SAN FRANCISCO BAY
BIRD OBSERVATORY

# Western Snowy Plover Monitoring in the San Francisco Bay Annual Report 2017

Prepared By:
Ben Pearl, Plover Program Director
Anqi Chen, Biologist

San Francisco Bay Bird Observatory
524 Valley Way, Milpitas, CA 95035

For:
Cheryl Strong, Wildlife Biologist
Don Edwards San Francisco Bay National Wildlife Refuge
And
John Krause, Wildlife Biologist
California Department of Fish and Wildlife

April 2018

Contents

**LIST OF FIGURES**

**LIST OF TABLES**

**SUMMARY**

The San Francisco Bay Bird Observatory (SFBBO), Don Edwards San Francisco Bay National Wildlife Refuge (Refuge), California Department of Fish and Wildlife (CDFW), Hayward Area Recreation and Park District (HARD), and East Bay Regional Park District (EBRPD) form the Western Snowy Plover (*Charadrius nivosus nivosus*) Recovery Unit 3. The goal of this collaboration is to survey managed ponds and other habitats for Western Snowy Plovers, track breeding success, and contribute to the management and recovery of this species in the San Francisco Bay. During the 2017 breeding season, we monitored Snowy Plover numbers, nesting and fledging success, the use of experimental habitat enhancement sites, and potential predators.

As part of the Pacific Coast breeding season window survey (May 21-28), we counted 246 adult Snowy Plovers in the San Francisco Bay. Over the course of the breeding season (March-September), we documented 343 plover nests in all of Recovery Unit 3. In the South Bay, we determined the fate of 343 and found that apparent nest success (defined as the percentage of nests that successfully hatched at least one egg out of the total nests monitored) was 50.2%. Remaining nests failed due to predation (42.0%), abandonment (2.3%), flooding (1.7%), failed to hatch (0.3%), or fate was unknown (3.5%). We summarize 2017 nesting activity by pond complex or management unit below:

On Refuge property, we determined the fate of 33 nests in the Alviso Complex (ponds A12, A16, and New Chicago Marsh (NCM)), 83 nests in the Ravenswood Complex (ponds RSF2, R3, R4, and R5), and 5 nests in the Dumbarton Complex (pond NPP1 and Hickory). Apparent nest success was 29%, 58%, and 80% in the Alviso, Ravenswood, and Dumbarton complexes, respectively.

Also on Refuge property, we located 14 nests in the Warm Springs complex (A22 and A23) in Fremont. Apparent nest success was 29% in Warm Springs.

We found 58% of Snowy Plover nests in Recovery Unit 3 at CDFW's Eden Landing Ecological Reserve (Eden Landing). We determined the fate of 199 nests and found that apparent nest success was 50%.

EBRPD reported nine Snowy Plover nests on the California Least Tern (*Sterna antillarum browni*) island at Hayward Shoreline, with a hatch rate of 78% (D. Riensche pers.comm.). No nests were reported at the Oliver Brother's North salt ponds at the Hayward Shoreline Interpretive Center (A. Graham, pers. comm.).

At the Napa-Sonoma Marshes Wildlife Area (ponds 7/7A, Green Island Unit, and Wingo Unit) CDFW biologists reported zero nests found (K. Taylor, pers. comm.). Sporadic monitoring efforts at the Hamilton Wetlands Restoration site in Novato were conducted by Avocet Research Associates. Although one Snowy Plover pair was observed in late

May, no nests were found (J. Evens, pers. comm.). At the Montezuma Wetlands in Solano County, a breeding window survey and incidental Snowy Plover information was collected by EcoBridges Consulting. No nests were confirmed during the 2017 breeding season (A. Wallace, pers. comm).

In 2017, SFBBO banded 55 Snowy Plover chicks from nests that successfully hatched within Eden Landing, Ravenswood and Dumbarton ponds. From band re-sighting surveys, we determined that at least 24 of these 55 chicks survived to fledging (28 days post-hatching) as of November 13, 2017. Our apparent fledging success was 44%.

Habitat availability surveys allowed for more accurate determination of nesting density compared to past seasons. During the 2017 breeding season, pond E12 had the highest nesting density among ponds with islands at 1.21 nests/ha, while pond E14 had the highest nesting density among ponds with dry pond bottom (panne), at 0.31 nests/ha (table 7).

Heavy precipitation in the winter resulted in minimal habitat being available for Snowy Plovers and other nesting shorebirds at select ponds during the beginning of the season. Between April-June, we observed 16 incidences of aggressive interactions between Snowy Plovers and American Avocets, Black-necked stilts, and Killdeer.

During avian predator surveys, we counted California Gulls (*Larus californicus*) and unidentified gulls (*Larus* spp.; likely California gulls due to the time of year and locations) as the most numerous potential avian predators in plover nesting areas. Corvids (Common Ravens (*Corvus corax*) and American Crows (*Corvus brachyrhynchos*)), Peregrine Falcons (*Falco peregrines*), Red-tailed Hawks (*Buteo jamaicensis*), and Northern Harriers (*Circus cyaneus*) were among other commonly sighted predatory species. Trail cameras documented Common Ravens as especially significant nest predators at pond E14 in Eden Landing. Five nests were documented being depredated by Common Ravens at this site, and it is likely that Common Ravens were responsible for some of the other depredated nests at E14 as well.

From 2008-2014, SFBBO and land managers conducted a pilot Snowy Plover habitat enhancement study at Eden Landing using 1-ha oyster shell pilot plots. The study indicated that oyster shell habitat enhancement increased plover nest abundance and nest success within treatment areas. With these findings as support, 20.23 hectares of oyster shell were spread in two plots (New 1 = 6.47ha; New 2 = 13.76ha) as a large-scale habitat enhancement project in September of 2014 at Eden Landing pond E14. Subsequent studies show that the oyster shell enhancement plots were used extensively by Snowy Plovers, and in 2017 contained a total of 59 nests over the course of the season.

California Least Tern (*Sternula antillarum browni*) nested at Eden Landing for the first time since 2009. From late May through early August, ~ 20 breeding pairs established 21 nests within the New 2 enhancement plot, producing at least 20 fledglings. The presence of a Least Tern colony appeared to have a positive effect upon Snowy Plover hatch success within E14. Prior to

establishment of the Least Tern colony, Snowy Plover nests had a hatch rate of 20% (n=36). After establishment of the colony, Snowy Plover nests had a hatch rate of 94% (n=16) within 100m of the colony, 69% hatch rate (n=13) within 500m of the colony, and 60% hatch rate (n=20) greater than 500m from the colony.

In future years, we recommend that the South Bay Salt Pond Restoration Project (the Project) carefully plan Phase II construction activities to avoid negatively impacting breeding Snowy Plovers. We propose that alternative breeding habitat be provided when construction activities impact Snowy Plover nesting ponds. We also recommend beginning construction activities before plover breeding season begins, and, if possible, discouraging Snowy Plovers from using ponds where construction activities are taking place during the nesting season, as long as sufficient alternate habitat is available.

As more areas are opened to tidal action or converted to ponds with islands, we recommend that the Project and local land managers take great care in maintaining adequate Snowy Plover nesting habitat to preserve and increase the number of nesting Snowy Plovers in the South Bay as outlined in the Recovery Plan (USFWS 2007). Management actions, including management of multiple ponds at shallow depth during the winter and large scale shell enhancement at appropriate nesting ponds, should continue. With the partial opening of public trails at the ponds E12-14 during the 2016 breeding season, further studies are needed to assess the impact of human disturbance on Snowy Plover nesting. As such, we recommend that no additional levee trails in close proximity to Snowy Plover nesting ponds be opened to the public until these impacts can be assessed. We also propose continued research, adaptive management and/or enhancement of Snowy Plover nesting sites.

**INTRODUCTION AND BACKGROUND**

The Pacific Coast population of the Western Snowy Plover (*Charadrius nivosus nivosus*, Snowy Plover) breeds along or near tidal waters and is behaviorally distinct from the interior population (Funk 2006). Coastal-breeding Snowy Plovers have declined as a result of poor reproductive success, likely due to habitat loss, habitat alteration, human disturbance, and increasing predation pressure (Page et al. 1991, USFWS 2007). In response to this decline, the U.S. Fish and Wildlife Service (USFWS) listed the Pacific Coast Western Snowy Plover population as federally threatened in 1993 (USFWS 1993). They are listed as a species of special concern in California (CDFW 1998).

Western Snowy Plover Recovery Unit 3 consists of the San Francisco Bay and includes Napa, Alameda, and Santa Clara counties, and the eastern portion of San Mateo County (USFWS 2007). Snowy Plovers in this Recovery Unit nest almost exclusively in dry salt panne habitat provided by former salt evaporation ponds, as well as on pond berms and levees. 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 the number of 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 Wildlife (CDFW) in 2000 to survey for Snowy Plovers at Eden Landing Ecological Reserve (Eden Landing). The San Francisco Bay Bird Observatory (SFBBO) and the Refuge have been jointly monitoring Snowy Plovers and determining nest fates since 2003.

From 2003-2017, SFBBO conducted annual Western Snowy Plover monitoring and research in support of the goals set forth by the Refuge. Specifically, we: 1) identified areas used by Snowy Plovers through regular surveys of all potential nesting habitat from March through September, 2) participated in U.S. Fish and Wildlife Service-coordinated breeding and winter window counts to estimate Recovery Unit 3 numbers, 3) recorded nest fates, nest densities, and chick fledging rates through nest-monitoring and chick-banding, 4) identified potential predators of Snowy Plover nests and chicks through avian predator surveys, and 5) identified areas of potential disturbances from predators, trespass, construction activities and other human activities.

During Phase I of the South Bay Salt Pond Restoration Project, tidal restoration actions and reconfiguration of seasonal Eden Landing ponds that formerly supported Snowy Plover breeding habitat resulted in the loss of approximately 7% of potentially available pond bottom breeding habitat for Snowy Plovers. In order to account for this loss, several different actions were taken. Nesting islands set back 600 feet from public levees were constructed in ponds E12 and E13. Several different seasonal ponds in Northern Eden Landing are managed to provide Snowy Plover breeding habitat. Lastly, SFBBO and the Project initiated a large-scale oyster shell habitat enhancement project, informed by previous pilot studies from 2008-2014, on Eden Landing pond E14. Enhancements were made in September and October 2014 after the breeding season was complete.

Phase II, focused on the Ravenswood Complex of the Refuge, will similarly result in an additional loss of 8% of potentially available breeding habitat. Actions during both Phases are intended to return full tidal action in some ponds, eventually restoring tidal marsh and providing habitat for marsh species. This represents an ecological trade-off between the needs of marsh species, for which the majority of habitat in the San Francisco Bay has been eliminated, and the needs of pond species, which have lost habitat elsewhere and have come to rely upon the ponds since their creation. Despite the loss of potential Snowy Plover breeding habitat (dry panne) through the Project's actions, the Project has set a management target of maintaining 125 breeding pairs of Snowy Plovers within its footprint (USFWS and CDFW 2007). In 2017, 246 breeding Snowy Plovers were observed throughout the San Francisco Bay during the Breeding Window Survey. Of these, 241 were found within the Project footprint, indicating that the project is close to meeting its stated goal of supporting 125 breeding Snowy Plover pairs.

SFBBO initiated a Volunteer Plover Docent program in June 2016 in order to encourage public support and advocacy for Snowy Plovers in the South Bay, and to encourage the public to practice eco-friendly recreation by discouraging trespassing and disturbance through education and outreach. Trained volunteer docents were stationed at key breeding sites once a month and communicated with the public, shared information on Snowy Plover breeding ecology, showed Snowy Plovers to the public using binoculars and scopes, and created a positive association with the species.

In this report, we summarize results from the 2017 breeding season; this includes data on Snowy Plover nest distribution and plover habitat use, nest (hatching) success, fledging success, interspecies aggression, habitat enhancement studies, and avian predator abundance and distribution. Although we report Snowy Plover numbers in the North Bay and at Hayward Regional Shoreline, this report focuses on Snowy Plover activity in the South San Francisco Bay, south of the San Mateo Bridge.

## METHODS

### Study Area

SFBBO and Refuge staff 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). The South Bay contains the majority of the Snowy Plover habitat in the Bay Area. CDFW biologists surveyed and contributed nesting information for one site in the North San Francisco Bay this year (North Bay; Figure 2). Additionally, SFBBO volunteers monitored sites with potential Snowy Plover habitat in the South Bay. 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 ponds, tidal marsh, mudflats, and uplands in the South Bay (Figure 1). Many of the ponds used by Snowy Plovers are currently managed as seasonal ponds, or are drawn down for the purpose of creating nesting habitat. For this study, we divided the Refuge into seven geographic locations: Warm Springs (Figure 3), Alviso (Figure 4), Mountain View (Figure 4), Ravenswood (**Error! Reference source not found.** 5), Dumbarton (Figure 7), Coyote Hills, and Mowry (**Error! Reference source not found.**). Alviso ponds A2E and A3N are owned and managed by the Refuge while Crittenden Marsh is co-owned by several agencies, including Midpeninsula Regional Open Space District and the National Aeronautics and Space Administration, Ames Research Center (NASA). This area is collectively termed Mountain View for the purposes of this report.

CDFW owns and manages Eden Landing (formerly known as Baumberg), which includes approximately 6,400 acres of former salt ponds, marsh, and tidal habitat (Figure 6). CDFW also owns and manages the Napa-Sonoma Marshes Wildlife Area (NSMWA), including ponds 7 and 7A, the Wingo Unit, and the Green Island Unit/Napa Plant Site (Figure 2).

Hayward Area Recreation 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 Park District (EBRPD; Figure 1). This area includes potential Snowy Plover foraging and nesting habitat in the Oliver Brothers North and Frank's Dump West ponds. EBRPD manages an island constructed for California Least Terns (*Sternula antillarum brownii*) within treatment ponds that is also used by nesting Snowy Plovers.

Hamilton Wetlands Restoration site is located in Novato at the former Hamilton Army Airfield and is owned by the State Coastal Conservancy. During restoration construction but prior to levee breach early in the 2015 breeding season, this area provided Snowy Plover foraging and nesting habitat on a dry area within the tidal restoration site. As a result of the breach, much of the former (temporary) nesting habitat is now tidal; however, there remains a portion of suitable nesting habitat in the North Seasonal Wetlands.

U.S. Geological Survey (USGS) biologists first reported Snowy Plovers nesting among California Least Tern colonies in the Montezuma Wetlands, Solano County in 2014. This is privately owned dredge placement site within the Montezuma Wetlands Restoration Project footprint. Adult plover numbers for the survey window are included in this report. Further nesting information is not included due to inconsistent survey methods.

**Snowy Plover Surveys**

Snowy Plovers in the San Francisco Bay nest predominantly on dry pannes, berms, and levees located within former salt production ponds. To document areas used by Snowy Plovers and to 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 salt panne) habitat monthly.

From March 21 to September 28, 2017, SFBBO and other 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 number and behavior of all Snowy Plovers present, identified the sex and age class of each individual using plumage characteristics (Page et al. 1991), and marked the approximate location of sightings on a geo-referenced map. We also recorded the color-band status, and combination if appropriate, of any banded plover sighted.

SFBBO plover volunteers surveyed the HARD ponds monthly and surveyed some low-priority Eden Landing ponds periodically to check for possible nesting activity during the season (Table 3). SFBBO staff biologists also surveyed the Coyote Hills, Dumbarton, and Mowry salt pond complexes twice in the Spring quarter and once in the Summer quarter as part of SFBBO's waterbird surveys (see Tarjan and Heyse 2017 for methods). It is important to note that the waterbird survey methods are designed to document overall waterbird abundance and

distribution rather than Snowy Plover nesting activity, and may not adequately detect Snowy Plovers or nests. However, limited breeding habitat is available in these areas.

From May 21-28, we participated in the Pacific Coast Snowy Plover breeding window survey. This survey was coordinated by the USFWS as part of an annual, regional effort to census all coastal-breeding Snowy Plovers during the same week. In Recovery Unit 3, the survey covered Refuge, Eden Landing, NSMWA, and HARD ponds, and we used the same methods for sighting and counting Snowy Plovers as described above. Nesting Snowy Plovers were also surveyed using the same method in the Montezuma Wetlands Restoration Project footprint in Solano County and Hamilton Wetlands in Marin County. These data are included in the 2017 breeding window survey.

*Snowy Plover Docent Surveys*

SFBBO plover docent volunteers were stationed at Eden Landing at ponds E12-E14 and at Ravenswood at ponds R4-R5S once per month during a 3-day window on the last weekend of the month. During each survey, docents looked for Snowy Plovers using a combination of spotting scopes and binoculars. To assist with interactions with pedestrians, docents were equipped with a handout that provided general information about Snowy Plovers, including pictures, physical description, range, conservation status, reasons for decline, and ways to get involved with Snowy Plover conservation. During encounters with the public, docents recorded the type (pedestrian, bicyclist, other) and size of group, the nature of the contact (positive, negative, neutral), what type of information was shared (ecology, salt pond history, conservation, etc.), and any other relevant information.

**Least Tern Surveys**

California Least Tern breeding activity was first observed opportunistically on May 28th during a Snowy Plover survey at pond E14. Due to the unexpected establishment of a Least Tern breeding colony, SFBBO did not have the resources to conduct independent Least Tern surveys. We conducted most Least Tern surveys concurrently with Snowy Plover surveys with two biologists surveying from the same vehicle. Specifically, while one biologist was conducting Snowy Plover brood resight surveys, which require resighting all broods and recording 20 minutes of brood behavior for four different broods, the other biologist would survey the pond for all Snowy Plover adult breeding activity. Once the Snowy Plover adult breeding survey was completed for that area, the biologist could record Least Tern activity while waiting for the brood behavior survey to finish.

Least Tern surveys followed survey protocol as developed and deployed by CDFW in 2013 (Frost 2015). Data recorded included number of nests, number of adults, downy chicks, feathered chicks, pre-fledge chicks (mostly feathered, <1 week to fledge), young fledges (just learned to fly), old fledges (fly well, close to leaving colony), and observed predators. It is important to note that although Least Tern nests were found and monitored, we chose not to enter the

colony more than once per week to limit disturbance to both Least Terns and Snowy Plovers. During some weeks, for logistical reasons, the colony was not entered. As we were not permitted to handle Least Tern eggs, we could not determine nest ages and we were often unsure of the nest fate. Due to these circumstances, Least Tern nesting was not used in statistical analyses as a covariate. Instead, we used only Least Tern colony descriptive statistics to help explain observed Snowy Plover nesting success trends.

**Nest Monitoring**

We located Snowy Plover nests by scanning for incubating females during weekly surveys. We then searched for nests on foot and recorded nest locations with a GPS unit (Garmin® GPS 60 or Garmin® eTrex Venture HC) and/or hand-held tablet (Apple® iPad 2 or Apple® iPad Mini 2). Volunteers located 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 leave levees or established trails to search for nests on the ponds.

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, failed to hatch, unknown, or other. In addition, we recorded whether the nest was located in an oyster shell enhancement or control plot (see *Oyster Shell Habitat Enhancements* methods below.)

We defined a nest as successful if it hatched at least one egg. We calculated apparent nest success as the percentage of nests that successfully hatched at least one egg out of the total nests monitored.

**Chick Color Banding**

Beginning in 2008 and continuing through the 2017 breeding season, SFBBO and Refuge biologists banded Snowy Plover chicks to study their movements and to estimate fledging success rates in the South Bay. Chick banding was limited by staff availability. To band chicks, biologists checked nests daily, starting four days before the estimated hatch date. Due to the precocial nature of chicks, arrival at nests must be timed to allow complete hatching of chicks prior to their movement away from the nest; this is typically a several hour window. We banded each chick with a unique four-color combination by placing two bands on each leg below the tibiotarsal joint. Each combination consisted of three darvic (XCLA Darvic Leg Bands

I/D 3.1mm n.d.) or acetal (XCLA Acetal Leg Bands I/D 3.1mm n.d.) color bands and one silver U.S. Geological Survey band. All bands were then wrapped in colored auto pin-striping tape. Both darvic and acetal color bands were used depending on availability. See discussion for further details.

We defined a fledged chick as one that survived to 31 days of age, at which point it is considered to be capable of flight (Warriner et al. 1986). We calculated apparent fledging success as the percentage of fledged, banded chicks out of the total chicks banded. Since re-sighting banded chicks on salt panne habitat is extremely difficult, this method of estimating fledging success has significant limitations and is a conservative estimate.

**Oyster Shell Habitat**

*Pilot Studies*

From 2009-2014, SFBBO conducted a pilot study on the effects of oyster shell enhancement on Snowy Plover breeding using a randomized block design. Each block consisted of a 1-ha oyster shell treatment plot (shells spread at 5-8 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.

*E14 Large Scale Enhancement*

With support from the findings from our 2008-2014 pilot study, we began a large-scale habitat enhancement project in September 2014 at Eden Landing pond E14, where 20.23 hectares were treated with oyster shells at the previously tested density. Two distinct plots were created within the pond – a western plot totaling 6.47 hectares (referred to as New 1) and an eastern plot totaling 13.76 hectares (referred to as New 2); the remaining untreated areas are termed non-shelled in this report. We designed a spatial configuration in which the shell blocks alternated with the control blocks in order to avoid clustering treatments in one region of the pond, as well as to address pre-existing variation in habitat quality for breeding Snowy Plovers.

*Apparent Estimates*

We compared apparent nest success in 1-ha shell plots (Pilot), control plots, and all other Eden Landing nesting areas (Non-Shelled) from 2009-2017 (Figure 15). Nests in E14 1-ha shell plots and control plots are not treated independently in 2015-17 as they were impacted by large scale enhancement, and were omitted from this analysis.

**Avian Predator Surveys**

To identify avian predators in the area that might affect Snowy Plovers, we conducted predator surveys on the same ponds surveyed weekly for Snowy Plovers (Tables 1-2). Volunteers conducted avian predator surveys at ponds surveyed monthly for Snowy Plovers. In order to better capture predator activity, avian predator surveys were conducted concurrently with

plover surveys, rather than afterwards. Observers chose survey points that provided a comprehensive scan of all required ponds for predators. Observers recorded the survey point, the location, start time, and stop time, species, abundance, behavior, and habitat type of any predators present. The approximate locations of the predators were marked on a map. In addition, observers documented any predator nests in the area and their fates when possible. We calculated the average number of predators observed per survey at each pond during the season. While most predators likely have a larger territory than a single pond (Olsen et al. 1988), we felt it meaningful to present indices of predator abundance at the pond scale since both predator and plover surveys were conducted at this level.

We defined avian predators as any species that could potentially prey on a Snowy Plover nest, chick, or adult. Raptor species included American Kestrels (*Falco sparverius*), Bald Eagles (*Haliaeetus leucocephalus*), Cooper's Hawks (*Accipiter cooperii*), Golden Eagles (*Aquila chrysaetos*), Merlins (*F. columbarius*), Northern Harriers (*Circus cyaneus*), Peregrine Falcons (*F. peregrines*), Red-Tailed Hawks (*Buteo jamaicensis*), and White-Tailed Kites (*Elanus leucurus*); gull species included Boneparte's Gulls (*Chroicocephalus philadelphia*), California Gulls (*Larus californicus*), Glaucous-winged Gulls (*L. glaucescens*), Herring Gulls (*Larus argentatus smithsonianus*), Mew Gulls (*L. canus*), Ring-Billed Gulls (*Larus delawarensis*), and Western Gulls (*Larus occidentalis*); Corvid species included American Crows (*Corvus brachyrhynchos*) and Common Ravens (*C. corax*); wader species included Black-crowned Night-Herons (*Nycticorax nycticorax*), Cattle Egrets (*Bubulcus ibis*), Great Blue Herons (*Ardea herodias*), Great Egrets (*A. alba*), and Snowy Egrets (*Egretta thula*); other species included Loggerhead Shrikes (*Lanius ludovicianus*). While mammalian predators and their signs (e.g., tracks) were also recorded opportunistically, these surveys were not designed to detect mammals, particularly since many are nocturnal. Observed mammalian predators included red foxes (*Vulpes vulpes*) and domestic cats (*Felis catus*). Among all predators, we considered raptors, gulls, corvids, and mammals to be the most critical potential predators to Snowy Plover adults, eggs, and chicks due to consistent previous documentation of effects.

In order to document plover nest depredations, we deployed wildlife trail cameras (Reconyx PC900 HyperFire) throughout the season at active nests in pond E14. Cameras were placed directly on the ground between 1-2 meters from each selected nest; this method was used after testing more distant, but unsuccessful placements. Cameras were housed in a camouflage case and made even less conspicuous by using oyster shells, wood and other debris from the surrounding area. Three rapid-fire still images were taken whenever motion was detected, in color by day and monochrome infrared by night.

We distributed nest cameras among all treatment types throughout the season. Cameras were checked each time the nest was checked, typically once per week, at which time the memory card and batteries were replaced as needed.

**Habitat Availability**

Habitats within the South San Francisco Bay ponds change based on precipitation, management, and other factors. In order to better measure the available potential nesting habitat over the course of the season, habitat availability surveys were continued during the 2017 breeding season.

Maps for each pond were overlaid with a grid composed of 50m x 50m squares. During each survey, the approximate location of available habitat within each pond was marked on the corresponding map. Available habitat included barren dry pond bottom, dry levees, and dry areas with sparse vegetation cover; unavailable habitat included standing water, saturated pond bottom or mud, and areas with full vegetation cover. Each square was considered available or unavailable for breeding based on which cover type constituted >50% of its space. Habitat availability surveys were conducted on the same day as each breeding survey in order to maintain comparability with nesting behavior.

**Analytical Methods**

*E14 Analysis*

Due to small sample sizes and analytical complications, we chose to lump all observations in all western shelled treatment plots (three old 1ha plots and New 6.47ha plot) and termed this area New 1 (Figure 8). The 13.76ha eastern shell treatment plot in pond E14 is termed New 2, and all remaining untreated areas are termed Control.

*Nest Densities*

We calculated apparent nest densities for each pond and by each treatment area (New 1, New 2, Control; Figure 3) by dividing the number of nests found within each area by the available habitat in hectares.

*Nest Survival*

We conducted a nest survival analysis for all nests in E14 during the 2017 breeding season in program R (version 3.3.3) (Rotella 2016). We built encounter histories with information including date nest found, last date nest known to be present, last date nest checked, and fate date. Each encounter history also included year, treatment type (New 1, New 2, Control), camera presence, and distance to nearest levee (m) as additional covariates in order to determine their effect on nest survival rates.

*Fledging Survival*

Apparent fledge rates were calculated by dividing the number of banded chicks that survived to fledge (31 days post-hatching) by the total number of chicks banded. Using the same data for broods in which all chicks were banded, we obtained an estimate of the number of chicks fledged per male.

## RESULTS

### Snowy Plover Surveys

*South Bay Overall*

During the 2017 Pacific Coast breeding season window survey (May 21-28), we counted 246 adult Snowy Plovers in the Bay (Table 44). We observed a mean of 272 birds per week from March 21 through September 28 in the entire South Bay. We consistently observed the greatest numbers of Snowy Plovers at Eden Landing (Table 44, Figure 7a). We documented Snowy Plover nesting activity at 21 South Bay ponds (Figure 8, Figure 9).

*Refuge*

We documented a mean of 109 Snowy Plovers per week from March 21 through September 28 on Refuge property. We observed an average of 68 Snowy Plovers per week in the Ravenswood complex, an average of three Snowy Plovers per week in the Warm Springs complex, and an average of 33 Snowy Plovers per week in the Alviso complex, and 3 Snowy Plovers per week in the Dumbarton complex (Figure 7b).

*Eden Landing*

We observed the most Snowy Plovers throughout the season at Eden Landing (Figure 7a), with a mean of 168 birds observed per week from March 21 through September 28. This was higher than in 2016 when we observed a mean of 143 birds per week during the same time period. Pond E14 supported large numbers of Snowy Plovers during the breeding season again this year, averaging 87 birds per week.

*Early and Late Season Trends*

In March, we observed large flocks of Snowy Plovers at E12 and E14, averaging 30 and 96 Snowy Plovers per week during this period, respectively. In August, we observed large flocks at A16 and E14, averaging 63 and 98 Snowy Plovers per week for the month, respectively (Figure 7c). In both cases, many of these birds may have been staging (for migration), arriving for the breeding season (in March) or early arrival wintering birds (in August).

*Interspecies Interactions*

During the 2017 breeding season, SFBBO Biologists observed 17 incidences of direct physical aggression between Snowy Plovers and other breeding shorebird species (Table 12). These interactions were observed at a higher rate than normal (pers. obs.), and may have been due to a lack of suitable habitat during the first half of the breeding season. See p. 33 for a more thorough discussion of this topic.

### Least Tern Surveys

Least Tern surveys were conducted from June 1 to September 4. During this timeframe, an average of 38 least terns were observed over 20 surveys at pond E14, with a high count of 131

adults observed on August 3. Between June 1 and July 24, an average of 24 least tern adults were recorded over 12 surveys, with a high of 49 adults observed on July 18. Between June 1 and July 24, 21 Least Tern nests were confirmed and monitored. Of these, nine nests hatched at least one chick, one was depredated, and the fate of 11 nests was unknown. Over the course of monitoring Least Terns during the 2017 breeding season, the highest observed count of both chicks and fledglings was 13 old fledglings, six young fledglings, and five pre-fledged chicks on August 3. The second highest observed count for both chicks and fledglings was 18 old fledglings, two young fledglings, and one pre-fledged chick on August 11.

**Nest Abundance and Success**

*South Bay Overall*

In 2017, we determined the fate of 342 Snowy Plover nests in the South Bay. Of these, 172 nests hatched (apparent nest success = 50.4%), 144 nests were depredated (42.2%), eight were abandoned (2.3%), six were flooded (1.8%) one failed to hatch (0.3%), and the fate of ten nests were unknown (3.0%, Table 5, Figure 12). We found the highest number of nests ever documented in the South Bay in 2017 (previous high of 298 nests in 2015). The predation rate was much lower compared to 2016 (55%), suggesting that high nest numbers may have been due to an increasing breeding population, rather than renesting attempts (Figure 9). Consistent with findings from previous years, predation serves as the most significant cause of nest failure.

*Refuge*

In 2017, SFBBO determined the fate of 130 Snowy Plover nests on Refuge property (Table 5). Refuge Biologists determined the fate of 14 nests in the Warm Springs complex (A22 and A23), four of which hatched (29%), nine were depredated (64%), and one was abandoned (7%). We determined the fate of 33 nests in the Alviso Complex (NCM, A12, and A16). Out of these nests, nine hatched (27%), 17 were depredated (52%), one was abandoned (3%), and the fate of six nests could not be determined (18%). We determined the fate of 83 nests in the Ravenswood Complex. Of these, 48 hatched (58%), 34 were depredated (41%), and one failed to hatch (1%). Note than on August 25, a one chick brood was observed on R1 on a permanently exposed section of pond bottom in the southwest corner of the pond. Although it is likely that this brood came from an undetected nest in this area, it is not included in nest totals. We found the most nests in the Ravenswood complex on pond RSF2 (32 nests; Table 5).

We found no nests at Mountain View Ponds A3N, CM-W, or CM-E. These ponds have occasionally supported breeding Snowy Plovers in recent years, with the availability of suitable habitat largely dependent upon winter precipitation and pond management. As a result of high water levels, minimal habitat was available in these areas in 2017.

*Eden Landing*

We determined the fate of 199 Snowy Plover nests at Eden Landing. Of these, 100 hatched (50%), 82 were depredated (41%), six were abandoned (3%), five were flooded (3%), and the fate of six nests were unknown (2%) (Table 5). Pond E14 had the most nests (85 nests), followed by pond E16B and E8 (30 nests each) and pond E13 (22 nests; Table 5). E14 alone

comprised 43% of the nests found in Eden Landing and 25% of the nests found in the entire South Bay in 2015. The Eden Landing complex hosted 58% of all the nests found in RU3 (Figure 10).

*Hayward Shoreline*
EBRPD reported nine Snowy Plover nest on the California Least Tern Island at HARD, seven of which hatched and two were depredated, one each by a California Gull and Canada Goose (D. Riensche, pers. comm.; Table 5). No nests were detected this season at the Oliver Brothers North Salt ponds at Hayward Regional Shoreline (A. Graham, pers. comm).

*Napa-Sonoma Marshes Wildlife Area*
No nesting activity was observed by CDFW during monthly surveys of Least Tern nesting sites (K. Taylor, pers. comm.; Table 5).

*Montezuma Wetlands*
In 2017, during the breeding window, 3 Snowy Plovers were observed. However, no nests, broods, or breeding behavior was observed during the season. Excessively dry pond bottoms and associated cracking may have affected Snowy Plover nest site selection, though this is only anecdotal observation (A. Wallace, pers. comm.).

*Hamilton Wetland Restoration Area*
During monthly surveys, biologists observed a pair of Snowy Plovers displaying breeding behavior along pond 6 within the Northern Seasonal Wetlands. However, due to erosion of berms, the area was flooded prior to the window survey, and likely resulted in the pair abandoning the site for breeding. No nests or broods were observed during the 2017 breeding season (J. Evens, pers. comm). There are plans to repair and raise the berms in the future, allowing for more precise management of water levels on site.

*Cargill Salt Evaporation Ponds*
We determined the fate of 5 nests in the Dumbarton complex (NPP1 and Hickory), four of which hatched (80%) and one was flooded (20%). No Snowy Plover breeding activity was reported at the Redwood City or Newark Plant Sites in 2017.

*Breeding Chronology*
Apparent nest densities calculated using weekly habitat availability data, rather than the total area of at each pond provided more accurate nesting densities in South Bay ponds as water levels changed throughout the season. Overall, average apparent nest density in the South Bay (across all ponds with dry panne) was 0.13 nests per hectare. We documented the highest apparent nest density in pond E12 at 1.21 nests/ha (Table 7). We note that the available nesting habitat in this pond and E13 (0.197 nests/ha) is provided by a handful of nesting islands, interior berms, and graveled levees, and available nesting habitat averaged 2.6 ha and 16.3 ha throughout the season, respectively. The next highest apparent nest density in Eden Landing was at pond E14 at 0.31 nests/ha (Table 7). Pond E14 is more representative of the dry panne

habitat that Snowy Plovers rely on for nesting in the South Bay. The second highest apparent nest density in RU3 was in pond A12 at 0.49 nests/ha (Table 6).

We recorded two peaks of nest initiation during the breeding season. During the week of April 30, a total of 31 nests were initiated (Figure 13). During the week of June 4, a second peak of 29 nests was initiated. From the week of April 9 through the week of June 25, a nest initiation rate of 20.8±6.4 nests per week was recorded, for a total of 250 nests initiated during this period. This is an increase of over four nests initiated per week and 51 nests initiated total compared to the same time frame last year (April 10-June 26).

Rather than two peaks in active nests, as was observed last year, we saw an extended peak of active nests. Between the weeks of April 30 and July 9, an average of 109.3±12.3 nests were active, with a high of 127 nests active (Figure 13). During the same time frame last year, an average of 82.4±10.7 nests were active, with a high of 97 nests active.

*Chick Fledging Success.*

We banded 55 Snowy Plover chicks in 2017 and determined that at least 24 chicks fledged (44%,Table 8). Note that two chicks banded at Hickory were seen at 29 days, and as plovers become flight capable between 28-31 days (Warriner et al. 1986), it is likely that these two birds fledged as well. While most fledgling sightings were recorded during the breeding season, several came during post breeding season band resighting surveys. Due to the difficulties of resighting fledged chicks within the South San Francisco Bay Ponds, it is possible that additional chicks fledged as well (*see Discussion*).

**Oyster Shell Habitat Enhancements**

During the third season of large-scale enhancement at pond E14, we documented a total of 85 nests; 31 nests in New 1, 27 nests in New 2, and 27 nests in the non-shelled areas of the pond. Due to the small sample size and their geographic configuration, data from the three 1-ha pilot plots were combined with New 1 for analysis.

Apparent nest success rates in 2017 went up considerably compared to 2016. Both enhanced areas (New 1 and New 2), had higher apparent nest success rates compared to Control areas (45%, 63%, and 44%, respectively) (Table 7, Figure 10). As a whole, E14 had an apparent nest success rate of 51%. Depredation was the most significant cause of nest failure in all areas of E14 (New 1=52%, New 2=30%, and Control=44%). The average nest density in enhanced areas (New 1 and New 2 combined) during peak breeding months (April 30-July 9, Figure 12) was calculated at 0.92 ± 0.23 nests/ha, and 0.33 ± 0.22 nests/ha in Control areas. When analyzed separately, New 1 held the highest average nest density during peak breeding months at 1.07 ± 0.14 nests/ha.

Our chi-squared analysis examined whether plovers randomly selected nest sites or were selecting nest sites based upon if they were in shelled or unshelled areas. We determined that

plovers did not randomly select nest locations in 2017 ($p=3.12e^{-7}$) or 2015-2017 ($p < 2.2e^{-16}$). While New1+New2 accounted for 41% and 40% of available nesting area in E14 during 2017 and 2015-17, respectively, these areas accounted for 68% (58/85) and 73% (199 of 271) of all nests found in E14 during that time.
For a thorough nest survival analysis and more detailed information regarding these study results, refer to Pearl et al. (2017).

*Apparent Estimates*
From 2009-2014, we documented higher apparent nest densities and increased hatching rates (Figure 15) in the 1-ha pilot shell plots compared to paired control plots. In 2017, 30 nests were found among all pilot plots, with the highest total found in E14 (9; Table 10). Due to the installation of large oyster shell enhancement plots that covered much of E14, nests from this pond were not included in Figure 15 beginning in 2015. The small sample size of nests in pilot and control plots after shells have been in use for several years' limits the applicability of these data.

**Avian Predators**

*Refuge*
We found that California Gulls and unidentified gulls (presumably mostly California Gulls given time of year and location) were the most abundant avian predators in all areas of the Refuge (Figure 27-Figure 29), as has been reported in past years. Excluding gulls, Common Ravens and Peregrine Falcons were the most abundant predators observed throughout Recovery Unit 3. At Ravenswood, we frequently observed corvids walking on the pond bottom and flying over the ponds, several times in the area with a high density of Snowy Plover, American Avocet, and Black-Necked Stilt nests (Figure 27a). Red tail hawks were the most frequently sighted raptor at Ravenswood, and were often perched on the PG&E towers and available perches on the pond bottom. In Alviso, Common Ravens were the most frequently sighted critical avian predator, and were primarily observed at A16 (Figure 28a). Peregrine Falcons and Northern Harriers were the only raptors observed at Alviso, and were observed infrequently at ponds A12 and A16. California Gulls were very abundant in A12 ((Figure 28b), and considering the high depredation rate in this pond and general lack of other predators observed in this pond, it is likely that they were the cause of many of the recorded nest depredations. At Warm Springs (A22 and A23), Common Ravens were the most frequently observed predator, with most sightings occurring in A22 (Figure 29a). Red-tailed hawks were the most frequently observed raptor, and were seen with equal frequency in both ponds. Peregrine Falcons and Northern Harriers were infrequently observed at both ponds.

*Eden Landing*
As was the case at the Refuge, California Gulls and unidentified gulls were the most numerous predators at Eden Landing (Figure 30-Figure 32). Peregrine Falcons were the next most frequently observed predator at Eden landing. They were especially numerous at the Mt. Eden Creek loop (ponds E14B-16B, E10-11) (Figure 32) and Old Alameda Creek loop (ponds E6A, E6B,

and E8) (Figure 31), where they used old wooden structures, hunting blinds and power towers as hunting perches. Common Ravens were the third most commonly observed predator, and the most commonly observed predator at pond E14. At pond E14, camera traps recorded Common Ravens depredating 5 nests throughout the course of the season (Table 11). Northern Harriers were also commonly observed hunting in pond E14 (Figure 31).

In January of 2016, hunting blinds in adjacent ponds E14 and E9 used extensively as nesting and perching sites by raptors were demolished or wrapped in landscape cloth. This was done in an attempt to reduce predation risk for adults, chicks, and nests. During the 2017 breeding season, the landscape cloth was still intact, resulting in no observed raptor nesting within these blinds.

*Hayward Shoreline*
Predator data was not available for the 2017 breeding season. However, EBRPD reported two nest depredation events at the California Least Tern Island, one each by a California Gull and Canada Goose (*Branta canadensis*) (D. Riensche, pers. comm.).

*Napa-Sonoma Marshes Wildlife Area*
Predator data was not available for the 2017 breeding season.

**Mammalian Predators**

Red fox were the only frequently observed mammalian predator at Eden Landing (Figure 30-Figure 32). We frequently observed Red Fox at Eden Landing while arriving in the morning for surveys, particularly at the Whales Tail (E12-14) and Mt. Eden Creek (E11, E10, E14B-16B) loops. No mammalian predator trapping or removal was conducted at Eden Landing during the 2017 breeding season due to lack of funding.

On several occasions we directly observed or found evidence of humans trespassing on the ponds that are closed to the public. At E12, a trespasser was observed walking in the saltworks. One brood and a large flock of Snowy Plovers were known to have been in this area in the week prior, and thus this activity may have caused disturbance to the brood and/or flock. At Ravenswood, pedestrians were occasionally seen trespassing into restricted areas. At R4, pedestrians, including a dog in one instance, trespassed the gate onto the restricted levee at R4, and at R5 and R5S, pedestrians were occasionally seen walking on the pond bottom. Biologists made concerted attempts to inform the pedestrians of their trespass, and when appropriate, called Refuge Law Enforcement.

**DISCUSSION**

**Population Size**

During the May breeding window survey, we counted 246 breeding adult Snowy Plovers. This is the highest amount of Snowy Plovers observed during the breeding window since 2011 (249),

and third highest overall (275 in 2010)(Table 4). Eden Landing continues to host the majority (58%) of breeding adult Snowy Plover in 2017, as it did in 2016 as well. The number of adults counted at Eden Landing increased from 120 (2016) to 144 (2017), indicating that the population continues to recover after a major decline following the breach of pond E8A in 2011. At Ravenswood, the percentage of the population appeared to increase from 20% (42 adults) in 2016 to 31% (76 adults) in 2017 (Table 4). While some of this may be attributed to population growth, it is also possible that some of the increase in numbers was due to differences in detection ability caused by changing pond conditions. Due to the large size and varied texture of the Ravenswood ponds, detection of Snowy Plovers, especially incubating birds, is generally more challenging than other Snowy Plover sites in the San Francisco Bay. During the 2016-17 winter, precipitation levels were high compared to recent years, resulting in a significant amount of R4, and all of R3, being inundated with water. This was the case during the breeding window survey, and as a result, the size of the dry panne was greatly reduced, allowing a higher detection rate of Snowy Plover adults.

**Nest Abundance and Success**

In 2017, we found 341 nests in Recovery Unit 3, representing the highest total recorded since SFBBO began monitoring Snowy Plovers in 2003 (previous high of 298 nests in 2015). As the breeding population has continued to recover following a decline after 2011, it makes biological sense that we would find an increasing number of nests each year. Increased research focus, including brood surveys at E14 and chick banding at multiple ponds within Eden Landing and Ravenswood, also likely contributed to increased detection of nests. However, since the probability of detecting unsuccessful nests is lower than that of successful nests (Mayfield 1975) and Snowy Plovers renest readily (Warriner et al. 1986), nest totals should be viewed as an index rather than a precise total. With moderate depredation rates in some ponds, nest totals are likely under-represented.

The overall depredation rate within Recovery Unit 3 was 42% (144/341; Table 5). This represents a major reduction in nest depredation rates compared to last year (54%, 142/261). In total, 62 more nests hatched in 2017 (172) compared to 2016. Apparent nest success varied greatly by pond and pond complex. At Eden Landing, the ponds with the highest depredation rates were E6B (82%; 9/11) and E8 (60%; 18/30), while E13 (41%, 9/22), E14 (42%, 36/85), and E16B (7%, 2/30) had the lowest. Although all of these ponds are located within close proximity, there is a clear separation in nest success based upon the ponds, indicating that various differences in microhabitat and surrounding macrohabitat i.e. power towers, marsh, developed land) may affect overall plover breeding success. At the Refuge, the ponds with the highest nest depredation rates were A12 at 77% (17/22) and A23 at 86% (6/7), while R3 (31%, 4/13), RSF2 (31%, 10/32), and New Chicago Marsh (0%, 0/5) had the lowest. In recent years, Warm Springs has seen high depredation rates, while Alviso and Ravenswood have been mixed based upon the ponds in which nesting occurred. Low nest success is a major limiting factor in the recovery of Snowy Plovers in the South Bay and across the Pacific Coast (USFWS 2007, USFWS and CDFW 2007). Better understanding of the different factors affecting nest success in these areas is pivotal to creating more robust breeding

sites throughout RU3, which will provide greater stability and protect against localized population decline.

*Refuge*

In 2017, Snowy Plovers nested on ten refuge ponds, as well as one area directly adjacent to refuge lands (Hickory). At Alviso, we recorded nesting activity at three ponds, including A12, A16, and New Chicago Marsh. A13, which was kept flooded during the majority of the breeding season to prevent methyl-mercury formation, had no recorded breeding activity in 2017. This was a departure from 2016, when 16 nests were confirmed on A13, and an additional 10 were suspected. Snowy Plovers instead initiated a large amount of nests in A12, with 22 found over the course of the breeding season (Table 5). Based upon the timing of brood observations, it is likely that several more nests went undetected.

During the 2017 breeding season, we recoded a very high depredation rate (77%) in A12. This is in stark contrast to A13 during the 2015 and 2016 seasons, when we recorded depredation rates of 0% and 6%, respectively. One potential explanation for this vast difference in nest success is related to time of the season and water levels. At A12, the only available habitat in the early part of the season was the four islands located on the west side of the pond. Snowy Plovers established the first five nests in A12 on three of these islands, in close proximity to several American Avocet nests. Of these five nests, three were depredated (as were all Avocet nests) and one appeared to hatch based upon shell fragments. However, as the brood was never seen, it is likely that the chicks were lost at hatch or shortly thereafter. California Gulls were the most abundant predator in A12 during the 2017 breeding season as there is a large gull colony on the adjacent levees (Figure 28b), and with these islands the only place to roost early in the season, a large flock landing on these islands could have resulted in the aforementioned nests being depredated. The fifth nest, which contained only one egg, was abandoned, and may have been due to aggressive interactions between Snowy Plovers and avocets. See the discussion section *Interspecies Interactions* below for more on this topic.

As habitat began to dry out in A12, pond topography may have influenced depredation rates. When deeper ponds first begin to dry out, they appear to attract a large amount of foraging gulls (B. Pearl pers. obs.). This may be due to higher food concentration and availability for gulls as water levels recede. Concurrently, as water levels expose pond bottom, Snowy Plovers move in to use dry pond for nesting, with the edge of the pond bottom near the water often drying out first. In A12, which is deeply subsided, there is a small elevation difference between exposed pond bottom where Snowy Plovers nest, and water channels where gulls forage, especially when the ponds are transitioning from flooded to dry. As a result, California Gulls may be more likely to randomly find Snowy Plover nests while foraging in A12 if the pond is drying during the course of the season. Conversely, Snowy Plovers didn't nest in A13 until late in 2015, by which point there was a large amount of available nesting habitat. The pond was kept dry through the winter of 2015-16, and thus, the vast majority of pond bottom was exposed and available for Snowy Plover nesting. Importantly, by that time there was a large elevation difference between the pond bottom and the water levels, which may have reduced

the probability of gulls randomly finding Snowy Plover nests. Thus, in deeper ponds that tend to attract a large amount of gulls, depredation rates may be reduced by either drying these ponds out prior to the beginning of the season, or not drying them out at all. Not drying them out at all results in no Snowy Plover nesting habitat. Drying them out earlier in the year reduces habitat for a large number of foraging ducks and shorebirds during a crucial migratory period. These trade-offs are important to make on a larger landscape scale.

For the third consecutive year, no Snowy Plover nests were found at Island 3 at A16, where social attraction was deployed to encourage Snowy Plover nesting (see Hartman et al. 2017 for further details of the social attraction project). However, six Snowy Plover nests were found on islands used in the social attraction project for Caspian Terns (*Hydroprogne caspia*). To our knowledge, this marks the first time that Snowy Plovers and Caspian Terns have been documented nesting in close proximity in the San Francisco Bay area. Three nests were located on Island 11, where Caspian Terns nested in 2017, and three nests were located on Island 12, where Caspian Terns didn't nest. In order to reduce the potential for negative interactions between plovers and terns, , the Snowy Plover nests located on Island 11 were visited only once, after which biologists attempted to confirm incubation using scopes from the levee. However, we could not determine the fate of these nests beyond "unsuccessful." It is possible that these nests were depredated within the one-week period between surveys. However, we cannot rule out aggression from Caspian Terns, and it is possible that Snowy Plovers abandoned their nests and the eggs were subsequently depredated post-abandonment. It should be noted that US Geological Survey biologists did not see any aggression towards plovers during their 2-3x/week surveys.

With relatively little available habitat elsewhere in Alviso, Snowy Plovers nested in dry sections of New Chicago Marsh (NCM) for the first time since 2013. Five nests were monitored within NCM, all of which hatched. This is in stark contrast to Forster's Tern nest success in NCM during 2017, where a high depredation rate was attributed in part to mammalian predators (J. Fasan, pers. comm.). The Snowy Plover nests were located in sparsely vegetated Spreckles Marsh area, while Forster's Tern breeding occurred in the main area of NCM, which is largely dominated by dense pickleweed stands. Nesting in an area with minimal vegetative cover for mammalian predators may have provided Snowy Plovers with a higher predator detection rate. Additionally, nesting in an area used less frequently by other nesting birds may have meant less predators frequenting the area, and thus, a lower overall predation pressure. Broods from these nests also appeared to have a high fledge rate, as two three-chick broods were seen weekly in the Spreckles Marsh area until early August, when four juveniles were observed in the same area.

At Warm Springs, depredation rates were high for the second consecutive year (64% in 2017; 75% in 2016), and consistent with the trend in recent years (average 80% 2011-2014). Numerous American Avocets also attempted to nest on-site, with no indication that any nests made it to hatch (C. Strong, pers. comm.). This site had the highest concentration of Common Raven sightings in all of Recovery Unit 3 (Figure 27-Figure 32). The presence of power towers in

the driest areas of A22 and A23 may have contributed to low success, as Peregrine Falcons are frequently seen hunting from these towers. California Gulls may have also contributed to the high depredation rate. Contrary to 2016, when nest material (pre-egg laying) from 132 California Gull nests were removed at A22, nest material from only 16 California Gull nests were removed in 2017 (Strong & Michishita 2017). Despite fewer California Gulls attempting to nest at Warm Springs, this area is located adjacent to the Mowry ponds (M1-M5), where approximately 8380 California Gulls nested in 2017 (Tarjan & Butler 2017). Warm Springs is also adjacent to Newby Island Landfill. Analysis of abatement efforts at Newby Island from 2008-2017 show that the number of gulls at the landfill has been significantly reduced compared to pre-abatement (Tarjan & Heyse, 2017). This may indicate that with a reduction in availability of a significant food source in the South Bay (trash), California Gulls are spreading out in search of other foraging patches. If so, this could have negative impacts on nearby Snowy plover nesting sites. In addition, coyote tracks were observed on the pond bottom (C. Strong, pers. comm.), indicating that mammalian predators may play a significant role in nest success at this site. Use of nest cameras at Warm Springs may allow for determination of key nest predators, and in turn, inform targeted management efforts to reduce depredation and increase nest abundance at this site.

At the Ravenswood Complex, 83 nests were located (Table 5), tying the record for the highest number of nests recorded in the complex (2015). The depredation rate within the complex was 41%, comparable to 2016 (45%), although only 38 nests were found in 2016. The apparent large fluctuations in breeding effort within the complex from 2015-2017 may reflect changes in habitat availability and resulting detection ability. Over the past three breeding seasons, we observed a large fluctuation within the season in available habitat, especially during the first half of the season. Between the first week of March and first week of June, the average available habitat in all of Ravenswood was 154.3 ha in 2015, 238.1 ha in 2016, and 110.1ha in 2017. During this same period, we recorded 54 nests in 2015, 24 nests in 2016, and 59 nests in 2017. In comparing the habitat availability and nest totals, there appears to be a negative correlation between the amount of available habitat and number of nests found, though with a small sample size (number of years), statistical significance cannot be determined. This data aligns with our anecdotal observations of detection ability within the Ravenswood complex, particularly at R4 and R3, the 5$^{th}$ (121.3ha) and 7$^{th}$ (115.0 ha) largest Snowy Plover breeding ponds in Recovery Unit 3. The All-American Canal separates these ponds, and spanning nearly 1400 m, encompasses a large proportion of the perimeter of R4 (4359m) and R3 (5976m). As the adjacent levees are not drivable, and walking the levee is not feasible for time and disturbance reasons, there are large areas radiating from the All-American Canal levees in both ponds that are very difficult to adequately scan. In examining the history of nest locations in these ponds, there are few confirmed nests in these aforementioned areas. Furthermore, the highly textured nature of these two ponds due to gypsum on the pond bottoms reduces detection ability. Thus when habitat availability is greater, Snowy Plovers will spread out and use more of the pond, and as a result, our detection ability will go down. Throughout all of the San Francisco Bay, broods from unknown nests are most consistently observed at R3 and R4, providing further evidence that our detection of nests is lower at these ponds compared to

other sites. In future seasons, we plan to record the number of unknown broods (based upon number of known hatched nests and date hatched) observed during surveys at all ponds. This data will allow us to determine a minimum number of nests missed at each pond.

At RSF2, we found and monitored 32 nests (Table 5), representing the second highest total ever recorded within this pond (33 in 2010). The pond was very successful, with an apparent hatch rate of 69%. Over the season, there was a clear trend in nest initation at RSF2, with 26 nests initiated between April 4 and June 1, and only 6 nests initiated afterwards. Although this corresponds with observed nest initiation peaks in Recovery Unit 3 (Figure 16), at least 13 nests were initiated in R3 and R4 during this time. A similar trend was observed in 2015, when 25 nests were initiated at RSF2 between March 12 and June 1, and only six nests were initiated thereafter, while 26 nests were initiated in R1, R3, and R4 combined during the same time frame. Furthermore, counts of adults during July and August indicate that RSF2 is used very little at the end of the season (Figure 10). It may be that over the course of the season, the quality and quantity of foraging habitat is reduced as water levels recede within internal channels and the borrow ditch, pushing Snowy Plovers to nest, roost, and forage in other ponds. As such, ensuring that the borrow ditches and interior channels are kept relatively full throughout the course of the season may prove beneficial for both breeding and post-breeding Snowy Plovers.

With the impending restoration of the Ravenswood complex as part of Phase 2 of the Project, approximately 27% of currently available Snowy Plover breeding habitat will be opened to tidal action (pond R4). Based upon the large number of Snowy Plover nests found in the complex in 2015 and 2017, as well as evidence to suggest that a moderate number of nests go undetected in R3 and R4 each year, we expect that post-restoration, R3 and RSF2 will host a larger number of Snowy Plover nests, similar to the high concentration of nesting seen at E14. At R3, improving nesting habitat in multiple ways will be critical, potentially including consolidation of smaller islands into larger areas, spreading oyster shells, gravel, or other material to increase crypsis, and providing permanent vegetative cover for broods in foraging areas. At both R3 and RSF2, it will be imperative that water levels are managed appropriately to provide quality foraging habitat throughout the season.

Within the Dumbarton Pond complex, we confirmed Snowy Plover nesting activity for the first time since 2007. In early June, USGS biologists notified SFBBO of potential Snowy Plover breeding activity at pond NPP1 (J. Fasan, pers. comm.). Upon surveying the pond on June 8, SFBBO biologists discovered one Snowy Plover nest along with several American Avocet nests. Due to a mix-up in communication, Cargill, who operates the pond for salt production, were not properly notified of the nesting. As a result, the aforementioned Snowy Plover and Avocet nests were flooded out. SFBBO continued to monitor the area for Snowy Plover breeding activity. The following week, a one-chick brood that was approximately two weeks old was spotted on NPP1, possibly coming from an adjacent panne, termed Hickory for this report (Figure 7). SFBBO began surveying Hickory and NPP1 weekly, finding four nests, as well as observing another undetected brood from Hickory. All four nests hatched, and two chicks from

one nest were banded. Although the chicks were not confirmed as fledged (31 days post hatch), they survived to 29 days, and it is likely they fledged (Table 9). We observed a Snowy Plover male adopting an entire three chick brood. The first two confirmed nests in Hickory were projected to hatch within days of each other, and on August 1, both nests were confirmed hatched. The following week, biologists observed what appeared to be six week-old Snowy Plover chicks all foraging along the NPP1 shoreline, which we believe were from the aforementioned hatched nests. Furthermore, upon observing the chicks closely for 30 minutes, it was determined that all six chicks were brooding with one male. Biologists continued to watch, observing no other Snowy Plover male in the area. During the following weeks, we observed the six-chick brood repeatedly, and believe that all six chicks fledged. Although rare cases of Snowy Plovers adults adopting chicks have been reported (Warriner et al. 1986), the adoption of a three-chick brood by a male with his own three-chick brood has so far been unreported.

*Eden Landing*

For the second consecutive year, Snowy Plovers nested at ponds E12 and E13, hosting 15 and 22 Snowy Plover nests, respectively (Table 5). Nests in these ponds were relatively successful, with an apparent hatch rate of 53% (E12) and 45% (E13). We recorded 8 Snowy Plover nests on islands in these ponds, with five in E12 and three in E13. Collectively, these nests had an apparent hatch rate of 63%, the highest recorded on the islands since their construction in 2013. Despite the high apparent hatch rate on the islands, brood survival may be low if they stayed on islands. Upon arrival to Eden Landing on July 17, biologists observed a large gull flock (mostly California) roosting in the medium salinity cell of E12 on the pond and nesting island. A Snowy Plover nest located on the island had been projected to hatch on July 13, and biologists spent time searching for the brood. Eventually, the three-chick brood was found on the nesting island, located on the side of the island where gulls were not roosting. From observation, the male and chicks were stressed, as the male was running around frantically back and forth and the chicks would occasionally hunker down low on the ground. Under normal circumstances, biologists would have devised a plan to carefully flush the gulls, hopefully allowing the brood to escape likely depredation by the gulls. However, that same day, a nest located only 300m away on the E12/13 interior levee was also projected to hatch, and surrounded on both sides of the levee were more gulls. Not wanting to flush the gull flock directly towards the hatching nest, and knowing that the brood was currently safe, albeit stressed, biologists chose not to attempt to flush gulls. Although the fate of the island brood is unknown, they were not seen on the island afterwards. Similarly, although we observed broods on the other islands not long after they hatched, they were not seen in consecutive weeks. It is possible that the broods swam to a berm or levee. The closest distance to the nearest berm from any of the nesting islands is 40m, a distance that could take a several day old Snowy Plover chick 5-10 minutes to cross. Considering the need for young chicks to regularly brood for thermoregulation, a long swim in cold water could prove fatal. By placing islands closer to berms and levees, these risks could be mitigated, but this must be balanced with the need to protect nesting birds form mammalian predators and human disturbance.

Our findings from nest monitoring at reconfigured ponds A16, E12, E13, and RSF2 suggest that Snowy Plovers select nesting habitat on large pond bottoms rather than on islands. One possible explanation may be the behavior employed by incubating adults to escape detection by predators. Breeding Snowy Plovers flush from their nest at a distance of 174.9m when approached by trail walkers (Robinson 2008). The larger size of dry pond bottoms may provide greater crypsis from approaching predators for incubating adults that have flushed, compared to smaller nesting islands where flushed adults may be less able to escape detection. Creating larger islands may create conditions more similar to dry pond bottoms. In addition, due to the semi-colonial nature of Snowy Plovers, creating larger islands may encourage increased nesting on islands. Increased island size may also reduce the potential for gull flocks to land on islands and opportunistically find Snowy Plover nests and young broods However, larger islands could also attract gulls to nest, and thus, these competing risks must be considered.

E16B had the lowest depredation rate among nesting ponds at Eden Landing, at 7%. From a nest success standpoint, 2017 represented the most successful breeding season for Snowy Plovers at E16B, with both the highest amount of nests recorded at the pond (30), and the lowest depredation rate during years with at least 15 nests in the pond (SFBBO 2009-11, 2016-17). At this pond, Peregrine Falcons were sighted more frequently than any other pond (0.462 per survey; Figure 19). Several times a Peregrine family (1-2 adults with 3 fledglings) was seen perched on the power towers in the back of the pond (B. Pearl, pers. obs.). On one of these occasions, a Common Raven was observed being attacked in mid-air by one of the adult Falcons, preventing the Raven from hunting in the pond. Thus, it is possible that the continuous presence of Peregrine Falcons at E16B may have acted to increase nest survival by keeping Common Ravens and other avian nest predators from hunting within the pond. Despite the high nest survival, the known fledge rate in the pond was only 31%, indicating that the pond may not provide enough cover for chicks to survive.

*Napa-Sonoma Marshes Wildlife Area.*

For the first time since 2007, no breeding activity was observed at the Napa Sonoma Marsh Wildlife Area. This area is CDFW property, and is monitored primarily for Least Tern breeding activity. In the future, sending volunteers monthly to monitor specifically for Snowy Plovers may lead to more complete knowledge of Snowy Plover breeding in the area.

**Least Tern Nesting**

The 2017 breeding season marked the first time that Least Terns attempted to nest at Eden Landing since nesting there in 2007 (5-6 pairs), 2008 (2 pairs), and 2009 (1 pair). From 2007- 2009, no fledglings were produced at the colony due to depredation. By contrast, 2017 appeared to be very successful for Least Tern breeding at E14. The apparent nest depredation rate was low (5%), while the fledging rate appeared to be high, with 18 older fledglings and two younger fledglings observed late in the season. The location of the colony indicates that large oyster shell enhancements may also attract and benefit breeding Least Terns. Assuming Least Terns may return to nest at E14 in future years, we will allocate staff and resources ahead of time, allowing for more complete nest

monitoring. We also plan to utilize Least Tern decoys to encourage continued nesting at E14 and install chick shelters to provide additional hiding spots for Least Tern chicks (Jenks-Jay 1982).

**Interspecies Interactions**

Due to the high levels of precipitation during the winter of 2016-17, there was less available habitat throughout the South Bay during the first several months of the 2017 breeding season. During this timeframe, we found Snowy Plovers nesting in very close proximity to numerous species, including American Avocets, Black-necked Stilts, and Caspian Terns. As a result of this close nesting, we observed fifteen separate aggressive physical interactions between Snowy Plovers and other species (Table 12).

Due to pond management actions and high precipitation, RSF2 began the 2017 breeding season with relatively little suitable breeding habitat. In one of the dry areas suitable for nesting, ten Snowy Plover nests were initiated between April 5 and May 20, and two aggressive interactions between plovers, avocets, and stilts were recorded. In one situation, we observed a Snowy Plover female incubating a hatching nest approximately 5m away from an Avocet nest. Over the course of two hours, we observed the Avocet repeatedly chase the Snowy Plover female off her nest. In another case, we observed a male Snowy Plover incubating a nest and tossing nesting material. At one point, the male chased away a nearby Black-necked Stilt, after which point he resumed tossing and incubating.

Similar to RSF2, high early season water levels at R4 resulted in Snowy Plovers nesting in clusters in the northwest and southwest corners of the ponds. Within an approximately 4.30 hectare area in the northwest, 15 nests were established between April 1 and April 30, with fourteen of these nests active concurrently, resulting in a nest density of 3.3 nests/ha. Within this same area, we also observed numerous American Avocet and Black-necked Stilt nests. On April 27, a Snowy Plover pair was chased by an adult avocet with a nearby brood. Later that same morning, we observed two separate instances of Snowy Plover females charging a Black-necked Stilt. In one instance, an incubating female plover charged a nearby stilt, while in the other instance, a paired female charged a nearby stilt. In all three cases, the elevated level of activity could have attracted the attention of predators, and with the adult birds distracted, resulted in depredation of adults, nests, or chicks of all three species.

At A12, the only available habitat in the early part of the season was the four islands located on the west side of the pond. Snowy Plovers established the first five nests in A12 on three of these islands. During the same time frame, a number of American Avocet nests were also located on these islands, in some cases less than 10m away from Snowy Plover nests. On May 17, a female Snowy Plover and American Avocet associated with nests located approximately 10m away were observed fighting each other, with the Snowy Plover also doing a broken wing. Similar behavior was observed later that morning and the following week, indicating that this was a continuous conflict. Another Snowy Plover nest, located on a nearby island approximately 10m away from Avocet nests, was abandoned. Although no aggressive

interactions were recorded between the incubating plover and Avocets, it remains a possibility that this nest was abandoned due to these types of interactions.

In all of these situations, the close proximity to other nests, regardless of species, may have played a role in the high depredation rate. Powell (2001) found that Snowy Plover nest success was highest at close (51-100m) and medium distance (101-200m) from other Snowy Plover nests, while lowest at very close (<50m) and far distance (201-500m) from other nests. At RSF2, the three nests in close proximity were located 34.5±14.5m from the nearest Snowy Plover neighbor, while the other four nests that were depredated were 90.0±30.4m. At R4, the six nests plover that were depredated were located 45.6±13.9m from the nearest Snowy Plover neighbor. At A12, the distance between Snowy Plover neighbors was 45.3±36.2m. In all of these situations, Snowy Plover nests were also in very close proximity to American Avocet and/or Black-Necked Stilt nests. Although these species do defend their nests from aerial predators, the semi-colonial nature of these species may attract a large amount of predators to the area. Further research is needed to examine how plovers breeding in close proximity to other shorebirds species affects plover breeding success.

**Nesting Behavior**

The use of trail cameras in E14 allowed for close documentation of interactions between breeding Snowy Plovers and California Least Terns nesting in close proximity. The closest plover nest was located 3m and 8m from two California Least Tern nests, and we recorded six incidences of aggression between the two species. In five of the events, aggression may have occurred because an adult Least Tern landed within 1-2 feet of the Snowy Plover nest. During the sixth event, all three Snowy Plover chicks had hatched that day, and the attending male was more aggressive, chasing off a Least Tern adult located approximately 5m from the chicks. While these interactions were minor, and overall the two species appeared to coexist peacefully, potential conflict should be considered when attempting to promote these two species to breed in the same areas.

**Chick Fledging Success**

The apparent fledging rate within Recovery Unit 3 increased from 27% in 2016 to 44% in 2017 (Table 8.) Among ponds with at least two broods banded, E14 had the highest apparent fledge rate, at 53% (Table 9). This is an increase from 2016, when the fledge rate within E14 was 44%. Due to high nest depredation rates early in the season, the first brood at E14 was not banded until June 7. By this time, the Least Tern colony was established on the pond. The apparent increased fledging success at E14 may have been due to the umbrella effect of Least Terns defending their colony (Powell 2001).

Another factor that may have influenced chick survival is the presence of thick stands of pickleweed in foraging areas. In an attempt to prolong the integrity of the shells, E14 had not been flooded since the winter of 2014, when New 1 and New 2 shell sites were spread. This resulted in growth of vegetation throughout the pond, namely perennial pickleweed (*Salicornia pacifica*) and slenderleaf iceplant. Dense vegetation is undesirable in nesting habitat, as it

reduces available nesting habitat and the ability of plovers to detect predators. However, it may also provide a benefit to broods as hiding places. This was especially the case on the west end of the pond next to the borrow ditch. At this location, many broods were observed throughout the season using the area for both foraging and shelter. At Assateague Island National Seashore in Maryland, Loegering and Fraser (1995) found that Piping Plover (*Charadrius melodus*) brood survival was higher when broods were reared on bayside beaches and the island interior compared to ocean beaches. At both bayside and island interior sites, broods were often found along the margin of vegetation, providing readily available shelter for broods from predators, while at Ocean beaches, there was a lack of vegetation due to seasonal wave action. Similarly, vegetation in foraging areas may facilitate higher brood survival for Snowy Plover broods in salt ponds.

On refuge lands, seven chicks were banded in total, with five and two at RSF2 and Hickory, respectively (Table 9). At RSF2, a two-chick brood was resighted once, three days after they were first banded, while two chicks from a three-chick brood survived to fledge. At this pond, predation pressure on chicks appeared to be high, as few unbanded broods were observed on a weekly basis despite an apparent hatch rate of 69% within the pond (pers. obs.). This pond may require more active water management to increase the quantity and quality of foraging habitat. Spreading additional oyster shells, chick shelters, or other material at foraging sites may provide additional cover for chicks.

At Hickory, two chicks from a three-chick brood were banded on August 14. Through September 12, the two banded chicks were subsequently resighted weekly at NPP1 on the shoreline and later the pond bottom. The following week, this pond was inundated as part of Cargill's pond operations, resulting in the flock of 30-40 Snowy Plovers that had been present for several weeks moving elsewhere. As these two chicks were seen through 29 days, it is likely that they fledged and flew elsewhere once the pond was inundated.

Our ability to re-sight Snowy Plover chicks in the ponds is limited by uneven topography spanning a large and complex network of ponds, sloughs, and levees. In two instances, a brood of chicks was banded and not seen again as chicks, only to show up later as fledged juveniles. At E6B, a three-chick brood was banded on June 10, but not observed during following weekly surveys and presumed dead. However, on August 18 we received a report from biologists at Bolsa Chica Ecological Reserve of a banded juvenile with a combination matching one of the banded chicks (P. Knapp, pers. comm.). This same bird was photographed two weeks later by trail cameras on E14, confirming that the chick had in fact fledged, flown down to Bolsa Chica, before flying back up to Eden Landing. In September, another chick from the same brood was confirmed as fledged at Eden Landing. At E8, a similar situation occurred, in which a brood was banded but never seen again as chicks. Over two months later, one chick from the brood was confirmed as fledged via a trail camera at E14 set out to photograph plover band combinations.

This season, Snowy Plovers nested on 23 ponds totaling nearly 1800 ha, and ranging in size from 0.2-185 ha. Often, ponds are only accessible by kayak, and the pond bottom can be difficult to traverse due to soft mud and deep, wide channels. Use of radio telemetry to track adult males with broods may hold some promise for improving the accuracy of plover fledging success estimates in the San Francisco Bay All methods must balance the need for more intensive monitoring with the potential impacts caused to Snowy Plovers.

**Oyster Shell Habitat Enhancements**

*Apparent Estimates*

For the second consecutive year, apparent nest success was lower in pilot shell plots (49%) than other areas of Eden Landing (54%)(Figure 18). This may be due to the gradual degradation of these shell plots over time. The brightness and density of the shells in many plots has degraded over time, resulting in reduced camouflaging effects. In some instances, this may be due to seasonal flooding of ponds for wintering birds, resulting in movement of shells and silting over of shells (E6B plots 2 and 3; E8 plots 2 and 4). In other areas, natural precipitation and wind have similar effects on shells (E16B plot 2).

*Large Scale Enhancement Study*

Overall nest abundance throughout the pond, and nest density in the new oyster shell enhancement plots were substantially higher in 2017 when compared to pre-enhancement conditions (prior to 2015). Nest abundance and density patterns in 2017 were similar to the first season 2015, and overall water levels and management in nearby ponds were comparable.

After high nest depredation rates in 2016, nest success rates at E14 improved markedly during the 2017 breeding season (Table 5). There is evidence to suggest that Snowy Plover success was at least partially driven by the presence of a California Least Tern colony at E14. Prior to establishment of the colony, Snowy Plover nests had an apparent hatch rate of 20% (n=36). After establishment of the colony, Snowy Plover nests had a hatch rate of 94% (n=16) within 100m of the colony, 69% hatch rate (n=13) within 500m of the colony, and 60% hatch rate (n=20) greater than 500m from the colony. These results correlate closely with the findings of Powell (2001), who found that plover nests located within 100m of a Least Tern colony had a hatch rate of 85%, 72% within 101-500m, and 62% for plover nests greater than 500m from a Least Tern colony.

Using the program RMark (Laake 2013) to conduct a nest survival analysis, we found that time of season had a significant effect upon Daily Survival Rate (DSR) for the entire pond, starting at 84.6% on the first day of the season and ending at 99.6%. Examining each plot separately, only New 2, where the Least Tern colony was located, showed a significant trend between time and DSR, going from 11.5% on the first day of the season to 99.8% on the last. For complete nest survival analysis and behavioral statistical analysis of Snowy Plover breeding in E14 in 2017 and during the three years of the study (2015-2017), see Pearl et al. (2017).

Three years of monitoring large-scale oyster shell enhancements indicates that they can increase nest density. However, for the third consecutive year, predators appeared to cue in on areas of high nest density, as has been found at Mono Lake (Page et al., 1983). In 2017, Common Ravens were the most numerous predator observed at E14 (Figure 31a). Common Ravens were documented depredating five nests during 2017, as opposed to 30 nests in 2016 (Table 11). In addition, red fox appeared to be increasing at Eden Landing as they were frequently sighted(Figure 31a), and were documented depredating two Snowy Plover nests for the first time in Recovery Unit 3 (Table 11). Despite this, the fledging rate at E14 increased this season (53%) compared to last (44%) (Table 9). Success for plovers may have been a combination of oyster shell enhancements and the presence of the Least Tern colony.

It is critical that monitoring and research continue at the E14 enhancement site. Consistent monitoring will document how Snowy Plover use of the enhancement site may change over time, a critical piece of knowledge to inform future restoration efforts within Recovery Unit 3 and across the Pacific Coast.

*Additional Considerations*

At Alviso, Snowy Plover use of ponds shifted over the course of the season. In March and April, little habitat was available for breeding Snowy Plovers, with small flocks split between A16 and NCM (Figure 10). During this time, Snowy Plovers also attempted to nest on islands in A16, although these may not be suited for Snowy Plovers due to the high number of potential predators found on the pond (Figure 28). In July and August, large flocks were found in A12, where habitat had dried out and become available. In future years, we recommend that at least one pond with large areas of dry pond is available for Snowy Plovers to begin the breeding season at Alviso.

Nesting sites can be attributed to habitat availability as a result of water level management and rainfall, as well as habitat conversion due to tidal restoration projects. Accurately documenting changes in breeding habitat availability is imperative as available habitat shifts. Calculating nesting densities using actual available area will help establish nesting projections needed to support breeding Snowy Plovers in a changing landscape. We recommend continuing our weekly habitat availability surveys.

As the amount of available Snowy Plover nesting habitat around the Bay is reduced due to tidal marsh restoration, Snowy Plover nesting density will need to increase in order to maintain and/or increase breeding numbers within a smaller habitat footprint. Although shell plots are one way to achieve the higher nest densities needed to reach the Recovery Unit goal of 500 breeding birds, there are a couple of issues with oyster shells that warrant further consideration. Oyster shells degrade over time and shell plots may need to be supplemented with new shells on a consistent basis (approximately every 5-10 years) in order to maintain their benefits for Snowy Plover breeding. Due to the closing of Drake's Bay Oyster Company in Marin County in 2014, large amounts of local oyster shells are no longer available, necessitating the need for another source. In San Francisco and the North Bay, The Wild Oyster Project has

established an oyster collection and curing program (wildoysters.org). Collaborating with this organization to establish a similar program in the South Bay may provide a reliable source of oyster shells for future restoration efforts. Gravel and cobble, which have shown promise as a nesting substrate that increases nest survival along the Eel River (Colwell et al. 2011) and at Point Reyes (L. Stenzel, pers. comm.), as well as attracting nesting plovers to levees and berms at ponds E12 and E13, may also prove useful for enhancement efforts. Prior to large-scale implementation, any new materials should be tested in a pilot study for efficacy and durability.

With increased nest density, predator management becomes more important. At E14, the presence of a Least Tern colony may help reduce Snowy Plover nest depredation. Predator management should continue, and possibly increase as tidal marsh restoration efforts further concentrate Snowy Plover breeding. We should identify all potentially suitable areas for plover nesting and identify management actions to improve nesting habitat. At these sites, installation of new water control structures or other vegetation management may increase Snowy Plover habitat during the breeding season.

**Avian Predators**

Common Ravens appear to focus their foraging efforts on ponds with the highest concentration of Snowy Plover breeding. While lethal control of ravens may be beneficial in the short term, the large population of ravens in the Bay Area will result in new ravens taking over the territory of the removed ravens. Longer-term efforts such as conditioned taste aversion, in which mimic eggs are treated with an emetic chemical and placed out for nest predators to eat and induce vomiting and nausea, may provide a mechanism to reduce predation as long as the ravens remain present within their territory. However, this method has shown limited success with Common Ravens in Least Tern colonies (Avery et al. 1995) and Steller's Jays (*Cyanocitta stelleri*) in Marbled Murrelet (Brachyramphus marmoratus) breeding territories (Gabriel & Golightly 2014) Another method that could prove useful in the future is the deployment of smart drones. In Australia, drones programmed to identify sharks have been implemented at beaches to locate sharks and quickly warn beachgoers(Gallagher 2016). At Snowy Plover breeding sites, drones trained to identify and haze ravens could be deployed. Extensive field tests must be conducted to determine the impact of drones may affect breeding Snowy Plovers.

Peregrine Falcons were consistently seen hunting throughout Eden Landing, including three fledglings in mid-June. Although no nest was located, it is likely that they nested on or near Eden Landing, as has been reported in past years. For the second consecutive year, Peregrine Falcons and Common Ravens were observed fighting in flight at Eden Landing, providing some evidence that these two species compete for resources. Whenever possible, biologists flushed Peregrine Falcons away from sensitive plover habitat and investigated prey remains for evidence of plover predation; however, no plover remains were found.

We frequently observed Red-tailed Hawks, Peregrine Falcons and Common Ravens perched in the transmission towers within ponds throughout the South Bay. The Refuge coordinated with

Pacific Gas and Electric (PG&E) to remove five Common Raven nests and three Red-tailed Hawk nests in towers over sensitive habitat in the South Bay in 2017 (Strong & Michishita 2017). The Refuge will continue to coordinate the removal of nests from towers and boardwalks with PG&E.

The total number of California Gulls nesting in the South Bay was 43,570 breeding birds in 2017, an increase of over 5,500 from the previous year, yet still lower than the 47,866 breeding birds recorded in 2015 (Tarjan & Heyse 2017). The second largest gull colony in the bay (Alviso A9/A10/A14 colony) was located adjacent to A12, and was likely the source for the high number of California Gulls observed on that pond At Hayward Shoreline, one plover? nest was observed being depredated by a California Gull. This marks the first time since 2011 that California Gulls were confirmed depredating a Snowy Plover nest. Between 2009-2011, California Gulls were identified as a major predator to nesting Snowy Plovers (Robinson-Nilsen et al. 2011, Demers et al. 2012). Since 2011, SFBBO and Refuge biologists have coordinated a gull-hazing program and successfully prevented gulls from nesting in areas identified as sensitive plover habitat (Robinson & Demers 2012; Tarjan & Butler, 2017.). At several sensitive sites in 2017, California Gull nests were removed while in their early stages. For example, at A22, only 16 nests were removed, a significant decline from the 233 California Gull nests that were removed in 2016 (Strong and Michishita 2017). Continued California Gull hazing and tracking is essential to prevent gulls from nesting in sensitive areas in future years.

**Mammalian Predators**

During the 2017 breeding season, non-native red foxes continued to use a den located in the former saltworks in E13 with pups observed on levees and pond bottoms throughout Eden Landing, particularly during the early morning hours when biologists arrived on site. For the first time, red fox were recorded on camera depredating Snowy Plover nests in Recovery Unit 3, occurring twice at E14. At E16B, Red fox were seen several times on the pond bottom and adjacent levee, and based upon the circumstances, may have depredated one of the two depredated nests at E16B. On July 11, one nest was found depredated. During the first predator survey point that morning prior to checking nests, one adult red fox was seen on the pond bottom approximately 170m from the depredated nest, while a fox pup was observed a short time later on the levee approximately 400m from the nest.

Aside from red fox, an unknown mammalian predator was also recorded on camera depredating a nest. The event took place at night, and since the predator was standing directly next to the camera, the identity of the predator cannot be confirmed. Based upon the apparently dark fur color and general shape, we suspect that it was a striped skunk. It is unknown how frequently nests and chicks are depredated by mammalian predators. Increased use and distribution of trail cameras may help identify how much of an impact mammalian predators have on nest success.

Though Snowy Plover nest predation pressure remained high in some areas this season, we continued to decide against the use of single nest exclosures because of the risk of adult

mortality and of making nests more conspicuous to predators (Dave Lauten, pers. comm.). Exclosures improve rates of nest success but are ineffective in supporting chick survival or fledge success. We continue to investigate alternative methods of predator control where resources allow.

**Restoration and Snowy Plover Nesting**

We suggest that construction activities on Snowy Plover nesting ponds occur outside of the breeding season whenever possible, and that actions be taken before the nesting season begins in order to deter Snowy Plovers from nesting on ponds where heavy equipment will be operating. Focusing the construction in a small footprint and keeping the human disturbance constant (throughout daylight hours/seven days a week) may help reduce the number of Snowy Plovers nesting in the area.

For future restoration planning, we recommend that the Project work carefully to maintain enough nesting habitat to support the existing population of Snowy Plovers during construction activities. As Phase II of the Project will enhance pond R3 for plover nesting habitat while breaching other pond R4 in the same complex, we advocate for nesting habitat enhancement to occur prior to breaching. This will help to ensure that there is high quality nesting habitat available to Snowy Plovers when overall habitat availability decreases. Prior to construction, we recommend further enhancement of RSF2 for Snowy Plover breeding, potentially including spreading of oyster shells, removal of remaining predator perches as possible, and installation of chick shelters or other materials to provide cover at foraging sites. During construction, we urge managers to provide nesting habitat in areas adjacent to those ponds being drained for construction (for example, R1 and R2). While this will not entirely prevent plover nesting in the dry construction ponds, it may reduce the number of nests in them therefore decreasing conflict between plovers and construction activities. Furthermore, managers should begin drying ponds in the winter prior to construction in order to allow pond bottoms enough time to dry and become available by the start of breeding season.

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. Four of the ponds opened to tidal action or converted to other management regimes historically hosted large numbers of Snowy Plovers (A8, E12-13 and E8A; Figure 14, Figure 17, Figure 18, and Figure 19). Losing the breeding habitat in these nesting ponds may reduce the number of Snowy Plovers nesting in the San Francisco Bay Area in the long-term, although this has not yet happened. Nest numbers in 2017 were the highest in the history of the Recovery Unit. Reducing the amount of habitat available to nesting Snowy Plovers may have unintended consequences on the success of breeding attempts as nest densities increase. In 2015, SFBBO documented significant issues resulting from high density nesting in E14, including brood aggression and high nest abandonment rates. In 2016, it appeared that predators, especially Common Ravens, keyed in on the high nesting density at E14, resulting in extremely high nest

depredation. In 2017, a wet winter resulted in relatively little available breeding habitat to start the season, and we observed increased interspecies aggression. Snowy Plovers may need to have quality habitat spread throughout the bay to minimize these affects.

The USFWS (in cooperation with USGS and the US Army Corps of Engineers) implemented a social attraction effort on islands in ponds RSF2 and A16 over the 2014-15 winter season involving decoys and audio equipment. This project targeted Caspian Terns, but also included Snowy Plover social attraction on one island at each pond in an attempt to maximize the ecological benefits on these breeding ponds. Six decoys of Snowy Plovers were placed on each island, and calls played over the course of the season. SFBBO monitored these ponds as part of normal breeding surveys during the 2017 breeding season. No Snowy Plovers were observed on either island with Snowy Plover decoys. Instead, Snowy Plovers nested on both Caspian Tern islands at A16, but were unsuccessful. The results of monitoring these social attraction efforts indicate that nesting islands may not be appropriate for Snowy Plover breeding.

*Human Disturbance*

Past studies have indicated that human disturbance can have a significant effect upon Snowy Plover nest site selection and behavior (Lafferty et al. 2006). Within the South San Francisco Bay, Trulio et al. (2012) found that Snowy Plovers flushed from their nests when trail walkers were an average of 145m away, regardless of the distance of the nest from the levee. At E14 this year, only six nests were located within 145m from potential trail walkers along the western levee, and were found an average of 114±16m from the trail. The western levee is the most frequently used by people, providing birding opportunities and views within the tidal pond E9 and Whale's Tail Marsh.

We found eleven nests located an average of 78±38m from the northern levee trail. This trail is seasonally closed to protect Snowy Plover nesting habitat and appears to be less frequently used (B. Pearl pers. obs.). One Snowy Plover nest was found directly on this portion of the trail, the first time that a Snowy Plover nest has been found on a public trail at Eden Landing since it was opened to the public. It is unlikely that Snowy Plovers would initiate a nest on a public trail if it were used frequently. Importantly, the trail junction contains a gate, which allowed us to temporarily close the northern levee trail until the nest was no longer active.

It appears that consistent trail use may influence Snowy Plover nest site selection, while less frequent trail use may not. Further research focusing on intensity of trail use and nest site selection is needed to further identify the relationship. This will be critical for planned restoration activities at Ravenswood as part of Phase II of the project if trail access will be increased. Trail use at portions of Ravenswood is consistently high and available Snowy Plover nesting habitat could be limited where public trails are adjacent.

Research at coastal sites has shown that human disturbance not only effects nest success, but can directly impact chick survival (Ruhlen et al. 2003). Installing fencing or barriers that limit pedestrians and cyclists from entering sensitive nesting areas should be implemented in future

projects. Managers should consider low fencing (~2 feet tall, such as is present at RSF2, and as is planned for R3) and smaller diameter chick fencing to keep Snowy Plover chicks off of trails and roads. This may be beneficial along the E14 western levee, as it won't affect the ability of broods to move between foraging habitats throughout the season. 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 ponds should include projects that address the following topics:

1. Expanded banding and/or tracking via telemetry of chicks and adults to provide more reliable data on survival rates. This is vital information needed to inform the recovery goal of 500 birds in Recovery Unit 3.
2. Closely examine the effects of Least Tern and Snowy Plover nesting in close proximity within Recovery Unit 3.
3. Impacts of predators on chick survival.
4. Efficacy of avian and mammal predator management on Snowy Plover breeding success.
5. Effectiveness of taste aversion studies in reducing egg depredation by Common Ravens.
6. Long-term use of E14 large-scale oyster shell enhancement by breeding and wintering Snowy Plovers.
7. Potential impacts to nesting Snowy Plovers of human disturbance from recreational trail use.
8. Northern Harrier (and other marsh predators) territory size and habitat use and impacts on nesting Snowy Plovers, especially as tidal marsh nesting habitat increases for harriers.
9. Snowy Plover foraging habitat use (borrow ditches, open channel, muted tidal, shallow pools, dry substrate) and invertebrate prey availability within the ponds.
10. Nest success of Snowy Plovers on islands in managed ponds, and methods to improve nesting use and success on islands.

### Monitoring Recommendations

1. The Recovery Unit 3 Snowy Plover monitoring program should continue. Monitoring numbers of breeding birds and reproductive performance is important to track progress towards recovery goals and the response of Snowy Plovers to management actions, including the effects of pond restoration.
2. Recovery Unit 3 should identify other potential Snowy Plover breeding habitat in the San Francisco Bay area, outside of the South Bay Salt Pond Restoration Project area, that can be managed for Snowy Plovers. Nearly all plover nests are within the Project area. A goal of the Project is to support 250 breeding adults, whereas the USFWS Recovery

Goal is 500 breeding adults; therefore, in order to reach the USFWS target in the San Francisco Bay, additional habitat may need to be identified and managed for Snowy Plovers.

3. Monthly surveys should continue to include scouting components to visit areas that are not consistently used by Snowy Plovers, including Patterson Pond in Coyote Hills, Frank's Dump in Hayward, Crown Beach in Alameda, Montezuma Wetlands in Suisan Bay, and bayfront habitat in Foster City and Redwood City. As the amount of managed pond habitat decreases, Snowy Plovers may use historical or new areas for nesting within the South Bay.
4. SFBBO, along with the Refuge, should continue to coordinate monitoring efforts in sites where Snowy Plovers have been seen breeding throughout RU3, including Cargill managed ponds (PP1, the Redwood City Plant Site and others) as habitat is available.
5. SFBBO should continue to monitor the large-scale oyster shell habitat enhancement at pond E14, and apply these findings to future enhancement opportunities, such as at pond R3.

**Management Recommendations**

1. Refuge and CDFW management should continue to meet Snowy Plover habitat requirements by: a) providing areas of drying ponds with nearby high salinity foraging habitat, b) managing ponds in several areas around the South Bay for Snowy Plovers to reduce impacts from predation, flooding, or disease.
2. If construction activities occur on ponds where Snowy Plovers are nesting, or on levees in between nesting and foraging ponds, there should be a trained biologist onsite during working hours to minimize impacts to Snowy Plovers.
3. If construction occurs adjacent to or within a Snowy Plover nesting area, then weekly meetings should be coordinated with all parties involved to ensure that all parties understand their roles in regards to minimizing impacts to listed species.
4. The predator management and gull hazing programs should continue in 2018 in the South Bay, with additional resources devoted to increase efficacy as needed.
5. Managers should explore using alternative habitat enhancement materials or methods (oyster shell, cobble, or other) as a tool for Snowy Plover recovery, and spread them in areas that will not be flooded on a consistent basis.
6. Water levels in pond A22 and A23 should continue to be raised over the winter to prevent nesting and roosting by California Gulls.
7. Efforts should continue to remove grasses and halophytic vegetation on the pond bottom that are reducing available nesting habitat. This may be achieved through flooding ponds, applying salt or gypsum, direct removal, or a combination of these methods.
8. Efforts should continue to remove predator perches in and adjacent to Snowy Plover nesting ponds
9. At E16B, water levels should be kept higher to reduce the likelihood of Snowy Plovers nesting in low lying areas that are prone to flooding. This action, along with adding

interior channels, should also be implemented to increase the amount of foraging habitat in the pond.

10. At common Snowy Plover foraging areas, oyster shells, cobble, chick shelters, or other materials should be deployed to provide increased cover for chicks.
11. Cell 3 in RSF2 should be amended to include: large scale oyster shell enhancement, raising water levels and increasing water connectivity between the borrow ditch and interior channels will create more foraging habitat.
12. If the Ravenswood ponds R1 and R2 are to support more Snowy Plovers in the future, these ponds should be drained before the breeding season begins, to expose panne habitat for nests. The reconfiguration of pond R3 as part of the Project will allow for better water management (construction projected to begin in 2018). Removal of remnant salt production structures used as predator perches would be beneficial for adult and chick survival.
13. 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. Smaller structures should be removed or treated with a bird deterrent such as Nixalite to discourage predator perching.
14. Law enforcement patrols should be increased in areas with Snowy Plover breeding habitat to minimize disturbance from trespassing humans. This will become progressively more important as additional areas are opened to the public as part of the Project.
15. All researchers who are out on the ponds during the nesting season should continue to coordinate with SFBBO and the Refuge/CDFW to minimize disturbance to Snowy Plovers.
16. SFBBO, along with CDFW and the Refuge, should continue to develop a Snowy Plover outreach program in areas that are adjacent to public access to educate the public on Snowy Plover conservation and disturbance issues.
    - **a.** Additional interpretive panels should be placed in public areas to provide information on Snowy Plover habitat needs, disturbances, and conservation issues. New panels are being planned near pond R3 as part of a collaboration with Facebook campus and pedestrian bridge.
    - **b.** SFBBO should continue to station volunteer docents at public areas adjacent to nesting sites, and trained to give guided plover surveys to create public awareness and support for Snowy Plovers, thereby reducing the human disturbance.

## ACKNOWLEDGEMENTS

In 2017, Western Snowy Plover monitoring was supported by the U.S. Fish and Wildlife Service and Alameda County Fish and Game Commission. Past program support and in-kind contributions were provided by the California Coastal Conservancy, California Department of Fish and Wildlife, Cargill Inc., Drake's Bay Oyster Farm, H. T. Harvey and Associates, McMillen

LLC, Orange County Community Foundation, Oracle, Santa Clara Valley Water District, Triton Marine, and U.S. Geological Survey. We are especially grateful to Cheryl Strong of the Don Edwards San Francisco Bay National Wildlife Refuge and John Krause of CDFW for logistical support at the Refuge and Eden Landing, respectively. We thank former SFBBO former Plover Program Director Karine Tokatlian, SFBBO biologist Cole Jower, SFBBO intern Lani Renshaw, and SFBBO support staff Alex Rinkert and Kelly Overduijn. We also thank our dedicated volunteers, Diane and Tom Bennett, Bill and Tanya Hoppes, Richard Jeffers, Mike Mammoser, and Mike Rogers for conducting plover surveys. Karen Taylor of CDFW, Ann Graham of HARD and David Riensche of EBRPD, Anne Wallace of EcoBridges Environmental Consulting, and Jules Evens of Avocet Research Associates for contributing information about plover nesting activity in Napa Sonoma Marsh Wildlife Area, Hayward Shoreline, Montezuma Wetlands Restoration area and Hamilton Wetland Restoration area, respectively.

**REFERENCES**

Avery, M. L., M.A. Pavelka, D.L. Bergman, D.G. Decker, C.E. Knittle, and G.M. Linz. 1995. Aversive conditioning to reduce raven predation on California Least Tern eggs. Colonial Waterbirds 18:131–138

Colwell, M.A., J.J. Meyer, M.A. Hardy, S.E. McAllister, A.N. Transou, R.R. Levalley, and S.J. Dinsmore. (2011). Western Snowy Plovers Charadrius alexandrinus nivosus select nesting substrates that enhance egg crypsis and improve nest survival Ibis 153: 303-311

Demers, S. A. and C. W. Robinson-Nilsen. 2012. Monitoring Western Snowy Plover nests with remote surveillance systems in the San Francisco Bay, California. Journal of Fish and Wildlife Management 3: 123-132.

Donehower, C., Tokatlian, K., and C. Robinson-Nilsen. 2012. Western Snowy Plover Monitoring in the San Francisco Bay: Annual Report 2012. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Frost, N. 2015. California least tern breeding survey, 2014 season. California Department of Fish and Wildlife, Wildlife Branch, Nongame Wildlife Program Report, 2015-01. Sacramento, CA. 23 pp + Appendices.

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. U.S. Fish and Wildlife Service. Catalog No: 1522.

Gabriel, P. O. and R.T. Golightly. 2014. Aversive conditioning of Steller's jays to improve marbled murrelet nest survival. The Journal of Wildlife Management 78, 894–903. doi:10.1002/jwmg.725

Gallagher, A.J. 2016. Coexisting with sharks: a response to Carter and Linnell. Trends Ecol. Evol., 31(11), 817-818.

Hartman, C.A., J.T., Ackerman, M.P., Herzog, C., Strong, D., Trachtenbarg, , K.A., Sawyer, and C.A. Shore. 2016. Evaluation of Caspian tern (Hydroprogne caspia) and snowy plover (Charadrius alexandrinus nivosus) nesting on modified islands at the Don Edwards San Francisco Bay National Wildlife Refuge, California—2015 Annual Report: U.S. Geological Survey Open-File Report 2016-1049, 36 p., http//dx.doi.org/10.3133/ofr20161049.

Hays, H. and M. LeCroy. 1971. Field criteria for determining incubation stage for the Common Tern. Wilson Bulletin 83: 425-429.

Hartman, C.A., J.T. Ackerman, M.P. Herzog, C. Strong, D. Trachtenbarg, and C.A. Shore. 2017. Evaluation of Caspian tern (Hydroprogne caspia) and snowy plover (Charadrius alexandrinus nivosus) nesting on modified islands at the Don Edwards San Francisco Bay National Wildlife Refuge, California—2016 Annual Report: U.S. Geological Survey Open-File Report 2017-1055, 37 p., https://doi.org/10.3133/ofr20171055.

Jenks-Jay, N. 1982. Chick shelters decrease avian predation in Least Tern colonies on Nantucket Island, Massachusetts. Journal of Field Ornithology 53:58–60.

Lafferty, K.D., D. Goodman, and C.P. Sandoval. 2006. Restoration of breeding by snowy plovers following protection from disturbance. Biodiversity & Conservation 15(7): 2217-2230.

Laake, J.L. 2013. RMark: an R interface for analysis of capture-recapture data with MARK. *Alaska Fish Sci. Cent.* Processed Rep. 2013-01, p. 25

Mabee, T. J. 1997. Using eggshell fragments to determine nest fate of shorebirds. Wilson Bulletin 109: 307-313.

Mayfield, H. R. 1975. Suggestions for calculating nest success. Wilson Bulletin 87: 456-466.

Olsen, P. D. and J. Olsen. 1988. Breeding of the peregrine falcon (Falco peregrinus): I. weather, nest spacing and territory occupancy. Emu 88:195–201.

Page, G. L.E. Stenzel, J.S. Warriner, J.C. Warriner, and P.W. Paton. 2009. Snowy Plover (*Charadrius alexandrinus*), The Birds of North America Online (A. Poole, ed.). Ithaca: Cornell Lab of Ornithology

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: 245-255.

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. Auk 100: 13-24.

Pearl., B., K. Tokatlian, and J. Scullen. 2015. Western Snowy Plover Monitoring in the San Francisco Bay Annual Report 2015. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Powell A.N., 2001. Habitat characteristics and nest success of snowy plovers associated with California Least Tern colonies. Condor 103: 785–792.

Robinson, C. 2008. Western Snowy Plover use of managed salt ponds at Eden Landing, Hayward, CA. M.S. thesis. San Jose State University, San Jose, CA.

Robinson, C. and D. Le Fer. 2007. Western Snowy Plover Numbers, Nesting Success, and Avian Predator Surveys in the San Francisco Bay, 2007. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Robinson, C. and J. Demers. 2008. Western Snowy Plover Numbers, Nesting Success, Fledging Success, and Avian Predator Surveys in the San Francisco Bay, 2008. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Robinson-Nilsen, C. and J. Demers. 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.

Robinson-Nilsen, C. and J.B. Demers. 2010. 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. and J.B. Demers. 2011. Western Snowy Plover Numbers, Nesting Success, Fledging Success and Avian Predator Surveys in the San Francisco Bay, 2011. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Robinson-Nilsen, C. and J.B. Demers. 2012. California Gull breeding surveys and hazing project, 2011. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Robinson-Nilsen., C., K. Tokatlian, J. Scullen, and C. Burns. 2013. Western Snowy Plover Monitoring in the San Francisco Bay Annual Report 2013. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Ruhlen, T. D., S. Abbott, L.E., Stenzel, and G.W. Page 2003. Evidence that human disturbance reduces Snowy Plover chick survival. Journal of Field Ornithology 74(3): 300-304.

Strong, C. and S. Michishita. 2017. Avian predator nest removal, Spring 2017. Unpublished report. Don Edwards San Francisco Bay National Wildlife Refuge, USFWS.

Strong, C. M., N. Wilson, and J. D. Albertson. 2004. Western Snowy Plover numbers, nesting success and avian predator surveys in the San Francisco Bay, 2004. Unpublished report. San Francisco Bay Bird Observatory, Alviso, CA.

Tarjan, M. and K. Butler. 2017. Citizen Science-Based Colonial Waterbird Monitoring 2017 Nesting Summary. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Tarjan, M.. and V. Heyse. In Prep. Nuisance Species Abatement Plan 2016 Annual Report Newby Island Landfill & Recyclery. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Tarjan, M.. and V. Heyse. 2017. South Bay Salt Pond Waterbird Surveys September 2016-August 2017. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Tokatlian, K. 2017. Evaluation of Oyster Shell Enhancement on Western Snowy Plover Breeding Success. Unpublished Master's thesis. San Jose State University, San Jose, CA.

Tokatlian, K., Scullen, J., and C. Burns. 2014. Western Snowy Plover Monitoring in the San Francisco Bay Annual Report 2014. Unpublished report. San Francisco Bay Bird Observatory, Milpitas, CA.

Trulio, L., C. Robinson-Nilsen, J. Sokale and K. D. Lafferty. 2012. Report on Nesting Snowy Plover Response to New Trail Use in the South Bay Salt Pond Restoration Project. Unpublished report.

U.S. Fish and Wildlife Service. 1993. Endangered and threatened wildlife and plants; determination of threatened status for the Pacific Coast population of the Western Snowy Plover, final rule. Federal Register 58: 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, CA. xiv + 751 pp. Western Snowy Plover (*Charadrius alexandrinus nivosus*) Pacific Coast population draft recovery plan. Portland, OR. xix + 630 pp.

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 Caldwall, and Geomatrix. Available: http://www.southbayrestoration.org/EIR/downloads.html.

Warriner, J. S., J. C. Warriner, G. W. Page, and L. E. Stenzel. 1986. Mating system and

reproductive success of a small population of polygamous Snowy Plovers. Wilson Bulletin 98: 15-37.

XCLA Acetal Leg Bands I/D 3.1mm. (n.d.). Retrieved December 30, 2015, from https://www.avinet.com/en/bands/xcla-acetal-leg-bands-id-31mm

XCLA Darvic Leg Bands I/D 3.1mm. (n.d.). Retrieved December 30, 2015, from https://www.avinet.com/en/bands/xcla-darvic-leg-bands-id-31mm

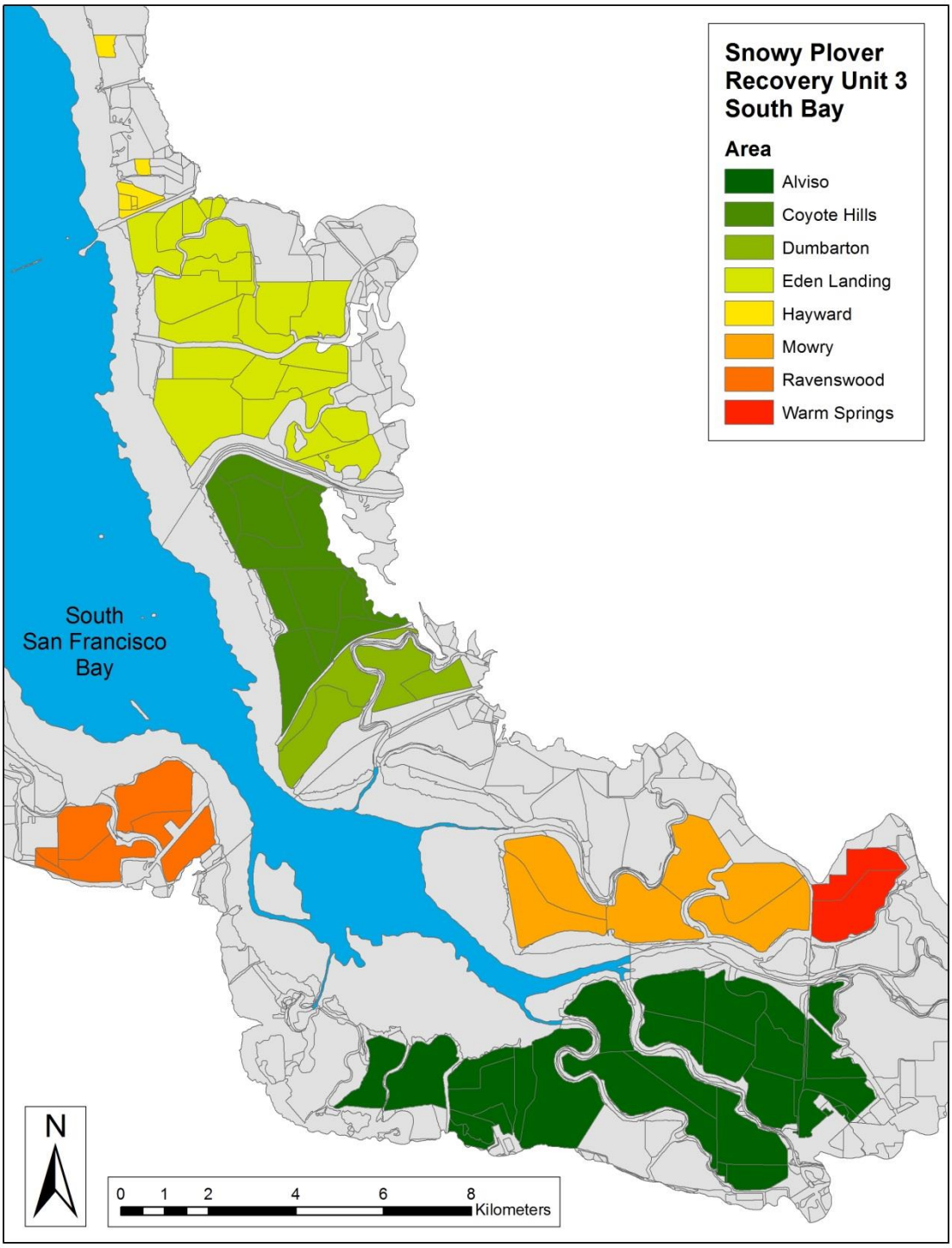


**Figure 1**. The Don Edwards San Francisco Bay National Wildlife Refuge (USFWS), CDFW's Eden Landing Ecological Reserve, East Bay Regional Park District and Hayward Area Recreation and Park District lands in the South San Francisco Bay, California.

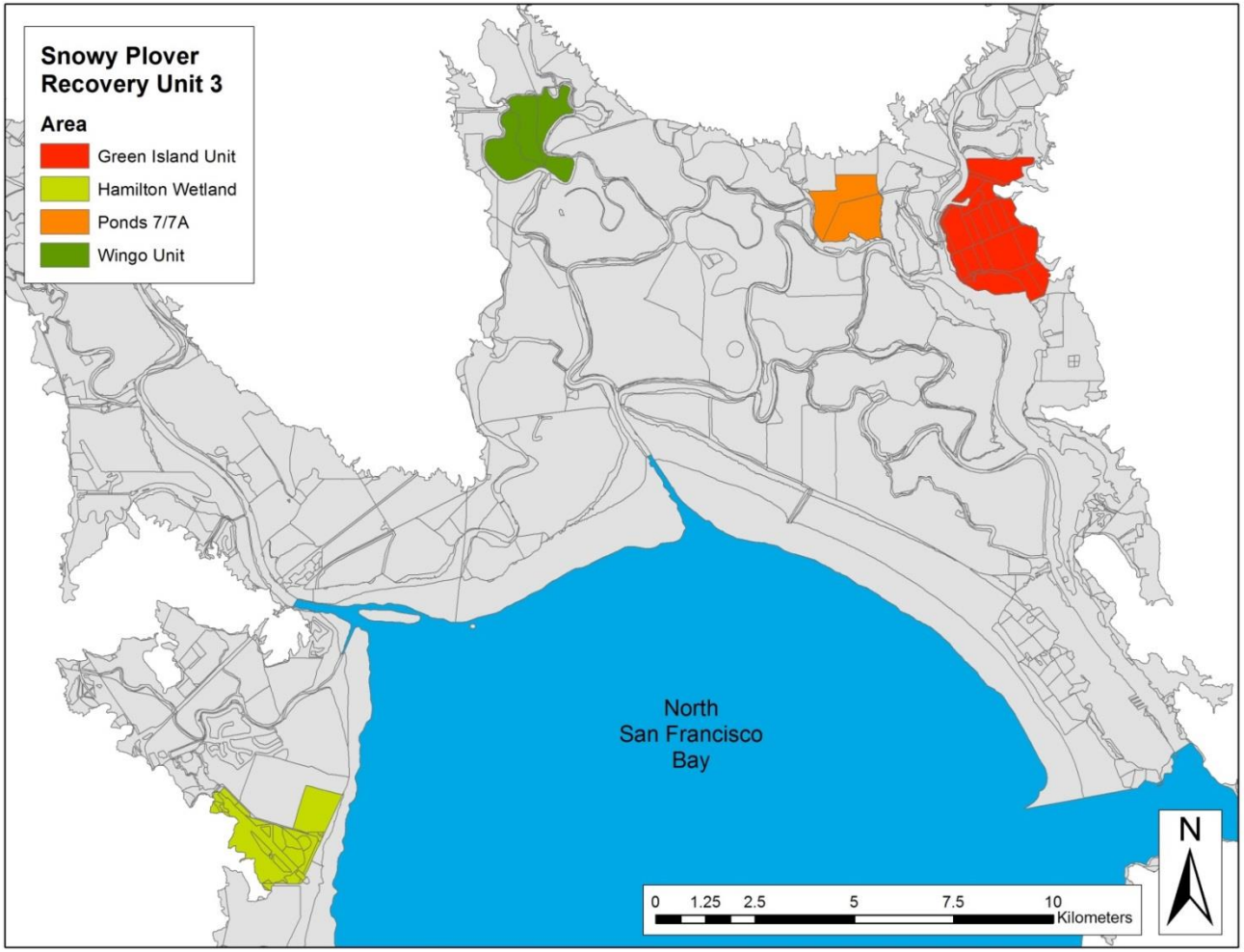


**Figure 2**. Snowy Plover nesting areas in the CDFW's Napa-Sonoma Marshes Wildlife Area: the Wingo Unit, ponds 7/7a, and the nesting islands at the Green Island Unit (formerly called the Napa Plant Site), North San Francisco Bay, California.

*SFBBO Snowy Plover Report 2017*


A22
A23
N
0 0.1 0.2 0.4 0.6 0.8
Kilometers
Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics,
Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP,
swisstopo, and the GIS User Community

**Figure 3**. Ponds located in the Refuge's Warm Springs area, near Fremont, South San Francisco Bay, California. See **Error! Reference source not found.**1 for location of Warm Springs within South San Francisco Bay.


**Figure 4**. Ponds in the Refuge's Alviso Complex, including Mountain View, at the southern end of the South San Francisco Bay, California. See **Error! Reference source not found.**1 for location of Alviso within South San Francisco Bay.


**Figure 5**. Ponds in the Refuge's Ravenswood Complex, at the west end of the Dumbarton Bridge, South San Francisco Bay, California. See **Error! Reference source not found.** for location of Ravenswood within South San Francisco Bay.


**Figure 6.** Ponds in the CDFW's Eden Landing Ecological Reserve, near Hayward, South San Francisco Bay, California. See **Error! Reference source not found.**1 for location of Eden Landing Ecological Reserve within South San Francisco Bay.


**Figure 7**. Ponds in the Refuge's Dumbarton Complex, at the east end of the Dumbarton Bridge, South San Francisco Bay, California. See **Error! Reference source not found.**1 for location of Dumbarton within South San Francisco Bay.

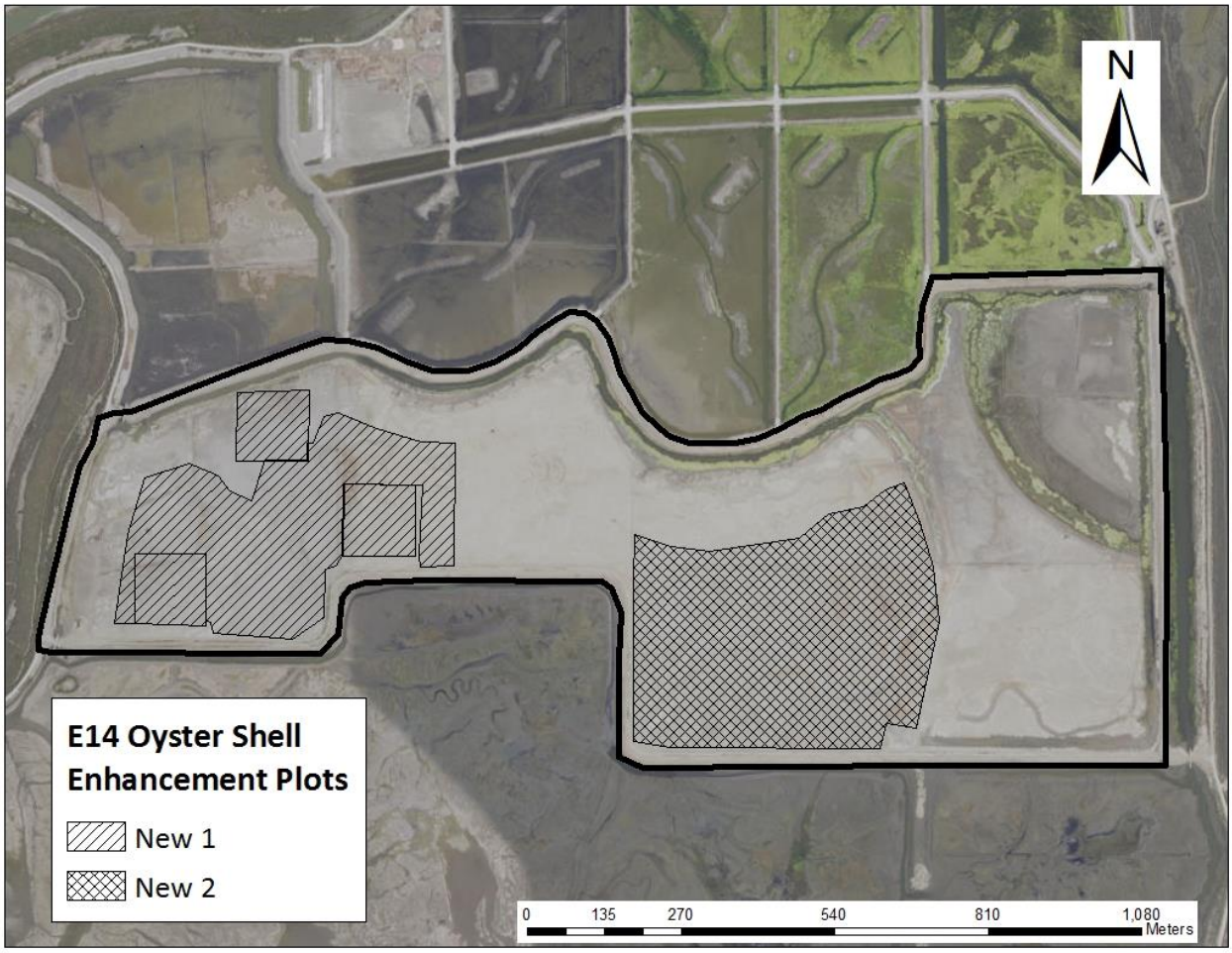


**Figure 8.** Large scale oyster shell enhancement plots spread in 2014 in pond E14, Eden Landing Ecological Reserve, Hayward, California. The three western squares represent the old, 1-ha pilot oyster shell plots spread in 2009; they are combined with the western large scale plot to form New 1 for the purposes of this report. All other areas of E14 are termed Control for this report.

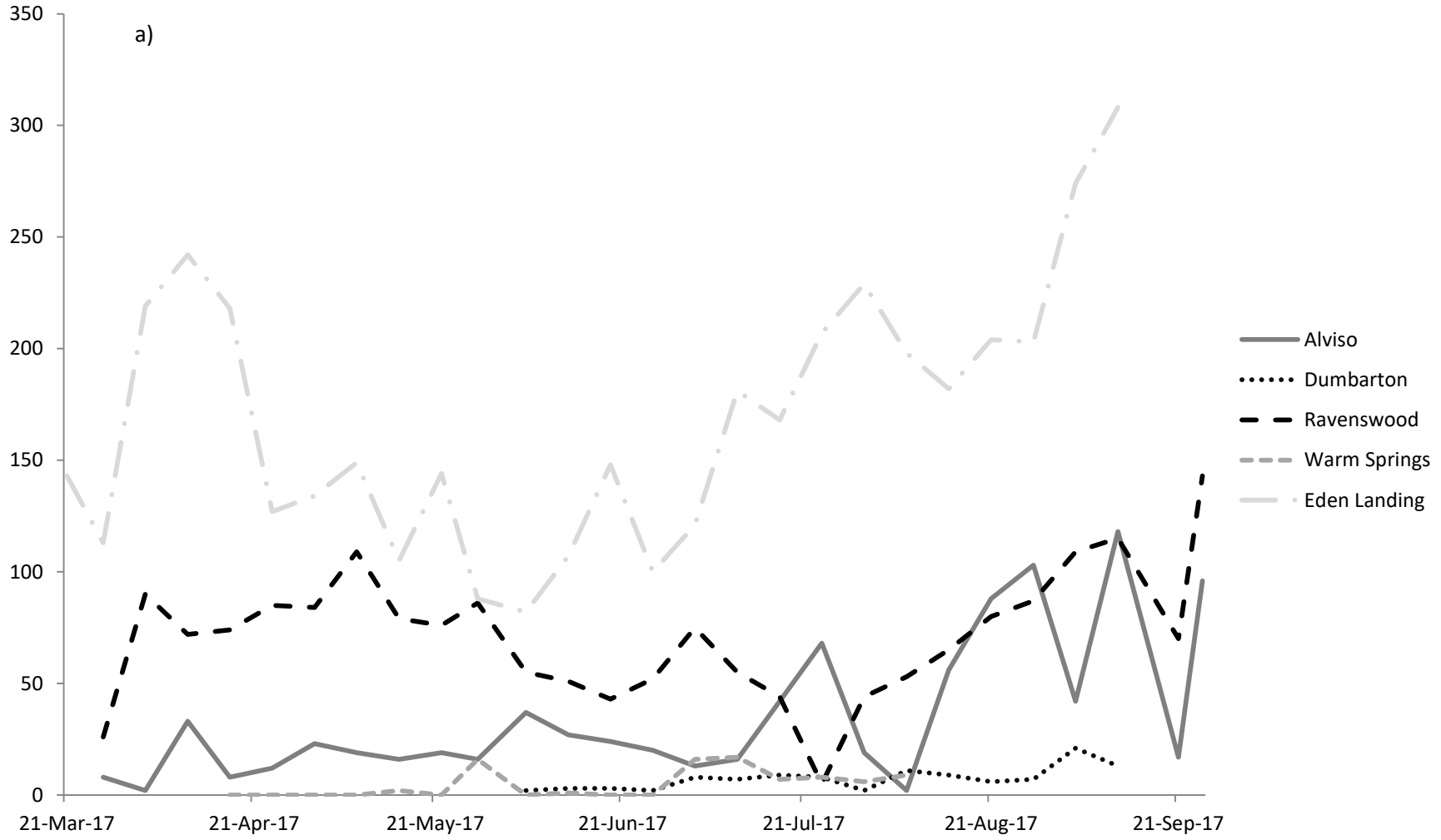


**Figure 9a.** Weekly counts of adult Snowy Plovers by week and area, San Francisco Bay, California, 2017. Data are presented here for all locations monitored where plovers were observed. Note the high number of Snowy Plovers observed in April and September are presumed to be migrating and not breeding in the San Francisco Bay.

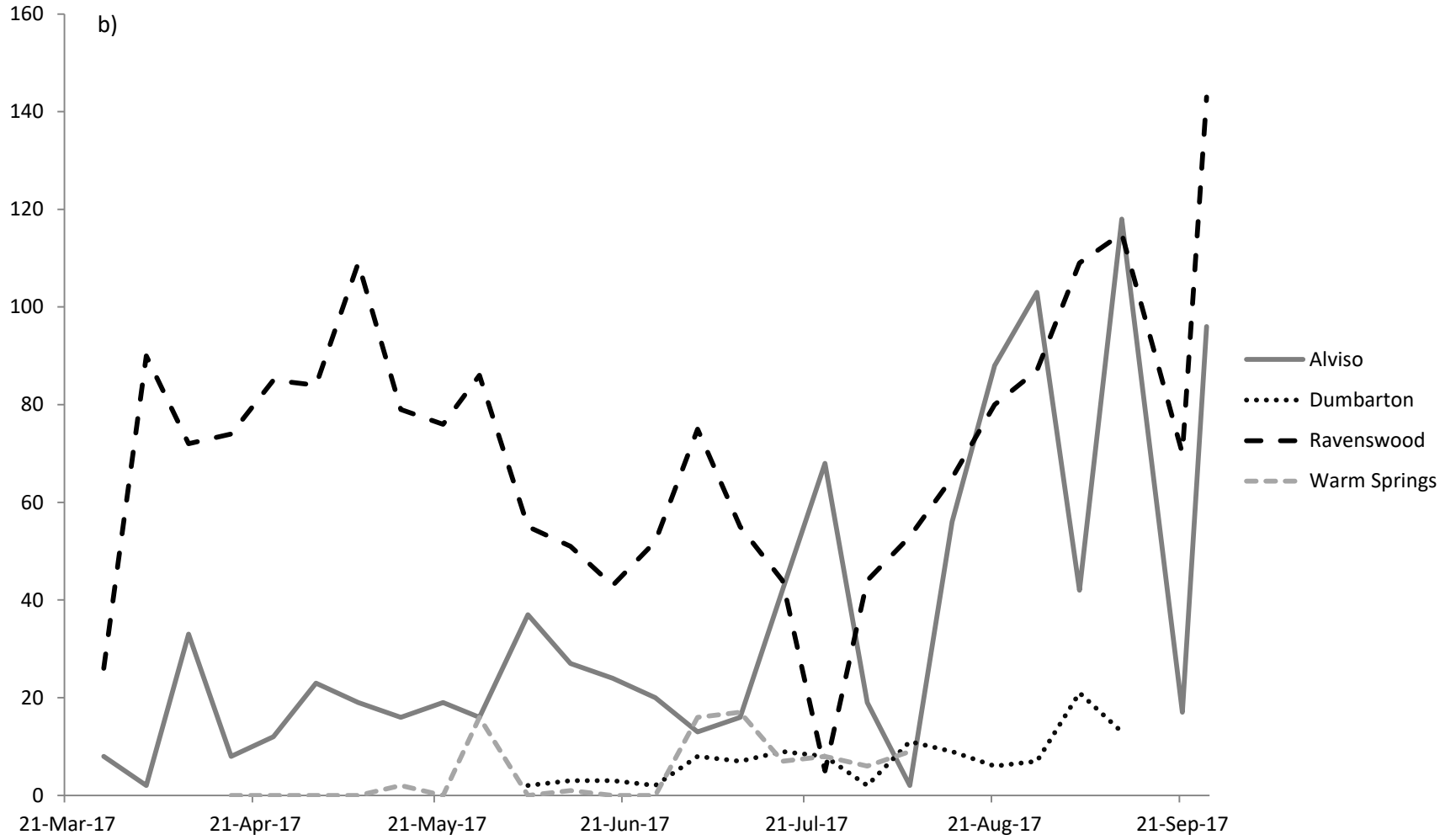


Figure 9b. Counts of adult Snowy Plovers by week and area, San Francisco Bay, California, 2017. To facilitate interpretation, data are presented for all locations monitored excluding Eden Landing. Note the high number of Snowy Plovers observed in April and September are presumed to be migrating and not breeding in the San Francisco Bay.

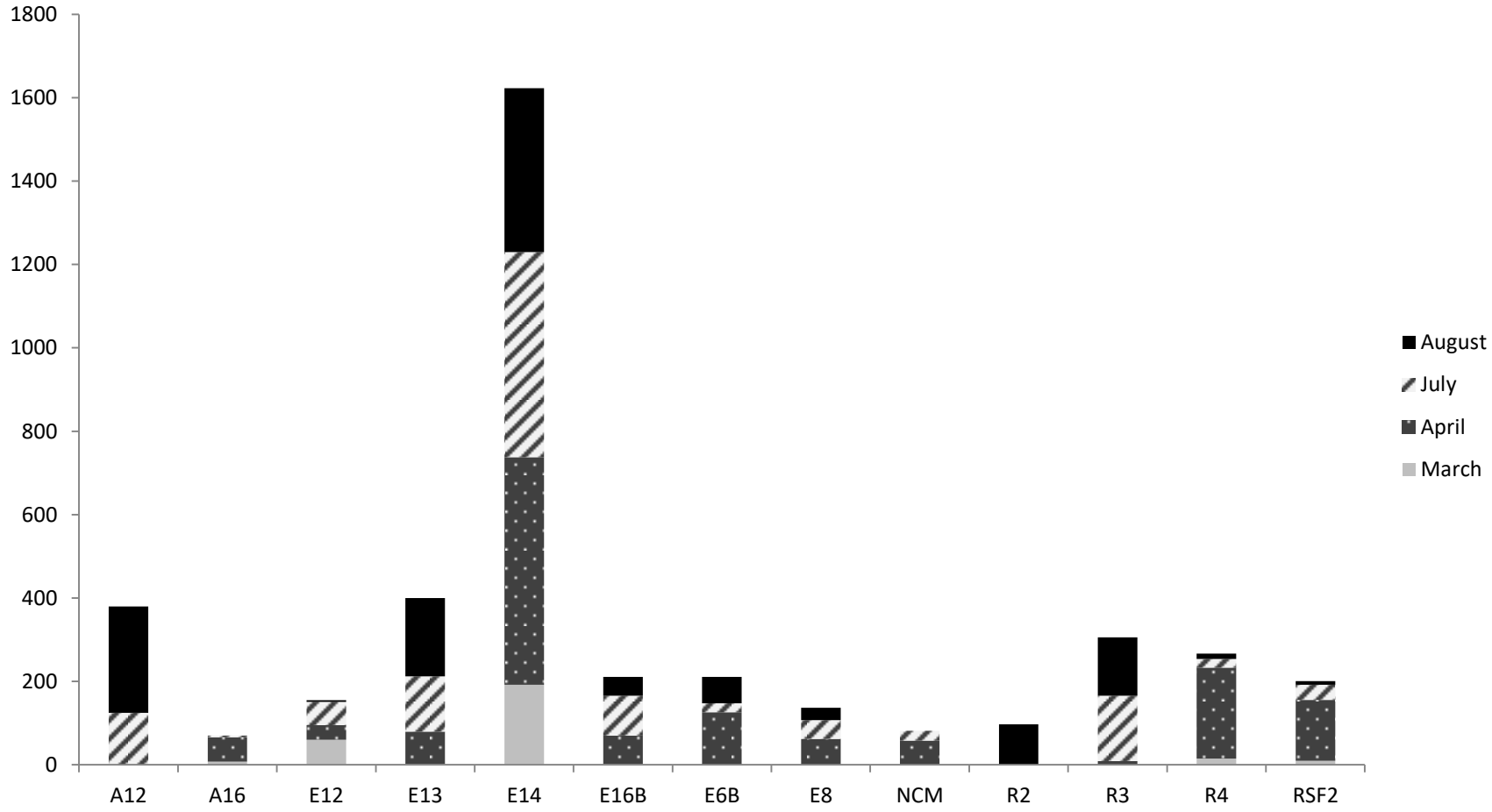


**Figure 10.** Abundance of adult plovers at significant ponds during March, April, July and August, 2017. The purpose of this figure is to show that ponds are used by plovers in varying intensity during the beginning and end of the breeding season.

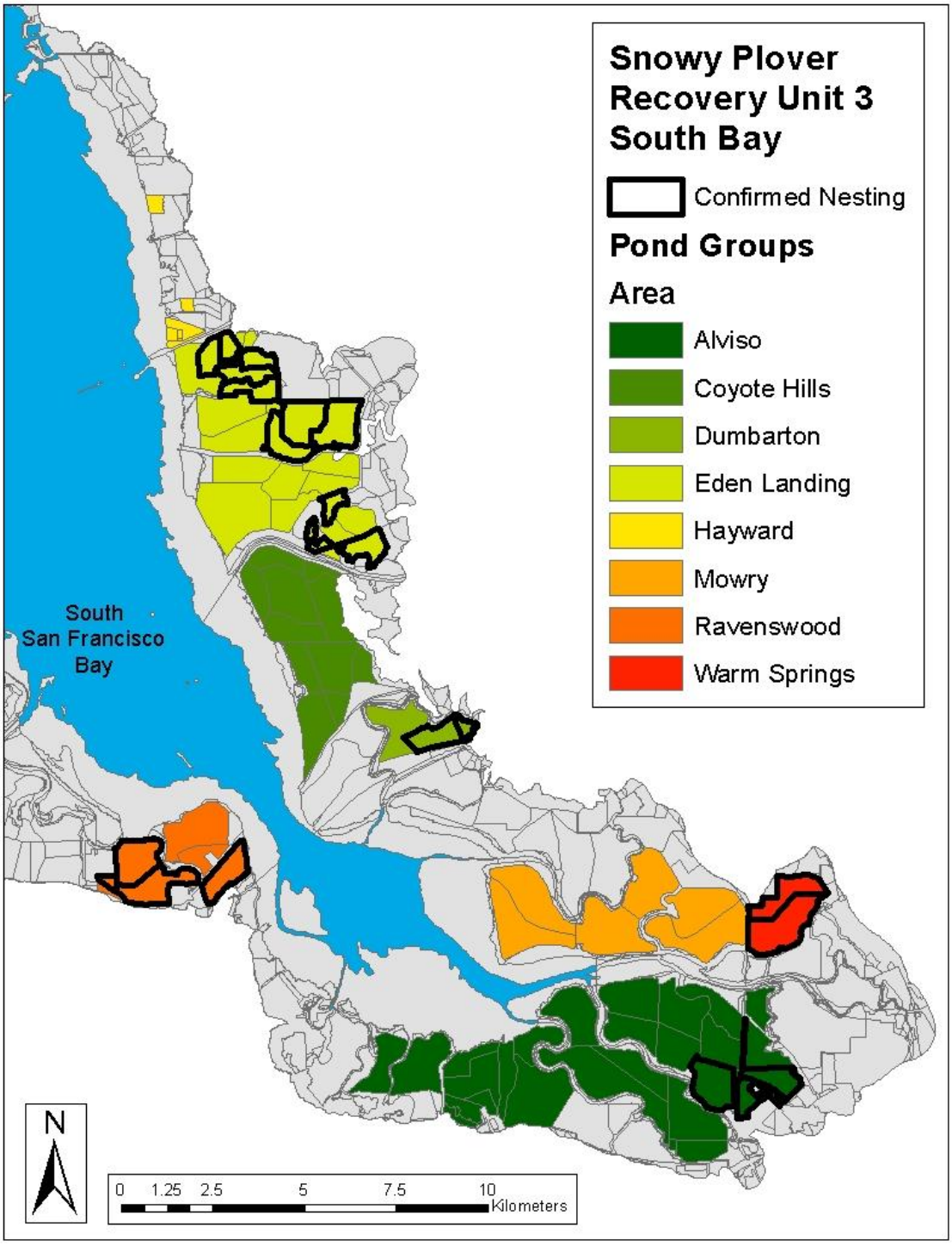


**Figure 11**. Areas (black outline) with documented Snowy Plover nesting activity during the 2017 breeding season, South San Francisco Bay, California.

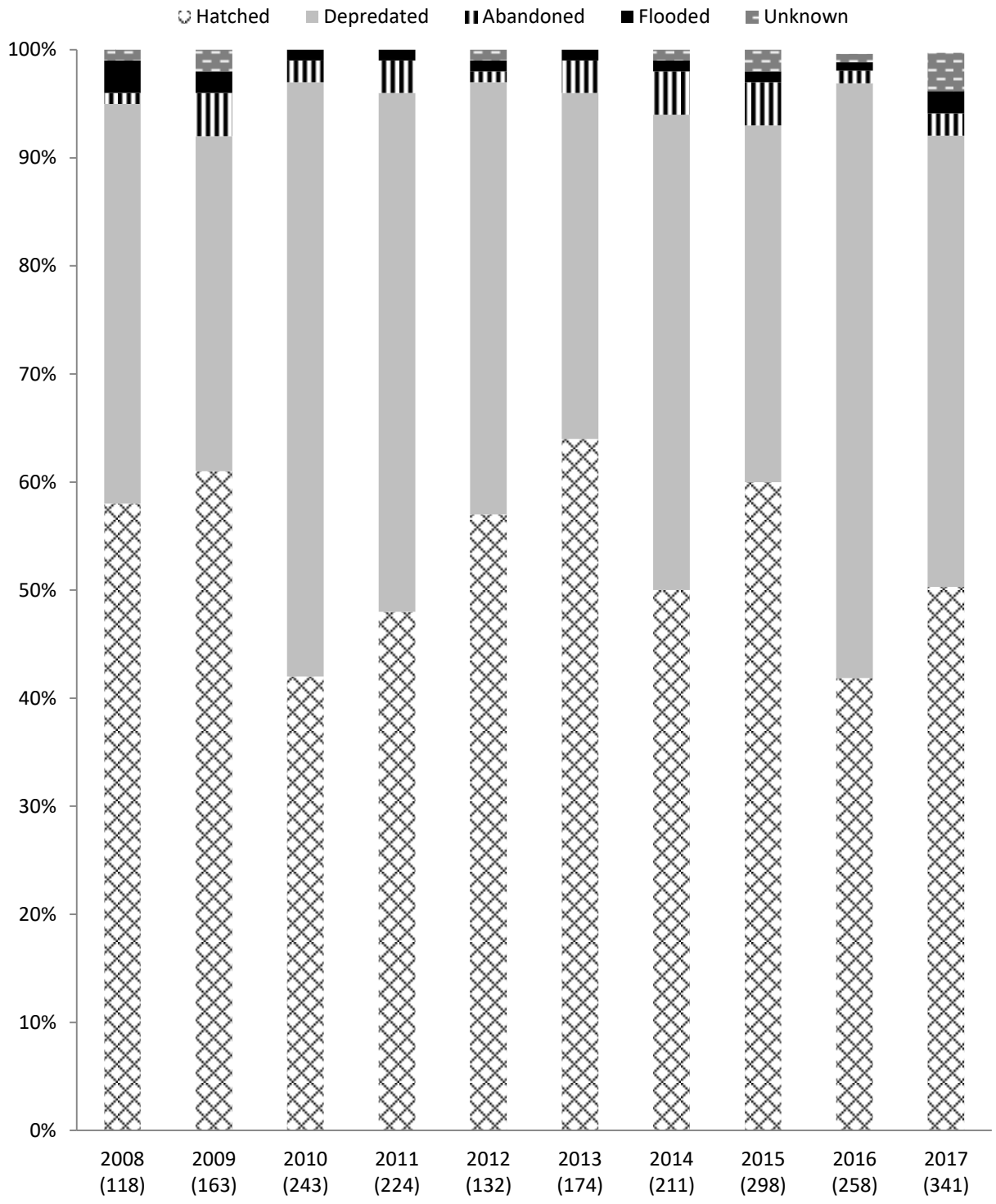


**Figure 12.** Annual apparent Snowy Plover nest fates in the South San Francisco Bay, California, 2008-2017. The number of nests monitored is indicated in parentheses beneath the year.

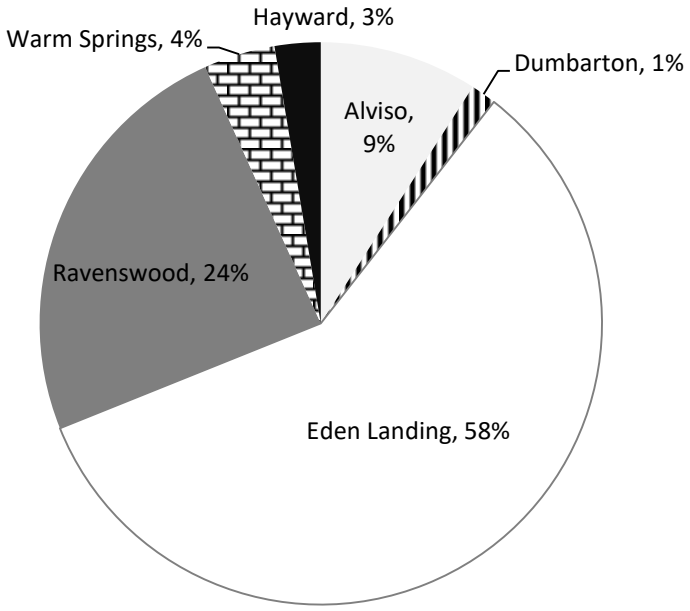


**Figure 13**. The proportion of Snowy Plover nests found in each pond complex in the South San Francisco Bay, California, 2017.
*Percentages rounded to nearest whole number, resulting in <100%

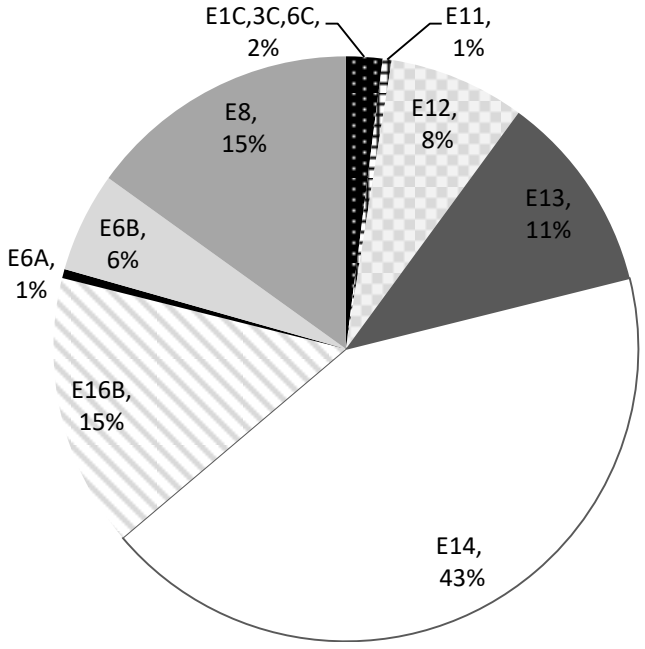


**Figure 14**. The proportion of Snowy Plover nests found in each Eden Landing pond within the Eden Landing Ecological Reserve in Hayward, California, 2016. Note that 43% of Eden Landing nests were found in pond E14.
*Percentages rounded to nearest whole number, resulting in >100%

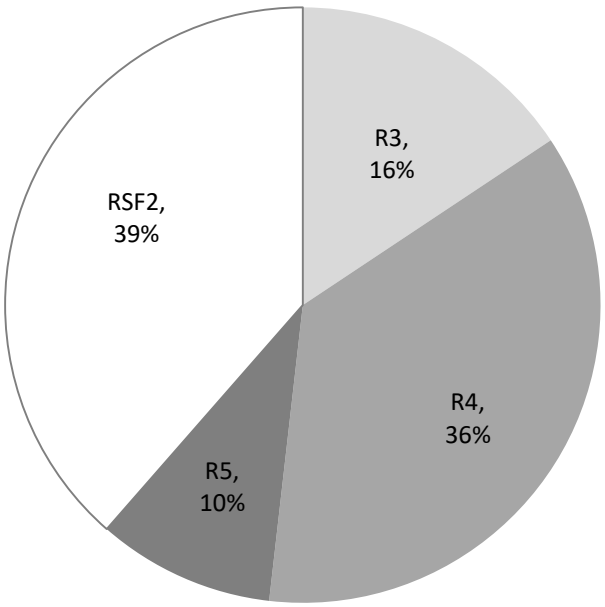


**Figure 15**. The proportion of Snowy Plover nests found in each Ravenswood pond within the Ravenswood Complex, Menlo Park, California, 2017.
*Percentages rounded to nearest whole number, resulting in >100%

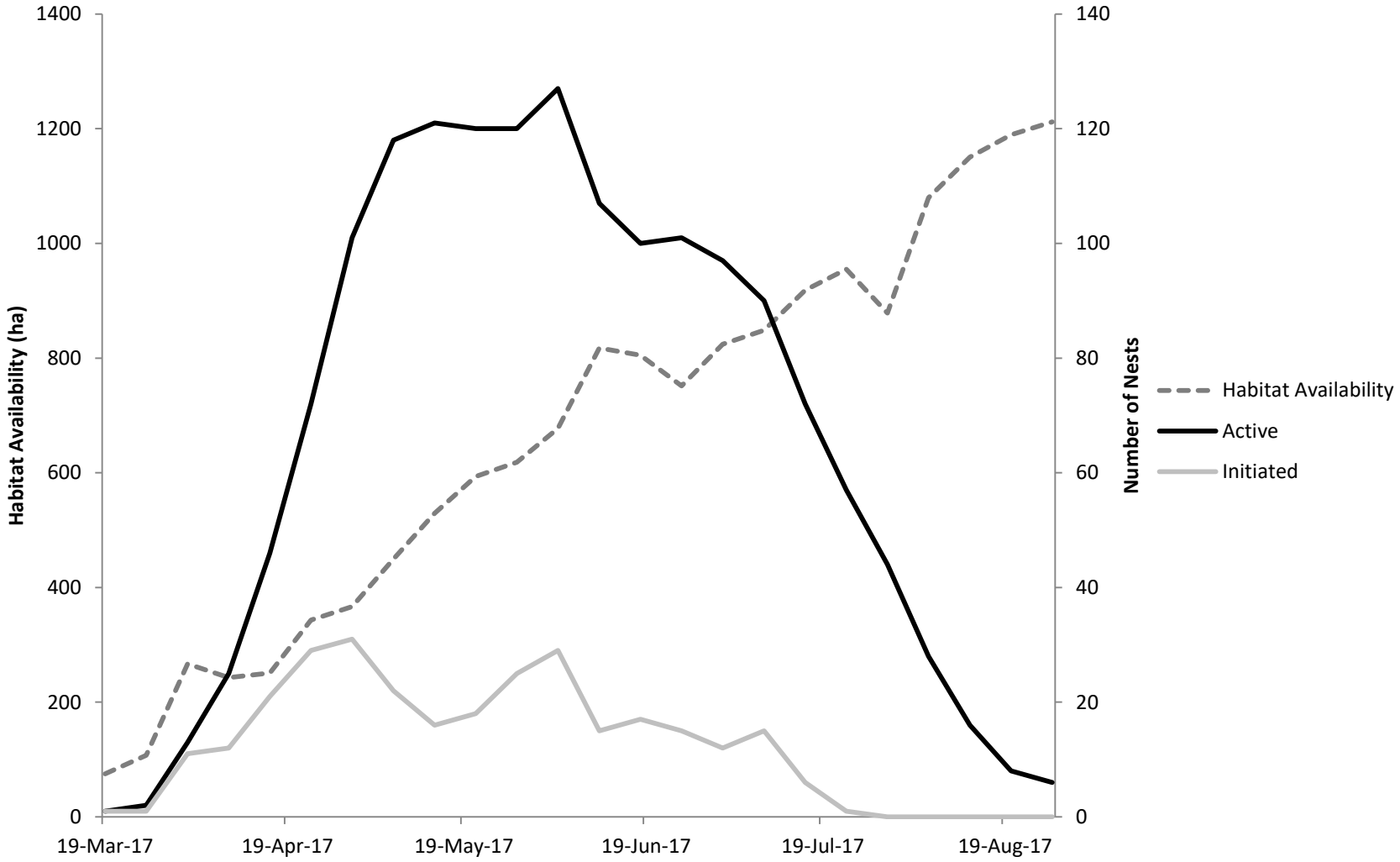


**Figure 16**. The weekly number of initiated and active Snowy Plover nests and estimated habitat availability in the South San Francisco Bay, California, 2017.
Note: Surveys of R1 and R2 began on the week of August 6

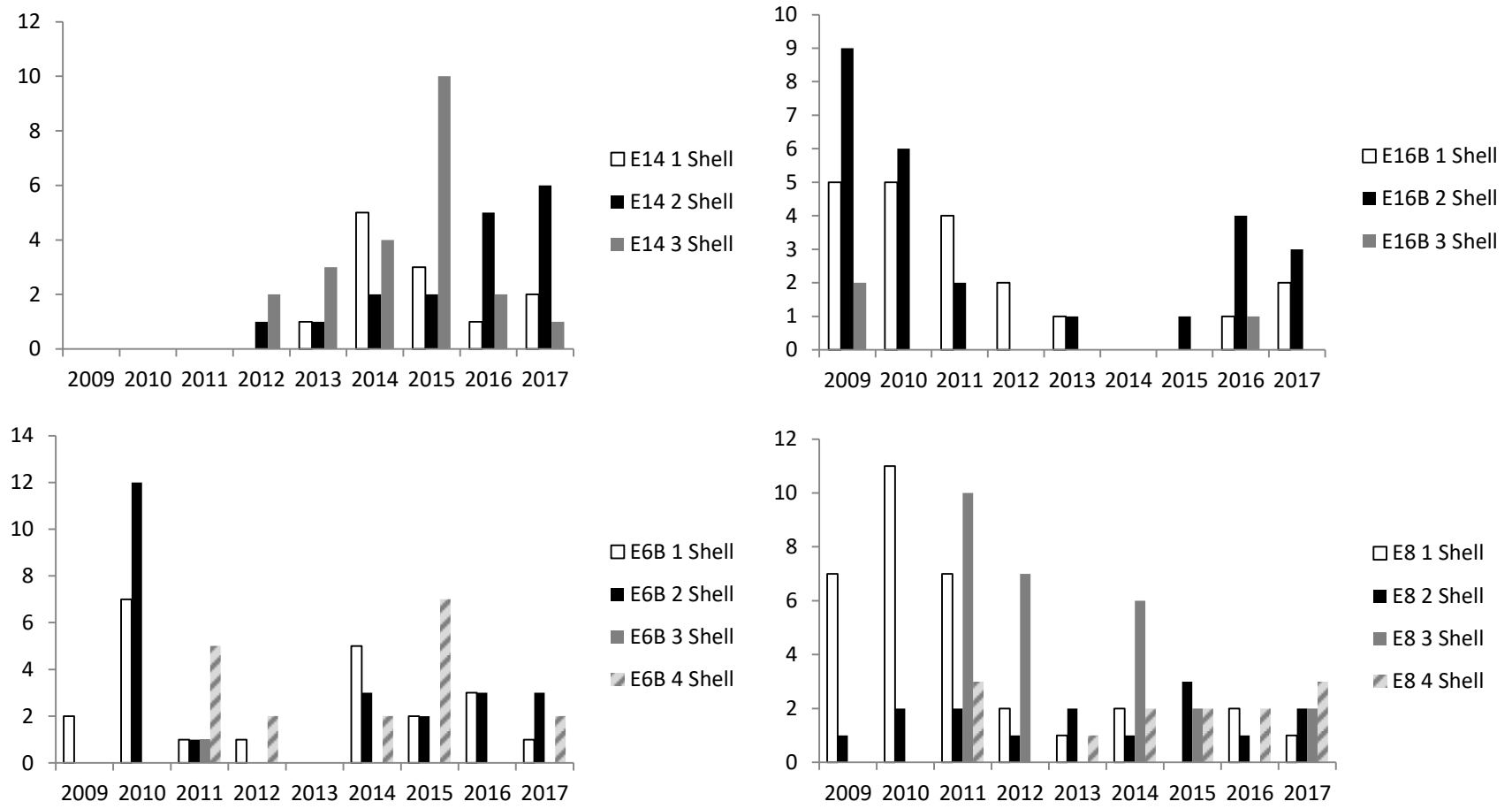


**Figure 17**. The number of Snowy Plover nests in each shell plot at Eden Landing Ecological Reserve, South San Francisco Bay, California, 2009-2017. Miniscule numbers were used to represent "0" nest values versus "null" values on each graph in order to signify years in which plots were not yet established. Shell plots considered to be in good condition are E6A-1, E16B-1 and 3, E6B-1 and 4, and E8-1 and 3. Shell plots considered to be in poor condition are E16B-2, E6B-2 and 3, and E8-2 and 4. Note that E14 shell plots are surrounded by a new large shell plot, and thus no longer serve the same function since 2015.

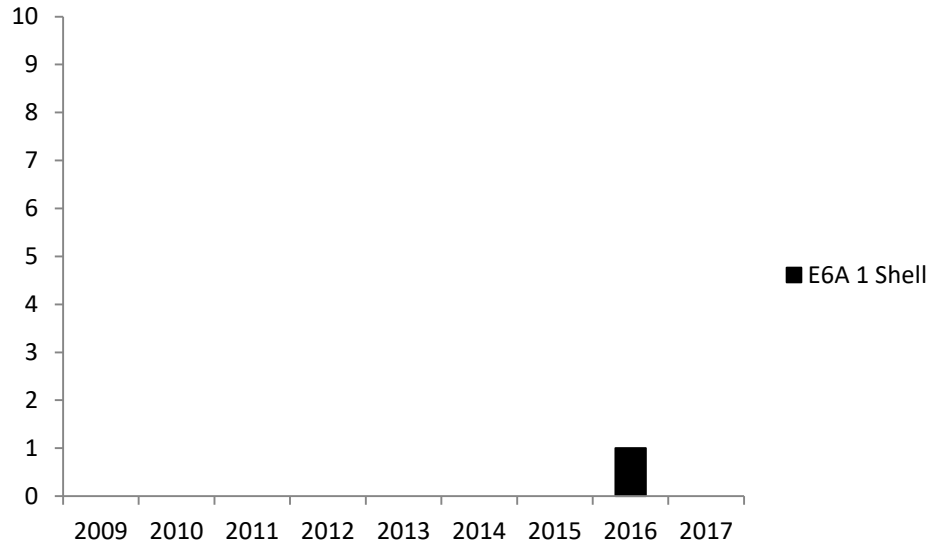


Figure 17 (ctd). The number of Snowy Plover nests in each shell plot at Eden Landing Ecological Reserve, South San Francisco Bay, California, 2009-2017. Miniscule numbers were used to represent "0" nest values versus "null" values on each graph in order to signify years in which plots were not yet established. Shell plots considered to be in good condition are E6A-1, E16B-1 and 3, E6B-1 and 4, and E8-1 and 3. Shell plots considered to be in poor condition are E16B-2, E6B-2 and 3, and E8-2 and 4. Note that E14 shell plots are surrounded by a new large shell plot, and thus no longer serve the same function since 2015.

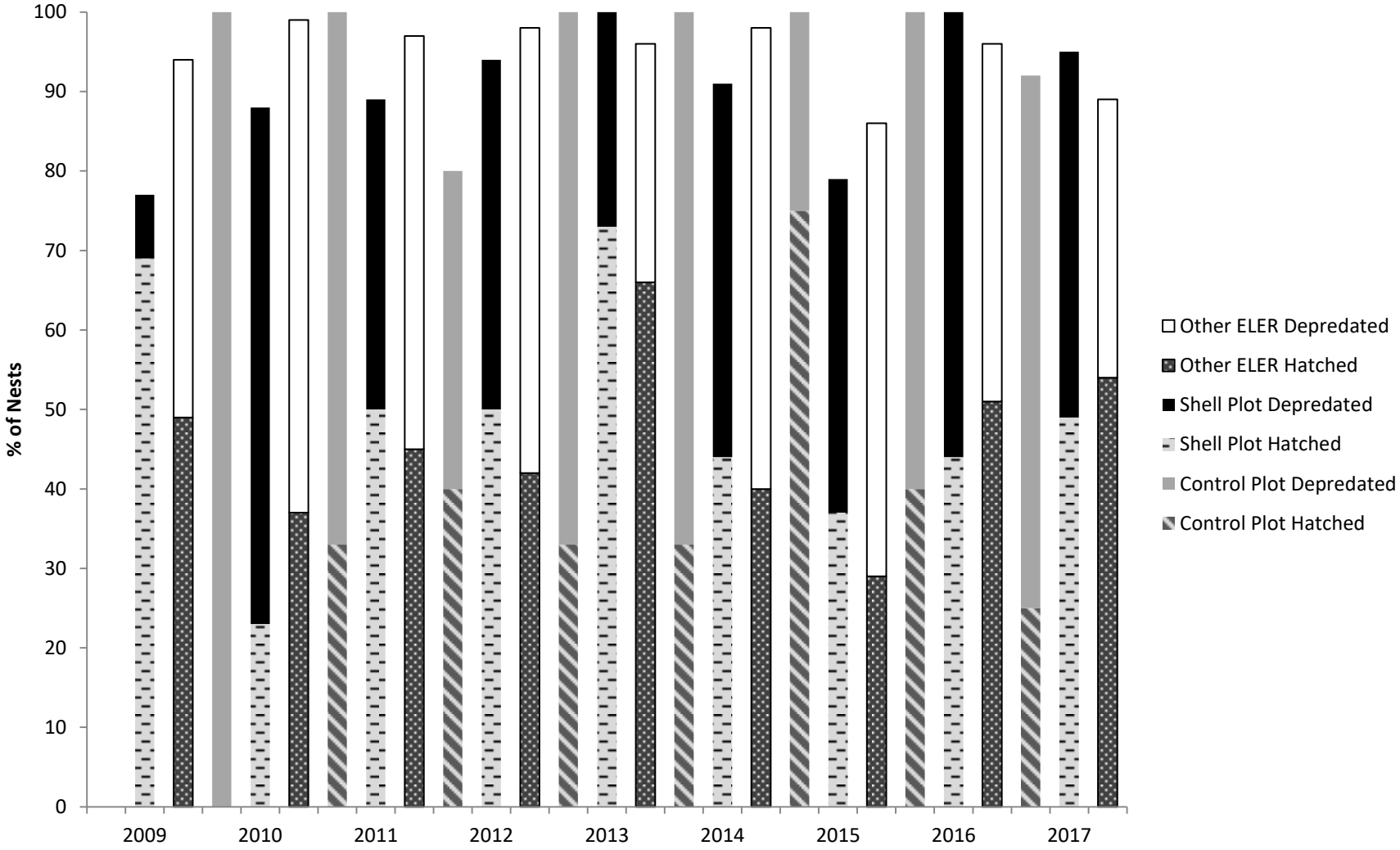


**Figure 18.** The fate of nests in shell plots, control plots, and all other areas of Eden Landing Ecological Reserve. In some instances the fate of nests was unknown, resulting in a number less than 100%.

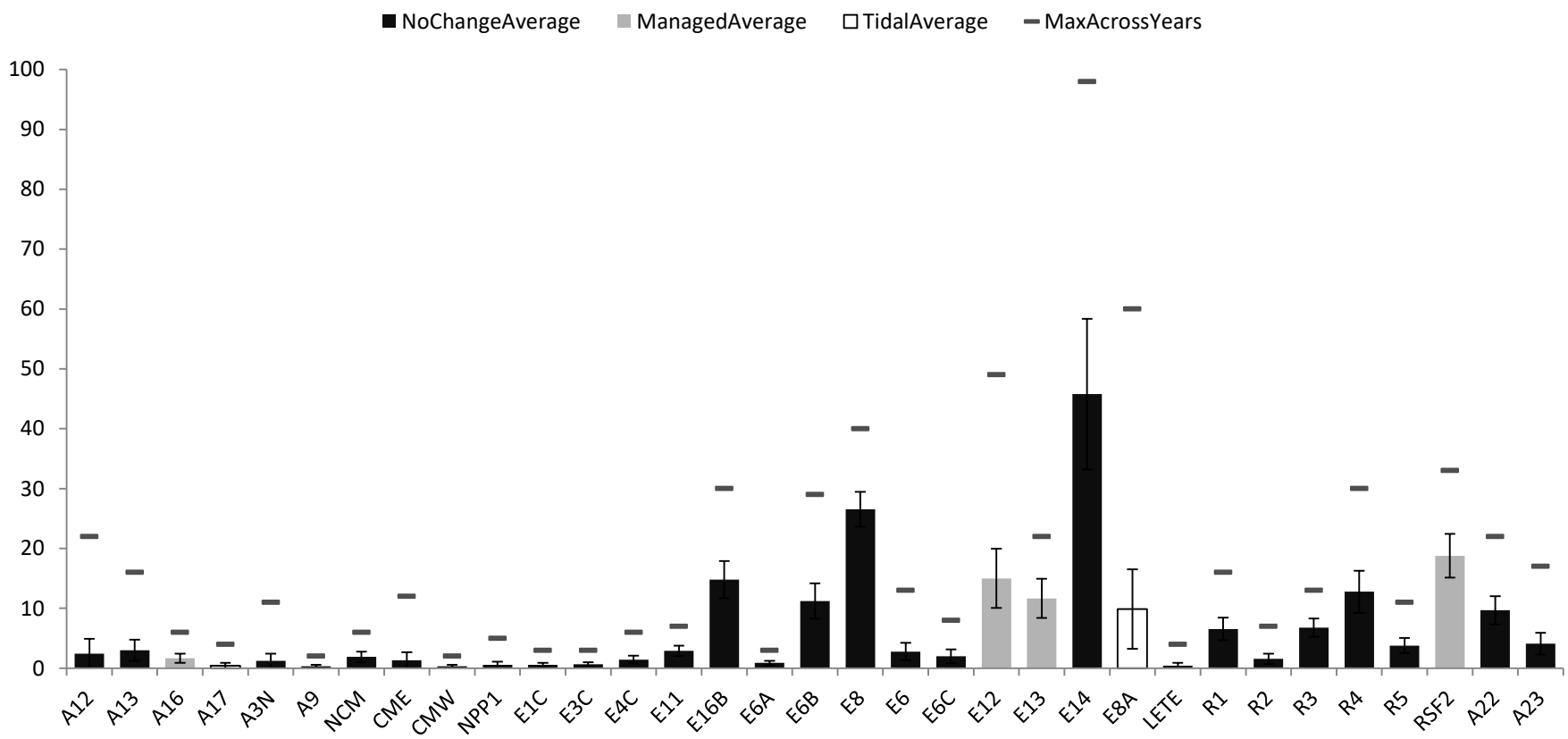


**Figure 19**. Average number of Snowy Plover nests initiated by pond in South San Francisco Bay, California from 2009-2017. Data are shown as mean + 1SD. The purpose of this figure is to illustrate which ponds have supported Snowy Plover nesting activity in recent years, and of these, which ponds are included in Phase 1 restoration plans of the South Bay Salt Pond Restoration Project. White bars denote ponds that have been returned to tidal influence, gray bars denote ponds that are (or will be) managed for multiple species (at higher water levels) and the amount of habitat available to Snowy Plovers will be reduced, black bars denote ponds that will not be directly affected by Phase 1 actions, and black dashes denote the maximum number of nests at each pond across all years. Note that "NCM" = New Chicago Marsh and "LETE" = Hayward Least Tern Island; refer to Figs. 3-6 for other pond names and locations.

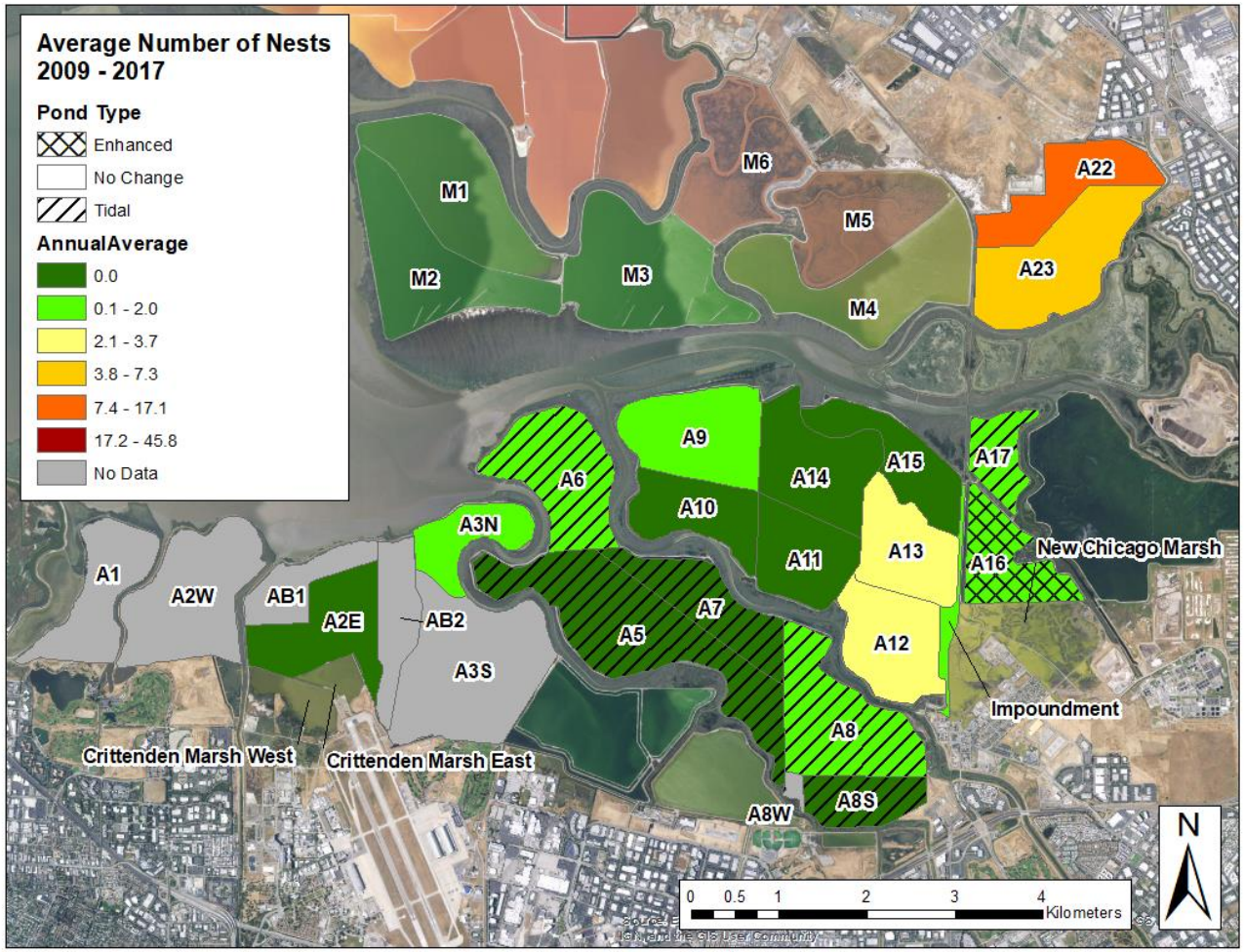


**Figure 20.** Average number of Snowy Plover nests initiated by pond in the Alviso Complex, South San Francisco Bay, California from 2009-2017. The purpose of this figure is to illustrate which ponds have supported Snowy Plover nesting activity in recent years, and of these, which ponds are included in Phase 1 restoration plans of the South Bay Salt Pond Restoration Project. Diagonal lines denote ponds that have been returned to tidal (or muted tidal) influence, hatch lines denote ponds that are (or will be) enhanced for multiple species and the amount of habitat available to Snowy Plovers may be reduced (not A16), and solid colors denote ponds that will not be directly affected by Phase 1 actions. The gradient shading denotes the average number of plover nests on the pond. Note that Snowy Plovers did not start nesting on ponds A16 and A17 until they were drained for construction; they were not historically nesting ponds.

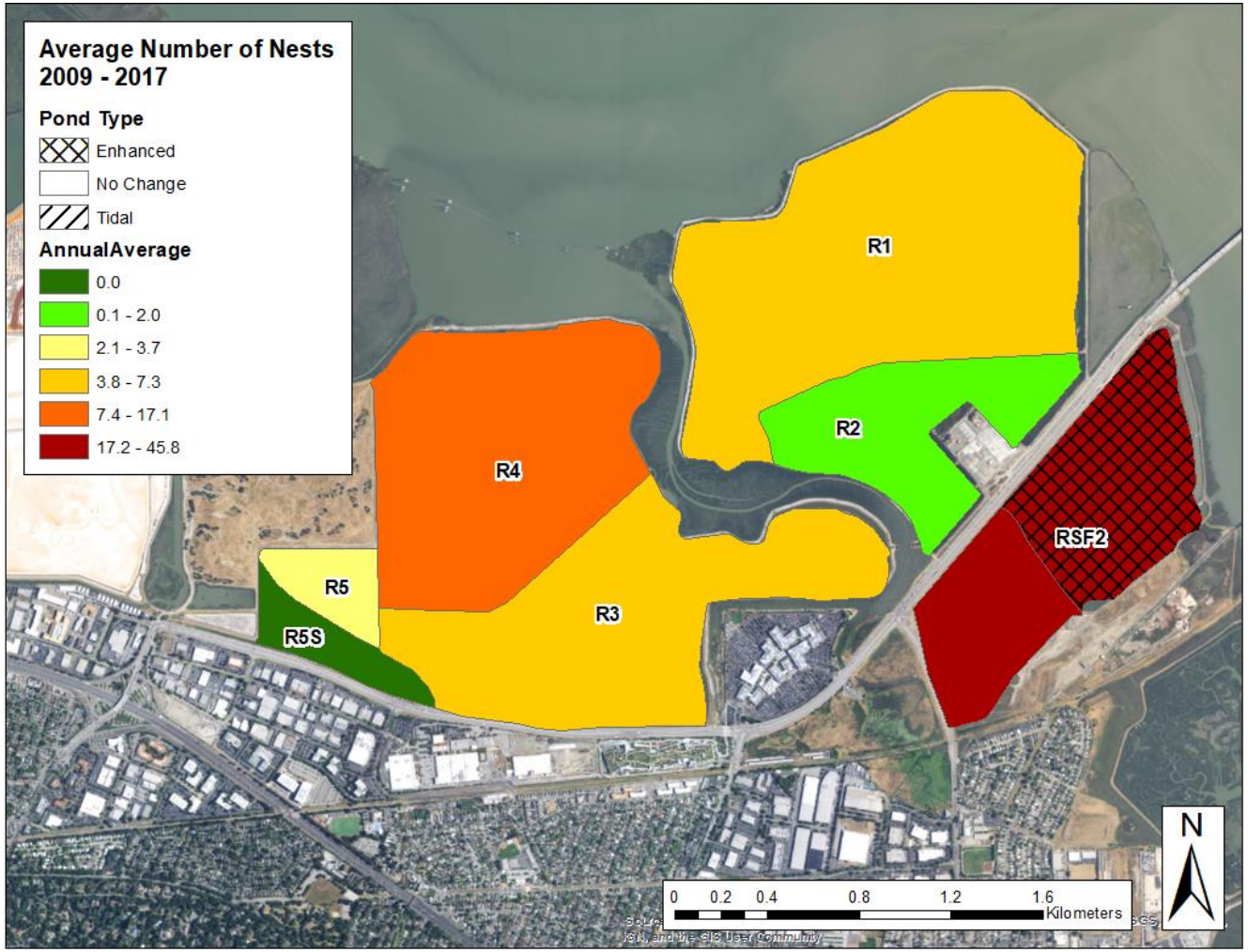


**Figure 21.** Average number of Snowy Plover nests initiated by pond in the Ravenswood Complex, South San Francisco Bay, California from 2009-2017. The purpose of this figure is to illustrate which ponds have supported Snowy Plover nesting activity in recent years, and of these, which ponds are included in Phase 1 restoration plans of the South Bay Salt Pond Restoration Project. Crossed hatch lines denote ponds that have been enhanced for multiple species and the amount of habitat available to Snowy Plovers is reduced compared to recent years, and solid colors denote ponds that will not be directly affected by Phase 1 actions. The gradient shading denotes the average number of plover nests on the pond.

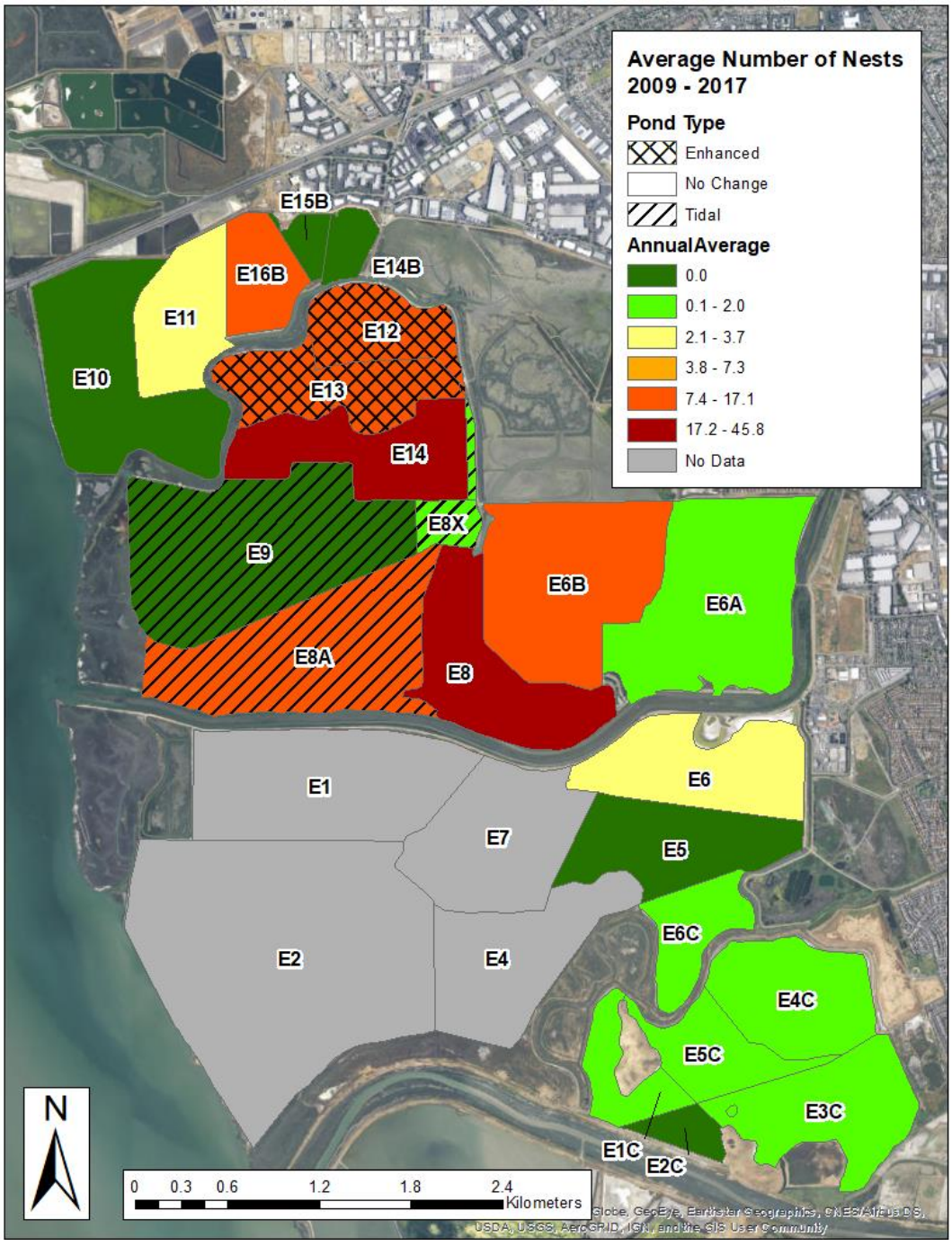


Figure 22. Average number of Snowy Plover nests initiated by pond in the Eden Landing Ecological Reserve, South San Francisco Bay, California from 2009-2017. The purpose of this figure is to illustrate which ponds have supported Snowy Plover nesting activity in recent years, and of these, which ponds are included in Phase 1 restoration plans of the South Bay Salt Pond Restoration Project. Diagonal lines denote ponds that have been returned to tidal influence, crossed hatch lines denote ponds that are managed for multiple species and the amount of habitat available to Snowy Plovers will be reduced, and solid colors denote ponds that will not be directly affected by Phase 1 actions. The gradient shading denotes the average number of plover nests on the pond. Note that pond E3C is owned by Cargill and managed largely as open water.

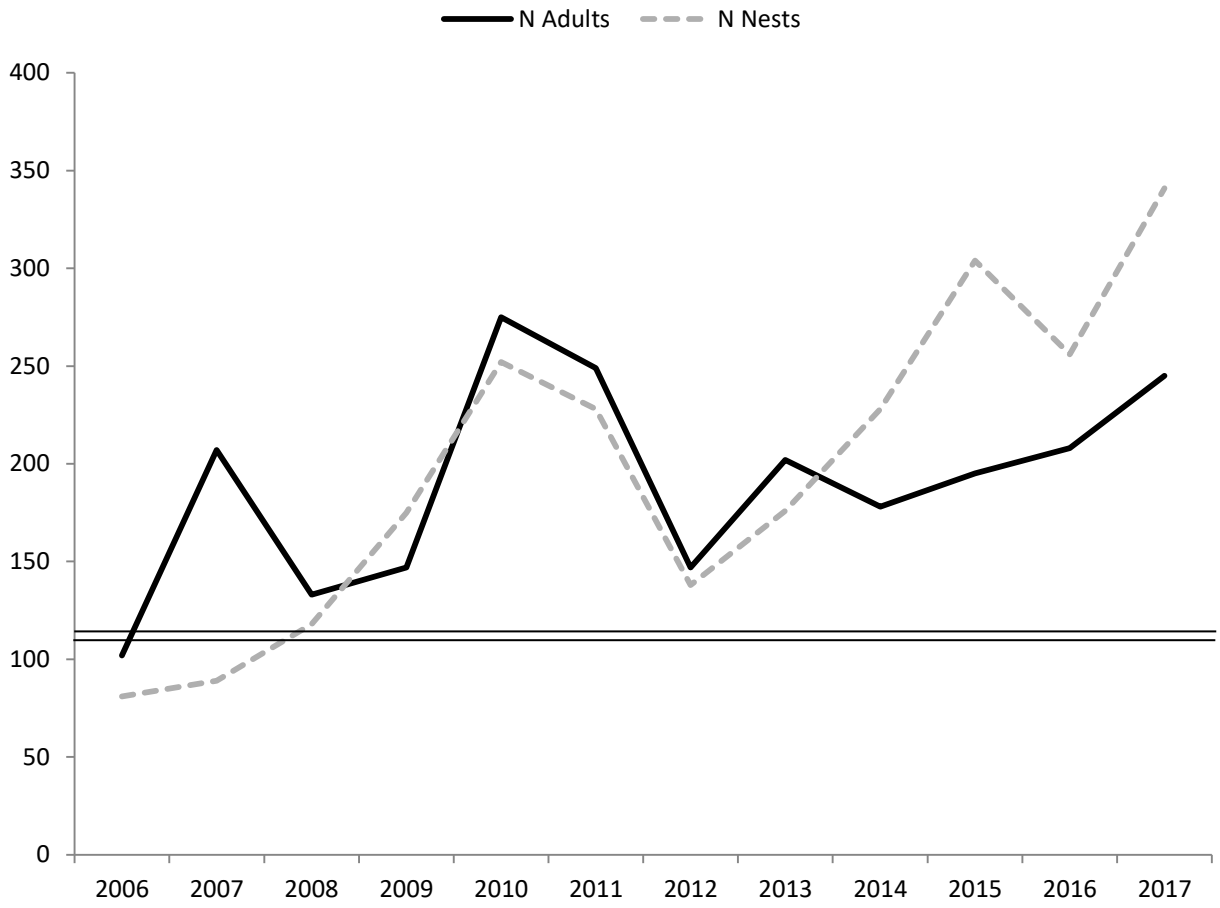


**Figure 23.** The total number of Snowy Plover adults counted during the breeding window survey and the total number of Snowy Plover nests counted during the season in all regularly monitored Recovery Unit 3 (RU3) areas, San Francisco Bay, from 2006-2017. The double line indicates the South Bay Salt Pond Restoration Project NEPA/CEQA baseline of 113 breeding adults in RU3, established from the average number of breeding birds from 2004-2006.

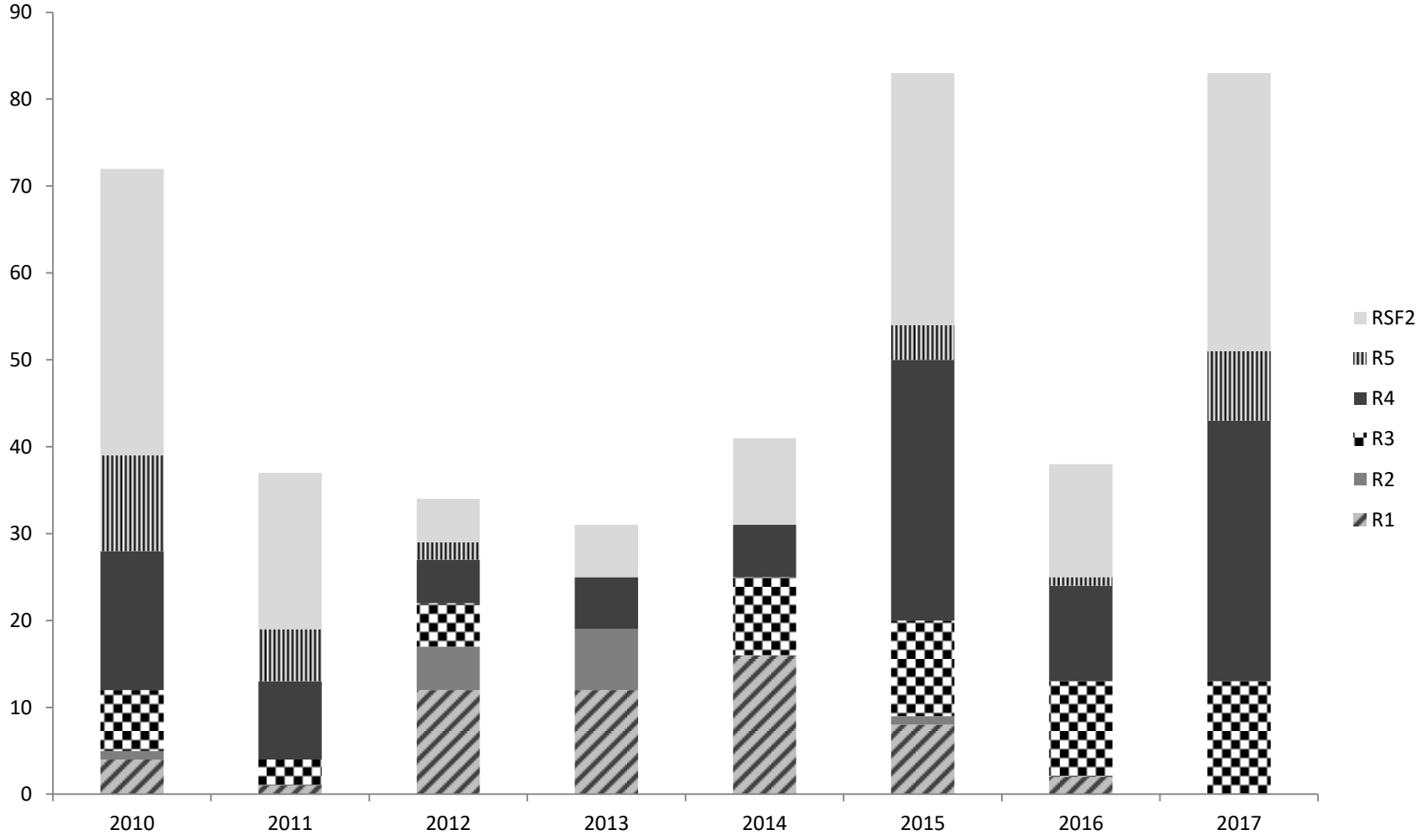


**Figure 24**. The number of snowy plover nests in the Ravenswood complex (ponds R1-5, RSF2) in Don Edwards National Wildlife Refuge, South San Francisco Bay, California, from 2010-201**7**. Each year is subdivided into individual ponds where the nests were located. The purpose of this figure is to show the variability in use of these ponds for nesting between years.

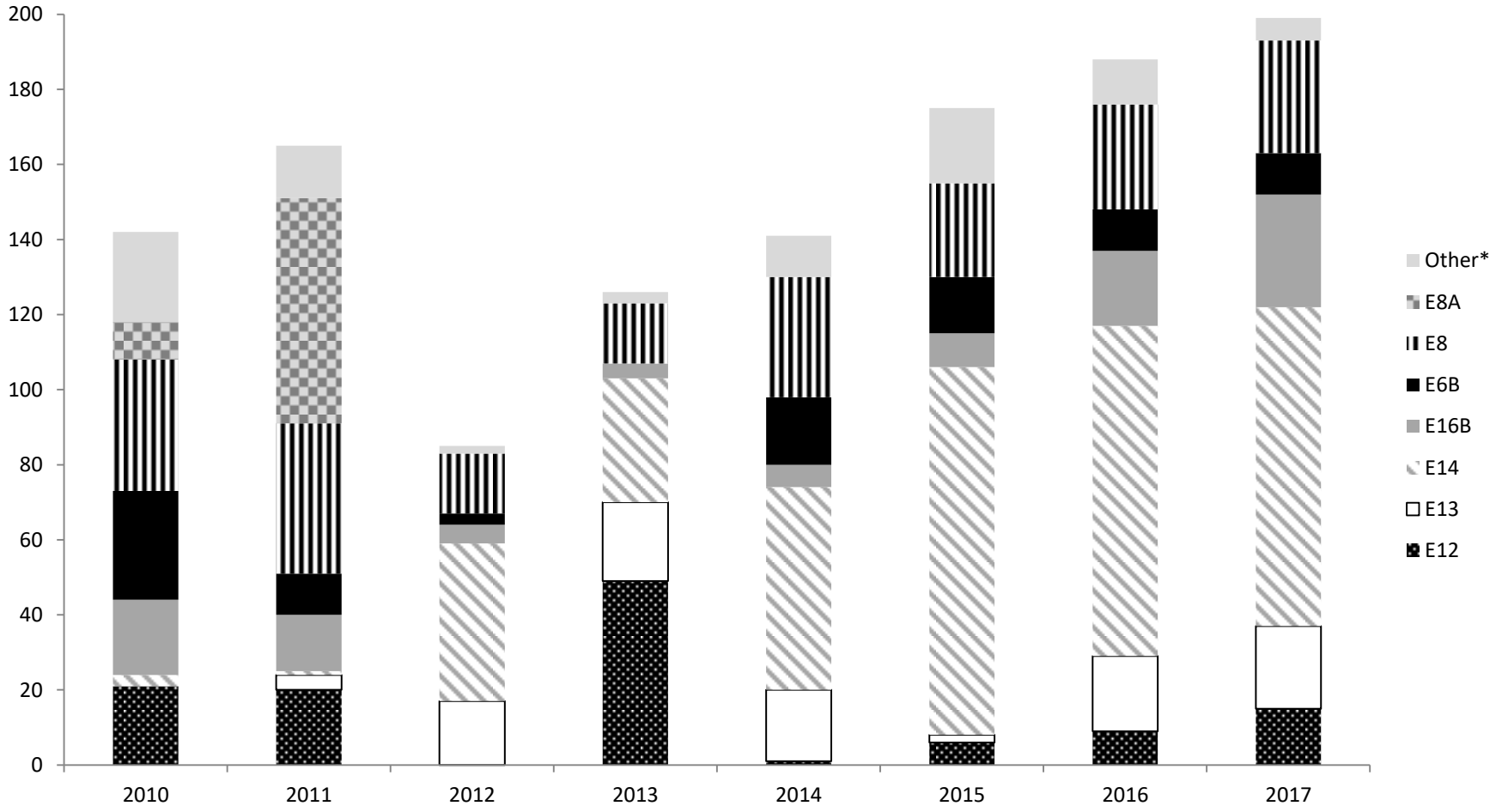


**Figure 25.** The number of Snowy Plover nests in Eden Landing Ecological Reserve, South San Francisco Bay, California, from 2010-2017. Each year is subdivided into individual ponds where the nests were located. The purpose of this figure is to show the variability in use of these ponds for nesting between years. It also shows an apparent positive trend in number of nests from 2012-2017. Following the 2011 breach of pond E8A, a reduction in total number of nests at Eden Landing was observed. The positive trend observed has restored the total number of nests at Eden Landing to pre-breach numbers.
*Includes ponds E11, E6A, E6, E1C-E6C

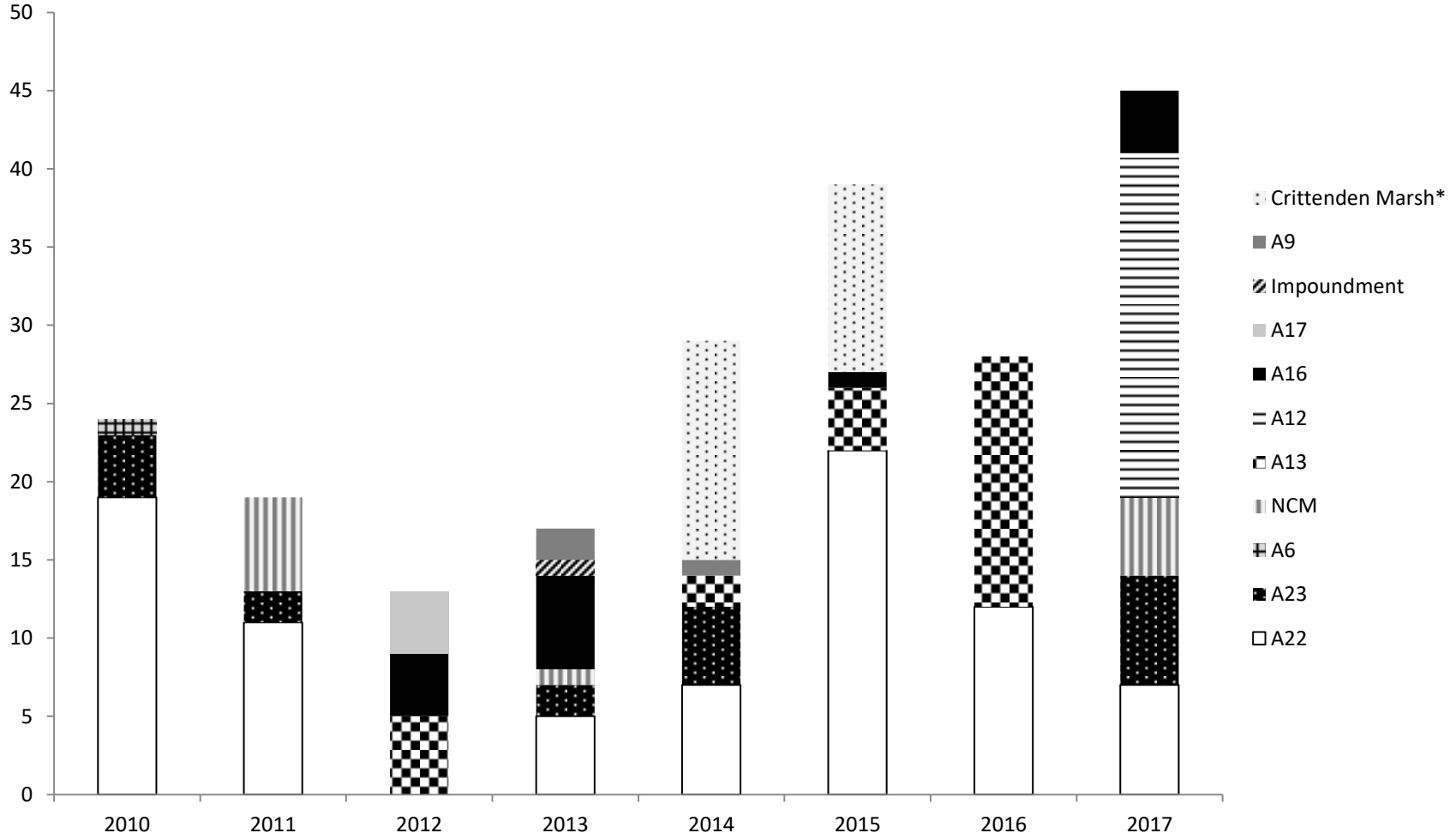


**Figure 26.** The number of Snowy Plover nests in the Alviso Complex in Don Edwards National Wildlife Refuge, South San Francisco Bay, California, from 2010-2017. Each year is subdivided into individual ponds where the nests were located. The purpose of this figure is to show the variability in use of these ponds for nesting between years.
*Includes ponds CMW, CME, and A3N

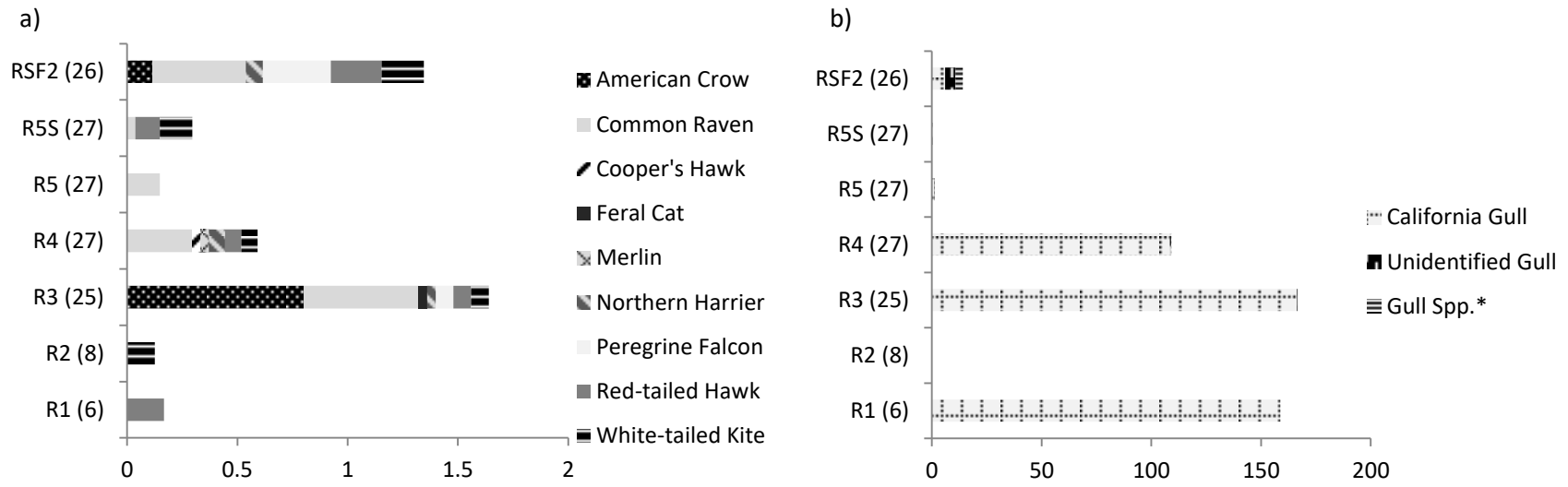


**Figure 27**. The average number of critical predators, a) excluding gull species, and b**) only** gull species, observed per survey at the Ravenswood Complex, South San Francisco Bay, California, March-August 201**7**. Survey sample size is in parentheses next to pond number.
*Includes Ring-billed, Herring, Western Gulls (in order of average seen per survey)

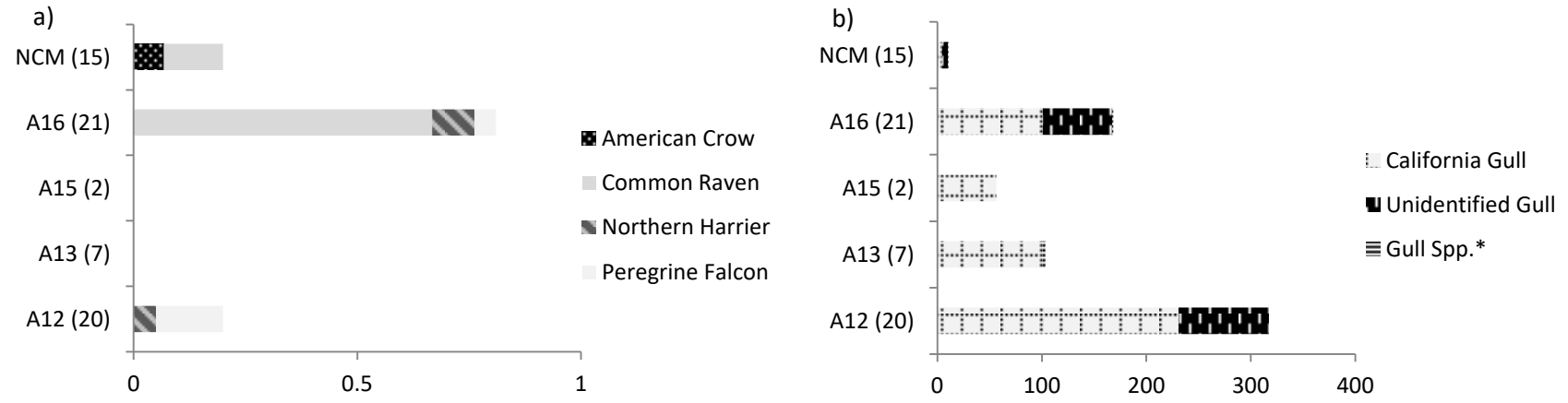


**Figure 28**. The average number of critical predators, a) excluding gull species and b**) only** gull species, observed per survey at the Alviso Complex, South San Francisco Bay, California, March-August 201**7**. Survey sample size is in parentheses next to pond number.
*Includes Herring, Ring-billed, Western, and Glaucous Gulls (in order of average seen per survey)

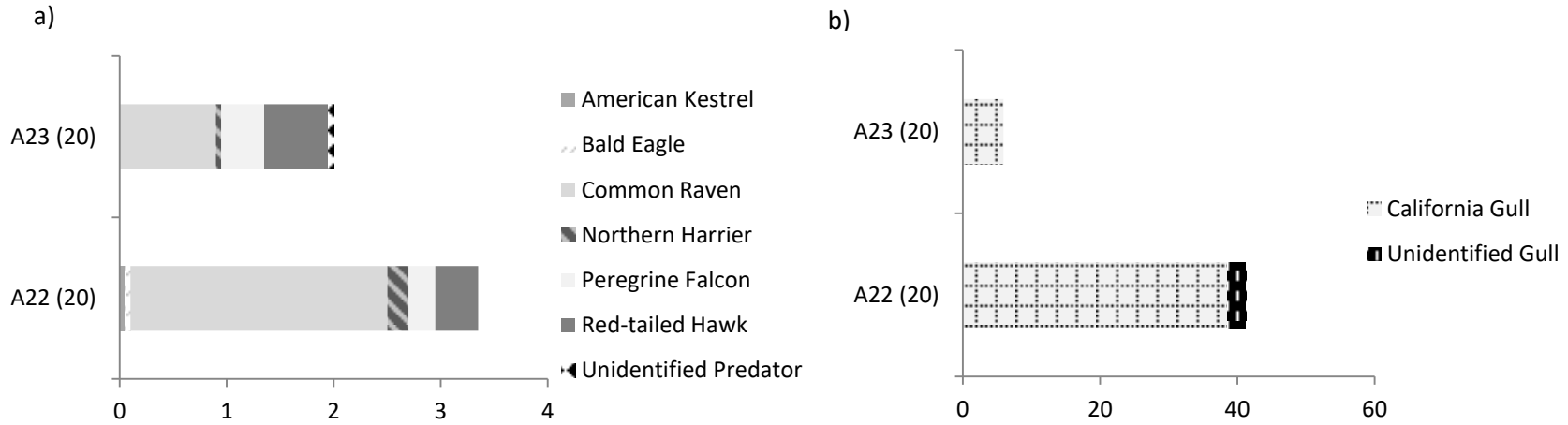


**Figure 29**. The average number of critical predators a) excluding gull species and b**) only** gull species, observed per survey at Warm Springs, South San Francisco Bay, California, March-August 201**7**. Survey sample size is in parentheses next to pond number**.**

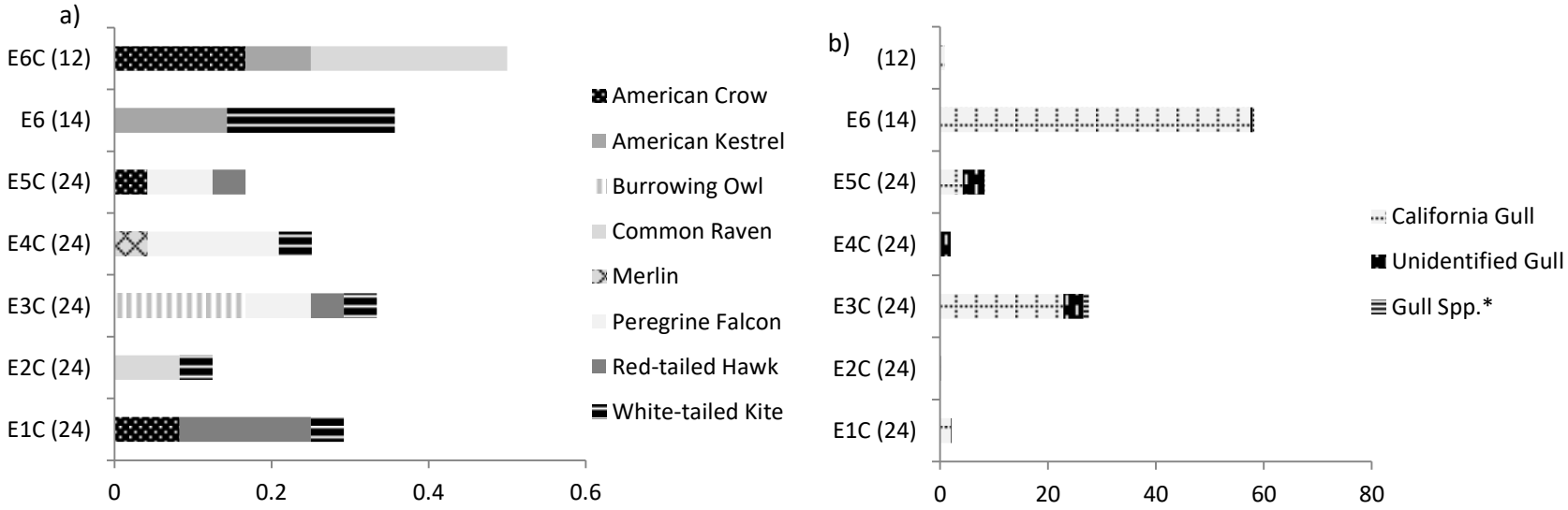


**Figure 30**. The average number of critical predators a) excluding gull species and b) **only** gull species, observed per survey in South Eden Landing Ecological Reserve, South San Francisco Bay, California, March-August 201**7**. Survey sample size is in parentheses next to pond number. *Includes Western, Ring-Billed, Bonaparte's and Herring Gulls (in order of average seen per survey)

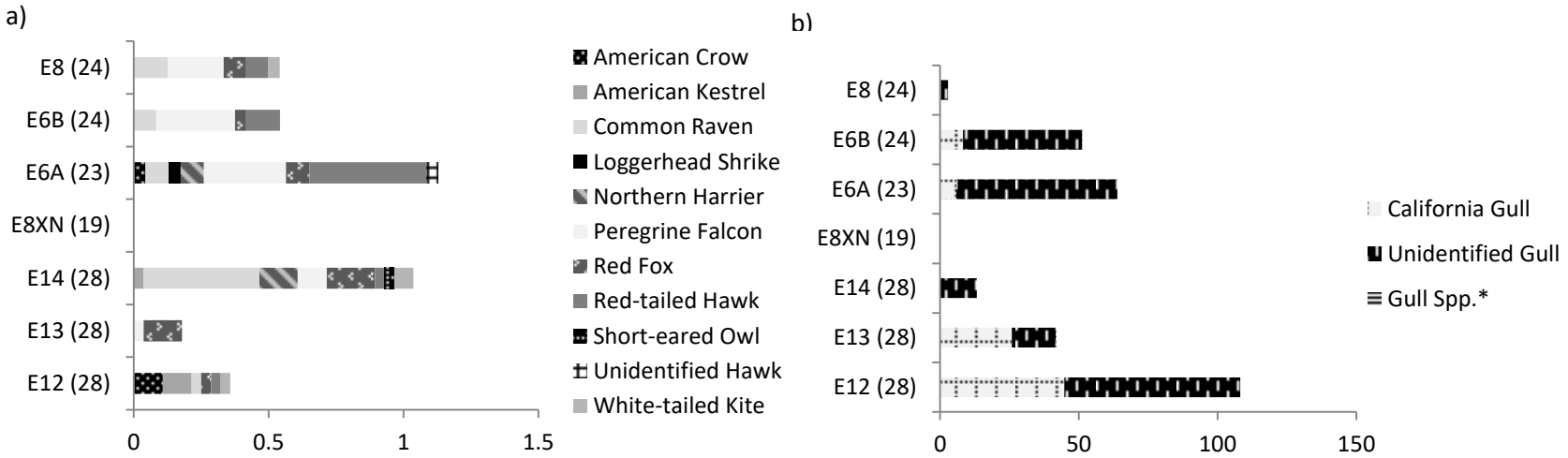


**Figure 31**. The average number of critical predators a) excluding gull species and b**) only** gull species, observed per survey at the Whales Tail and Old Alameda Creek Loops, Eden Landing Ecological Reserve, South San Francisco Bay, California, March-August 201**7**. Survey sample size is in parentheses next to pond number.

* Includes Ring-billed and Herring Gulls (in order of average seen per survey)

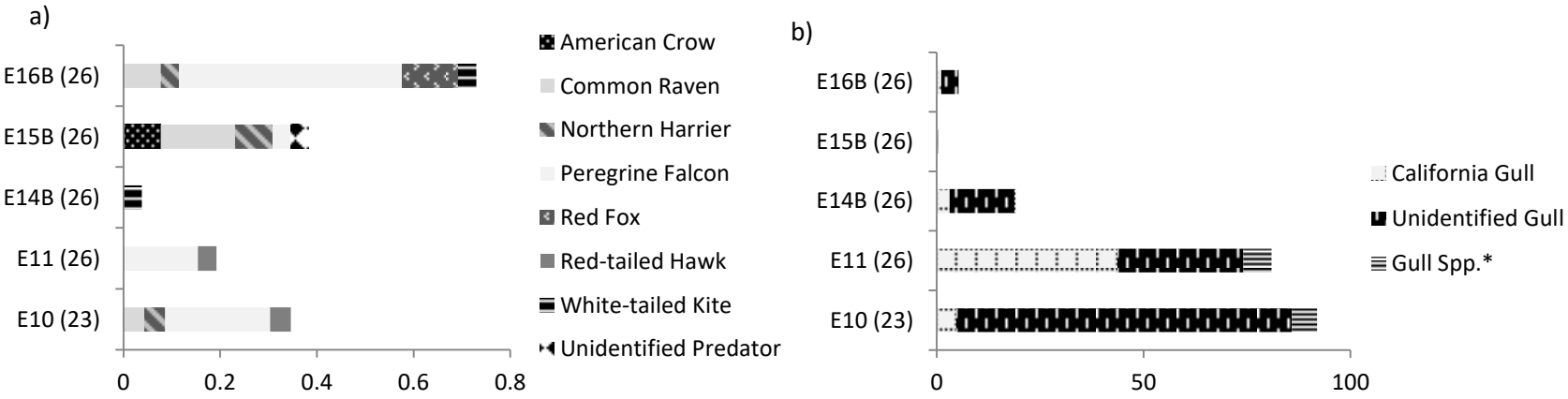


**Figure 32**. The average number of critical predators a) excluding gull species and b) **only** gull species, observed per survey at the Mount Eden Creek loop, Eden Landing Ecological Reserve, South San Francisco Bay, California, March-August 201**7**. Survey sample size is in parentheses next to pond number.

* Includes Western, Ring-billed, and Mew Gulls (in order of average seen per survey)

Table 1. Ponds surveyed weekly within the Don Edwards San Francisco Bay National Wildlife Refuge, South San Francisco Bay, California, 2017.

| Location | Ponds |
|---|---|
| Alviso | A12, A13, A15, A16, Impoundment, NCM |
| Dumbarton | NPP1, Hickory |
| Ravenswood | R1, R2, R3, R4, R5, R5S, RSF2 |
| Warm Springs | A22, A23 |

Table 2. Ponds surveyed weekly within California Department of Fish and Wildlife's Eden Landing Ecological Reserve, San Francisco Bay, California, 2017.

| Location | Ponds |
|---|---|
| Eden Landing Ecological Reserve | E6, E6A, E6B, E8, E8XN, E10, E11, E12, E13, E14, E14B, E15B, E16B, E1C, E2C, E3C, E4C, E5C, E6C |

Table 3. Additional areas surveyed in the San Francisco Bay, California, 2017. These areas were surveyed less often than weekly surveys and as presence/absence surveys, or were surveyed by biologists from different agencies.

| Location | Land Owner | Ponds |
|---|---|---|
| Oliver Brother's ponds | HARD | OBN1-16 |
| Coyote Hills Regional Park | EBRPD | Patterson Pond |
| Least Tern Island | EBRPD | Island 5 |
| Napa-Sonoma Marshes Wildlife Area | CDFW | 7/7A, Green Island Unit, Wingo Unit |
| Dumbarton | Cargill | N1, N2, N3 |
| Eden Landing Ecological Reserve | CDFW | E8A, E9, North Creek Managed Pond |

**Table 4**. Number of Western Snowy Plovers observed at Recovery Unit 3 sites during annual breeding window surveys in May, 2005-2017

| REGION | SITE | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alameda** | Eden Landing | 91 | 84 | 162 | 94 | 88 | 184 | 185 | 82 | 97 | 94 | 76 | 120 | 144 |
| | Coyote Hills | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | Crown Beach | - | - | - | - | - | - | - | - | - | 0 | 0 | 0 | - |
| | Dumbarton | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | Hayward | 0 | 0 | 0 | 1 | 4 | 12 | 8 | 9 | 32 | 7 | 2 | 4 | 0 |
| | Warm Springs | 23 | 7 | 0 | 3 | 14 | 27 | 17 | 3 | 1 | 11 | 24 | 14 | 2 |
| **Marin** | Hamilton Wetlands | - | - | - | - | - | - | - | - | - | - | - | 0 | - |
| **Napa** | Napa | 0 | | | 0 | 12 | 10 | 1 | 0 | 3 | 10 | 10 | 0 | - |
| **San Mateo** | Ravenswood | 3 | 3 | 23 | 24 | 21 | 42 | 27 | 33 | 59 | 45 | 68 | 42 | 76 |
| **Santa Clara** | Alviso | 7 | 8 | 20 | 11 | 8 | 0 | 11 | 20 | 10 | 0 | 1 | 21 | 19 |
| | Mountain View | - | - | - | - | - | - | - | - | - | 11 | 0 | 0 | 0 |
| **North Bay Delta** | Montezuma Wetlands | - | - | - | - | - | - | - | - | - | - | 14 | 6 | 3 |
| **Total Unit 3** | | **124** | **102** | **207** | **133** | **147** | **275** | **249** | **147** | **202** | **178** | **195** | **208** | **246** |

**Table 5**. Snowy Plover nest fates by pond in the South San Francisco Bay, California, 2017.

| Location | Hatched | Depredated | Abandoned | Flooded | Failed to Hatch | Unknown | Total Nests |
|---|---|---|---|---|---|---|---|
| **Alviso** | | | | | | | |
| NCM | 5 | 0 | 0 | 0 | 0 | 0 | **5** |
| A9 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| A12 | 4 | 17 | 1 | 0 | 0 | 0 | **22** |
| A13 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| A16 | 0 | 0 | 0 | 0 | 0 | 6 | **6** |
| **Dumbarton** | | | | | | | |
| NPP1 | 0 | 0 | 0 | 1 | 0 | 0 | **1** |
| Hickory | 4 | 0 | 0 | 0 | 0 | 0 | **4** |
| **Eden Landing** | | | | | | | |
| E6A | 0 | 1 | 0 | 0 | 0 | 0 | **1** |
| E6B | 2 | 9 | 0 | 0 | 0 | 0 | **11** |
| E8 | 11 | 18 | 1 | 0 | 0 | 0 | **30** |
| E12 | 8 | 7 | 0 | 0 | 0 | 0 | **15** |
| E13 | 10 | 9 | 1 | 1 | 0 | 1 | **22** |
| E14 | 43 | 36 | 1 | 0 | 0 | 5 | **85** |
| E16B | 22 | 2 | 2 | 4 | 0 | 0 | **30** |
| E11 | 1 | 0 | 0 | 0 | 0 | 0 | **1** |
| E6 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| E1C | 1 | 0 | 0 | 0 | 0 | 0 | **1** |
| E3C | 0 | 0 | 1 | 0 | 0 | 0 | **1** |
| E4C | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| E6C | 2 | 0 | 0 | 0 | 0 | 0 | **2** |
| **Ravenswood** | | | | | | | |
| R1 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| R2 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| R3 | 8 | 4 | 0 | 0 | 1 | 0 | **13** |
| R4 | 15 | 15 | 0 | 0 | 0 | 0 | **30** |
| R5 | 3 | 5 | 0 | 0 | 0 | 0 | **8** |
| RSF2 | 22 | 10 | 0 | 0 | 0 | 0 | **32** |
| **Warm Springs** | | | | | | | |
| A22 | 3 | 3 | 1 | 0 | 0 | 0 | **7** |
| A23 | 1 | 6 | 0 | 0 | 0 | 0 | **7** |
| **Hayward** | | | | | | | |
| LETE | 7 | 2 | 0 | 0 | 0 | 0 | **9** |
| OBN1 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| OBN12 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| OBN13 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| OBN14 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| OBN16 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| **Total South Bay** | **172** | **144** | **8** | **6** | **1** | **10** | **341** |
| NSMWA - 7/7A | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| NSMWA - GIU | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| NSMWA - Wingo | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| **Total North Bay** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **RU3 Total** | **172** | **144** | **8** | **6** | **1** | **12** | **343** |

**Table 6**. Snowy Plover averaged apparent nest densities (nest/ha) by pond on Refuge property in the South San Francisco Bay, California, 2017. We calculated nest densities (nest/ha) in each pond every week using data from habitat availability surveys; weekly densities were then averaged. By using the actual available nesting habitat rather than the total area of each pond potentially available for nesting, we are able to calculate more accurate nesting densities within ponds as water levels changed throughout the season.

| Location | Average Nest/Ha |
|---|---|
| A12 | 0.49 |
| A22 | 0.03 |
| A23 | 0.03 |
| NCM | 0.08 |
| NPP1 | 0.18 |
| Hickory | 0.08 |
| R3 | 0.03 |
| R4 | 0.12 |
| R5 | 0.18 |
| RSF2 | 0.24 |

**Table 7**. Snowy Plover averaged apparent nest densities (nests/ha) by pond at Eden Landing Ecological Reserve in the South San Francisco Bay, California, 2017. We calculated nest densities (nest/ha) in each pond every week using data from habitat availability surveys; weekly densities in each pond were then averaged. By using the actual available nesting habitat rather than the total area of each pond potentially available for nesting, we are able to represent more accurate nesting densities within ponds as water levels changed throughout the season.

| Location | Average Nest/Ha |
|---|---|
| E12 | 1.21 |
| E13 | 0.30 |
| E14 | 0.31 |

| | |
|---|---|
| E16B | 0.27 |
| E1C | 0.01 |
| E3C | 0.04 |
| E6C | 0.04 |
| E6A | 0.03 |
| E6B | 0.10 |
| E8 | 0.10 |

**Table 8**. Apparent fledging success (all sites combined) of Snowy Plover chicks in the South San Francisco Bay, California, 2008-2017. Chicks were considered fledged if they survived to 31 days (2008-2016) or 28 days (2017). *N* is the number of chicks banded.

| Year | Fledgling Success | N |
|---|---|---|
| 2017 | 44% | 55 |
| 2016 | 27% | 66 |
| 2015 | 34% | 116 |
| 2014 | 27% | 52 |
| 2013 | 36% | 14 |
| 2012 | 50% | 8 |
| 2011 | 14% | 36 |
| 2010 | 41% | 39 |
| 2009 | 25% | 113 |
| 2008 | 29% | 83 |

**Table 9**. Apparent fledging success of Snowy Plover chicks by pond in the South San Francisco Bay, California, 2017. Chicks were considered fledged if they survived to 31 days. *N* is the number of individuals banded.

| Pond | N Chicks | N Adults | Fledgling Success |
|---|---|---|---|
| E14 | 17 | 0 | 53% |
| E13 | 5 | 0 | 20% |
| E6B | 3 | 0 | 67% |
| E8 | 7 | 0 | 43% |
| E16B | 16 | 0 | 31% |
| RSF2 | 5 | 0 | 40% |
| Hickory | 2 | 0 | 100% |
| **Total** | **55** | **0** | **44%** |

**Table 10. The number of nests in each shell plot at Eden Landing Ecological Reserve in the South San Francisco Bay, California, 2009-2017.**

| Pond | Shell plot | Year shells spread | 2009 Total nests | 2010 Total nests | 2011 Total nests | 2012 Total nests | 2013 Total nests | 2014 Total nests | 2015 Total nests | 2016 Total nests | 2017 Total nests |
|---|---|---|---|---|---|---|---|---|---|---|---|
| E14 | 1 | 2009 | - | 0 | 0 | 0 | 1 | 5 | 3 | 1 | 2 |
| E14 | 2 | 2009 | - | 0 | 0 | 1 | 1 | 2 | 2 | 5 | 6 |
| E14 | 3 | 2009 | - | 0 | 0 | 2 | 3 | 4 | 10 | 2 | 1 |
| | **Total** | | **-** | **0** | **0** | **3** | **5** | **11** | **15** | **8** | **9** |
| E16B | 1 | 2008 | 5 | 5 | 4 | 2 | 1 | 0 | 0 | 1 | 2 |
| E16B | 2 | 2008 | 9 | 6 | 2 | 0 | 1 | 0 | 1 | 4 | 5 |
| E16B | 3 | 2008 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Total** | | **16** | **11** | **6** | **2** | **2** | **0** | **1** | **6** | **7** |
| E6A | 1 | 2008 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | **Total** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **0** |
| E6B | 1 | 2008 | 2 | 7 | 1 | 1 | 0 | 5 | 2 | 3 | 1 |
| E6B | 2 | 2009 | | 12 | 1 | 0 | 0 | 3 | 2 | 3 | 3 |
| E6B | 3 | 2009 | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| E6B | 4 | 2010 | | | 5 | 2 | 0 | 2 | 7 | 0 | 2 |
| | **Total** | | **2** | **19** | **8** | **3** | **0** | **10** | **11** | **6** | **6** |
| E8 | 1 | 2008 | 7 | 11 | 7 | 2 | 1 | 2 | 0 | 2 | 1 |
| E8 | 2 | 2008 | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 1 | 2 |
| E8 | 3 | 2010 | - | - | 10 | 7 | 0 | 6 | 2 | 0 | 2 |
| E8 | 4 | 2010 | - | - | 3 | 0 | 1 | 2 | 2 | 2 | 3 |
| | **Total** | | **8** | **13** | **22** | **10** | **4** | **11** | **7** | **5** | **8** |
| **Totals** | | | **26** | **43** | **36** | **18** | **11** | **32** | **34** | **26** | **30** |

**Table 11.** Recorded depredation events determined with nest cameras at Eden Landing Ecological Reserve in the South San Francisco Bay, California, 2009-2011, 2015-2017.

| Year | Pond | Predator Spp. | Count |
|---|---|---|---|
| 2009 | E16B | RTHA | 2 |
| 2009 | E8X | UNID | 1 |
| 2009 | E12 | CORA | 1 |
| 2009 | E8 | NOHA | 1 |
| 2009 | E8A | NOHA | 1 |
| 2009 | E12 | NOHA | 1 |
| 2010 | E6B | RUTU | 1 |
| 2010 | E8 | CAGU | 1 |
| 2010 | E6 | CAGU | 1 |
| 2010 | E6B | GRFO | 1 |
| 2011 | E12 | CAGU | 1 |
| 2011 | E8A | CAGU | 1 |
| 2011 | E13 | CAGU | 1 |

| | | | |
|---|---|---|---|
| 2011 | E8 | RTHA | 1 |
| 2015 | E14 | CORA | 6* |
| 2015 | E14 | UNID | 1 |
| 2016 | E14 | CORA | 30* |
| 2017 | E14 | CORA | 5 |
| 2017 | E14 | UNID | 1 |
| 2017 | E14 | REFO | 2** |

*One nest hatched after partial depredation event

**One nest depredated after one chick hatched

**Table 12.** Aggressive interactions between breeding Snowy Plovers and other shorebirds during the 2017 breeding season.

| Date | Aggressor Species | Target Species | Pond | Habitat Type | SNPL Nest Stage |
|---|---|---|---|---|---|
| 4/7/2017 | SNPL | BNST | RSF2 | Island | Incubating |
| 4/27/2017 | AMAV | SNPL | R4 | Pond | Pair |
| 4/27/2017 | SNPL | BNST | R4 | Pond | Incubating |
| 4/27/2017 | SNPL | BNST | R4 | Pond | Pair |
| 5/12/2017 | AMAV | SNPL | RSF2 | Pond | Incubating |
| 5/15/2017 | AMAV | SNPL CHICK | E13 | Pond | Chicks |
| 5/17/2017 | AMAV/SNPL | SNPL/AMAV | A12 | Island | Adult |
| 5/18/2017 | AMAV/SNPL | SNPL/AMAV | R4 | Pond | Adult |
| 5/22/2017 | AMAV | SNPL | E13 | Pond | Adult |
| 5/24/2017 | AMAV | SNPL | A12 | Island | Incubating |
| 5/24/2017 | AMAV | SNPL | NCM | Pond | Adult |
| 5/30/2017 | AMAV | SNPL | E13 | Island | Pair |
| 5/30/2017 | UNID | SNPL EGG | E13 | Pond | Eggs |
| 6/5/2017 | AMAV | SNPL CHICK | E13 | Island | Chicks |
| 6/19/2017 | AMAV | SNPL | E14 | Pond | Pair |
| 6/26/2017 | AMAV | SNPL | E13 | Pond | Incubating |
| 7/31/2017 | SEPL/SNPL | SNPL/SEPL | E14 | Pond | Chicks |