Waterbird Nest Monitoring Program in San Francisco Bay (2005–10)

Open-File Report 2012–1145

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Cover:
Top Row (left to right): American Avocet Adult (Ken Phenicie); Black-necked Stilt Adult (Ken Phenicie); Forster's Tern Adult (Ken Phenicie).
Bottom Row (left to right): Forster's Tern Nest (Michael Kern); Forster's Tern Chick (Michael Kern); American Avocet Chick (Ken Phenicie).
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By Josh T. Ackerman and Mark P. Herzog

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Introduction

Historically, Forster's Terns *(Sterna forsteri)*, American Avocets (*Recurvirostra americana)*, and Black-necked Stilts (*Himantopus mexicanus)* were uncommon residents of San Francisco Bay, California (Grinnell and others, 1918; Grinnell and Wythe, 1927; Sibley, 1952). Presently, however, avocets and stilts are the two most abundant breeding shorebirds in San Francisco Bay (Stenzel and others, 2002; Rintoul and others, 2003). More than 4,000 avocets and 1,000 stilts, roughly 20 percent of their San Francisco Bay wintering populations, breed within the estuary, making San Francisco Bay the largest breeding area for these species on the Pacific Coast (Stenzel and others, 2002; Rintoul and others, 2003). Forster's Terns were first observed breeding in the San Francisco Bay in 1948 (110 nests); they had increased to over 4000 individuals by the 1980s (Sibley, 1952; Gill, 1977; Harvey and others, 1992; Carter and others, 1990) and were estimated at 2000–3000 for 1998–2002; (Strong and others, 2004).

It is hypothesized that the relatively large size of the current waterbird breeding populations is a result of the creation of artificial salt evaporation ponds from the 1930s through the 1950s (Gill, 1977; Goals Project, 1999). Until recently, these salt ponds and associated islands used by waterbirds for nesting have been managed relatively similarly and have supported large breeding waterbird populations. Recently, the South Bay Salt Pond Restoration Project has implemented plans to convert 50–90 percent of the 15,000 acres of salt ponds in the South San Francisco Bay back to tidal marsh habitat. Therefore, there is concern that the Restoration Project, while benefiting other native species, could negatively influence local breeding populations of waterbirds that are reliant on salt pond habitats for both breeding and foraging. A primary goal of the South Bay Salt Pond Restoration Project is to maintain current breeding waterbird populations (South Bay Salt Pond Long-Term Restoration Project, 2004); thus, specific efforts are planned to ensure that the Restoration Project enhances the habitats of the remaining salt ponds for breeding waterbirds.

Here, we provide a summary of nesting ecology data for Forster's Terns, American Avocets, and Black-necked Stilts, collected from 2005 to 2010 in the areas of the South Bay Salt Pond Restoration Project, including lands managed by the Don Edwards San Francisco Bay National Wildlife Refuge and Eden Landing Ecological Reserve (fig. 1). These results provide baseline conditions for breeding waterbirds prior to implementation of most restoration actions and can be used to both guide future restoration actions as well as to determine the effect of the South Bay Salt Pond Restoration Project on breeding waterbirds. It is imperative to continue to collect nesting waterbird data annually to assess the response of birds to the South Bay Salt Pond Restoration Project.

Nest Abundance

Methods

Nest abundance is defined as the cumulative total number of nests initiated over the entire breeding season. Nest abundance was estimated separately for the three focal species at each site and for each year. To estimate true nest abundance it is important to take into account the limitations of nest monitoring methodology; specifically, that it is not possible to observe nests that initiate and fail within the interval between nest checks (typically 7 days in this study). If we only presented the number of nests observed, we would underestimate the true number of nests that were actually initiated. To correct for this, we adjusted the number of new nests we observed during each visit to include nests that we did not find. We did this by dividing the number of new nests by the estimated survival rate of a nest during that period. We then summed all the adjusted nests initiated over each visit to estimate the total number of nests initiated during the breeding season. This method of estimating nest abundance is more accurate than surveying pair numbers or counting peak numbers of nests (Seavy and Reynolds, 2009; Herzog and Ackerman, unpublished data). We were unable to correct nest abundance estimates for any site that contained less than 0.01 percent overall nest success and, therefore, instead present the total nests observed in these cases (9 occasions).

Results and Discussion

Because nest monitoring effort varied across years and among sites, it is currently not possible to estimate the total abundance of nesting waterbirds across the entire South San Francisco Bay. While our estimates might be able to provide an index of breeding waterbird populations, there are no data that exist to estimate true baseline numbers of breeding waterbirds on lands managed by the South Bay Salt Pond Restoration Project for either the Don Edwards San Francisco Bay National Wildlife Refuge or Eden Landing Ecological Reserve. Thus, in this report, we provide population estimates and trends for each species within ponds where U.S. Geological Survey (USGS) nest monitoring has occurred for multiple years.

Forster’s Tern nest abundance within specific ponds tends to be variable (fig. 2). Some of the most important and consistent breeding locations for Forster’s Terns in the San Francisco Bay are in salt ponds on nesting islands. In particular, salt ponds A7, A8, and A16 in the Alviso Salt Pond Complex, and A1, A2W, AB1, and AB2 in the Moffett Salt Pond Complex, contain nearly 60 percent of all the monitored breeding Forster’s Terns in the South San Francisco Bay. The important nesting islands in Ponds A7 and A8 will likely be submerged in 2011 when the A5/A7/A8 complex is flooded as part of the opening of A8 to Alviso Slough for flood control purposes. If these nesting sites do indeed become unusable, then more than 300 nesting pairs will be displaced. This represents 25–35 percent of the monitored population of Forster’s Terns in the South San Francisco Bay. Continued monitoring of Forster’s Tern breeding populations is necessary to determine if these birds relocate within lands managed under the South Bay Salt Pond Restoration Project or if they are lost from the breeding effort in the entire South San Francisco Bay. Similarly, salt ponds A1 and A2W are very important breeding habitat and contain 21 percent of all the monitored breeding Forster’s Tern nests in the South San Francisco Bay. Nesting islands in ponds A1 and A2W would benefit from being bolstered to avoid continued erosion. Careful consideration of the value of these islands as nesting sites can be a useful part of planning if these ponds are to be converted to tidal marsh habitat.

American Avocets are more ubiquitous in the South San Francisco Bay, nesting in more wetlands than Forster's Terns. However, avocets generally nest on islands in salt ponds sympatrically with Forster's Terns. The primary nesting locations for avocets are salt ponds A7, A8, and A16 in the Alviso Salt Pond Complex, New Chicago Marsh, and A1 and A2W in the Moffett Salt Pond Complex. Similar to their importance to terns, the islands within A7 and A8 currently provide nesting habitat for approximately 300–400 nesting pairs annually, and A8 supports by far the most American Avocets compared to any other monitored site (fig. 2). Continued monitoring and management activities to enhance other wetland areas for breeding are necessary to ensure the South Bay Salt Pond Restoration Project does not lose this breeding effort when A7 and A8 salt ponds are converted into tidal marsh.

Black-necked Stilts are not as ubiquitous as avocets or Forster's Terns. When they do nest with Forster's Terns and avocets, they tend to nest at much lower densities. Instead, the vast majority of the entire South San Francisco Bay population of stilts nests within New Chicago Marsh in the Alviso area. New Chicago Marsh is a managed marsh that is dominated by pickleweed (*Salicornia virgnica*) vegetation. The average number of stilt nests initiated annually in New Chicago Marsh was 180, whereas in all others sites where we sampled more than 1 year, the average number of stilt nests was less than 50 (fig. 2). The next most abundant stilt nesting area in the South San Francisco Bay is in Eden Landing Ecological Reserve. These data demonstrate the over-riding importance of New Chicago Marsh for stilt breeding in the South San Francisco Bay and could act as a model for the creation of similar semi-tidally inundated habitat for breeding waterbirds in the South Bay Salt Pond Restoration Project.

Nest Success

Methods

Nest survival was estimated separately for each species, site, and year by performing an intercept-only logistic exposure model (Shaffer, 2004). For data prior to 2010, weekly nest visit data are currently not available electronically; thus, the number of exposure days was calculated as the days between when the nest was first detected and the date when the final fate (success/failure) was determined. A successful nest was defined as a nest where at least one egg hatched. For some nests, it was possible to determine the exact date of the nest's fate. For example, when wet chicks were found in the nest bowl, we assumed that hatching occurred within the past 24 hours. However, in most cases, the final nest fate date was estimated in the same manner as is done for Mayfield nest success—that is, the date that represents the midpoint of the final visit interval that determined the nest fate (Mayfield, 1961; Mayfield, 1975; Johnson, 1979). Only nests where at least 1 day of exposure occurred were included in analyses. The USGS has proposed to digitize the complete nest histories for all 11,000 waterbird nests monitored in the South San Francisco Bay. Once these data are in a relational database, more powerful and complex analyses on the factors that affect nest survival and other reproductive parameters will be possible. For 2009 and 2010 data, we were able to enter nest data at the nest visit level. Thus, for these 2 years, exposure days were estimated uniquely for each visit.

Once daily nest survival was estimated, nest success was calculated by exponentiating the daily nest survival estimate by the expected nest age for a successful nest. For these waterbirds, we chose a nest age of 27 days, representing a day for the laying of each egg (3–4 egg clutch) and a 23–24 day incubation period (Robinson and others, 1997; Robinson and others, 1999; McNicholl and others, 2001).

Results and Discussion

For all three waterbird species, nest success was highly variable among sites and years. For example, we observed almost complete colony failure in some years in wetlands that historically have been very productive. These results indicate that waterbird reproductive success is highly dependent on local conditions, such as predation and wetland management activities. Overall, nest success was 64 percent for Forster's Terns, 39 percent for avocets, and 36 percent for stilts in the South San Francisco Bay (fig. 3).

Clutch Size

Methods

Average clutch size was estimated separately for each species, site, and year. Only nests where researchers were confident that full clutch size was observed were included. Thus, nests that failed, were partially depredated during laying, or were found more than 8 days after incubation (as determined by floating eggs to determine development stage; Ackerman and Eagles-Smith, 2010) were excluded from analyses.

Results and Discussion

Clutch size was generally consistent across wetland sites and years for each species. Average clutch size for Forster's Terns was 2.3 eggs, for avocets was 3.5 eggs, and for stilts was 3.5 eggs in the South San Francisco Bay. See table 1 for details.

Nest Initiation Date

Methods

Nest initiation date was defined as the date at which an individual female laid the first egg in the nest. Median nest initiation date was estimated separately for each species, site, and year. Only nests where researchers were confident that nest initiation date could be estimated were included. Nest initiation date was estimated by subtracting the initial clutch size, plus the average incubation stage of the eggs on the day the nest was first discovered, from the date the nest was found.

Results and Discussion

Stilts and avocets initiated nests earlier (10 percent of nests occurred on or before April 15) than Forster's Terns (10 percent of nests occurred on or before May 15; table 1). Comparisons of the median nest initiation date showed that stilts nested 12 days earlier (May 3) than avocets (May 15) and almost a month earlier than Forster's Terns (May 30). The nesting period (defined as the central span of days where 80 percent of the individuals initiated nests, centered on the mean) was shorter for Forster's Terns (38 days) than stilts (48 days) or avocets (59 days), indicating that Forster's Terns were more synchronous in their nesting activities, which is common for breeding seabirds. Accordingly, Forster's Terns could be considered to be at a higher risk to perturbations during the shorter period for breeding. Management activities for Forster's Terns can usefully focus on providing ideal breeding conditions during this window of time and restrict potential disturbances.

Hatching Success

Methods

Hatching success is defined as the proportion of eggs that hatched within a nest that was successful (for example, where at least one egg hatched). Thus, only successful nests, where full clutch size and final fate for each individual egg were known, were included in our analyses.

Results and Discussion

Overall, hatching success was 95 percent for Forster's Terns, 94 percent for avocets, and 98 percent for stilts in the South San Francisco Bay. Although not as variable as nest success, hatching success also varied among wetland sites and years. See table 1 for details.

Case Studies: The Value of a Long-Term Waterbird Nest Monitoring Program for the South San Francisco Bay

These data represent the foundation of a long-term adaptive management monitoring program for breeding waterbirds in the South San Francisco Bay and are summarized in this report and provided to the Integrated South Bay Avian Database (ISBA-db) for easy access by managers. These breeding waterbird data have been collected by the USGS since before the initial phases of the South Bay Salt Pond Restoration Project and have already informed managers about significant components of the Restoration Project. Tracking trends in nest abundance and nest survival at specific sites can inform managers about the direct effects of management actions (such as changes in water levels or the creation of new nesting islands). Coupled with ancillary data (such as methyl mercury contamination in waterbird eggs and fish, water quality data, and vegetation and landscape metrics), these data are an even stronger tool to guide the implementation of management actions under the South Bay Salt Pond Restoration Project as well as for the regular management of wetlands on Federal and State Wildlife Refuges. In the following sections, we present two scenarios for the application of science produced by the annual USGS Waterbird Nest Monitoring Program in South San Francisco Bay.

Example 1. Waterbird Response to Wetland Management

The South Bay Salt Pond Restoration Project in San Francisco Bay will restore 50–90 percent of 15,000 acres of salt ponds to tidal marsh in order to reverse the loss (greater than 80 percent) of tidal marsh habitats within the San Francisco Bay Estuary. While the restored tidal marsh habitats will benefit many animals, another goal of the Restoration Project is to maintain current breeding populations of birds that currently use these pond habitats heavily (South Bay Salt Pond Long-Term Restoration Project, 2004). A way to mitigate this loss of nesting habitat is to create additional nesting habitat within the few ponds that remain after habitat restoration. Thus, the South Bay Salt Pond Restoration Project is implementing plans to reconfigure and enhance existing ponds by increasing foraging opportunities and the number of nesting islands.

In cooperation with the Don Edwards San Francisco Bay National Wildlife Refuge, we experimentally manipulated water levels in pond A12 to examine the response of waterbird breeding effort and nest success to different water levels and to assess the bioaccumulation of methylmercury in bird eggs and fish, which was an unintended consequence of this management action (Ackerman and others, 2010a). We compared results from pond A12 to adjacent reference ponds and marshes. In 2008, a number of nesting islands were created by lowering water levels in pond A12. Our nest monitoring data were able to detect a strong waterbird nesting response to the Refuge's water management action, with over 500 nests initiated during the following nesting season. However, at the same time, we found that mercury concentrations in waterbird eggs were higher at pond A12 than in reference ponds and marshes. Therefore, whereas water management actions had a strong positive effect of enhancing waterbird nesting opportunities in A12, it also could have had the unintended consequence of increasing the production and bioaccumulation of mercury in waterbird eggs, which is known to affect reproductive success in these species (Ackerman and others, 2007; Ackerman and Eagles-Smith, 2008). Continued adaptive management processes coupled with annual monitoring are necessary to limit the potential for negative outcomes (fig. 5).

Example 2. Effects of Gull Intrusions on Breeding Waterbird Colonies

Because of the USGS's on-going nest monitoring program, we had the opportunity to couple nest survival data with movement patterns of predatory California Gulls. We leveraged our nest monitoring data in 2009 to assess the effect of California Gull (*Larus californicus*) predation on nest survival of waterbirds (Ackerman and others, 2010b).

During 2009, we monitored nests of Forster's Terns, avocets, and stilts at pond A16 by using standard USGS nest monitoring protocol. Simultaneously, we monitored California Gull intrusions in pond A16 by using a novel telemetry surveillance technique. We placed radio-telemetry data loggers on two waterbird nesting islands in pond A16 to detect gull intrusion events near the nesting colony. Fifty California Gulls were radio-marked in the previous spring of 2008 with transmitters that lasted for an estimated 18-month period. Thus, the recorded intrusions depended on previously radio-marked California Gulls returning to San Francisco Bay to breed, the transmitters surviving more than 1 year, and the radio-marked gulls actually using pond A16. Besides general information on nest success for waterbird species on pond A16, our results also detected seasonal and diurnal patterns in the use of A16 by California Gulls. Of significant importance was our finding that while many gulls visited pond A16, there were specific gulls that spent substantially more time with the waterbird colonies than others. Thus, management actions might not need to focus on the entire California Gull colony but rather on those "specialist" gulls that specifically affect waterbirds by depredating eggs and chicks (Ackerman and others, 2006; Ackerman and others, 2009).

Conclusions

With 6 years of USGS waterbird nest monitoring data, a significant amount of knowledge about the conservation needs of breeding waterbirds has been gained within San Francisco Bay. At the same time, we also have been able to understand what data are still needed. First, and foremost, is the need to recognize the value of a long-term waterbird nest monitoring program and continue it into the future. Given the finite amount of available breeding habitat and the significant linkages between environmental conditions and reproductive success, breeding waterbirds could be the taxonomic group most sensitive to management actions by the South Bay Salt Pond Restoration Project. As seen in this report, nesting waterbirds show immediate responses to wetland management and are useful indicators to assess these management actions. Many of the restoration actions (water management, creating and enhancing islands for nesting, and others) affect breeding waterbirds directly, and therefore, monitoring the nesting effort and success of waterbirds can give immediate feedback to the adaptive management process of the South Bay Salt Pond Restoration Project.

It is a high priority within the South Bay Salt Pond Restoration Project to ensure that restoration efforts do not negatively affect breeding waterbird populations. To successfully achieve this goal, the Restoration Project is enhancing or creating new breeding waterbird habitats in order to compensate for losses elsewhere as a result of salt pond restoration. The Restoration Project has recognized that there are a number of uncertainties in many of these actions and has embraced an adaptive management approach as an essential method to inform management by using continued research and monitoring. We believe three overarching conclusions resulting from this study are:

1. The implementation of an annual waterbird nest monitoring program, comparable to the monthly salt-pond surveys for birds, will develop a long-term dataset to inform wetland management, assess the effectiveness of restoration and management actions, and guide future implementation of the South Bay Salt Pond Restoration Project. The USGS has been able to fund this current 6-year nest monitoring dataset through studies on the effects of mercury contamination on avian reproductive success (Ackerman and others, 2007; Ackerman and Eagles-Smith, 2008). However, without these projects, the nest monitoring activities will not be possible.
2. A comprehensive survey is needed to estimate the total populations of breeding waterbirds in the South San Francisco Bay that use wetlands within the South Bay Restoration Project, the Don Edwards San Francisco Bay National Wildlife Refuge, and Eden Landing Ecological Reserve. Currently, there are no appropriate data to estimate population sizes of breeding waterbirds for the entire South Bay; therefore, we currently have no way to assess the effect of the South Bay Salt Pond Restoration Project on breeding waterbird population sizes.
3. In order for the adaptive management process of the South Bay Salt Pond Restoration Project to be most effective, communication between researchers and wetland managers is essential. Given the high priority that has been placed on maintaining avian populations and the rapid rate of the Restoration Project, it is important to develop an annual meeting in which an informal discussion can take place between researchers and managers, where researchers can inform managers of recent findings and, importantly, managers can help guide the necessary research and nest monitoring questions that need to be addressed.

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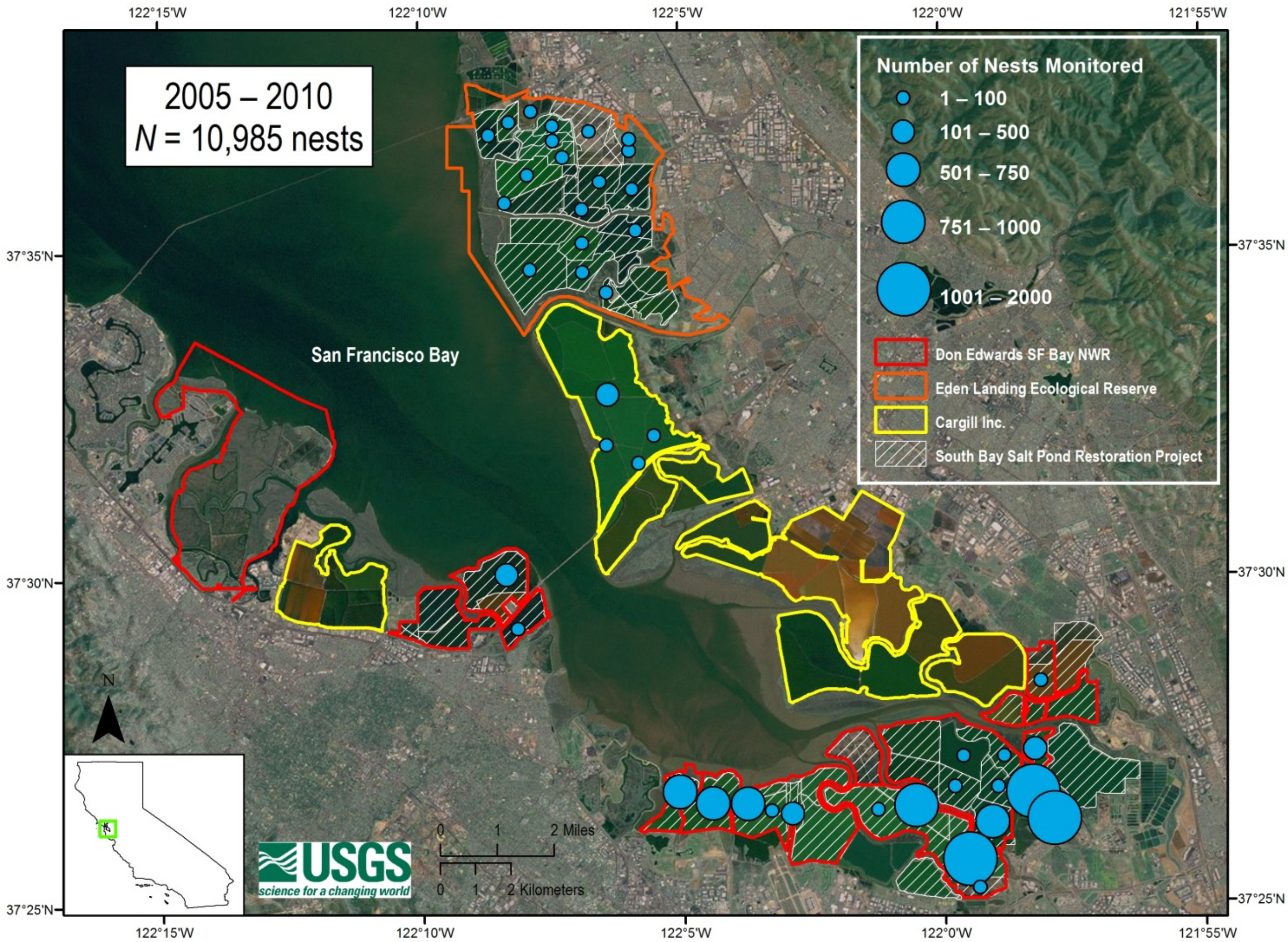

Figure 1. Distribution and abundance of nearly 11,000 waterbird nests monitored by the USGS during 2005–10 in salt ponds and managed wetlands planned for restoration within the South Bay Salt Pond Restoration Project (white hatching), Don Edwards San Francisco Bay National Wildlife Refuge (red), and Eden Landing Ecological Reserve (orange) in the San Francsico Bay, California.

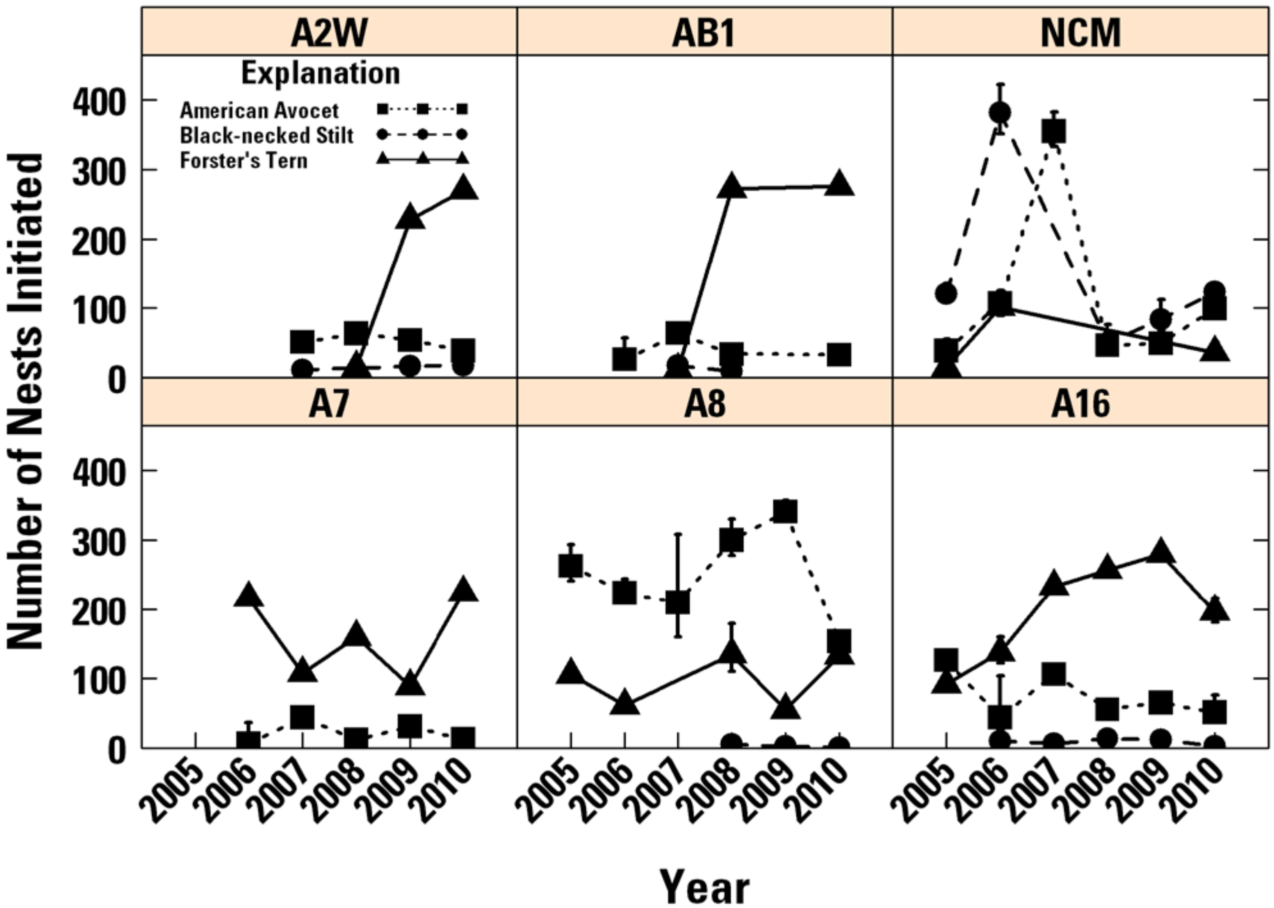

Figure 2. Estimated numbers and 95 percent confidence interval of Black-necked Stilt, American Avocet, and Forster's Tern nests initiated in South San Francisco Bay, California (2005–10). Numbers of nests have been corrected to account for nests that initiated and failed (and thus not observed) between nest checks; this method should be used rather than counting only the number of observed nests.

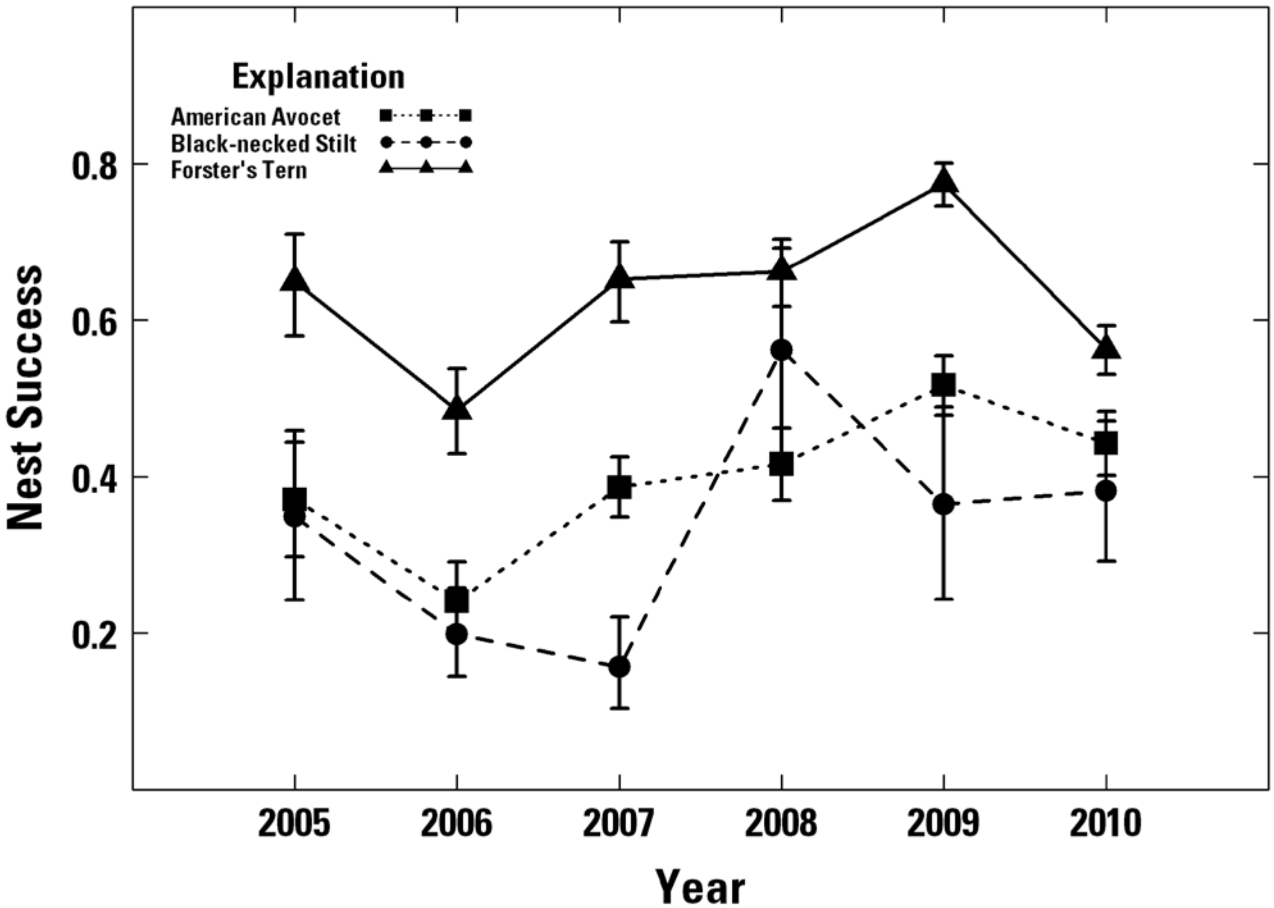

Figure 3. Annual nest success and 95 percent confidence interval for Black-necked Stilt, American Avocet, and Forster's Tern in South San Francisco Bay, California (2005–10). Overall, nest success was 64 percent for terns, 39 percent for avocets, and 36 percent for stilts.

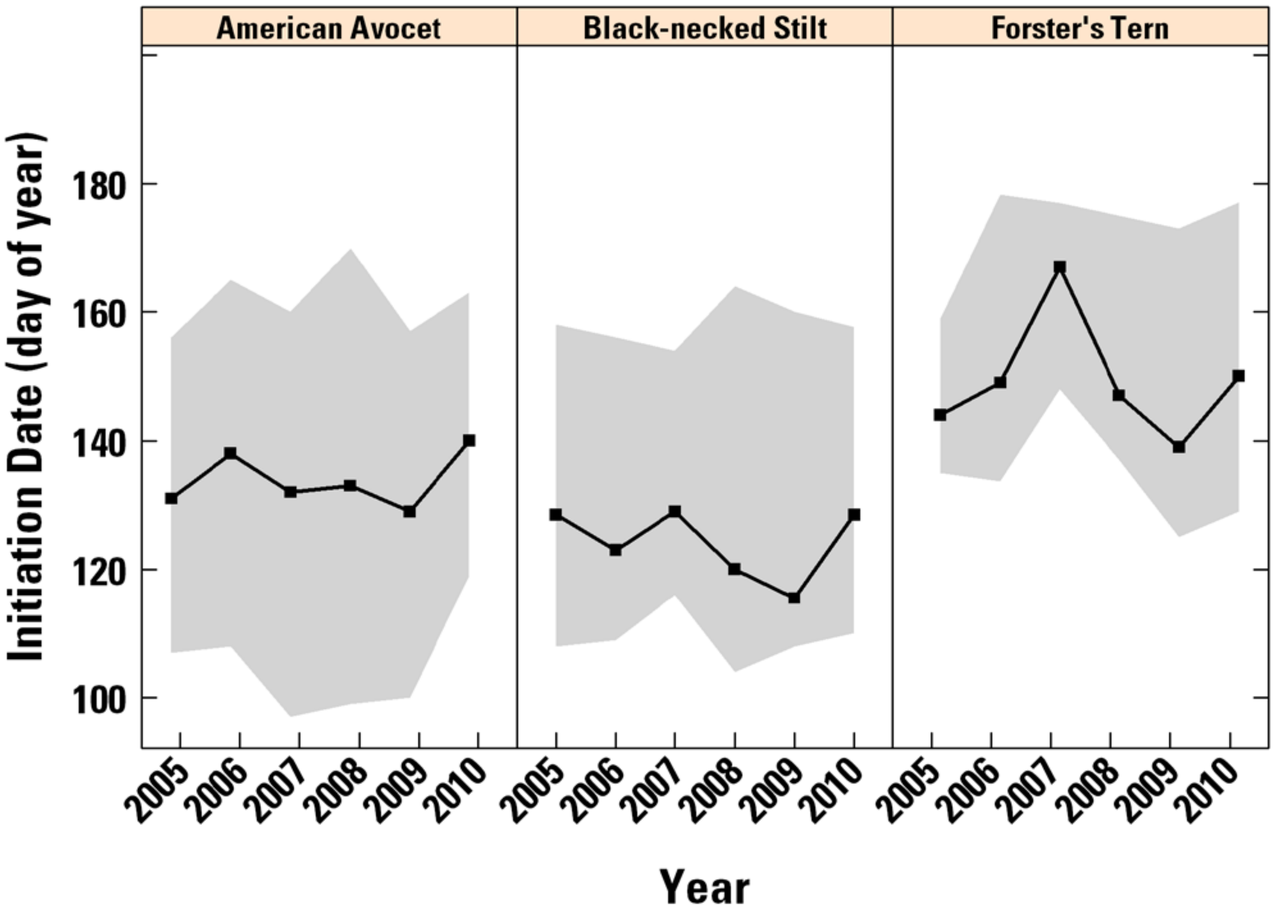

Figure 4. Nesting period for Black-necked Stilt, American Avocet, and Forster's Tern in South San Francisco Bay, California (2005–10). Median nest initiation date and the nesting period (defined as the central span where 80 percent of all initiation dates occurred) are displayed in gray shading. The average annual nesting period was shorter for terns (38 days) than stilts (48 days) or Avocets (59 days).

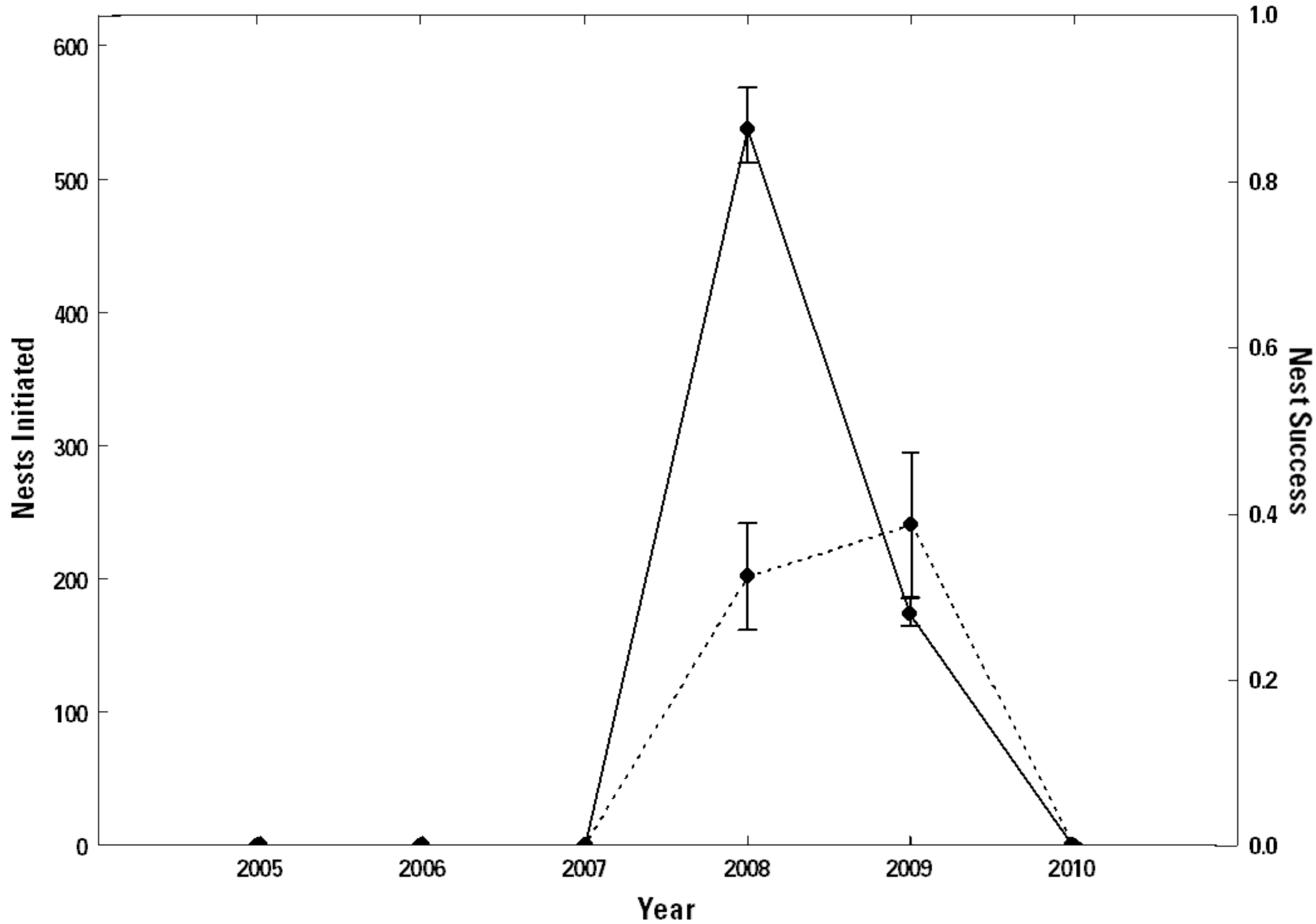

Figure 5. Waterbird nest abundance and nesting success with 95 percent confidence intervals in pond A12 during the creation of new nesting islands (all species combined). Prior to 2008, the water level was high and no nesting islands were present. In 2008, water levels were reduced, exposing island habitat. Our data show the immediate nesting response of waterbirds, with over 500 nests initiated in pond A12 the breeding season after the management actions. This creation of nesting habitat might have only provided improved breeding opportunities for the first two years because by 2010, both nest abundance and nest success were quite low.

Table 1. Summary of nesting parameter estimates for American Avocet, Black-necked Stilt, and Forster's Tern in South San Francisco Bay, California (2005–10).

Species	Total Number of Nests[1]	Clutch Size[2]	Nest Success[2]	Hatching Success[2]	Central Period of Nest Initiations
American Avocet	4351	3.47 (2.36 – 4.58)	0.37 (0.33–0.40)	0.93 (0.82 – 0.98)	April 27–May 26
Black-necked Stilt	1047	3.48 (2.08 – 4.88)	0.24 (0.20–0.28)	0.99 (0.81 – 1.00)	May 7–May 26
Forster's Tern	4684	2.27 (1.60 – 2.94)	0.61 (0.58–0.64)	0.95 (0.66 – 0.99)	May 23–June 19

[1] Total number of nests used for parameter estimates provided in table 1. An additional 850 additional nests were excluded from parameter estimates, including other species that were monitored during 2005–10.

[2] Mean (and 95% confidence intervals)

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