Western Snowy Plover Monitoring in the San Francisco Bay
Annual Report 2018

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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*; Snowy Plover) Recovery Unit 3 working group. The goal of this collaboration is to survey managed ponds and other habitats for Snowy Plovers, track breeding success, and contribute to the management and recovery of this species in the San Francisco Bay. During the 2018 breeding season, SFBBO staff 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 20-27), we counted 235 adult Snowy Plovers in the San Francisco Bay. Over the course of the breeding season (March-September), SFBBO staff determined and documented the fates of 269 Snowy Plover nests in Recovery Unit 3, all located in the South Bay. EBPRD documented the fate of ten Snowy Plover nests found at Least Tern Island. Apparent nest success (defined as the percentage of nests that successfully hatched at least one egg out of the total nests monitored) was 41.6%. Of the remaining nests, 57.0% were depredated, 0.7% abandoned, 0.4% failed to hatch, and 0.4% had unknown fates. A summary of 2018 nesting activity by pond complex or management unit follows:

> On Refuge property, we monitored seven nests in the Alviso Complex (ponds A13 and A15), two nests in the Mountain View Ponds (pond A3N), 11 nests in the Warm Springs complex (ponds A22 and A23), and 30 nests in the Ravenswood Complex (ponds RSF2, R1, R2, R3, and R4). Apparent nest success was 43%, 0%, 27%, and 57% in the Alviso, Mountain View, Warm Springs, and Ravenswood complexes, respectively.

> We found 79% of Snowy Plover nests in Recovery Unit 3 at CDFW's Eden Landing Ecological Reserve (Eden Landing). We determined the fate of 212 nests and found that apparent nest success was 38%.

> On NASA-ARC/Mid-Peninsula Regional Open Space District property, we determined the fate of five nests on Crittenden Marsh and found that apparent nest success was 60%. On Wildlands Inc. property, we determined the fate of two nests on Hickory and found that apparent nest success was 50%.

> EBRPD reported ten Snowy Plover nests on the California Least Tern (*Sterna antillarum browni*) island at Hayward Shoreline, with a hatch rate of 80% (D. Riensche, pers. comm.). No nests were reported at the Oliver Brother's North ponds at the Hayward Shoreline Interpretive Center (A. Graham, pers. comm.).

No nests were found at any of the North Bay sites this year, including Napa-Sonoma Marshes Wildlife Area (CDFW ponds 7/7A, Green Island Unit, and Wingo Unit, K. Taylor, pers. comm.); Hamilton Wetlands in Novato (Avocet Research Associates, J. Evans, pers. comm.); Montezuma Wetlands in Solano County (EcoBridges Consulting, A. Wallace, pers. comm.).

In 2018, SFBBO banded 31 Snowy Plover chicks from nests that successfully hatched within Eden Landing and Mountain View nesting ponds. From band re-sighting surveys, we determined that at least 6 of these 31 chicks survived to fledging (28 days post-hatching) as of October 26th 2018. Our apparent fledging success was 19%.

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 Snowy 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. Red foxes and Common Ravens were documented by trail cameras as nest predators at pond E14 in Eden Landing, depredating ten and two nests, respectively. It is likely that these two species accounted for many of the other depredations at pond E14 and throughout Eden Landing.

From 2008-2014, we conducted a pilot Snowy Plover habitat enhancement study at Eden Landing using three 1-ha oyster shell pilot plots. The study indicated that oyster shell habitat enhancement increased Snowy 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 monitoring has shown that the oyster shell enhancement plots can attract a large number of Snowy Plovers to breed (109 nests in 2018), but have not improved nest success to date.

California Least Terns (*Sternula antillarum browni*) nested at Eden Landing pond E14 for the second consecutive year. From May 14 through early August 23, 30-45 breeding pairs established 141 nests within the New 1 and New 2 enhancement plots, with an estimated 1-3 total fledglings produced. Low nest success and fledging rates were attributed to high depredation rates, likely by red fox. As opposed to 2017, Snowy Plover hatching success appeared to be negatively affected by the presence of terns. Prior to establishment of the Least Tern colony, Snowy Plover nests had a hatch rate of 56% (n=41). After establishment of the colony, Snowy Plover nests had a hatch rate of 34% (n=104), and were located an average of 215.3±190.8m from the closest Least Tern nest.

During Phase I of the South Bay Salt Pond Restoration Project (the Project), restoration and reconfiguration of ponds that formerly supported Snowy Plover breeding habitat resulted in the loss of roughly 19% of available breeding habitat for Snowy Plovers. Phase II, focused on the

Ravenswood Complex of the Refuge, will result in an additional 8% loss of remaining available breeding habitat. Despite this, numbers of Snowy Plovers breeding within the project footprint have continued to increase, likely due to targeted management efforts and predator control.

In future years, we recommend that the Project continue to plan Phase II construction activities to avoid negatively impacting breeding Snowy Plovers. This includes providing alternative breeding habitat when construction activities impact or eliminate Snowy Plover nesting ponds and scheduling construction activities before Snowy 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 Project areas are opened to tidal action or converted to ponds with islands, we recommend that the Project and local land managers maintain 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 currently undertaken along these lines should be continued in future seasons, including management of multiple ponds with a mixture of exposed pond and shallow water depth during the winter and large scale shell enhancement at appropriate nesting ponds. With the opening of seasonal public trails at the ponds E12-14 in 2016, further studies are needed to assess the impact of human disturbance on Snowy Plover breeding. As such, we recommend that no additional levee trails in close proximity to Snowy Plover nesting ponds be opened to the public until impacts to Snowy Plover nest site selection and brood foraging habitat use can be assessed. We also propose continued research, adaptive management and/or enhancement of Snowy Plover nesting sites to reduce impacts from tidal restoration projects and improve recovery efforts in the future.

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 Alameda, Napa, Santa Clara, and Solano counties, and the eastern portion of Marin, San Mateo, and Sonoma Counties (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, levees, and in dry, degraded marsh habitat. In 1992, the Don Edwards San Francisco Bay National Wildlife Refuge (Refuge) began surveying for Snowy Plovers on Refuge lands.

From 2003-2018, SFBBO conducted annual Snowy Plover monitoring and research in support of the goals set forth by the RU3. 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) surveyed for potential avian predators , and 5) identified areas of potential disturbances from predators, trespass, construction activities and other human activities.

When the Project began active restoration in 2006, project lands supported approximately 62 Snowy Plover breeding pairs (Table 6). Despite the loss of Snowy Plover breeding habitat (dry panne) expected overall through the Project's actions, the Project set a management target of maintaining 125 breeding pairs of Snowy Plovers within its footprint (USFWS and CDFW 2007). To aid in achieving this goal, SFBBO and the Project initiated a large-scale oyster shell habitat enhancement project, informed by the previous pilot studies from 2008-2015, on Eden Landing pond E14. Enhancements were made in September and October 2014, and 2018 marked the fourth year of monitoring the enhancement project.

As the South Bay Salt Pond Restoration Project continues to restore tidal marshes in the Bay, more areas will become open for public and recreational use. Some of these areas are adjacent to sensitive Snowy Plover breeding and wintering sites. To encourage public support and awareness of Snowy Plovers as well as to discourage trespassing and disturbance, SFBBO has been stationing trained volunteer docents are at key breeding sites monthly since 2016 to help the public learn about and view Snowy Plovers during the breeding season.

In this report, we summarize results from the 2018 breeding season; this includes data on Snowy Plover nest distribution and habitat use, nest (hatching) success, fledging success, oyster shell enhancement studies, and avian predator abundance and distribution. Although we report Snowy Plover numbers in other areas of RU3, this report focuses on Snowy Plover activity in the South San Francisco Bay, south of the San Mateo Bridge.

METHODS

Study Area

From March 1 to August 31, SFBBO staff and volunteers conducted Snowy Plover and predator surveys in the South San Francisco Bay (South Bay) ponds, including all areas from the San Mateo Bridge (Highway 92) south to the extreme southern portion of the Bay (Figure 1, Table 1-2). EBRPD and HARD staff surveyed ponds just north of the San Mateo Bridge (Highway 92) (Figure 1, Table 3). In the North Bay CDFW biologists surveyed and contributed nesting information for Napa-Sonoma Marsh Wildlife Area, while Avocet Research Associates and EcoBridges Environmental Consulting contributed window survey information at Hamilton Wetlands and Montezuma Wetlands, respectively (North Bay; Figure 2). These surveys provide

full coverage of all known 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 dried 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 (Figure 5), Coyote Hills, Dumbarton (Figure 6), and Mowry. The Mountain View section includes Alviso ponds A2E and A3N as well as Crittenden Marsh, which is co-owned by Midpeninsula Regional Open Space District and the National Aeronautics and Space Administration, Ames Research Center (NASA-ARC).

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 7). In the North Bay, 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. This island was monitored by EBRPD.

In the North Bay, Hamilton Wetlands Restoration site is located in Novato at the former Hamilton Army Airfield and is owned by the State Coastal Conservancy. 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 nesting habitat is now tidal; however, there remains a portion of suitable nesting habitat in the North Seasonal Wetlands (Figure 8).

U.S. Geological Survey (USGS) biologists first reported Snowy Plovers nesting among California Least Tern colonies in the Montezuma Wetlands, Solano County in 2014 (Figure 9). This is a privately owned dredge placement site within the Montezuma Wetlands Restoration Project footprint. This year, Snowy Plover breeding and winter window surveys were performed here by contracted biologists, and adult numbers for the survey windows are included in this report. Further nesting information is not included due to inconsistent survey methods.

Cargill Inc. owns two large tracts of land used for salt production in Redwood City and Newark. Both locations contain potentially suitable Snowy Plover breeding habitat, depending upon pond management and resulting water levels. Although targeted Snowy Plover surveys are not

performed at either location, any opportunistic sightings of Snowy Plover adults and broods by Cargill staff are relayed to USFWS and reported here (Figure 10).

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 5 to September 16, 2018, SFBBO and agency biologists, interns, and volunteers surveyed all potential breeding 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 paper map. We also recorded the color-band status, and combination if appropriate, of any banded Snowy Plover sighted. Any observed instances of interspecies aggression between Snowy Plovers and other nesting shorebirds and/or seabirds were recorded.

SFBBO Snowy Plover volunteers surveyed the HARD ponds and some low-priority Eden Landing ponds monthly to check for possible nesting activity during the season (Table 3). Volunteers walked levees and stopped approximately every 0.3 miles to scan using spotting.

From May 20-27, 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.

Snowy Plover Docent Surveys

SFBBO Snowy Plover docent volunteers were stationed at Eden Landing ponds E12-E14 and at Ravenswood ponds R4-R5S monthly 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 information was shared (ecology, salt making history, conservation, etc.), and any other relevant information.

Least Tern Surveys

California Least Terns (*Sternula antillarum browni*) were first observed this year at pond E14 on April 23. Weekly breeding surveys began on April 23 and continued through the week of August 13, 2018. Least Tern surveys followed survey protocol as developed and deployed by CDFW in 2013 (Frost 2014). 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.

Due to delays in SFBBO's 10a1A permit renewal for California Least Tern activities, SFBBO staff were accompanied by permitted Refuge staff during all entries into the Least Tern colony. As a result, attempts to locate Least Tern nests were only made when Refuge staff were on-site. On some occasions nests that were previously observed remotely were gone by the time they were visited and the number of eggs and their fate could not be determined. Refuge staff did not have permit approval to handle Least Tern eggs; therefore, the stage of development could not be determined. This resulted in an additional amount of unknown nest fates for situations in which all eggs disappeared from a nest but the nest was active for at least three weeks and could have hatched.

Snowy Plover 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 hand-held tablet (Apple® iPad 2 or Apple® iPad Mini 2) and/or GPS unit (Garmin® GPS 60 or Garmin® eTrex Venture HC). 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, at Eden Landing pond E14, we recorded whether the nest was located in an oyster shell enhancement or non-shelled 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 and estimation of fledging rate

Since 2008, SFBBO and Refuge biologists have banded Snowy Plover chicks to study their movements and to estimate fledging success rates in the South Bay, when resources allowed. 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 was 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.

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.

In addition, at pond E14, brood surveys were performed to track banded broods, observed brood behavior, and measure fledging success.

Oyster Shell Habitat

E14 Large Scale Enhancement
Our oyster shell pilot study (2008-2014) provided evidence that Snowy Plovers preferentially selected shelled areas for nest locations (Robinson-Nilsen et al. 2013). Based upon these findings, we began a large scale habitat enhancement project in September 2014 at Eden Landing pond E14 by treating 20.23 hectares 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, totals 9.47 hectares when contiguous three pilot shelled one hectare plots included) and an eastern plot totaling 13.76 hectares (referred to as New 2, Figure 11); the remaining untreated areas are termed non-shelled in this report. We designed a spatial configuration in which the shell blocks alternated with the non-shelled 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.

Avian Predator Surveys

To identify avian predators in the area that might affect Snowy Plovers, SFBBO and Refuge biologists and interns conducted predator surveys concurrently when surveying ponds for Snowy Plovers (Tables 1-2). Volunteers conducted avian predator surveys at ponds surveyed monthly for Snowy Plovers. Observers chose survey points that provided a comprehensive scan of all required ponds for predators. At each survey point, the location, start time, and stop time were recorded. Observers recorded the number, species, behavior, and habitat type at the time of sighting 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 (Strong et al. 2004), we felt it meaningful to present indices of predator abundance at the pond scale since both predator and Snowy 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. This includes most raptors, gulls, corvids, herons, and egrets (Table 4) found within Snowy Plover breeding habitat in Recovery Unit 3. While there are a number of potential mammalian predators (Table 5), and their signs (e.g., tracks) were recorded opportunistically, these surveys were not designed to detect mammals, particularly since many are nocturnal. Among all predators, we considered raptors, gulls, corvids, and red fox 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 Snowy Plover nest depredations, wildlife trail cameras (Reconyx PC900 HyperFire) were also deployed throughout the season at active nests in pond E14. Cameras were placed directly on the ground between 2-3 meters from each selected nest; this method was used after testing other further 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 attempted to equally distribute 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.

Due to the frequency of red foxes seen on camera depredating Snowy Plover nests, we suspected that they may have been cueing in on the wildlife trail cameras. We deployed test cameras, away from active nests but otherwise similar in placement, in order to test this theory. Upon observing red foxes approaching several of the test cameras, we decided to stop placing cameras at Snowy Plover nests in case the cameras were attracting foxes. In future seasons, we plan to deploy test cameras to begin each season to further test this theory. If any predator appears to be attracted to cameras, we will stop camera deployment immediately.

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 2018 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 dry pond bottom, dry levees, and sparse vegetation cover; unavailable habitat included standing water, saturated pond bottom or mud, and full vegetation cover. Each square was considered available or unavailable for breeding based on which 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. Though the habitat availability maps are an estimate with some measure of error, they provide a much more accurate measure of potentially available nesting habitat over time compared to previous methods used from 2003-2014.

Analytical Methods

Nest Densities

Apparent nest densities were calculated for each pond and by each treatment area (New 1, New 2, Control) 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 2018 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.

RESULTS AND COMPARISONS TO 2017

Snowy Plover Surveys

South Bay Overall
During the 2018 Pacific Coast breeding season window survey (May 20-27), we counted 235 adult Snowy Plovers in the Bay (Table 6, Figure 12). We observed a mean of 262 birds per week from March 5 through August 31 in the entire South Bay. We consistently observed the greatest numbers of Snowy Plovers at Eden Landing (Figure 13a). We documented Snowy Plover nesting activity at 22 South Bay ponds (Figure 14, Table 7).

Refuge and Adjacent Lands
We observed a mean of 63 Snowy Plovers per week from March 5 through August 31 on Refuge property (Figure 13b). We observed an average of 28 Snowy Plovers per week in the Ravenswood complex, an average of 15 Snowy Plovers per week in the Warm Springs complex, an average of 12 Snowy Plovers per week in the Alviso complex, and an average 6 Snowy Plovers per week in the Dumbarton complex. In the Mountain View ponds, we documented a mean of 8 Snowy Plovers per week from June 11 through August 31.

Eden Landing
We observed a mean of 196 birds observed per week from March 5 through September 16 at Eden Landing (Figure 13a). Pond E14 supported large numbers of Snowy Plovers during the breeding season again this year, averaging 106 birds per week.

Early and Late Season Trends

In March, we observed large flocks at A23 and E14, averaging 34 and 163 Snowy Plovers per week during this period, respectively. In August, we observed large flocks at E6B and E14, averaging 97 and 98 Snowy Plovers per week for the month, respectively (Figure 15). 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 Aggression

No incidences of interspecies aggression were observed during the 2018 breeding season.

Least Tern Surveys

Least Terns were first observed at Eden Landing on April 23, after which we began weekly surveys, which continued through August 13. During this timeframe, an average of 60±58.7 Least Terns were observed over 18 surveys at pond E14. A maximum of 245 adults were observed on July 23rd, while a minimum of four adults were observed on April 23 and April 30.

Between May 14 and July 23, 30-45 pairs established at least 98 nests that were confirmed and monitored. Of these, twelve nests hatched at least one chick, 54 were depredated, one was non-viable, and the fate of 21 nests was unknown. An additional 43 likely nests, in which an adult was observed displaying incubating behavior but a permitted biologist was not on-site, were observed during the same time frame. These likely nests were gone by the next time a permitted biologist was on-site, therefore the number of eggs could not be determined. For additional information on Least Tern breeding at pond E14 in 2018, refer to *California Least Tern Breeding at Eden Landing Ecological Reserve* (Pearl & Wang 2018).

Snowy Plover Nest Abundance and Success

South Bay Overall
In 2018, we determined the fate of 279 Snowy Plover nests in the South Bay. Of these, 117 nests hatched (apparent nest success = 41.9%), 158 nests were depredated (56.6%), two were abandoned (0.7%), one failed to hatch (0.7%), and the fate of one nest was unknown (0.7%; Table 7, Figure 16). We found the third highest number of nests ever documented in the South Bay in 2018 (previous high of 341 nests in 2017). The predation rate was much higher compared to 2017 (42.0%). Many nests were likely undetected, as evidenced by the presence of 18 unaccounted broods on ponds throughout the season (Table 8). Therefore, a high nest total for the second consecutive year in a row provides evidence for recent population growth and stability. Consistent with findings from previous years, predation serves as the most significant cause of nest failure.

Refuge and Adjacent Lands
In 2018, SFBBO determined the fate of 57 Snowy Plover nests on Refuge property (Table 7). In the Warm Springs complex (A22 and A23), three nests hatched (27%) and eight were depredated (73%). In the Alviso Complex (A13 and A15), three hatched (43%) and four were depredated (57%). At the Ravenswood Complex (R1, R2, R3, R4, and RSF2), 17 hatched (57%) and 13 were depredated (43%). The Ravenswood Complex contained 11% of all nests found in RU3 (Figure 17), and we found the most nests in the Ravenswood complex on pond R4 (11 nests; Figure 18).

In the Mountain View ponds, we determined the fate of two nests on A3N, both of which were depredated. Within Crittenden Marsh, (NASA and Mid-Peninsula Regional Open Space District Property), three nests hatched and two were depredated.

In the Dumbarton Complex, on NPP1, one Snowy Plover brood was observed. This brood hatched from an undetected nest, either from NPP1 or adjacent Hickory. Adjacent to NPP1 on the Newark Slough Mitigation Bank Site (termed Hickory in this report) owned by Wildlands Inc., we monitored 2 nests, one of which hatched (50%) and one was depredated (50%).

Eden Landing
We determined the fate of 212 Snowy Plover nests at Eden Landing, comprising 79% of all nests found in RU3 (Figure 17). Of these, 81 hatched (38%), 127 were depredated (60%), two were abandoned (1%), one failed to hatch (0.5%), and the fate of one nest was unknown (0.5%) (Table 7). Pond E14 had the most nests (145 nests), followed by pond E8 (24 nests), E6B (12 nests) and pond E6A (9 nests; Table 7). E14 alone comprised 68% of the nests found in Eden Landing (Figure 19) and 54% of the nests found in the entire South Bay in 2018.

Hayward Shoreline
EBRPD reported ten Snowy Plover nests on the California Least Tern Island at HARD, eight of which hatched and two were depredated (D. Riensche, pers. comm.; Table 7). No nests were detected this season at the Oliver Brothers North Salt ponds at Hayward Regional Shoreline (A.

Graham, pers. comm.). Anecdotal information and photographs from citizen scientists on ebird indicate that some Snowy Plover breeding occurred at Frank's Dump West (ebird 2018).

Napa-Sonoma Marshes Wildlife Area
In 2018, two Snowy Plovers were observed during the breeding window survey, however no breeding activity was observed by CDFW during broad monthly surveys of the area (K. Taylor, pers. comm.; Table 7).

Montezuma Wetlands
In 2018, zero nests, broods, or breeding behavior was observed during the season (A. Wallace, pers. comm.).

Hamilton Wetland Restoration Area
In 2018, zero Snowy Plovers were observed. High water levels within the restoration site precluded Snowy Plover nesting at this site (J. Evens, pers. comm.).

Cargill Salt Evaporation Ponds
In 2018, no other observations of Snowy Plover adults or broods were reported.

Breeding Chronology and Density
Over the course of the season, average apparent nest density in the South Bay (across all ponds with dry panne) was 0.11 nests per hectare. On Refuge Lands, among ponds with at least 10 nests, we documented the highest apparent nest density in pond RSF2 at 0.05 nests per hectare (Table 9). At Eden Landing, we documented the highest apparent nest density in pond E14 at 0.48 nests/ha (Table 10), with 86% of all nests located within shell plots. This is the largest apparent nest density over the course of a season ever recorded in a RU3 pond using current methods, excluding ponds E12 and E13, which contain only small amounts of available habitat on levees and islands.

We recorded an extended period of high nest initiation during the breeding season. Between the weeks of April 8 and June 24, an average of 18.8±5.9 nests were initiated per week, for a total of 225 nests. This compares similarly to the same time frame last year, when an average of 20.8±6.4 nests initiated per week (250 nests total) was recorded. During the weeks of April 22, May 13, June 10 and June 24, a total of 25 nests, 28 nests, 28 nests, and 22 nests were initiated, respectively (Figure 20).

For the second year in a row, we observed one extended period of active nests across the season rather than two distinct periods. Between the weeks of April 29 and July 8, an average of 77.3±7.8 nests were active, with a high of 85 nests active (Figure 20). During the same time frame last year, an average of 109.3±12.3 nests were active, with a high of 127 active nests.

Chick Fledging Success

As part of our efforts to document breeding success within the San Francisco Bay, we banded 31 Snowy Plover chicks in 2018. At least six chicks fledged (19%, Table 11). We found three of the fledglings during the breeding season, and another three during post breeding season band resighting surveys (Table 12). Considerable effort was put into finding fledglings during band resighting surveys, yet due to the difficulties in finding and reading banded Snowy Plovers in San Francisco Bay, it is possible that additional chicks fledged as well.

Oyster Shell Habitat Enhancements

During the fourth season following large scale enhancement at pond E14, we documented a total of 145 nests in the pond; 52 nests in New 1 (which includes the three 1-ha pilot plots), 73 nests in New 2, and 20 nests in the non-shelled areas of the pond (Control).

The apparent nest success in all of E14 declined from 51% in 2017 to 40% in 2018. Examining the treatments individually, New 1 and New 2 apparent nest success in 2018 remained relatively stable, at 44% and 45%, respectively. Apparent nest success in Control fell considerably, from 63% in 2017 to 35% in 2018. Depredation was the most significant cause of nest failure in all areas of E14 (predation levels were New 1=50%, New 2=64%, and Control=50%).

We observed especially high nest density in New 1 and New 2 during peak breeding months (April 30-July 9, Figure 20). During this timeframe, the average nest density in shelled areas (New 1 and New 2 combined) was calculated at 1.99 ± 0.46 nests/ha, and 0.20 ± 0.09 nests/ha in Control areas. When analyzed separately, New 2 held the highest average nest density during this timeframe at 2.04 ± 0.94 nests/ha.

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 21-Figure 28), as has been reported in past years. Excluding gulls, Common Ravens, American Crows, and Red-tailed Hawks were the most abundant predators observed. At Ravenswood, we frequently observed corvids walking on the pond bottom and flying over the ponds, several times near active Snowy Plover nests (Figure 21a). 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 avian predator, and were primarily observed at A13 (Figure 22a). Red-tailed Hawks, Peregrine Falcons and Northern Harriers were the only raptors observed at Alviso, and were observed infrequently at ponds A13, A15, and NCM. At Warm Springs (A22 and A23), Common Ravens were the most frequently observed predator, with most sightings occurring in A22 (Figure 24a). Red-tailed hawks were the most frequently observed raptor, and were seen with

similar 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 26-Figure 28). Red-tailed Hawks were the next most frequently observed predator at Eden landing. They were especially numerous at the Old Alameda Creek loop (ponds E6A, E6B, and E8) (Figure 27) where they were commonly seen perched on the telephone poles. White-tailed Kites were the third most commonly observed predator, and the most commonly observed predator at pond E14B. Northern Harriers were also commonly observed hunting in pond E14 (Figure 27).

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 2018 breeding season, the landscape cloth was still intact, resulting in no observed raptor nesting within these blinds.

Predator data was not available for the 2018 breeding season for any other regions in RU3.

Mammalian Predators

Red foxes were the only observed mammalian predator at Eden Landing (Figure 26-Figure 28). We occasionally observed Red Foxes at Eden Landing while arriving in the morning for surveys, particularly at the Whales Tail (E12-14) and Old Alameda Creek (E6A, E6B, E8) loops.

DISCUSSION

Population Size

During the May breeding window survey, we counted 235 breeding adult Snowy Plovers, the fourth highest overall since surveys began in 2003 (Table 6). Eden Landing continues to host the majority (60%) of breeding adult Snowy Plover in 2018, as it has since breeding window surveys in RU3 began in 2004. The number of adults counted at Eden Landing remained stable from 2017 (144) to 2018 (142), and may indicate that the Eden Landing population has reached a plateau after the population sharply declined following the E8A breach in 2011.

The percentage of the population observed at Ravenswood ponds decreased from 31% (76 adults) in 2017 to 22% (51 adults) in 2018 (Table 6). Due to the large size and varied texture of these ponds, detection is generally more challenging than other sites in the San Francisco Bay. This is exacerbated by pond conditions in drier years, such as 2018, which result in greater habitat availability and a much larger area to survey. This potential variation in detection ability is a reminder that while the window survey methods allow examination of trends across years

and throughout the Pacific Coast, they merely provide an index of abundance and not an exact number of breeding Snowy Plovers in the San Francisco Bay.

Nest Abundance and Success

In 2018, we found 279 nests in Recovery Unit 3, representing the third highest total recorded since SFBBO began monitoring Snowy Plovers in 2003 (previous high of 341 nests in 2017). For the fifth consecutive year in a row, we found a greater number of nests than the number of adults counted during the breeding window survey. Continued research focus on high activity breeding areas, including brood surveys and chick banding at E14, likely contributed to a high rate of nest detection. However, nest totals should be viewed as an index rather than a precise total since not all successful nests are detected and unsuccessful ones are even more difficult to detect (Mayfield 1975). This is exemplified by our observation of at least 18 broods from unknown nests across the South Bay.

The overall depredation rate within Recovery Unit 3 was 57% (n=279; Table 7). Similar depredation rates were also observed in 2010 (54%; n=252) (Robinson et al. 2010) and 2016 (54%; n = 261) (Pearl et al. 2016). Apparent nest success varied greatly by pond. Across RU3, the ponds with the highest depredation rates (minimum 7 nests) were A22 (78%; n=9), E6B (75%; n=12) and E8 (71%; n=24). The ponds with the lowest depredation rate (minimum 9 nests) were R3 (29%; n=7), R4 (36%, n=11), and E6A (44%; n=9).

Depredation continues to be 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 influencing predator abundance throughout RU3, including accessibility, predator perches, proximity to predator source populations, among other potential causes, is pivotal to creating more successful breeding sites throughout RU3, which will provide greater stability and protect against localized population decline.

Refuge

In an attempt to provide more Snowy Plover breeding habitat in the Alviso ponds, in early May the Refuge cut a notch in the levee between A13 and A15, resulting in the gradual draining of A15. Although slow, this method was effective, as breeding habitat was eventually exposed. In total, four Snowy Plover nests were monitored on A15, of which two hatched and two were depredated. An additional four undetected successful nests were inferred by the presence of unaccounted for broods on the pond. Despite having water diverted into it, A13 hosted a total of three monitored nests, of which one hatched and two were depredated, with an additional two undetected broods identified later. Based upon our monitoring this season, A15 may provide high quality Snowy Plover breeding habitat. However, the first nest at Alviso was not initiated until April 28. The majority of Snowy Plover breeding habitat in Alviso dries out later in the season than other areas, before becoming appropriate habitat. In future seasons, drying out A15 near the beginning of the breeding season, while allowing some habitat to dry out in

A13 during the latter part of the season, may result in Alviso becoming a more productive breeding area.

At the Ravenswood Complex, 30 nests were located and monitored (Table 7). The depredation rate within the complex was 43%, comparable to 2017 (41%; n=83) (Pearl et al. 2018) and 2016 (45%; n=38) (Pearl et al. 2016). The apparent large fluctuations in breeding effort within the complex from 2015-2018 may not reflect the actual breeding effort, but rather changes in habitat availability and resulting detection ability. Over the past four breeding seasons, we observed a large fluctuation 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, 110.1 ha in 2017, and 307.5 ha in 2018 and we recorded 54, 24, 59, and 20 nests during that same time frame each year, respectively. 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, statistical significance can't be confidently determined. This aligns with our perceived low detection ability within the Ravenswood complex, particularly at R4 and R3, the 5th (121.3ha) and 7th (115.0 ha) largest Snowy Plover breeding ponds in RU 3. The highly textured nature of these two ponds further reduces detection ability throughout both ponds. Thus when habitat availability is greater, Snowy Plovers will spread out and use more of the pond, and as a result, our detection ability goes down. Among all ponds in RU3, broods from undetected 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 2018, we observed 2 unknown broods at R3 and 4 unknown broods at R4 (Table 8).

At RSF2, we found and monitored ten nests (down from 32 in 2017; Table 7), all of which were located within cell U3 (Figure 29). Zero Snowy Plover observations were made in the other cells of RSF2, which consist of flooded pond and islands. Three undetected successful nests were inferred by the presence of unaccounted for broods (Table 8). In comparing the previously mentioned habitat availability for nearby ponds R3 and R4 to the number of nests found in RSF2 over the same time period, a similar negative correlation was observed. During wet years, a large number of nests were observed in RSF2 (29 in 2015, 32 in 2017), while in dry years, relatively few nests were found (13 in 2016, 10 in 2018). RSF2 U3 has a smoother texture compared to R3 and R4, and with levees surrounding the cell on three sides, we feel confident in our ability to adequately survey the pond. Therefore, the observed trend in pond nest site selection suggests that when available, R3 and R4 may provide higher quality breeding habitat for Snowy Plovers in the Ravenswood Complex. Unlike RSF2, R3 and R4 do not have large power towers or telephone poles in or nearby to them, thereby reducing the number of perches for avian predators. Ponds R3 and R4 are completely surrounded by a ditch full of water, which may reduce the threat of mammalian predators. While RSF2 U3 does have a ditch that completely surrounds the pond, there is a PG&E boardwalk that provides access to the pond. The boardwalk is gated on the north side, but not on the south side, providing mammals with easy access to the pond. Red fox scat was observed on this boardwalk in 2018, indicating that mammals do hunt on the pond.

With the impending tidal restoration of pond R4 in the Ravenswood complex as part of Phase 2 of the Project, approximately 27% of currently available Snowy Plover breeding habitat in the complex will be opened to tidal action. Based upon the large amount of Snowy Plover nests found in the complex in some years, we expect that post-restoration, R3 and RSF2 will consistently host a higher number of Snowy Plover nests. At R3, improving nesting habitat will be critical. This could include removing predator perches on the pond, spreading oyster shells, gravel, or other materials to increase crypsis, and providing vegetative cover for broods in foraging areas. At both R3 and RSF2, it will be imperative that water levels are managed appropriately to prevent extensive vegetative growth and to provide quality foraging habitat throughout the season.

For the second consecutive year, we confirmed Snowy Plover breeding activity at Hickory (Newark Slough Mitigation Bank), located directly next to pond NPP1 in the Dumbarton Pond complex. This site, owned by Wildlands Inc., was monitored throughout the season for Snowy Plover breeding activity. Over the course of the season, two nests were monitored, with one hatched and one depredated (Table 7), and at least one successful nest went undetected based upon brood sightings (Table 8). Although Hickory is a marsh mitigation bank and will eventually be opened to tidal action, in the meantime the degraded, dry marsh serves as suitable Snowy Plover breeding habitat. With minimal habitat management and enhancement, such as removing dense and tall vegetation from the pond and levees, Hickory could serve as a moderate quality breeding site for Snowy Plovers until it is restored to tidal action.

Two nests were monitored in A3N, both of which were depredated (Table 7). Snowy Plover breeding activity was last observed at A3N in 2015; 2018 marks only the second time that breeding activity has been observed since 2003. A3N provides poor quality Snowy Plover breeding habitat for several reasons. The pond contains eleven large power towers and three PG&E boardwalks, upon which Peregrine Falcons, Red-tailed hawks, and Common Ravens were consistently observed perched on (Figure 23). Water levels within this pond fluctuate with A3W, with which it is hydrologically connected via a dysfunctional water control structure. During the middle of the breeding season, high temperatures and lower high tides may result in portions of A3N becoming exposed, as was the case during 2018. However, when higher tides return, water levels will rise, potentially inundating Snowy Plover nests in A3N. This situation occurred in 2018, however inundation of an active A3N nest was avoided by fully opening the discharge gates at A3W. Lastly, because A3N is inundated for most of the year and has no high elevation areas, there is no plant growth on the pond, and thus no areas for Snowy Plover broods to hide. In future years, we recommend ensuring water levels are high enough in A3N to preclude Snowy Plover breeding.

On NASA-ARC and MROSD land, five nests were monitored on Crittenden Marsh West, of which three hatched and two were depredated (Table 7). One additional brood was seen on the pond (Table 8). Snowy Plover breeding activity was last observed at Crittenden Marsh in 2015 (Pearl et al. 2015); 2018 marks the third time that Snowy Plover breeding activity has been observed

at Crittenden Marsh since 2003. In 2018, NASA-ARC began environmental remediation of a raised peninsula within Crittenden Marsh West, which required dewatering the pond. As a result, a moderate amount of the dry area was available for Snowy Plover nesting. Following observation of Snowy Plover breeding behavior during the breeding window survey, SFBBO began weekly coordination with NASA-ARC and California Environmental Services, the biological consulting firm on site, to ensure minimal disturbance to breeding Snowy Plovers.

Two of the nests monitored at Crittenden Marsh West were located unusually close to the remediation site (≈90m). Although Snowy Plovers in the San Francisco Bay have been observed flushing at a distance up to 174.9m when approached by trail walkers (Robinson 2008), SFBBO staff determined that the two incubating females were not flushed by the nearby remediation activities. While there is no clear explanation for Snowy Plovers selecting nest sites near the remediation site, it may be that the construction activity deterred avian predators from hunting in the immediate area, thus providing a benefit to the nearby Snowy Plover nests. All remediation activities occurred on the raised peninsula and were contained by a wildlife exclusion fence, ensuring that broods could not walk onto the remediation site.

Eden Landing

In contrast to the previous four years, ponds E12 and E13 were used by breeding Snowy Plovers with low frequency, hosting three and seven Snowy Plover nests, respectively (Table 7). Nests in these ponds experienced mixed success, with an apparent hatch rate of 67% (E12) and 29% (E13). USDA Wildlife Services (the predator management professionals on site) confirmed an active den located in the E13 saltworks, and red fox tracks on the E12/13 levee and adjacent berms (M. Bigelow, pers. comm.). Two Snowy Plover nests were found on the levee and berms, both of which were depredated. The consistent presence of red fox could have deterred Snowy Plovers from using these areas. It may be that Snowy Plovers selected to nest in E14, which provides high quality habitat, rather than nest in the marginal habitat provided by the levees and berms.

In 2018, E6C and E6 were used sparingly by breeding Snowy Plovers (Table 7). In recent years, these and ponds E11 and E4C have provided a moderate amount of decent quality breeding habitat for Snowy Plovers.   Use of these ponds by breeding Snowy Plovers may be increased by removing derelict structures to prevent predators from perching, and removing vegetation to increase Snowy Plover predator detection. Drying out the ponds early in the season and hazing foraging gulls may also improve Snowy Plover breeding. Rotating which ponds are managed specifically for Snowy Plover breeding year to year may reduce the tendency of predators to key in on breeding areas.

Nesting Islands

We monitored five Snowy Plover nests on nesting islands in E12 and E13, finding an apparent hatch rate of 40%. Zero Snowy Plover nests were found on nesting islands at A16 or RSF2, and Snowy Plovers were not observed on these islands. These findings suggest that Snowy Plovers preferentially select nesting habitat on large, dry pond bottoms rather than nesting islands. The

larger size of dry pond bottoms may provide more escape time and reduce predator detection for incubating adults flushing in response to approaching predators than the smaller nesting islands. 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. However, larger sized islands may be more attractive to breeding gulls, and smaller islands have been recommended for other breeding shorebirds and terns in the South Bay (Ackerman et al. 2014).

North Bay

For the second consecutive year, zero Snowy Plover breeding was documented in the North Bay. Least Tern colonies at both Montezuma Wetlands and Napa-Sonoma Marshes Wildlife Area experienced complete reproductive failure, with zero nests hatched at either location (A. Wallace and K. Taylor, pers. comm.). Snowy Plovers were reported during the breeding window survey at Napa-Sonoma Marshes Wildlife Area.

Habitat Outside SBSPRP

Identifying and improving Snowy Plover habitat outside of the Project footprint will be critical to reaching the RU3 population goal of 500 adults. Crittenden Marsh is the only site outside of this footprint in the South Bay that was active in 2018. There is anecdotal evidence of Snowy Plover breeding along Hayward Shoreline. Other areas that have supported Snowy Plover breeding in the past include New Chicago Marsh (NCM) in Alviso and Patterson Pond in the Coyote Hills ponds. Some of these areas, or other as yet identified areas, could potentially be managed and enhanced to provide additional habitat for Snowy Plover breeding.

Crittenden Marsh Habitat Usage

As habitat in Crittenden Marsh West (CMW) and East (CME) dried out over the course of the season, moderate numbers of Snowy Plovers were observed in both ponds. At CMW, flock sizes in August averaged 14 adults, with a high of 34 adults observed on August 26 (Figure 15). These flocks also included two broods that fledged five chicks, including two that were color banded. At CME, flocks of 8 adults were observed in late July and early August, and a high of 16 adults was observed on September 10. In addition, occasional citizen science reports indicate that a flock of at least 8-10 individuals continued to use CME and CMW as wintering habitat following the 2018 breeding season (ebird 2018). While some of the exposed habitat that these flocks used was a direct result of dewatering the pond for remediation, removal of the peninsula, measuring approximately 1.75 ha in size and 4 feet in height, will likely provide additional available breeding habitat for Snowy Plovers. Removal of the peninsula may also increase the ability of breeding Snowy Plovers to detect approaching predators, which would increase the effective size of the available habitat. Therefore, Crittenden Marsh may host more consistent Snowy Plover breeding activity in future breeding seasons.

Interspecies Aggression

The 2017-18 rainy season was relatively dry, and there was a high amount of nesting habitat to begin the breeding season. We did not witness the aggressive interspecific interactions

between Snowy Plovers and other breeding species that we saw in 2017, which was a relatively wet year with correspondingly less nesting habitat. In 2018, only four incidences of breeding species interactions were recorded, all between Snowy Plovers and Least Terns at E14 (Table 13). There appeared to be ample habitat in nearby ponds, yet these two species chose to nest in loosely mixed colonies. At all four nests, Snowy Plovers and Least Terns intermittently displayed aggression towards each other with no apparent injury to eggs, chicks, or adults of either species.

In future years, low habitat availability caused by high precipitation or tidal marsh restoration may result in aggressive interactions between nesting species. The effect of these interactions on the breeding success of Snowy Plovers and other species should be further studied.

Chick Fledging Success
The apparent fledging rate within Recovery Unit 3 decreased from 44% in 2017 to 19% in 2018 (Table 11); however our sample size is small. At E14, 23 chicks were banded, with four confirmed as fledged (Table 12). We consistently observed older (unbanded) chicks, defined as two to four weeks old, between May 21 and September 4. Snowy Plover chick survival increases with age, especially between the time of hatching and ten days old (Dinsmore et al. 2017). The large amount of older chicks consistently present at E14 suggests that the fledging rate within E14 was likely higher than ascertained from our band resighting efforts.

We also banded a three chick brood at E8 and two chicks from a three chick brood at E6B. These chicks were not resighted after being banded. Our ability to re-sight Snowy Plover chicks in the ponds is limited by uneven topography/substrate spanning a large and complex network of ponds, sloughs, and channels. These factors, in combination with heat waves and long scoping distances create difficult conditions for locating broods, and identifying and reading bands. This is illustrated by a three chick brood that was banded at CMW. Although broods were observed at CMW on a weekly basis, it was not until we conducted a walking band resighting survey on the pond that two of the three chicks were confirmed as fledged.

Banding a small subset of hatched chicks in a few ponds limits our ability to accurately estimate fledge rates, both within those ponds or in RU3 as a whole. Ponds vary greatly and survival rates likely differ greatly among them. SFBBO staff were limited in 2018 by a lack of band combinations and qualified Snowy Plover banders. In 2019, we will have more band combinations available to use and plan to train additional staff to assist in banding. In the future, increased and consistent banding at significant breeding ponds will help improve our estimates of chick fledging success. In addition, use of radio telemetry or GPS tagging to track adult males with broods may help improve the accuracy of plover fledging success estimates, but will also require increased resources to implement. Regardless of the methods used, we must carefully balance the need for more intensive monitoring with the potential impacts caused by increased disturbance to Snowy Plovers.

Oyster Shell Habitat Enhancement

Large Scale Enhancement Study
The implementation of large-scale oyster shell enhancement at pond E14 in Eden Landing allowed us to test the efficacy of oyster shells as camouflage for nesting Snowy Plovers. Overall nest abundance throughout the pond, and nest density in enhancement plots New 1 and New 2 were substantially higher in 2018 when compared to pre-enhancement conditions (prior to 2015). Nest abundance and density patterns in 2018 were also similar to the first three years of the enhancement (2015-2017), and overall water levels and management in nearby ponds were comparable. This suggests that large-scale oyster shell enhancement was the primary factor in the rise of nest abundance and density in 2015-2018.

We found evidence to suggest that Snowy Plover breeding behavior and success was influenced by the presence of a California Least Tern colony at E14, although the effect on success was opposite to 2017. After Least Terns established a colony in 2018, the apparent hatch rate for snowy plover nests declined from 56% (n=41) to 34% (n=104). In 2018, Least Terns began nesting at E14 on May 14, 2.5 weeks earlier than 2017 (June 1 in 2017), and over twice as many Least Terns attempted to nest in 2018 (45 pairs) compared to 2017 (21 pairs). The greater number of Least Terns in the area may have attracted the attention of more predators, including red fox. Although red foxes are seen frequently at Eden Landing, they had not been documented by cameras as a significant nest predator at E14 until 2018.

Using RMark to conduct a Nest Survival Analysis (Laake & Rexstad 2008), we found the constant Daily Survival Rate (DSR) of Snowy Plover nests at E14 to be 95.1%. No significant effects were observed between time, distance, or enhancement plot and DSR.

After four years of monitoring the large scale oyster shell enhancements, we have seen increased nest density in Snowy Plovers and attracted Least Terns. In 2018, we had the highest count of Snowy Plover nests within E14, with 1.5 times more nests found in the pond than the previous high (98 nests in 2015, 145 nests in 2018). However, predators appeared to cue in on areas of high nest density, as has been found at Mono Lake (Page et al., 1983). While our anecdotal observations suggest that the presence of Least Terns may reduce the effects of Common Raven predation of Snowy Plover nests, the potential increase in mammalian predators attracted by their presence may negate any benefits to Snowy Plovers. Consistent predator control must also be implemented each year.

Monitoring and research should continue at the E14 enhancement site. A larger data set will strengthen the power of our analyses and document how various factors affect Snowy Plover breeding in the pond. Consistent monitoring will document how Snowy Plover use of the enhancement site changes over time, a critical piece of knowledge to inform future restoration efforts within Recovery Unit 3 and across the Pacific Coast.

Additional Considerations.

As the amount of available Snowy Plover nesting habitat around the South Bay is reduced due to tidal marsh restoration, Snowy Plover nesting density will need to increase in order to maintain or increase breeding numbers within a smaller habitat footprint. Shell plots are one way to achieve the higher nest densities. However, the efficacy of oyster shells degrade over time, and 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. The closing of Drake's Bay Oyster Company in Marin County in 2014 means that large amounts of local oyster shells are no longer available, necessitating the need for an alternative source. In San Francisco and the North Bay, The Wild Oyster Project has established an oyster collection and curing program. Establishment of 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 along the Eel River (Colwell et al. 2011), at Point Reyes (L. Stenzel, pers. comm.), and in RU3, 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.

Avian Predators

Common Ravens were the most consistently observed predator at ponds throughout Recovery Unit 3 in 2018. At E14, trail cameras only recorded ravens depredating nests on two occasions, as opposed to five occasions during 2017 and 30 in 2016 (Table 14). We observed Least Terns mobbing Common Ravens that were in the vicinity of their colony in 2018. The two depredated Snowy Plover nests were located relatively far away from the nearest active Least Tern nest, at 250m and 475 m, respectively. This provides further evidence that Least Terns may provide some protection from avian predators for Snowy Plovers.

We frequently observed Red-tailed Hawks, Peregrine Falcons and Common Ravens perched in transmission towers near Snowy Plover breeding ponds throughout the South Bay. The Refuge coordinated with Pacific Gas and Electric (PG&E) to remove ten Common Raven nests and two Red-tailed Hawk nests in towers over sensitive habitat in the South Bay in 2018. The Refuge will continue to coordinate the removal of nests from towers and boardwalks with PG&E annually (Strong & Schwarz 2018).

The total number of California Gulls nesting in the South Bay was 46,766 breeding birds in 2018, an increase of over 3,000 from the previous year (Tarjan & Heyse 2018). The fourth largest gull colony was found at ponds M4/M5, directly next to ponds A22 and A23. Gulls were frequently observed obtaining nesting material from A22, and could have opportunistically depredated Snowy Plover eggs and/or chicks. To protect nearby nesting Snowy Plover, 307 empty California Gull nests and 29 California Gull nests in the early stages of initiation were removed from the AB2 levee. No gulls attempted to nest on the A22/23 levee for the first time since 2015.

Mammalian Predators

In 2018 red foxes were recorded depredating 10 Snowy Plover nests at E14 (Table 14), and were likely responsible for many of the depredated Least Tern nests as well (Pearl & Wang 2018). At E8, red fox tracks were observed on the pond throughout the season, indicating that they may have also been responsible for the low apparent nest success at that pond as well. While consistent predator control and the presence of a borrow ditch at many sites may reduce the future likelihood of red fox predation on Snowy Plovers, several ponds are easily accessible by land, including A22, A23, RSF2, and parts of NCM.

Restoration and Snowy Plover Nesting

The majority of RU3's Snowy Plover nesting habitat is located within the South Bay Salt Pond Restoration Project area. The Project aims to restore large areas of former salt ponds to a mix of wetland habitats, including managing former salt ponds as managed wildlife ponds. One of the Project's long-term goals is to support 250 breeding Snowy Plover adults within the Project area (USFWS and CDFW 2007). 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 pond R4 in the same complex, we recommend that nesting habitat enhancement 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 at R4, we recommend further enhancement of RSF2 for Snowy Plover breeding, potentially including spreading of a camouflage enhancing substrate (oyster shells, gravel, etc.) and removal of remaining predator perches. During construction, we strongly 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 therefore decreasing conflict between plovers and construction activities. When possible, these ponds should be drawn down before the start of the breeding season.

We recommend converting ponds to tidal action slowly, and studying the impacts to breeding Snowy Plovers and other ground nesting species that use ponds. Four of the ponds opened to tidal action or converted to other management regimes historically hosted moderate to large numbers of Snowy Plovers (A8, E12-13 and E8A; Figure 30-Figure 36). 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. The breeding population in RU3 has grown slightly in the years following completion of Phase I activities. Reducing the amount of habitat available to nesting Snowy Plovers may impact breeding success as nest densities increase. In 2015, SFBBO documented brood aggression and high nest abandonment rates. In 2016, it appeared that Common Ravens, keyed in on the high nesting density at E14, resulting in high nest depredation. In 2017, a wet winter resulted in relatively little available breeding habitat to start the season, and we observed frequent interspecies

aggression. In 2018, both Snowy Plovers and Least Terns nested in high density and experienced poor reproductive success due to a lack of prior predator control. This provides evidence that Snowy Plovers will need to have quality habitat spread throughout the bay to minimize these effects and allow continued population growth.

Human Disturbance

On several occasions we directly observed or found evidence of humans trespassing in areas closed to the public. At E12-14, a trespasser was observed walking along the Eastern levee near the pump house. The trespasser mentioned that he had walked along the closed portion of the trail on several other occasions. At Ravenswood, pedestrians were occasionally seen trespassing into restricted areas. At R4, a pedestrian walking two off-leash dogs was observed trespassing onto the Bayfront levee. On another occasion, several kids were observed riding bikes near the borrow ditch adjacent to the Bayfront levee, but were gone before SFBBO staff could speak with them. All of these incidents of trespass could have disturbed breeding Snowy Plovers. These incidents were reported to Refuge and Eden Landing staff when appropriate.

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. The western levee at E14 is the most frequently used, as it provides the longest possible route (additional 0.5 miles) as well as birding opportunities and views within the tidal pond E9 and Whale's Tail Marsh. In 2018, seven Snowy Plover nests were located within 145m from potential trail walkers along the western levee, and were found an average of 120±23m from the trail. If Least Terns continue to nest in the shell enhancement plots of E14, their sensitivity to disturbances must also be considered. Prior research in Florida has determined that a buffer of 100m is sufficient to prevent terns from flushing (Rodgers et al 1995). In 2018, one Least Tern nest was located within 100m of the western levee, at a distance of 82m.

Along the lesser-utilized northern levee trail of E14, we found nineteen Snowy Plover nests and fourteen Least Tern nests located an average of 95±35m and 70±25m from the trail, respectively. Due to Least Terns nesting in the New 1 shell plot this year, Least Tern volunteer monitors were initially sent on this northern public trail to monitor the colony. This trail is seasonally shortened to 0.25 miles to protect Snowy Plover nesting habitat. Volunteers noticed that the Least Terns flushed while they walked along the trail and intermittently during their survey. Thus, volunteer monitors were directed to monitor from the western levee where they would not disturb nesting Snowy Plovers or Least Terns. In addition, a Least Tern nest was found on the public portion of the northern levee, the second consecutive year that a nest has been found on this levee (Snowy Plover nest in 2017), indicating that this trail is used less frequently.

Consistent trail use may influence both Snowy Plover and Least Tern 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 better identify the relationship. Accounting for trail use is critical for planned restoration activities at Ravenswood as part of Phase II of the project. Trail use at Ravenswood is already consistently high and access is expected to be expanded. Snowy Plover habitat enhancements should be located at least 150m from trails, public trails limited near available Snowy Plover nesting habitat, and trail segments may be seasonally closed.

Human disturbance not only effects nest success, but can directly impact chick survival (Ruhlen et al. 2003). Part of the design of restoration at R3 and R4 includes barriers that limit pedestrians and cyclists from entering sensitive nesting areas and "chick fencing" (≈2 feet tall, such as is present at RSF2) to keep Snowy Plover chicks off of trails and road. This may also 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

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, disturbance and/or disease, c) discouraging Snowy Plover breeding at ponds with low quality habitat by keeping them flooded
2. Recovery Unit 3 should identify alternative habitat enhancement materials or methods (oyster shell or other) and implement them in areas that will not be flooded on a consistent basis.
3. 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. Based on the number of nests found in the San Francisco Bay in recent years, nearly all 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 must be identified and managed for Snowy Plovers.
4. Construction activities on Snowy Plover nesting ponds should occur outside of the breeding season whenever possible.
    - 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.
    - Actions should be taken to deter Snowy Plover nesting on ponds where heavy equipment will be operating. Focusing the construction in a small footprint and keeping human disturbance constant (5-7 days a week during daylight hours)

may reduce the number of Snowy Plovers attempting to nest in the vicinity of construction.

- 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.

5. The predator management and gull hazing programs should continue in 2019 in the South Bay, with focus on Eden Landing and Ravenswood.

6. At the north end of pond E8 and RSF2 cell U3, efforts should continue to remove 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.

7. At E16B, repair or replacement of the water control structure would allow for better management of the pond, including the prevention of Snowy Plovers nest inundation in low lying areas that are prone to flooding. This action, along with adding interior channels, should be implemented to increase the amount of foraging habitat in the pond.

8. Additional oyster shell or other materials such as gravel at RSF2 cell 3 may facilitate increased nest density, and could reduce depredation risk for young broods. Raising water levels and increasing water connectivity between the borrow ditch and interior channels will create more foraging habitat.

9. Recovery Unit 3 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 bird spikes to discourage predator perching.

10. Recovery Unit 3 should continue to develop a Snowy Plover Outreach Program. Increased outreach and interaction with the public is necessary as more trails near Snowy Plover breeding habitat are opened to the public.

- Continue to station trained docents at public areas adjacent to nesting sites, to provide information on Snowy Plover conservation and disturbance issues and viewing opportunities of nesting birds. This would create public awareness and support for Snowy Plovers, thereby reducing the human disturbance.
- Additional interpretive panels should be placed in public areas to provide information on Snowy Plover habitat needs, disturbances, and conservation issues.
- Law enforcement patrols should be increased in areas with Snowy Plover breeding habitat to minimize human disturbance. This will become progressively more important as additional areas are opened to the public as part of the Project.

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 GPS tags or radio telemetry of chicks and adults to provide more reliable data on Snowy Plover 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. Potential impacts to nesting Snowy Plovers of human disturbance from recreational trail use.
4. Long-term use of E14 large-scale oyster shell enhancement by breeding and wintering Snowy Plovers.
5. Impacts of Common Raven, Peregrine Falcon, and California Gulls on nesting Snowy Plovers and the efficacy of avian predator management on Snowy Plover breeding success.
6. Northern Harrier territory size and habitat use and impacts on nesting Snowy Plovers, especially as tidal marsh nesting habitat increases for harriers.
7. Snowy Plover nesting habitat selection (use versus availability).
8. Methods to improve Snowy Plover nesting use and success on constructed islands.
9. Effectiveness of taste aversion studies in reducing egg depredation by Common Ravens

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. Monthly surveys should continue to include scouting components to visit areas that are not consistently used by breeding Snowy Plovers, including Patterson Pond in Coyote Hills, Frank's Dump in Hayward, Crown Beach in Alameda, 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.
3. Monthly surveys in the North Bay should be conducted to better document Snowy Plover breeding effort.

ACKNOWLEDGEMENTS

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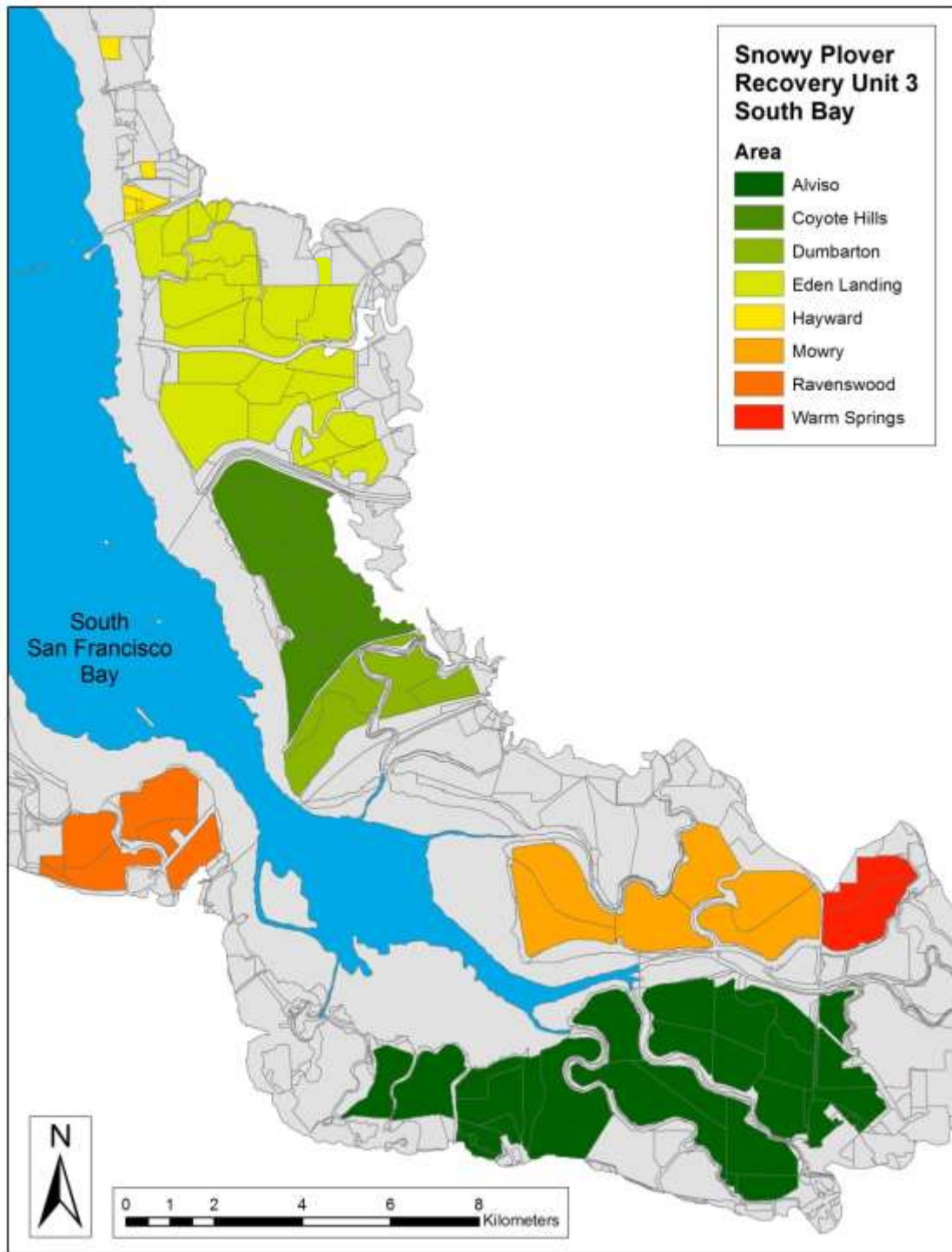
Figure 1. The Don Edwards San Francisco Bay National Wildlife Refuge, CDFW's Eden Landing Ecological Reserve, East Bay Regional Park District and Hayward Area Recreation and Park District lands in the South San Francisco Bay, California.
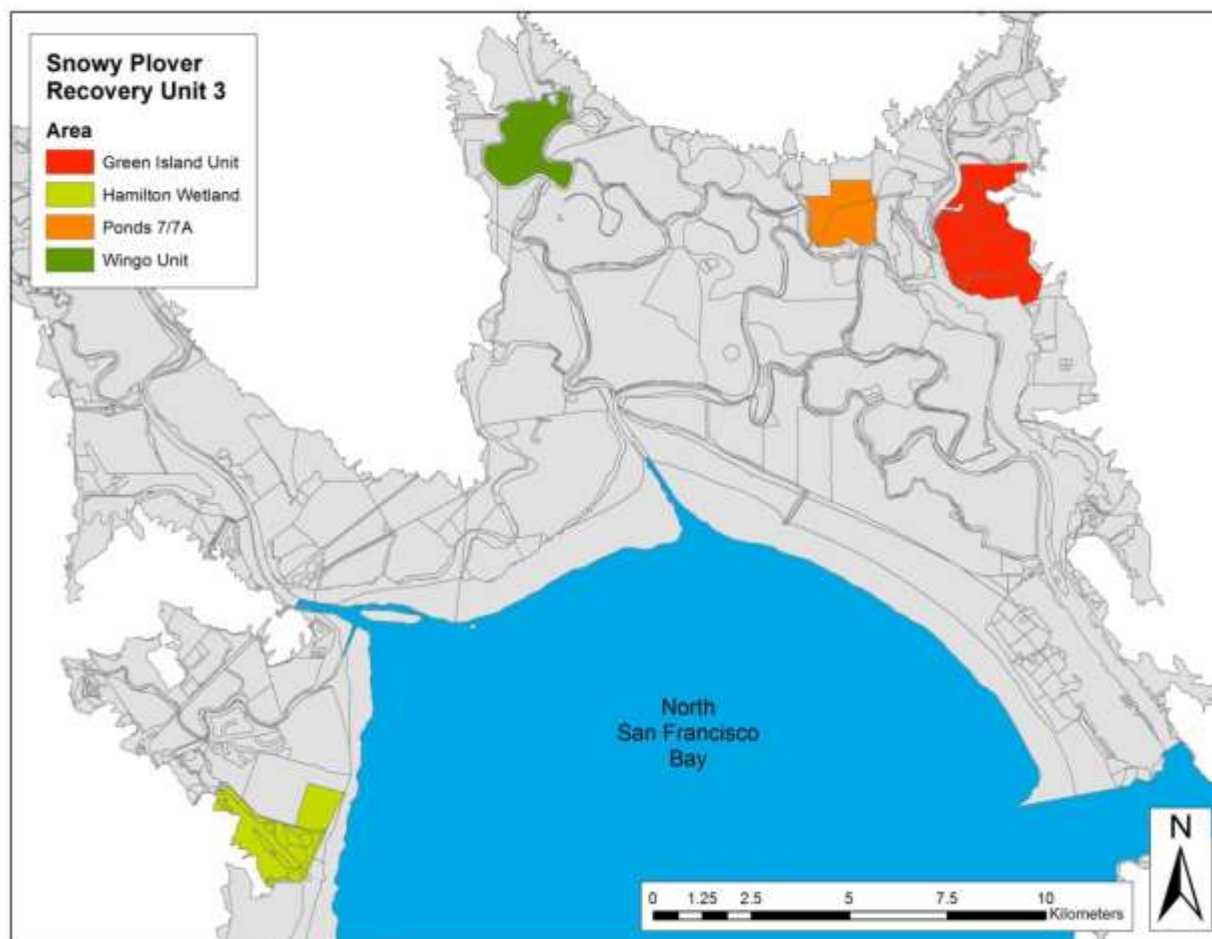
Figure 2. Snowy Plover nesting areas in the CDFW's Napa-Sonoma Marshes Wildlife Area: the Wingo Unit, ponds 7/7a, and the nesting islands at the Green Island Unit (formerly called the Napa Plant Site); Coastal Conservancy's Hamilton Wetlands, North San Francisco Bay, California.

Figure 3. Ponds located in the Refuge's Warm Springs area, near Fremont, South San Francisco Bay, California. See Figure 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 Figure 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 Figure 1 for location of Ravenswood within South San Francisco Bay.

Figure 6. Ponds in the Refuge's Dumbarton Complex, at the east end of the Dumbarton Bridge, South San Francisco Bay, California. See Figure 1 for location of Dumbarton within South San Francisco Bay.

Figure 7. Ponds in the CDFW's Eden Landing Ecological Reserve, near Hayward, South San Francisco Bay, California. See Figure 1 for location of Eden Landing Ecological Reserve within South San Francisco Bay.

Figure 8. Close-up of Hamilton Wetlands, Novato, CA. The northern seasonal wetlands, which may remain suitable for Snowy Plover breeding, are outlined in red.

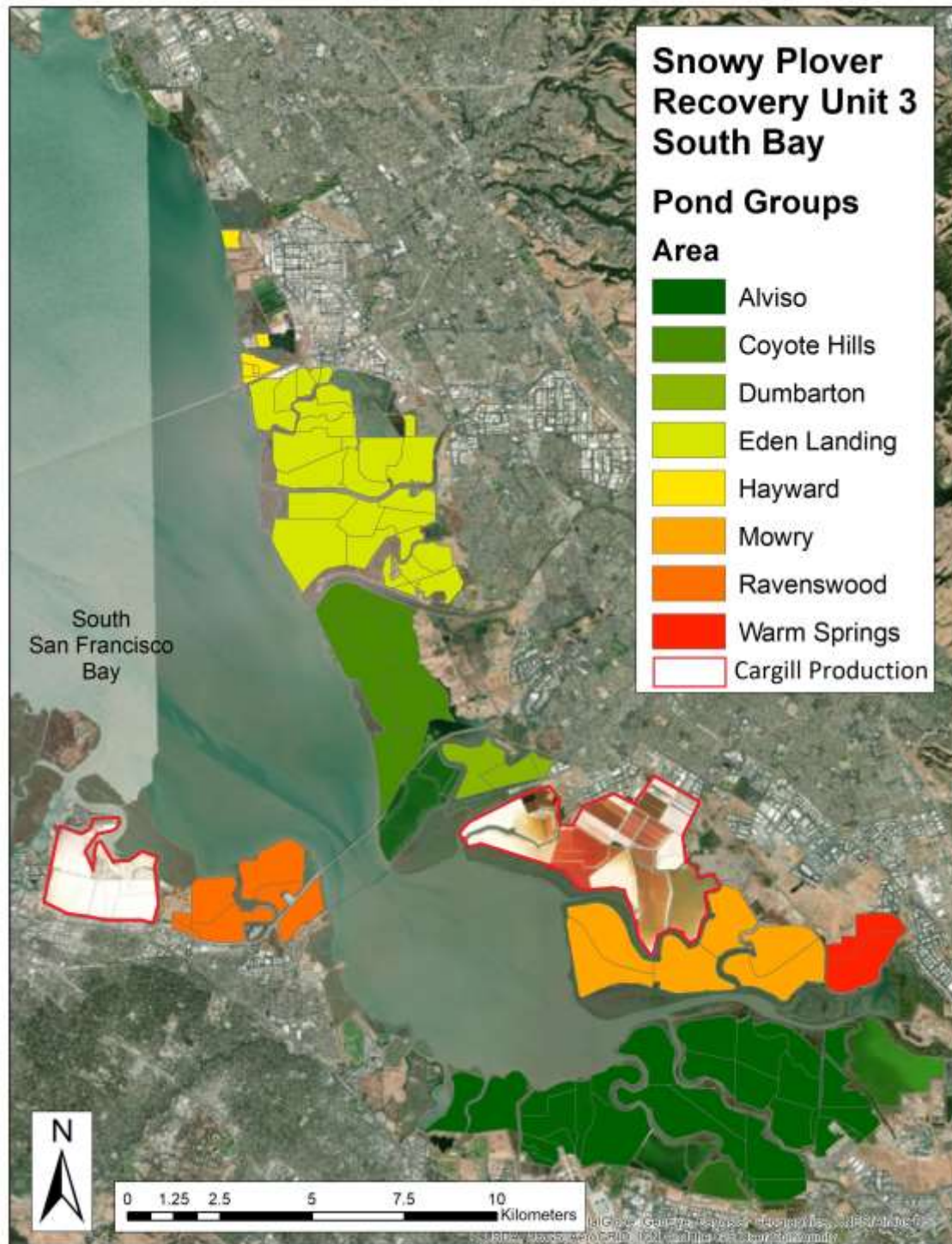Figure 9. Montezuma Wetlands Project Site location in Suisun County, CA.

Figure 10. Cargill salt production ponds in relation to other pond groups, South San Francisco Bay, CA. The Redwood City plant is located west of the Ravenswood ponds, while the Newark plant is located north of the Mowry ponds.
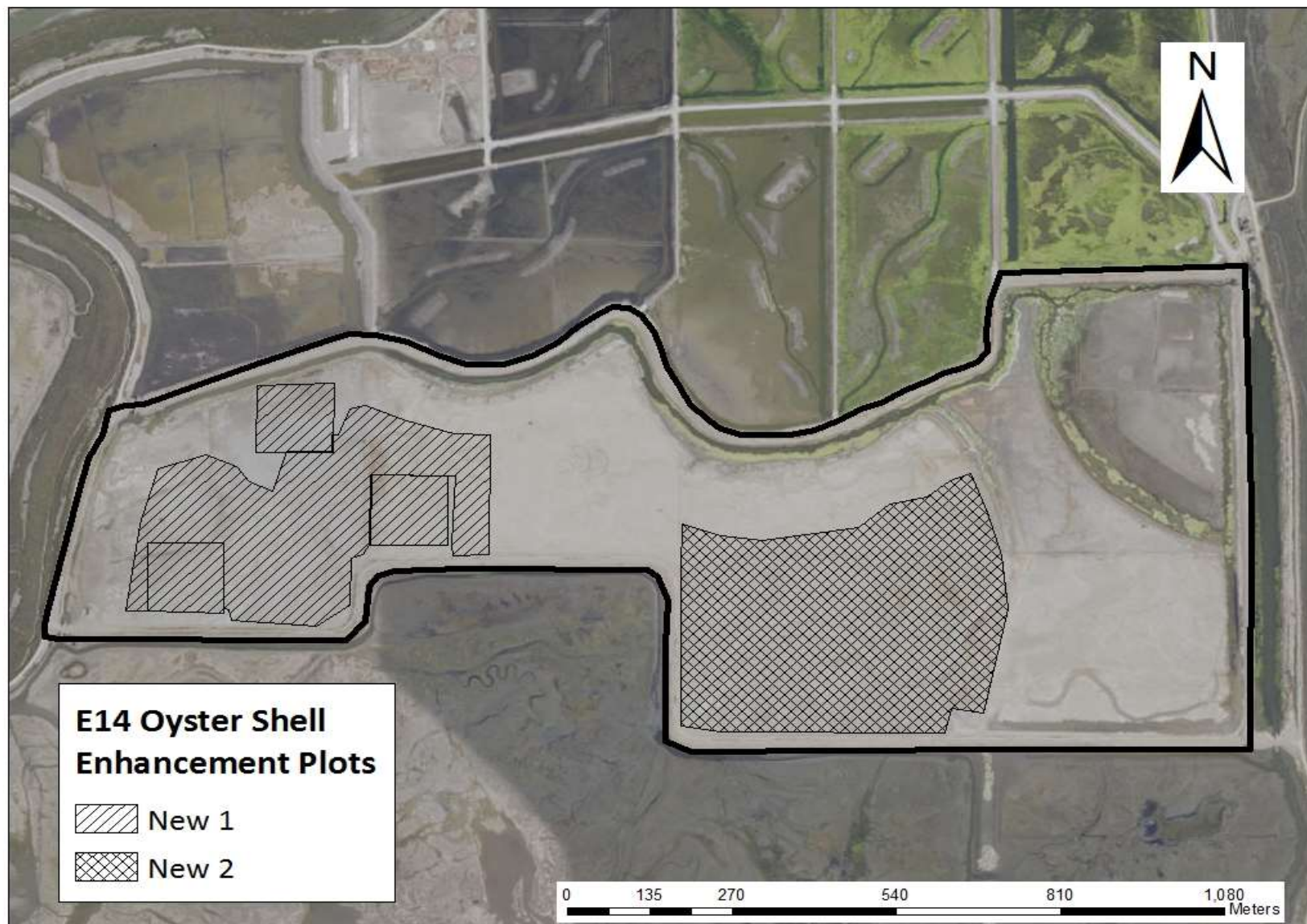
Figure 11. Oyster shell enhancement plots at Pond E14, Eden Landing Ecological Reserve, Hayward, CA.
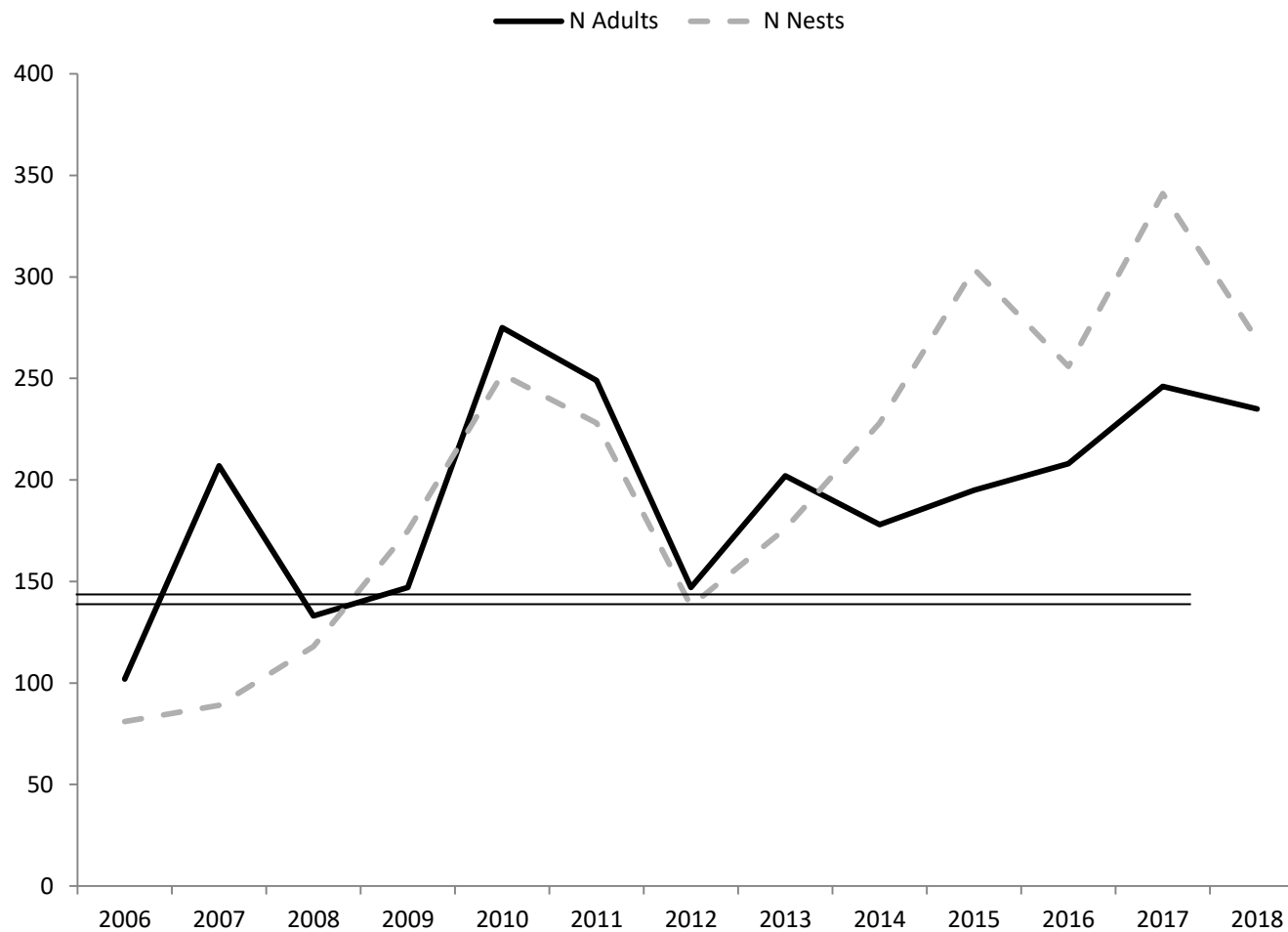
Figure 12. The total number of Snowy Plover adults counted during the breeding window survey and the total number of Snowy Plover nests counted during the season in all regularly monitored Recovery Unit 3 (RU3) areas, San Francisco Bay, from 2006-2018. The double line indicates the South Bay Salt Pond Restoration Project NEPA/CEQA baseline of 113 breeding adults in RU3, established from the average number of breeding birds from 2004-2006.
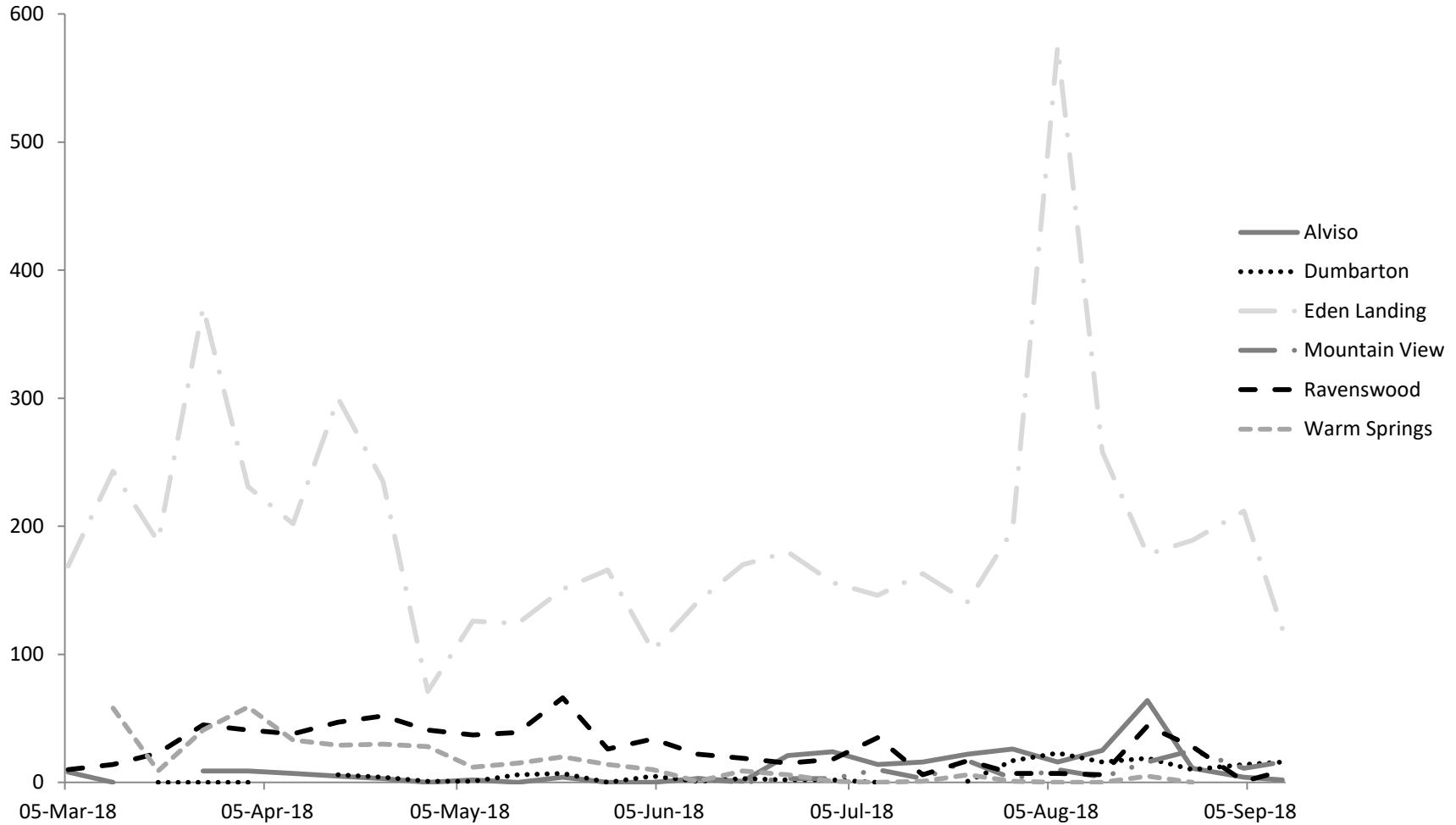
Figure 13a. Weekly counts of adult Snowy Plovers by week and area, San Francisco Bay, California, 2018. Data are presented here for all locations monitored where Snowy Plovers were observed. Note the high number of Snowy Plovers observed in April and September are presumed to be migrating and not breeding in the San Francisco Bay.
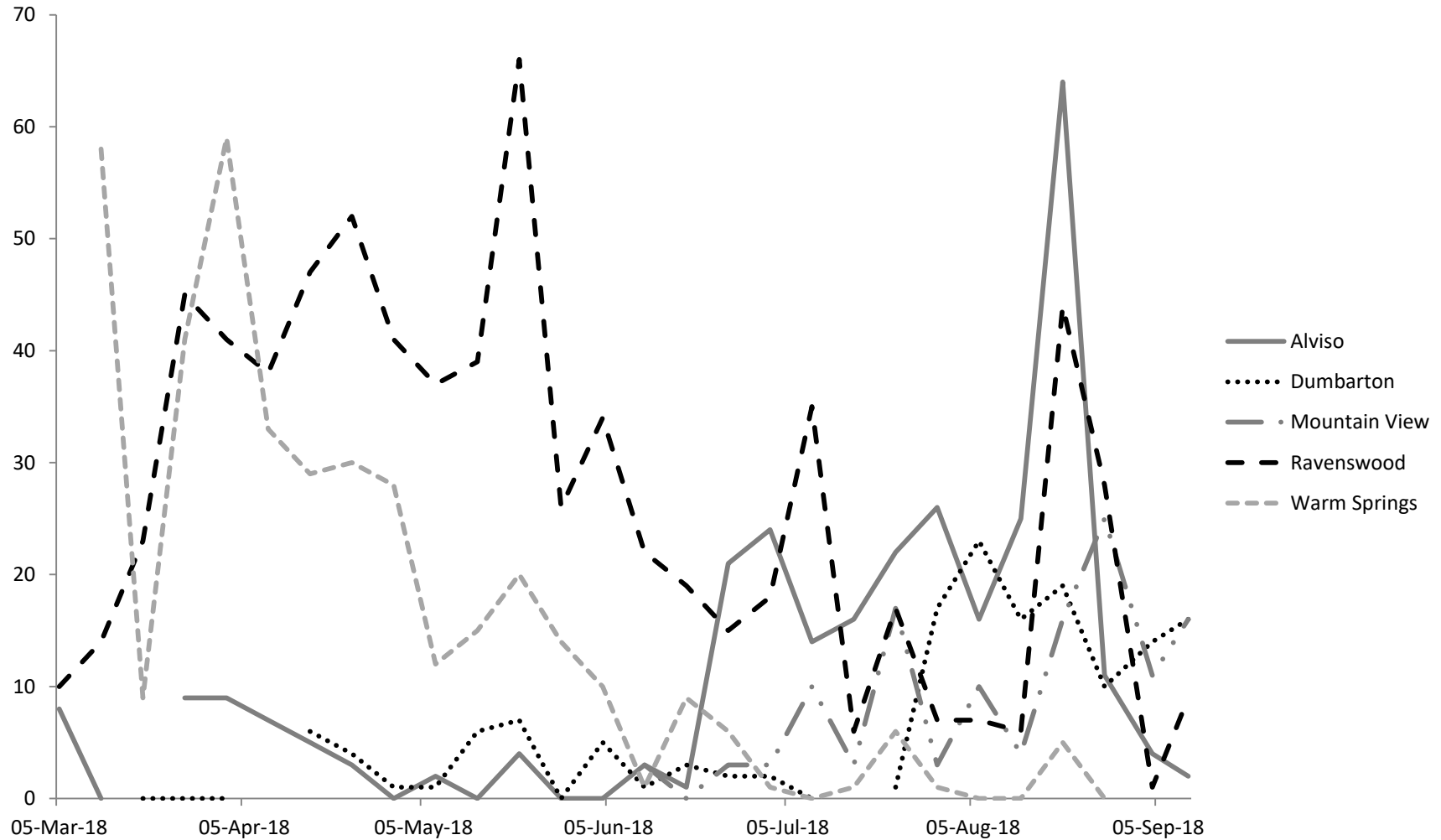
Figure 13b. Weekly counts of adult Snowy Plovers by week and area, San Francisco Bay, California, 2018. To facilitate interpretation, data are presented for all locations monitored excluding Eden Landing. Note the high number of Snowy Plovers observed in April and September are presumed to be migrating and not breeding in the San Francisco Bay.
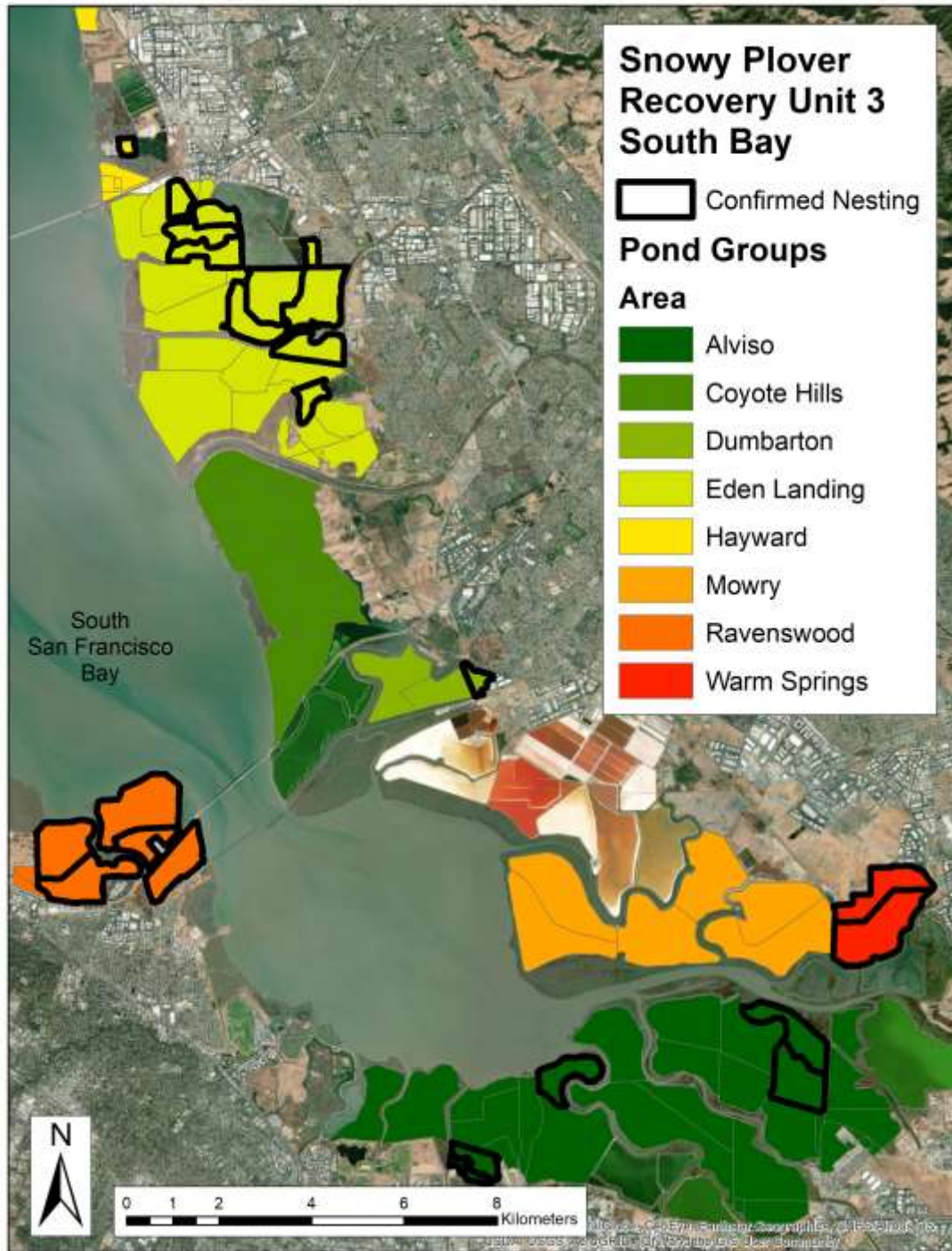
Figure 14. Areas (black outline) with documented Snowy Plover nesting activity during the 2018 breeding season, South San Francisco Bay, California.
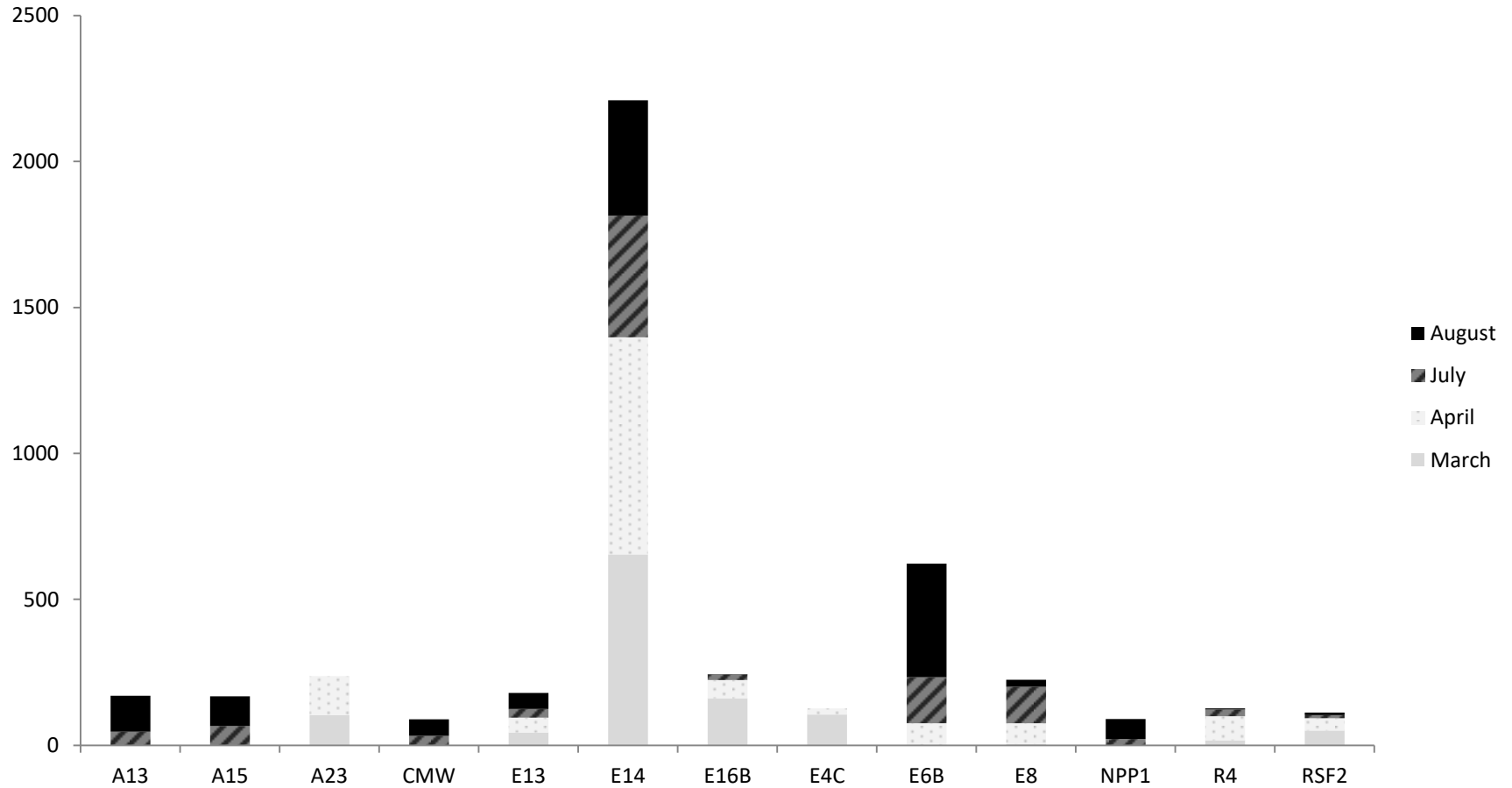
Figure 15. Abundance of adult plovers at significant ponds during March, April, July and August, 2018. The purpose of this figure is to show that ponds are used by Snowy Plovers in varying intensity during the beginning and end of the breeding season.
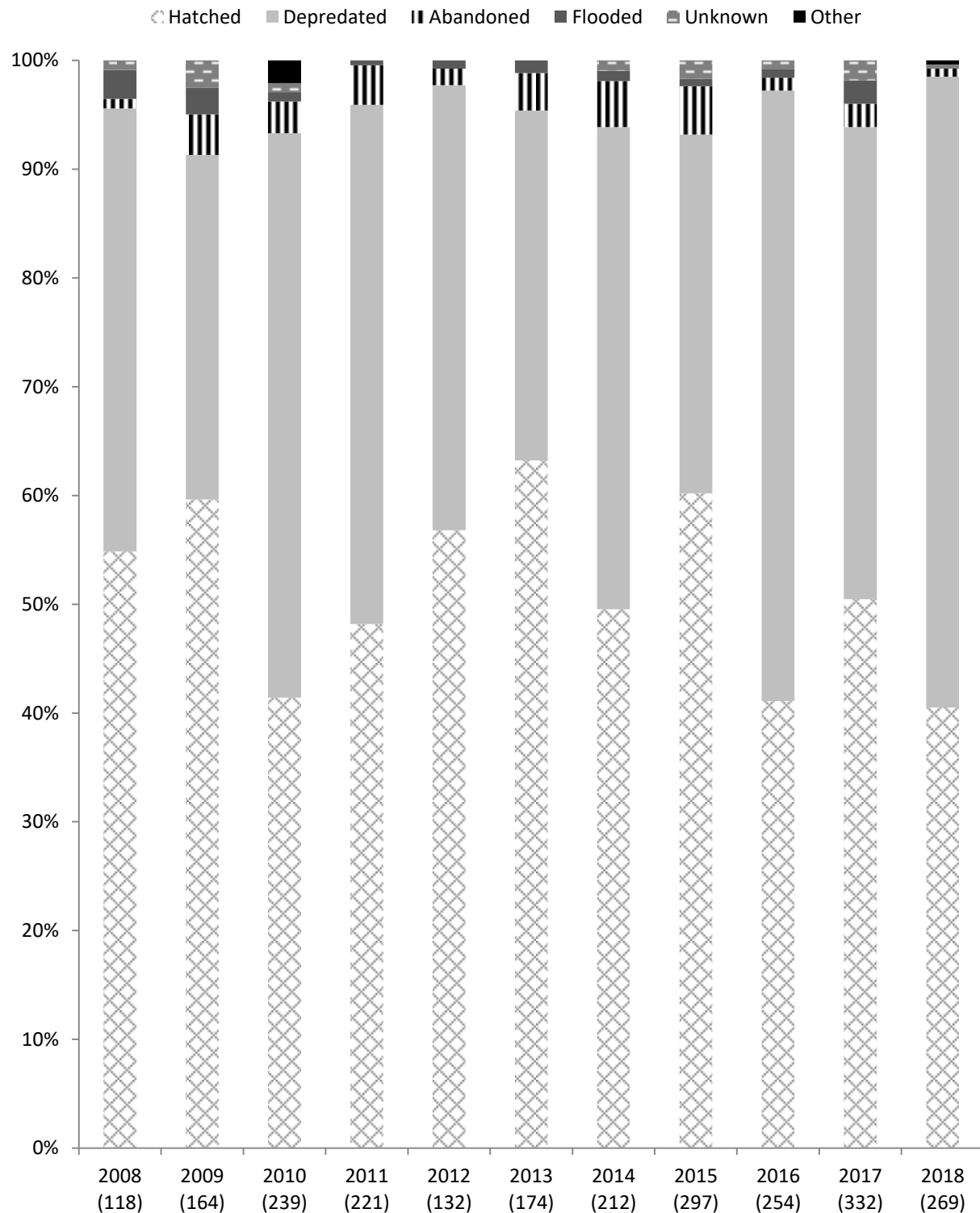
Figure 16. Annual apparent Snowy Plover nest fates in the South San Francisco Bay, California, 2008-2018. The number of nests monitored is indicated in parentheses beneath the year.
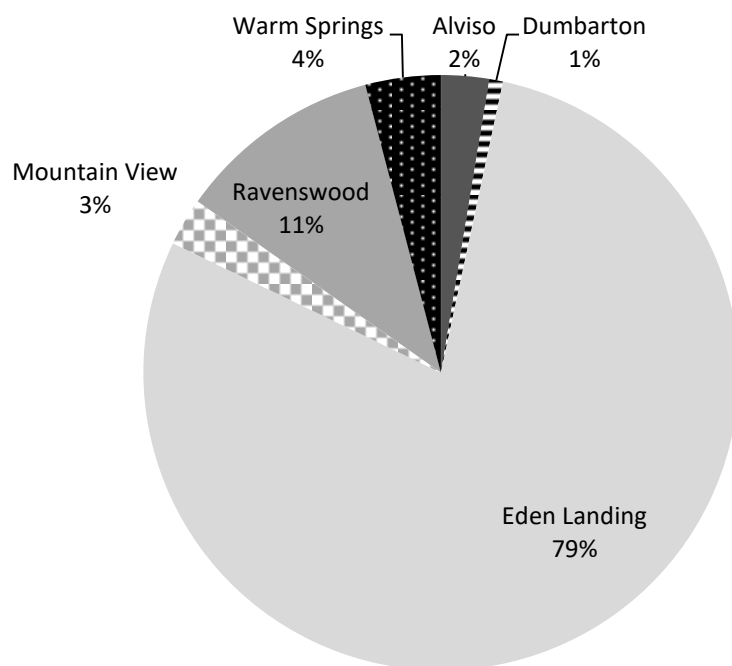
Figure 17. The proportion of Snowy Plover nests found in each pond complex in the South San Francisco Bay, California, 2018.
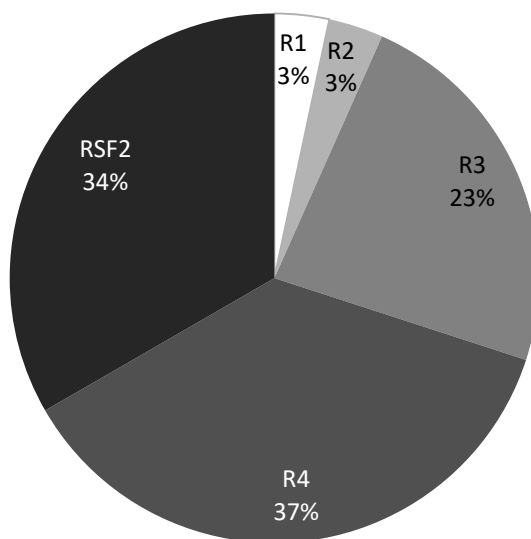
Figure 18. The proportion of Snowy Plover nests found in each Ravenswood pond within the Ravenswood Complex, Menlo Park, California, 2018.
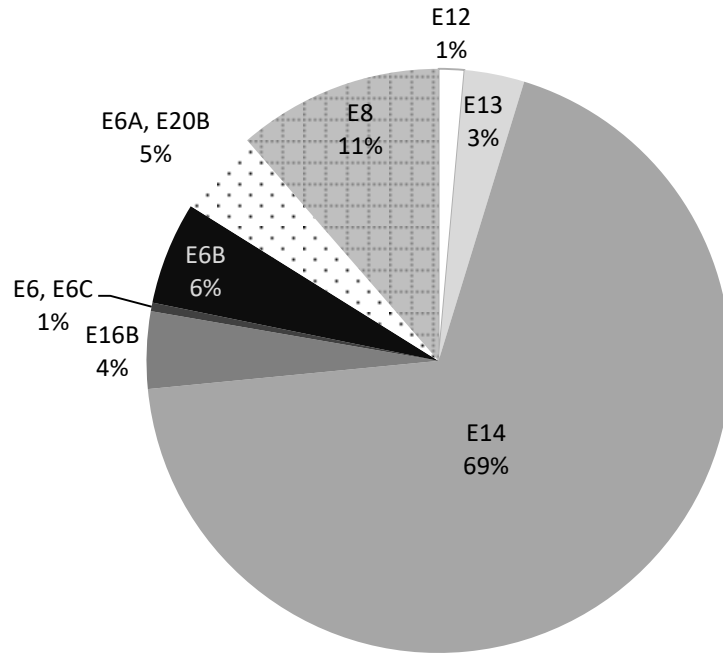
Figure 19. The proportion of Snowy Plover nests found in each Eden Landing pond within the Eden Landing Ecological Reserve in Hayward, California, 2018. Note that 69% of Eden Landing nests were found in pond E14.
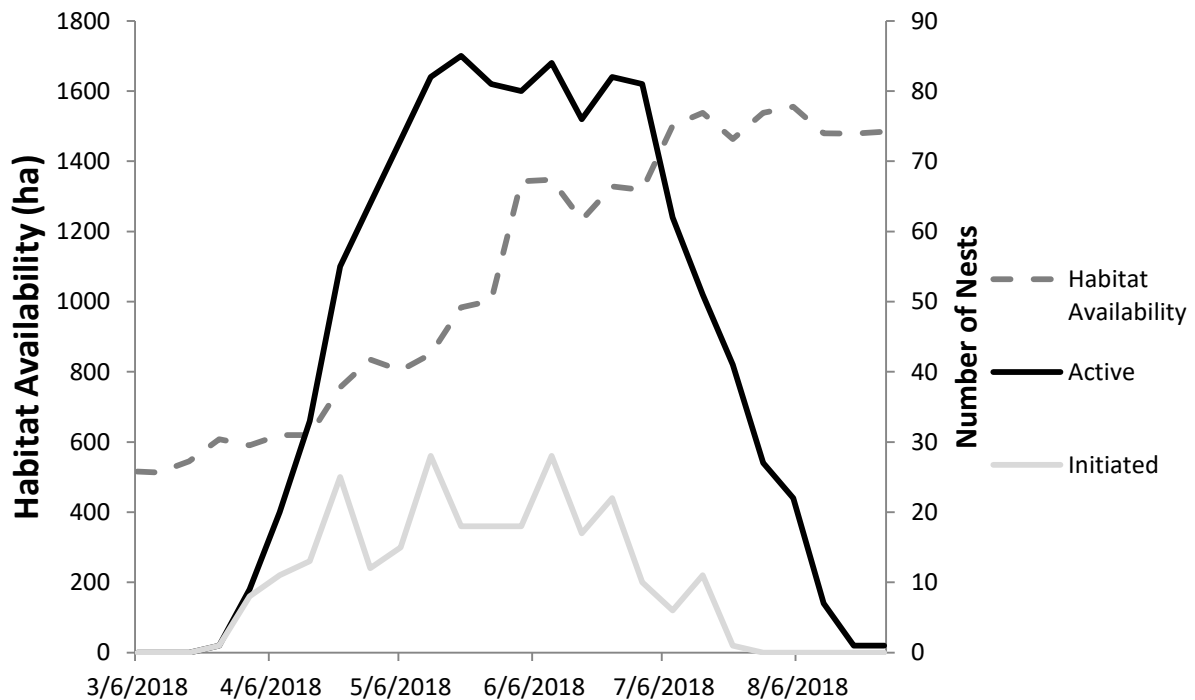
Figure 20. The weekly number of initiated and active Snowy Plover nests and estimated habitat availability in the South San Francisco Bay, California, 2018.

Figure 21. 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-September 2018. Survey sample size is in parentheses next to pond number.
*Includes Ring-billed, Western, and Herring Gulls (in order of average seen per survey)

Figure 22. 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-September 2018. Survey sample size is in parentheses next to pond number.
*Includes Ring-billed, Western, and Herring Gulls (in order of average seen per survey)

a)

b)
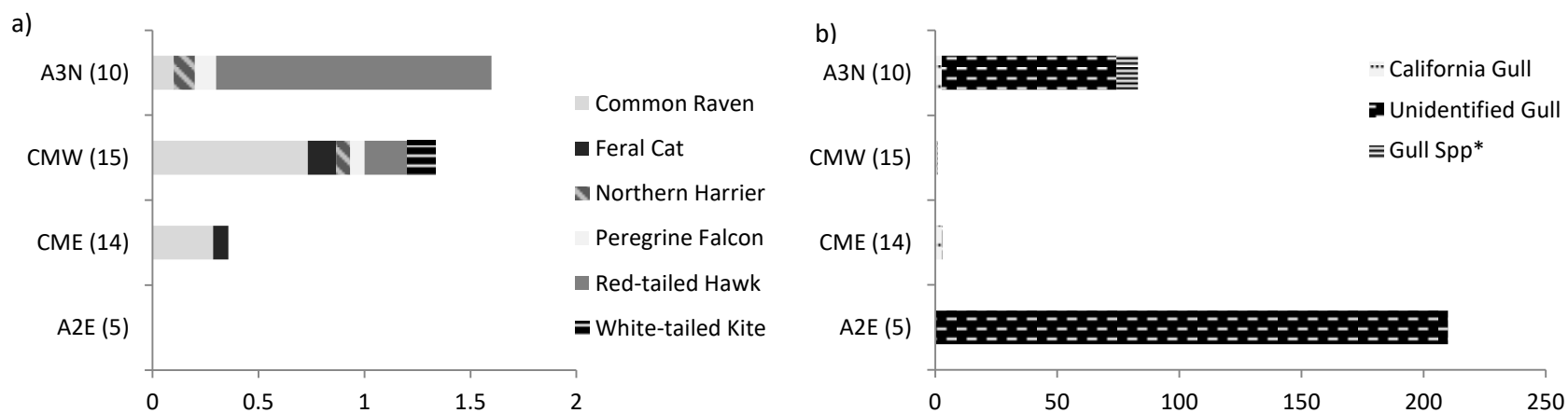
Figure 23. The average number of critical predators a) excluding gull species and b) only gull species, observed per survey at Mountain View Ponds, South San Francisco Bay, California, March-September 2018. Survey sample size is in parentheses next to pond number.
*Includes Ring-billed and Herring Gulls (in order of average seen per survey)

a)

b)
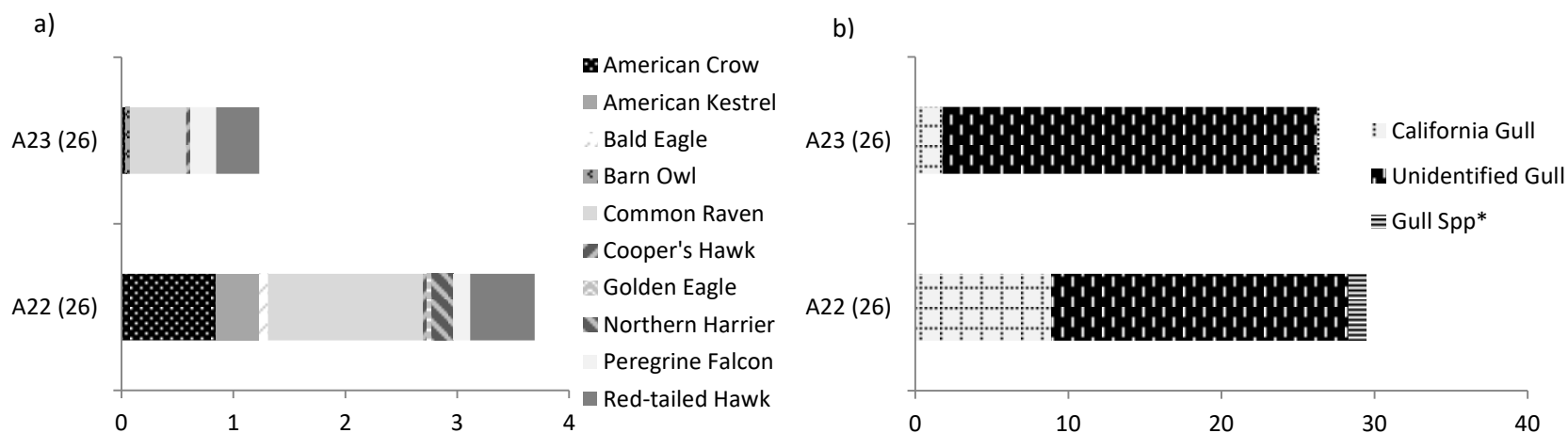
Figure 24. The average number of critical predators a) excluding gull species and b) only gull species, observed per survey at Warm Springs, South San Francisco Bay, California, March-September 2018. Survey sample size is in parentheses next to pond number.
*Includes Western and Herring Gulls (in order of average seen per survey)
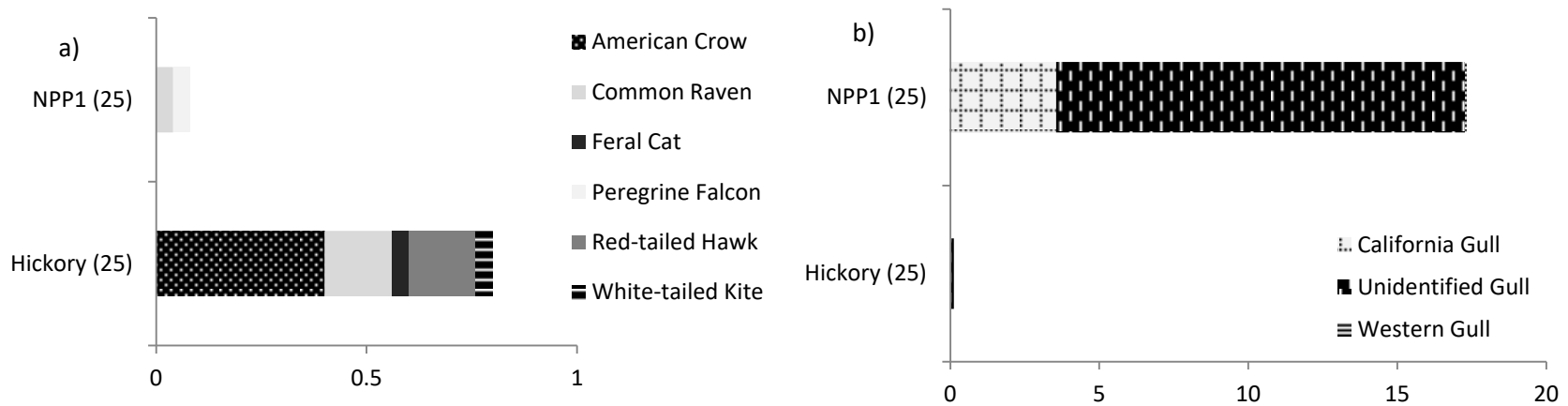
Figure 25. The average number of critical predators a) excluding gull species and b) only gull species, observed per survey at Dumbarton Complex, South San Francisco Bay, California, March-September 2018. Survey sample size is in parentheses next to pond number.
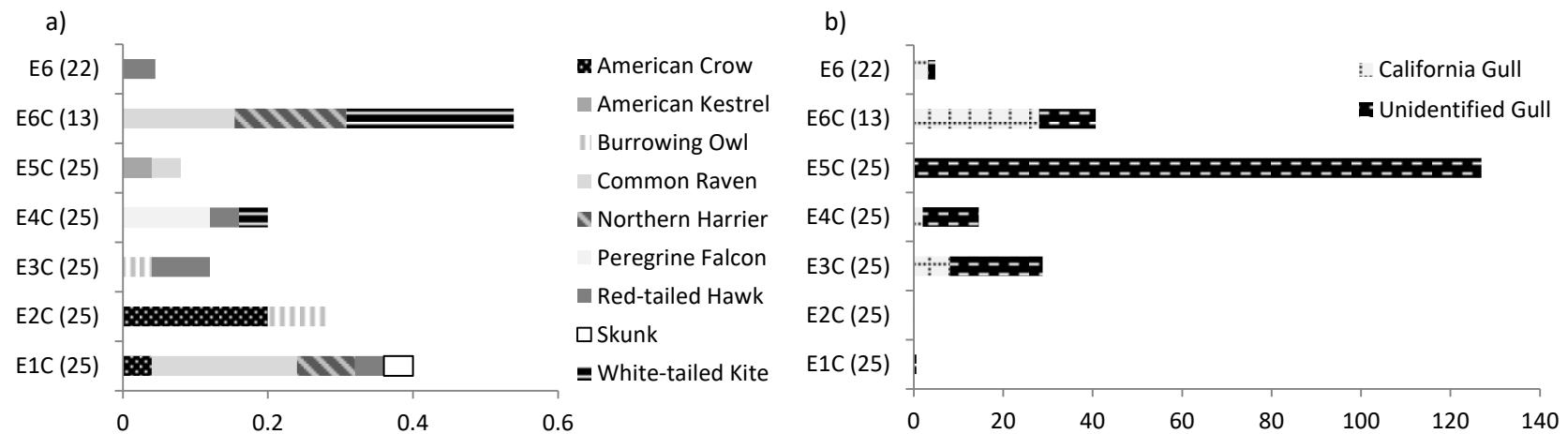
Figure 26. The average number of critical predators a) excluding gull species and b) only gull species, observed per survey in South Eden Landing Ecological Reserve, South San Francisco Bay, California, March-September 2018. Survey sample size is in parentheses next to pond number.

a)

b)
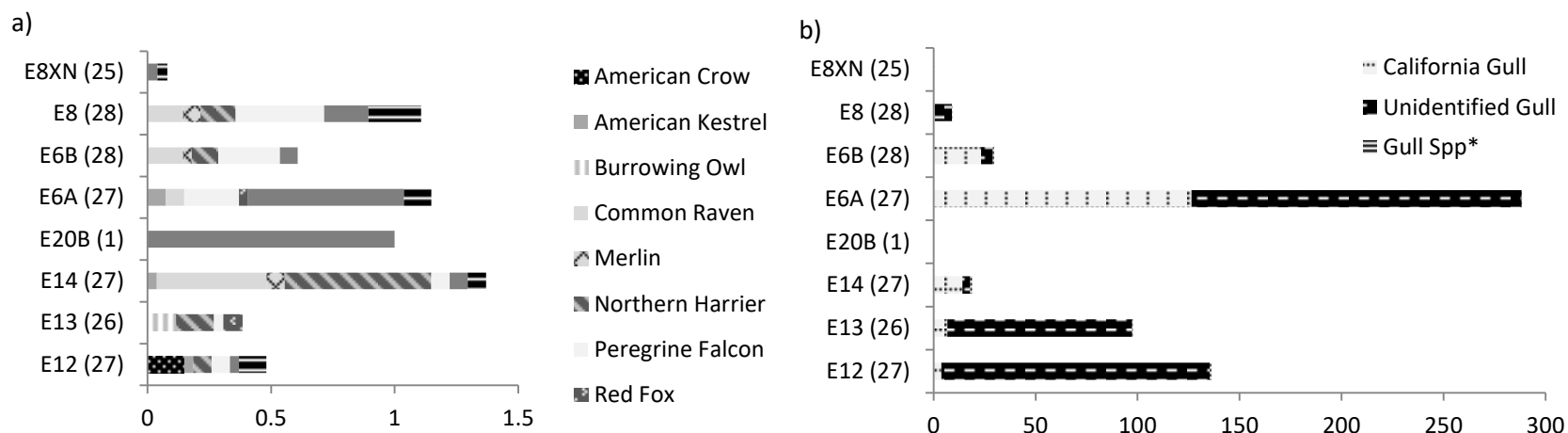
Figure 27. The average number of critical predators a) excluding gull species and b) only gull species, observed per survey at the Whales Tail and Old Alameda Creek Loops, Eden Landing Ecological Reserve, South San Francisco Bay, California, March-September. Survey sample size is in parentheses next to pond number.

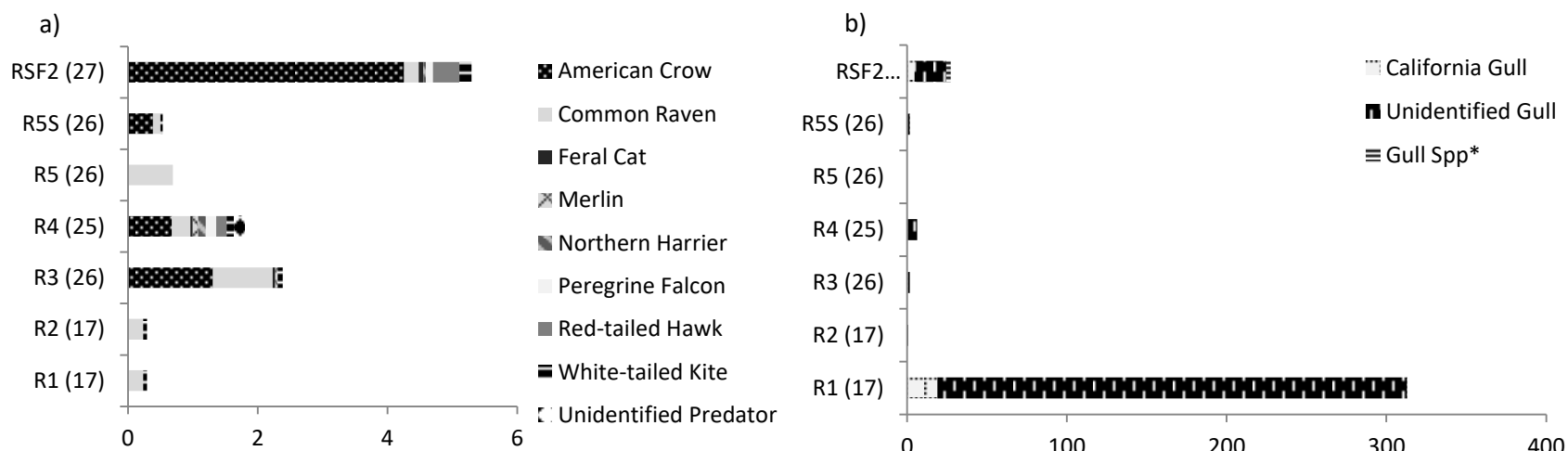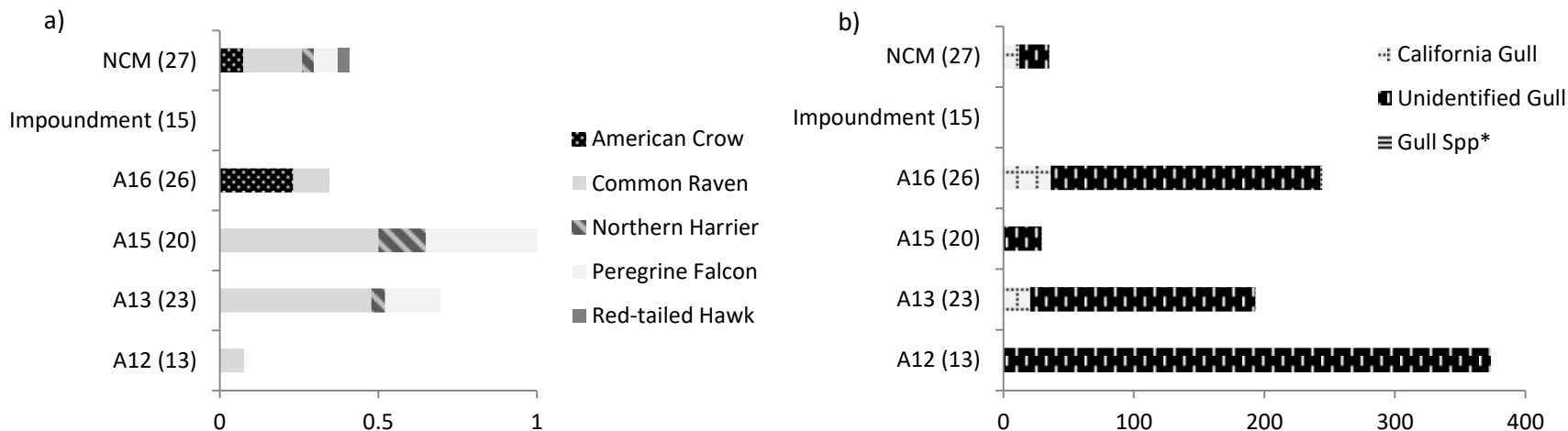* Includes Ring-billed, Western, Herring, Glaucous-winged, and Bonaparte's Gulls (in order of average seen per survey)

a)

b)
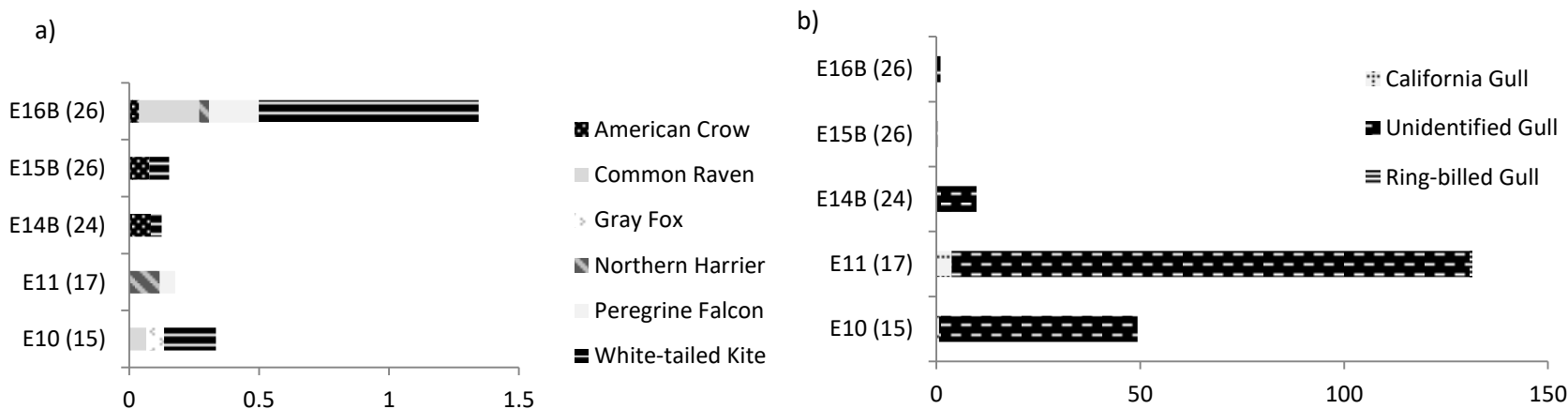
Figure 28. The average number of critical predators a) excluding gull species and b) only gull species, observed per survey at the Mount Eden Creek loop, Eden Landing Ecological Reserve, South San Francisco Bay, California, March-September 2018. Survey sample size is in parentheses next to pond number.

Figure 29. Individual cells within reconfigured Pond RSF2, Menlo Park, CA. Cell U3 is designated as Snowy Plover breeding habitat.
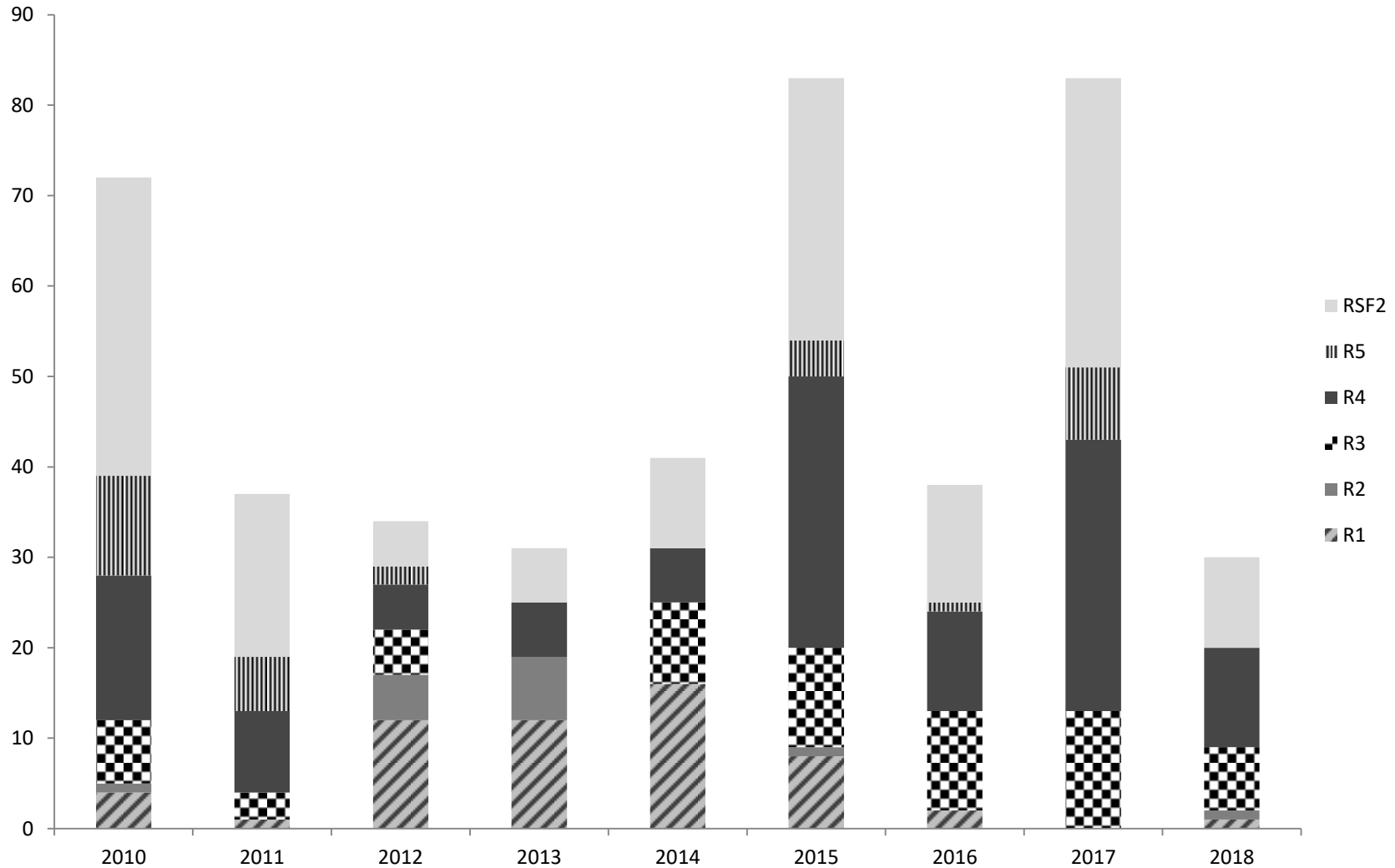
Figure 30. The number of snowy plover nests in the Ravenswood complex (ponds R1-5, RSF2) in Don Edwards National Wildlife Refuge, South San Francisco Bay, California, from 2010-2018. Each year is subdivided into individual ponds where the nests were located. The purpose of this figure is to show the variability in use of these ponds for nesting between years.
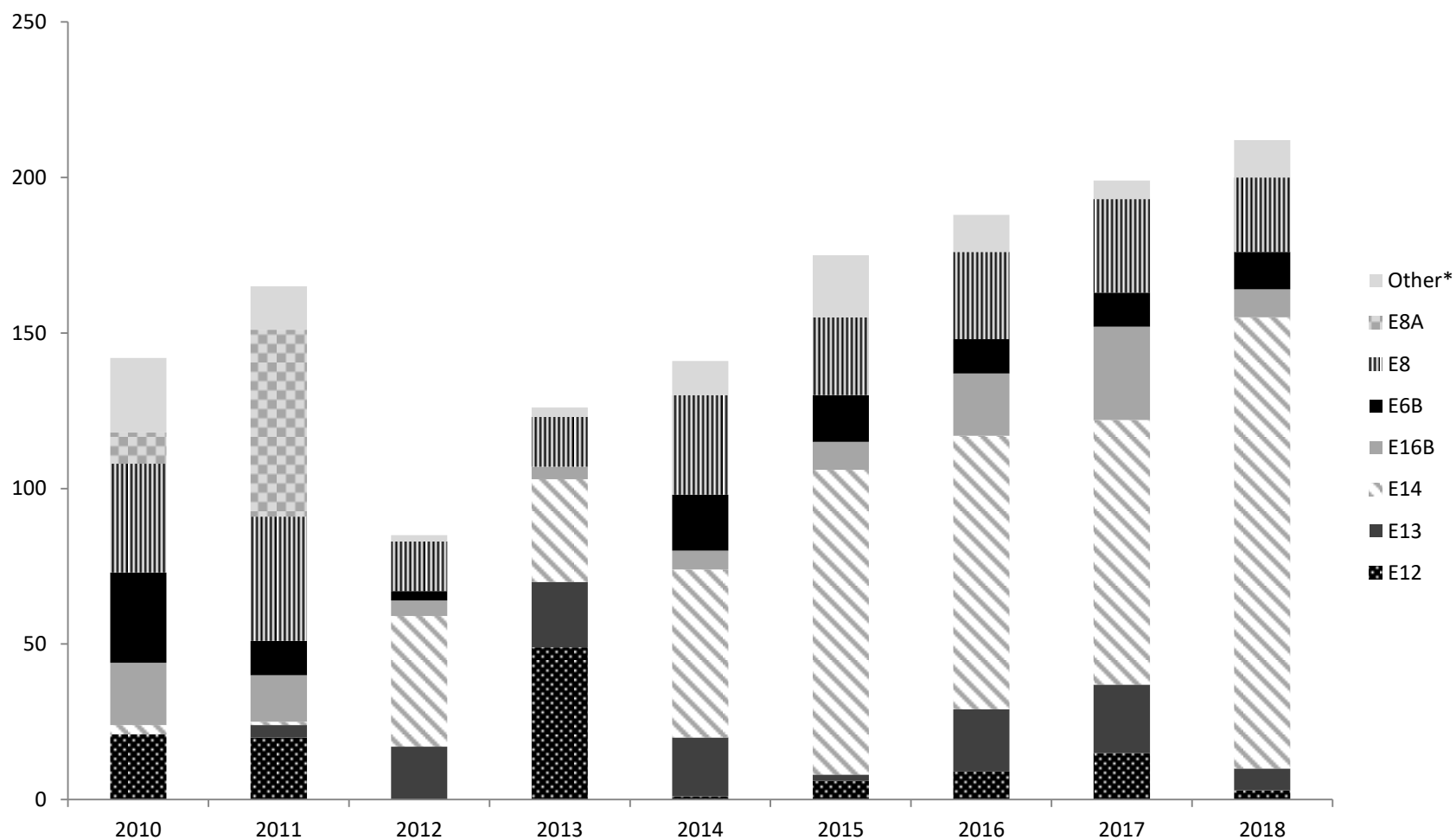
Figure 31. The number of Snowy Plover nests in Eden Landing Ecological Reserve, South San Francisco Bay, California, from 2010-2018. Each year is subdivided into individual ponds where the nests were located. The purpose of this figure is to show the variability in use of these ponds for nesting between years. It also shows an apparent positive trend in number of nests from 2012-2018. 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, E20B
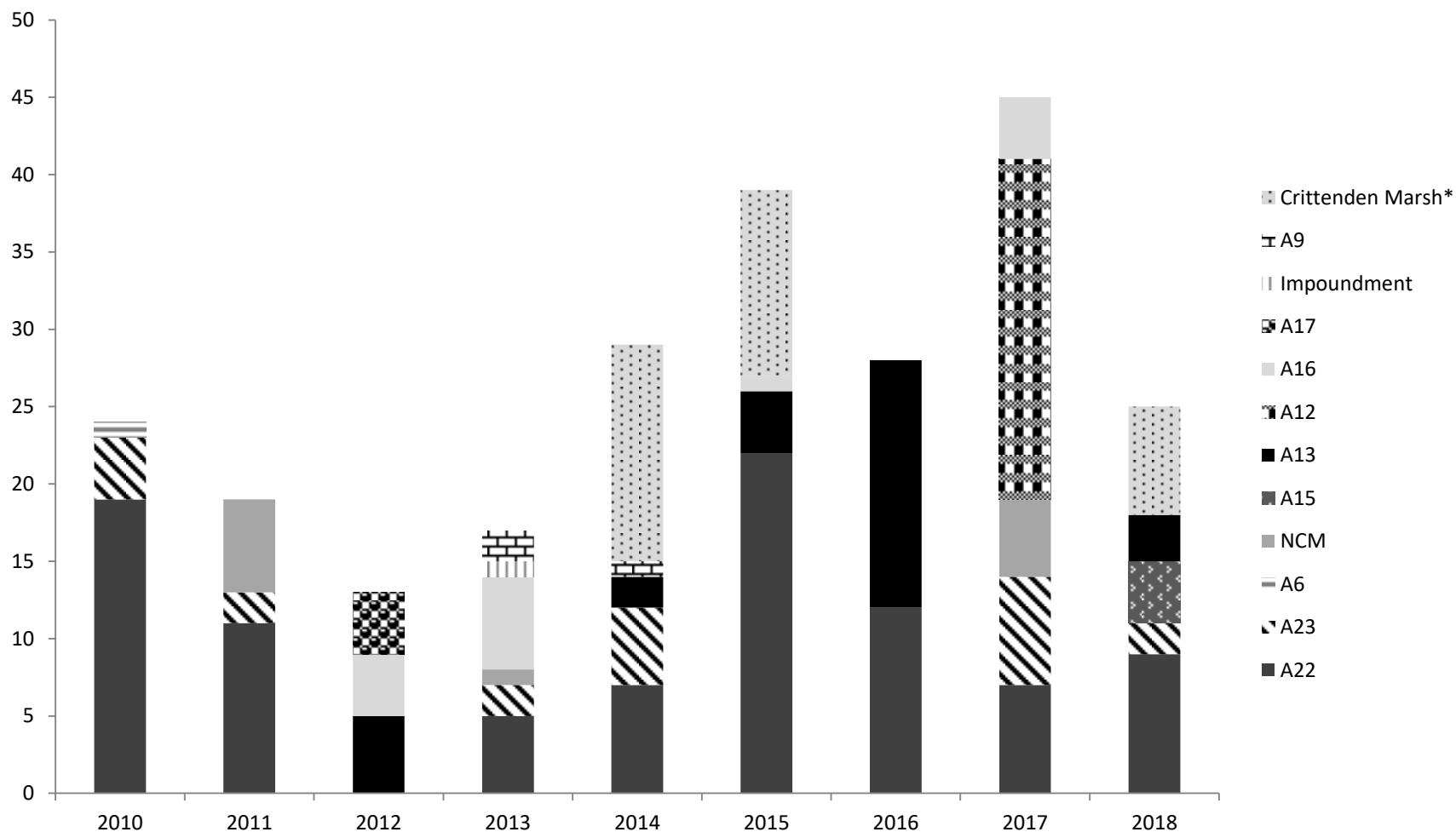
Figure 32. The number of Snowy Plover nests in the Alviso Complex in Don Edwards National Wildlife Refuge, South San Francisco Bay, California, from 2010-2018. Each year is subdivided into individual ponds where the nests were located. The purpose of this figure is to show the variability in use of these ponds for nesting between years.
*Includes ponds CMW, CME, and A3N
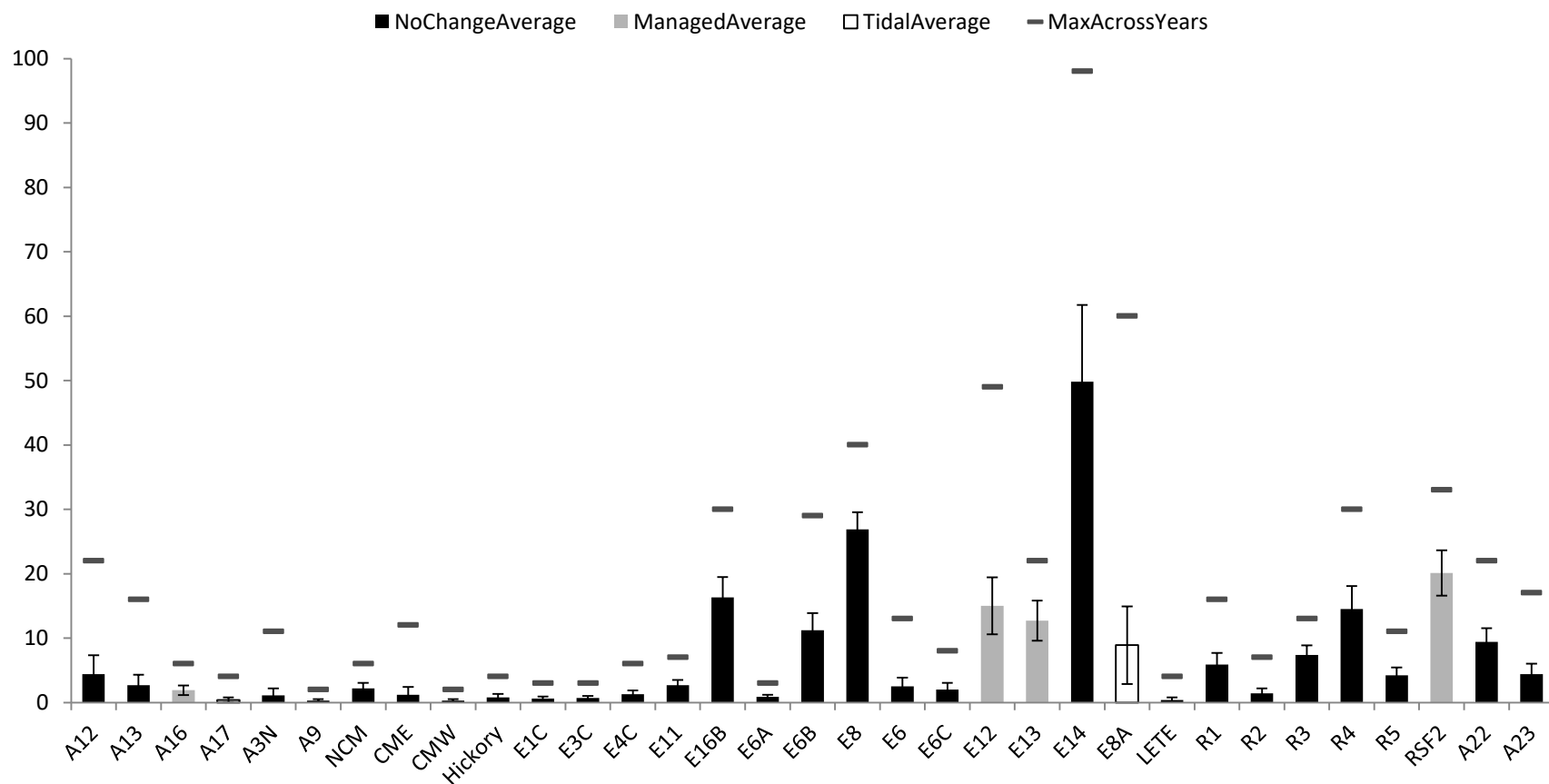
Figure 33. Average number of Snowy Plover nests initiated by pond in South San Francisco Bay, California from 2009-2018. Data are shown as mean + 1SD. The purpose of this figure is to illustrate which ponds have supported Snowy Plover nesting activity in recent years, and of these, which ponds are included 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, "CME" = Crittenden Marsh East, "CMW" = Crittenden Marsh West, and "LETE" = Hayward Least Tern Island; refer to Figs. 3-6 for other pond names and locations.
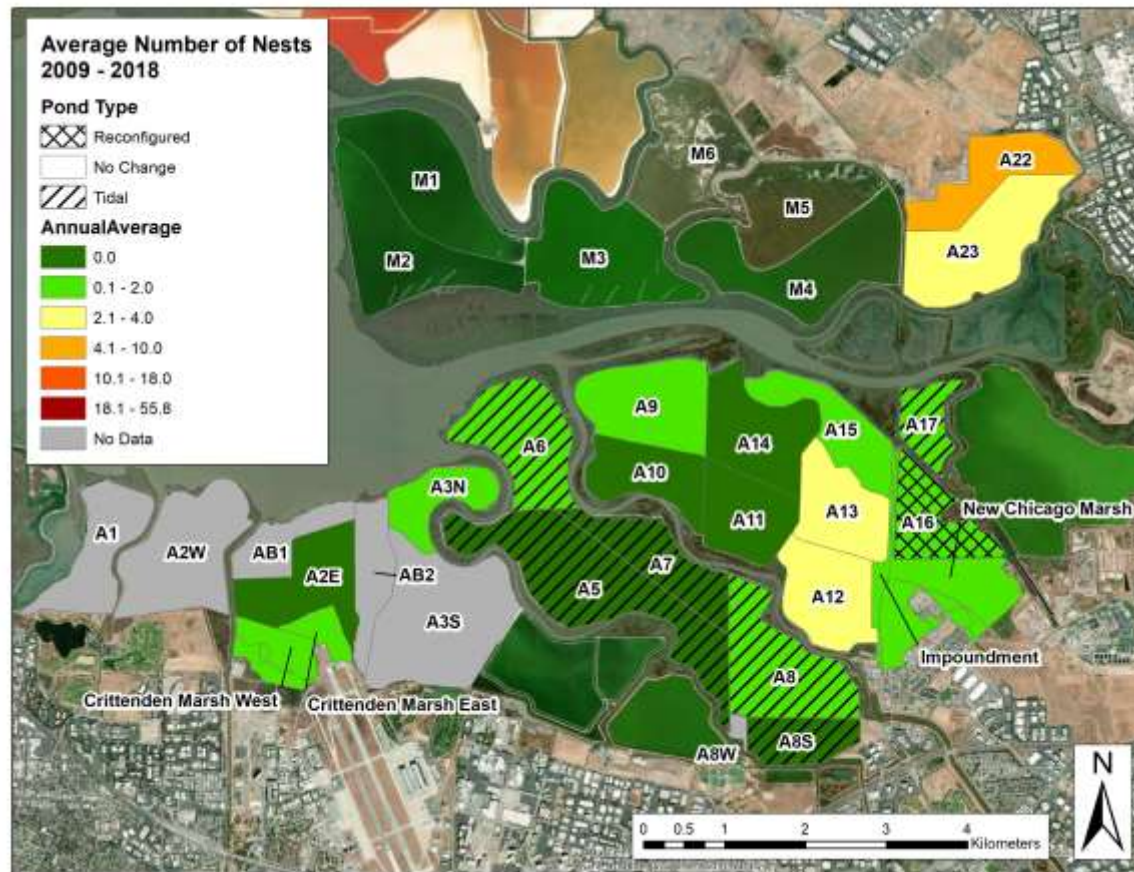
Figure 34. Average number of Snowy Plover nests initiated by pond in the Alviso Complex, South San Francisco Bay, California from 2009-2018. The purpose of this figure is to illustrate which ponds have supported Snowy Plover nesting activity in recent years, and of these, which ponds were included in Phase 1 actions 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 were enhanced for multiple species and the amount of habitat available to Snowy Plovers was reduced (not A16), and solid colors denote ponds that were not directly affected by Phase 1 actions. The gradient shading denotes the average number of Snowy 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.
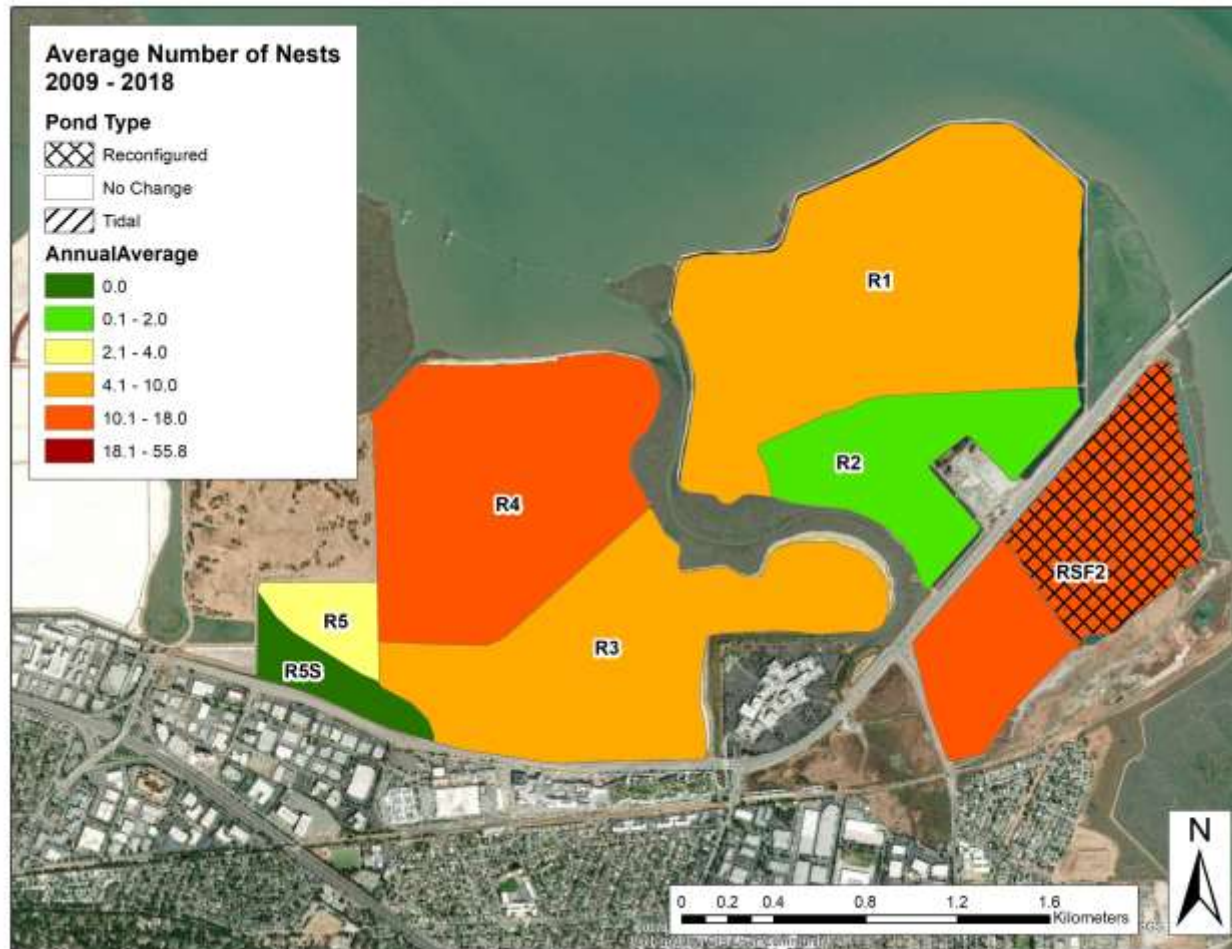
Figure 35. Average number of Snowy Plover nests initiated by pond in the Ravenswood Complex, South San Francisco Bay, California from 2009-2018. The purpose of this figure is to illustrate which ponds have supported Snowy Plover nesting activity in recent years, and of these, which ponds are included 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 Snowy Plover nests on the pond.
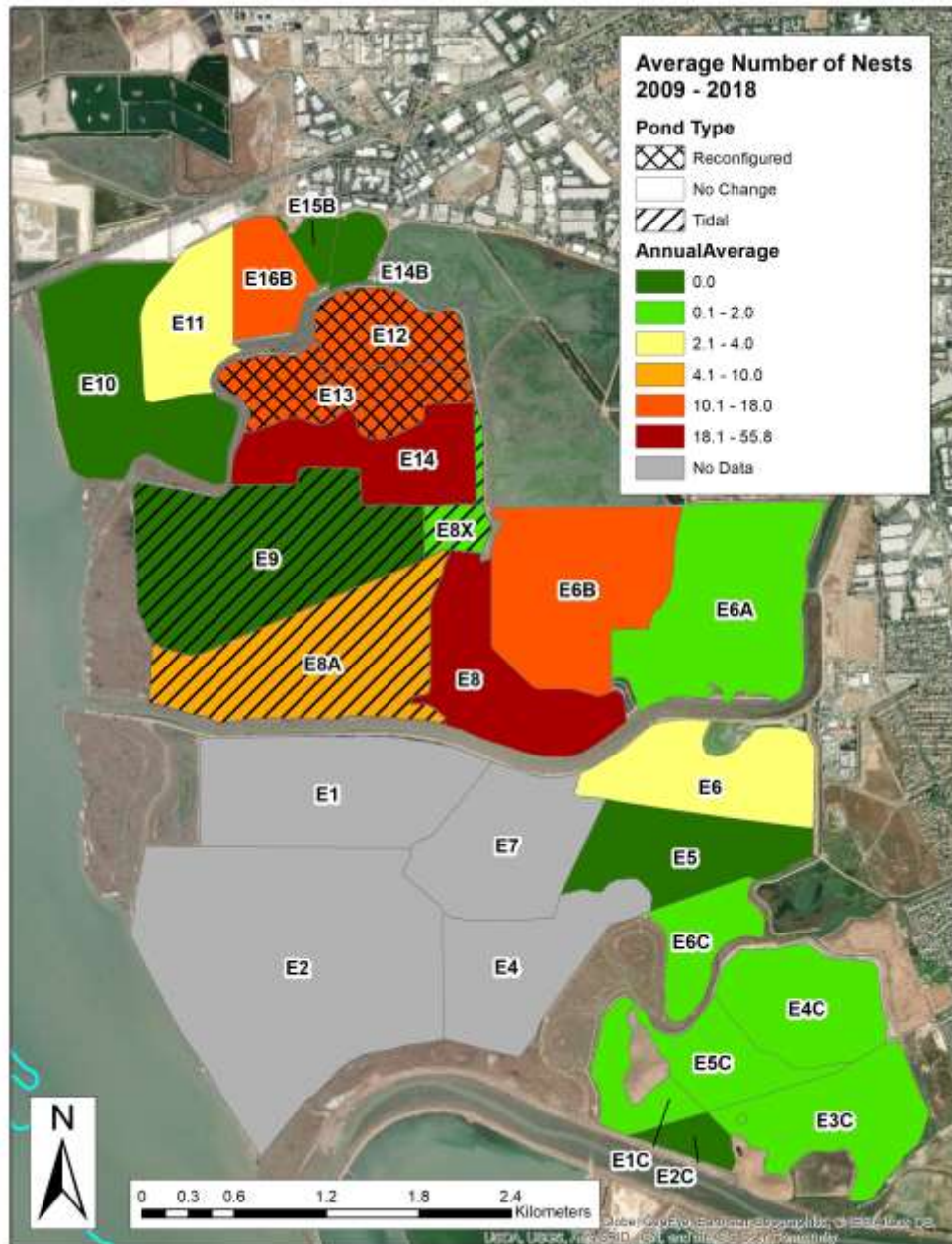
Figure 36. Average number of Snowy Plover nests initiated by pond in the Eden Landing Ecological Reserve, South San Francisco Bay, California from 2009-2018. The purpose of this figure is to illustrate which ponds have supported Snowy Plover nesting activity in recent years, and of these, which ponds were included in Phase 1 actions 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 was reduced, and solid colors denote ponds that were not directly affected by Phase 1 actions. The gradient shading denotes the average number of Snowy Plover nests on the pond. Note that pond E3C is owned by Cargill and managed largely as open water.

Table 1. Ponds surveyed weekly within the Don Edwards San Francisco Bay National Wildlife Refuge, South San Francisco Bay, California, 2018.

Location	Ponds
Alviso	A12, A13, A15, A16, Impoundment, NCM
Dumbarton	NPP1, Hickory
Mountain View	CME, CMW, A2E, A3N
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, 2018.

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, 2018. 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	E1C-5C, E20B, North Creek Managed Pond

Table 4. Potential avian predator species

Common Name	Scientific Name
American Kestrel	*Falco sparverius*
Merlin	*Falco columbarius*
Peregrine Falcon	*Falco peregrines*
Prairie Falcon	*Falco mexicanus*
Bald Eagle	*Haliaeetus leucocephalus*
Golden Eagle	*Aquila chrysaetos*
Cooper's Hawk	*Accipiter cooperii*
Red-Tailed Hawk	*Buteo jamaicensis*
White-tailed Kite	*Elanus leucurus*
Northern Harrier	*Circus Cyaneus*
California Gull	*Larus californicus*

Western Gull	*Larus occidentalis*
Herring Gull	*Larus argentatus smithsonianus*
Glaucous-winged Gull	*Larus glaucescens*
Mew Gull	*Larus canus*
Ring-Billed Gull	*Larus delawarensis*
American Crow	*Corvus brachyrhynchos*
Common Raven	*Corvus corax*
Black-crowned Night-Heron	*Nycticorax nycticorax*
Cattle Egret	*Bubulcus ibis*
Great Blue Heron	*Ardea herodias*
Great Egret	*Ardea alba*
Snowy Egret	*Egretta thula*
Loggerhead Shrike	*Lanius ludovicianus*

Table 5. Potential mammalian predator species

Common Name	Scientific Name
Red fox	*Vulpes vulpes*
Grey Fox	*Urocyon cinereoargenteus*
Striped Skunk	*Mephitis mephitis*
Virginia Possum	*Didelphis virginiana*
Domestic Cat	*Felis catus*
Coyote	*Canis latrans*

Table 6. Number of Western Snowy Plovers observed at Recovery Unit 3 sites during annual breeding window surveys in May, 2005-2018

REGION	SITE	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Alameda	Eden Landing	91	84	162	94	88	184	185	82	97	94	76	120	144	142
	Coyote Hills	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Crown Beach	-	-	-	-	-	-	-	-	-	0	0	0	-	-
	Dumbarton	0	0	2	0	0	0	0	0	0	0	0	0	2	7
	Hayward	0	0	0	1	4	12	8	9	32	7	2	4	0	7
	Warm Springs	23	7	0	3	14	27	17	3	1	11	24	14	2	20
Marin	Hamilton Wetlands	-	-	-	-	-	-	-	-	-	-	-	0	-	0
Napa	Napa	0			0	12	10	1	0	3	10	10	0	-	2
San Mateo	Ravenswood	3	3	23	24	21	42	27	33	59	45	68	42	76	51
Santa Clara	Alviso	7	8	20	11	8	0	11	20	10	0	1	21	19	4
	Mountain View	-	-	-	-	-	-	-	-	-	11	0	0	0	2
North Bay Delta	Montezuma Wetlands	-	-	-	-	-	-	-	-	-	-	14	6	3	0
Total Unit 3		**124**	**102**	**207**	**133**	**147**	**275**	**249**	**147**	**202**	**178**	**195**	**208**	**246**	**235**

Table 7. Snowy Plover nest fates by pond in the South San Francisco Bay, California, 2018.

Location	Hatched	Depredated	Abandoned	Flooded	Failed to Hatch	Unknown	Total Nests
Alviso							
NCM	0	0	0	0	0	0	**0**
A12	0	0	0	0	0	0	**0**
A13	1	2	0	0	0	0	**3**
A15	2	2	0	0	0	0	**4**
A16	0	0	0	0	0	0	**0**
Dumbarton							
NPP1	0	0	0	0	0	0	**0**
Hickory	1	1	0	0	0	0	**2**
Eden Landing							
E20B	0	1	0	0	0	0	**1**
E6A	5	4	0	0	0	0	**9**
E6B	3	9	0	0	0	0	**12**
E8	7	17	0	0	0	0	**24**
E12	2	1	0	0	0	0	**3**
E13	2	5	0	0	0	0	**7**
E14	58	83	2	0	1	1	**145**
E16B	3	6	0	0	0	0	**9**
E11	0	0	0	0	0	0	**0**
E6	1	0	0	0	0	0	**1**
E1C - E5C	0	0	0	0	0	0	**0**
E6C	0	1	0	0	0	0	**1**
Mountain View							
CME	0	0	0	0	0	0	**0**
CMW	3	2	0	0	0	0	**5**
A3N	0	2	0	0	0	0	**2**
Ravenswood							
R1	1	0	0	0	0	0	**1**
R2	0	1	0	0	0	0	**1**
R3	5	2	0	0	0	0	**7**
R4	7	4	0	0	0	0	**11**
RSF2	4	6	0	0	0	0	**10**
Warm Springs							
A22	2	7	0	0	0	0	**9**
A23	1	1	0	0	0	0	**2**
Hayward							
LETE	8	2	0	0	0	0	**10**

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	**116**	**159**	**2**	**0**	**1**	**1**	**279**
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	**116**	**159**	**2**	**0**	**1**	**1**	**279**

Table 8. Undetected successful nests inferred by presence of unaccounted for broods on pond

Pond	# Nests
A13	2
A15	4
A22	1
CMW	1
NPP1	1
R3	2
R4	4
RSF2	3
Total	**18**

Table 9. Snowy Plover averaged apparent nest densities (nest/ha) by pond on Refuge property in the South San Francisco Bay, California, 2018. 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 Nests/Ha
A13	0.17
A15	0.05

Location	
A22	0.03
A23	<0.01
A3N	0.46*
CMW	0.35
Hickory	0.02
R1	<0.01
R2	0.02
R3	0.01
R4	0.02
RSF2	0.05

*Minimal amount of habitat available

Table 10. Snowy Plover averaged apparent nest densities (nests/ha) by pond at Eden Landing Ecological Reserve in the South San Francisco Bay, California, 2018. 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 Nests/Ha
E6	0.04
E6A	0.03
E6B	0.04
E6C	0.02
E8	0.1
E12	0.24
E13	0.09
E14	0.48
E16B	0.06
E20B	*N/A

*Habitat data not collected

Table 11. Apparent fledging success (all sites combined) of Snowy Plover chicks in the South San Francisco Bay, California, 2008-2018. Chicks were considered fledged if they survived to 31 days (2008-2016) or 28 days (2017-2018). *N* is the number of chicks banded.

Year	Fledgling Success	N
2018	19%	31
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 12. Apparent fledging success of Snowy Plover chicks by pond in the South San Francisco Bay, California, 2018. Chicks were considered fledged if they survived to 31 days. *N* is the number of individuals banded.

Pond	# Chicks	# Adults	Fledgling Success
E14	23	0	17%
E6B	2	0	0%
E8	3	0	0%
CMW	3	0	67%
Total	**31**	**0**	**19%**

Table 13 **.** Aggressive interactions between breeding Snowy Plovers and other ground nesting birds during the 2018 breeding season.

Date	Aggressor Species	Target Species	Pond	Habitat Type	SNPL Nest Stage
5/13/2018	LETE	SNPL	E14	Pond	Incubating
5/15/2018	LETE	SNPL	E14	Pond	Incubating
6/07/2018	LETE	SNPL	E14	Pond	Incubating
6/21/2018	LETE	SNPL	E14	Pond	Incubating

Table 14. 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	6^1
2015	E14	UNID	1
2016	E14	CORA	30^1
2017	E14	CORA	5
2017	E14	UNID	1
2017	E14	REFO	2^2
2018	E14	CORA	2
2018	E14	REFO	9
2018	E14	REFO	1^3

[1]One nest hatched after partial depredation event
[2]One nest depredated after one chick hatched
[3]At least two of three chicks depredated after hatch