering shorebirds than any other coastal wetland on the Pacific coast of the United States south of Alaska (Page et al. 1999) and has been designated as a site of hemispheric importance by the Western Hemisphere Shorebird Reserve Network (www.whsrn.org). Over 1 million shorebirds use SF Bay annually, with over 300,000, presenting more than 30 species occurring during the winter months (November – March). There is a need to better understand spatial and temporal trends in shorebird populations in SF Bay to inform local habitat management and conservation actions, as well to contribute to a broader understanding of shorebirds in the California Landscape Conservation Cooperative (CA LCC; www.calcc.org) and the broader Pacific Flyway. Currently there is no annual SF Bay-wide effort to monitor shorebirds despite ongoing habitat changes. Designing an efficient and robust annual shorebird monitoring program for SF Bay is an essential step towards the long-term conservation and management of shorebirds in the Western Hemisphere.

Previous monitoring of shorebirds in SF Bay primarily focused on individual sites (e.g. Recher 1966, Holoway 1990), although some larger-scale efforts evaluated shorebird populations throughout the bay (Bollman et al. 1970, Stenzel et al. 2002, Wood et al. 2010). Despite the value of these surveys to inform our understanding of shorebird ecology and status within SF Bay, they were too short in temporal duration or spatial extent to provide a rigorous assessment of spatial and temporal trends. A paired set of comprehensive surveys (1990 – 1992 [Stenzel et al. 2002], 2006 – 2008 [Wood et al. 2010]) provide very valuable baseline data on the total abundance of shorebirds in SF Bay in the early winter (November; Wood et al. 2010). However, annual surveys of this effort level are not sustainable.

A recent simulation study using the data from the comprehensive SF Bay surveys (roost counts in November; 1990 – 1992 and 2006 – 2008) suggest that a 75% reduction in survey effort using an appropriately weighted stratified sampling design could provide estimates of population change within

20% of the true change (Wood et al. 2010; Appendix I). This reduced effort would also be able to detect 50% population declines over 20-years with high power (>80%) for nearly all shorebird species. Based on these results, we propose a statistically robust, logistically feasible, long-term monitoring program for wintering shorebirds in SF Bay to track spatial and temporal population trends resulting from changing climate and habitat conditions. Specifically, we (1) recommend a sampling design and survey protocol, (2) provide the data storage and analytical framework for population and trend estimates to be made annually as new data come in through the online data portal in CADC, and (3) recommend a series of needed pilot studies including evaluating methods for estimating error rates in shorebird counts and determining the appropriate scale to measure habitat and the need for habitat tracking.

POPULATIONS BEING MONITORED

Although shorebirds occur in SF Bay at all times of their annual cycle (breeding, migration, and wintering), this monitoring plan focuses on the population of wintering shorebirds for several reasons. First, winter (November – April) and migration (July – November, April) are the periods with the most abundant numbers of shorebirds in SF Bay. Breeding birds are typically in low abundance and consist of few species. Second, although migration surveys are common in regions with no wintering birds, they require multiple surveys each year due to the variability in the timing of migration and pulses in shorebirds. This high level of variability makes estimates of trends and habitat associations very uncertain, furthermore SF Bay provides critical habitat for shorebirds. Lastly, winter is the longest time of consistent use by shorebirds in SF Bay and thus conservation actions may be most effective. Subsequently, this monitoring plan targets all regularly occurring shorebird species (Order: Charadriformes; Familes: Charadridae, Scolopacidae, Recurvirostridae, Haematopodidae) that winter in SF Bay. Thirty species of shorebirds were identified in previous comprehensive surveys of SF Bay (Table 1); 1990 – 1992 (Stenzel et al. 2001) and 2006 – 2008 (Wood et al. 2010).

Monitoring Objectives

1. Estimate trends in wintering shorebird populations so that a 50% decline over 20 years can be detected with 80% power at the alpha = 0.05 significance level.
2. Estimate the winter population size of shorebirds using SF Bay with a coefficient of variation (CV) < 20%.
3. Identify changes in the distribution of shorebird species within key areas of SF Bay.
4. Quantify habitat associations of roosting shorebirds within SF Bay.

Study Area

We divided SF Bay into 3 strata that represent distinct regions - North, Central, and South Bay (Fig. 1a). The key habitats for wintering shorebirds included as part of this monitoring plan include 28,000 acres of tidal mudflats and 34,500 acres salt ponds (Goals Project 1999). The relative abundance of habitats defined within our 3 strata is shown in Figure 2. This monitoring plan does not include the Suisun Marsh which will be included as part of a monitoring plan for the Central Valley.

The North Bay (San Pablo Bay) stratum included the region between the Carquinez Bridge and points San Pedro and San Pablo (Fig. 1a). The north and west shores of the North Bay are characterized by extensive tidal flats, salt marshes, hay fields, and other undeveloped diked baylands. The eastern shore of the North Bay stratum contains some residential and industrial development, and less extensive tidal marshes and tidal mud flats than the western shore.

The Central Bay includes areas between points San Pedro and San Pablo on the north and the San Mateo Bridge in the south. Point San Pablo to the Bay Bridge on the east side of SF Bay is heavily developed with high-density residential areas, marinas, and other commercial enterprises. Extensive rip-rap creates a rocky shoreline with small amounts of interspersed tidal marsh and mudflats. The area from the Bay Bridge to San Leandro is heavily urbanized and includes the Oakland International Airport, Oakland harbors, and other residential and industrial development. The majority of the shoreline is rocky with some sandy beaches and tidal marshes. San Leandro to the San Mateo Bridge includes the Hayward shoreline and consists of tidal marshes, wastewater treatment ponds, and managed wetlands located behind a rip-rapped shoreline. The western shore of the Central Bay, from the San Mateo Bridge to the Bay Bridge, is heavily residential and commercial. The shoreline is mostly rocky with some fringing marshes. From the Bay Bridge to Point San Pedro the shoreline is the heavily urbanized city of San Francisco waterfront and the less developed shoreline of west Marin County. The hardened shorelines in the south are composed of rock, sea walls, and piers.

The South Bay extends from the San Mateo Bridge south. From the San Mateo Bridge to the Dumbarton Bridge on the eastern shore are large tracts of active and derelict salt ponds, some of which are managed for wildlife. The ponds are bordered by large tracts of tidal marsh or levees with fringing marshes and extensive tidal flats at low tide. The South Bay, south of the Dumbarton Bridge, is similar to north of the bridge but has more residential development than on the western shore. On the western shoreline, from the Dumbarton Bridge to the San Mateo Bridge, the South Bay is characterized by large tracts of tidal marsh and extensive areas of salt ponds that are in disuse or are managed for wildlife. For a more detailed description of current and historic habitat in SF Bay, please refer to Goals Project (1999).

SAMPLING DESIGN

Long-term monitoring programs for shorebirds in large estuaries require sampling designs that are logistically feasible, and that minimize bias and variance in estimates of population size or population change (Braun 2005). Although a complete enumeration of all birds from a region (i.e. "comprehensive count") or population of interest is desirable, such comprehensive data are often impractical to collect. Alternatively, both spatial and temporal sampling can be used to estimate the population within a selected region over a period of time.

From historic surveys of SF Bay, we defined 340 sampling units (Fig. 1a), which provided nearly comprehensive coverage of the three SF Bay stratum described above. The sampling units roughly correspond to individual ponds and wetlands, of varying size, and thus each represents largely homogenous habitat. Although surveys of feeding shorebirds are desirable for understanding foraging habitat needs, tidal flat surveys are not logistically feasible during winter in SF Bay (Stenzel et al. 2002). Consequently, we recommend a high tide survey protocol to survey shorebirds in SF Bay while they are roosting in areas that are typically accessible during wet winter months.

The results of a simulation study using existing high-tide roost count surveys suggested that we could meet our quantitative objectives with a 75% reduced sampling effort (Appendix I). We used Generalized Random Tesselation Stratified (GRTS) sampling (Stevens and Olsen 2004) and the "spsurvey" package in R v.10.1 (© The R Foundation for Statistical Computing) to select ~30% of the sampling units in each of North Bay (n = 36), Central Bay (n = 29), and South Bay (n = 66) strata (Fig. 1b). Overall, the habitat composition of the selected sampling units was similar to the habitat composition across all sampling units (Fig. 2). Based on the sampling units selected, we determined that our sampling design would have captured ~50 – 60% of the total shorebirds observed during the 2006 – 2008 surveys had it been in place during that time and population estimates would have a CV of ~20% (Table 2).

We weighted the selection of sampling units within each stratum by the natural logarithm of the total shorebirds counted in the sampling unit during the comprehensive surveys, 2006 – 2008 (Wood et al. 2010). Stratifying based on historical data of where the birds were typically found is accomplished by this approach and is common in ecology (Krebs 1999). Also, several studies have identified high roost-site fidelity in SF Bay (Warnock and Takekawa 1996) and other coastal estuarine systems (Colwell et al. 2003, Conklin and Colwell 2007, Peters and Otis 2007). High consistency of site use should reduce the year to year variance in the data and subsequently improve estimates of population change. Although high site fidelity is common spatial shifts in the distribution of birds can occur (Wood et al. 2010). When considering a highly aggregated species, such as roosting shorebirds, weighting too heavily towards areas of historic abundance is beneficial in reducing sampling variance but can be yield biased trend estimates if there is a shift in the distribution of roosting shorebirds. We also evaluated the total abundance of shorebirds as a continuous weight to select sampling units. Simulation results suggested that our stratified weighting strategy, using the natural logarithm weighting structure would produce the most accurate results with limited bias; the non-transformed weighting structure resulted in high bias in trend estimates (Appendix I). The GRTS sampling algorithm provides flexibility in the sampling design as it provides a framework for additional samples to be selected which could be used to replace survey locations if accessibility were to become restricted or to add additional sample locations in the future.

To inform our quantitative goals of survey precision in detecting trend, we conducted a simulation-based power analysis to determine the proportion of times that we would detect a 50% decline in a population over a 20 year period. We examined annual, every-other year, and every 5-year survey frequencies using the reduced sampling effort detailed above. We determined that to successfully identify a trend with 80% power while reducing spatial coverage, annual surveys would be needed (Appendix I). We recommend that surveys should be conducted once annually during the survey window (November 15 – December 15) and should be coordinated across SF Bay to occur on one day.

Although our proposed monitoring plan provides a rigorous approach to long-term monitoring of wintering shorebirds in SF Bay, we recommend continued assessments of its functionality and rigor overtime to guard against selection and frame bias (Thompson 2002). The high degree of spatial aggregation in roosting shorebirds can be susceptible to bias in trend estimates if there is a significant shift in distribution of roosting birds from surveyed to non-surveyed sites, although we believe our weighted sampling design should prevent this "selection bias" from being significant. There is also the potential for new habitat to become available outside of the area covered by the current sampling frame. Subsequently, our inference about shorebird populations in SF Bay would be biased ("frame bias"). We recommend a comprehensive survey of all sampling units (n = 340) in SF Bay for 2 consecutive years every 10 years. Sample unit selection weights determined by the natural logarithm of the total shorebirds counted could be updated with the new data and applied to the existing sampling units to help reduce the influence of selection bias. New sampling units could also be added at this time, if necessary, to better represent the SF Bay sampling frame and reduce frame bias.

SURVEY PROTOCOL

Surveys for this monitoring program consist of area searches of each selected sampling unit (n = 121) in SF Bay for both roosting and non-roosting shorebirds. In each sampling unit, all shorebird species are identified and their abundance is estimated. Surveys are conducted when local tidal conditions (determined by the nearest tide station) are high enough to force shorebirds off of mudflat foraging areas throughout SF Bay (a tide that is ~6 feet higher than MLLW at the Golden Gate Bridge). Surveys should be conducted within the optimal 3-hour survey window around high tide to minimize variation due to bird movement as tidal conditions change. In addition, because factors on the day of the count (e.g., wind, atmospheric pressure) may influence tidal height and timing, we encourage observers to arrive at their survey area 30 minutes before the predicted start time to ensure adequate time to complete the survey. Surveys should not be conducted during winds >24 mph (>5 on scale below), heavy fog (<200m visibility), or steady rain.

The count is considered complete once all birds in the sampling unit have been recorded. We recommend matching the number of observers to the sampling unit size and the anticipated number of birds to allow the completion of the survey within the ~3-hour window. Please see Appendix II for the complete details of the survey protocol.

Data Centralization

All data collected as part of wintering shorebird monitoring in SF Bay will be entered into the California Avian Data Center (CADC). CADC (www.prbo.org/cadc) is a secure, well-tested platform for managing, analyzing, and visualizing avian monitoring data. It is also a node of the Avian Knowledge Network (www.avianknowledge.net), which represents several interconnected bird data repositories.

Data will be entered into CADC through an online data entry portal developed specifically for the SF Bay shorebird surveys and the broader Pacific Flyway Shorebird Survey (PFSS; http://data.prbo.org/partners/pfss/; see Appendix III). This portal allows for rapid collection of data from field surveys. It is particularly efficient for integrating data collected by many different observers across multiple monitoring programs.

Data Analysis

Basic Summaries.– As part of this monitoring program, we have developed an open-source interactive data summary tool. This tool interacts directly with shorebird data stored in CADC to produce simple summaries at user-defined spatial scales from the individual sampling unit to the entire SF Bay. These interactive tools also allow annual data from SF Bay to be compared to PFSS monitoring data collected from throughout California and, eventually, the entire Pacific Flyway.

Population Estimation.– Each year, we will estimate the population of shorebirds in San Francisco Bay using the methods described by Stevens and Olsen (2004). Using continuously weighted stratified data requires that we use the inclusion probability for each sampling unit (i.e. the probability that a given sampling unit is selected from all sampling units) in our calculations. The population estimate for each of the 3 strata of SF Bay can be estimated with a Horvitz-Thompson estimator (Cochran 1977):

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Where the total shorebird estimate (Z_T) for each stratum is the sum of the observed count in each sampling unit, z_i, divided by the inclusion probability of the sampling unit, p_i. The variance for the shorebird population estimate within each stratum is estimated using a locally weighted neighborhood estimator which has been shown to be more stable and precise than the *ad-hoc* approach of assuming the data come from an independent random sample (Stevens and Olsen 2003). For a complete SF Bay population estimate the stratum-specific estimates and standard errors are combined using standard methods for stratified samples (Cochran 1977). Inclusion probabilities can change if the abundance of birds within a site changes overtime or there is a change in the availability of habitat. Accounting for changes in the inclusion probability is important to achieve unbiased estimates of population size. Data collected from the two comprehensive surveys every 10 years could be used to re-estimate the inclusion probability for each sampling unit. This can be accomplished by rerunning the same GRTS sampling algorithm using the updated weighting data (i.e. shorebird counts and habitat).

Trend Estimation.– To achieve a primary objective of this monitoring plan, we will estimate shorebird population trends using hierarchical models (Link and Barker 2010). We will initiate this modeling effort using data from 2006 – 2008 and 2010. We will fit simple models to the data using 2 covariates: (1) year – a continuous variable standardized to 2006 = year 1; and (2) strata - a 3-level factor representing the three SF Bay regional strata. We will also consider an interaction term between stratum and year in our models to evaluate whether trends are different among strata. Because data will be collected annually and entered directly into CADC, we will use a Bayesian approach to modeling trend over time. This will allow for our estimates of trend to be updated annually in a rigorous fashion while accounting for existing information based on the previous year's model analyses and updated parameter estimates (Williams et al. 2002).

The hierarchical models developed above can also be used to quantify habitat associations of shorebirds and potentially the impact of management actions. This will require an initial study to develop the habitat models as well as regular tracking of shorebird habitat and management actions in SF Bay sampling units. See "Future Needs and Pilot Studies" section below.

SURVEY COORDINATION, LOGISTICS, AND SUSTAINABILITY

The survey of all sampling units should be completed on a single day. To successfully complete the survey at >100 sampling units within the same tide cycle on one day, a large constituency of trained observers is needed. Surveys will be conducted by both professional and volunteer biologists ("citizen scientists"). Training sessions will be held annually to familiarize new observers with survey protocols, data recording, species identification, methods of estimating shorebird numbers, and data entry through CADC. PRBO will take the lead role in the coordination of this annual survey in SF Bay and the broader PFSS. However, efficient survey coordination in SF Bay will continue to require close partnerships between PRBO Conservation Science (PRBO), San Francisco Bay Bird Observatory (SFBBO), U. S. Geological Survey (USGS), U. S. Fish and Wildlife Service (FWS), and Audubon California; all have coordinated substantial portions of the survey in previous years and in 2010 (Fig. 3b).

The sustainability of a long-term, monitoring program will also depend on maintaining active engagement by survey participants. We have developed and employed web-based tools including a PFSS webpage (http://data.prbo.org/partners/pfss/) and a blog (http://shorebirdscount.blogspot.com/) to engage citizen scientists and provide information about shorebirds and the PFSS. We also used survey monkey (http://www.surveymonkey.com/) to interact with citizen scientists and elicit feedback about their experience with the PFSS. We believe these social networking tools will increase citizen scientist retention and generate enthusiasm and support for shorebird monitoring in SF Bay and shorebird conservation.

FUTURE NEEDS AND PILOT STUDIES

Although this monitoring plan describes an approach to tracking abundance and trends of wintering shorebirds in SF Bay there is still additional work that needs to be completed.

Habitat Tracking and Bird-Habitat Models.– The area included by all 340 sampling units that defines our sampling frame represents >400-km^2 of land and intertidal habitat in SF Bay. Throughout SF Bay regular changes to the landscape affect the shorebird habitat. Plans to restore tidal marsh from salts ponds will likely affect the distribution and abundance of shorebirds in SF Bay (Stralberg et al. 2005) and climate change will also influence the habitat composition in SF Bay (Galbraith et al. 2002). Although we can record general habitat data at surveyed sampling units annually as part of the general monitoring protocol, changes at non-surveyed sites would go undetected. To track potential changes in shorebird habitat in SF Bay, and to understand how changes to habitat availability will influence shorebirds we need: (1) a consistent way of tracking landcover (e.g. EcoAtlas [http://www.sfei.org/ecoatlas/]) every other year or distinct changes in habitat (e.g. "habitat change reporting portal"); and (2) shorebird-habitat association models.

As discussed above changes in the distribution of birds or bird habitat can result in biased estimates of population size and trend from almost any sampling design. Currently, there is not a framework to regularly track habitat in the SF Bay although the ability to do so efficiently (e.g. remote sensing) is increasingly available and would benefit long-term monitoring of all biota in SF Bay. Typically, shorebird habitat management occurs within a wetland or wetland complex. The effectiveness of these localized spatial scale (<1 - 2 km) management strategies to attract shorebirds may vary due to changes in the availability of habitat in the surrounding landscape which may change over time from habitat conversion and management (e.g., salt ponds to tidal marsh in the San Francisco Bay Estuary). For managers to make informed management decisions requires understanding how their localized actions contribute to the overall shorebird habitat in the broader landscape. Habitat association models can serve as the basis to provide management recommendations to wetland habitat managers about how to allocate resources to maintain current shorebird population objectives.

Probability of Detection – Sampling Bias.– Sometimes not all birds occurring within a sampling unit are detected. The probability that a bird occurring within a sampling unit is detected is called the probability of detection (Thompson 2002). The probability of detection, which is often assumed to be equal to 1 (all birds are detected), can be influenced by many factors including habitat, distance from the observer to the bird, or the amount of habitat that is actually visible. Typically, the assumption is that birds that are present are undetected and thus the probability of detection is <1. Population estimates will be negatively biased ("sampling bias") if probability of detection is not corrected for in analysis in this scenario. Trend estimates are more robust to uncorrected counts as long as the probability of detection does not have a trend (i.e. the probability of detecting a bird given it is in the sampling unit is constant overtime).

It is difficult to efficiently estimate the probability of detection of wintering shorebirds for two reasons. First, wintering shorebirds often occur in large groups, clustered on the landscape. Estimating the size of these large groups is very challenging and likely, there is an equal probability of under-estimation (probability of detection < 1) as there is of over-estimation (probability of detection > 1). This makes the assumption that birds are only likely undetected somewhat untenable. Reconciling this problem is a challenge. Second, several commonly used approaches to estimating the probability of detection including the double-observer (Nichols et al. 2000), the Royle count model (Royle 2004), double sampling (Bart and Earnst 2002), and distance sampling (Buckland et al. 1993) have assumptions (e.g. closure) that cannot be met with wintering shorebirds or are logistically unfeasible using citizen scientists. A modified version of the Royle count model, the "unreconciled double-observer method" (Riddle et al. 2010), may provide a rigorous approach to estimating probability of detection in a citizen scientist driven project. Further investigation is needed to understand the magnitude of bias caused by probability of detection in shorebird surveys in coastal estuarine habitats and delineating effective strategies for correcting for this source of bias.

SUMMARY

Annual shorebird surveys in SF Bay that generate estimates of abundance and trend are needed and can greatly inform conservation and management in the face of a changing climate. Linking observed changes in the distribution and abundance of wintering shorebirds in SF Bay to changes in habitat within SF Bay will measure the impacts of local management actions. Evaluating annual shorebird monitoring shorebird data from SF Bay in the context of broader changes in shorebird populations across California and the Pacific Flyway will provide a complete picture of the impact of local management actions on Pacific Flyway shorebird populations. This monitoring plan details an approach to provide this essential information.

The new monitoring strategy was launched on November 19, 2010, with more than 100 citizen scientists and professional biologists conducting surveys and entering their data through the new online data portal. We will use the first 2-years of data to critically evaluate this monitoring plan.

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Table 1. List of species observed on San Francisco Bay shorebird surveys November 1990 – 1992 (Stenzel et al. 2002) and 2006 – 2008 (Wood et al. 2010). Species in italics are in low abundance in SF Bay and will only be captured well by a species-specific monitoring effort.

Species	
Black-bellied Plover	Red Knot
Snowy Plover	Sanderling
Semipalmated Plover	Western Sandpiper
Killdeer	Least Sandpiper
Black Oystercatcher	Dunlin
Black-necked Stilt	Dowitcher spp. (Long-billed / Short-billed)
American Avocet	*American Golden Plover*
Spotted Sandpiper	*Pacific Golden Plover*
Greater Yellowlegs	*Pectoral Sandpiper*
Willet	*Ruff*
Lesser Yellowlegs	*Sharp-tailed Sandpiper*
Whimbrel	*Surfbird*
Long-billed Curlew	*Wilson's snipe*
Marbled Godwit	
Ruddy Turnstone	
Black Turnstone	

Table 2. Total shorebird abundance in each year 2006 - 2008, the proportion of total in the selected sampling units for San Francisco Bay, and the coefficient of variation (CV), reported as a percentage, of population estimates based on the selected sampling units.

Year	Survey Totals	Sample Totals	Proportion Total	CV (%)
2006	355444	220533	0.60	20
2007	327322	203432	0.61	16
2008	351882	181883	0.51	21

Figure 1. (a) Location of the three regional strata within San Francisco Bay and all sampling units (n = 340) used to develop sampling design. (b) Location of sampling units (n = 121) selected for long-term monitoring and the lead organization coordinating the surveys at those locations.

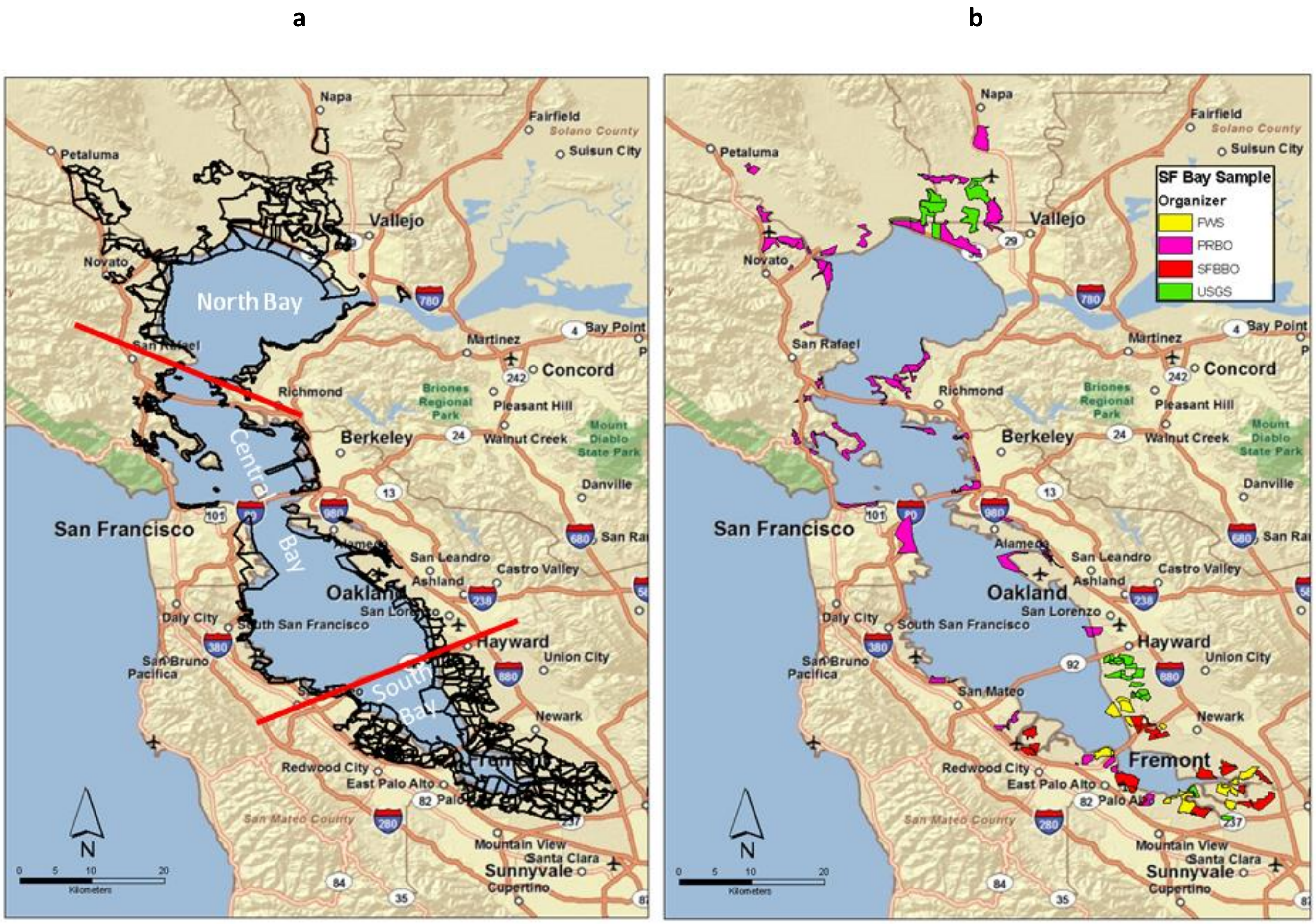
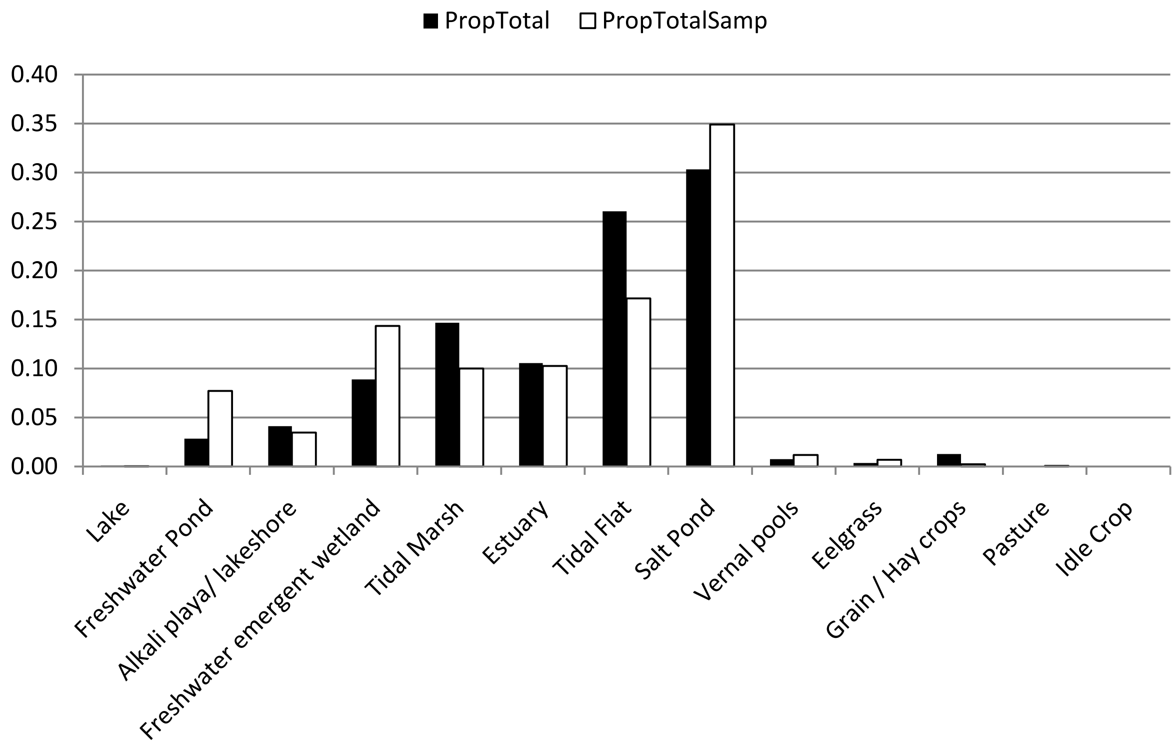


Figure 2. Habitat composition (proportion of total habitat) of all sampling units (PropTotal) in San Francisco Bay indicated in Figure 1a and habitat composition for those selected for long-term monitoring (PropTotalSamp) indicated in Figure 1b.



APPENDIX I: Simulation Study – DRAFT manuscript

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RRH: Simulations and shorebird monitoring

Historic Data and Simulations Inform Shorebird Monitoring in San Francisco Bay

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Key words: Charadriiformes, monitoring, San Francisco Bay, shorebirds, simulations, trend

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Abstract

Long-term monitoring programs for large-landscapes require sampling designs that are logistically feasible, and that minimize bias and variance in estimates of population size or population change. The San Francisco Bay (SF Bay) estuary provides habitat for over 1 million shorebirds (Charadriiformes) annually and >300,000 winter in the estuary. Understanding population trends for wintering shorebirds provides an indicator to habitat changes in SF Bay as well as to the broader Pacific Flyway. We utilized spatially-referenced data from comprehensive shorebird counts (1990-92, 2006-08) to simulate spatially and temporally explicit sampling scenarios at various levels of reduced sampling effort in SF Bay. Specifically we assessed: (1) How much can we reduce sampling effort and still accurately (±20%) detect changes in shorebird abundance? (2) What is the best sample selection framework to identify where to survey roosting shorebirds? (3) How frequently should surveys be completed to accurately detect 20-year population trends? Our results suggested that we could reduce sampling effort by 75 percent using a stratified weighted generalized random tessellation stratified sampling algorithm and achieve discrete population change estimates within 20% of observed in comprehensive surveys. Sampling should be conducted annually to conclude in >80% of model evaluations that there had been a 50% decline in the population over a 20-year period based on the criteria that the 95% credible interval from a over-dispersed Poisson regression did not overlap zero while sampling at 25% effort when a 50% decline had occurred. Based on these analyses, we propose a statistically robust, logistically feasible, long-term monitoring program for wintering shorebirds in SF Bay to track spatial and temporal population trends and the impact of changing climate and habitat conditions. We conclude that more monitoring programs should consider the sampling effort level needed to achieve the goals using historic data and simulation based approaches.

Long-term monitoring programs for large-landscapes require sampling designs that are logistically feasible, and that minimize bias and variance in estimates of population size or population change (Braun 2005). Although a complete enumeration of all birds from a region (i.e. comprehensive count) or population of interest is desirable, such comprehensive data are often unable to be collected. Thus both spatial and temporal sampling is predominantly used to estimate the population within a selected region over a period of time. However, whether assumed-to-be complete counts or sampling is used to estimate the population, subsequent estimates of population change and inference may be influenced by frame bias and selection bias.

Frame bias results when the total region over which a species occurs has not been adequately defined in which case declines in the observed sample may be either a real decline or movement of birds to a region not captured by the sampling frame (Bart et al 2005). Frame bias can exist in either a comprehensive count of a population or a sampled population if the entire region in which the population of interest occurs has not been properly defined or if the distribution of habitat changes over time. Selection bias occurs when some areas within the sampling frame cannot be included due to restricted accessibility (e.g. private land, large road-less areas). In light of these sources of potential bias, we face the question: are declines or increases observed in the limited sampling areas an unbiased measure of population trends across all areas?

Simulations are a powerful quantitative tool for understanding ecological systems and potential sources of bias in wildlife monitoring programs. Given the availability of at least some data from a region, they can provide insights about the ability of sampling designs to detect changes in the distribution and abundance of a population over time, variability of parameter estimates on inference, and model fit (Gelmen and Meng 1996, Manly 2007).

The San Francisco Bay Estuary (SF Bay) provides habitat for over 1 million shorebirds (Charadriiformes) annually (Page et al. 1999, Stenzel et al. 2002), and has been designated a site of "Hemispheric Importance" by the Western Hemisphere Shorebird Reserve Network. Comprehensive November surveys of roosting shorebirds in the SF Bay were completed in 1990-92 and 2006-08. These surveys consisted of counts in variably sized sampling units and it was assumed that all birds were counted within each sampling unit. The comprehensive counts yielded an estimate of the total birds in SF Bay and contributed to our understanding of the value of the estuary to wintering shorebirds but they required substantial logistical support to complete. Furthermore, the survey periods were 14 years apart thus provided limited data to detect trends and annual variation in the population, particularly as related to spatial and temporal trends in shorebird habitat. Moreover, conducting comprehensive surveys annually to track long-term trends and habitat associations of shorebirds using SF Bay may not be logistically feasible. Consequently, alternative sampling-based approaches to monitoring wintering shorebirds in SF Bay are needed.

We utilized spatially-referenced data from the comprehensive shorebird counts (1990-92, 2006-08) to simulate spatially and temporally explicit sampling scenarios at various levels of reduced sampling effort in SF Bay. Overall, we provide data to inform the development of a sampling design that could accurately capture changes in the abundance of shorebirds using SF Bay without having to conduct comprehensive counts. Specifically we assessed: (1) How much can we reduce sampling effort and still accurately (±20%) detect changes in shorebird abundance? (2) What is the best sample selection framework to identify where to survey roosting shorebirds? (3) How frequently should surveys be completed to accurately detect 20-year population trends?

METHODS

Data Compilation

We used 224 sampling units that were searched for roosting shorebirds in all 6 years of the November shorebird roost counts, 1990-92 and 2006-08 (Fig. 1). These represented 85% of the total sampling units searched at least one time in each of the 2 time periods and >90% of the total birds counted during the comprehensive counts. We considered these data to represent the "true" number of birds present in the estuary during each of the 6 years of monitoring. The 224 count locations were located within 3 general regions of the Bay: (1) San Pablo Bay (SPB); (2) the Central Bay (CB); and (3) the South Bay (SB).

For our simulation study, we considered only a subset of the species identified during the comprehensive counts. We selected 8 species or species-groups (species) that represented birds that were fairly common in SF Bay and represented a variety of body sizes (Table 1). Because of the limited amount of rocky coastline habitat in SF Bay, the suite of species we considered in these simulations did not include rocky shoreline dependent species (e.g. Black Oystercatcher). For each species, we calculated the finite rate of population change as:

$$\Delta_i = \frac{\sum_{j=2006}^{2008} count_j}{\sum_{j=1990}^{1992} count_j}$$

Where Δ_i indicates the change in the abundance of species, *i*, between 1990-92 and 2006-08;

$\sum_{j=2006}^{2008} count_j$ is the sum of the counts of species, *i*, across all sampling units in each year, *j*,

between 2006 and 2008; and $\sum_{j=1990}^{1992} count_j$ is the sum of the counts of species, *i*, across all sampling units in each year, *j*, between 1990 and 1992. Values of Δ_i > 1 identified an increase in the abundance of species, *i*, while values of Δ_i < 1 identified a decrease in the abundance of species, *i*, between the 2 time periods.

Simulations

For all simulations, we generally considered a repeated survey framework (Duncan and Kalton 1987). In each iteration of a simulation, a sample of sampling units was selected and then those same sampling units were used to subset all 6 years of the survey data as if those same sampling units were surveyed in all 6 years. We considered 3 levels of sampling effort, measured by the percentage of the total number of sampling units surveyed, to evaluate how much we could reduce sampling effort within each year and still generate an estimate of change ±20% of the observed change based on 100% effort (i.e. all 224 locations surveyed): (1) 75%, (2) 50%, and (3) 25%. In combination with reduced effort, we considered 4 approaches to drawing samples to determine where we should survey: independent random sample (IRS); stratified random sample (SRS); generalized-random tessellation sample (GRTS); and stratified generalized-random tessellation sample (SGRTS).

We used 3 approaches to stratification. First we sampled each of 3 distinct areas of SF Bay (SPB, CB, and SB) as strata and ensured that at least 25%, 50% and 75% of the sampling units within each of the strata were sampled. Second, we stratified by weighting the drawing of a sample location proportional to the natural-logarithm of the total number of shorebirds observed at each sample location in the years 1990-92. Stratifying based on historical data of where the birds were typically found is represented by this approach and is common in ecology (Krebs 1999). Also, several studies have identified high roost-site fidelity in SF Bay (Warnock and Takekawa 1996) and other coastal estuary systems (Colwell et al. 2003, Conklin and Colwell 2007, Peters and Otis 2007). High consistency of site use should reduce the year to year variance in the survey data and subsequently in estimates of population change. High site fidelity suggests that spatial shifts in the distribution of birds are not very likely, however changes in the spatial distribution of birds can result in both selection and frame bias if samples are weighted too strongly toward shorebird clusters. We considered both the total count of shorebirds as well as the natural logarithm of the total as the continuous stratification weight. We compared the performance of these weighting strategies. Third, we considered both stratification approaches together.

Using these criteria, we defined a total of 24 scenarios and employed the spsurvey package in program R (© 2008 The R Foundation for Statistical Computing) to implement simulations. For each scenario, we conducted 1000 iterations. For each iteration of each simulation in each effort scenario for each species, we calculated Δ_i and the squared-error of Δ_i (the squared difference between the simulation estimate of Δ_i and the "true" Δ_i). Therefore, each scenario for each species resulted in a distribution of 1000 Δ_i s, and 1000 squared-errors of Δ_i .

Comparing Scenarios

We compared effort and sample selection scenarios using measures of bias, variance, and overall accuracy, both within and among species groups, and across all species together. We calculated the bias of each scenario for each species as the squared difference between the observed change and the median change estimate from the distribution of 1000 change estimates. We quantified variance as the difference between the 25th and 975th ranked values of the 1000 simulated estimates of change (i.e. the width of the 95% CI of change based on the percentile method). Lastly, we measured the overall accuracy of each scenario based on the mean of the distribution of 1000 squared-errors (mean squared error = MSE). Although species specific differences were of interest, we primarily wanted to evaluate which effort and sampling scenarios performed the best across all the species considered in our analysis. We averaged the bias, variance, and MSE across the 8 species-species groups to quantify the overall performance of each scenario.

Post-hoc, we further evaluated differences in the inclusion probabilities between using the log-transformed and the non-transformed total count of shorebirds as the continuous stratification weight. We summarized the proportion of times out of the 1000 iterations that each sampling unit was selected in the sample.

Power Analysis

Although our first set of simulations compared spatial sampling designs and effort level with spatially comprehensive surveys at 100% effort, we were unable to assess the effectiveness of alternative temporal sampling designs (e.g. annual surveys, every other year surveys). We were only able to assess the relative value of alternative spatial sampling designs using two sets of 3 years (1990-92 and 2006-08) of surveys separated by 14 years. We conducted a second set of simulations to determine the power of different temporal sampling designs to detect population trends. We used the criteria of being able to detect a 50% population decline over 20 years with 80% power at the $p = 0.05$ significance level. This is a fairly strict criteria, so we also evaluated the power to detect a 50% decline over 20 years at $p = 0.15$ significance level (Butcher et al. 1999)

For each iteration of this simulation, we drew a sample using one of the spatial sampling designs at a specified effort level (see "Simulations" above). We partitioned data at the selected sampling units from the full dataset. We then simulated a 20 year dataset by bootstrap sampling the 6 years of data at each sampling unit and applying ~3.5% decline in abundance per year (Efron and Tibshirani 1993). For each simulated 20-year dataset, we fit an over-dispersed Poisson regression model with random effects using Markov Chain Monte Carlo (Gilks et al. 1996) in the MCMCglmm package in program R v2.8.1. Our model consisted of a continuous fixed-effect of year and 2 random effect variance terms accounting for correlation within sites and within years. We conducted 100 iterations in each simulation and calculated the proportion of the iterations where the upper value of the 95% credible interval or 85% credible interval of the trend estimate was < 0 as our measure of the probability to detect trend given the available information.

RESULTS

Between the two time periods 5 of the 8 species showed evidence of an increase in abundance while *Calidris* sandpipers, dowitchers, and stilts decreased. Overall change values ranged from 20% declines to 60% increases (Fig. 2). Yellowlegs (Mann-Whitney $U = 0$, $p \approx 0.10$) and whimbrel (Mann-Whitney $U = 0$, $p \approx 0.10$) were the only species that had statistically significant changes; both were increases.

Overall, our simulation results across all species were predictable based on sampling theory. By increasing overall sampling effort, from 25% to 75% of the total sampling units, bias, variance, and the overall MSE of our estimates of change were reduced (Fig. 3). Averaged across sampling regimes and species, MSE was reduced from 0.44 (min = 0.13, max = 1.02) at 25% effort to 0.08 (min = 0.05, max = 0.13) at 50% effort to 0.03 (min = 0.01, max = 0.04) at 75% effort. Generally, increasing sampling effort from 25 – 50% of the total effort resulted in a larger increase in accuracy than an increase from 50 – 75% (Fig. 3).

There were noticeable differences in the bias and variance among our sampling designs. Sampling designs that weighted sampling effort towards areas of historic abundance of roosting shorebirds tended to be slightly more biased than other designs, whereas they exhibited much lower variance in their change estimates than designs without a weighted stratification by historic data. These patterns were consistent among all sampling efforts and species. However, using the non-transformed count values to weight the selection of sites resulted in very high bias (0.21); nearly an order of magnitude larger than any other scenario and is not presented in Fig. 3. The strength of the variance component in the calculation of the overall accuracy (MSE) was apparent as overall, designs with high variance but low bias tended to have much higher MSE when compared with the slightly more biased but less variable sampling designs (Fig. 3). The non-transformed count weighting structure also had low variance however, the bias was too large to make its overall accuracy competitive with the other sampling scenarios.

Our *post-hoc* assessment identified clear differences in the inclusion probabilities for the log-transformed total versus the non-transformed count total as the continuous stratification weight. The log-tranformed weight resulted in inclusion probabilities ranging from 0 to 0.65 and only 4 of the 224 sampling units were never selected in 1000 samples (Fig. 4a). The nontranformed weight resulted in inclusion probabilities ranging from 0 to 1 however only 130 sampling units were ever selected (Fig. 4b). This suggested that the log-tranformed approach evened the inclusion probabilities between high and low abundant sampling units which resulted in lower bias in change estimates.

The level of effort and stratification using historical data had a greater influence on the performance of each sampling design at each effort level than sampling using GRTS versus IRS. However, GRTS exhibited greater bias in the weighted sampling than IRS, suggesting that by trying to both achieve a spatially-balanced design while also being constrained by weighted sample locations may result in slight bias, given the distribution of roosting shorebirds evaluated here. However, stratified sampling designs using historical 1990s data to weight the selection of locations resulted in the lowest MSE observed when using either the GRTS algorithm or IRS.

Overall, patterns among species were consistent with those averaged across all species we evaluated (Table 3). The only notable difference across species was that, on average, yellowlegs and whimbrel had larger bias and variance, given the sampling effort and sampling design, than the other species groups. However, these species were substantially less abundant than the other 6 species.

The power analyses suggested that in order to meet the criteria of having 80% power to detect a 50% decline in 20 years at the p = 0.05 or p = 0.15 significance level using an over-dispersed Poisson regression model and a stratified, 25% sampling effort, surveys should be conducted annually (Table 4). Reducing sampling from every year to every other year reduced power for all species from on average across species, 0.89 to 0.06 at 25% survey effort. Sampling every five years performed poorly a well compared to annual sampling. Power to detect trends was >0.80 for all species using annual surveys at 25% effort.

DISCUSSION

The effort-intensive, comprehensive November surveys of roosting shorebirds conducted from 1990-92 (Stenzel et al. 2002) and again from 2006-08 (Wood et al. 2010) provide an accurate measure of wintering shorebird use of the Bay. These data also provide a unique opportunity to assess sampling design and survey methodology for long-term monitoring of wintering shorebird populations in SF Bay. Our analysis using subsets of the full data set suggested a properly designed sampling framework for shorebirds in SF Bay could meet our accuracy standards while also reducing the overall effort needed to accomplish the surveys. Consequently, this creates an opportunity to conduct the surveys more regularly, preferably annually, to better understand annual variability in SF Bay shorebird numbers, link shorebird populations in SF Bay with specific management actions, and identify spatial and temporal variation in wintering shorebird populations at scales larger than SF Bay if combined with monitoring data from other regions in the Pacific Flyway.

Overall, the populations of shorebird species that we evaluated were relatively stable in SF Bay between the two time-periods and the observed changes were fairly small. However some spatial shifts were detected in the populations of some species (Wood et al. 2010). Our simulations identified the possibility for bias in estimates as a result of spatially shifting populations, if samples are weighted too much on the historical data of a species' distribution, and if that species tended to be highly aggregated. In our analysis, samples (whether drawn randomly or using the GRTS algorithm) with weighted stratification based on the historical data tended to have slightly larger bias than samples without this stratification. This bias was likely induced by spatial shifts in the population, combined with samples that were weighted towards areas where there were already high numbers of birds based on historic data. This was particularly apparent in the comparison of bias between the two continuous weighting strategies. The non-transformed weighting selected some sites with an inclusion probability of 1. Thus when large roosts at those sites moved to un-selected sampling units there was a large bias. However, based on the MSE criteria, the log-total count weighted designs were most accurate and provided good estimates of change at very low sampling effort.

The value of using these historical data for testing sampling designs was not surprising given that many species of shorebirds tend to exhibit high roost site fidelity and that overall the spatial distribution of shorebirds has been relatively stable across SF Bay. However, spatial patterns of shorebirds around SF Bay are likely to change as the result of changes in the distribution of habitat in this landscape created by large scale restoration projects (Stralberg et al. 2008), and over a longer term, rising sea levels (Galbraith et al. 2002). Any ongoing monitoring program for shorebirds in SF Bay will have to accommodate changes in the sampling frame (e.g., new habitat, lost habitat) within SF Bay and the in the broader landscape to prevent frame and selection bias. Wide-ranging species like shorebirds may respond to changing habitat availability on the landscape over much larger scales than even SF Bay. Understanding how trends in SF Bay compare to species population trends over wider geographical regions is needed to help understand whether trends in SF Bay reflect Pacific Flyway population trends or more localized trends in populations within SF Bay only.

Our simulations were limited to the general survey design used to collect the data. All survey locations were sampled once in each of the 6 sampling years in this repeated survey design (Duncan and Kalton 1987). Sampling the same areas repeatedly is convenient and provides data on how changes in habitat will affect birds at specific locations, but may not reflect the change in the population as a whole if the sample is not representative of that population. Drawing a new sample of survey locations every year can avoid this potential bias, yet may be logistically implausible and makes linking habitat changes with species response more difficult. One alternative is a split panel design where one sample is a repeated sample while a second set of sites are selected at random each year (Duncan and Kalton 1987).

Lastly, our power analyses suggested that annual surveys would be needed to be able to detect 50% declines in shorebird populations over a 20-year time period with 80% power when surveying with 25% effort whether using the 95% or 85% credible interval cut-off. Annual surveys were a substantial improvement over sampling every other year or every fifth year. Reducing the sample size by half (i.e. annual surveys to every-other year surveys) resulted in a 96% decline in the probability to detect a trend. These data provide quantitative support of the need for annual surveys in addition to their qualitative appeal for facilitating continued volunteer engagement in the monitoring program.

Our simulation analysis suggest that using a properly stratified sampling design, effort to survey roosting shorebirds in San Francisco Bay could be reduced by up to 75% and still achieve reasonably accurate (±20%) estimates of population change and meet criteria to detect 20-year trends. Given our results and the high roost site fidelity of shorebirds we suggest the use of historical data to guide the distribution of sampling, however, we caution that by not monitoring areas where the birds have been absent or found only in small numbers previously could yield biased trend estimates overtime. This is a mixture of both frame and selection bias. Thus, the weights used to stratify the sampling distribution need to be evaluated carefully and strategies to adequately cover areas not captured in the initial sampling design over time are needed to prevent biased trend estimates.

Based on our data and initial simulation results, we recommend that any long-term monitoring program of shorebirds in SF Bay consider a sampling design in which one set of sampling units would be selected randomly, weighted towards historic roost sites, and counted annually. The remaining region of SF Bay would be surveyed every 10-years to evaluate changes in the sampling frame (e.g. new habitat and spatial shift in habitat) that could bias trend estimates. These every 10-year updates would help inform the sampling frame for the following 10 year period. Ultimately, finding efficient ways to monitor shorebird populations annually in the Bay are needed for their conservation and management. Simulations using historical data provided a critical first step in developing a robust monitoring protocol.

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Table 1. Species-species groups used in simulations to assess sampling scenarios for November roost counts of shorebirds in San Francisco Bay.

Species-Species Group	**Reference Name**
American Avocet	Avocet
Black-necked Stilt	Stilt
Willet	Willet
Greater Yellowlegs, Lesser Yellowlegs	Yellowlegs
Long-Billed Curlew, Marbled Godwit	Curlew-Godwit
Whimbrel	Whimbrel
Least Sandpiper, Western Sandpiper, Dunlin	Calidris
Long-billed Dowitcher, Short-billed Dowitcher	Dowitchers

Table 2. Definition of 8 sampling regimes used to draw samples for simulations of sampling scenarios for November roost counts of shorebirds in San Francisco Bay.

Sampling Regime	**Code**
Generalized Random-Tesselation Stratified Sampling	GRTS
Generalized Random-Tesselation Stratified Sampling with additional stratification by San Pablo Bay, Central Bay, and South Bay	SGRTS
Generalized Random-Tesselation Stratified Sampling with additional stratification weighted by the abundance of shorebirds in the 1990-92 sample years.	GRTSW
Generalized Random-Tesselation Stratified Sampling with additional stratification by San Pablo Bay, Central Bay, and South Bay and weighted by the abundance of shorebirds in the 1990-92 sample years.	SGRTSW
Independent Random Sampling	IRS
Stratified Random Sampling with stratification by San Pablo Bay, Central Bay, and South Bay	SIRS
Stratified Random Sampling with stratification weighted by the abundance of shorebirds in the 1990-92 sample years.	IRSW
Stratified Random Sampling with stratification by San Pablo Bay, Central Bay, and South Bay and weighted by the abundance of shorebirds in the 1990-92 sample years.	SIRSW

Table 3. Summary of bias, variance (var), and mean squared error (mse) for each species-species group in each simulation scenario for November roost counts in San Francisco Bay. Weighted scenarios ("W") used the natural logarithm of the total count in the sampling unit (1990 – 1992).

		Avocet			Stilt			Curlew-Godwit			Dowitchers		
Sampling	**Effort**	**bias[a]**	**var[b]**	**mse**	**bias[a]**	**var[b]**	**mse**	**bias[a]**	**var[b]**	**mse**	**bias[a]**	**var[b]**	**mse**
GRTS	25	0.0013	1.9885	0.2898	0.0021	2.8372	0.5681	0.0015	3.3244	0.8097	0.0000	1.5637	0.1694
GRTS	50	0.0000	1.0642	0.0685	0.0001	1.1669	0.1023	0.0005	1.6633	0.1808	0.0000	0.8342	0.0436
GRTS	75	0.0000	0.5885	0.0234	0.0003	0.7364	0.0351	0.0000	0.8796	0.0524	0.0001	0.4240	0.0118
SGRTS	25	0.0003	1.8756	0.2569	0.0064	2.5350	0.5298	0.0029	3.1629	0.7387	0.0002	1.5396	0.1627
SGRTS	50	0.0002	1.0995	0.0712	0.0004	1.3061	0.1260	0.0002	1.6919	0.1954	0.0000	0.7742	0.0399
SGRTS	75	0.0002	0.5912	0.0240	0.0000	0.7675	0.0367	0.0000	0.9659	0.0626	0.0000	0.4649	0.0146
GRTSW	25	0.0550	0.9349	0.1006	0.0311	1.0794	0.1084	0.1093	1.4867	0.1881	0.0321	0.7705	0.0635
GRTSW	50	0.0447	0.3918	0.0408	0.0146	0.1692	0.0236	0.0955	0.5124	0.0963	0.0278	0.2531	0.0312
GRTSW	75	0.0195	0.2068	0.0184	0.0061	0.0545	0.0060	0.0126	0.3269	0.0383	0.0092	0.1093	0.0087
SGRTSW	25	0.0380	1.0054	0.1052	0.0288	1.1932	0.0913	0.0847	1.4548	0.2122	0.0338	0.7314	0.0687
SGRTSW	50	0.0339	0.3133	0.0551	0.0174	0.2366	0.0179	0.0966	0.4685	0.0907	0.0280	0.2232	0.0330
SGRTSW	75	0.0184	0.1787	0.0213	0.0059	0.0538	0.0063	0.0094	0.2945	0.0455	0.0079	0.0880	0.0104
IRS	25	0.0001	2.0056	0.3021	0.0028	2.6104	0.5221	0.0004	3.3097	0.8705	0.0003	1.6300	0.1889
IRS	50	0.0007	1.0628	0.0746	0.0001	1.2118	0.1130	0.0013	1.5960	0.1708	0.0003	0.8839	0.0495
IRS	75	0.0000	0.5793	0.0221	0.0001	0.7743	0.0400	0.0000	0.9766	0.0617	0.0001	0.4672	0.0144
SIRS	25	0.0001	1.8861	0.2484	0.0017	2.3454	0.4428	0.0008	3.4959	0.9143	0.0019	1.6129	0.1730
SIRS	50	0.0000	1.0231	0.0675	0.0000	1.3595	0.1296	0.0001	1.7419	0.1826	0.0000	0.8134	0.0468
SIRS	75	0.0000	0.5435	0.0194	0.0001	0.7703	0.0392	0.0000	0.9124	0.0571	0.0000	0.4591	0.0135
IRSW	25	0.0454	1.0660	0.1025	0.0232	1.3314	0.1302	0.0773	1.5789	0.2079	0.0286	0.7971	0.0625
IRSW	50	0.0251	0.5346	0.0316	0.0131	0.4821	0.0272	0.0380	0.7415	0.0707	0.0154	0.3672	0.0227
IRSW	75	0.0038	0.1824	0.0031	0.0024	0.0645	0.0025	0.0010	0.3144	0.0061	0.0015	0.1147	0.0023
SIRSW	25	0.0304	1.0643	0.1021	0.0148	1.4040	0.1315	0.0706	1.6371	0.2095	0.0265	0.8504	0.0594
SIRSW	50	0.0190	0.4848	0.0395	0.0112	0.5587	0.0237	0.0345	0.7522	0.0714	0.0147	0.3633	0.0226
SIRSW	75	0.0007	0.1326	0.0054	0.0023	0.0591	0.0026	0.0010	0.2604	0.0128	0.0016	0.0818	0.0027

[a]bias = (observed change – median of simulated change)^2

[b]var = (975th ranked simulated estimate of change – 25th ranked simulated estimate of change)^2

Table 3. cont'd.

Sampling	Effort	Calidris bias[a]	Calidris var[b]	Calidris mse	Whimbrel bias[a]	Whimbrel var[b]	Whimbrel mse	Willet bias[a]	Willet var[b]	Willet mse	Yellowlegs bias[a]	Yellowlegs var[b]	Yellowlegs mse
GRTS	25	0.0005	1.5047	0.1456	0.0014	4.4527	1.7536	0.0001	2.8746	0.5338	0.0000	2.2674	0.1221
GRTS	50	0.0000	0.7179	0.0365	0.0001	1.7026	0.2022	0.0002	1.4470	0.1298	0.0005	1.2886	0.0432
GRTS	75	0.0001	0.4538	0.0131	0.0004	0.9651	0.0610	0.0000	0.8161	0.0430	0.0003	0.6767	0.0129
SGRTS	25	0.0000	1.3642	0.1336	0.0024	4.7511	3.4265	0.0014	2.6499	0.5128	0.0002	2.2623	0.1188
SGRTS	50	0.0000	0.8127	0.0401	0.0001	1.6137	0.1879	0.0000	1.3901	0.1360	0.0004	1.0874	0.0348
SGRTS	75	0.0002	0.4385	0.0129	0.0002	0.9706	0.0638	0.0000	0.8372	0.0464	0.0000	0.6378	0.0109
GRTSW	25	0.0301	0.7297	0.0552	0.0213	1.5472	0.1778	0.0734	1.3629	0.1585	0.1941	0.9633	0.1476
GRTSW	50	0.0187	0.2776	0.0228	0.0286	0.4974	0.0375	0.0390	0.3860	0.0644	0.1695	0.3096	0.1358
GRTSW	75	0.0053	0.0766	0.0053	0.0333	0.2208	0.0323	0.0067	0.1723	0.0144	0.0871	0.1835	0.0859
SGRTSW	25	0.0250	0.6875	0.0618	0.0258	1.6533	0.1789	0.0609	1.2743	0.1640	0.1427	1.0845	0.1974
SGRTSW	50	0.0171	0.2156	0.0264	0.0288	0.5633	0.0380	0.0511	0.4085	0.0505	0.1358	0.3873	0.1695
SGRTSW	75	0.0050	0.0744	0.0058	0.0333	0.1769	0.0325	0.0057	0.1623	0.0159	0.0859	0.1726	0.0871
IRS	25	0.0000	1.4323	0.1408	0.0075	5.0053	5.2314	0.0000	2.5760	0.4955	0.0000	2.4438	0.1293
IRS	50	0.0006	0.8612	0.0455	0.0000	1.9233	0.2476	0.0010	1.4068	0.1357	0.0000	1.3095	0.0416
IRS	75	0.0000	0.4759	0.0147	0.0001	1.0022	0.0643	0.0000	0.8424	0.0424	0.0000	0.7177	0.0141
SIRS	25	0.0001	1.4565	0.1475	0.0023	4.2660	1.9910	0.0001	2.5285	0.4559	0.0006	2.3727	0.1200
SIRS	50	0.0000	0.7934	0.0412	0.0000	2.1920	0.3218	0.0001	1.4378	0.1226	0.0000	1.2592	0.0319
SIRS	75	0.0001	0.4490	0.0131	0.0003	0.9610	0.0598	0.0000	0.8272	0.0425	0.0000	0.7293	0.0121
IRSW	25	0.0183	0.7620	0.0590	0.0285	1.7770	0.2123	0.0434	1.4714	0.1520	0.1648	1.0715	0.1257
IRSW	50	0.0093	0.3718	0.0181	0.0315	0.7842	0.0524	0.0234	0.6058	0.0491	0.1282	0.4638	0.0904
IRSW	75	0.0012	0.1203	0.0013	0.0316	0.2604	0.0246	0.0014	0.1688	0.0029	0.0404	0.1738	0.0412
SIRSW	25	0.0175	0.8363	0.0549	0.0068	1.7294	0.2407	0.0385	1.4007	0.1588	0.1027	1.2073	0.1703
SIRSW	50	0.0078	0.3754	0.0210	0.0341	0.6806	0.0546	0.0243	0.6982	0.0440	0.0898	0.5561	0.1282
SIRSW	75	0.0008	0.0568	0.0022	0.0316	0.1930	0.0276	0.0010	0.1418	0.0048	0.0412	0.1862	0.0404

[a]bias = (observed change – median of simulated change)^2

[b]var = (975th ranked simulated estimate of change – 25th ranked simulated estimate of change)^2

Table 4. Summary of power (probability) to detect a 50% decline in abundance over 20-years at the p = 0.05 significance level using 25% effort and a stratified-weighted GRTS sampling for surveys conducted annually, every other year (EOY) and every fifth year (FFY). The p = 0.15 significance level was also used for all species.

Species	**Annual**[a]	**EOY**[b]	**EFY**[c]
Avocet	0.89	0.05	0.00
Stilt	0.89	0.01	0.00
Willet	0.94	0.02	0.00
Yellowlegs	1.00	0.07	0.00
Curlew-Godwit	0.80	0.04	0.00
Whimbrel	0.88	0.03	0.00
Calidris	0.88	0.04	0.00
Dowitchers	0.83	0.04	0.00
All - p = 0.05	0.99	0.06	0.00
All - p = 0.15	1.00	0.63	0.00

Figure 1. Distribution of 224 sampling locations used in simulations to assess sampling frameworks for wintering shorebirds in the San Francisco Bay.

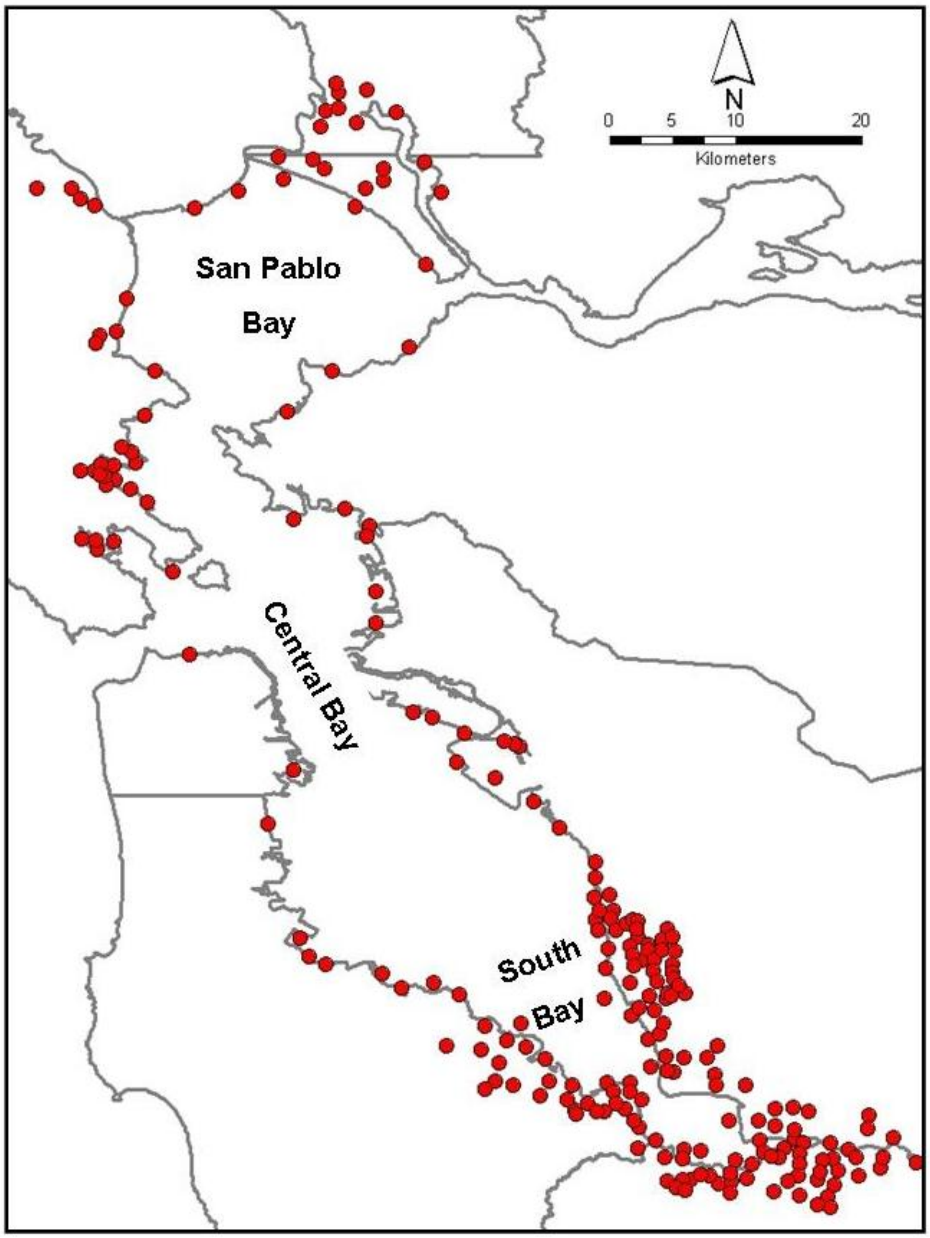


Figure 2. Observed change in the abundance of roosting shorebirds in each species-species group between 1990-92 and 2006-08 based on the complete set of 224 survey locations in the San Francisco Bay. Hollow diamonds indicate a significant change (*p* = 0.10) based on the non-parametric Mann-Whitney U test.

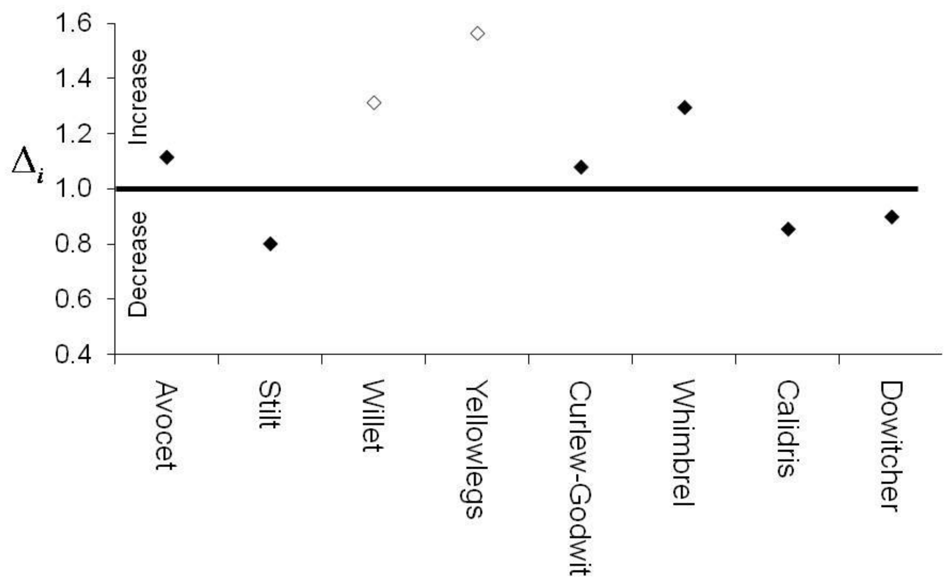


Figure 3. Average bias, variance, and mean-squared error across all 8 species-species groups for each sampling regime and effort level evaluated using November shorebird roost count data from the San Francisco Bay, 1990-92 and 2006-08. See Table 2 for sampling scenario codes. All weighted scenarios ("W") used the natural logarithm of the total count in the sampling unit (1990 – 1992) as the continuous weighting values.

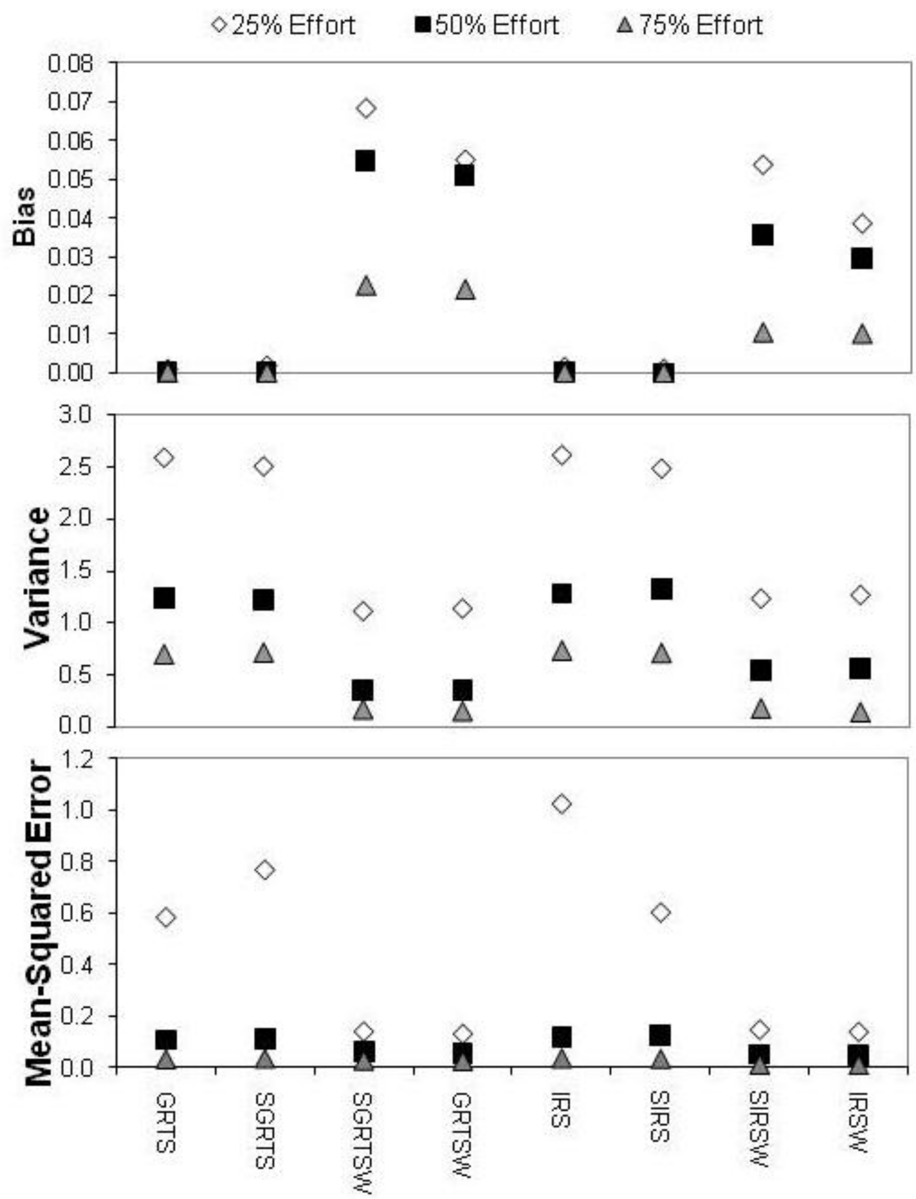
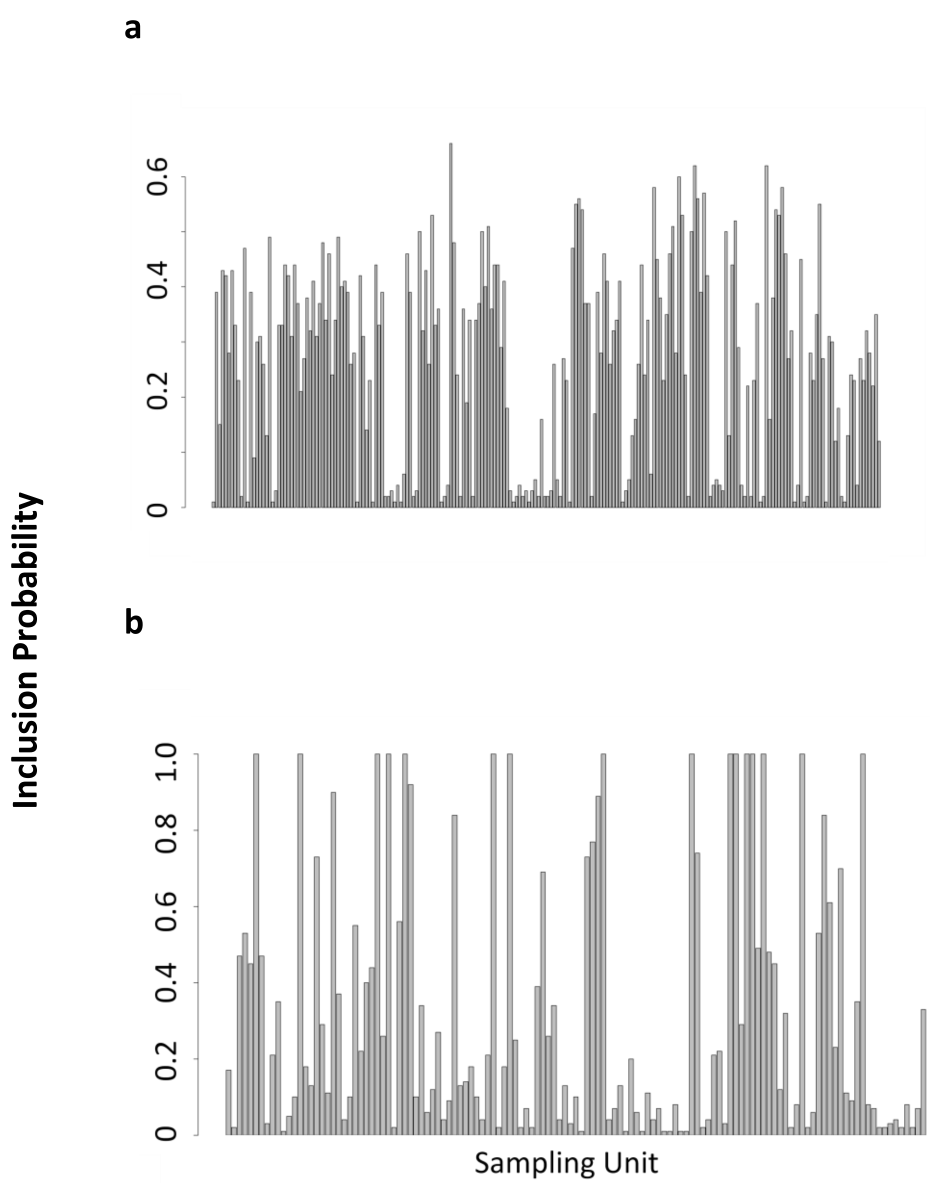


Figure 4. Inclusion probabilities for 224 sampling units in San Francisco Bay based on 1000 draws of a stratified GRTS sample using (a) the natural-logarithm of the total shorebird count as a continuous weight, and (b) the non-transformed total shorebird count as a continuous weight.



APPENDIX II:

Area Search Protocol for Roosting Shorebirds

San Francisco Bay Only

PLEASE READ: *The usefulness of data collected as part of these surveys requires that all observers closely follow the protocol outlined here. Please read the protocol and associated documents (area description(s), map(s), and data forms) thoroughly before conducting a survey. If you have any questions please contact Lishka Arata (larata@prbo.org) or Len Liu (lliu@prbo.org). Thank you in advance for your hard work and enthusiasm for birds.*

PURPOSE

These surveys are designed to obtain data on annual variation and long-term trends in wintering shorebird use of the San Francisco Bay Estuary (SF Bay). These data will be combined annually with shorebird survey data from across California and the Pacific Flyway to assess spatial and temporal patterns of shorebird abundance at a scale larger than SF Bay. This will allow for trends observed in SF Bay to be put into a broader context of shorebird populations.

SURVEY DESIGN

These surveys consist of searching a randomly selected set of pre-defined survey areas (n = 100) in SF Bay for BOTH roosting and non-roosting shorebirds and identifying the species present and estimating their abundance. Surveys are conducted when local tidal conditions (determined by the nearest tide station) are high enough to force shorebirds off of mudflat foraging areas throughout SF Bay (a tide that is ~6 feet higher than MLLW at the Golden Gate Bridge). Surveys should be conducted as close to high tide as possible to minimize variation due to bird movement as tidal conditions change. Surveys will be conducted once annually during the survey window (November 15 – December 15), and efforts will be made to coordinate the timing of these surveys across SF Bay. All data will be entered directly into the California Avian Data Center (CADC) via an online data entry portal.

SURVEY PROTOCOL AND DATA COLLECTION

** Because factors on the day of the count (e.g., wind, atmospheric pressure) may influence tidal height and timing, please try to be at your area slightly before the predicted start time to ensure adequate time to complete the survey.

**Surveys should not be conducted in weather with winds >24 mph (>5 on scale below), heavy fog (<200m visibility), or steady rain.

**Surveys should be conducted by one observer. Having multiple observers counting simultaneously may bias results. We recommend working in pairs where one person counts birds and a second person records data. In large areas or areas with large numbers of birds, additional observers should split the count effort in order to complete the count in the allotted tidal window (~1.5 hours before and after high tide). The total number of observers (people counting) should be listed on the data sheet and entered into the California Avian Data Center (CADC).

**Read accompanying datasheet along with this protocol.

** If possible, we urge you to visit your survey area prior to the day of the survey so you are certain how to easily access the area.

** Some areas require access keys and permits. If this applies to you, these materials will be included in your packet.

Begin each count of each survey area by indicating the **start time** on the datasheet (24-hr clock; e.g. 3PM = 1500). Then move around, as needed, to count and identify to species all shorebirds using the area. This <u>includes birds that enter or leave</u> the survey area during the count. For a bird to be considered "using" the survey area, it needs to be on the ground within the defined survey area for at least part of the time it takes to do the survey. Thus, birds that fly over the survey area but do not land in it should <u>NOT</u> be counted. Try not to double count birds if they leave and then re-enter the survey area. Also, record the number and species of raptors (e.g. hawks, falcons) that are within, perched adjacent to, or soaring over the survey area during the count.

Efforts should be made to complete roost counts within the optimal 3 hour survey window around high tide. Once all birds in the survey area have been recorded, the count is considered complete. At that point, the **end time** should be noted on the datasheet and thereafter <u>NO</u> additional birds should be recorded for that survey area. The number of observers should be matched to the survey area size and the anticipated number of birds to allow the completion of the survey within the ~3 hour window. **NOTE:** In 2010 please conduct surveys of your areas over as much time as needed to complete the counts. However, in future years we hope to conduct the surveys of all locations in as small of a window as possible. Please indicate how many observers were surveying your area on the data form. Also indicate in the survey notes the number of people that would be needed to complete the counts in a 2 – 3 hour time allotment if you were not able to do so. This will inform our future efforts.

Species are recorded in the appropriate column of the datasheet. Regardless of whether the observer tracks sub-tallies in the **tally** column for each species (see "PFSS_RecTips.pdf" for sub-tally techniques), ONLY the total number of each species observed during the count of each survey area should be entered into the **Count** column. It usually will be possible to make exact counts of small groups of birds (<50 individuals), but estimation may be needed for larger flocks. Please see the accompanying document ("PFSS_HowToCount.pdf") for recommendations on counting techniques and estimating the abundance of birds in flocks.

Because of poor lighting, quick or distant views, similarity of species, or other factors, it may not be possible to identify a few or, sometimes, even large numbers of shorebirds. If individual species cannot be identified and counted within a flock, note the species that are in the flock and estimate the total flock size. Even better, estimate the proportion or the ratio of the species in a flock. If the proportion of each species is determined this should be used along with the total in the flock to estimate the number of each species. If the proportion of each species CANNOT be determined species should be recorded as a mix of the species identified in the flock. Please see the species list provided ("PFSS_SpeciesList.pdf") for commonly recorded mixed-species flocks.

Try to count or estimate numbers by whatever technique works best as listed here in order of preference:

- Identify species and their abundance (i.e., 148 Western Sandpipers, 153 Dunlin, 308 Least Sandpipers)
- Estimate the proportion of species in flock and use the proportions and total flock size to calculate the total of each species (i.e., 600 birds: 25% Western, 25% Dunlin, 50% Least = 150 Western, 150 Dunlin, and 300 Least)**This is not necessarily preferable to below if the proportions are highly inaccurate. Please use a mixed-species code if necessary.
- Estimate size of flock and species present (i.e., 500 birds, composed of Marbled Godwits and Long-billed Curlew.).

Following bird observations in each survey area, please fill out the remainder of the datasheet completely, including **Date** (mm/dd/yyyy), **Observer(s)** who counted birds (full name[s]), **Total observers** (number of people counting birds) and **weather conditions** (see below). Data should be recorded on a separate datasheet for each unique **Survey Area,** which is assigned a specific ID code.

Survey area ID codes are found on the survey area map. Please fill out a datasheet **even if no birds were detected**. This will help us determine the total effort expended during each survey and knowing that zero birds were observed is important data too.

SITE CONDITIONS

Please record weather and habitat conditions for each survey area using the following codes.

WEATHER

Wind speed (**Wind**).

**Do not conduct surveys when wind speed is > 24mph (> category 5 below).*

0 – *calm*: smoke rises vertically (<1 mph)

1 – *light air*: smoke drifts (1 – 3 mph)

2 – *light breeze:* felt on face, leaves rustle (4 – 7 mph)

3 – *gentle breeze*: leaves and small twigs in constant motion (8 – 12 mph)

4 – *moderate breeze*: dust, leaves, and loose paper rise up; small branches move (13 – 18 mph)

5 – *fresh breeze*: small trees sway (19 – 24 mph)

Cloud cover (**Sky**):

0 – no clouds

1 – 1-25% cloud cover

2 – 26-50% cloud cover

3 – 51-75% cloud cover

4 – 76-100% cloud cover

Precipitation (**Precip**):

0 – none

1 – light intermittent; mist, sprinkle, drizzle

2 – fog

3 – rain (NOTE: surveys should not be conducted in rain but if the survey is conducted please record this code.)

HABITAT

Area Surveyed (**Area**):

**Because roosting shorebirds can only be detected through visual observation, visual obstructions (e.g. levee, tall vegetation) may limit your ability to survey some portions of the survey area. Please indicate how much of the survey area you could see and subsequently count.*

0- 0%

1 – 1-25%

2 – 26-50%

3 – 51-75%

4 – 76-100%

WHAT TO TAKE IN THE FIELD:

Site Map(s)
Protocol
Datasheets
Area entry permit (if applicable)
Species list
Pencils or Permanent Ink Pen (≥2; NO ballpoint pens)
Binoculars
Scope and tripod
Watch
Sunscreen
Water
Field guide
Bicycle (if permitted and advisable in your area's directions)

Data Entry

Data should be entered directly into the SFSS project in CADC within a few days of the survey. If you have not registered for a CADC account please see http://data.prbo.org/partners/pfss for instructions on how to register with CADC and enter data.

Shorebird Species Identification

View or download instructional shorebird identification materials at PRBO's Pacific Flyway Shorebird Survey website: http://data.prbo.org/partners/pfss/.

San Francisco Bay Shorebird Survey Field Form

Site Name (e.g., Brooks Island) ________ Site Code (e.g., A21) ________

Date (MM/DD/YYYY) ________ StartTime (24-hr) ________ EndTime ________

Observers (names) ________ Total Observers ________

Wind (0 - 5) ________ Sky (0 - 4) ________ Precip (0 - 3) ________

Area (0 - 4) ________

Site / Survey Notes:

Species	Count	Tally	Species	Count	Tally
Black-bellied Plover			Whimbrel		
			Willet		
Snowy Plover					
Semipalmated Plover					
			large sandpiper, unid spp.		
Killdeer			curlew/godwit		
Am Golden-Plover					
Pac Golden-Plover			curlew/whimbrel		
golden-plover, Am/Pac					
Black Oystercatcher			curlew/whimbrel/godwit		
Black-necked Stilt					
			curl/whim/godwit/willet		
American Avocet			godwit/willet		
Greater Yellowlegs			Wandering Tattler		
			Surfbird		
Lesser Yellowlegs			Ruddy Turnstone		
yellowlegs, unid species			Black Turnstone		
Solitary Sandpiper					
Buff-breasted Sandpiper			Red Knot		
Spotted Sandpiper					
Long-billed Curlew					
			Sanderling		
Marbled Godwit			Dunlin		

Species Notes

Field Form

Species	Count	Tally	Species	Count	Tally
Western Sandpiper			med-sized shorebirds **		
			Wilson's Snipe		
			Wilson's Phalarope		
			Red-necked Phalarope		
			red-necked/red phalarope		
Least Sandpiper			red-necked/Wilson's phal.		
			Red Phalarope		
			phalarope unid. spp.		
			OTHER SPECIES :		
western/least sandpiper					
western/least/dunlin					
western/dunlin			RAPTORS:		
			Turkey Vulture		
west/leas/dunl/sanderling			Osprey		
small sandpiper, unid spp.			White-tailed Kite		
Semipal Sandpiper			Northern Harrier		
Baird's Sandpiper			Sharp-shinned Hawk		
Pectoral Sandpiper			Cooper's Hawk		
Sharp-tailed Sandp			Red-shouldered Hawk		
Rock Sandpiper			Swainson's Hawk		
Stilt Sandpiper			Red-tailed Hawk		
Ruff (Reeve)			Ferruginous Hawk		
sm shorebird, sandp/plov **			Rough-legged Hawk		
Shrt-billed Dowitcher*			American Kestrel		
Lng-billed Dowitcher*			Merlin		
dowitcher, unid spp. *			Peregrine Falcon		
			OTHER RAPTORS:		

Dowitchers: We suggest that observers count all dowitchers as dowitcher spp.

Try not to use these categories

Add up your tallies and enter sum in count column.

Enter data directly into the California Avian Data Center: http://data.prbo.org/cadc/

Make a photocopy of this form as a backup and mail the original form and maps to:

Len Liu
PRBO Conservation Science
3820 Cypress Drive #11
Petaluma, CA 94954

Primary contact information

Name ______________________

Mailing address ______________________

Phone Number ______________________

Email ______________________

Example: *Sampling Unit Description*

D10: Bay Farm Island NW shore

By bike, take BART to Fruitvale Station and head south across the bridge to Alameda Island. Turn left at Fernside Dr., which will take you all the way to the Bay Farm Island bridge. The bike path is on the north-bound side of the road however, so be careful. After you cross over, pass under the bridge and start the survey of the shoreline (**D10**) via the public trail.

If traveling by car, take I-880 to the High St. exit in Oakland and head southwest toward Alameda. Cross over the High St. bridge and take the first left onto Fernside Blvd. and follow to CA-61. Turn left and cross over the bridge to Bay Farm Island, then turn right at the first light onto Island Drive. Follow Island Drive to the 2nd intersection and turn right at Robert Davey Jr., and then another right at the next intersection, Packet Landing Rd. There is Bay Trail parking in the lot at the end of Packet Landing Rd.

There is another parking lot at the ferry terminal (circled in blue on the overview map). To reach this lot, return to Robert Dave Jr. and turn right. At the "T" intersection with Aughinbaugh Way, turn left. Take this to Mecartney Rd., and at the end of Mecartney on the left is the ferry parking lot.

You will probably encounter few shorebirds until you reach the open areas around Harbor Bay Pkwy., where you'll likely hear and find Killdeer just south of the ferry terminal. Conditions improve dramatically at the southern tip of the site, at a small marsh. The public shoreline trail eventually ends as the business parks begin, so the last sections of the marsh have to be viewed by visiting each individual business park and looking for gaps in fences and vegetation where you can see suitable habitat.

Good luck, thank you, and have fun!


Court St
Bayview Dr
Fillmore St
Calhoun St
Fernside Blvd
Nantucket Way
Otis Dr
Peach St
Bay Farm Island Bridge
D10
Sea View Pkwy
Bay Park Terrace
Palm Beach Ln
Norwich Rd
Oak Park Dr
Packet Landing Rd
Avington Rd
Roxburg Ln
Purcell Dr
Centre Ct
Berkshire Rd
320 m
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61
Google


Otis Dr
D10
D05
D07
D08
D07
Doolittle Dr
D10
D10
1128 m
Image © 2008 TerraMetrics
© 2008 Tele Atlas
© 2007
Google


D10
Silva Ln
Pyne Ln
N Loop Rd
A St
Harbor Bay Pkwy
S Loop Rd
Oakland Int'l Airport
Image © 2008 TerraMetrics
© 2008 Tele Atlas
412 m
Google


Court St
Bayview Dr
Fillmore St
Calhoun St
Fernside Blvd
Nantucket Way
Otis Dr
Peach St
Bay Farm Island Bridge
D10
Sea View Pkwy
Bay Park Terrace
Palm Beach Ln
Norwich Rd
Avington Rd
Oak Park Dr
Purcell Dr
Packet Landing Rd
Centre Ct
Roxburg Ln
Berkshire Rd
320 m
61
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Pacific Flyway Shorebird Survey Species List

The following list contains species that you are likely to see during winter shorebird surveys within California. This list is NOT comprehensive and we ask that you record all shorebirds (suborder: Charadrii) that you identify. The California Avian Data Center (CADC) will allow you to look up the “Species Code” for species that are not listed here (see “PFSS_CADCprotocol.pdf”). Most protocols, as part of PFSS, ask that you only record shorebirds and diurnal raptors. These species are listed first as “Primary Species”. Additional species that may be counted as part of other protocols are listed below as well.

SECTION I: Primary Species

Shorebirds

Species	Species Code
Black-bellied Plover	BBPL
American Golden-Plover	AMGP
Pacific Golden-Plover	PAGP
Snowy Plover	SNPL
Semipalmated Plover	SEPL
Killdeer	KILL
Mountain Plover	MOPL
Black Oystercatcher	BLOY
Black-necked Stilt	BNST
American Avocet	AMAV
Spotted Sandpiper	SPSA
Solitary Sandpiper	SOSA
Wandering Tattler	WATA
Greater Yellowlegs	GRYE
Lesser Yellowlegs	LEYE
Greater/Lesser Yellowlegs	XYEL
Willet	WILL
Whimbrel	WHIM
Long-billed Curlew	LBCU
Whimbrel/Curlew	XNUM
Marbled Godwit	MAGO
Curlew/Godwit	XCGO
Whimbrel/Curlew/Godwit	XWCG
Godwit/ Whimbrel/Willet/Curlew	XWNG
Ruddy Turnstone	RUTU
Black Turnstone	BLTU

Surfbird	SURF
Red Knot	REKN
Sanderling	SAND
Semipalmated Sandpiper	SESA
Western Sandpiper	WESA
Least Sandpiper	LESA
Baird's Sandpiper	BASA
Pectoral Sandpiper	PESA
Rock Sandpiper	ROSA
Dunlin	DUNL
Western/Least Sandpiper	XWLS
Western/Least/Dunlin	XWLD
Stilt Sandpiper	STSA
Ruff	RUFF
Short-billed Dowitcher	SBDO
Long-billed Dowitcher	LBDO
Short-billed/Long-billed Dowitcher	XDOW
Wilson’s Snipe	WISN
Wilson's Phalarope	WIPH
Red-necked Phalarope	RNPH
Red Phalarope	REPH
Wilson's/Red-necked Phalarope	XWRP
Wilson's/Red-necked/Red Phalarope	XPHL

DIURNAL RAPTORS

Species	Species Code
Turkey Vulture	TUVU
Osprey	OSPR
White-tailed Kite	WTKI
Bald Eagle	BAEA
Northern Harrier	NOHA
Sharp-shinned Hawk	SSHA
Cooper's Hawk	COHA
Unidentified Hawk	XXHA
Red-shouldered Hawk	RSHA
Swainson's Hawk	SWHA
Red-tailed Hawk	RTHA
Ferruginous Hawk	FEHA
Rough-legged Hawk	RLHA
Golden Eagle	GOEA
American Kestrel	AMKE
Merlin	MERL
Peregrine Falcon	PEFA
Prairie Falcon	PRFA

TIPS FOR COUNTING SHOREBIRDS

This document includes information to help with identifying shorebirds, counting multi-species flocks, counting techniques, keeping track of where you are, and handling field difficulties. Because most non-breeding shorebirds occupy unvegetated or sparsely-vegetated habitat in which they can be easily observed, the accepted method of estimating their abundance in an area is to count them directly through visual observation. This requires that a person conducting an area survey (an observer) possess two important skills, in addition to being familiar with the survey protocol: (1) the ability to ***readily*** identify all species likely to occur in the area, and (2) the ability to count the number of each species present.

Identifying Shorebirds. Attending field trips led by experienced observers is a good way to learn shorebird identification; these are often offered by local Audubon, natural history societies, colleges, adult education programs, and PRBO Conservation Science (see http://data.prbo.org/partners/pfss/). Practicing on your own with one of the many good field guides available is essential to honing your skills. If you are a beginner, ultimately, you will need to go out with an experienced observer to validate your identification skills. Observers must develop a slightly different set of skills than casual bird watchers because they are counting all the birds in an area, not just those that are conveniently near or well lit for viewing. You may need to identify shorebirds that are in silhouette, shorebirds that are tightly packed in a roosting flock, or very large numbers of shorebirds in mixed flocks. You need to be able to identify them fairly rapidly, before they have a chance to move or fly; this is particularly an issue where raptors are active. Familiarity with the subtle differences in the shape, posture, behavior, and coloring between species is invaluable during a census.

Counting techniques. Direct counting is useful for low numbers of birds, and estimation is essential for large flocks. Some techniques involve a combination of counting and estimation. It is not unusual in the middle of a census to have shorebird flocks fly up, circle in the air, and land again; they may land where they previously arose, may land to join a nearby flock, or may leave the immediate area. Rising or falling tide levels, human disturbance, and raptors in the areas may cause this to happen multiple times during a census. In order to obtain counts before flock movement causes you to have to start counting over again, you need to balance the need for highly refined counts with the need to complete the count quickly.

For fewer than 50, or widely scattered, shorebirds you probably will count individual birds. This may not be the most accurate count method for large flocks because of flock movement. With larger flocks, you should start at one side of the flock and count 5, 10, 20, or 50 shorebirds at a time. Once you have a good idea of what, say, 20 birds look like in that flock, you can count the remainder of the flock in groups of 20 birds. For very large flocks, it may be necessary to count in much larger multiples. After you have conducted many surveys you will hone your ability to quickly estimate group sizes of birds. However, it always is useful to count out bird groups in the beginning of each survey, as a defense against developing estimating biases.

Counting shorebirds in multi-species flocks*.* When beginning a survey of shorebirds at a site you must quickly decide whether to count all the birds together or scan the flock successively for each species present. With experience you will learn which method is most efficient for you, given the abundance, species composition, and dispersion of the shorebirds. Mixed species assemblages may be present as two or more species in relatively equal abundance, as predominantly one species with a few uncommon species, or some combination. We recommend having a recording assistant to whom you can enumerate the uncommon species as you maintain a running count of the most common species while you scan the flock. With experience, you may learn to count more than one species simultaneous as you are scanning or you may develop your own technique for handling multiple species counts.

Keeping track of where you are is essential when you are conducting a survey. Few areas can be covered from a single vantage point and you will have to move between points to count all birds. It often is difficult to relocate where you left off counting from a new vantage point, so think about all possible clues you will be able to use from your next location. Geographically distinct points in the wetland or background habitat (think about what it will look like from your next vantage point), a break in the flocks, or an individual of an uncommon species can be used to mark where you have left off counting. Move quickly to the next vantage point, locate where you left off, and begin counting.

Recording shorebird counts in the field involves counting multiple species, keeping track of where you are in the flock, and writing it all down. The way you keep your written field records will determine how difficult it is to tally a final count afterwards. On a separate handout (“PFSS_RecTips.pdf”), there are some tips on recording your data in the field. However, to minimize recording errors it is best if a second person can serve as the data recorded.

Some other techniques you may find useful:

- Obtaining an initial impression of the numbers of shorebirds you will be counting can be very useful if a survey is interrupted because the birds have flown out of easy viewing range. When you first arrive at a viewing location, make on-the-spot order of magnitude estimates of the numbers of at least the most abundant species.

- Order of magnitude estimates (OMEs) can be based on powers of ten, using arithmetic divisions of low, mid, or high ranges. With this method, if there were more than 9 but fewer than 100 shorebirds, you would estimate either low tens (10-39), mid-tens (40-69), or high tens (70-99); estimates are similar for low, mid, or high hundreds (100-399, 400-699, 700-999), thousands, and so on.
- If you are training or refreshing yourself in counting methods, you might make OMEs first, then count the birds you've spot estimated, to check and refine your estimating accuracy.

Tally your survey total for each species, on the day you conduct the survey. If there are any uncertainties or errors in what you wrote in the field, you will best be able to decipher or catch them when the survey is fresh in your mind. See "PFSS_DataEntry.pdf".

TIPS FOR RECORDING COUNTS IN THE FIELD

Version 2 - September 22, 2010

Be sure that the way you record shorebird counts in the field doesn't confuse you when you tally the final counts afterwards. Here are some commonly used recording techniques that you can try to keep your notes readable when you are hurriedly trying to get it all down on paper.

For species that occur in large flocks, counts of birds are commonly recorded as numbers separated by a "+" or a "," or blank space:

225 + 48 + 677 + 32 OR 225, 48, 677, 32 OR 225 48 677 32

When you record this way, be sure that commas are distinguishable from "1"s, plus signs cannot be mistaken for numbers, and that blanks are wide enough to unambiguously separate numbers.

For species that are counted in smaller multiples, symbolic recording techniques may be helpful. Below are two that are commonly used. If, for some species, you use both numbers and symbols, physically separate them on the recording sheet.

❶ Most people are accustomed to crossed slashes for tallying in groups of 5, where:

1 = I 2 = II 3 = III 4 = IIII 5 = ┼┼┼┼

You can take shortcuts with this method. For example, if you have already tallied two (II) and you next see three, you could simply cross the vertical slashes (┼┼─), knowing that every horizontal slash indicates 5, even if it crosses fewer than 4 verticals. We use the X (Roman numeral) symbol within this system to indicate 10, and C to indicate 100. ***Do not intersperse this symbolic method with regular numbers***, where eleven is indicated as 11 (use X I in tally form) or one hundred eleven as 111 (use C I in tally form).

❷ Ten birds also can be accumulated with a symbolic combination of dots and connecting lines. You keep adding them till you have an X inside a box. The first through the fourth birds are indicated by dots at the four corners of a square: 1 = . 2 = . . 3= : . 4 = ::

The next four birds are indicated by connecting the dots: 5= I : 6 = I I 7 = Π 8 = ☐

The ninth and tenth birds are added with the two diagonal slashes to create an X within the box (**%** and ☒).

APPENDIX III

California Avian Data Center

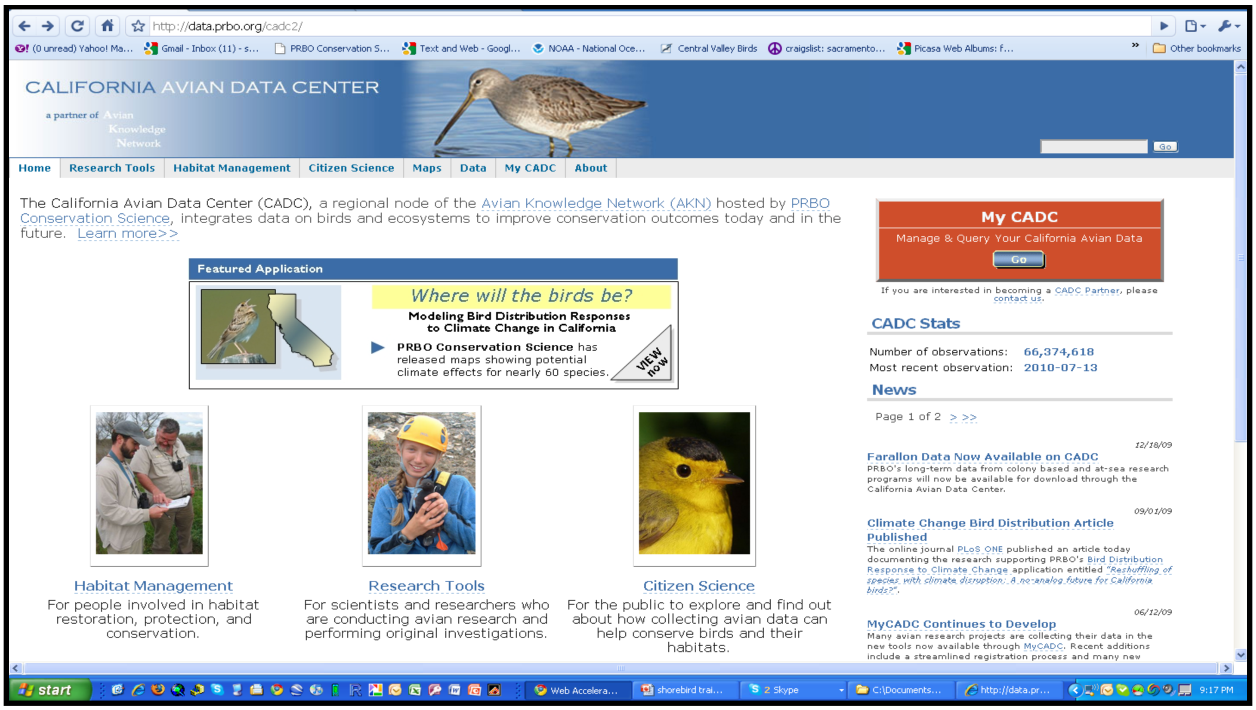
Registration & Data Entry

October 1, 2010

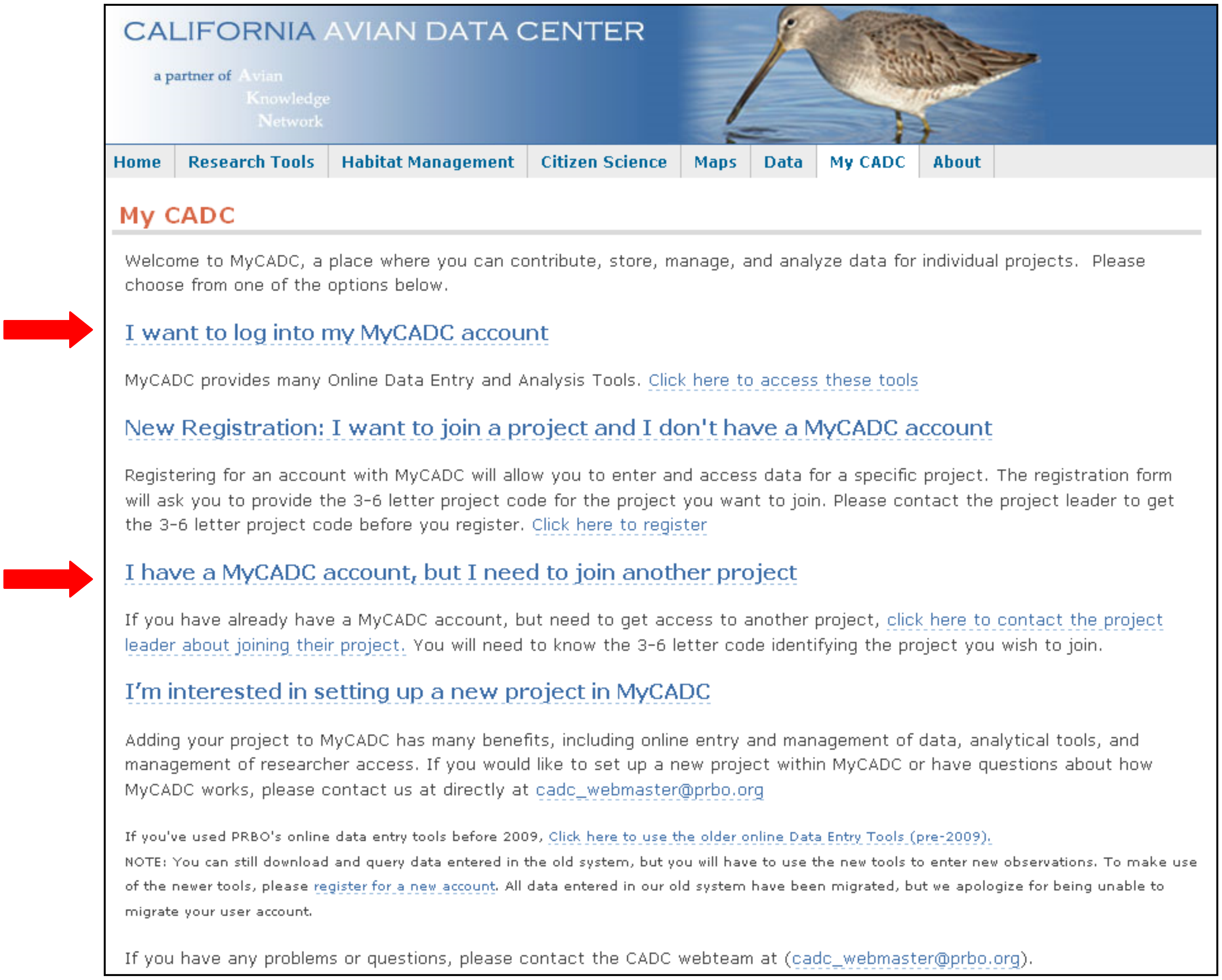
TO REGISTER

First time users must first register and create and user name and password.

1. Go to www.prbo.org/cadc
2. Click on the blue "**Go**" button in the red box in the upper right hand part of the page.



3. Select the appropriate selection on the next screen (below). Most will select "New Registration: I want…". However if you already have a MyCADC account you may join additional projects by selecting "I have a MyCADC account, but…".



4. Enter the information requested on the following page.

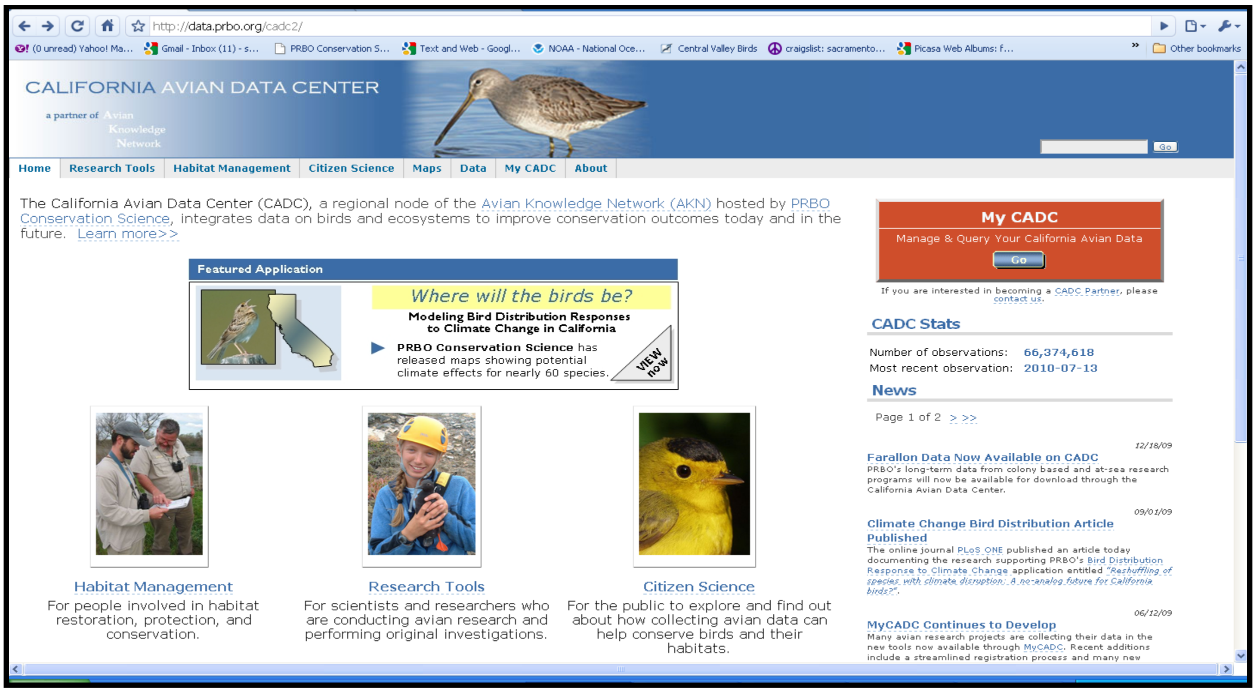
*****Note:* In Step 5 of the registration process when asked "Please enter the project you would like to join", enter **XXXX. (*Project code here*)**

After completing the registration page, an email from "no-reply@prbo.org" will be sent to the email account you entered. You will need to click the link provided in the email in order to complete your registration. The link will expire in 24 hours and you will have to re-register. If you do not receive your confirmation email promptly, check your junk or spam folder. After checking your spam folder, if you did not receive an email from no-reply@prbo.org please contact CADC help at "cadc_webmaster@prbo.org" with your name and email address used to register.

TO ENTER DATA:

A. Log-In

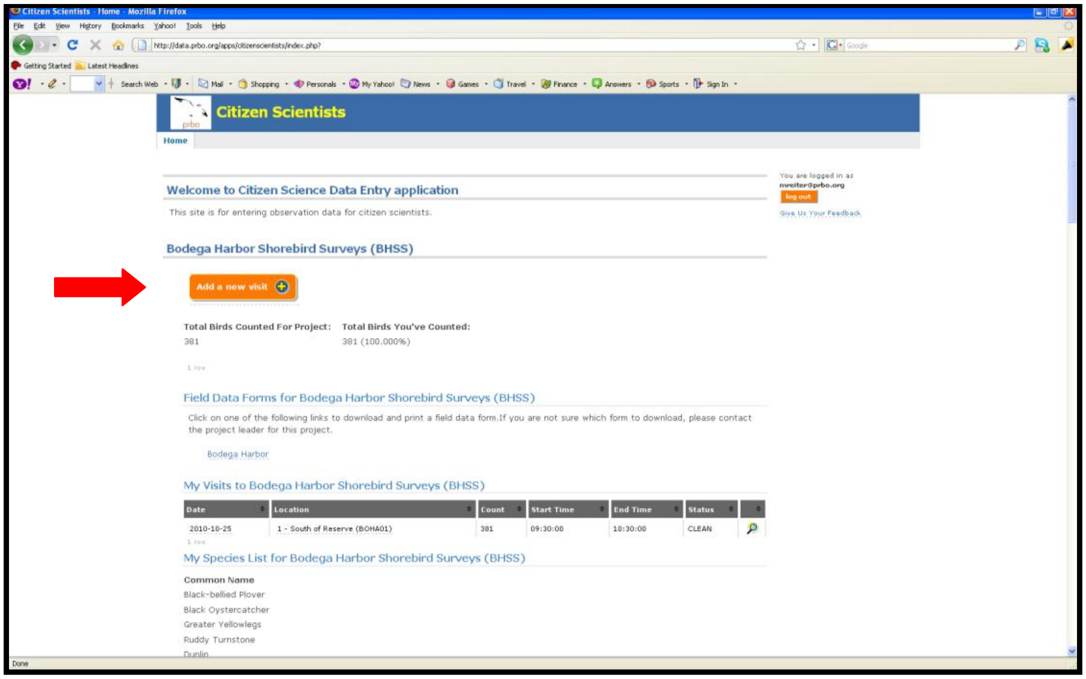
1. Go to www.prbo.org/cadc
2. Click on the blue "**Go**" button in the red box in the upper right hand part of the page (see below).



3. Next page, click on the link that says I want to log into MyCADC account
4. Next page, click on the link that says Citizen Scientists
5. Next page, enter email address and press enter
6. Next page, enter your password and press Log On

B. Select Project

Once you are logged-on, all the projects that you are associated with will show-up on the screen (see below.)



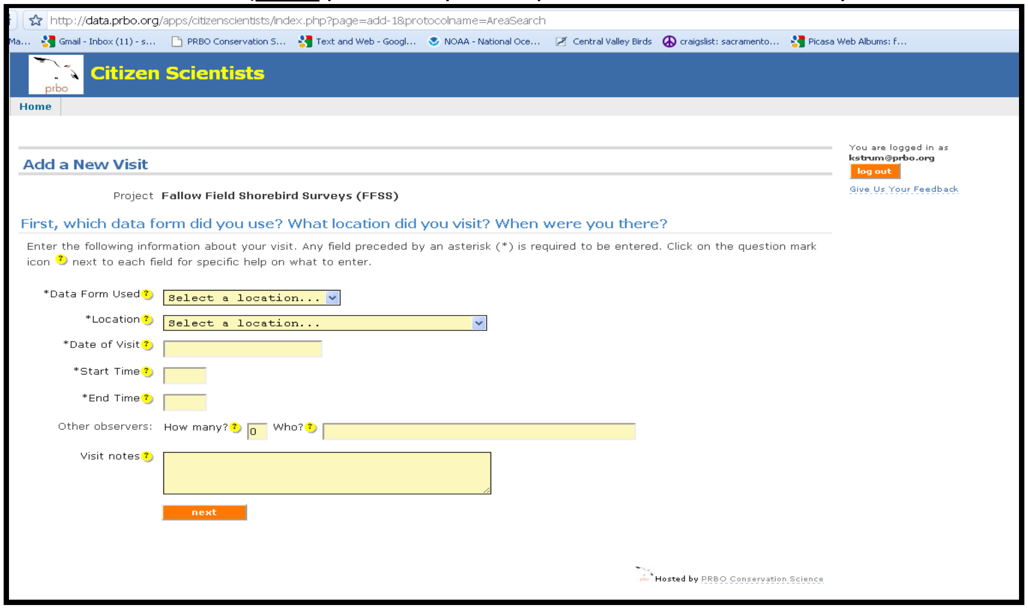
To enter new data click on the "**Add a new visit**" button (in orange above) that is associated with the project for which you want to enter data.

__**Note:**__ Each survey point or survey area should be recorded on a separate data sheet and should be entered separately as a new visit.

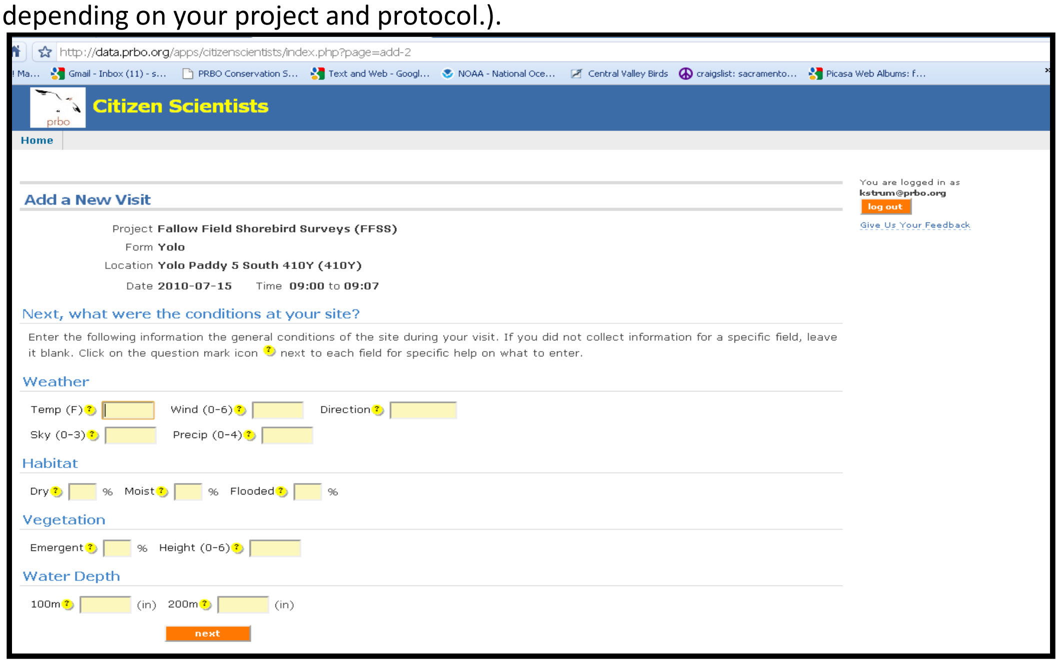
C. Enter Data

There are 3 data entry screens for getting PFSS data into CADC.

1. "Where did you survey? When did you survey? Who did the survey?" screen. The fields on this screen should match the fields on your data form. After filling in the fields press "**next"** at the bottom of the screen (**note:** press the yellow question marks next to any field to obtain help).

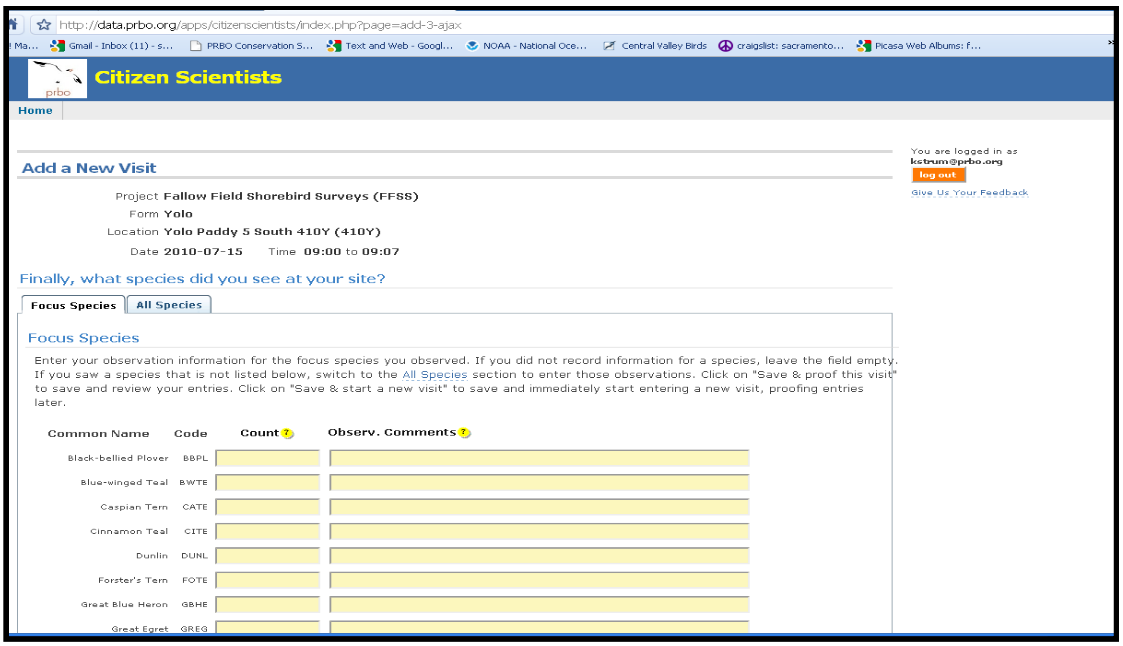


2. "What were the conditions at your site?" screen (below). The fields on this screen should match the fields on your data form and be described in the survey protocol. After filling in the fields press "**next"** at the bottom of the screen (**note:** fields may different than the example below depending on your project and protocol.).



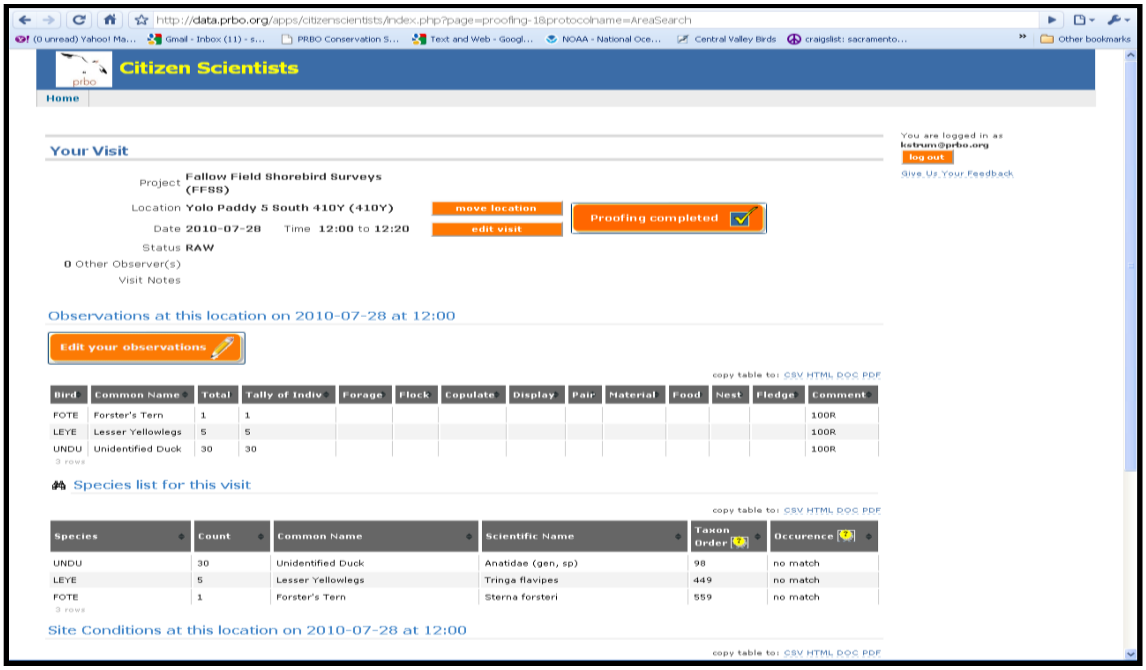
3. "Finally, what species did you see at your site?" screen (below).

   a. The "**Focus Species**" table contains the large majority of species that you will see on your surveys.
   b. Enter the "Count" for each species from your data sheet.
   c. You do NOT need to enter "0" for species you did not see.
   d. If you saw no birds at a survey site scroll to the bottom of the species table and press the orange "**No species observed Save & proof this visit**" button.
   e. If a species does not appear in the Focus Species table, use the "**All Species**" tab to enter data for species not listed in the table.
      a. Enter the name of the species in the provided space.
      b. Select the correct four-letter code from those listed and that match those in "PFSS_SpeciesList.pdf"
      c. Enter the "Count" for each species
      d. Press "**next**" before moving on the next species OR before switching back to the "Focus Species" table
   f. You can use the Focus Species and All Species tables interchangeably to enter data. However, please only enter data for species within the guilds listed in the project protocol and the project species list (i.e. do not enter gulls or terns.)
   g. Once you have entered all the species detection data press "**Save and Proof this Visit**"

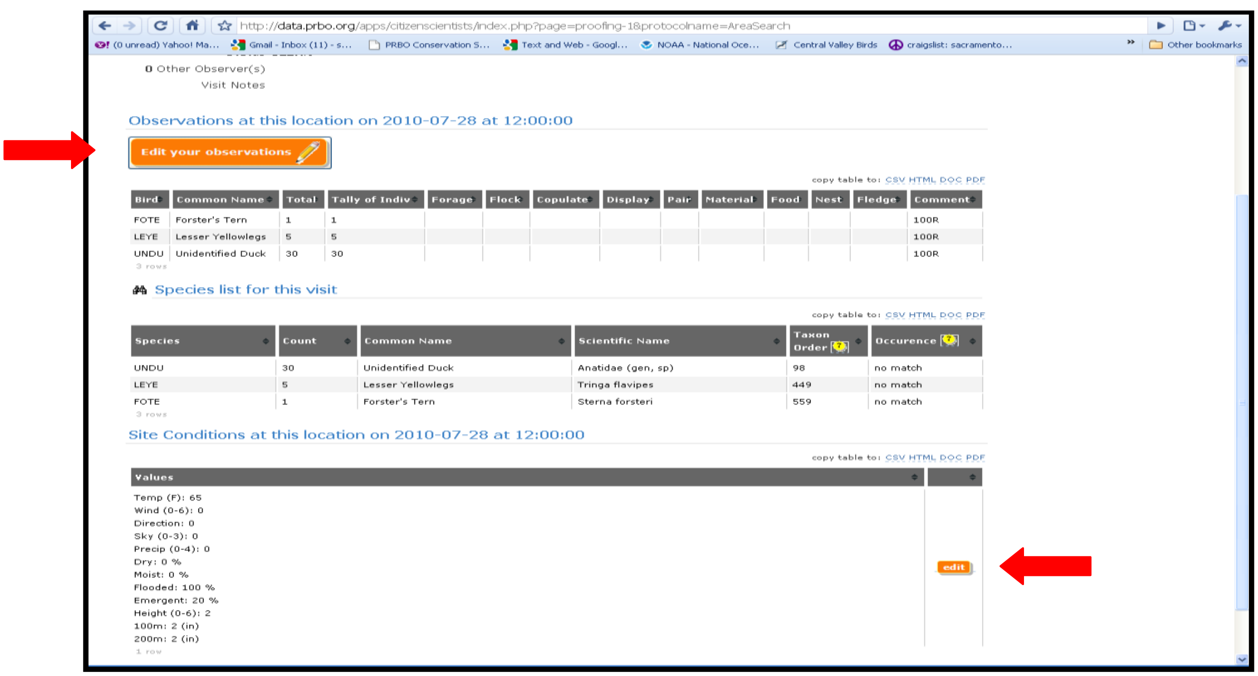


D. Proof Data

After clicking "**Save and Proof this Visit**" you should be taken to the following screen:



You must proof the data you entered in order for it to become part of the database. Look carefully through the data you entered and compare it to the data on your datsheet. If you note inconsistencies between your datasheet and what appers on the screen, follow the steps beginning with Step 1 below in the "Editing Data"section.



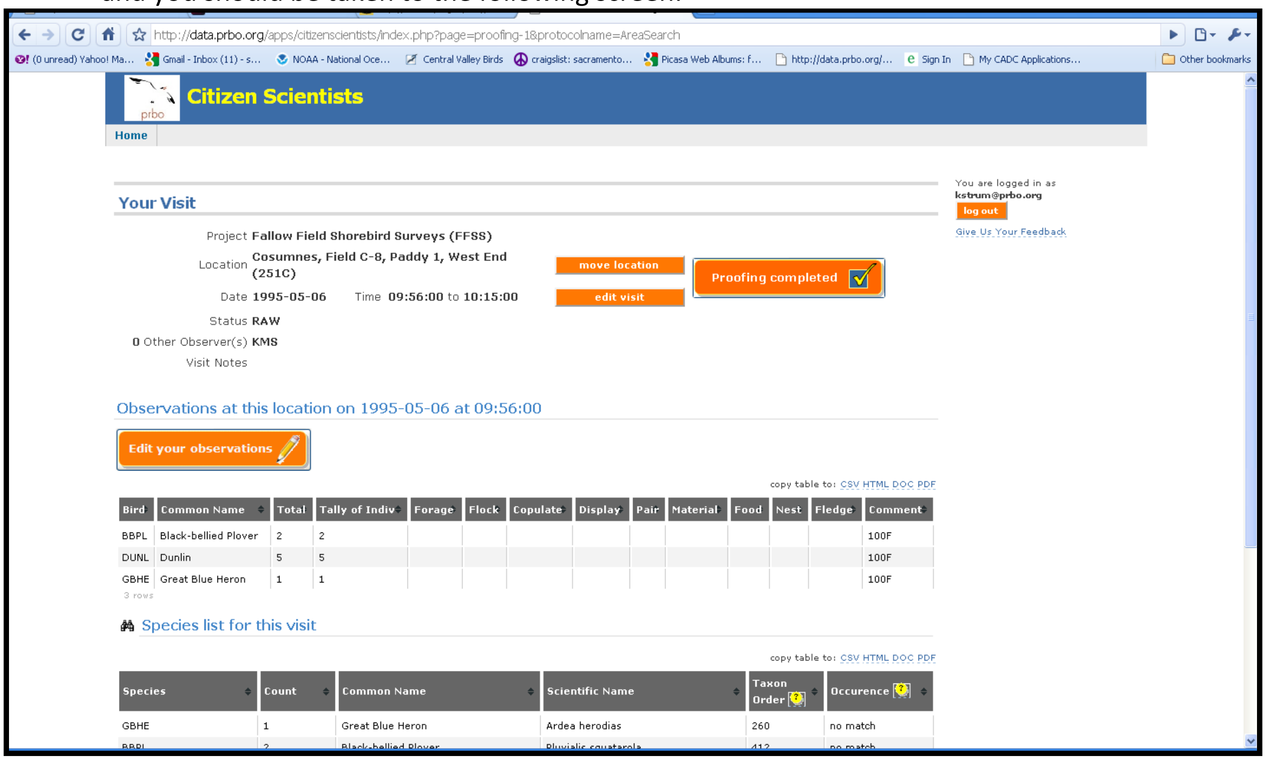
When you are finished proofing make sure to click on "**Proofing completed**" at the top of the page.

Go back and follow each step to enter data for the rest of the survey points or areas.

E. Edit Data

After you enter your data you may be asked to make corrections or you may realize you have entered something incorrectly. Each section of data (site condicitons, dectections, etc.) has a unique place for editing data.

1. To edit your data, log on into CADC (see **A. Log In** above).
2. Click the magnifying glass  next to the observation in the project that you would like to edit and you should be taken to the following screen:



3. To edit the ***Location*** click "**Move Location**". Choose the correct location for the observations and then click "**Move**".

4. To edit the ***Visit Information*** (Date, Start Time, End Time, Observers, Visit Notes) click "**Edit Visit**". Make sure to click "**Save**" when you are finished editing your data.

5. To edit your ***Observations*** (Species, Number, Comments, Add new species) click "**Edit your Observations**". On the following screen, click on the data to activate the table. If you want to add an additional species, enter data in a blank field and click "**Next**". Make sure to click "**Save & Proof this Data**" when you are finished editing your data.

6. To Edit ***Site Conditions*** (e.g. Weather) click "**Edit Site Conditions**". Make sure to click "**Save**" when you are finished editing your data.

7. Finally, when you are finished editing your data click "**Proofing Completed**"