



SAN FRANCISCO BAY
BIRD OBSERVATORY



Western Snowy Plover Numbers, Nesting Success, Fledging Success and Avian Predator Surveys in the San Francisco Bay, 2011.



C. Robinson-Nilsen

Prepared By:

Caitlin Robinson-Nilsen, Waterbird Program Director
Jill Bluso Demers, Executive Director
San Francisco Bay Bird Observatory
524 Valley Way
Milpitas, CA 95035

and

Cheryl Strong, Wildlife Biologist
Don Edwards San Francisco Bay National Wildlife Refuge
9500 Thornton Avenue
Newark, CA 94560

30 December 2011

Table of Contents

ABSTRACT.....	4
INTRODUCTION AND BACKGROUND	6
METHODS.....	7
Study Area.....	7
Snowy Plover Surveys	7
Reproductive Success	8
Chick Color Banding	9
Avian Predator Surveys.....	10
RESULTS.....	10
Snowy Plover Surveys	10
<i>South Bay Overall</i>	10
<i>Refuge</i>	11
<i>Eden Landing</i>	11
<i>Napa-Sonoma Marshes Wildlife Area and Napa Plant Site</i>	11
Nest Abundance and Success	11
<i>South Bay Overall</i>	11
<i>Refuge</i>	12
<i>Eden Landing</i>	12
<i>Hayward Shoreline</i>	12
<i>Napa-Sonoma Marshes Wildlife Area and Napa Plant Site</i>	12
Nest Density and Breeding Chronology.....	12
Chick Fledging Success	13
Habitat Enhancement Project: Oyster Shell Plots	13
Avian Predators.....	14
<i>Refuge</i>	14
<i>Eden Landing</i>	14
<i>Hayward Shoreline</i>	14
<i>Napa-Sonoma Marshes Wildlife Area</i>	15
Nest Cameras	15
Mammalian Predators	15
DISCUSSION.....	15
Snowy Plover Surveys	15
Reproductive Success	15
Chick Fledging	18
Habitat Enhancement Project: Oyster Shell Plots	18
Avian Predators.....	19
Restoration and Snowy Plover Nesting	20
RECOMMENDATIONS	21
Research Recommendations	21
Monitoring Recommendations.....	22
Management Recommendations	22
ACKNOWLEDGEMENTS.....	24
REFERENCES	24

List of Figures

Figure 1. The Don Edwards San Francisco Bay National Wildlife Refuge, CDFG’s Eden Landing Ecological Reserve, and Hayward Area Recreation District lands in the South San Francisco Bay. 27

Figure 2. Snowy Plover nesting areas in the Napa-Sonoma Marshes Wildlife Area: the Wingo Unit, ponds 7/7a and the nesting islands at the Green Island Unit, North San Francisco Bay, California. 28

Figure 3. Salt ponds located in the Refuge’s Warm Springs area, near Fremont, South San Francisco Bay. See Figure 1 for location of Warm Springs within South San Francisco Bay..... 29

Figure 4. Salt ponds in the Refuge’s Alviso complex, at the southern end of the South San Francisco Bay. See Figure 1 for location of Alviso within South San Francisco Bay. . 29

Figure 5. Salt ponds in the Refuge’s Ravenswood complex, at the west end of the Dumbarton Bridge, South San Francisco Bay. See Figure 1 for location of Ravenswood within South San Francisco Bay. 30

Figure 6. Salt ponds in the CDFG’s Eden Landing Ecological Reserve Complex, near Hayward, South San Francisco Bay. See Figure 1 for location of Eden Landing Ecological Reserve within South San Francisco Bay. 31

Figure 7. Weekly counts of adult Snowy Plovers by week and area, South San Francisco Bay, California, 2011. 32

Figure 8. Weekly counts of adult Snowy Plovers by week and area, South San Francisco Bay, California, 2011, excluding Eden Landing Ecological Reserve. 32

Figure 9. The weekly number of initiated and active Snowy Plover nests in the South San Francisco Bay, California, 2011. 33

Figure 10. Annual apparent Snowy Plover nest fates in the South San Francisco Bay, California, 2004-2011..... 33

List of Tables

Table 1. Ponds surveyed weekly within the Don Edwards San Francisco Bay National Wildlife Refuge, South San Francisco Bay, California, 2011. 34

Table 2. Ponds surveyed weekly within California Department of Fish and Game property, San Francisco Bay, California, 2011. 34

Table 3. Snowy Plover nest fates by pond in the South San Francisco Bay and the Napa-Sonoma Marshes Wildlife Area, California, 2011. 35

Table 4. Summary of nest data for Snowy Plovers in Alviso, Eden Landing, Ravenswood and Warm Springs complexes, 2006-2011. Mean initiation dates is given by day of the year and the calendar date. Sample size is the number of nests used in the nest success analysis..... 36

Table 5. Snowy Plover nest densities (nest/acre) by pond on Refuge property in the South San Francisco Bay, California, 2011..... 37

Table 6. Snowy Plover nest densities (nests/acre) by pond at Eden Landing Ecological Reserve in the South San Francisco Bay, California, 2011..... 37

Table 7. Total number of chicks banded, chicks fledged and percent fledged per pond in the South San Francisco Bay, California, 2011..... 37

Table 8. Number of nests monitored, fates and densities for control plots, shell plots and all other nests at Eden Landing Ecological Reserve in the South San Francisco Bay, California, in 2009 through 2011. 38

Table 9. Number of chicks banded, chicks fledged and percent fledged in the shell plots per pond at Eden Landing Ecological Reserve in the South San Francisco Bay, California, 2011. 38

Table 10. The mean numbers of predators per survey in each area of the San Francisco Bay, California, 2011. (We did not include the Alviso California Gull colony of 11,956 individuals in our estimates.)..... 39

ABSTRACT

The San Francisco Bay Bird Observatory (SFBBO), Don Edwards San Francisco Bay National Wildlife Refuge (Refuge), California Department of Fish and Game (CDFG), Hayward Area Recreational and Park District (HARD), and East Bay Regional Parks District (EBRPD) form the Western Snowy Plover Recovery Unit 3. The goal of this collaboration is to survey managed ponds and other habitats for Western Snowy Plovers (*Charadrius nivosus nivosus*), determine nest success of Snowy Plover nests and contribute to the management of the San Francisco Bay’s population of breeding Snowy Plovers. In 2011, we recorded Snowy Plover numbers, site use, nest success, fledging success, use of habitat enhancement project sites, species of nest predators and avian predator numbers throughout the Snowy Plover breeding season.

During the 2011 breeding season window survey of the Pacific coast (24 May – 7 June) we counted 249 adult Snowy Plovers in the Bay. In 2011, we determined the fate 224 Snowy Plover nests in the South San Francisco Bay (South Bay). One hundred and seven of the nests hatched (47.7%), 108 were depredated (48.4%), eight were abandoned (3.1%), and two were flooded (>1%). We define a nest as successful if it hatched at least one egg.

On Refuge property, we determined the fate of six nests in the Alviso pond complex (all within the dry pan area of New Chicago Marsh) and nest success was 41%. We monitored 37 nests in the Ravenswood complex (ponds SF2 and R1 – R5) and nest success at Ravenswood was 62%. We monitored 13 nests in the Warm Springs complex (ponds A22 and A23), where nest success was 15%.

This year we determined the fate of 165 Snowy Plover nests at Eden Landing Ecological Reserve (Eden Landing). Of the 165 nests, 70 hatched, 86 were depredated, 2 were flooded, and 7 were abandoned. Nest success at Eden Landing was 20%.

There were three Snowy Plover nests on EBRPD’s California Least Tern (*Sterna antillarum browni*) island; one hatched and two were depredated.



CDFG biologists determined the fate of four plover nests in the North Bay; two at the Napa Sonoma Marshes Wildlife Area (one in the Wingo Unit and one in the Huichica Creek Unit) and two at the Napa Plant Site. Three of the four nests hatched (75%).

Throughout the South Bay, we banded 36 chicks. From visual observations, we determined that five chicks of the 36 banded survived to fledging (14%) as of 30 September 2011.

During avian predator surveys we counted California Gulls (*Larus californicus*) and unidentified gulls as the most numerous avian predators in all areas surveyed.

SFBBO and the Refuge began a Snowy Plover habitat enhancement study in the winter of 2008 at Eden Landing Ecological Reserve. Enhancements consisted of oyster shells spread by hand at densities of five to eight shells/m² over fifteen one ha plots. In 2011, more plovers nested in shell plots than in control plots (n=3; $t=3.902$, $df=14$, $P=0.002$); however there was no difference in the likelihood of nests in shell plots hatching successfully compared to Eden Landing nests outside of the shell plots ($\chi^2=0.473$, $df=1$, $P=0.0492$).

SFBBO deployed camera systems at Snowy Plover nests at Eden Landing Ecological Reserve for a third and final year. We placed camera systems at 17 nests and recorded footage 24 hours a day. We recorded four depredation events, including two separate events where California Gulls depredated Snowy Plover nests. The camera systems also recorded a Common Raven (*Corvus corax*) and Red-tailed Hawk (*Buteo jamaicensis*) depredating Snowy Plover nests.

We recommend that the South Bay Salt Pond Restoration Project (the Project) carefully plan construction activities to avoid negatively impact breeding Snowy Plovers. We recommend providing alternative breeding habitat when construction activities impact Snowy Plover nesting ponds. We also recommend beginning construction activities before Snowy Plover breeding season begins, and, if possible, discouraging plovers from using ponds where construction activities are taking place. As more areas are opened to tidal action or converted to ponds with islands, the Project and local land managers will need to take great care in maintaining enough Snowy Plover nesting habitat to preserve and increase the number of nesting Snowy Plovers in the South Bay. This will likely include more active management or enhancement of Snowy Plover nesting sites. In addition, as areas are opened to the public, managers will need to take steps to reducing recreational impacts to nesting Snowy Plovers. The Project and other restoration projects will impact Snowy Plovers in multiple ways and managers and researchers should continue to study and monitor the plovers South Bay to reduce negative impacts in the future.

INTRODUCTION AND BACKGROUND

The Pacific coast Western Snowy Plover (*Charadrius nivosus nivosus*, Snowy Plover) population breeds along or near tidal water and is behaviorally distinct from the interior population (Funk 2007). The Snowy Plover population has declined in response to poor reproductive success, likely due to habitat loss, habitat alteration, human disturbance, and increasing predator populations (Page et al. 1991). In response to the population decline, the U.S. Fish and Wildlife Service listed the Pacific coast Western Snowy Plover population as a threatened species in 1993 (USFWS 1993).

Western Snowy Plover Recovery Unit 3 consists of the San Francisco Bay and includes Napa, Alameda, Santa Clara counties and the eastern portion of San Mateo County (USFWS 2007). In 1992, the Don Edwards San Francisco Bay National Wildlife Refuge (Refuge) began surveying for Snowy Plovers on Refuge lands. The Refuge developed five goals for its Snowy Plover Recovery program: 1) identify areas used by Snowy Plovers for foraging, roosting and nesting, 2) estimate Snowy Plover numbers, including breeding pairs, 3) determine nest success, 4) assess predation pressures on Snowy Plovers and 5) protect Snowy Plover breeding areas from predators and other disturbances. The Refuge joined with the California Department of Fish and Game (CDFG) in 2000 to survey Snowy Plovers on the Eden Landing Ecological Reserve property (hereafter Eden Landing). San Francisco Bay Bird Observatory (SFBBO) and the Refuge have been surveying plovers and determining nest fates since 2003.

In order to achieve the five goals put forth by the Refuge, we: 1) identified areas used by Snowy Plovers, 2) determined number of adult Snowy Plovers in the San Francisco Bay throughout the breeding season, 3) determined nest fate, nesting density and chick fledging rates, 4) determined predators of Snowy Plover nests and chicks through our avian predator surveys and nest camera monitoring, and 5) identified areas of potential disturbances from predators, humans and construction activities. We also investigated the effect of habitat enhancements on nest success, nest density, and chick fledging rates.

The South Bay Salt Pond Restoration Project (the Project) plans to restore 15,100 acres of former artificial salt pond habitat to tidal marsh and managed ponds. Despite the loss of Snowy Plover breeding habitat (dry salt ponds) expected overall through the Project's actions, the Project has set a goal of maintaining 125 breeding pairs of Snowy Plovers within its footprint (USFWS and CDFG 2007). To aid in achieving this goal, SFBBO and the Refuge initiated a habitat enhancement study on ponds currently managed for Snowy Plovers at Eden Landing. Enhancements were made during the winters of 2008 – 2010, and included removing potential raptor perches from the ponds and surrounding levees and adding oyster shells to the pond bottoms within experimental plots to potentially provide camouflage for nesting plovers and small plover chicks. We tested the effectiveness of oyster shell treatments in increasing nest success, nest density, and chick fledging rates during the breeding season 2009 - 2011.

This report summarizes the 2011 breeding season data, including Snowy Plover surveys, nest success, fledging success, habitat enhancement projects and avian predator surveys.

METHODS

Study Area

SFBBO and Refuge conducted Snowy Plover and predator surveys in the South San Francisco Bay (South Bay) ponds, which includes the area just north of the San Mateo Bridge (Highway 92) and extends to the extreme southern portion of the Bay (Figure 1), and contains the majority of the Snowy Plover habitat in the Bay Area. We also conducted Snowy Plover and predator surveys at one site in the North Francisco Bay (North Bay) ponds (Figure 2). These surveys provide full coverage of all Snowy Plover breeding habitat in Western Snowy Plover Recovery Unit 3.

The Refuge includes approximately 30,000 acres of former salt pond habitat, tidal marsh, mudflats and upland habitat in the South Bay. For this study, we divided the Refuge into six geographic locations: Warm Springs, Alviso, Ravenswood, Coyote Hills, Dumbarton and Mowry (Figure 3, Figure 4, Figure 5).

CDFG owns and manages Eden Landing (formerly known as Baumberg), which includes approximately 5,500 acres of salt ponds, marsh and tidal habitat (Figure 6). CDFG owns and manages the Napa-Sonoma Marshes Wildlife Area, including ponds 7 and 7a, the Wingo Unit and the Napa Plant Site (Figure 2).

Hayward Area Recreational and Park District (HARD) owns the land directly north of Highway 92, on the east side of the San Francisco Bay, which is co-managed by East Bay Regional Parks District (EBRPD). This area includes potential Snowy Plover foraging and nesting habitat in the Oliver Brother North ponds and Frank's Dump West. EBRPD manages a separate island constructed for California Least Terns (*Sternula antillarum brownii*) in the adjacent area that is also used by nesting Snowy Plovers.

Snowy Plover Surveys

Snowy Plovers in the San Francisco Bay nest predominantly on dry former salt ponds. To identify areas used by Snowy Plovers and estimate the number of Snowy Plovers in the South Bay, we identified ponds with potential nesting habitat and surveyed those ponds weekly. We surveyed other ponds with less suitable (i.e., ponds without dry pan habitat) habitat monthly.

From 1 March to 31 August 2011, SFBBO and Refuge biologists, interns and volunteers surveyed the ponds by driving slowly on the levees or walking levees without vehicle

access. We stopped approximately every 0.3 miles to scan for Snowy Plovers with spotting scopes. During each survey, we recorded the numbers and behavior of adult Snowy Plovers, identified the sex of each Snowy Plover based on plumage characteristics (Page et al. 1991), and marked its approximate location on a geo-referenced map. Also, if appropriate, we recorded the number of nests, the number of chicks in each pond, and the color-band combinations for both banded Snowy Plover adults and chicks.

In total, SFBBO and Refuge biologists and interns surveyed 12 Refuge ponds and 17 Eden Landing ponds weekly (Table 1, Table 2). SFBBO volunteers surveyed the Dumbarton, Napa-Sonoma Marshes Wildlife Area and HARD ponds monthly. SFBBO surveyed the Coyote Hills, Dumbarton, and Mowry salt pond complexes monthly as part of SFBBO's Cargill salt pond waterbird surveys (see Robinson-Nilsen et al. 2010a for methods).

At the end of May, the Snowy Plover breeding window survey was conducted as part of a West Coast-wide effort to census all Snowy Plovers during that time period. The methods for the Recovery Unit 3 (San Francisco Bay) window survey are the same as described above.

For the purposes of data analysis, we defined a survey as one complete survey of a single pond.

Reproductive Success

To determine reproductive success of Snowy Plovers, we located nests by visually searching for incubating females during weekly surveys. We then searched for the nest on foot and recorded the nest location with a GPS unit (Garmin® GPS 60). Volunteers locating nests visually during monthly surveys marked the location of the nest on a map and described nearby landmarks. Later, SFBBO or Refuge staff searched for the potential nests on foot. Volunteers did not search for nests on the pond bottoms.

We monitored nests weekly until we determined the fate of the nest. On each visit, we recorded whether the nest was still active (eggs present and adults incubating), and the number of eggs or chicks in the nest. We floated the eggs (Hays and LeCroy 1971) to estimate egg age. Snowy Plover nests are active for an average of 33 days, from initiation (the date the first egg was laid) to hatching (Warriner et al. 1986), and using the known egg age, we calculated the nest initiation date and predicted hatch date for all nests monitored. When there were no longer eggs in the nest, we assigned each nest a fate based on evidence seen at the nest (Mabee 1997). Nest fates included: hatched, depredated, flooded, abandoned, lost at hatch, or unknown. In addition, we recorded if the nest was in an oyster shell plot (see Oyster Shell Habitat Enhancement methods below).

We defined a successful nest as a nest that hatched at least one egg. We calculated observed nest success rates for the South Bay Snowy Plover population by calculating the percentage of total nests that hatched at least one egg. For nests in Alviso, Eden Landing, Ravenswood, and Warm Springs, we used a logistic exposure model to estimate daily nest survival (Shaffer 2004). We did not estimate daily nest survival for nests in other areas as sample sizes were not adequate. We modeled daily nest survival as a function of pond complex, year and nest initiation date. We used the top ranking model to produce estimates of daily nest survival. Nest survival varied significantly by initiation date; therefore we calculated nest success for each complex and year based on the weighted mean initiation date. We then estimated nest success as the product of daily nest survival over the complete life of the nest (33 days for Snowy Plovers, Warriner et al. 1986). Additionally, we calculated nest density in the ponds by dividing the number of nests in each pond by the size in hectares.

Chick Color Banding

Beginning in 2008 and continuing through the 2011 breeding season, SFBBO and Refuge biologists banded Snowy Plover chicks to study their movements and to estimate fledging success rates for the South Bay. To band chicks, biologists checked nests daily, starting four days before the estimated hatch date. Snowy Plover chicks are precocial, therefore, we attempted to time our arrival at nests when chicks had just hatched, but had not yet left the nest scrape. We banded each chick with a unique four-color combination, placing two bands on each lower leg of a chick. Each combination consisted of three darvic color bands and one silver U.S. Fish and Wildlife Service band wrapped in auto pin-striping tape to act as the fourth color in the combination.

We defined fledging success as a chick surviving to 31 days of age, at which point, they are considered to be capable of flight (Warriner et al. 1986). We calculated fledging success rates for the South Bay Snowy Plover population by calculating the percentage of chicks fledged per chicks banded.

Oyster Shell Habitat Enhancement

To test the effect of oyster shell enhancements on breeding Snowy Plovers, we placed treatments on the ponds at Eden Landing using a randomized block design. Each block consisted of two plots placed on the pond bottom, a 1-ha oyster shell treatment plot (shells spread at five to eight shells/m²) and a 1-ha control plot (no shells or other treatment). Drake's Bay Oyster Farm donated the oyster shells, and SFBBO staff, volunteers, and the California Conservation Corps spread the shells by hand.

We recorded when nests were located in a shell or control plot. In each year of the study, we compared nest density in shell plots to the control plots with a one-tailed t-test, and compared nest success of the nests in the shell plots to all nests outside of the shell plots with a chi-squared test.

Avian Predator Surveys

To determine the avian predators in the area that might possibly affect Snowy Plovers, SFBBO and Refuge biologists and interns conducted weekly avian predator surveys on the same ponds surveyed weekly for plovers (Table 1, Table 2). Likewise, volunteers conducted monthly avian predator surveys at ponds surveyed monthly. We defined avian predators as any species that could potentially prey on a Snowy Plover nest, chick or adult and included: Common Ravens (*Corvus corax*), American Crows (*Corvus brachyrhynchos*), Northern Harriers (*Circus cyaneus*), American Kestrels (*Falco sparverius*), Peregrine Falcons (*Falco peregrines*), Merlins (*Falco columbarius*), Red-tailed Hawks (*Buteo jamaicensis*), White-tailed Kites (*Elanus leucurus*), Golden Eagles (*Aquila chrysaetos*), Great Blue Herons (*Ardea herodias*), Great Egrets (*Ardea alba*), Snowy Egrets (*Egretta thula*), Loggerhead Shrikes (*Lanius ludovicianus*), and Burrowing Owls (*Athene cunicularia*).

We conducted avian predator surveys by driving slowly on levees or walking levees without vehicle access, stopping every 0.3 miles to survey for predators. We recorded the avian predator species present, number of individuals, their behavior and marked their approximate location on a map. In addition, we recorded any predator nests in the area and attempted to determine the fate of those nests by visual observation. We calculated the average number of predators present per survey in each pond complex by dividing the total number of individuals seen in each area by the number of surveys conducted. We calculated the average number of predators by pond complex, as most predators have a larger territory than one pond (Strong et al. 2004).

Nest Cameras

In order to determine the predators depredating Snowy Plover nests, we placed camera systems at a subsample of nests to record nest activities. We used security cameras placed in camouflaged ammunition boxes positioned 10 to 30 m from Snowy Plover nests. We used a coupled electrical and coaxial cable to connect the cameras to marine batteries and a DVR unit, which recorded the images collected at the nest. We stored the marine batteries and DVR units in plastic bins placed up to 300 m from the nest. The cameras were equipped with infrared to record images at night and ran continuously.

RESULTS

Snowy Plover Surveys

South Bay Overall

During the 2011 breeding season window survey of the Pacific Coast, we counted 249 Snowy Plovers in the San Francisco Bay. We observed a mean of 275 birds observed per week from 6 March through 28 August in the entire South Bay (Figure 7).

We consistently observed the greatest numbers of Snowy Plovers in the South Bay at Eden Landing. Throughout the breeding season, we found the largest number of Snowy Plovers on ponds E6B and E8A. We also regularly observed Snowy Plovers on Refuge ponds SF2, R4 and A22 (Figure 7, Figure 8).

Refuge

On the Refuge, we observed the most Snowy Plovers in the Warm Springs pond A22 and Ravenswood pond SF2 throughout the season. The mean number of Snowy Plovers we observed per week from 6 March through 28 August on Refuge property was 75 birds per week (Figure 8).

We did not observe any Snowy Plovers in the Dumbarton, Coyote Hills or Mowry complexes this breeding season.

Eden Landing

We observed the most Snowy Plovers throughout the season at Eden Landing with a mean of 201 birds observed per week from 9 March through 28 August (Figure 7). Ponds E6B and E8A consistently had large numbers of Snowy Plovers throughout the season.

During the months of March, April and August, we observe large flocks Snowy Plovers at Eden Landing. For example, on E6B we recorded flocks ranging in size from 54 to 193 individuals, roosting in shell plots. Many of these birds are presumably either migrating or wintering birds because the mean number of Snowy Plovers at Eden Landing from 1 May through 30 July was 161 birds observed per week (Figure 7).

Hayward Shoreline

We observed small numbers of birds at Hayward Shoreline this season (mean of 8 birds per survey), both on the Oliver Brothers North ponds and on the Least Tern Island.

Napa-Sonoma Marshes Wildlife Area and Napa Plant Site

A SFBBO volunteer and the CDFG biologist regularly observed small numbers of Snowy Plovers using ponds 7 and 7A, the Napa Plant Site and the Wingo Unit (mean of four birds per survey).

Nest Abundance and Success

South Bay Overall

We determined the fate for 224 Snowy Plover nests in 2011 in the South Bay. Out of these nests, 107 hatched, 108 were depredated, seven were abandoned, and two were flooded (Table 3). We found fewer Snowy Plover nests in the South Bay in 2011 (n=224) than in 2010 (n=243). However, the number of nests we monitored in 2010 and 2011 was greater than the number of nests we have monitored in previous years (163 in 2009, 118 in 2008 and 89 in 2007).

Refuge

In 2011, SFBBO determined the fate for 56 Snowy Plover nests on Refuge property (Table 3). In the Alviso complex, we determined the fate of six nests in the dry pan areas of New Chicago Marsh, four of which hatched; two were depredated.

We determined the fate for 37 nests in the Ravenswood complex. Of these, 27 hatched and 10 were depredated. We found the most nests on pond SF2 (n=18; Table 3).

We determined the fate for 13 nests in the Warm Springs area on the Refuge. Of these, five hatched and eight were depredated (Table 3). Pond A22 had the most nests (n=11).

Eden Landing

We determined the fate for 165 Snowy Plover nests at Eden Landing (Table 3). Of these, 70 hatched, 86 were depredated, seven were abandoned, two were flooded, one nest was lost at hatch and one nest had an unknown fate. Pond E8A had the most nests (n=60), followed by pond E8 (n=40) and E12 (n=20; Table 3).

Hayward Shoreline

This year, there were three Snowy Plover nests on the Least Tern Island at HARD. Two nests were depredated and one hatched (D. Riensche, pers. comm.; Table 3).

Napa-Sonoma Marshes Wildlife Area and Napa Plant Site

In 2011, CDFG biologists found and determined the fate for one Snowy Plover nest in the Huichica Creek Unit (on the levee separating ponds 7 and 7a) and one nest in the Wingo Unit of the Napa-Sonoma Marsh Wildlife Area, one of which hatched (50%). They also monitored two nests at the Napa Plant Site, both of which hatched (K. Taylor, pers. comm.; Table 3).

Area, year, and nest initiation date are important factors influencing nest survival, and summed model weights for these factors were > 0.99. In particular, nests initiated later in the season survived at higher rates. Plover nest success was consistently higher in the Ravenswood ponds (62%-69%) and lowest (with the exception of 2009) in the Warm Springs ponds (13%-65%; Table 4). The nest success at Eden Landing was consistently low from 2006 through 2011 with values ranging from 21% in 2011 to 31% in 2006 (Table 4).

Nest Density and Breeding Chronology

The average nest density in the South Bay was 0.19 nests per hectare. The pond with the highest nest density was E8A, with 0.58 nests per hectare while R1, R3, A23 and E4C all had the lowest nest densities with less than 0.03 nests per hectare (Table 5 and Table 6).

The mean nest initiation dates varied by complex, with Ravenswood having the earliest mean nest initiation date (May 8) and Warm Springs having the latest mean nest initiation date (June 3; Table 4). The peak Snowy Plover nest initiation week in the South Bay was 24 April 2011 with 32 nests initiated and a second peak of nest initiation during the week of 12 June 2011 with 19 nests initiated (Figure 9). The number of active nests peaked during the week of 8 May 2011 with 74 active nests and 3 July, with 66 active nests (Figure 9).

Chick Fledging Success

We banded 36 Snowy Plover chicks at Eden Landing and determined that five chicks fledged (14% fledging rate). In comparison, the fledging rate was 41% in 2010, 24.8% in 2009 and 28.9% in 2008.

In 2011, the number of chicks fledged varied by pond and ranged from 0% on ponds E6, E6B and E16B (n=9) to 25% on pond E12 (n=4; Table 7).

Habitat Enhancement Project: Oyster Shell Plots

We spread fifteen 1-ha size shell plots prior to the 2011 breeding season. We spread seven plots in the winter of 2008, five plots in the winter of 2009 and three plots in the winter of 2010. Three plots were on E16B, four plots on E8, four on E6B, three on E14 and one on E6A. For each of these plots, we established a paired control plot at the same time.

Thirty-five of 165 (21%) nests monitored at Eden Landing were located in shell plots. In comparison, in 2010, 42 of 142 (29%) monitored nests at Eden Landing were located in shell plots (Table 8; Robinson-Nilsen et al. 2010b.), and in 2009, 24 of 97 (24%) monitored nests were in shell plots (Robinson-Nilsen et al. 2009). In all three years, more Snowy Plovers nested in shell plots than control plots (2011: shell=35, control=3; 2010: shell=42, control=3; 2009: shell=24, control=0; all $t \geq 2.927$, all $P \leq 0.015$). In all three years, we recorded the highest density of active nests in shell plots (2011 = 3 active nests/ha; 2010 = 9 active nests/ha (Robinson-Nilsen et al. 2010); 2009 = 6 active nests/ha (Robinson-Nilsen et al. 2009)).

Given the small sample size of nests within control plots, we compared observed nest success in shell plots to all nests outside of shell plots at Eden Landing. In 2011, observed nest success in the shell plots was 45%, whereas the nest success at Eden Landing outside of the shell plots was 42% (Table 8). There was no difference in the likelihood of a nest hatching between shell plot nests and non-shell plot nests ($\chi^2 = 0.473$, $df=1$, $P=0.0492$). Similarly, in 2010, there was no difference in the likelihood of a nest hatching between shell plot nests and non-shell plot nests (observed shell nest success = 31%, observed Eden Landing nest success = 32%; $\chi^2 = 0.0002$, $df=1$, $P=0.98$; Robinson-Nilsen et al. 2010). However, in 2009, nests in the shell plots hatched at higher

than expected rates compared to all other areas at Eden Landing (observed shell nest success = 66%, observed Eden Landing nest success = 50%; $\chi^2=4.98$, $df=1$, $P=0.026$; Robinson-Nilsen et al. 2009).

In 2011, the fledging rate of banded chicks from shell plots (0% in ponds E16B, E6B and E8) was lower than the overall South Bay fledging rate of 14% (Table 9). Similarly, in 2010 the fledging rate of banded chicks from shell plots (0% in ponds E16B, E6B and E8) was much lower than the overall South Bay fledging rate of 41% (Robinson-Nilsen et al. 2010). In 2009, the fledging rate of banded chicks from shell plots (25% in E16B and 23.1% in E8) was nearly identical to the overall South Bay fledging rate of 24.8% (Robinson-Nilsen et al. 2009).

Avian Predators

Refuge

The most commonly observed avian predators in all areas of the Refuge were California Gulls and unidentified gulls (presumably mostly California Gulls given time of year and location; Table 10). Other frequently observed predators in Alviso included Common Ravens in ponds A8 and A12 and Red-tailed Hawks throughout the complex. We observed many California Gulls in the Dumbarton ponds. In the Ravenswood complex, we observed groups of Common Ravens and American Crows foraging on pond SF2 throughout the season. We usually observed the corvids west of the PG&E towers running through the pond, in the dry pond area as well as on pond R3 near the business park. We also regularly observed Red-tailed Hawks and Peregrine Falcons perched on the PG&E towers in SF2 and Ravenswood. We observed large numbers of gulls, Common Ravens and American Crows at Warm Springs (Table 10). California Gulls attempted to nest on the levee between ponds A22 and A23 this spring, but biologists were able to deter them from nesting on that levee by hazing them for a month during the nest initiation period (Robinson-Nilsen and Demers 2011).

Eden Landing

The most commonly observed avian predators at Eden Landings were California Gulls and unidentified gulls (Table 10). We also observed many Snowy Egrets and Great Egrets feeding in the sloughs and in pond E9.

Great Blue Herons nested again this season on a former hunting blind in E6B, referred to as the "heron house." We also observed herons nesting on former hunting blinds in E9 and E14.

Hayward Shoreline

California Gulls and unidentified gulls were the most commonly observed avian predator at Hayward Shoreline (Table 10).

Napa-Sonoma Marshes Wildlife Area

We observed Northern Harriers, Peregrine Falcons, Great Blue Herons and Great Egrets at the Napa-Sonoma Marsh Wildlife Area (Table 10).

Nest Cameras

We recorded footage at 17 nests throughout the 2011 season, and filmed four depredation events. We recorded two California Gulls, a Common Raven and a Red-tailed Hawk depredating Snowy Plover nests.

Mammalian Predators

We observed grey foxes, skunks, raccoons, opossums, and domestic cats around nesting ponds. Biologists observed two cats jumping over the Eden Landing predator fence, north of E6A, into the Ecological Reserve. We also observed a domestic cat depredating a Sora (*Porzana carolina*) within Eden Landing. However, the feral cat feeding station present in previous years did not appear to be active outside the Veasy Street gate during the 2011 breeding season.

DISCUSSION

Snowy Plover Surveys

It is difficult to estimate the exact number of breeding Snowy Plovers in the San Francisco Bay because the majority of the Bay's adult Snowy Plovers are not color banded and surveys of all areas take several days to complete. We counted 249 Snowy Plovers in the Bay during the breeding window survey conducted the last week in May. However, this number is most likely higher than the actual number breeding here; many wintering Snowy Plovers may have stayed in the Bay later than usual due to storms late in the spring. The average number of Snowy Plovers in the Bay between the middle of May and the middle of July was 210 which is slight higher than last year during the same time period when we were observing an average of 195 Snowy Plovers per week. Eden Landing continues to host the majority of the Bay Area's Snowy Plovers.

Reproductive Success

We found fewer Snowy Plover nests in the South Bay in 2011 ($n=224$) than in 2010 ($n=243$). However, the number of nests we monitored in 2010 and 2011 was greater than the number of nests we have monitored in previous years (163 in 2009, 118 nests in 2008 and 89 in 2007). While the increase in nests in 2010 and 2011 may indicate that there are more Snowy Plovers nesting, the increase may also be due to increased survey efforts and a more experienced staff, rather than an actual increase in the number of

nests. The increased number of nests may also reflect the high number of depredated nests; Snowy Plovers are known to reneest up to six times in one season (Warriner et al. 1986), and we may have been finding numerous nest attempts by the same individuals after predation events on previous nests.

Nest success varied by area and was lowest at Warm Springs and Eden Landing. Snowy Plover nest success in most areas was lower than American Avocet nest success reported in the South Bay (Ackerman et al 2010). Low nest success continues to be a limiting factor for Snowy Plover recovery in the South Bay.

In 2011, fewer Snowy Plovers nested on Refuge ponds than in previous years. We found 37 nests in the Ravenswood ponds, which was down from 72 nests monitored in 2010. Pond R1 was flooded for much of the beginning of the breeding season and did not provide any habitat early on. This year we monitored 18 nests on SF2, compared to last year when we monitored 33 nests. The construction on pond SF2 finished before the beginning of the breeding season; the pond is now flooded, reducing the overall amount of breeding habitat on that pond. Two-thirds of SF2 is now ponded with nesting islands and one-third of the pond is dryer area enhanced with osier shells for nesting Snowy Plovers. Most of the nests we found on SF2 were in this Snowy Plover area, although we did find five Snowy Plover nests on the constructed islands. However, it is unlikely that any chicks fledged from these islands as the Bay sediments used to create the islands dried, large cracks formed on the islands. We found two dead newly-hatched chicks stuck in the cracks that presumably fell in the cracks and could not get out.

We found fewer nests on the Warm Springs ponds than in 2010 and these nests had higher rates of nest depredation than in 2010. These ponds are located between the Newby Island Landfill and the Tri-Cities Landfill; large numbers of gulls and corvids fly between the landfills during the day, and we recorded large numbers of gulls roosting on pond A23 during the non-breeding season. During the breeding season, approximately 10,232 adult California Gulls nested on Mowry ponds M1/M2 and M4/M5, which are adjacent to the Warm Springs ponds (Figure 1; Robinson-Nilsen et al. 2011). We also observed large flocks of corvids in the flying in the cow pastures to the north west of the Snowy Plover nesting ponds. Pond A23 was flooded before breeding season and most of A22 was flooded early in the season, with the exception of the north east side. This water management regime worked well because it kept the gulls from roosting and attempting to nest on the pond bottoms while leaving a small area on the eastern side for Snowy Plover nesting habitat. While gulls did attempt to nest on the levee between ponds A22 and A23, daily hazing prevented them from laying eggs in the area (Robinson-Nilsen and Demers 2011).

The pan area of New Chicago Marsh was the only area in Alviso where we observed Snowy Plovers breeding. Plovers previously breed on pond A8, which is now operated as a muted tidal pond. Pond A12 had large numbers of gulls roosting and foraging on the exposed islands, which likely prevented Snowy Plovers from nesting in that area

although water levels in the pond had been drawn for nesting waterbird and islands were exposed. In July, we observed plovers roosting on A13, which had also been drawn down for nesting birds, however no plovers ultimately nested on this pond.

At Eden Landing, Snowy Plovers nested on ten ponds, with the majority of the nesting occurring on ponds E8A, E8, E12 and E16B. E16B was dry at the beginning of the breeding season and contained three shell plots, which likely increased the attractiveness of the pond to nesting Snowy Plovers before other ponds dried out. Many of these nests were depredated and Snowy Plover use of E16B dropped off once other ponds dried out. In addition to high predation rates, the steep drop to the borrow ditch in this pond may not provide adequate chick foraging habitat, likely requiring chicks to go elsewhere to forage. Adjacent to E16B is the tidal Mount Eden Creek. Male Snowy Plovers may lead their chicks across this channel to forage and crossing this wetland may be dangerous for small Snowy Plover chicks.

We found high numbers of Snowy Plover nests on E8A and E8 this year. Both ponds provided a mix of wet and dry habitats throughout the breeding season. The pond bottom of E8A was covered in gypsum deposits, which provided camouflage for incubating Snowy Plovers and their nests. In contrast, the pond bottom of E8 is fairly dark, though the pond contains some gypsum in the northern section of the pond as well as four oyster shell plots.

Ponds E13 and E14 were flooded during the majority of the season to keep Snowy Plovers from nesting in the ponds during construction for the E8A-E9 project of the South Bay Salt Pond Restoration Project. In response to the limited habitat available, we found four nests on levees that host vehicular traffic. Although the nests on levees did not impede any construction activities, all four of these nests on levees were depredated. (For more on Eden Landing, please see the Restoration and Snowy Plover Nesting section below.)

There were four Snowy Plover nests this season in the North Bay. This is the third year that the number of nests and the nest fates were documented for the North Bay ponds. Most of these nests were on levees surrounding former salt ponds and two nests were on an island which also hosted nesting California Least Terns. This year CDFG found Snowy Plovers nesting at the Wingo Unit, which was the first time they were documented nesting in the area. Based on observations, CDFG suspects there were more Snowy Plovers nesting in this unit but they could not monitor all the nests due to lack of resources. In 2010, CDFG completed habitat enhancements to the Wingo Unit and now manages it as a seasonal wetland (K. Taylor, pers. comm.). This area may provide a small amount of additional breeding habitat for Snowy Plovers in the future.

Chick Fledging

The 2011 South Bay fledging rate of 14% was lower than previous years. The fledging rate was 41% in 2010, 24.8% in 2009 and 28.9% in 2008. This year's low fledging rate is not surprising due to a continued high number of predators seen in the area.

Habitat Enhancement Project: Oyster Shell Plots

This year we found fewer nests in shell plots, even though there were more shell plots than in previous years. The amount each plot was used varied, most likely based on location of plot within the pond, amount of wet and dry areas within the pond, and the brightness of the shells as compared to the pond substrate. The plots that were not used were either located under PG&E transmission line towers, had been flooded for much of the winter and were covered with large amounts of sediment or were flooded throughout the breeding season. The brightness of the shells varied on the plots that had been flooded for most of the winter; some shells were completely covered in sediment while other shells remained mostly white. Even if covered in sediment, the shells all provided some relief in topography but may not have provided enough camouflage for nests or chicks.

Despite the fact that we did not observe as high of nest densities in the shell plots in 2011 compared to previous years, overall nest density in shell plots in 2011 was still greater than the average density for the South Bay. As the amount of available nesting habitat around the Bay is reduced by tidal marsh restoration, Snowy Plover nesting density will need to increase in order to maintain and/or increase the Snowy Plover breeding population within a smaller habitat footprint. Shell plots may be one way to achieve the higher nest densities needed to reach the Bay-wide recovery goal of 500 breeding birds, however, we may also need to develop additional strategies to increase nest density.

Increasing nest densities and concentrating nesting plovers in fewer locations may result in increased predation pressure. For example, Page et al. (1983) found that Snowy Plovers nesting in higher densities had higher depredation rates at Mono Lake. However, we are not currently observing increased nest depredation rates in the shell plots. As in 2010, the 2011 observed nest success within the shell plots (45%) was no different than nests outside of the shells (42%) at Eden Landing. The proportion of depredated nests was slightly lower in the shell plots (43% in the shell plots compared to 54% outside of the shell plots). In contrast, in 2009, the percentage of depredated nests within the shell plots (8%) was much lower than the rest of Eden Landing (44%; Robinson-Nilsen et al. 2009). It is possible that predators have cued in on the presence of the shells plots as a food source after the first year of use by Snowy Plovers. If predation rates in the plots increase in the future, then the plots may eventually function as an ecological trap by attracting nesting Snowy Plovers to a low quality habitat. Given the expense, time and limited success of the plots, the use of oyster shell

should only be considered as a small part of a larger Snowy Plover management effort. Future oyster shell enhancements should include covering a larger area of the pond with shells, and placing the shells in irregular patterns, unlike the square plots.

Avian Predators

California Gulls continue to be the main predator of concern. As in 2009 and 2010, this year we captured evidence using nest cameras that California Gulls directly impact Snowy Plovers by nest depredation. California Gulls were the only predator in which we filmed depredating Snowy Plover nests in all three years of the camera study. California Gulls are opportunistic feeders and have been documented depredating other shorebird nests and chicks in the South Bay (Ackerman et al. 2006, Herring et al. 2011). Three of the largest gull colonies (Alviso A9/A14 colony, Mowry M4/M5 colony and the Coyote Hills N3A colony) are close to Snowy Plover nesting areas. In 2011, California Gulls attempted to nest on the levee between Warm Springs ponds A22 and A23 where plovers annually breed, but SFBBO biologists were able to haze them off the levee and prevent them from nesting (Robinson-Nilsen and Demers 2011). That levee is a roost site of gulls during the non-breeding season, as it is located between the Tri-Cities Landfill and the Newby Island Landfill. No California Gulls nested at Eden Landing; however a pair of Western Gulls nested on an island in E2. Continued funding for the hazing and tracking of California Gulls needs to be secured in order to prevent gulls from nesting in highly sensitive Snowy Plover breeding areas.

The former colony on pond A6, which hosted approximately 23,103 breeding adults (Tokatlian et al. 2010), was restored to tidal action in December 2010, reducing the amount of breeding habitat available to California Gulls. A portion of the displaced gulls (11,956; Robinson-Nilsen et al. 2011) appears to have relocated and nested on the levees between ponds A9, A10, A11 and A14. The total number of California Gulls breeding in the South Bay decreased from over 46,000 in 2010 to 38,000 in 2011 (Robinson-Nilsen et al 2011). It is unknown if the gulls that did not breed in the Bay Area will return next year or if the gulls will try to nest in Snowy Plover nesting areas.

Northern Harriers continue to be a predator of concern. As well as documenting the predation of Snowy Plover nests and chicks with nest cameras in 2009, we frequently observed Northern Harriers hunting ponds with Snowy Plover nests in 2011. The restoration of marsh habitat in the future will increase potential Northern Harrier nesting habitat in the South Bay. An increase of the local Northern Harrier population may result in higher predation pressure on pond nesting waterbirds, including Snowy Plovers.

We frequently observed both Red-tailed Hawks and Common Ravens perched in the transmission towers within ponds at all three Refuge complexes. These species should be discouraged from nesting in the towers, preferably before Snowy Plover nesting

season starts. The Refuge will continue to coordinate the removal of nests from towers with PG&E annually.

Restoration and Snowy Plover Nesting

The majority of the South Bay's Snowy Plover nesting habitat is located within the South Bay Salt Pond Restoration Project area. The Project aims to restore large areas of former salt ponds to a mix of wetland habitats including managing former salt ponds as managed wildlife ponds. Some of the ponds that will remain managed wildlife ponds, such as SF2, E12/13 and A16, will have islands constructed on them to provide waterbird nesting, roosting and shallow-water foraging habitat. Long-term, one of the Project's goals is to support 250 breeding Snowy Plovers adults within the Project area (USFWS and CDFG 2007).

Construction started in July 2011 at Eden Landing on three ponds with active Snowy Plover nests. Crews were working on the levees surrounding the ponds and heavy equipment ran frequently on the levees between Snowy Plover nesting and foraging ponds. We observed Snowy Plovers with broods crossing these levees or foraging within meters from the side of the levees. We met weekly with the project managers (Ducks Unlimited), CDFG, and the contractor the breeding (and construction) season at Eden Landing to coordinate activities. These meetings helped to facilitate arrangements between all parties involved and minimize impacts to Snowy Plovers and work schedules. We found this type of on-the-ground communication essential in order to limit the take of nests and broods due to construction activities. Despite active coordination, one Snowy Plover nest was flooded when the water levels were raised for construction activities.

The largest impact that the Project will have on South Bay Snowy Plovers is the long-term reduction of nesting habitat as dry ponds are opened to tidal action. We recommend converting ponds to tidal action slowly, and studying the impacts to breeding Snowy Plovers. Many of the first ponds to be opened to tidal action or converted to ponds with islands have historically hosted large numbers of Snowy Plovers (A8, E12/E13 and E8A), and losing these nesting ponds may reduce the number of Snowy Plovers nesting in the Bay Area. Snowy Plovers in the San Francisco Bay prefer to nest in dry salt ponds or on large, open salt pan areas located near foraging habitat. While three Snowy Plovers nested on EBRPD's Least Tern Island this season, and we found five nests on SF2 islands, it is unknown how many pairs the created islands in ponds A16, SF2 and E12/13 will support in the future. In addition, the newly created islands on pond SF2 formed large cracks as the mud dried. These cracks covered the islands and were often over 8 cm wide. We suspect the cracks were too wide for a Snowy Plover chick to successfully cross, and we found two dead newly hatched chicks deep in the cracks on one of islands. Although four of the five nests on the islands hatched, we did not observe live chicks on the islands and believe that no chicks fledged from this site. Due to the nature of Bay mud sediments, we expected cracking to occur

on these islands. Mitigation measures have not yet been determined for SF2, but future island building projects are planned to include sand or other toppings in order to limit the negative effects of the mud cracking. Given the above, dry salt pan habitat may need to be actively managed and maintained currently, and in the future, as primary nesting habitat.

In 2011, the Project's Phase 1 construction activities continued on some of the ponds used by nesting Snowy Plovers. We recommend the Project works carefully to maintain enough nesting habitat to support the existing population of Snowy Plovers during construction activities. We strongly suggest that managers provide nesting habitat in areas adjacent to those ponds being drained for construction to limit Snowy Plovers nesting in construction areas. While this will not stop Snowy Plovers from nesting in the construction ponds, it may reduce the number of nests in the construction ponds. Also, if Snowy Plover nesting ponds are to be flooded to exclude Snowy Plovers, managers should drain other nearby ponds in January and February, before Snowy Plover breeding season in order to provide nesting habitat.

We suggest that construction activities on Snowy Plover nesting ponds start before or after the breeding season whenever possible and actions be taken before the nesting season starts in order to deter Snowy Plovers from nesting on ponds where heavy equipment will be operating. Although not often feasible, this action would avoid much of the Snowy Plover and construction conflicts.

Another goal of the Project is to increase public access in certain areas. Currently, most Snowy Plover nesting areas are closed to the public. Snowy Plovers in the South Bay are very sensitive to recreational disturbance and flush from their nests when walkers are at an average 164 meters when approached directly, or 145.6 meters when passed tangentially (Robinson 2008 and L. Trulio, pers. comm.). Therefore, public access should be limited or prohibited on trails adjacent to Snowy Plover nesting ponds during the breeding season (March-August). Additionally, fencing or barriers that limit pedestrians from entering sensitive nesting areas and reduce human disturbance should be installed. Overall, larger tracts of land may need to be kept free of public access entirely, in order to accommodate sensitive species such as Snowy Plovers.

RECOMMENDATIONS

Research Recommendations

Future research involving Snowy Plovers and their nesting areas within the salt ponds should include projects that address the following topics:

1. Continue to band and track Snowy Plover chicks, and begin to band adults, to examine how Snowy Plovers use the habitats throughout the breeding season. Additionally, banding provides data on Snowy Plover adult survival rates, better

population estimates, and chick fledging success rates. This is vital information to reach the recovery goal of 500 birds in Recovery Unit 3.

2. Impacts of California Gulls on nesting Snowy Plovers.
3. Potential impacts of disturbance from trail use at Eden Landing and SF2.
4. Research on the effectiveness of avian predator management on increasing Snowy Plover nest success.
5. Further studies on Northern Harrier territory size and habitat use.
6. Snowy Plover foraging habitat use (borrow ditches, open channel, muted tidal, shallow pools, dry substrate) and invertebrate availability within the salt ponds.
7. **Determine the nesting success of Snowy Plovers on islands in managed ponds.**

Monitoring Recommendations

1. The Recovery Unity 3 Snowy Plover monitoring program should continue into the future. Monitoring population size and reproductive success are important to track the progress towards recovery goals, the response of plovers to management actions, and the effects of salt pond restoration.
2. Recovery Unit 3 should indentify other potential Snowy Plover breeding habitat in the San Francisco Bay area outside of the South Bay Salt Pond Restoration Project area to manage for Snowy Plovers. Based on the number of nests we found in the San Francisco Bay in 2011, 97% of the nests found were within the Project area. A goal of the Project is to support 250 breeding adults; therefore, in order to reach the recovery goal of 500 breeding birds in the San Francisco Bay, other habitat will need to be managed for plovers.
3. Snowy Plover chicks and adults should continue to be banded, and should be re-sighted every three days to determine chick and adult survival, fledging rates and movements. Banding chicks will be required to assess the progress toward the recovery goal of 1.0 chick fledged per male.
4. SFBBO, along with CDFG and the Refuge, should develop a Snowy Plover outreach program in areas that will be open to the public within the next few years. Actions should be taken now to educate the public on Snowy Plover conservation and disturbance issues.
 - a. Interpretive panels should be placed in areas open to the public to educate people on Snowy Plover habitat needs, and disturbance and conservation issues (such as the panel at pond SF2).

Management Recommendations

1. Refuge and CDFG management should continue to meet Snowy Plover habitat requirements by: a) providing areas of drying ponds with nearby high salinity foraging habitat, b) manage ponds in several areas around the South Bay for Snowy Plovers to reduce impacts from predation, flooding, or disease, c) the locations of Snowy Plover ponds should vary from year to year to reduce predation rates.

2. If construction activities are taking place on ponds where Snowy Plovers are nesting, or on levees in between nesting and foraging ponds, there should be a trained biologist on site during working hours to minimize impacts to Snowy Plovers.
3. If construction takes place adjacent to or within a Snowy Plover nesting area, then weekly meetings should be coordinated with all parties involved so that everyone understands their roles and expectations in regards to minimizing impacts to listed species.
4. The South Bay Salt Pond Restoration Project should look into ways to minimize or mitigate cracking on newly created islands to prevent loss of newly hatched chicks.
5. The predator management program should continue in 2011 in the South Bay. This should include removing mammalian and avian predators and predator nests. An avian predator management plan should be finalized for the Refuge.
6. Water levels in pond A23 should be raised over the winter to prevent nesting and roosting by California Gulls.
7. Water levels should be kept higher or interior channels should be added to pond E16B to increase the amount of foraging habitat in this pond.
8. If the Ravenswood ponds are to support more Snowy Plovers in the future, the ponds should be drained before the breeding season begins, to expose the pan habitat for nests. The water level in the borrow ditches should be higher in order to keep water and the interior channels. This will create better foraging habitat and potentially increase the numbers of Snowy Plovers using the complex. More water control structures should be added to the Ravenswood pond system to increase water management in this system.
9. Managers and biologists should continue to work with PG&E to remove predator nests from the towers. Tower design modifications should be researched to discourage ravens and Red-tailed Hawks from nesting in the towers near Snowy Plover habitat.
10. Law enforcement patrol should be increased in areas with Snowy Plover breeding habitat to minimize disturbance from humans. This will become progressively more important as additional areas are open to the public as part of the Project.
11. All researchers who are out on the ponds during the nesting season should continue to coordinate with SFBBO and the Refuge to minimize disturbance of Snowy Plovers.

ACKNOWLEDGEMENTS

This project was supported by U.S. Fish and Wildlife Service, Santa Clara Valley Water District, Ducks Unlimited, and the California Coastal Conservancy. Thank you Drake's Bay Oyster Farm for donating tons of shells to the project and to Juan Flores of USFWS Refuge staff for picking up and delivering the shells. Thanks to John Krause of CDFG for logistical support at Eden Landing and to Scott Demers of H.T. Harvey and Associates for helping design the nest cameras. Thanks to our Snowy Plover field crew: Karine Tokatlian, Jessica Gonzalez and Elizabeth Robertson. Special thanks to SFBBO volunteers: Tami Cosio, Ann Graham, Megan Heileman, Richard Jeffers, Mike Mammoser, Spike Marlowe, Dolores Morrison, Brenda Senturia, John Robeson, Mike Rogers, and Nancy Teater.

REFERENCES

- Ackerman, J.T., C.A. Eagles-Smith, M.P. Herzog, G. Herring, C. Strong and E. Mruz. 2010. Response of Waterbird Breeding Effort, Nest Success, and Mercury Concentrations in Eggs and Fish to Wetland Management. Data Summary, U.S. Geological Survey, Western Ecological Research Center, Davis, CA. 28 pp.
- Ackerman, J.T., J.Y. Takekawa, C. Strong, N. Athearn and A. Rex. 2006. California Gull Distribution, Abundance and Predation on Waterbird Eggs and Chicks in South San Francisco Bay. Final Report, U.S. Geological Survey, Western Ecological Research Center, Davis and Vallejo, CA 61 pp.
- Funk, W., T.D. Mullins, and S.M. Haig. 2006, Conservation genetics of North American and Caribbean snowy plovers (*Charadrius alexandrinus*) - population genetic structure and delineation of subspecies: US Fish and Wildlife Service, p. 1-55. Catalog No: 1522.
- Hays, H. and M. LeCroy. 1971. Field criteria for determining incubation stage for the common tern. *Wilson Bulletin* 83(4): 425-429.
- Herring, G., J.T. Ackerman, J.Y. Takekawa, C. A. Eagles-Smith and J.M. Eadie. 2011. Identifying Nest Predators of American Avocets (*Recurvirostra americana*) and Black-Necked Stilts (*Himantopus mexicanus*) in San Francisco Bay, California. *The Southwestern Naturalist*, 56(1):35-43. 2011.
- Mabee, T. J. 1997. Using eggshell fragments to determine nest fate of shorebirds. *Wilson Bulletin* 109(2): 307-313.
- Mayfield, H. F. 1961. Nesting success calculated from exposure. *Wilson Bulletin* 73:255-261.

- Page, G.W., L.E. Stenzel, D.W. Winkler and C.W. Swarth. 1983. Spacing out at Mono Lake: breeding success, nest density, and predation in the Snowy Plover. *The Auk* 100:13-24.
- Page, G.W., L.E. Stenzel, W.D. Shuford and C.R. Bruce. 1991. Distribution of the Snowy Plover on its western North American Breeding Grounds. *Journal of Field Ornithology* 62(2): 245-255.
- Robinson, C., J. Demers and C. Strong. 2008. Western Snowy Plover Population, Nesting Success, Fledging Success and Avian Predator Surveys in the San Francisco Bay, 2008. Unpubl.Rep. San Francisco Bay Bird Observatory, Milpitas, CA.
- Robinson, C. 2008. Western Snowy Plover Use of Managed Salt Ponds at Eden Landing, Hayward, CA. Masters of science thesis. San José State University.
- Robinson-Nilsen, C. and J. Demers. 2011. California Gull Breeding Surveys and Hazing Project, 2011. Unpublished Report. San Francisco Bay Bird Observatory, Milpitas, CA.
- Robinson-Nilsen, C., K. Tokatlian, and J. Demers. 2011. Colonial Waterbird Nesting Summary for the South San Francisco Bay, 2011. Unpublished Report. San Francisco Bay Bird Observatory, Milpitas, CA.
- Robinson-Nilsen, C., J. Demers, and J. Scullen. 2010a. Cargill Salt Pond Waterbird Surveys Report, October 2009 - September 2010. Unpublished Report. San Francisco Bay Bird Observatory, Milpitas, CA.
- Robinson-Nilsen, C., J. Demers, and C. Strong. 2010b. Western Snowy Plover Numbers, Nesting Success, Fledging Success and Avian Predator Surveys in the San Francisco Bay, 2010. Unpublished Report. San Francisco Bay Bird Observatory, Milpitas, CA.
- Robinson-Nilsen, C., J. Demers, and C. Strong. 2009. Western Snowy Plover Numbers, Nesting Success, Fledging Success and Avian Predator Surveys in the San Francisco Bay, 2009. Unpublished Report. San Francisco Bay Bird Observatory, Milpitas, CA.
- Shaffer, T. L., 2004. A unified approach to analyzing nest success. *Auk*, 121: 526–540.
- Strong, C. M., and N. Wilson and J. D. Albertson. 2004. Western Snowy Plover Numbers, Nesting Success and Avian Predator Surveys in the San Francisco Bay, 2004. Unpubl. Report. San Francisco Bay Bird Observatory, Alviso, CA.

- Tokatlian, K, C. Robinson-Nilsen and J. Demers. 2010. Colonial Waterbird Nesting Summary for the South San Francisco Bay, 2010. Unpublished Report. San Francisco Bay Bird Observatory, Milpitas, CA.
- U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants; determination of threatened status for the Pacific coast population on the western snowy plover; final rule. Federal Register 58 (42): 12864-12874.
- U.S. Fish and Wildlife Service. 2007. Recovery Plan for the Pacific Coast Population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*). In 2 volumes. Sacramento, California. xiv + 751 pages. Western Snowy Plover (*Charadrius alexandrinus nivosus*) Pacific Coast Population Draft Recovery Plan. Portland, Oregon. xix + 630 pp.
- U.S. Fish and Wildlife Service. 2002. Salinas River National Wildlife Refuge: Comprehensive Conservation Plan Summary.
- U. S. Fish and Wildlife Service and California Department of Fish and Game. 2007. South Bay Salt Pond Restoration Project Final Environmental Impact Statement/Environmental Impact Report. Prepared by EDAW, Philip Williams and Associates, Ltd., H. T. Harvey & Associates, Brown and Caldwell, and Geomatrix. [Online.] Available at <http://www.southbayrestoration.org/EIR/downloads.html>.
- Warriner, J. S., J.C. Warriner, G.W. Page, L.E. Stenzel. 1986. Mating System and Reproductive Success of a Small Population of Polygamous Snowy Plovers. Wilson Bulletin 98(1):15-37.

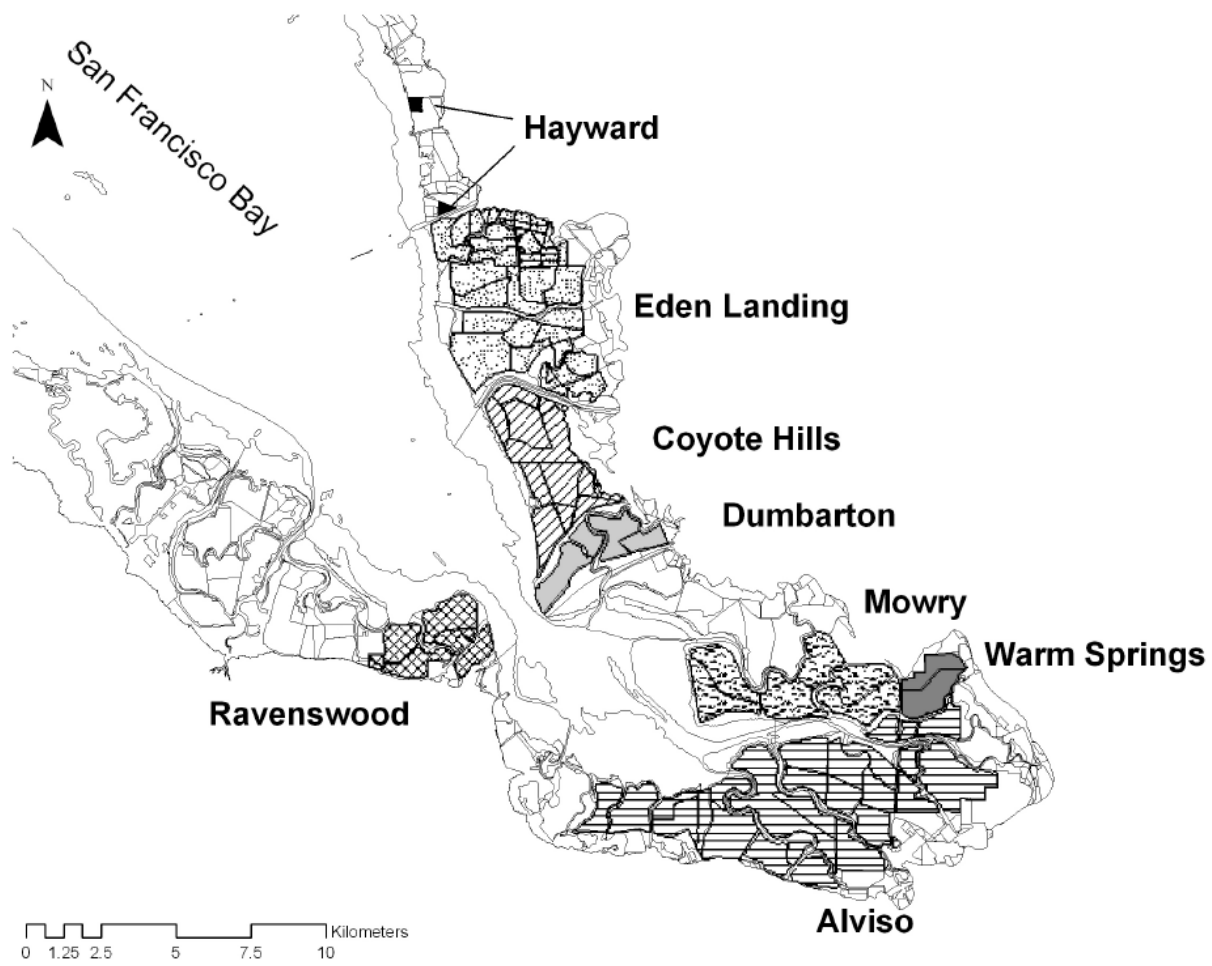


Figure 1. The Don Edwards San Francisco Bay National Wildlife Refuge, CDFG’s Eden Landing Ecological Reserve, and Hayward Area Recreation District lands in the South San Francisco Bay.

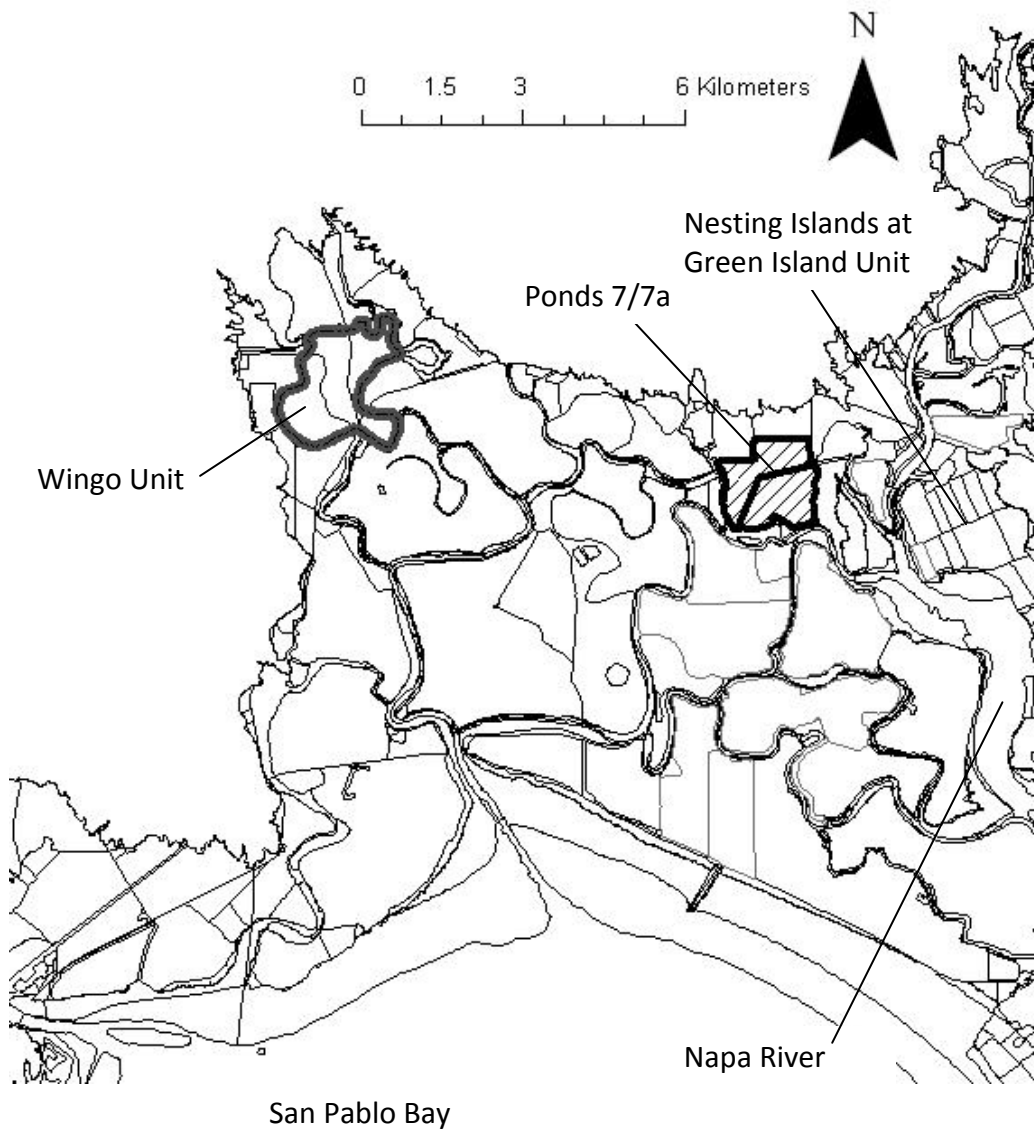


Figure 2. Snowy Plover nesting areas in the Napa-Sonoma Marshes Wildlife Area: the Wingo Unit, ponds 7/7a and the nesting islands at the Green Island Unit (formerly called the Napa Plant Site), North San Francisco Bay, California.

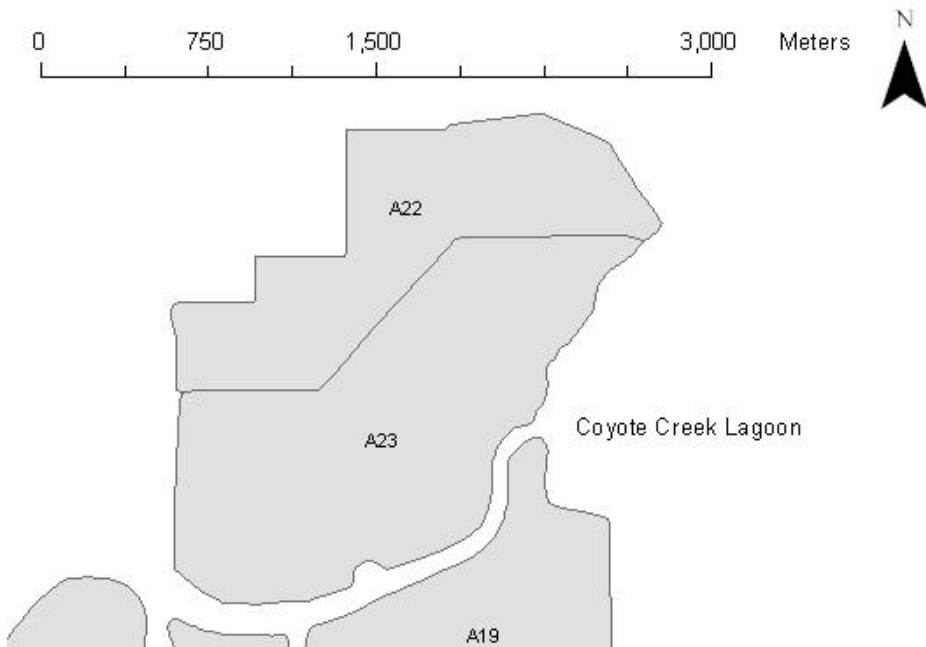


Figure 3. Salt ponds located in the Refuge’s Warm Springs area, near Fremont, South San Francisco Bay. See Figure 1 for location of Warm Springs within South San Francisco Bay.

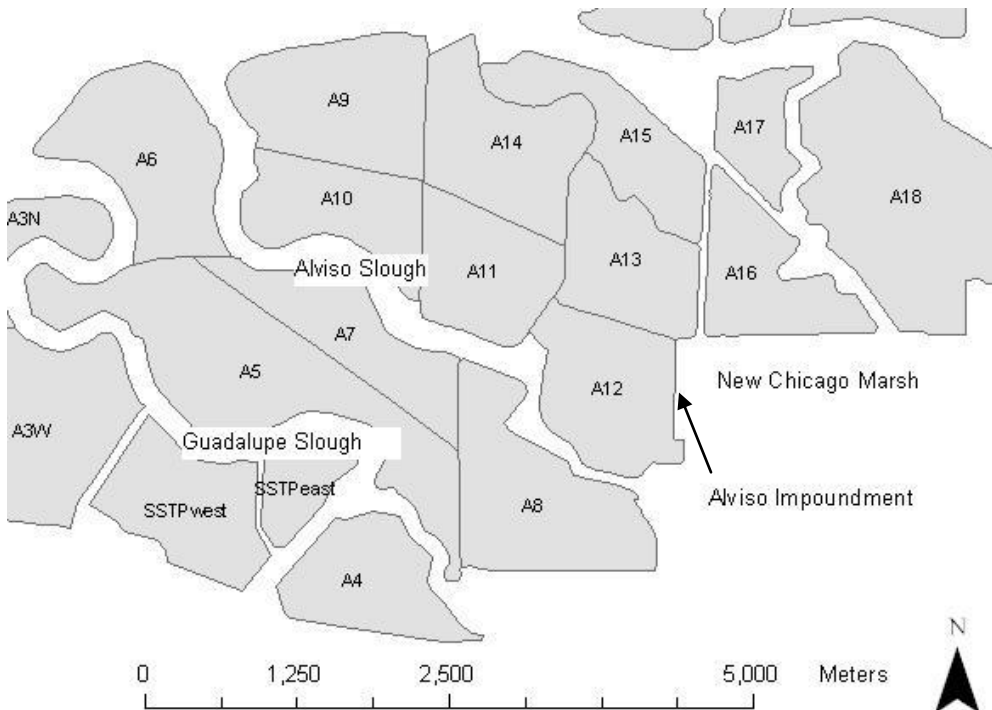


Figure 4. Salt ponds in the Refuge’s Alviso complex, at the southern end of the South San Francisco Bay. See Figure 1 for location of Alviso within South San Francisco Bay.

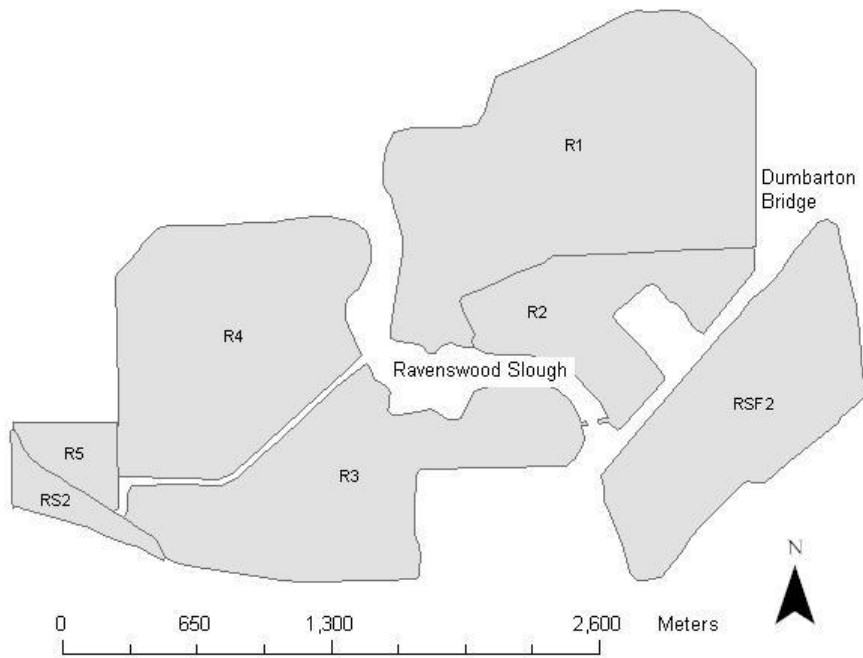


Figure 5. Salt ponds in the Refuge's Ravenswood complex, at the west end of the Dumbarton Bridge, South San Francisco Bay. See Figure 1 for location of Ravenswood within South San Francisco Bay.

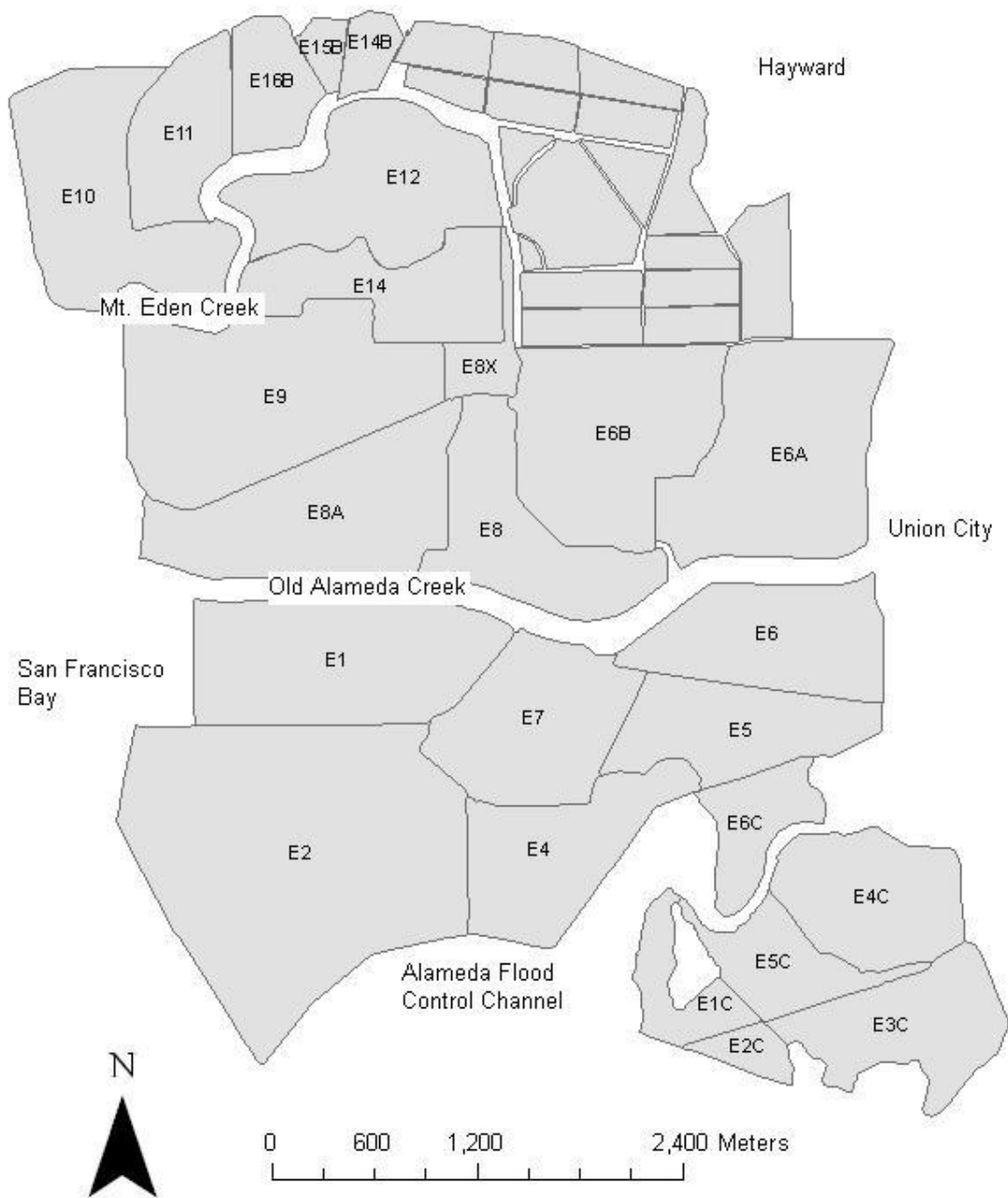


Figure 6. Salt ponds in the CDFG's Eden Landing Ecological Reserve Complex, near Hayward, South San Francisco Bay. See Figure 1 for location of Eden Landing Ecological Reserve within South San Francisco Bay.

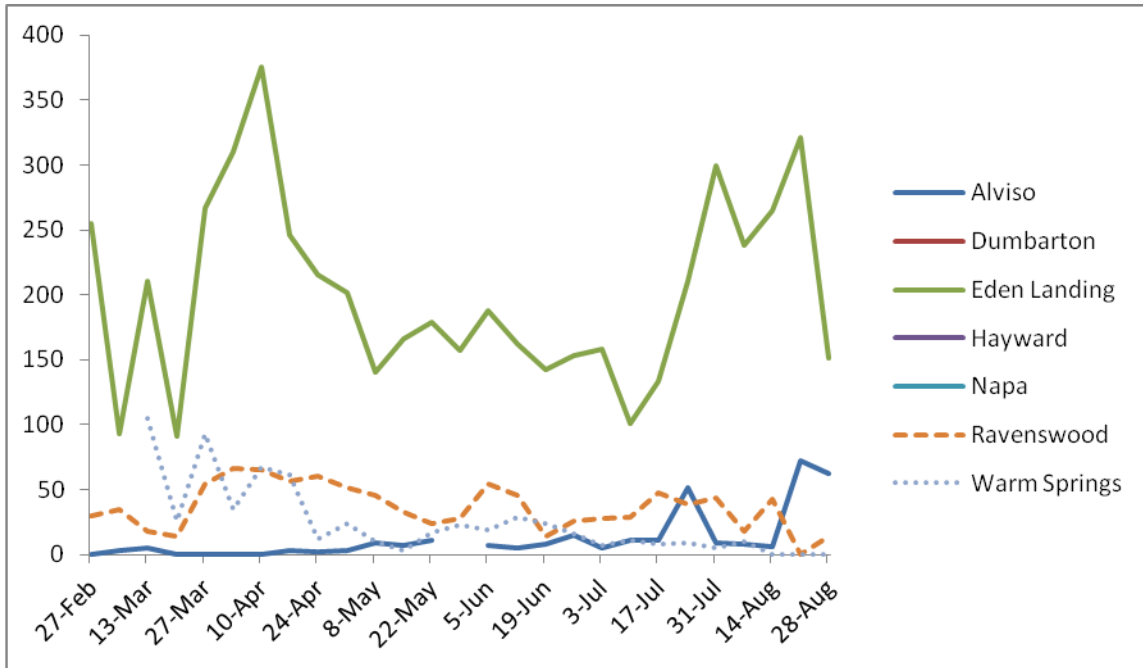


Figure 7. Weekly counts of adult Snowy Plovers by week and area, South San Francisco Bay, California, 2011.

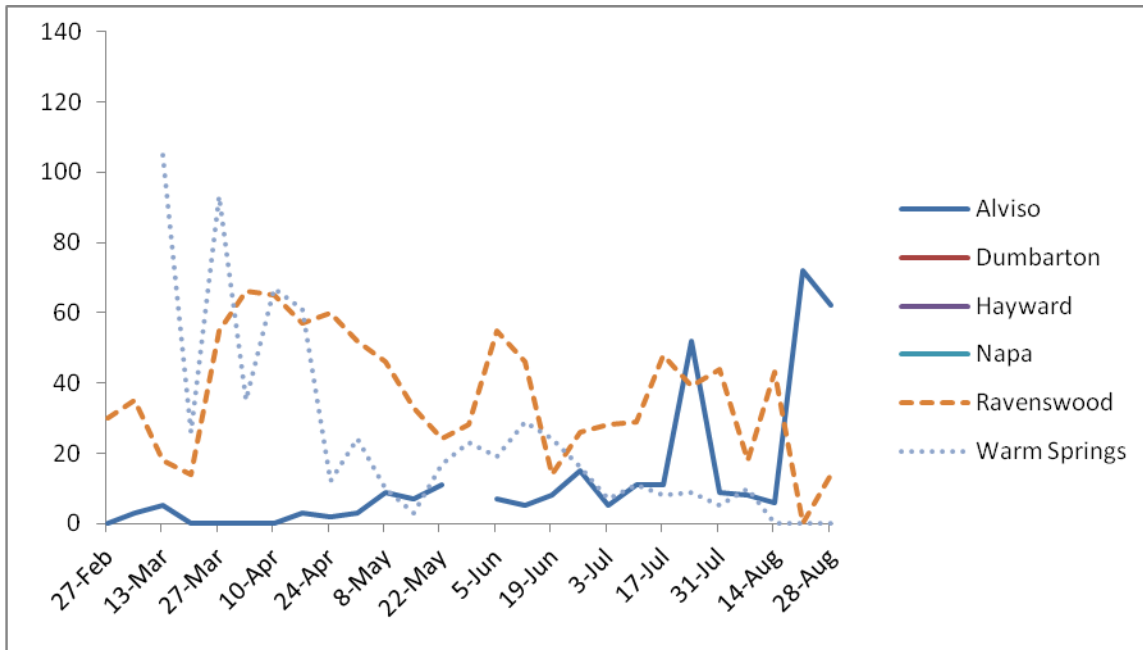


Figure 8. Weekly counts of adult Snowy Plovers by week and area, South San Francisco Bay, California, 2011, excluding Eden Landing Ecological Reserve.

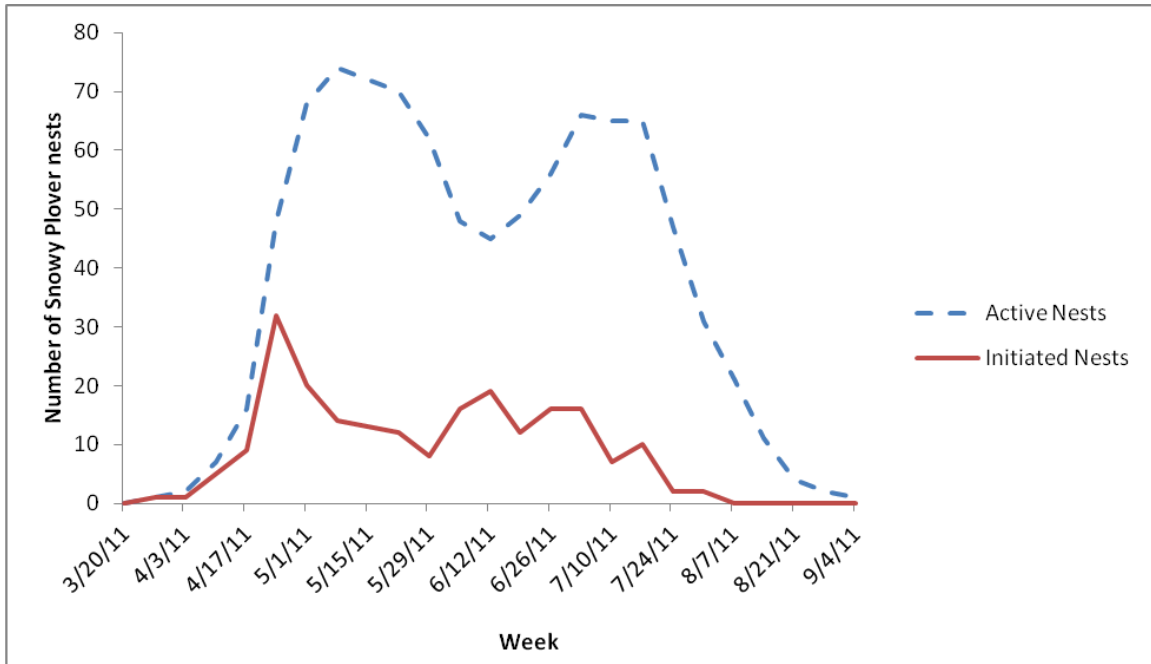


Figure 9. The weekly number of initiated and active Snowy Plover nests in the South San Francisco Bay, California, 2011.

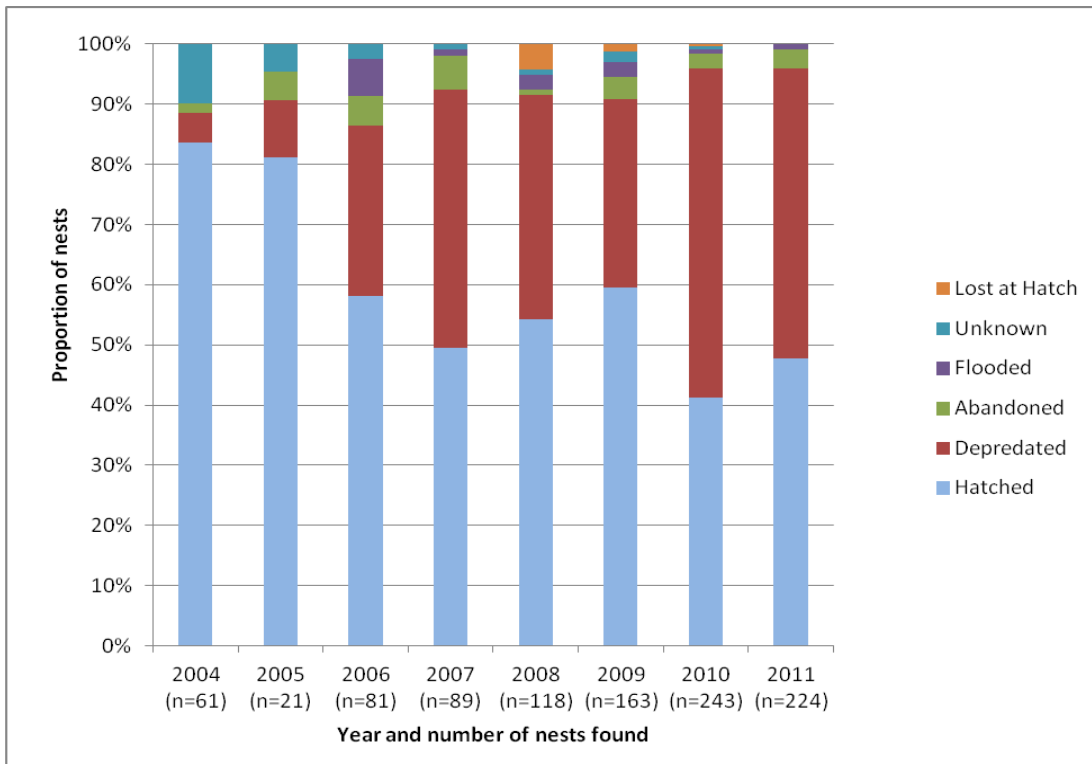


Figure 10. Annual apparent Snowy Plover nest fates in the South San Francisco Bay, California, 2004-2011.

Table 1. Ponds surveyed weekly within the Don Edwards San Francisco Bay National Wildlife Refuge, South San Francisco Bay, California, 2011.

Location	Ponds
Alviso	A5, A6, A7, A8, A12, A13, Impoundment, New Chicago Marsh
Dumbarton	N1, N2, N3, PP1
Ravenswood	R1, R2, R3, R4, R5, SF2
Warm Springs	A22, A23

Table 2. Ponds surveyed weekly within California Department of Fish and Game property, San Francisco Bay, California, 2011.

Location	Ponds
Eden Landing Ecological Reserve	E6, E6A, E6B, E8, E8A, E8X, E11, E12, E13, E14, E15B, E16B, E1C, E2C, E3C, E4C, E5C
Napa-Sonoma Marshes Wildlife Area	7, 7A

Table 3. Snowy Plover nest fates by pond in the South San Francisco Bay and the Napa-Sonoma Marshes Wildlife Area, California, 2011.

Location	Hatched	Depredated	Abandoned	Flooded	Unknown	Other	Lost at Hatch	Total nests
Alviso								
New Chicago Marsh	4	2	0	0	0	0	0	6
Eden Landing								
E6B	3	8	0	0	0	0	0	11
E8	19	18	3	0	0	0	0	40
E8A	22	35	2	1	0	0	0	60
E12	12	7	1	0	0	0	0	20
E13	1	3	0	0	0	0	0	4
E14	0	1	0	0	0	0	0	1
E16B	6	9	0	0	0	0	0	15
E11	4	1	0	0	0	0	0	5
E6	3	3	0	1	0	0	0	7
E4C	0	1	1	0	0	0	0	2
Ravenswood								
R1	0	1	0	0	0	0	0	1
R3	2	1	0	0	0	0	0	3
R4	6	3	0	0	0	0	0	9
R5	3	3	0	0	0	0	0	6
RSF2	16	2	0	0	0	0	0	18
Warm Springs								
A22	4	7	0	0	0	0	0	11
A23	1	1	0	0	0	0	0	2
Hayward Shoreline								
Hayward	1	2	0	0	0	0	0	3
Total South Bay	107	108	7	2	0	0	0	224
Napa Plant Site	2	0	0	0	0	0	0	2
Huichica Creek Unit	0	1	0	0	0	0	0	1
Wingo Unit	1	0	0	0	0	0	0	1
RU3 Total	110	109	7	2	0	0	0	228

Table 4. Summary of nest data for Snowy Plovers in Alviso, Eden Landing, Ravenswood and Warm Springs complexes, 2006-2011. Mean initiation dates is given by day of the year and the calendar date. Sample size is the number of nests used in the nest success analysis.

Area	Year	Nests Monitored	Mean Initiation Date	Nest Success	Confidence Limits		
					Lower 95%	Upper 95%	
Alviso	2006	11	131	(May 11)	53%	0.15	0.81
	2007	2	92	(April 2)	51%	0.11	1.00
	2008	6	133	(May 13)	48%	0.09	0.81
	2009	7	164	(June 13)	46%	0.06	0.81
	2010	2	97	(April 7)	44%	0.04	0.81
	2011	6	145	(May 25)	41%	0.03	0.81
Eden Landing	2006	70	145	(May 25)	32%	0.00	0.80
	2007	80	147	(May 27)	29%	0.00	0.80
	2008	90	138	(May 18)	27%	0.00	0.80
	2009	97	134	(May 14)	25%	0.00	0.80
	2010	142	147	(May 27)	23%	0.00	0.80
	2011	165	148	(May 28)	20%	0.00	0.80
Ravenswood	2006			No nests monitored			
	2007	7	158	(June 7)	69%	0.12	0.94
	2008	17	146	(May 26)	67%	0.09	0.94
	2009	33	125	(May 5)	65%	0.06	0.94
	2010	72	124	(May 4)	63%	0.04	0.94
	2011	37	128	(May 8)	62%	0.03	0.94
Warm Springs	2006			No nests monitored			
	2007			No nests monitored			
	2008	4	121	(May 1)	21%	0.00	0.79
	2009	21	141	(May 21)	65%	0.00	0.78
	2010	23	131	(May 11)	17%	0.00	0.78
	2011	13	154	(June 3)	15%	0.00	0.78

Table 5. Snowy Plover nest densities (nest/acre) by pond on Refuge property in the South San Francisco Bay, California, 2011.

Pond	R1	R3	R4	R5	RSF2	A22	A23
Nests per ha	0.01	0.03	0.08	0.46	0.18	0.10	0.01

Table 6. Snowy Plover nest densities (nests/acre) by pond at Eden Landing Ecological Reserve in the South San Francisco Bay, California, 2011.

Pond	E6	E6A	E6B	E8	E8A	E11	E12/13
Nests per ha	0.18	0.007	0.25	0.48	0.10	0.15	0.23
	E14	E16B	E1C	E3C			
	0.0476	0.61	0.18	0.05			

Table 7. Total number of chicks banded, chicks fledged and percent fledged per pond in the South San Francisco Bay, California, 2011.

	Chicks Banded	Chicks Fledged	Percent Fledged
Eden Landing			
E8A	11	2	18.2%
E6	1	0	0.0%
E6B	3	0	0.0%
E12	4	1	25.0%
E16B	7	0	0.0%
E8	12	2	16.7%
Total	36	5	13.9%

Table 8. Number of nests monitored, fates and densities for control plots, shell plots and all other nests at Eden Landing Ecological Reserve in the South San Francisco Bay, California, in 2009 through 2011.

	2009			2010			2011		
	Control Plot	Shell Plot	All other Eden Landing Areas	Control Plots	Shell Plots	All other Eden Landing Areas	Control Plots	Shell Plots	All other Eden Landing Areas
Number of Plots	7	7		12	12		15	15	
Nests monitored	0	24	66	3	42	97	3	35	127
Density (nests/ha)	0	3.43 *	0.07	0.25	3.50*	0.10	0.20	2.33*	0.19
Observed Hatched	0	67% **	56.06%	0%	31%	32%	33%	45%	42%
Observed depredated	0	13%	43.94%	100%	64%	66%	66%	43%	54%

*Indicates significantly higher nest density in shell compared to control plots within the same year (all $P > 0.015$)

**Indicates greater chances of nests hatching in shell plots compared to all of Eden Landing nests within the same year ($P=0.026$)

Table 9. Number of chicks banded, chicks fledged and percent fledged in the shell plots per pond at Eden Landing Ecological Reserve in the South San Francisco Bay, California, 2011.

	Chicks Banded in Shell Plots	Chicks Fledged in Shell Plots	Percent Fledged
E16B	3	0	0
E8	4	0	0
E6B	8	0	0

Table 10. The mean numbers of predators per survey in each area of the San Francisco Bay, California, 2011. (We did not include the Alviso California Gull colony of 11,956 individuals in our estimates.)

	Species	Alviso	Dumbarton	Eden Landing Ecological Reserve	Hayward	Napa Sonoma Marshes Wildlife Area	Ravens- wood	Warm Springs
Predators of Concern	Northern Harrier	1.00		1.22		1.00	1.00	1.11
	Common Raven	2.67		1.40			1.93	4.00
	Peregrine Falcon			1.08		1.00	1.00	1.00
	American Crow			1.75			4.00	2.18
	White-Tailed Kite		1.00	1.13			1.25	1.00
	American Kestrel			1.00				1.00
	Red-Tailed Hawk	2.00		1.20			1.07	1.00
	California Gull	131.04	38.56	26.58	2.50		21.35	206.92
Unidentified Gull	121.64		11.39	2.00		9.47	80.28	
Other Predators	Black-Crowned Night Heron	1.00		1.68			1.00	
	Great Blue Heron	1.00		1.49		1.00	1.00	
	Snowy Egret	1.43		3.94			2.90	1.00
	Great Egret	1.31		1.97		1.00	1.38	1.00
	Loggerhead Shrike							1.50
	Golden Eagle							1.00
	Number of Surveys	15	3	103	1	4	64	25