# Modeling Bird Abundance and Habitat Value

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## Annual Report

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***Task 1 – Gather and Integrate Existing Data (August 15, 2009 – May 15, 2010)***
***Task 2 – Develop and Verify Bird Abundance Model (February 15, 2010 – May 15, 2010)***
*Task 3 – Synthesize Results for Presentations (November 15, 2010 – May 15, 2011)*
*Task 4 – Report Preparation (August 15, 2009 – August 15, 2011)*

**PROGRESS SUMMARY**

Year 1 of the project has included information gathering and preliminary model development. I have developed a preliminary structure for the western sandpiper model, which will be further refined in Year 2 for better performance, integration of management actions and potential system response, incorporation of spatial variability and scaling, and modification of species-specific parameters to extend the model to other avian species. Additionally, please note that the sub-model described here does not include more recent bird survey and water quality data (through May 2010) that I obtained from USGS in late July 2010 and was not able to incorporate here. These revised data represent some improvements in the calculations of water depth as well as an extended time frame and could result in model parameter modifications. The following sub-model is intended to provide a progress update, but should not be distributed as a final product.

## BACKGROUND

During the past 200 years, over 90% of historic San Francisco Bay (SFB) salt marshes have been lost (Goals Project 1999), resulting in diminished habitat for native marsh species and fragmentation of remaining marshlands. Commercial salt ponds have been a part of SFB's landscape since 1856. Today, these salt ponds represent an unprecedented opportunity to reclaim and restore vital habitat for native wildlife. In 2003, the U.S. Fish and Wildlife Service and the California Department of Fish and Game in SFB acquired over 10,700 ha of commercial salt ponds for the purpose of restoring tidal wetlands. However, SFB estuary has been recognized as a site of hemispheric importance for migratory birds, and salt ponds support large numbers of migratory and wintering shorebirds and waterfowl. One goal of the South Bay Salt Pond Restoration Project is to maintain existing ecological value for waterbirds (Trulio et al. 2005), but information is needed to ensure that habitat requirements of large numbers of waterbirds can be met with reduced salt pond acreage. Although the ponds supported large numbers of waterbirds during their salt production period, the primary management goal during that time was salt production; providing bird habitat was not intended. Furthermore, many ponds consistently go mostly unused by birds while other ponds support high densities. These observations suggest that it should be possible to maintain past bird numbers on fewer ponds, provided that we understand the habitat characteristics that support high bird densities and retain these features or build them in to ponds that will be managed for open water habitat in the future. However, it is difficult to set management targets because bird numbers even at individual salt ponds are highly variable between surveys (Takekawa et al. 2005). A simulation model can help managers to understand the degree of variability that may be normal within the system and to examine how optimizing different variables can maximize bird abundance.

## MODEL OBJECTIVES

My long-term objective is to develop a bird abundance and habitat value model for the SBSPRP. This model will be used to develop potential baseline bird abundance ranges in the project area. Additionally, the model will be used to evaluate potential changes in bird abundance due to restoration actions. An evaluation of model parameters and degrees of uncertainty will help identify area where additional system information will be needed to reduce uncertainty in the model. My objective for this annual report is to provide an update of the modeling process to address pond selection by one species, the western sandpiper (*Calidris mauri*).

The goal of this preliminary sub-model was to approximate the abundance of sandpipers at a single salt pond throughout the winter season in response to water depth, and salinity, and pond size. This model will later be refined and expanded upon to improve performance, incorporate management actions, and accommodate additional waterbird species.

## METHODS

Model development followed the model building cycle:

*Observations of nature.—* The idea for the model was derived from observations of bird distributions at salt ponds. I observed that certain species of birds were very often present at a few specific salt ponds, and that other species of birds were generally absent. Medium and small shorebirds were often in close proximity to one another, but diving ducks were rarely observed in the same part of the pond at the same time, and different bird species were apparent in winter than in summer.

*Formulation of pattern that explains nature.—* The high winter abundance of many species of birds, including sandpipers, was due to migration patterns. More birds were present in the bay during winter months than during the summer, when birds moved to breeding grounds elsewhere. Shorebirds, including sandpipers, used shallowly inundated areas, whereas diving ducks used deeper ponds. Some birds, such as diving ducks, were limited to low salinity ponds. Shorebirds, however, were present in ponds within a wide range of salinities, but not in ponds with salinity >160 ppt. Quantitative relationships were derived elsewhere using statistical approaches.

*Hypothesis formation.—* Western sandpipers during the winter will be most abundant on a pond when water level conditions and salinity are within the optimal ranges, and will proportionally reflect baywide population fluctuations and pond size.

*Design model and plan for testing and manipulating it.—* I limited the scope of the preliminary sub-model to include one species, the western sandpiper, and one salt pond (Alviso pond A5). Because sandpipers are mostly absent during the summer, the time period covered by the model is the winter season, beginning 01 October and lasting 210 days. I employed a daily time step to include variability in daily bird movement but not sub-daily bird movement in response to tide (e.g., Warnock et al. 2002). The basic model design included a source population of sandpipers in the bay, western sandpiper population at a salt pond, and variables to define habitat quality and quantity for sandpipers at that salt pond including water depth, salinity, and pond size. Once the model was developed, I planned to test the model with sensitivity analysis on the key variables, water depth, salinity, and pond area. I planned to compare model results with data and observations to adjust equations and constants as necessary and appropriate.

*Construct model, debug and correct it, then run model experiments.*— I used Stella 9.0.3 (isee systems, inc., Lebanon, New Hampshire, USA) to develop the model (Fig. 1). I used one reservoir stock to represent the sandpiper population in the salt pond and set its initial value to 0, as would be expected prior to sandpiper migration. One converter represents the full population size of western sandpipers estimated at about 3.5 million birds (range = 2.8–4.3 million; Bishop et al. 2000, Morrison et al. 2001). Population estimates in San Francisco Bay from 4 recent

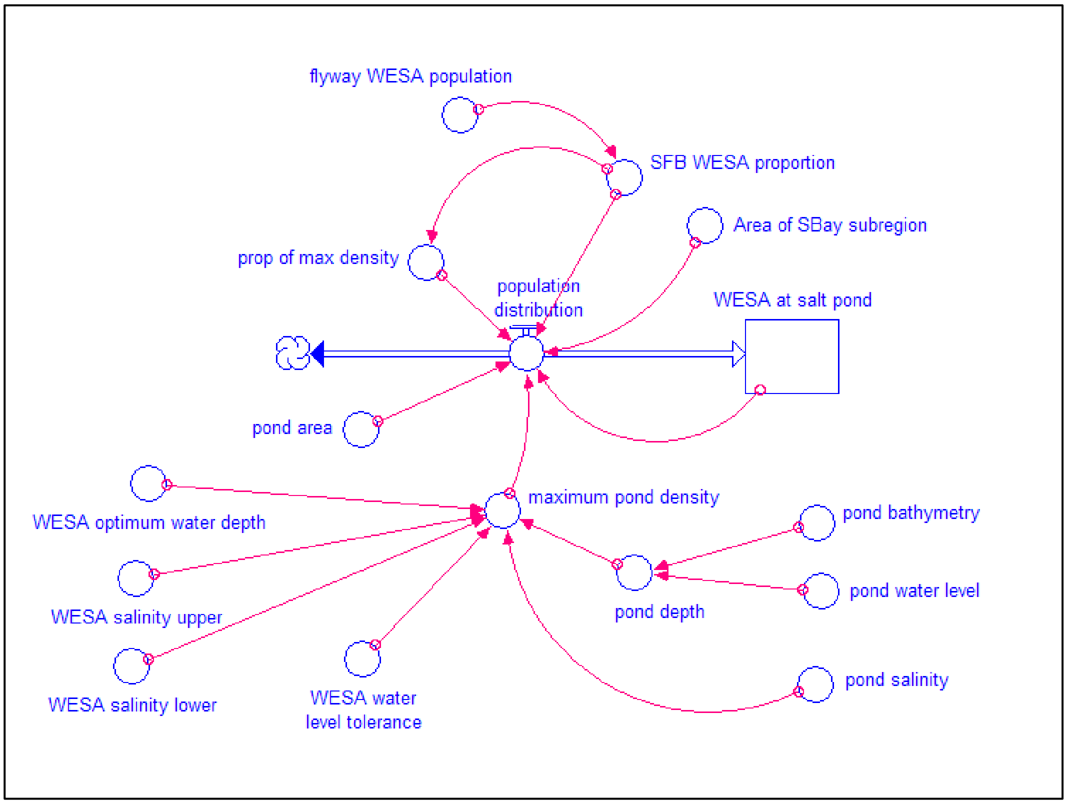


**Figure 1.** Stella model describing the distribution of western sandpipers into salt ponds in San Francisco Bay.

baywide shorebird surveys range from 92,500 to 123,000 (N. Warnock, pers. comm.). Nearly 40,000 birds were counted at South Bay salt ponds in the project area alone during December 2006, and these were primarily at a few ponds (author's unpubl. data). Because there is annual variability in both the full population size and the number of birds in the bay, I left "flyway WESA population" as a constant of 3.5 million, but included a random feature in the "SFB WESA proportion" to fall between 2.2 and 3.8% of the total population size. The "SFB WESA proportion" converter provided the total number of birds in the bay that were available to move into the salt pond, and "prop of maximum density" provided an estimate of the proportion of birds present related to maximal bird numbers (a proxy for percent of full bay capacity).

“Maximum pond density” was a proxy for habitat quality. It compares the species-specific optimum parameters (set up as constant converters to be easily interchangeable to other species values) to pond water depth and salinity. If the values for either fall outside the bird’s tolerance range, the maximum density of the pond is zero. If they are within the bird’s tolerance range, they are converted to bird density estimates based on a regression relationship developed from a subset of data across salt ponds (Takekawa et al. 2005, Takekawa et al. 2006*a*). Alternatively, a simple positive or negative relationship could be used in the absence of data.

“Population distribution” was a biflow between the WESA pond population and a cloud representing other habitats within the bay, including other ponds. “Maximum pond density” was combined with “pond area” to obtain a maximum population size for the current pond given the current conditions. If the population size increased above that level, then it was reduced by 1% each time step until it fell below the maximum. During the first 30 days of the season, birds were still moving into the area and the flow was decreased during this time. Otherwise, the flow was determined by the initial bay population, the pond size in relation to the South Bay subregion, a proportionality factor to account for populations not at full carrying capacity, and a random constant to account for daily movements and normal variability from disturbance, movement among ponds, weather patterns, and other factors.

Sandpipers are found across a wide salinity range, but not above 160 ppt (Athearn and Takekawa 2006). Thus, the salinity relationship was simply one where no birds would be present at high salinities, and testing results are not presented here. I assumed that sandpipers prefer mean water depth values of about 5 cm with a tolerance of about 75% (because these values are related to the proportion of shallow water habitat available). Any water depth outside that range would not be useful for sandpipers, but within that range the use would be variable, with shallow values generally more valuable for shorebirds. To test how well the model performed given these assumptions, I ran sensitivity analysis on water level (normally set to a random function between 0.91 and 0.99 to simulate realistic depths for this pond) between 0.85 and 1.00 (10 runs). The model performed realistically, as lower depths generally generated higher bird numbers and higher depths reflected no bird use at all (Fig. 2).

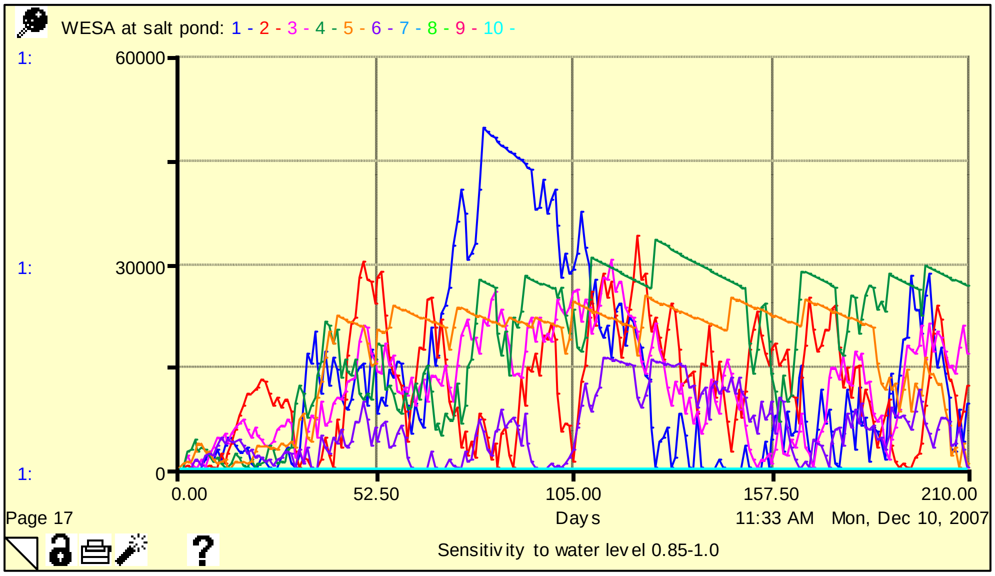


**Figure 2.** Sensitivity analysis of pond water level between 0.85 and 1.0; lowest to highest.

Bird populations should also be directly related to pond area, because it represents the amount of habitat available for a given habitat quality (i.e., maximum pond density represented by water level and salinity). I set water level to 0.91 and ran sensitivity analysis on pond area (normally set to a constant of 263 ha for this pond) between 50 and 500 (10 runs). The model performed realistically, as larger ponds generally resulted in larger populations (Fig. 3).

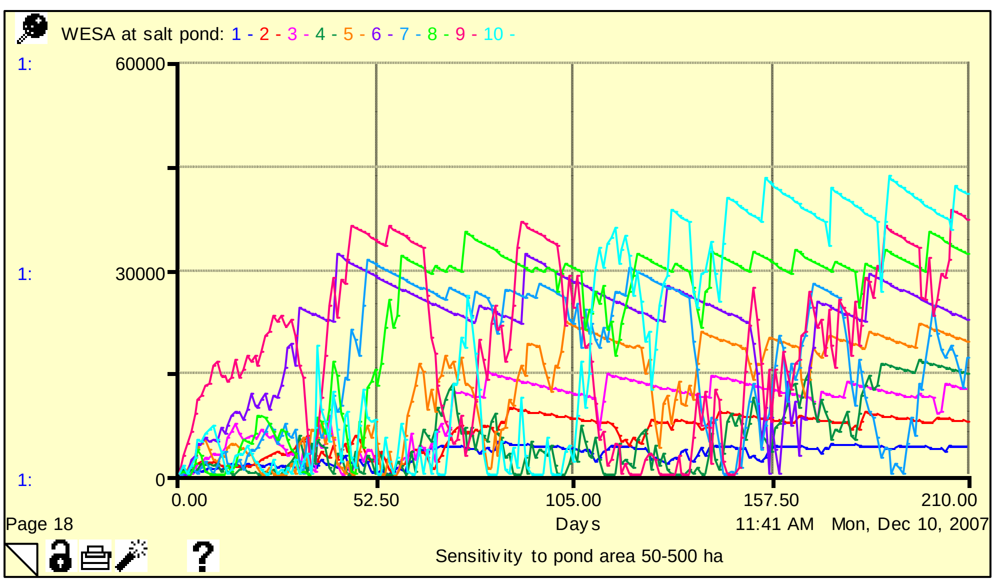


**Figure 3.** Sensitivity analysis of pond area between 50 and 500 ha; lowest to highest.

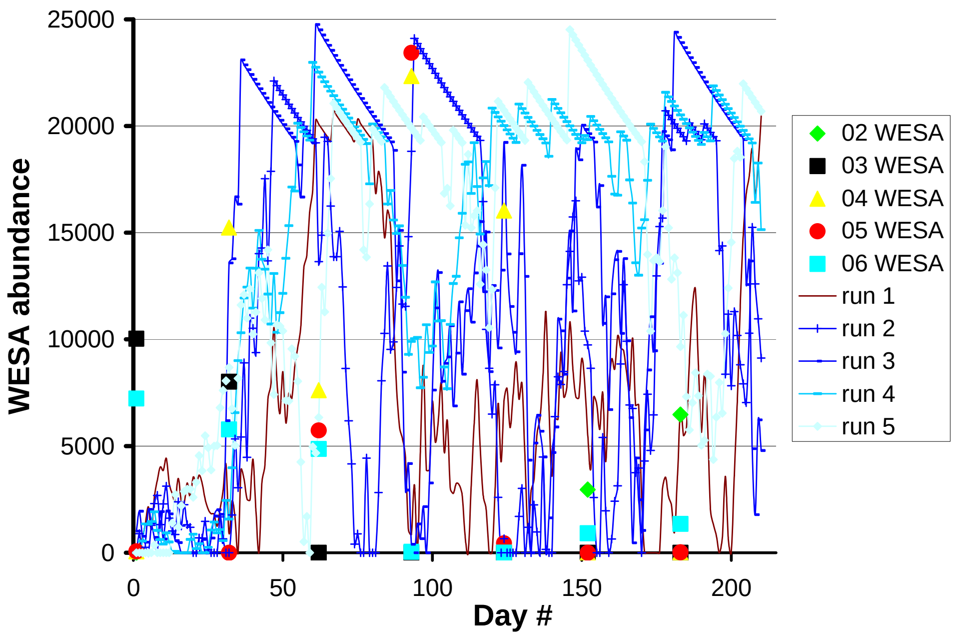


**Figure 4.** Comparison of 5 model runs to 5 seasons of monthly count data.

*Compare results to nature.—* I compared model runs with actual data, with salinity and water level set as random functions and pond area fixed. The model performed with a range of population sizes similar to real data (Fig. 4).

## DISCUSSION

The model responded to changes in water depth and pond area as expected given the known relationships of sandpipers to water depth. The gradual decline of pond numbers when the maximum density was reached, resulting in the characteristic pattern, was retained because it was somewhat representative of how large groups of birds will stay in a pond for several days when conditions are favorable. Although salinity was not modeled other than to exclude the presence of sandpipers beyond their tolerance range, it could be added in the same way that depth was. Because different foraging guilds relate to pond salinity and depth in different ways, some relationships provided in this model will need to be adjusted for different species. Knowledge of each species or guild's water depth and salinity preferences can be added to the model by changing existing converter values for sandpipers, but the relationship itself, within the "maximum pond density" converter, must also be changed to reflect species-specific preferences. Initial populations and proportions must also be changed.

This model provided a good starting point as a general tool for estimating sandpiper flow into salt ponds, but it also raised questions about the validity and usefulness of modeling bird use on a daily basis. Although the model seemed to perform reasonably well given the data available, it is difficult to translate monthly variability (provided by count data) into daily variable (estimated by the model). Furthermore, it is unlikely that daily data would ever be collected to test the model due to the great expense of such an effort. More importantly, management does not aim to maximize bird abundance on a given day but rather on a seasonal basis, and water level and salinity do not change appreciably from day to day. For these reasons, my choice of a daily time step was in retrospect not the best choice given the management focus of the model, and a monthly time step may have been more appropriate.

Nevertheless, this model can serve as a starting point for further model development. In the full model, many species could potentially (and do) use a single pond simultaneously, and a more sensitive indicator of water depth (representing proportions of ponds within certain bathymetric ranges) will help determine more appropriately scaled maximum pond densities for each guild. An additional challenge presented by the full model is to determine how birds may move among different ponds as well as between project ponds and other habitats. Although this model was a great simplification of reality, the relationships represented can be built upon for future model development.

## FUTURE DIRECTIONS

Future refinement will incorporate the monthly time step to more appropriately match monitoring efforts. I will also refine the parameter estimates and perhaps the model structure itself to better capture the relevant parameters and uncertainties. The model needs a clear "management switch" feature, as well as a more inclusive and explicit spatial focus in order to address system variability and scaling. Upcoming work will include consultation with USGS, PRBO Conservation Science, San Francisco Bay Bird Observatory, and FWS to ensure that the model meets management needs and appropriately incorporates system features.

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