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BIRD OBSERVATORY

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Western Snowy Plover Numbers, Nesting Success, Fledging Success and Avian Predator Surveys in the San Francisco Bay, 2010.

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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 alexandrinus 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 2010, 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 2010 breeding season window survey of the Pacific coast (24 May – 7 June) we counted 275 adult Snowy Plovers in the Bay. In 2010, we determined the fate 243 Snowy Plover nests in the South San Francisco Bay (South Bay). One hundred of the nests hatched (41%), 133 were depredated (54%), six were abandoned (2%), two were flooded (>1%), one had an unknown fate (>1%) and one was lost at hatch (>1%).

On Refuge property, we determined the fate of two nests in the Alviso pond complex (pond A6 and the dry pan area of New Chicago Marsh), 72 nests in the Ravenswood complex (ponds SF2 and R1 – R5) and 23 nests in the Warm Springs complex (ponds A22 and A23). Of these nests, 54 hatched (55.6%), 39 were depredated (40.2%), and 4 were abandoned (4.1%).

This year we determined the fate of 142 Snowy Plover nests at Eden Landing Ecological Reserve (Eden Landing). Of the 142 nests, 45 hatched (31%), 91 were depredated (64%), 1 was lost at hatching (1%), 2 were flooded (1.5%), 2 were abandoned (1.5%) and 1 had an unknown fate (1%).

We determined the fate of one nest at Hayward Shoreline, in the Old Oliver Brothers North salt ponds, which hatched. There were three nests on EBRPD's Least Tern island, all of which were depredated.

DFG biologists determined the fate of 9 plover nests in the North Bay; 3 at the Napa Sonoma Marshes Wildlife Area and 6 at the Napa Plant Site. Seven of the monitored nests in the North Bay hatched (77.8%).

Throughout the South Bay, we banded 39 chicks. From visual observations, we determined that 16 chicks survived to fledging (41%) as of 30 September 2010. 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/m^2 over twelve one ha plots. In 2010, more plovers nested in shell plots than in control plots, however there was no difference in the likelihood of nests in shell plots hatching successfully compared to nests outside of the shell plots (χ^2 =0.0002, df=1, *P*=0.98). This is in contrast to 2009 where nests in shell plots were more likely to hatch than nests outside of the shell plots (χ^2 =4.98, df=1, *P*=0.026).

SFBBO, with the help of H.T. Harvey and Associates, deployed camera systems at Snowy Plover nests at Eden Landing Ecological Reserve for a second year. We placed camera systems at 21 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 Grey Fox (*Urocyon cinereoargenteus*) and Ruddy Turnstone (*Arenaria interpres*) depredating Snowy Plover nests.

We recommend that the South Bay Salt Pond Restoration Project (Project) carefully plan construction activities so they do not 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 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 will need to take great care in maintaining enough Snowy Plover nesting habitat to maintain and increase the number of nesting Snowy Plovers in the South Bay. In addition, as areas are opened to the public, managers will need to take numerous steps to reducing recreational impacts to nesting Snowy Plovers. The Project will impact Snowy Plovers in multiple ways and managers and researchers should continue to study and monitor the plovers South Bay to reduce the negative impacts in the future.

INTRODUCTION AND BACKGROUND

The Pacific coast Western Snowy Plover (*Charadrius alexandrinus nivosus*) population, breeds along or near tidal water and is behaviorally distinct from the interior population

(Funk 2007). The Western 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 and San Mateo counties (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 (Project) plans to restore over 15,000 acres of artificial salt pond habitat to tidal marsh and managed ponds. Despite the loss of plover habitat (dry salt pond) expected through the Project's actions, the Project has set a goal of maintaining 125 breeding pairs of Western Snowy Plovers within its footprint. To aid in achieving this goal, in the winters of 2008-2010, SFBBO and the Refuge initiated a habitat enhancement study on ponds currently managed for Snowy Plovers at Eden Landing. Enhancements included removing potential raptor perches from the ponds and surrounding levees. In addition, using experimental plots, we added oyster shells to the pond bottoms to 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 and 2010.

This report summarizes the 2010 breeding season data, including Snowy Plover surveys, nest success, fledging success, habitat enhancement projects and avian predator surveys.

METHODS

Study Area

SFBBO and Refuge staff and volunteers conducted Snowy Plover and predator surveys in the South San Francisco Bay (South Bay) ponds (Figure 1) and at one site in the North Francisco Bay (North Bay) ponds (Figure 2). The South Bay, which includes the area just north of the San Mateo Bridge (Highway 92) and extends to the extreme southern portion of the Bay, contains the majority of the Snowy Plover habitat in the Bay Area.

The Refuge includes approximately 30,000 acres of former salt pond habitat, tidal marsh, mudflats and upland habitat in the South San Francisco 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 (formally 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, 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 an island constructed for California Least Terns (*Sternula antillarum brownii*) in the adjacent area which is also used by nesting Snowy Plovers.

Snowy Plover Surveys

Snowy Plovers in the San Francisco Bay nest predominantly on dry salt ponds. To identify areas used by plovers and estimate the number of Snowy Plovers in the South Bay, we identified ponds with potential plover nesting habitat and surveyed those ponds weekly. We surveyed other ponds with less suitable habitat monthly.

From 1 March to 31 August 2010, 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 16 Refuge ponds and 17 Eden Landing ponds weekly (Table 1, Table 2). SFBBO volunteers surveyed the Dumbarton, Napa-Sonoma Marshes Wildlife Area monthly and HARD ponds monthly. SFBBO surveyed the Mowry salt pond complex monthly as part of SFBBO's Cargill Salt Pond Waterbird Surveys (see Robinson-Nilsen et al. 2009a 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. We calculated the mean number of Snowy Plovers seen per area per survey (total number of Snowy Plovers seen over the season in an area pond or pond complex, divided by the number of surveys completed).

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 and Refuge staff searched for the potential nests on foot. Volunteers did not search for nests on foot.

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. 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 nest success rates for the South San Francisco Bay Snowy Plover population by calculating the percentage of total nests that hatched at least one egg. Additionally, we calculated nest density in the ponds by dividing the number of nests in each pond by the size in hectares. Using only nests that SFBBO monitored, we estimated nest success using the

Mayfield method (Mayfield 1961). We did not include North Bay data in these calculations.

Chick Color Banding

Beginning in 2008 and continuing through the 2010 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 (K. Neuman, pers. comm.).

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. To estimate the number of chicks fledged per male, we used the number of chicks fledged per brood when we banded all the chicks in a brood.

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 2 plots placed on the pond bottom, a 1 ha oyster shell treatment plot (shells spread at five to eight shells/m^2) 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. 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. Likewise, volunteers conducted monthly avian predator surveys at ponds surveyed for plovers 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).

As in past years, the Refuge supervised and directed the predator management program and USDA Wildlife Services provided predatory removal services for mammals on the Refuge and for avian predators and mammals at Eden Landing.

Nest Cameras

In order to determine the predators depredating Snowy Plover nests, we placed camera systems at nests to continuously record nest activities. We used security cameras placed in camouflaged ammunitions boxes positioned 10 to 30 m from 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 2010 breeding season window survey of the Pacific Coast, we counted 275 plovers in the San Francisco Bay. We observed a mean of 264 birds observed per week from 9 March through 16 August in the entire South Bay (Figure 7).

We consistently observed the greatest numbers of Snowy Plovers in the South Bay at Eden Landing during Snowy Plover surveys. Throughout the breeding season, we found the largest number of Snowy Plovers on pond E6B, which CDFG managed as Snowy

Plover nesting and foraging habitat. We also regularly observed Snowy Plovers on Refuge ponds A22, A23, SF2, and R4 (Figure 7).

Refuge

We observed the most Snowy Plovers in the Warm Springs ponds and pond SF2 throughout the season. The mean number of plovers we observed per week from 9 March through 16 August on Refuge property was 87 birds (Figure 7). Snowy Plovers used SF2 in the beginning of the season and decreased their use of pond SF2 and relocated to pond R1 at the beginning of July as R1 started to dry out (Figure 8). We observed Snowy Plovers in pond R4 throughout the season

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 159 birds observed per week from 9 March through 16 August (Figure 7). Pond E6B consistently had large numbers of Snowy Plovers throughout the season. Pond E16B had very large numbers of plovers in the beginning of the season, and pond E8A hosted large numbers once it dried near the end of the season.

During the last two weeks of August, we observed more than 400 Snowy Plovers at Eden Landing; presumably they were either migrating or wintering birds (Figure 7). At this point the Snowy Plovers move around the pond complexes daily and we may have counted birds more than once throughout the surveys.

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 former salt ponds and on the Least Tern Island.

Napa-Sonoma Marshes Wildlife Area and Napa Plant Site

A SFBBO volunteer and Karen Taylor, a biologist with CDFG, regularly observed small numbers of plovers using ponds 7 and 7A (mean of 15 birds per survey) and up to seven plovers at Napa Cargill Salt Pond Site.

Reproductive Success

South Bay Overall

We determined the fate for 243 Snowy Plover nests in the South Bay. Out of these nests, 100 hatched, 133 were depredated, six were abandoned, two were flooded, one was lost at hatch and one had an unknown nest fate (Table 3).

Refuge

In 2010, SFBBO determined the fate for 97 Snowy Plover nests on Refuge property (Table 3). In the Alviso complex, we determined the fate of one nest in the dry pan areas of New Chicago Marsh which hatched, and one nest in pond A6 which was depredated.

We determined the fate for 72 nests in the Ravenswood complex. Of these, 46 hatched (64%) and 22 were depredated (31%) and four were abandoned (5%). We found the most nests on pond SF2 (n=33; Table 3).

We determined the fate for 23 nests in the Warm Springs area on the Refuge. Of these, seven hatched (30%) and 16 were depredated (70%; Table 3). Pond A23 had the most nests (n=19).

Eden Landing

We determined the fate for 142 Snowy Plover nests at Eden Landing (Table 3). Of these, 45 hatched (31%), 91 were depredated (64%), two were abandoned (1.5%), two were flooded (1.5%), one nest were lost at hatch (1%) and one nest had an unknown fate (1%). Pond E8 had the most nests (n=35), followed by pond E6B (n=29) and E12/13 (n=21; Table 3).

Hayward Shoreline

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

SFBBO determined the fate for one nest on the Oliver Brothers North salt ponds. This nest hatched and we banded two of the three chicks.

Napa-Sonoma Marshes Wildlife Area and Napa Plant Site

In 2010, DFG biologists found and determined the fate for 3 Snowy Plover nests on the levee separating ponds 7 and 7a in the Napa-Sonoma Marsh Wildlife Area, one of which hatched (33.3%). They also monitored 6 nests at the Napa Plant Site, all which hatched (K. Taylor, pers. comm.; Table 3).

Mayfield Estimates

We observed 5439 nest exposure days (Mayfield 1961). One hundred thirty-four nests were lost to depredation or flooding. Therefore, mortality was 134/5439 or 0.025. Survival was calculated as 1 – 0.025 or 0.975. The probability that a nest survived the 33 days between nest initiation and hatching was 0.975^{33} or 0.44.

Nest Density and Breeding Chronology

The average nest density in the South Bay was 0.20 nests per hectare. The pond with the highest nest density was R5, with 0.84 nests per hectare while R1, R2 and A23 all had the lowest nest densities at 0.02 nests per hectare (Table 4 and Table 5).

The peak Snowy Plover nest initiation week in the South Bay was 2 May 2010 with 31 nests initiated (Figure 9). The number of initiated nests per week stayed fairly constant throughout the season, with the number ranging between 10 and 20 nests initiated per week. The number of active nests peaked during the week of 9 May 2010 with 87 active nests (Figure 9).

Chick Fledging Success

We banded 39 Snowy Plover chicks. We determined that 16 chicks fledged (41% fledging rate). The fledge rate was 39% at Eden Landing (n=33), 100% at Hayward Shoreline (n=2), and 25% at Ravenswood (n=4; Table 6). These are the only areas where chicks were banded.

The number of chicks fledged varied by pond and ranged from 0% on pond E6B, E8 and E16B (n=17) to 100% on pond E14 (n=3), E8A (n=2) and Oliver Brothers North pond 14 (n=2; Table 6).

Habitat Enhancement Project: Oyster Shell Plots

We spread twelve 1-ha size shell plots prior to the 2010 breeding season. Three plots were on E16B, two plots on E8, three on E6B, three on E14 and one on E6A. For each of these plots, we established a paired control plot at the same time.

Forty-two of the 142 nests that we monitored at Eden Landing were located in shell plots. More Snowy Plovers nested in shell plots (n=42) than control plots (n=3; t=2.927, df=11, P=0.013). Two of the E16B shell plots were used heavily in the beginning of the season with five nests in each plot. We recorded the highest known Snowy Plover nest density in the San Francisco Bay in one of the E8 shell plot which had 9 nests/ha active at the same time.

Given the small sample size of nests within control plots, we compared nest success in shell plots to all other nests at Eden Landing. Observed nest success in the shell plots was 31%, whereas the nest success at Eden Landing outside of the shell plots was 32%. There was no difference in the likelihood of a nest hatching between shell plot nests and non-shell plot nests (χ^2 =0.0002, df=1, P=0.98). Sixty-four percent of the shell plot nests were depredated compared to 66% of nests at Eden Landing outside of the shell plots. The observed nest success was lower than the Mayfield nest success both inside the shell and control plots, and for all other nests at Eden Landing (Table 8). The nest

density corrected with the Mayfield estimate was lower than the observed nest density, both inside the shell plots and for all other nests at Eden Landing (Table 8).

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% (Table 9).

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 at this time of year and location; Table 10). Other frequently observed predators in Alviso included Common Ravens in A8 and A12 and Great Egrets and Snowy Egrets, which we observed foraging in ponds A5 and A7. We also 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. At one point we saw a group of 26 crows foraging on the pond bottom. We usually observed the corvids west of the PG&E towers running through the pond, in the designated Snowy Plover area. Another predator that we observed on SF2 throughout the season was a Red-tailed Hawk, which was perched on the PG&E towers. We observed large numbers of gulls and Common Ravens at Warm Springs (Table 10).

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.

At the beginning of the season, we regularly observed a pair of Red-tailed Hawks perched along the small power lines that are by E12/E13 to the Eden Landing Road access gate. We also observed different Red-tailed Hawks along Old Alameda Creek, perched on the old power poles.

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 were the most commonly observed avian predator at Hayward Shoreline (Table 10). A volunteer also observed unidentified gulls and Red-tailed Hawks at the ponds.

Napa-Sonoma Marshes Wildlife Area

Unidentified gulls and California Gulls were the most commonly observed avian predator at the Napa-Sonoma Marsh Wildlife Area (Table 10). In the North Bay, the

"unidentified" gulls could also be Western Gulls (*Larus occidentalis*) as this species nests in large numbers in the vicinity. A volunteer also observed Northern Harriers and Great Egrets at the Napa-Sonoma Marsh Wildlife Area.

Nest Cameras

We recorded footage at 21 nests throughout the season, and filmed four depredation events. We recorded two California Gulls, a Gray Fox (*Urocyon cinereoargenteus*) and a Ruddy Turnstone (*Arenaria interpres*) depredating Snowy Plover nests.

Mammalian Predators

In addition to the Gray Fox recorded depredating a Snowy Plover nest on camera, we saw skunks, raccoons, opossums, and feral cats around nesting ponds. However, the feral cat feeding station did not appear to be operating outside the Veasy Street gate to Eden Landing during the 2010 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 275 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 plovers may have stayed in the Bay later than usual due to storms late in the spring. The average number of plovers in the Bay between the middle of May and the middle of July was 195 which is slight higher than last year during the same time period when we were observing an average of 189 plovers per week. Eden Landing continues to host the majority of the Bay Area's Snowy Plovers, though numbers increased this season at pond SF2 and at the Warm Springs ponds.

Reproductive Success

We found more Snowy Plover nests in the South Bay in 2010 (n=243) than in previous years (163 in 2009, 118 nests in 2008 and 89 in 2007). While the increase in nests may indicate that there are more plovers nesting this year; 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; plovers are known to renest up to six times in one season and we

may have been finding numerous nest attempts by the same individuals (Warriner et al. 1986).

Observed nest success in the South Bay decreased in 2010 from 59% in 2009 to 41% in 2010. This is the lowest nest success recorded in the South Bay since 2004 (Figure 10). This may be due to decreased predator management activities in the area because of lack of funding in 2010. In 2009, Wildlife Services was able to maintain a full time biologist at Eden Landing; in 2010, this was reduced to less than one-quarter time.

In 2010, more plovers nested on Refuge ponds than in previous years. We found 72 nests in the Ravenswood ponds, which is more than we found in all areas of the Refuge in previous years. However, the Warm Springs ponds and pond A22 in particular, had high rates of nest depredation. These ponds are located between the Newby Island Landfill and the Tri-Cities Landfill; large numbers of gulls 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 10,800 adult California Gulls bred on Mowry ponds M1/M2 and M4/M5, which is adjacent to the Warm Springs ponds (Tokatlian et al. 2010). We also observed large flocks of corvids in the flying between the landfills and in the cow pastures to the north west of the plover nesting ponds.

Pond A8 was flooded this year to exclude Snowy Plovers from nesting there due to construction on this pond. This lack of habitat within the Alviso complex may have caused a Snowy Plover pair to nest on pond A6, which hosts the largest California Gull breeding colony in the Bay. Plovers also nested on the dry pan area of adjacent New Chicago Marsh once it dried out later in the season.

As in 2009, the Ravenswood ponds R1 and R2 where the majority of the Ravenswood Snowy Plovers nested in 2007 and 2008, were flooded during the winter. These ponds were still flooded at the beginning of breeding season, and, likely in response, large numbers of plovers nested on SF2 again. Once R1 dried in July, the plover use of SF2 decreased, and we began to observe plovers nesting on R1. (For more on pond SF2, please see the Restoration and Snowy Plover Nesting section below.)

At Eden Landing, Snowy Plovers nested on 13 ponds, with the majority of the nests on ponds E16B, E8A, E8 and E12/E13. 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 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 and chicks would need to go elsewhere to forage. Adjacent to E16B is Mount Eden Creek which is tidal. Male plovers may lead their chicks elsewhere to forage and crossing this wetland may be dangerous for small plover chicks.

Ponds E12/E13, E14 and E8A were flooded during the majority of the season to keep plovers from nesting in the ponds during construction for the South Bay Salt Pond Restoration Project. In response to the limited habitat available, we found four nests on levees that host vehicular traffic, and three on levees that were not drivable. Although the levee nests did not impede any construction activities, nesting on levees can endanger plover adults, chicks, and nests due to human disturbance, vehicle traffic, and easy access for mammalian predators. All of the seven nests on levees in 2010 were depredated.

There were nine Snowy Plover nests this season in the North Bay this season. This is the second 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 fall the Napa Plant Site, which hosted 6 plover nests this season, was open to tidal action which may change the plover use of this area.

Chick Fledging

The 2010 South Bay fledging rate of 41% was higher than the 2009 rate of 24.8% and the 2008 rate of 28.9%. However, this year we focused our banding efforts on nests within shell plot areas and nests within construction areas; therefore the sample of banded chicks was not random and may not be comparable to previous years' samples. We also banded more chicks later in the season, which is when we observe the greatest number of chicks surviving. This year's higher fledging rate is surprising due to the large numbers of gulls and other predators seen in nesting areas, the high rates of predation on Snowy Plover chicks in other years (Robinson et al. 2008, Robinson-Nilsen et al. 2009b), and predation rates on other shorebird chicks in the South Bay (Ackerman et al. 2006).

At pond SF2, we banded four Snowy Plover chicks, but confirmed that only one chick survived to fledging. We consistently saw flocks of American Crows as well as Common Ravens walking and scavenging on the pond bottom. These birds roosted in the trees in adjacent business parks and the PG&E substation near pond R2. The trees near the PG&E substation are due to be removed over the 2010/2011 winter, so these roost sites will not support these birds in future breeding seasons. We also regularly observed Red-tailed Hawks and a Peregrine Falcon roosting on the PG&E towers running through the western side of the pond.

The chicks banded in pond E12/E13 had the highest fledgling success rate at Eden Landing, as in 2008 and 2009. The E12/E13 chicks may have benefited from hatching later in the season when there are additional predator food sources in the ponds in July and August with the return of migratory shorebirds.

Habitat Enhancement Project: Oyster Shell Plots

Snowy Plovers nested in the oyster shells plots more frequently than in control plots. However, as in 2009, the amount each plot was used varied, most likely based on location of plot within the pond, pond conditions, and the brightness of the shells. The plots that were not used were either located under PG&E transmission line towers or had been flooded for much of the winter and large amounts of sediment was deposited on the shells. The brightness of the shells varied on the plots that had been flooded for most of the winter; some shells were completed covered in sediment while others were still mostly white. Even if covered in sediment, the shells all provided some relief in topography.

We recorded highest nest density in the South San Francisco Bay within a shell plot on E8 in 2010 which was spread in 2008. Of the 11 nests in this plot, nine were depredated and two hatched. Overall nest density in shell plots was much higher than the average for the South Bay. This has important implications as the amount of available nesting habitat on salt ponds is reduced by the South Bay Salt Pond Restoration Project. Snowy Plover nesting density will need to increase in order to increase the Snowy Plover breeding population within a smaller habitat footprint. The nest densities observed within the oyster shell plots demonstrates that it may be possible to achieve the higher nest densities needed to reach the recovery goal of 500 breeding birds in the San Francisco Bay. However, in 2010, observed nest success within the shell plots (32%) was no different than nests outside of the shells (31%) at Eden Landing and the proportion of depredated nests was very similar as well (64% in the shell plots compared to 66% 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 the nests at Eden Landing (44%; Robinson-Nilsen et al. 2009b). Page et al. (1983) found that plovers nesting in higher densities had higher depredation rates at Mono Lake. Likewise, it is possible that predators cued in on the presence of the shells plots as a food source. If this is the case, then, oyster shells may eventually function as an ecological trap by attracting many nesting plovers to a low quality habitat. It is also possible that the reduced predator removal effort at Eden Landing may have contributed to the decreased success as well. Additional data will be needed to determine if oyster shell enhancements are an effective conservation tool for plovers in the San Francisco Bay. To that end, in the fall of 2010, SFBBO spread shells at three additional 1-ha plots, for a total of 15 plots, in order to further test the effectiveness of shells in reducing nest predation, increasing nest density, and increasing chick fledging rates. Given the expense, time and limited success of the shells this year, the use of oyster shell should only be considered as a small part of a larger plover management effort. It is unlikely that oyster shells alone will enable plovers to reach their Recovery Goal in the San Francisco Bay.

Avian Predators

From the data collected by the cameras, and the data collected during avian predator surveys, California Gulls continue to be a predator of concern. As in 2009, this year we captured evidence using nest cameras that California Gulls directly impact Snowy Plovers by nest depredation. California Gulls are opportunistic feeders and have been documented depredating other shorebird nests and chicks in the South Bay (Ackerman et al. 2006). Three of the largest gull colonies (Alviso A6 colony, Mowry M4/M5 colony and the Coyote Hills colony) are close to Snowy Plover nesting areas. This year we saw more gulls using the ponds at Eden Landing for foraging and roosting and the first gull nest was found there (D. Spatz, pers. comm.).

The largest colony on pond A6 hosted approximately 23,103 breeding adults (Tokatlian et al. 2010), a decrease from 2009 (24,190 breeding adults; Robinson-Nilsen et al. 2009c). Pond A6 was breached in December 2010, reducing the amount of breeding habitat available to California Gulls. Presumably, California Gulls will move elsewhere in the Bay Area to breed. If California Gulls begin breeding on or closer to Snowy Plover nesting ponds, gulls may further impact plovers by depredating nests and chicks, or encroach on nesting habitat.

We recorded one other avian predator depredating Snowy Plover nests in 2010: a Ruddy Turnstone. This small shorebird has been documented depredating nests, including those of Common Terns (*Sterna hirundo;* Farraway et al. 1986). The turnstone depredated a plover nest located in a shell plot.

Northern Harriers continue to be a predator of concern. As well as documenting the predation of plover nests and chicks with nest cameras in 2009, we frequently observed Northern Harriers hunting ponds with Snowy Plover nests in 2010. 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 plovers.

We frequently observed both Red-tailed Hawks and Common Ravens perched in the transmission towers within nesting ponds at all three 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.

This year we recorded camera footage of a Gray Fox depredating a plover nest at Eden Landing. Not only was this our first evidence of mammalian predators depredating nests, but it was our first recorded nocturnal depredation event. There is an active predator management program at Eden Landing for introduced mammalian predators;

native Gray Foxes are ear-tagged and released when trapped. This program may need to be reevaluated in the future if Gray Foxes continue to depredate Snowy Plover nests.

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 (the 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. The Project has agreed to support 125 breeding pairs of Snowy Plovers within the Project area. Here we make recommendations to reduce conflicts between restoration constructions activities and nesting plovers, manage habitats to help reach the Project's goal of 125 breeding Snowy Plover pairs, and reduce recreational disturbance that may result as the Project opens more areas to public use.

In 2010, the Project's Phase 1 construction activities continued on some of the ponds used by Snowy Plovers for nesting. We observed several negative effects on breeding Snowy Plovers, and recommend in the future 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 nearby or adjacent areas to ponds drained for construction to avoid plovers nesting in construction areas. In the future, if current Snowy Plover nesting ponds are to be flooded to exclude plovers, managers should drain other nearby ponds before 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 and actions be taken before the nesting season starts to deter Snowy Plovers from nesting on ponds where heavy equipment will be operating. For example, in Ravenswood pond SF2, construction began in late March, for the second year in a row, at the same time as Snowy Plovers were nesting on the pond. Unfortunately, construction is often able to begin only after rains have stopped, and this corresponds to nesting season in the Bay Area. At SF2, the Refuge manager designed a plan to pump dredge material into R1 rather than into SF2 as planned, which lessened the impacts to nesting plovers within this pond due to construction activities in 2010. SFBBO and Refuge biologists worked carefully with the construction crews so as not to crush known Snowy Plover nests or chicks with heavy equipment or step on them while walking through the ponds. However, two nests were depredated when construction crews were working within the 183 m (600 ft) buffer that the South Bay Salt Pond Restoration Project set in their Biological Opinion. Additionally, the Refuge collected a third nest before the construction equipment moved within 40 m of the nest. These eggs were incubated and hatched at the Monterey Bay Aquarium and at the age of 11

days, transported to International Bird Rescue Research Center where they were raised until fledging.

Construction started this July at Eden Landing on three ponds that had active Snowy Plover nests. Crews were working on the levees surrounding the ponds and heavy equipment was constantly running on the levees between plover nesting and foraging ponds. We observed plovers with broods crossing these levees or foraging within meters from the side of the levees. Coordination between the project managers (Ducks Unlimited), CDFG, and the contractor required weekly meetings during the breeding (and construction) season at Eden Landing. These meetings helped to facilitate arrangements between all parties involved and minimize impacts to plovers and work schedules.

The largest impact that the Project will have on South Bay Snowy Plovers is the reduction of nesting and foraging habitats, as 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 panne areas located near foraging habitat. While three Snowy Plovers nested on EBRPD's Least Tern Island this season, and one nest was found on an island in A12 in 2008, it is unknown how many pairs the created islands in ponds A16, SF2 and E12/13 will support. Therefore, dry salt panne habitat may need to be actively managed and maintained in the future as primary nesting habitat in order to reach the Project's goal of 125 breeding Snowy Plover pairs.

Another goal of the Project is to increase public access in certain areas. Currently, most Snowy Plover nesting areas are closed to the public; however, we routinely see trespassers in the closed area at Warm Springs and at Eden Landing. Research has shown that the 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 may need to 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 will need to be installed. Larger tracts of land may need to be kept free of public access 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 plovers use the habitats throughout the breeding season. Additionally, banding provides data on Snowy Plover adult survival rates, better population estimates, and chicks fledging success rates. This is vital information to reach the recovery goal of 500 birds in Recovery Unit 3, with 250 birds supported in the South Bay Salt Pond Restoration Project area.
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 the avian predator management on increasing Snowy Plover nest success.
5. Further studies on Northern Harrier territory size and habitat use.
6. Plover foraging habitat use (borrow ditches, open channel, muted tidal, shallow pools, dry substrate) and invertebrate availability within the salt ponds.
7. Determine whether Snowy Plovers in the Bay will nest on islands constructed as part of the South Bay Salt Pond Restoration Project.

Recommendations for Snowy Plover Recovery Unit 3

1. The Western Snowy Plover monitoring program should continue into the future. Monitoring the South Bay population is important to track how the Snowy Plover population changes as nesting habitat is reduced due to construction and habitat conversion to tidal.
2. 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.
3. 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. SFBBO, along with CDFG and the Refuge, should design interpretive panels to be placed in areas open to the public to educate people on Snowy Plover habitat needs 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 the potential 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 if they are working on levees in between nesting and foraging ponds, there should be a trained biologist on site all day to minimize impacts to plovers.
3. If construction takes place adjacent to or within a 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 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.
5. Pond E6A and A22 should be flooded to reduce vegetation that is growing on the pond bottoms, and which may be discouraging Snowy Plovers from using these ponds.
6. Pond E11 has fissures throughout the mid section of the pond. Some of these cracks are over half a meter deep and could be a hazard for Snowy Plover chicks. The pond should be flooded to prevent Snowy Plover nesting.
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 panne habitat for nests and 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 the amount of management the Refuge can do 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. More effort should be put into enforcement of regulations and area closures of 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 coordinate with SFBBO and the Refuge to minimize disturbance on Snowy Plovers.

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REFERENCES

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.

Farraway, A., K. Thomas, and H. Blokpoel. 1986. Common Tern egg predation by Ruddy Turnstones. The Condor 88:521-522.

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.

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., J. Demers, and J. Scullen. 2009a. Cargill Salt Pond Waterbird Surveys Report, October 2008 - September 2009. Unpublished Report. San Francisco Bay Bird Observatory, Milpitas, CA.

Robinson-Nilsen, C., J. Demers, and C. Strong. 2009b. 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.

Robinson-Nilsen, C, J. Demers and C. Schacter. 2009c. Colonial Waterbird Nesting Summary for the South San Francisco Bay, 2009. Unpublished Report. San Francisco Bay Bird Observatory, Milpitas, CA.

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.

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.

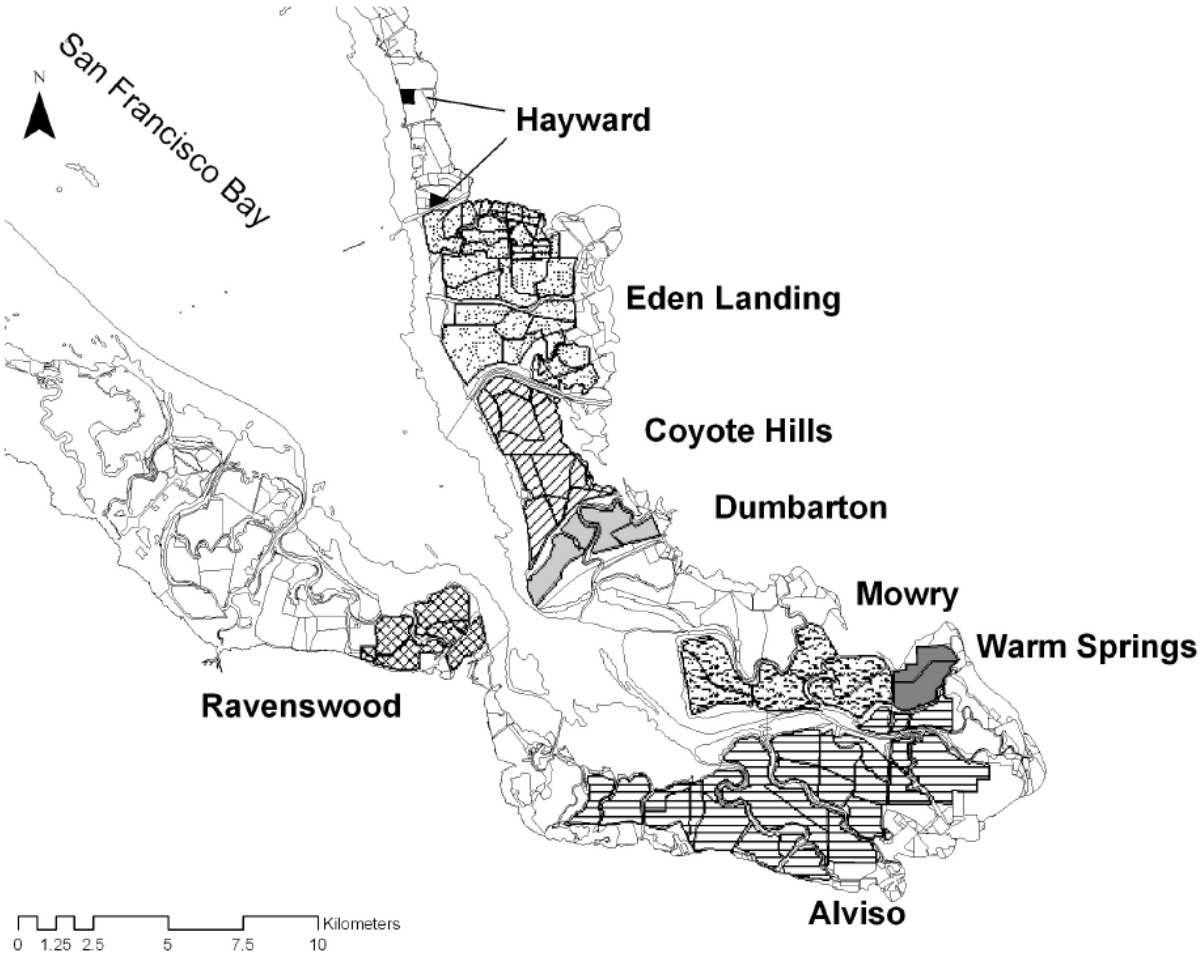

Figure 1. The Don Edwards San Francisco Bay National Wildlife Refuge, CDFG's Eden Landing Ecological Reserve, and Hayward Area Recreation District lands in the South San Francisco Bay.

Figure 2. Salt ponds located in the CDFG's Napa-Sonoma Marshes Wildlife Area, near Napa, San Pablo Bay.

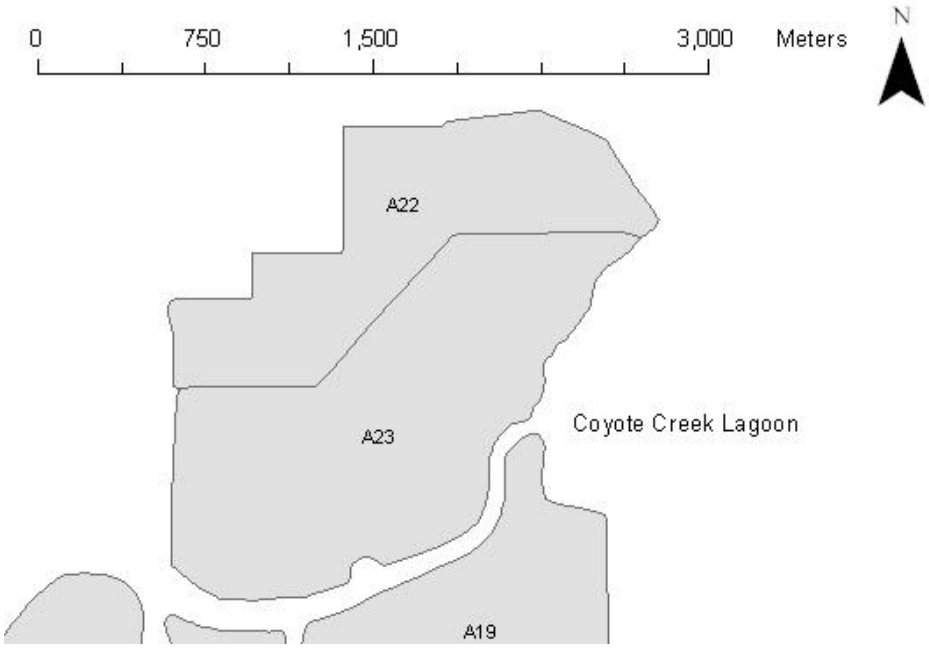

Figure 3. Salt ponds located in the Refuge's Warm Springs area, near Fremont, South San Francisco Bay.

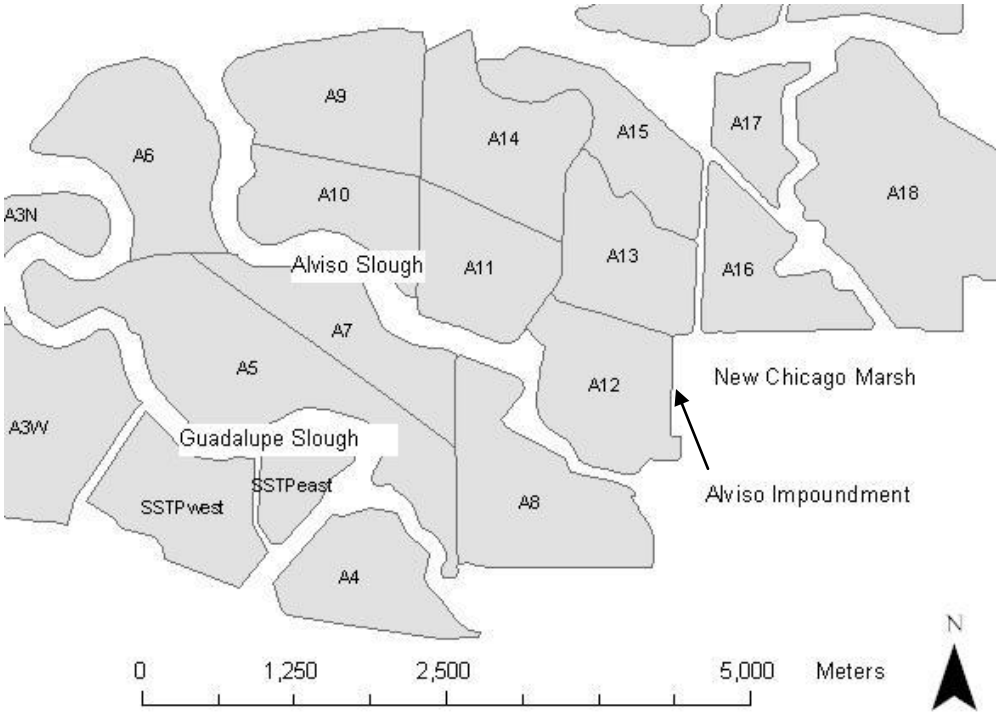

Figure 4. Salt ponds in the Refuge's Alviso complex, at the southern end of the South San Francisco Bay**.**

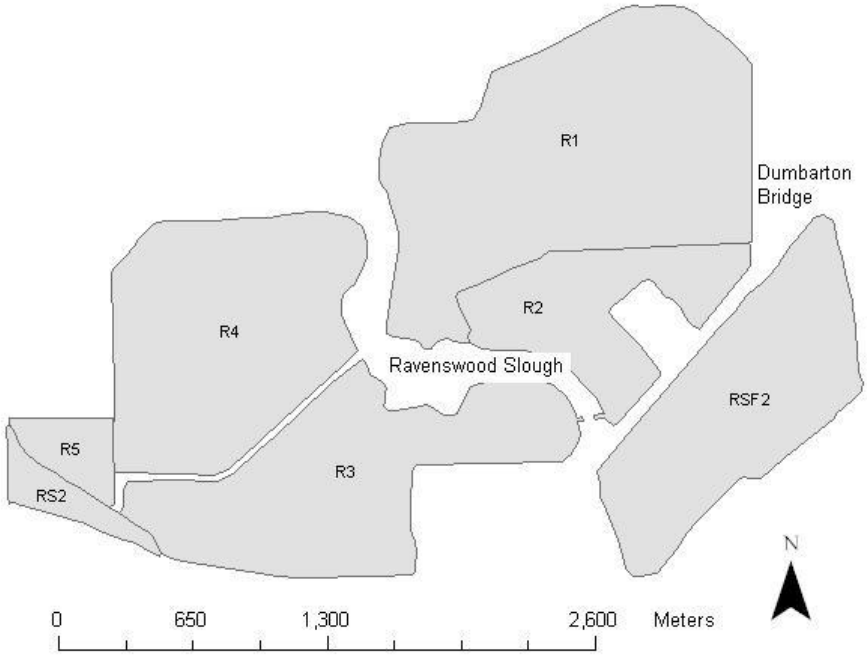

Figure 5. Salt ponds in the Refuge's Ravenswood complex, at the west end of the Dumbarton Bridge, South San Francisco Bay.

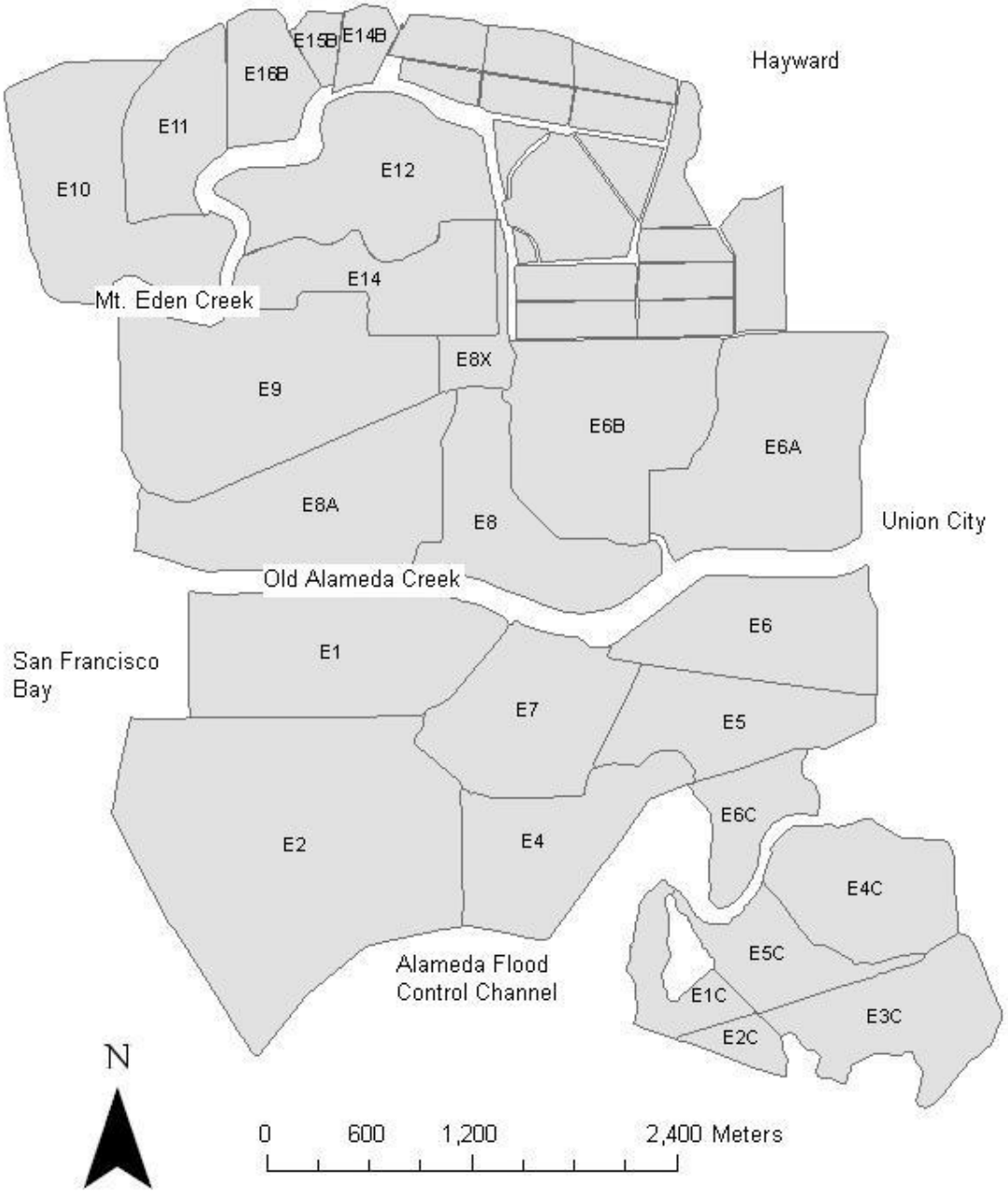

Figure 6. Salt ponds in the CDFG's Eden Landing Ecological Reserve Complex, near Hayward, South San Francisco Bay.

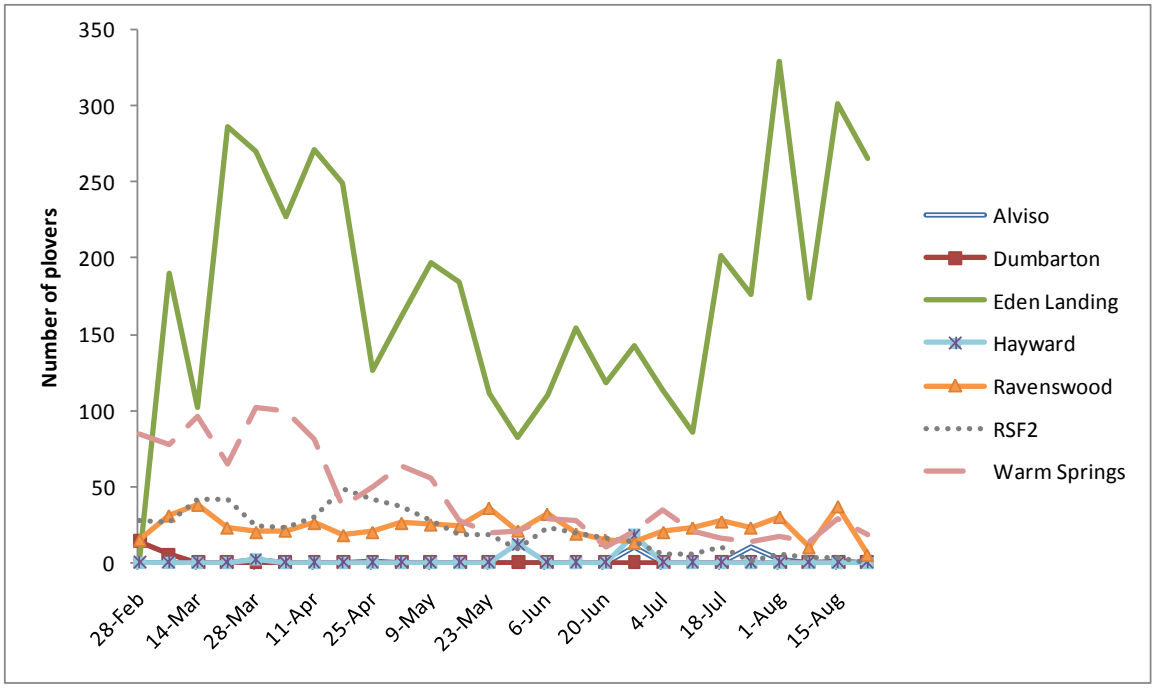

Figure 7. Weekly counts of adult Snowy Plovers by week and area, South San Francisco Bay, California, 2010.

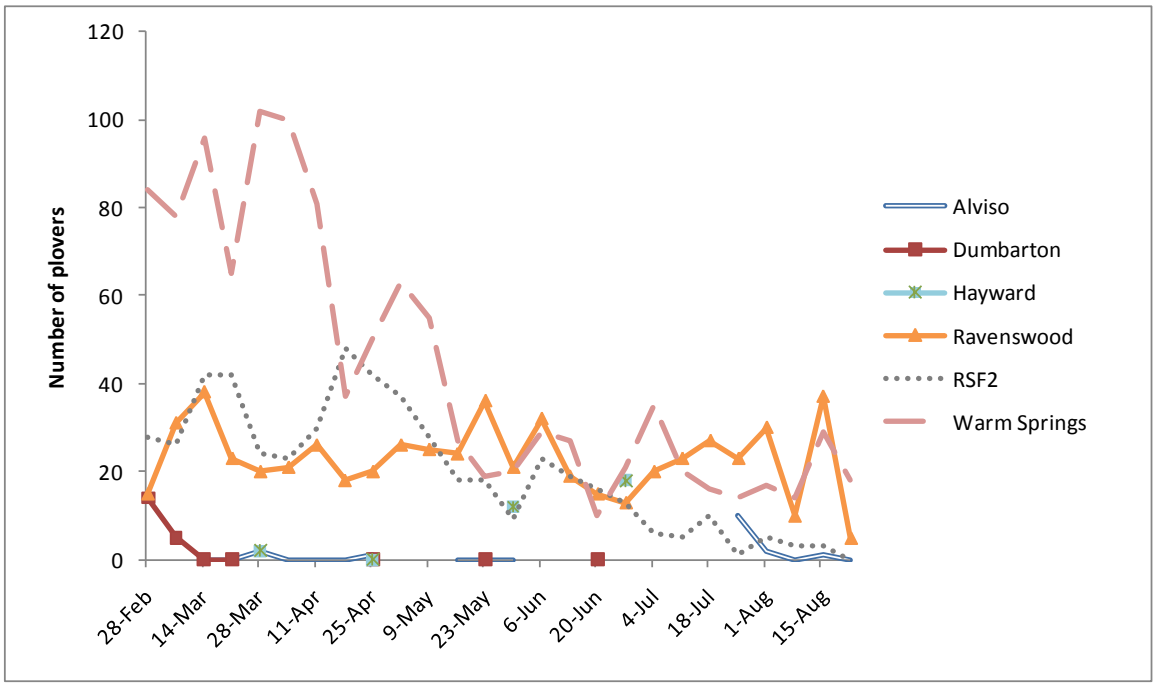

Figure 8. Weekly counts of adult Snowy Plovers by week and area, South San Francisco Bay, California, 2010, excluding Eden Landing Ecological Reserve.

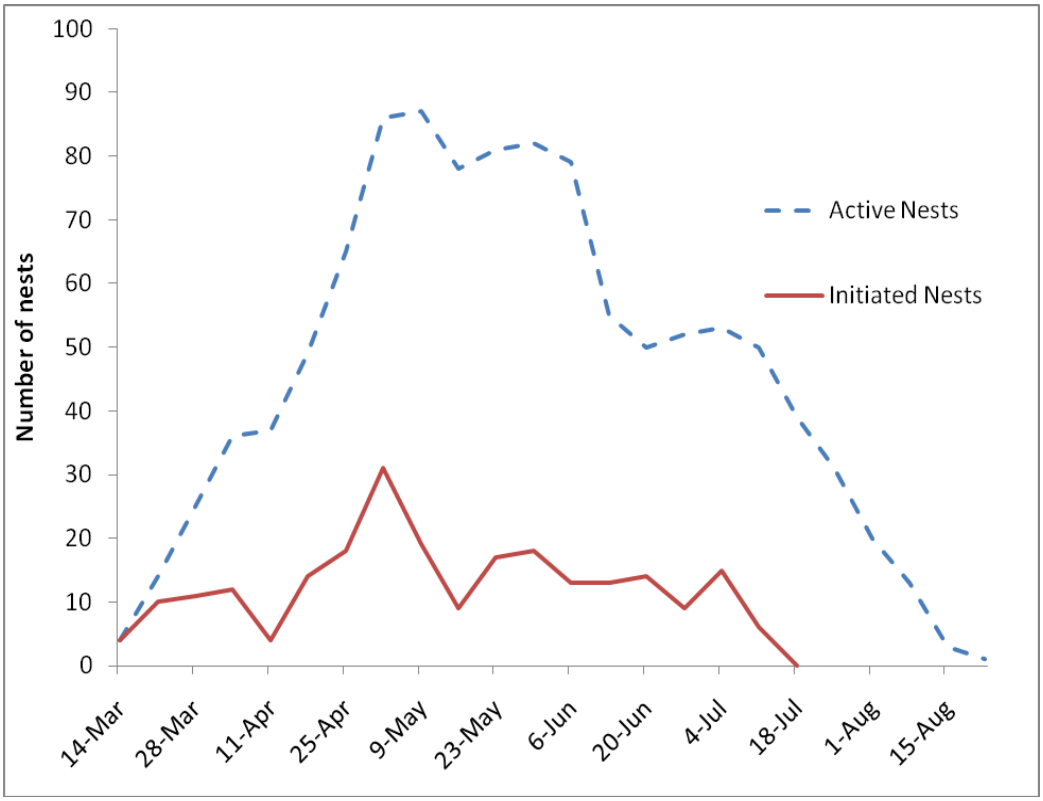

Figure 9. The weekly number of initiated and active Snowy Plover nests in the South San Francisco Bay, California, 2010.

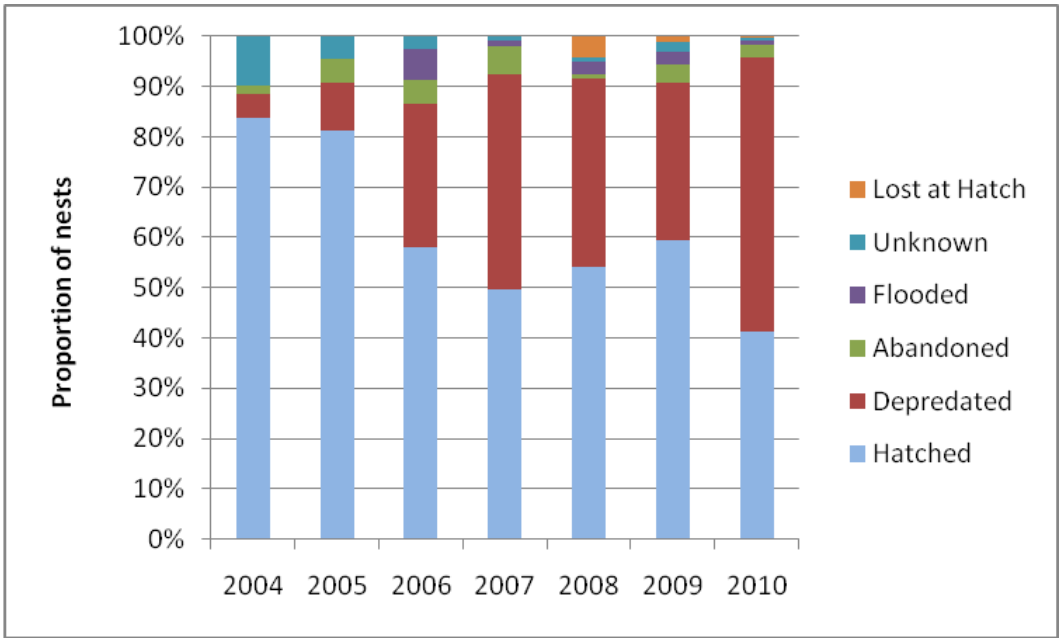

Figure 10. Annual Snowy Plover nest fates in the South San Francisco Bay, California, 2004-2010.

Table 1. Ponds surveyed within the Don Edwards San Francisco Bay National Wildlife Refuge, South San Francisco Bay, California, 2010.

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 on California Department of Fish and Game property, San Francisco Bay, California, 2010.

Location	Ponds
Eden Landing Ecological Reserve	E6, E8, E8A, E8X, E11, E12, 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, 2010.

Location	Hatched	Depredated	Abandoned	Flooded	Unknown	Lost at Hatch	Total nests
Alviso							
A6		1					1
New Chicago Marsh	1						1
Eden Landing Ecological Reserve							
E6A	1						1
E6B	5	22	1		1		29
E8	12	23					35
E8A	5	5					10
E12	12	9					21
E14	1	2					3
E16B	5	13	1			1	20
E11		7					7
E6	4	9					13
E3C		1		2			3
Ravenswood							0
R1	3		1				4
R2	1						1
R3	5	2					7
R4	7	8	1				16
R5	8	3					11
SF2	22	9	2				33
Warm Springs							
A22	5	14					19
A23	2	2					4
Hayward Shoreline							0
Hayward		3					3
OBN-14	1						1
Total South Bay	**100**	**133**	**6**	**2**	**1**	**1**	**243**
Napa Plant Site	6						6
Napa Sonoma Marshes Wildlife Area	1	2					3
RU3 Total	**107**	**135**	**6**	**2**	**1**	**1**	**252**

Table 4. Snowy Plover nest densities (nest/acre) by pond on Refuge property in the South San Francisco Bay, California, 2010.

Pond	R1	R2	R3	R4	R5	SF2	A22	A23
Nests per ha	0.02	0.02	0.06	0.13	0.85	0.34	0.17	0.02

Table 5. Snowy Plover nest densities (nests/acre) by pond at Eden Landing Ecological Reserve in the South San Francisco Bay, California, 2010.

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 6. Total number of chicks banded, chicks fledged and percent fledged per pond in the South San Francisco Bay, California, 2010.

	Chicks Banded	Chicks Fledged	Percent Fledged
Eden Landing Ecological Reserve			
E8A	2	2	100.0%
E6	3	2	66.7%
E6B	4	0	0.0%
E12/E13	8	6	75.0%
E16B	3	0	0.0%
E8	10	0	0.0%
E14	3	3	100.0%
Ravenswood			
SF2	4	1	25.0%
Hayward			
OBN-14	2	2	100.0%
All Areas	**39**	**16**	**41.0%**

Table 7. 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.

	Control Plot	Shell Plot	All other Eden Landing Ecological Reserve nests
Nests monitored	0	24	66
Density (nests/ha)	0	3.43	0.07
Observed Hatched	0	67%	56.06%
Observed depredated	0	13%	43.94%
Mayfield Nest Success	0	0.79	0.59
Density within plot correct by Mayfield (nests/ha)	0	2.71	0.04

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 2010.

	Control Plots	Shell Plots	All other Eden Landing Ecological Reserve nests
Nests monitored	3	42	97
Density (nests/ha)	0.25	3.50	0.10
Observed Hatched	0%	31%	32%
Observed depredated	100%	64%	66%
Mayfield nest success	0.17	0.40	0.35
Density within plot correct by Mayfield (nests/ha)	0.04	1.38	0.04

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, 2010.

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

Table 10. The mean numbers of predators per survey in each area of the San Francisco Bay, California, 2010. (We did not include the Alviso California Gull colony of 23,103 individuals in our estimates.)

Predators of concern	Alviso	Dumbarton	Eden Landing Ecological Reserve	Hayward	Napa Sonoma Marshes Wildlife Area	Ravenswood	Warm Springs
Northern Harrier	0.33		0.20	0.33	0.50	0.22	0.35
Common Raven	2.17		0.32	0.67	0.33	1.31	8.35
Peregrine Falcon	0.17		0.14		0.17		0.08
American Crow	0.17		0.11			2.73	0.35
White-Tailed Kite	0.17		0.09			0.13	
American Kestrel	0.17		0.04				1.08
Red-Tailed Hawk	0.33		0.59	1.67		0.73	1.00
California Gull	2304.83	173.33	55.26	31.00	7.00	31.64	44.85
Unidentified Gull	2559.67		72.00		28.50	61.78	559.96
Other Predators							
Ring-Billed Gull			0.02		1.00	0.04	
Western Gull	0.17		0.02		0.50	0.02	
Black-Crowned Night Heron	0.83		0.71		0.17	0.04	0.50
Great Blue Heron	0.67		1.99		1.17	0.11	0.12
Snowy Egret	0.50		17.00			2.02	0.73
Great Egret	0.50		5.28		2.83	0.22	0.23
Loggerhead Shrike							0.77
Golden Eagle							0.04
Number of Surveys	25	5	91	5	5	60	30