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# Evaluation of Caspian Tern (*Hydroprogne caspia*) and Snowy Plover (*Charadrius alexandrinus nivosus*) Nesting on Modified Islands at the Don Edwards San Francisco Bay National Wildlife Refuge, California—2016 Annual Report

Open-File Report 2017–1055

U.S. Department of the Interior
U.S. Geological Survey

**Cover:** Photograph showing Caspian tern (*Hydroprogne caspia*) chicks and decoy on an enhanced island in Pond SF2 of the Don Edwards San Francisco Bay National Wildlife Refuge, California. Photograph by Crystal Shore, U.S. Geological Survey, May 11, 2016.

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U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

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# Conversion Factors

U.S. customary units to International System of Units

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| inch (in.) | 2.54 | centimeter (cm) |
| foot (ft) | 0.3048 | meter (m) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |
| meter (m) | 1.094 | yard (yd) |
| | Area | |
| square meter ($m^2$) | 0.0002471 | acre |
| square meter ($m^2$) | 10.76 | square foot ($ft^2$) |

# Abbreviations

| | |
|---|---|
| BiOp | Biological Opinion |
| DENWR | Don Edwards San Francisco Bay National Wildlife Refuge |
| RPAs | Reasonable and Prudent Alternatives |
| SBSP | South Bay Salt Pond |
| USACE | U.S. Army Corps of Engineers |
| USDA-APHIS | U.S. Department of Agriculture Animal and Plant Health Inspection Service |
| USGS | U.S. Geological Survey |

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# Evaluation of Caspian Tern (*Hydroprogne caspia*) and Snowy Plover (*Charadrius alexandrinus nivosus*) Nesting on Modified Islands at the Don Edwards San Francisco Bay National Wildlife Refuge, California—2016 Annual Report

By C. Alex Hartman[1], Joshua T. Ackerman[1], Mark P. Herzog[1], Cheryl Strong[2], David Trachtenbarg[3], and Crystal A. Shore[1]

## Executive Summary

In order to address the 2008/10 and Supplemental 2014 NOAA Fisheries Biological Opinion for operation of the Federal Columbia River Power System, the U.S. Army Corps of Engineers (USACE) and the Bureau of Reclamation (Reclamation) developed and have begun implementation of Caspian tern (*Hydroprogne caspia*) management plans. This implementation includes redistribution of the Caspian terns in the Columbia River estuary and the mid-Columbia River region to reduce predation on salmonids listed under the Endangered Species Act. Key elements of the plans include (1) reducing nesting habitat for Caspian terns in the Columbia River estuary and the mid-Columbia River region, and (2) creating or modifying nesting habitat at alternative sites within the Caspian tern breeding range. USACE and Reclamation developed Caspian tern nesting habitat at the U.S. Fish and Wildlife Service Don Edwards San Francisco Bay National Wildlife Refuge (DENWR), California, prior to the 2015 nesting season. Furthermore, to reduce or eliminate potential conflicts between nesting Caspian terns and threatened western snowy plovers (*Charadrius alexandrinus nivosus),* nesting habitat for snowy plovers also was developed. Seven recently constructed islands within two managed ponds (Ponds A16 and SF2) of DENWR were modified to provide habitat attractive to nesting Caspian terns (5 islands) and snowy plovers (2 islands). These 7 islands were a subset of 46 islands recently constructed in Ponds A16 and SF2 to provide waterbird nesting habitat as part of the South Bay Salt Pond (SBSP) Restoration Project.

[1] U.S. Geological Survey.
[2] U.S. Fish and Wildlife Service.
[3] U.S. Army Corps of Engineers.

We used social attraction methods (decoys and electronic call systems) to attract Caspian terns and snowy plovers to these seven modified islands, and conducted surveys between March and September of 2015 and 2016 to evaluate nest numbers, nest density, and productivity. Results from the 2015 nesting season, the first year of the study, indicated that island modifications and social attraction measures were successful in establishing Caspian tern breeding colonies at Ponds A16 and SF2 of DENWR. The success of 2015 continued in 2016, the second year of the study. In 2016, Caspian terns nested on two of the five islands modified for Caspian terns (one island in Pond A16 and one island in Pond SF2). Caspian terns initiated at least 317 nests, fledged at least 158 chicks, and had a breeding success rate of 0.50 fledged chicks per breeding pair. This represents a 42 percent increase in nests initiated, a 9 percent decrease in the number of fledged chicks, and a 36 percent decrease in the number of chicks fledged per breeding pair in 2016 compared to 2015. Although overall productivity decreased from 2015, these results indicate that the Caspian tern breeding population on modified islands of the DENWR is increasing relative to 2015, the first year of the effort, and relative to years prior to 2015 when no breeding colonies of Caspian terns existed in Ponds A16 or SF2. These results indicate the effectiveness of social attraction measures in helping to establish tern nesting colonies in San Francisco Bay. Conversely, for the second year in a row, snowy plovers did not attempt to nest on any island in Ponds A16 and SF2. Social attraction measures similar to those used in this study, but targeting other colonial species such as Forster's terns (*Sterna forsteri*) and American avocets (*Recurvirostra americana*), may help to establish waterbird breeding colonies at wetlands enhanced as part of the SBSP Restoration Project.

## Introduction

The U.S. Army Corps of Engineers (USACE), Walla Walla and Portland Districts, and the Bureau of Reclamation (Reclamation) (Action Agencies) are in the process of addressing the 2008/10 and 2014 Supplemental NOAA Fisheries Biological Opinion (BiOp) for operation of the Federal Columbia River Power System that includes Reasonable and Prudent Alternatives (RPAs) 45, 47, 66, and 68. As part of implementing these RPAs, the Action Agencies have developed, and are in the process of implementing, pertinent parts of Caspian tern (*Hydroprogne caspia*) management plans (U.S. Fish and Wildlife Service, 2005; U.S. Army Corps of Engineers, 2015). This implementation includes redistributing nesting Caspian terns out of the Columbia River estuary and the mid-Columbia River region to reduce predation on salmonids listed under the Endangered Species Act. As part of implementing these management plans, the Action Agencies developed Caspian tern and western snowy plover (*Charadrius alexandrinus nivosus*) habitat at the U.S. Fish and Wildlife Service Don Edwards San Francisco Bay National Wildlife Refuge (DENWR) prior to the 2015 nesting season. Previous studies indicated that salmonids make up a small proportion of the diet of Caspian terns nesting in south San Francisco Bay, and that most smolts consumed by Caspian terns were hatchery-raised and non-listed (Evans and others, 2011; Collis and others, 2012), suggesting that development of Caspian tern nesting colonies in south San Francisco Bay is unlikely to negatively affect endangered salmonids. Nesting habitat for the threatened snowy plover was developed to reduce or eliminate potential conflicts between nesting terns and plovers.

Seven existing islands within two managed ponds of DENWR were modified to provide habitat attractive to nesting Caspian terns and western snowy plovers (fig. 1). These seven islands were selected from 46 islands recently constructed in Ponds A16 and SF2 to provide waterbird nesting habitat as part of the South Bay Salt Pond (SBSP) Restoration Project. At Pond A16, two islands (Islands 11 and 12) were modified for nesting Caspian terns and one island (Island 3) was modified for nesting snowy plovers (fig. 2). At Pond SF2, three islands (Islands 12, 17, and 21) were modified for nesting Caspian terns and one island (Island 10) was modified for nesting snowy plovers (fig. 3). Islands modified for nesting snowy plovers were selected based on locations of snowy plover observations during previous breeding seasons, and islands modified for nesting Caspian terns were selected so that they were centrally located within the ponds but away from snowy plover islands. Islands modified for Caspian terns were groomed to a slope of 4 to 1 or less, were covered in 3/8-in. crushed rock 18 in. deep, and 3-in. rock was placed around the island perimeter. Islands modified for snowy plovers were covered with 1/4-in. crushed rock (Island 10 at Pond SF2) or 3/4-in. crushed rock (Island 3 at Pond A16) 5 in. deep, and a 6-ft buffer was left around the edge of the island for plover foraging habitat. Construction was completed in February 2015.

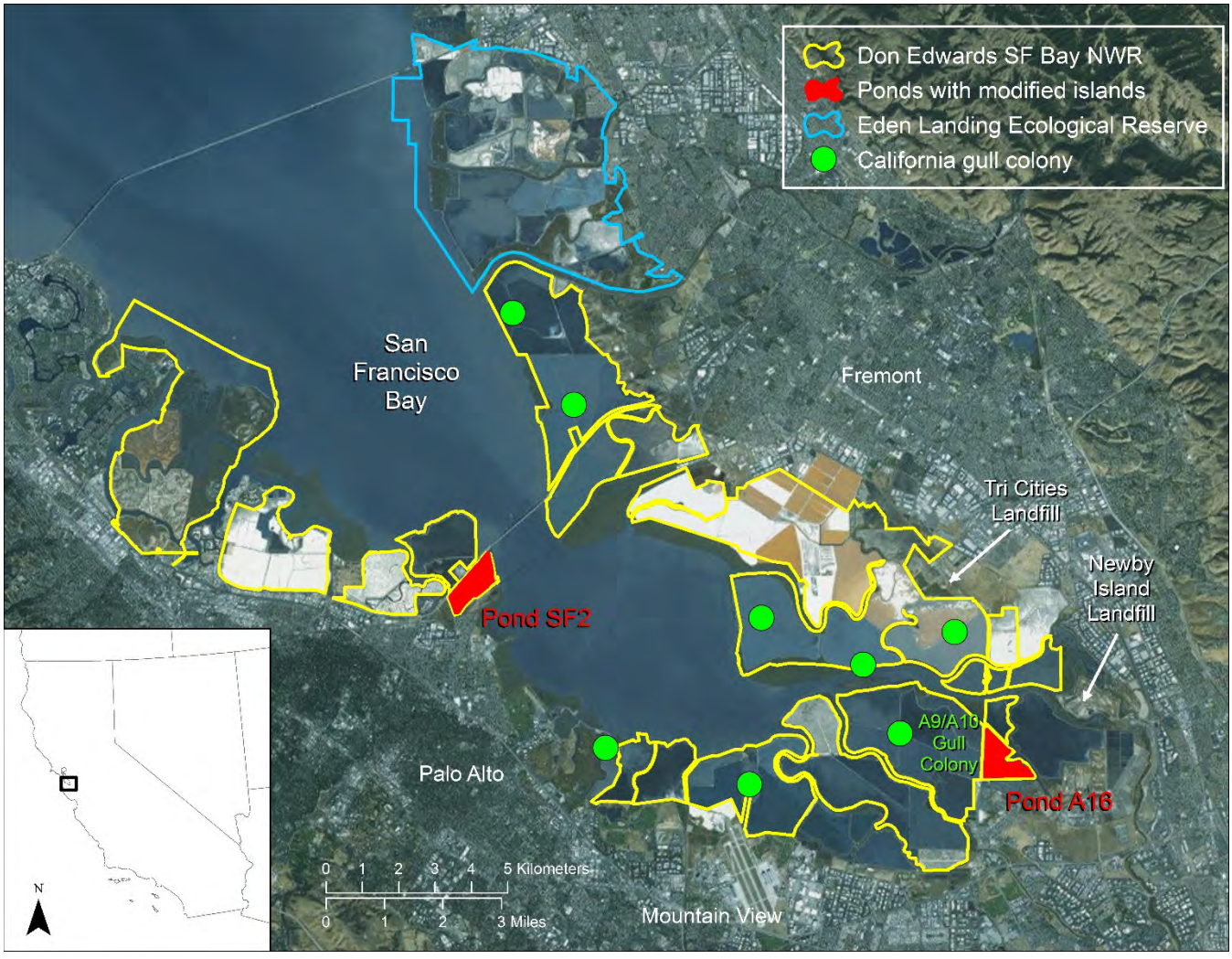


Figure 1. Locations of Ponds A16 and SF2 containing islands modified for Caspian terns and snowy plovers, Don Edwards San Francisco Bay National Wildlife Refuge, California.

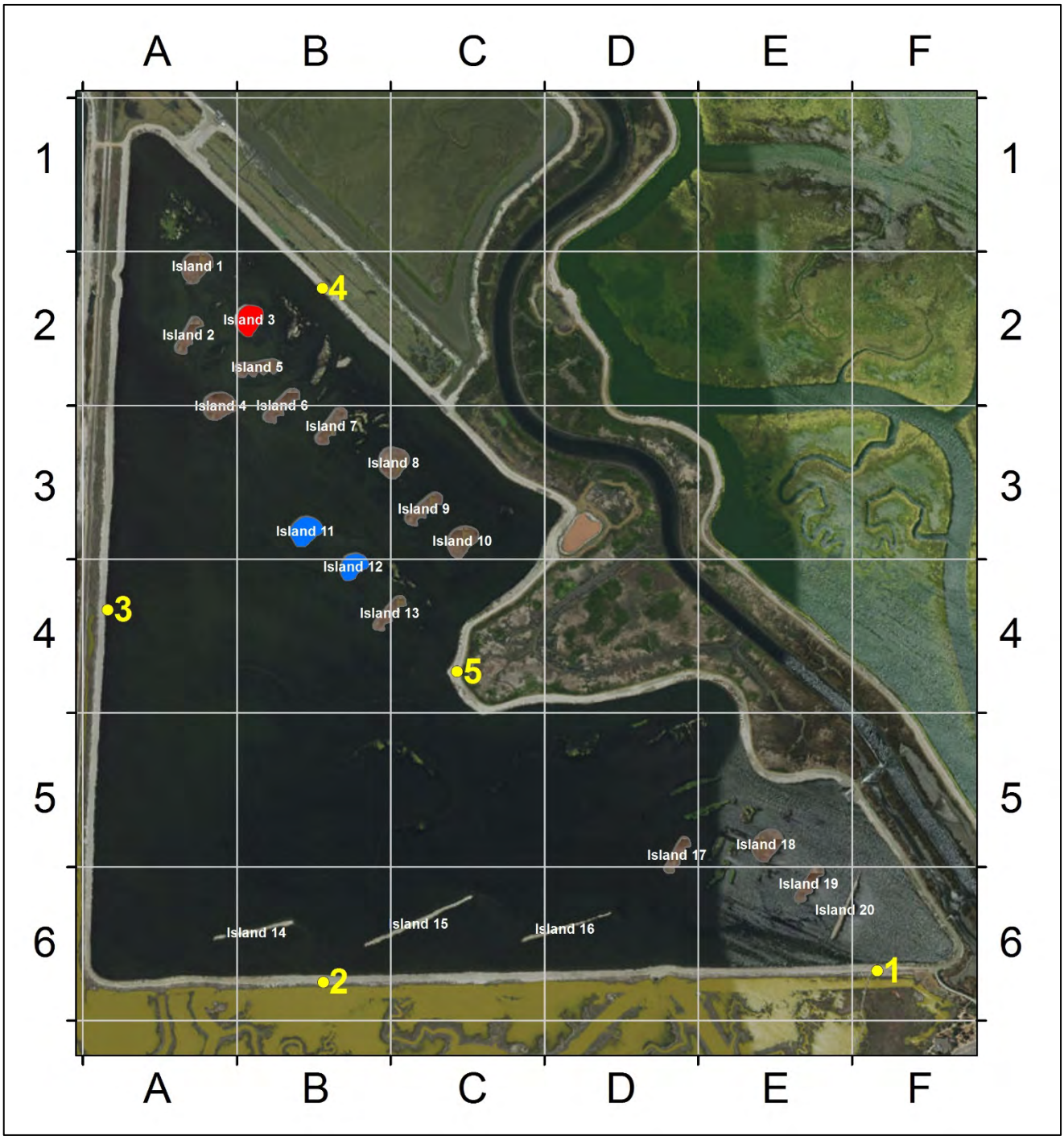


Figure 2. Locations of islands modified for nesting Caspian terns (Islands 11 and 12) and nesting snowy plovers (Island 3) in Pond A16, Don Edwards San Francisco Bay National Wildlife Refuge, California. Numbered yellow dots designate vantage points used to count birds in the pond during pond surveys. Square grid cells are 250 by 250 meters.

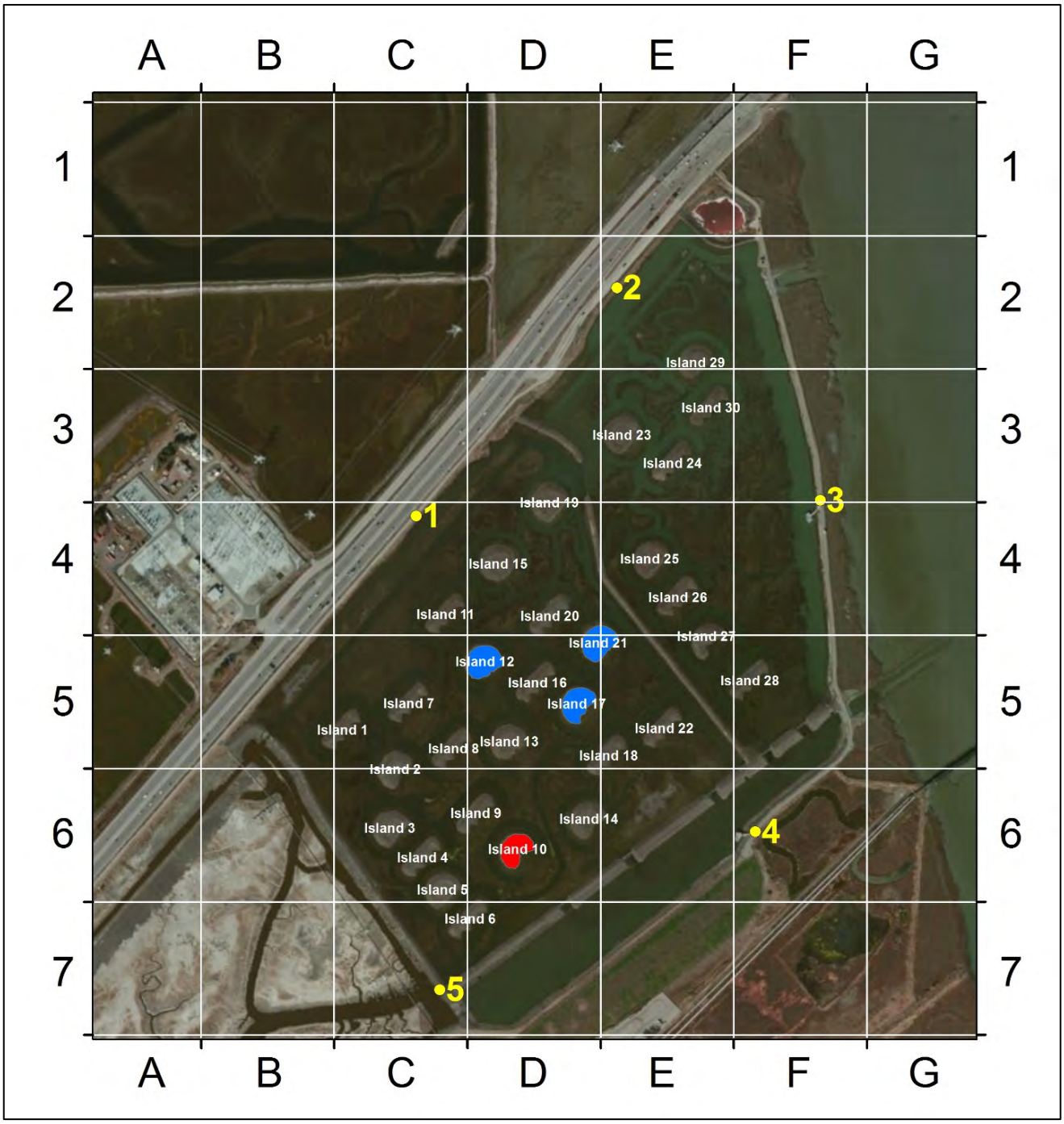


Figure 3. Locations of islands modified for nesting Caspian terns (Islands 12, 17, and 21) and nesting snowy plovers (Island 10) in Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California. Numbered yellow dots designate vantage points used to count birds in the pond during pond surveys. Square grid cells are 250 by 250 meters.

In coordination with USACE, Reclamation, and DENWR, the U.S. Geological Survey (USGS) implemented social attraction measures to attract Caspian terns and snowy plovers to these recently modified islands during the 2015 and 2016 breeding seasons. Social attraction is known to be an effective wildlife-management technique whereby adult birds are lured to potential nesting sites to assist in the establishment of successful breeding colonies (Arnold and others, 2011; Jones and Kress, 2012). Colonial waterbirds, such as terns, are excellent candidate species for social attraction efforts because they are readily attracted to decoys of adult birds as well as sound recordings of adult vocalizations (Kress, 1983; Roby and others, 2002). Furthermore, the presence of conspecifics may influence selection of nest sites by snowy plovers (Patrick and Colwell, 2014), and the use of decoys and vocalizations may encourage nesting (California State Parks and Redwood National Park, 2014). In 2015, the first year of the study, social attraction efforts were successful in establishing Caspian tern breeding colonies at Ponds A16 and SF2. Caspian terns nested on three of the five islands modified for Caspian terns (one island in Pond A16 and two islands in Pond SF2), initiated at least 224 nests, fledged at least 174 chicks, and had a breeding success rate of 0.78 fledged chicks per breeding pair (Hartman and others, 2016). During the 2016 nesting season, USGS conducted the second of 3 years of post-construction social attraction and monitoring efforts at DENWR.

The objectives were to:

1. Deploy and maintain social attraction measures (decoys and call systems) for Caspian terns and snowy plovers on seven islands within Ponds A16 and SF2;
2. Monitor and evaluate nesting by Caspian terns and snowy plovers on the seven modified islands as well as surrounding islands of Ponds A16 and SF2;
3. Evaluate factors limiting breeding success of Caspian terns and snowy plovers at Ponds A16 and SF2;
4. Implement gull (*Larus* spp.) dissuasion efforts, as needed, in coordination with DENWR and U.S. Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS)-Wildlife Services to limit potential negative effects of gulls on nesting Caspian terns and snowy plovers; and
5. Provide information, based on field observations, to DENWR, USACE, and USDA-APHIS on additional predator-management options for limiting potential negative effects of other terrestrial and avian species on nesting Caspian terns and snowy plovers.

# Methods

## Social Attraction Measures for Caspian Terns and Snowy Plovers

We deployed social attraction measures (decoys and call systems) on seven islands (three islands in Pond A16, four islands in Pond SF2) between March 1 and 9, 2016. Five islands (Islands 11 and 12 in Pond A16; Islands 12, 17, and 21 in Pond SF2) each received 105 Caspian tern decoys arranged in the interior of each island, and spaced 1–1.5 m apart (table 1, figs. 4–6), which is the nest spacing commonly observed in Caspian tern colonies (Cuthbert and Wires, 1999). The remaining two islands (Island 3 in Pond A16; Island 10 in Pond SF2) each received six snowy plover decoys, arranged in male-female pairs at three locations on the island (fig. 7). We installed a call system (Murremaid Music Boxes, South Bristol, Maine) on each of the seven modified islands and broadcast either Caspian tern colony calls or snowy plover calls continuously through two omni-directional outdoor speakers. Each call system was powered by two 6V Optima® AGM batteries and charged by a 135 W Kyocera© solar panel, enabling it to broadcast continuously without intervention. Call box and solar panels were deployed on the south side of each island, about 20 m from the decoy spread. Speakers were deployed on opposite ends of the decoy spread and connected to the call box by speaker wire loosely buried in the gravel. We used a 20-minute recording of a winter flock of snowy plovers obtained from Little River State Beach in Humboldt County, California, supplied by Amber Transou of California State Parks, and a 42-minute recording of a breeding Caspian tern colony obtained from Rice Island (lower Columbia River estuary) by Kathy Turco of Alaska's Spirit Speaks. The Caspian tern recording is the same one used in social attraction efforts at the other USACE constructed sites in southeastern Oregon and northeastern California as part of implementing the Columbia River estuary Caspian tern management plan. Decoys, and call systems broadcasting on a constant loop, remained on the islands until they were retrieved in August or September.

Table 1. Summary of social attraction efforts at three islands in Pond A16 and four islands in Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California, 2016.

| Pond | Island No. | Decoy/Call type | Number of decoys | Date of decoy and call system | |
|---|---|---|---|---|---|
| | | | | Deployment | Removal |
| A16 | 3 | Snowy plover | 6 | March 2 | August 28 |
| A16 | 11 | Caspian tern | 105 | March 2 | September 19 |
| A16 | 12 | Caspian tern | 105 | March 1 | September 19 |
| SF2 | 10 | Snowy plover | 6 | March 9 | August 4 |
| SF2 | 12 | Caspian tern | 105 | March 8 | September 22 |
| SF2 | 17 | Caspian tern | 105 | March 9 | September 22 |
| SF2 | 21 | Caspian tern | 105 | March 8 | September 22 |

Figure 4. Arrangement of social attraction measures (decoys and call system) for Caspian terns on modified Island 11 (top) and Islands 11 and 12 (bottom) in Pond A16, Don Edwards San Francisco Bay National Wildlife Refuge, California. Bottom photograph shows Island 12 in foreground and Island 11 in background. Top and bottom photographs by Crystal Shore, USGS, May 23 and April 5, 2016, respectively.

Figure 5. Arrangement of social attraction measures (decoys and call system) for Caspian terns on modified Island 12 (top) and Island 17 (bottom) in Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California. Top photograph by Alex Hartman, USGS, March 3, 2015. Bottom photograph by Kimberley Sawyer, USGS, March 17, 2015.

Figure 6. Arrangement of social attraction measures (decoys and call system) for Caspian terns on modified Island 21 in Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California. Top and bottom photographs by Crystal Shore, USGS, March 17 and April 12, 2016.


Figure 7. Arrangement of social attraction measures (decoys and call system) for snowy plovers on modified Island 10 in Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California. Photograph by Alex Hartman, USGS, March 2, 2015.

## Gull Dissuasion Efforts

We visited Ponds A16 and SF2 at least 3–4 times a week for surveys and, if necessary, to haze gulls from islands (both modified islands and other islands nearby). The California gull (*Larus californicus*) population in San Francisco Bay has increased from fewer than 200 breeding gulls in 1982 to more than 47,000 breeding gulls in 2015 (Strong and others, 2004; Washburn and Butler, 2016). They occur in large numbers around the project area, and have been identified as dominant predators of waterbird eggs and chicks (Herring and others, 2011; Ackerman, Herzog, Hartman, and Herring, 2014; Ackerman, Herzog, Hartman, and Takekawa, 2014). Thus, gull dissuasion was considered a potentially important component for successful nesting of Caspian terns and snowy plovers. Hazing measures included green lasers and most often boating to islands and making noise to flush gulls from the islands.

## Evaluation of Nesting by Caspian Terns and Snowy Plovers

We conducted 55 survey bouts each at Pond A16 and Pond SF2 in 2016. Survey bouts were conducted 4–5 days per week at each pond from March 18 to April 8, 2–3 days per week from April 11 to 29, and twice weekly from May 2 to September 12. Both ponds were surveyed on the same day, one in the early morning and the other in the afternoon, and the time of day was alternated at each pond during consecutive survey bouts. Each survey bout was separated into three separate surveys, which were conducted from the surrounding levee using a 20–60× spotting scope.

First, a pond survey was conducted where we traversed around each pond (A16 or SF2) by truck and stopped at set vantage points to record the number and location (grid cell, figs. 2 and 3) of all tern, shorebird, and gull species known to nest in south San Francisco Bay, as well as potential nest predators (for example common raven [*Corvus corax*], raptors, gulls). This survey was completed within 60 minutes so as to limit double-counting of individuals and avoid biasing abundance estimates at each pond.

Second, immediately following the pond survey, we conducted an additional 60-minute behavioral survey from a single vantage point, where we scanned the pond about every 10 minutes and documented the location and behaviors of all Caspian terns and snowy plovers. This survey was designed to provide breeding chronology information such as initiation of courtship, nest-building, and incubation, and to document factors negatively influencing nesting birds such as predation or disturbance.

Third, immediately following the behavioral survey, we conducted island surveys from a vantage point on the surrounding levee closest to each particular island, where we recorded the number of adults, the number of incubating adults, the number of nests with chicks, the number of chicks, and the number of fledglings of Caspian terns and snowy plovers observed on each island. In total, each survey bout consisted of about 150–180 minutes of observation. During each survey bout, we attempted to record color-band combinations of any color-banded Caspian tern observed. Additionally in 2016, we conducted separate weekly 2-hr band-resight surveys of Caspian tern nesting colonies at Ponds A16 and SF2 to record any banded terns. These band-resight surveys were conducted from a small pop-up blind installed each day on an island (Pond A16) or internal levee (Pond SF2) adjacent to the nesting colony. During the band-resight surveys, we recorded the band combination and behaviors of all banded Caspian terns observed. These data then were provided to Yasuko Suzuki of Oregon State University to identify the origin of banded Caspian terns and potentially indicate the movement of terns from the Columbia River Basin to modified islands of the DENWR. We also recorded the number of adults, the number of incubating adults, the number of nests with chicks, the number of chicks, and the number of fledglings within Caspian tern nesting colonies during our band-resight surveys.

### Estimating Colony Size and Productivity of Caspian Terns

Because it was important to limit disturbance of these newly formed colonies to avoid causing nest and (or) colony failures, visits to islands with active colonies were limited. Thus, we could not mark and follow the fates of individual nests to estimate the total number of breeding pairs within a colony over the course of the breeding season. Rather, we estimated the number of breeding pairs of Caspian terns from direct counts of the number of active nests (sum of nests being incubated and nests with chicks) observed during our island surveys. We then used the high count, or peak number of active nests, from these surveys to estimate the total number of breeding pairs within a colony. However, Caspian terns were observed incubating eggs over a 4.5-month period from mid-April through late August (fig. 8), with the peak number of active nests occurring in early June. As a result, nests initiated after the peak in early June would not be included, and the number of breeding pairs likely would be biased somewhat low.

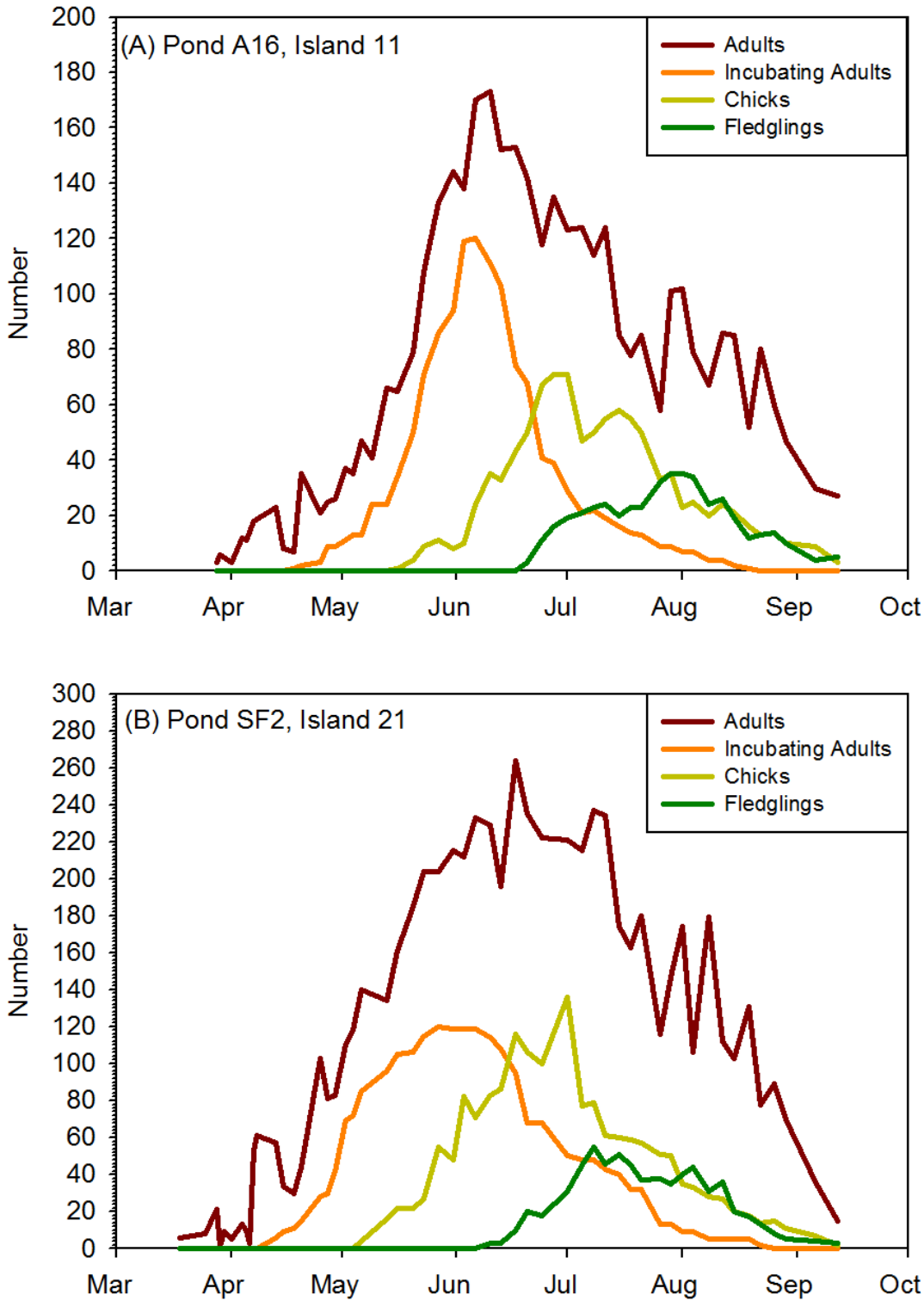


Figure 8. Number of Caspian tern adults, incubating adults, chicks, and fledglings by date at (A) Pond A16, Island 11; and (B) Pond SF2, Island 21, Don Edwards San Francisco Bay National Wildlife Refuge, California, 2016.

As with the number of breeding pairs, we estimated the total number of Caspian tern fledglings produced using the high count of the number of fledglings observed during our island surveys. However, fledglings were observed over a 3-month period at both Ponds A16 and SF2 (fig. 8), and many, if not most, of the fledglings observed in early September likely were not the same individuals observed in early July. Furthermore, there appeared to be two pulses of fledglings at Ponds A16 and SF2, one occurring in early July and another occurring in early August (fig. 8). Thus, we produced a second estimate of the number of Caspian tern fledglings produced by adding the peak number of fledglings observed during the two pulses of fledglings. We considered a chick fledged if it was similar in size to adults and had well-developed flight feathers, and (or) if it was observed flying. We estimated breeding success as the number of fledglings per breeding pair by dividing the estimated number of fledged Caspian tern chicks produced by the number of breeding pairs estimated.

### Estimating Apparent Nest Density of Caspian Terns

We calculated two measures of apparent nest density. First, we calculated nest density at each colony as a function of the total island area for that colony. Island areas were determined using real-time kinematics (RTK; Leica GNSS RTK Rover, Leica Geosystems, Atlanta, Georgia). Between August 24 and 27 of 2015, we traced the gravel perimeter of each island with the RTK unit while collecting latitude, longitude, and elevation data at 1-second intervals. These data were imported into ArcGIS™ 10.2 (Environmental Research Systems Institute, Redlands, California) and converted to polygon shapefiles for determination of island area. We then divided the peak number of nests at each colony by the corresponding island area. Second, we calculated nest density at each colony as a function of only the area of the island used by the colony. For this second measure, we used aerial photographs of the colonies to map locations of terns on each island. We determined the area of each island used by Caspian terns from digitized aerial colony photographs taken on May 27 and provided by Real Time Research (Bend, Oregon). From these photographs, we identified Caspian terns and Caspian tern decoys and created a minimum convex polygon shapefile around each colony and calculated area using ArcGIS™ 10.2. We then divided the peak number of nests at each colony by the area used by Caspian terns. Both of these estimates are of apparent nest densities, not accounting for influences of nest depredation or nest abandonment (Mayfield, 1961), as in the interest of limiting disturbance, we limited access to the islands during the nesting season. Therefore, these estimates likely are biased somewhat low.

# Results and Discussion

## Abundance of Caspian Terns and Other Avian Species in Ponds A16 and SF2

Weekly high counts of the most abundant surveyed species, and snowy plovers, at Ponds A16 and SF2 are shown in figure 9. At Pond A16, California gulls were the most abundant species (56 percent of surveyed birds observed), followed by American avocets (*Recurvirostra americana*; 16 percent), Caspian terns (10 percent), black-necked stilt (*Himantopus mexicanus*; 8 percent), and Forster's terns (*Sterna forsteri*; 7 percent) (table 2). The number of American avocets, Caspian terns, and Forster's terns at Pond A16 increased in 2016 relative to 2015, whereas the number of black-necked stilts and California gulls decreased in 2016 (fig. 10). At Pond SF2, American avocets were the most abundant species (45 percent of surveyed birds observed), followed by Caspian terns (28 percent), California gulls (18 percent), Forster's terns (5 percent), and ring-billed gulls (*Larus delawarensis*; 2 percent) (table 2). The number of American avocets and Caspian terns at Pond SF2 increased in 2016 relative to 2015 (fig. 11). California gull and Forster's tern numbers at Pond SF2 were lower in 2016 through June, but were markedly higher in August through September (fig. 11). Snowy plover numbers at Pond SF2 also were higher in 2016, although this was mostly due to large flocks observed in late March and early April that did not remain to breed (fig. 9).

We observed an average ±1 standard deviation of 80±51 and 145±88 Caspian terns during 55 pond surveys at Ponds A16 and SF2, respectively. These values represent a 51 percent increase at Pond A16 (average of 53±31 during a comparable period in 2015) and a 39 percent increase at Pond SF2 (average of 104±68 in 2015). High counts of Caspian terns occurred on June 3 (n=188) and July 5 (n=296) at Ponds A16 and SF2, respectively. Caspian terns were observed at least once on 19 islands in Pond A16, including all 3 modified islands, and 18 islands in Pond SF2, including all 4 modified islands (table 3). At Ponds A16 and SF2, Caspian terns were overwhelmingly drawn to those islands with Caspian tern social attraction measures. During the 55 behavioral surveys conducted between March 18 and September 12, 92 and 93 percent of Caspian tern observations in Ponds A16 and SF2, respectively, occurred on islands with social attraction measures for Caspian terns (fig. 12).

## Breeding Chronology of Caspian Terns

Caspian terns were first observed on March 8 at Pond SF2 during decoy and call system set up, and on March 25 at Pond A16. Courtship behaviors (for example, fish feeding, displays, copulation) began soon after Caspian terns arrived at the ponds, and were first observed on March 18 at Pond SF2 and on March 29 at Pond A16. Caspian terns began nesting at Pond SF2 about 5 days earlier than at Pond A16, with the first incubating birds observed on April 13 and April 18 at Ponds SF2 and A16, respectively. Caspian terns were observed incubating eggs over a 19-week period at Pond A16 and over a 20-week period at Pond SF2 (fig. 13). The first chicks were observed at Pond SF2 on May 9 and at Pond A16 on May 16. The 2015 nesting season was longer than has been observed for Caspian terns in San Francisco Bay. Roby and others (2009) reported that by early August 2009, three Caspian tern colonies in San Francisco Bay had completed nesting and were abandoned. In contrast, pre-fledged chicks continued to be observed as late as early September at Ponds A16 and SF2 in 2016 (fig. 13).

## Size and Productivity of Caspian Tern Breeding Colonies

Caspian terns nested on Island 11 in Pond A16 and on Island 21 in Pond SF2. They did not nest on the other 3 islands modified for Caspian terns (Island 12 in Pond A16, Islands 12 and 17 in Pond SF2; figs. 14–18). The number of nests being incubated peaked on May 27 on Island 21 in Pond SF2 and on June 6 on Island 11 in Pond A16, and totaled 120 nests at both ponds (fig. 8).

Table 2. Cumulative number of individuals counted and percentage of total observations of waterbirds (gulls, terns, and shorebirds) and potential egg and chick predators observed during 55 pond surveys conducted at (A) Pond A16, and (B) Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California, March 18–September 12, 2016.

[Focal species Caspian terns and snowy plover are bolded. <, less than]

| Species common name | Species scientific name | Cumulative number of individuals counted | Percentage of total |
|---|---|---|---|
| (A) Pond A16 | | | |
| California gull | *Larus californicus* | 21,815 | 56 |
| American avocet | *Recurvirostra americana* | 6,247 | 16 |
| **Caspian tern** | ***Hydroprogne caspia*** | **3,820** | **10** |
| Black-necked stilt | *Himantopus mexicanus* | 3,109 | 8 |
| Forster's tern | *Sterna forsteri* | 2,756 | 7 |
| Ring-billed gull | *Larus delawarensis* | 518 | 1 |
| Western gull | *Larus occidentalis* | 185 | <1 |
| Bonaparte's gull | *Chroicocephalus philadelphia* | 164 | <1 |
| **Snowy plover** | ***Charadrius alexandrinus nivosus*** | **41** | **<1** |
| Common raven | *Corvus corax* | 22 | <1 |
| Turkey vulture | *Cathartes aura* | 6 | <1 |
| Glaucous-winged gull | *Larus glaucescens* | 1 | <1 |
| (B) Pond SF2 | | | |
| American avocet | *Recurvirostra americana* | 11,377 | 45 |
| **Caspian tern** | ***Hydroprogne caspia*** | **7,147** | **28** |
| California gull | *Larus californicus* | 4,445 | 18 |
| Forster's tern | *Sterna forsteri* | 1,181 | 5 |
| Ring-billed gull | *Larus delawarensis* | 564 | 2 |
| **Snowy plover** | ***Charadrius alexandrinus nivosus*** | **478** | **2** |
| American crow | *Corvus brachyrhynchos* | 25 | <1 |
| Western gull | *Larus occidentalis* | 11 | <1 |
| Black-necked stilt | *Himantopus mexicanus* | 4 | <1 |
| Common raven | *Corvus corax* | 2 | <1 |
| Northern harrier | *Circus cyaneus* | 1 | <1 |
| Osprey | *Pandion haliaetus* | 1 | <1 |
| Peregrine falcon | *Falco peregrinus* | 1 | <1 |
| Red-tailed hawk | *Buteo jamaicensis* | 1 | <1 |

Table 3. Number of pond surveys in which Caspian terns were observed and the total number of Caspian terns counted on each island during 55 pond surveys conducted at (A) Pond A16, and (B) Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California, March 18–September 12, 2016.

[Islands modified for Caspian terns or snowy plovers are bolded]

| Island No. | Number of surveys where Caspian terns observed | Total number of Caspian terns counted during all surveys |
|---|---|---|
| (A) Pond A16 | | |
| 1 | 5 | 6 |
| 2 | 4 | 4 |
| [1]**3** | 1 | 1 |
| 4 | 25 | 66 |
| 5 | 4 | 5 |
| 6 | 11 | 15 |
| 7 | 9 | 12 |
| 8 | 13 | 18 |
| 9 | 4 | 7 |
| 10 | 1 | 1 |
| [2,3]**11** | 52 | 3,530 |
| [2]**12** | 7 | 8 |
| 13 | 3 | 3 |
| 14 | 1 | 1 |
| 15 | 4 | 4 |
| 16 | 1 | 1 |
| 18 | 2 | 3 |
| 19 | 1 | 1 |
| 20 | 1 | 1 |
| (B) Pond SF2 | | |
| 4 | 1 | 1 |
| 7 | 1 | 1 |
| 9 | 1 | 1 |
| [1]**10** | 1 | 1 |
| [2]**12** | 2 | 2 |
| 13 | 1 | 3 |
| 14 | 4 | 6 |
| 16 | 2 | 2 |
| [2]**17** | 29 | 211 |
| 18 | 15 | 65 |
| 19 | 6 | 18 |
| 20 | 5 | 16 |
| [2,3]**21** | 54 | 6,469 |
| 22 | 6 | 6 |
| 24 | 2 | 2 |
| 25 | 6 | 9 |
| 26 | 2 | 2 |
| 30 | 1 | 2 |

[1]Denotes islands with social attractions for snowy plovers.

[2]Denotes islands with social attractions for Caspian terns.

[3]Denotes islands where Caspian terns nested.

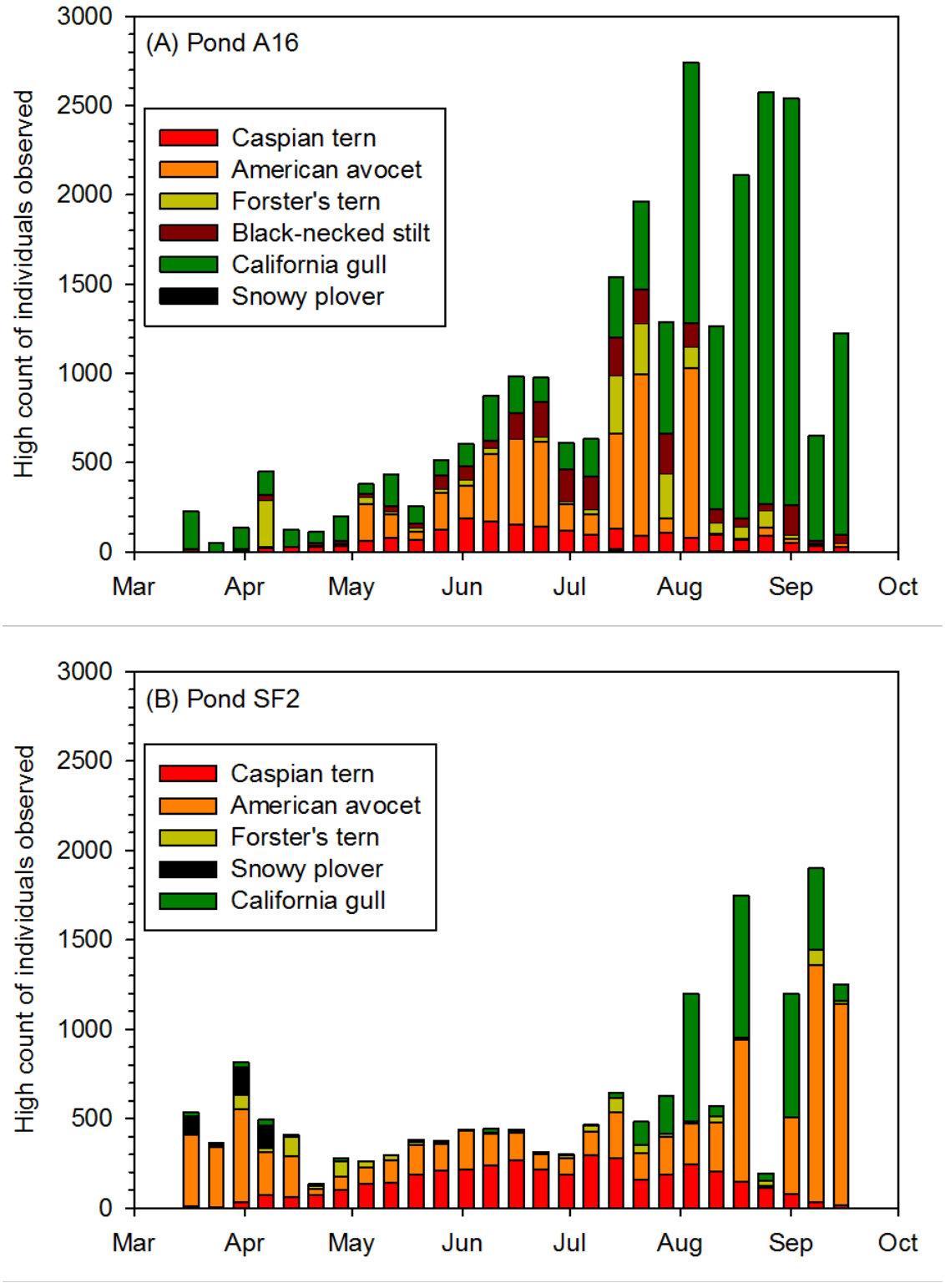


Figure 9. Weekly high counts of individuals of the most abundant surveyed waterbird species (and snowy plovers) observed during pond surveys at (A) Pond A16, and (B) Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California, March 18–September 12, 2016.

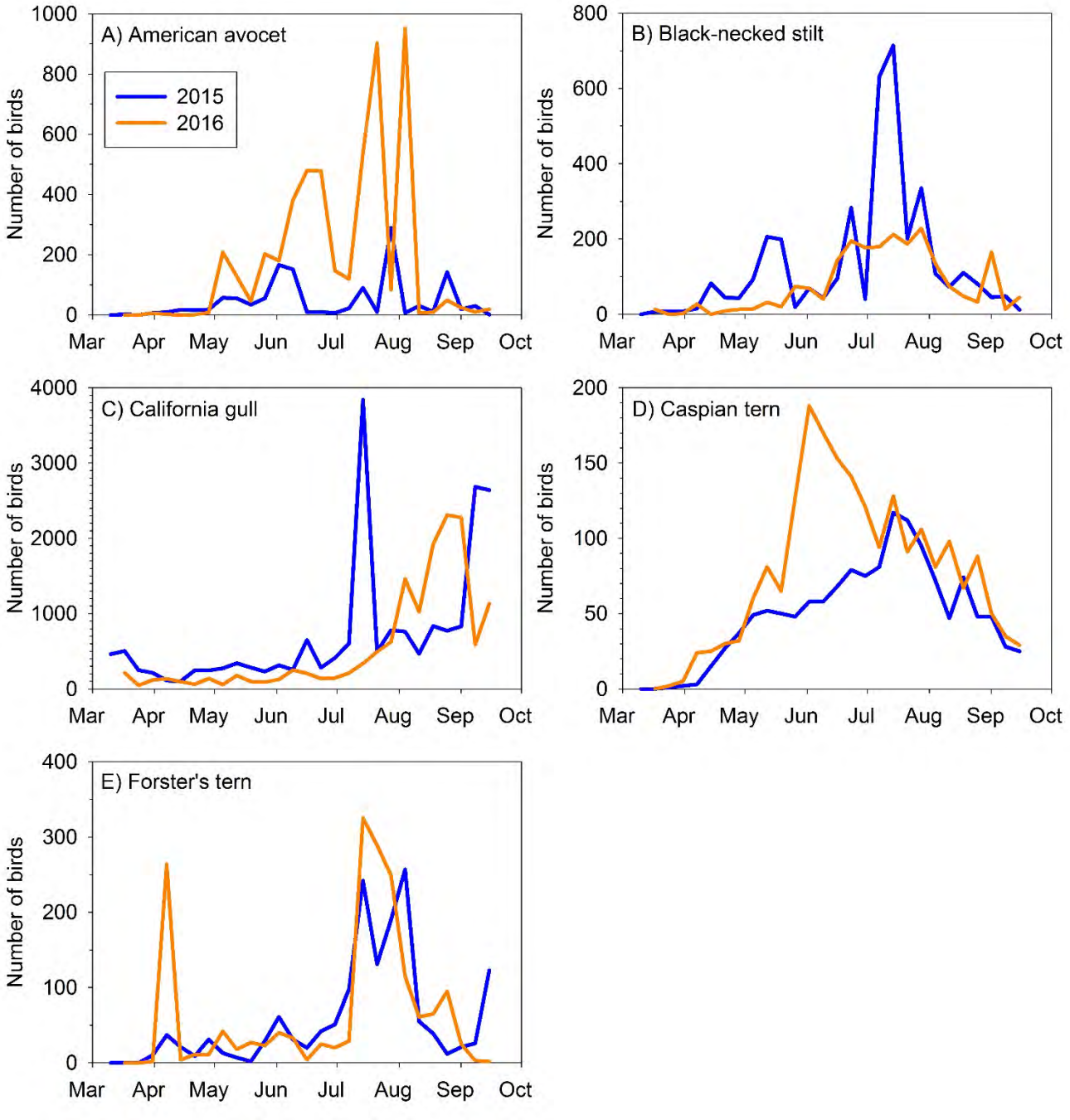


Figure 10. Weekly high counts of the number of (A) American avocets, (B) black-necked stilts, (C) California gulls, (D) Caspian terns, and (E) Forster's terns at Pond A16 of the Don Edwards San Francisco Bay National Wildlife Refuge, California, 2015 and 2016.

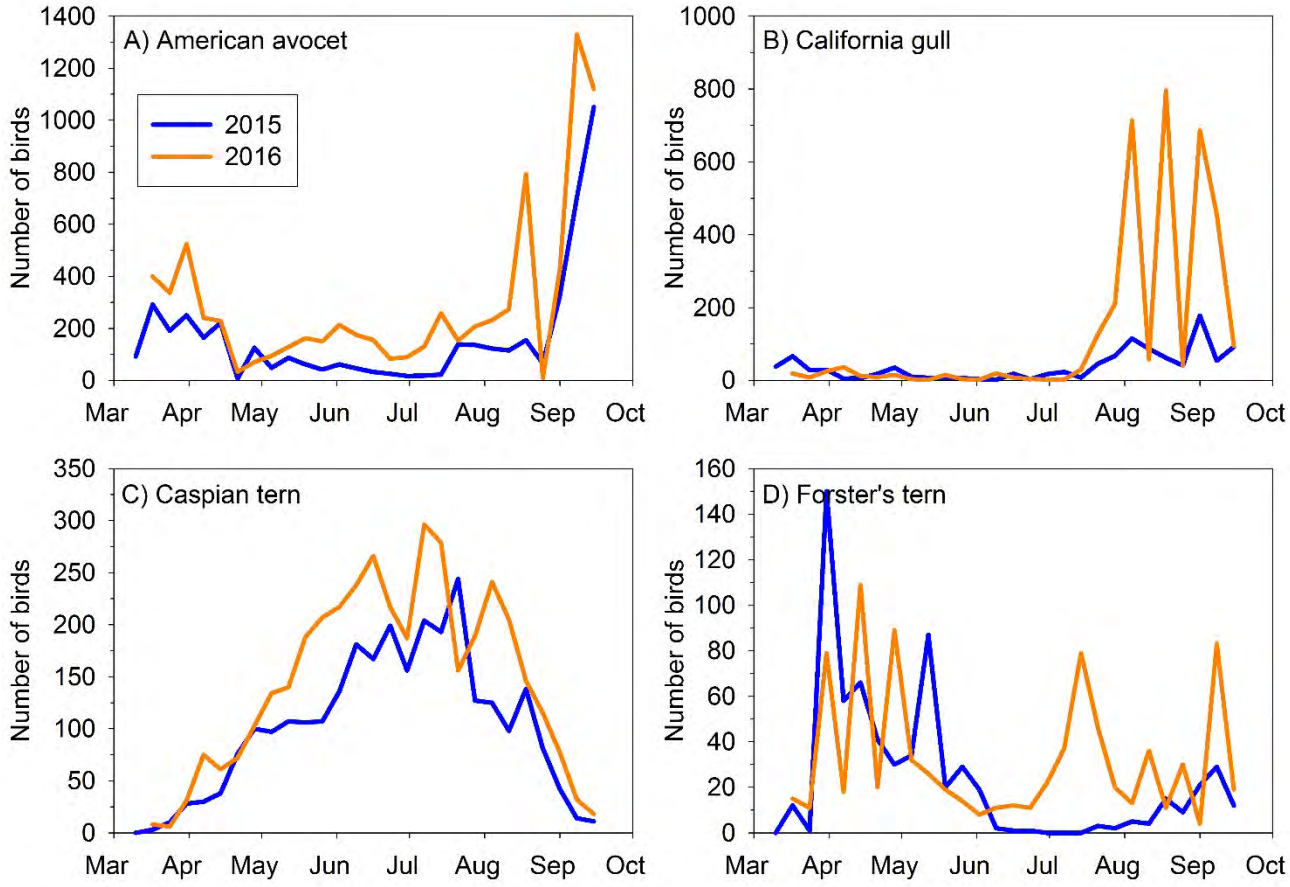


Figure 11. Weekly high counts of the number of (A) American avocets, (B) California gulls, (C) Caspian terns, and (D) Forster's terns at Pond SF2 of the Don Edwards San Francisco Bay National Wildlife Refuge, California, 2015 and 2016.

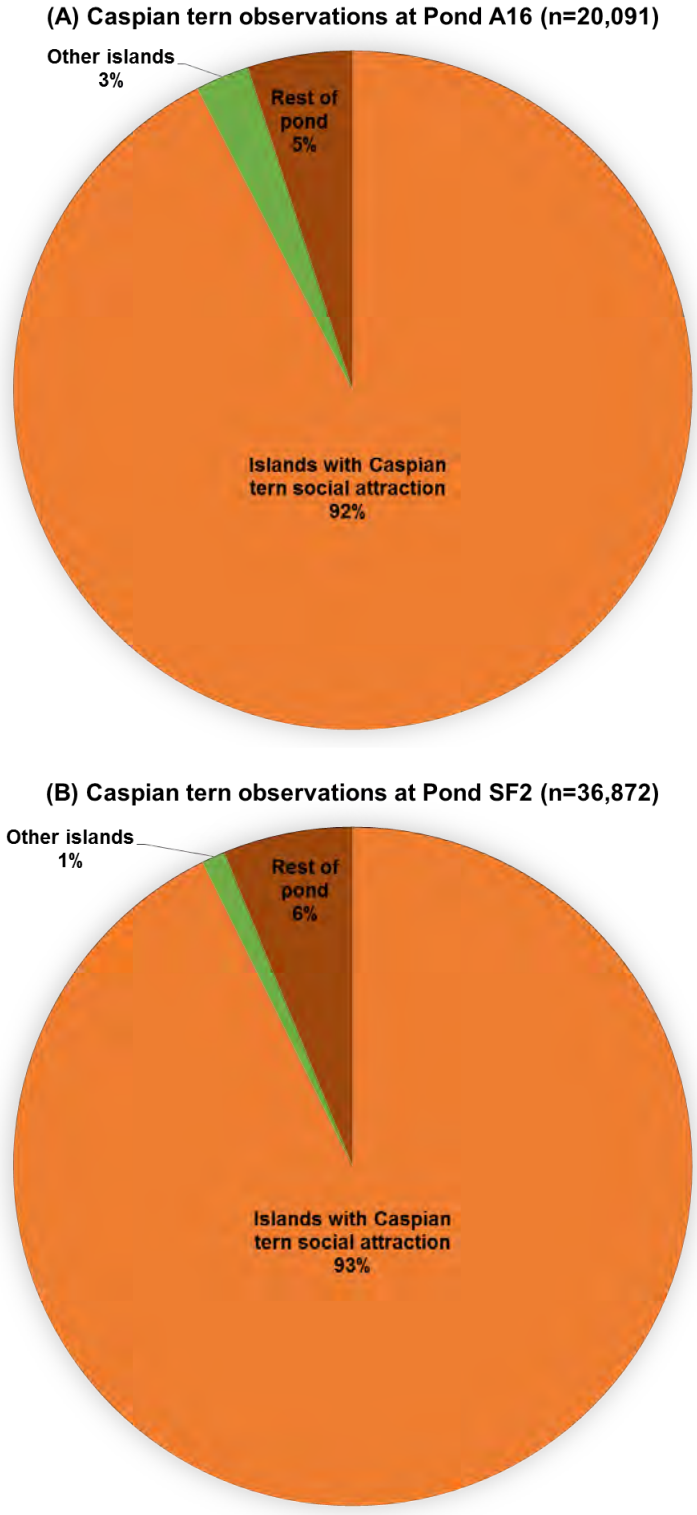


Figure 12. Percentage of Caspian tern observations by location during fifty-five 60-minute behavior surveys conducted at (A) Pond A16, and (B) Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California, March 18–September 12, 2016. Sample size includes multiple observations of the same individuals over each 60-minute behavioral survey.

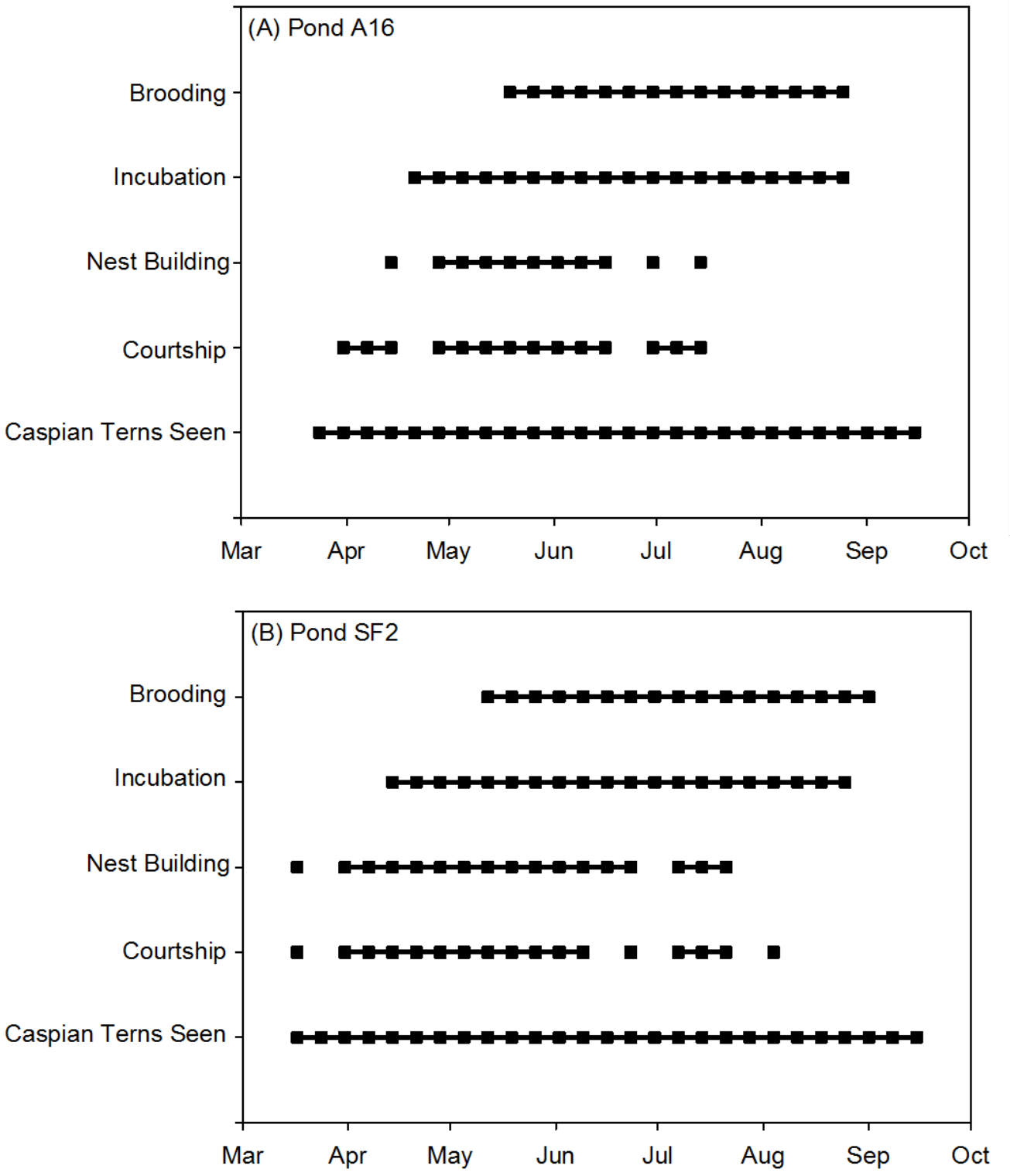


Figure 13. Breeding chronology of Caspian terns based on observed behaviors at (A) Pond A16, and (B) Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California, 2016. Surveys were conducted between March 18 and September 12.

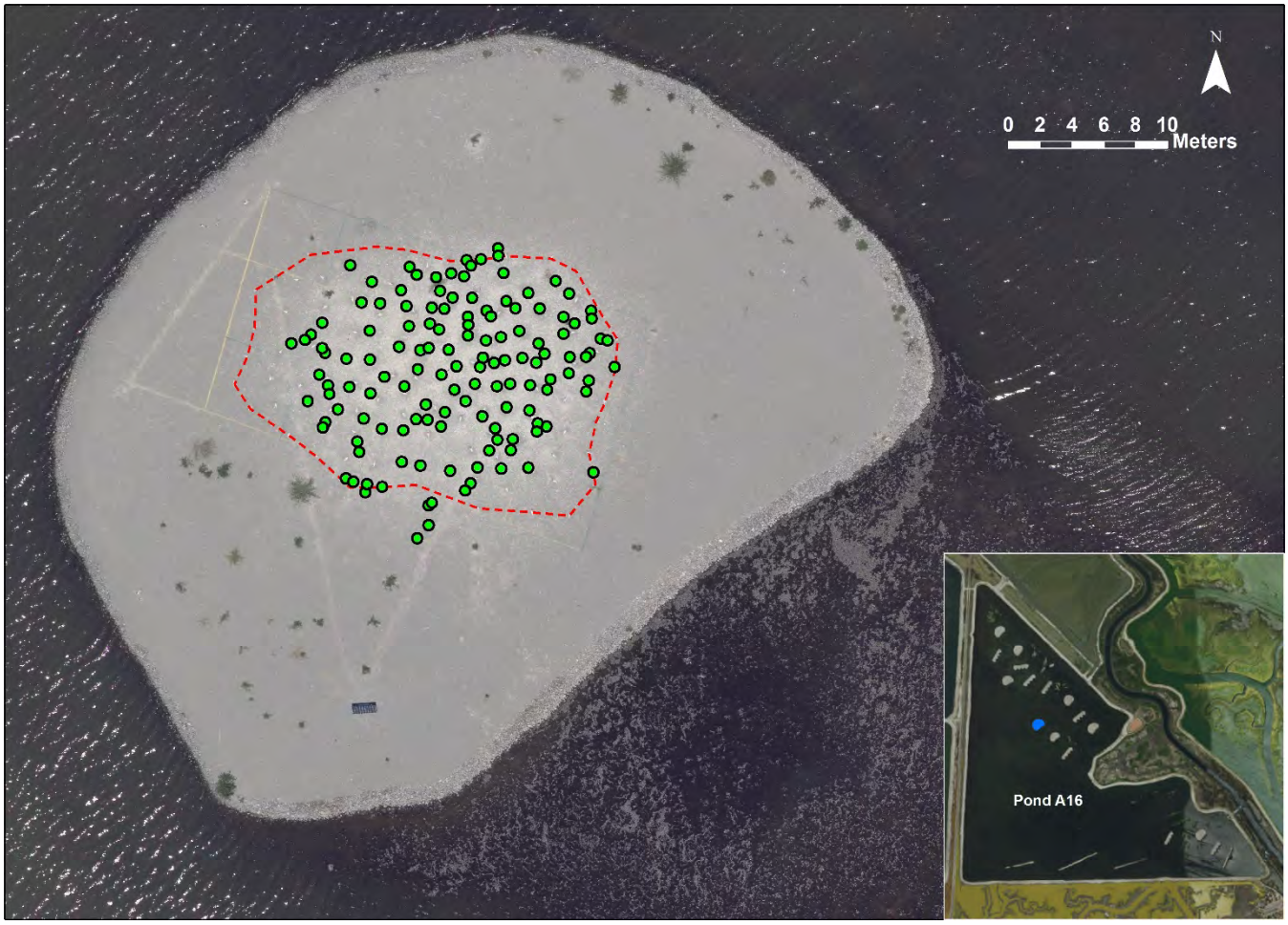


Figure 14. Aerial photograph of Island 11 modified for Caspian terns in Pond A16, Don Edwards San Francisco Bay National Wildlife Refuge, California. Dashed red line denotes the extent of the decoy spread. Green circles denote locations of individual Caspian terns. Photograph provided by Real Time Research, and taken May 27, 2016.


Figure 15. Aerial photograph of Island 12 modified for Caspian terns in Pond A16, Don Edwards San Francisco Bay National Wildlife Refuge, California. Dashed red line denotes the extent of the decoy spread. No Caspian terns nested in 2016. Photograph provided by Real Time Research, and taken May 27, 2016.


Figure 16. Aerial photograph of Island 12 modified for Caspian terns in Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California. Dashed red line denotes the extent of the decoy spread. No Caspian terns nested in 2016. Photograph provided by Real Time Research, and taken May 27, 2016.

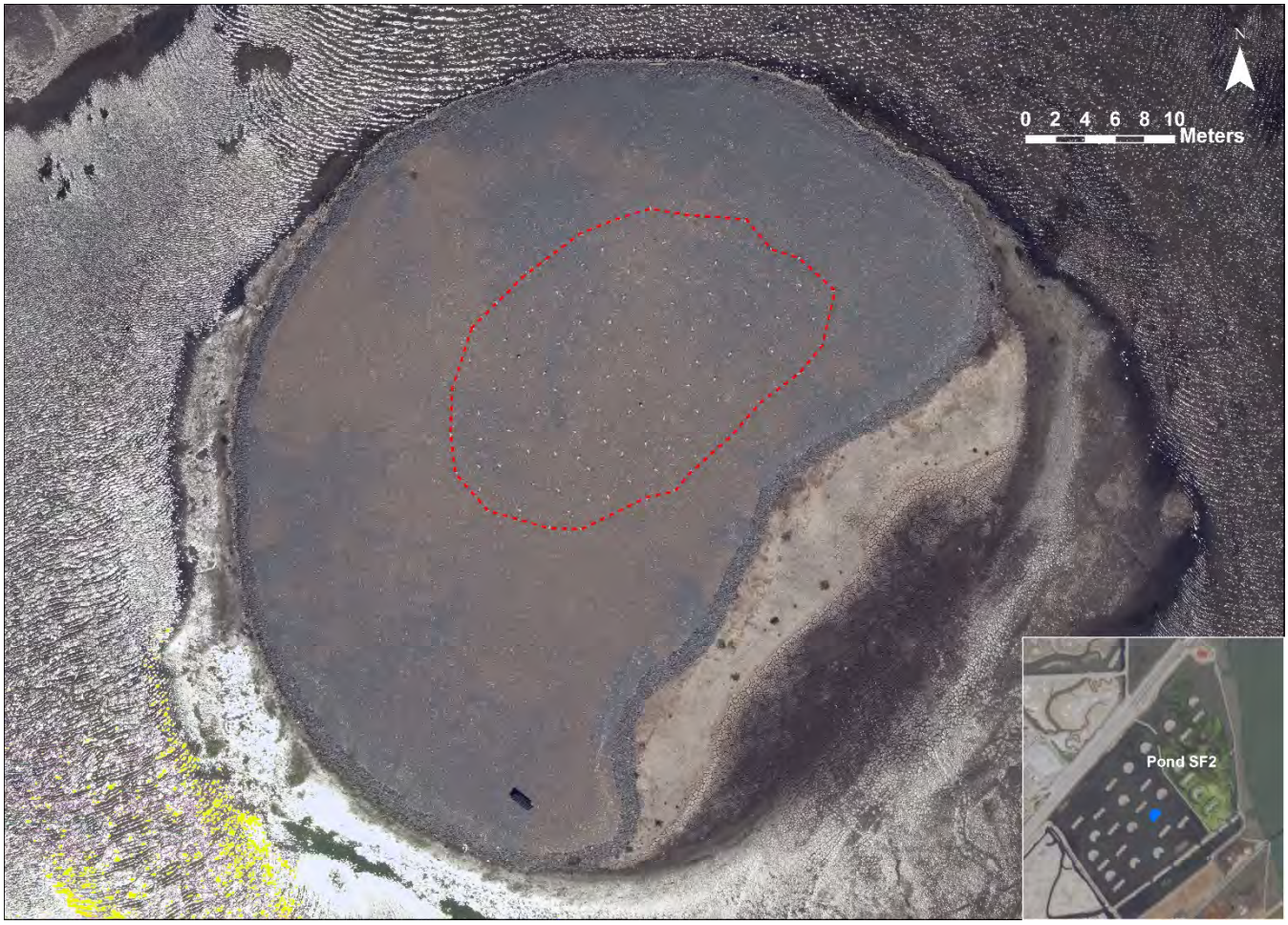


Figure 17. Aerial photograph of Island 17 modified for Caspian terns in Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California. Dashed red line denotes the extent of the decoy spread. No Caspian terns nested in 2016. Photograph provided by Real Time Research, and taken May 27, 2016.

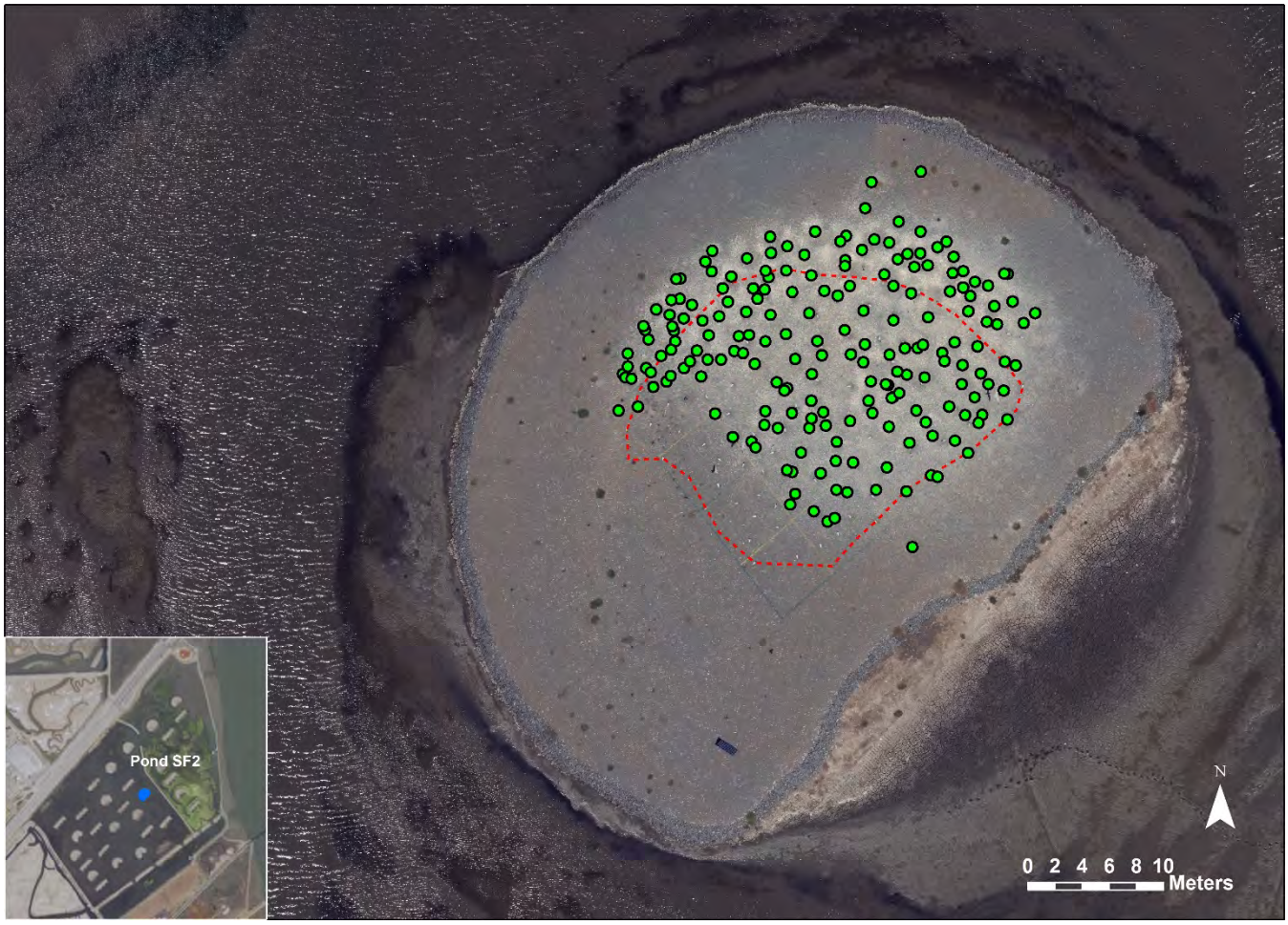


Figure 18. Aerial photograph of Island 21 modified for Caspian terns in Pond SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California. Dashed red line denotes the extent of the decoy spread. Green circles denote locations of individual Caspian terns. Photograph provided by Real Time Research, and taken May 27, 2016.

Peak counts of the total number of active nests (which include nests with eggs and nests with chicks) on Island 11 in Pond A16 occurred on June 6 (137 nests) and on Island 21 in Pond SF2 on June 3 (180 nests). Summing the peak number of active nests on these two ponds resulted in a total of 317 breeding pairs. The total number of Caspian tern breeding pairs increased 88 percent at Pond A16, 19 percent at Pond SF2, and 42 percent overall between 2015 and 2016 (fig. 19).

Peak counts of the number of fledglings occurred on August 1 (n=35) on Island 11 in Pond A16, and on July 8 (n=55) on Island 21 in Pond SF2. Adding these two numbers together yielded a minimum estimate of 90 Caspian tern fledglings produced in 2016. However, fledglings were observed over a 3-month period with two pulses, one in early July and another in early August (fig. 8), and many of the fledglings observed later in the season likely were not the same individuals observed earlier in the season. Therefore, we summed the high count of the number of fledglings observed during the two pulses to obtain a more representative estimate of the total number of fledglings produced. On Island 11 in Pond A16, the first peak of fledglings occurred on July 11 and totaled 24 individuals, and the second peak of fledglings occurred on August 1 and totaled 35 individuals. On Island 21 in Pond SF2, the first

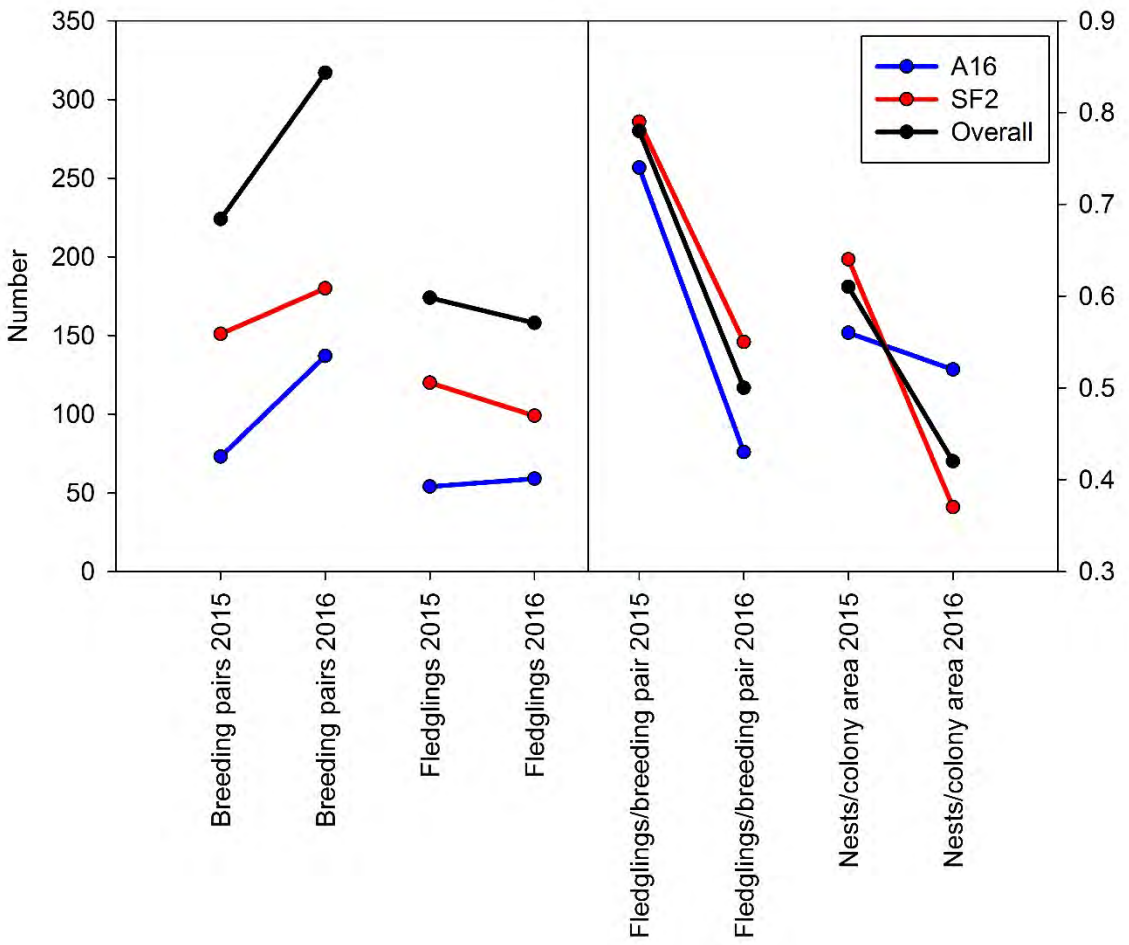


Figure 19. Total number of Caspian tern breeding pairs and fledglings, and the apparent breeding success (fledglings/breeding pair) and apparent nest density (nests/colony area) in 2015 and 2016 at Pond A16, Pond SF2, and overall on the Don Edwards San Francisco Bay National Wildlife Refuge, California.

peak of fledglings occurred on July 8 and totaled 55 individuals, and the second peak of fledglings occurred on August 4 and totaled 44 individuals. Summing the number of fledglings from the two peaks resulted in estimates of 59 and 99 Caspian tern chicks fledged from Island 11 in Pond A16 and Island 21 in Pond SF2, respectively. Combining these numbers, we estimated that 158 Caspian tern chicks fledged from Ponds A16 and SF2 in 2016. A more detailed mark-recapture study of tern chicks would yield better estimates of Caspian tern chicks and fledglings, although this would require weekly island visits which would increase the potential for disturbance.

The number of fledglings produced increased 9 percent at Pond A16, decreased 18 percent at Pond SF2, and decreased 9 percent overall between 2015 and 2016 (fig. 19). Dividing the estimated number of fledglings by the number of breeding pairs yielded an apparent breeding success (number of fledglings per breeding pair) of 0.43 for Island 11 in Pond A16 and 0.55 for Island 21 in Pond SF2 (table 4). Apparent breeding success decreased 42 percent at Pond A16, decreased 30 percent at Pond SF2, and decreased 36 percent overall between 2015 and 2016 (fig. 19). Overall, we estimated that Ponds A16 and SF2 together supported at least 317 breeding pairs of Caspian terns and fledged 158 Caspian tern chicks, for a breeding success rate of 0.50 fledglings per breeding pair (table 4).

## Nest Density of Caspian Terns

Nest density as a function of the total island gravel area available on each island was 0.11 nests/$m^2$ on Island 21 in Pond SF2 and 0.09 nests/$m^2$ on Island 11 in Pond A16 (table 4). However, on both islands, the proportion of total island area used by the colonies was relatively small (figs. 14 and 18). The colony on Island 11 in Pond A16 encompassed 266 $m^2$ (17 percent) of the 1,603 $m^2$ of island gravel surface available, and the colony on Island 21 in Pond SF2 encompassed 481 $m^2$ (28 percent) of the 1,693 $m^2$ of island surface available (table 4). This represents a doubling of the island area used by the colonies on each island relative to 2015 (130 $m^2$ on Island 11 in Pond A16, 236 $m^2$ on Island 21 in Pond SF2; Hartman and others, 2016). Nest densities estimated as a function of only the island area used by Caspian terns were 0.52 and 0.37 nests/$m^2$ on Island 11 in Pond A16 and Island 21 in Pond SF2, respectively (table 4). Nest density as a function of only the island area used by Caspian terns was slightly lower in 2016 than in 2015 on Island 11 in Pond A16 and almost one-half that of 2015 on Island 21 in Pond SF2 (fig. 19).

## Sightings of Color-Banded Caspian Terns

In 2016, we added an additional task to the project to re-sight Caspian terns that had been color banded elsewhere. We erected pop-up blinds on an unused island (Pond A16) or an internal levee (Pond SF2) adjacent to islands with Caspian tern nesting colonies. Between April and September we conducted 2-h observation bouts from these blinds and recorded all banded Caspian terns with field-readable color bands.

We observed 26 uniquely banded Caspian terns over the course of the 2016 surveys (table 5). Three banded terns (1 with color bands, 2 with alphanumeric engraved bands) were observed on Island 11 in Pond A16, and 23 banded terns (7 with color bands, 16 with alphanumeric engraved bands) were observed on Islands 17 and (or) 21 in Pond SF2. On Island 11 in Pond A16, 2 of the 3 banded terns were observed on a single occasion, whereas the third was observed four times between April and August. All 3 banded terns on Island 11 in Pond A16 were only observed loafing, and were never observed engaged in breeding behaviors. At Pond SF2, 9 banded terns were observed on a single occasion, whereas 14 were observed 2–9 times between April and August (table 5). A total of 8 Caspian terns were observed engaged in breeding behaviors at Pond SF2 (that is, copulation, nest scraping, courtship feeding, incubation, or attending to, feeding, or brooding a chick).

All information regarding the site of initial banding was provided courtesy of Yasuko Suzuki (Suzuki, Oregon State University, written commun., October 18, 2016). Two of the 3 banded Caspian terns at Pond A16 originally were banded as chicks on East Sand Island in the Columbia River estuary, Oregon. The other was banded as a chick at Sheepy Lake on the Lower Klamath National Wildlife Refuge. Among the 23 banded Caspian terns observed at Pond SF2, 2 were banded as chicks at the Port of Bellingham in Bellingham Bay, Washington; 2 were banded as chicks and 1 was banded as an adult at East Sand Island; 2 were banded as chicks on Goose Island in Potholes Reservoir, Washington; 2 were banded as chicks at Sheepy Lake; 9 were banded as chicks and 2 were banded as adults on Brooks Island in San Francisco Bay, California; 1 was banded as a chick on Knight Island in northern San Francisco Bay; and 1 was banded as a chick in Eden Landing in south San Francisco Bay (table 5). Of the 8 Caspian terns observed engaged in breeding behaviors at Pond SF2, 5 were banded on Brooks Island, 1 was banded at Eden Landing, 1 was banded at the Port of Bellingham, and 1 was banded at Sheepy Lake (table 5).

Table 4. Breeding metrics on seven modified islands with social attraction measures for (A) Caspian terns, and (B) snowy plovers in Ponds A16 and SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California, 2016.

[Dash (–) denotes that the calculation is not possible. $m^2$, square meter]

| Pond | Island No. | Number of breeding pairs[1] | Number of chicks fledged[2] | Breeding success (fledglings/ breeding pair)[3] | Island gravel area ($m^2$) | Colony area ($m^2$) | Apparent nest density | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | (nests/islands $m^2$)[4] | (nests/colony $m^2$)[5] |
| (A) Caspian tern | | | | | | | | |
| A16 | 11 | 137 | 59 | 0.43 | 1,603 | 266 | 0.09 | 0.52 |
| A16 | 12 | 0 | 0 | – | 1,247 | – | – | – |
| SF2 | 12 | 0 | 0 | – | 1,841 | – | – | – |
| SF2 | 17 | 0 | 0 | – | 1,518 | – | – | – |
| SF2 | 21 | 180 | 99 | 0.55 | 1,693 | 481 | 0.11 | 0.37 |
| TOTAL | | 317 | 158 | 0.50 | 7,903 | 747 | 0.04 | 0.42 |
| (B) Snowy plover | | | | | | | | |
| A16 | 3 | 0 | 0 | – | 1,318 | – | – | – |
| SF2 | 10 | 0 | 0 | – | 1,420 | – | – | – |
| TOTAL | | 0 | 0 | – | 2,738 | – | – | – |

[1]Calculated as the high count or peak number of nests.

[2]Calculated by summing the peak number of fledglings from the two pulses.

[3]Calculated by dividing the number of chicks fledged by the number of breeding pairs.

[4]Calculated by dividing the number of breeding pairs on the island by the total island area.

[5]Calculated by dividing the number of breeding pairs on the island by the colony area.

Table 5. Sightings of 26 color-banded Caspian terns at Ponds A16 and SF2, Don Edwards San Francisco Bay National Wildlife Refuge, California, 2016.

[Banding and past breeding information provided by Yasuko Suzuki (Oregon State University, written commun., October 18, 2016). **Tern:** 4, was unidentifiable; 5, bred at East Sand Island in 2015; 6, also was observed on SF2/21 in 2015; 11, bred at Tule Lake in 2015; 18, bred at Brooks Island in 2008 and 2009, and also was observed on SF2/21 in 2015; 20, bred at Blalock Islands in 2016; 26, bred at East Sand Island in 2014–16; each tern was banded on its left leg with a color band combination, and on its right leg with either a color band combination or a single alphanumeric band; a dash indicates that an individual did not have a particular band type; an X denotes a missing band]

| Tern | Left leg color band combination | | | Right leg color band combination | | | Right leg alphanumeric band | | | Number of days observed | Pond/island | Breeding behavior observed? | Banding location | Banding year | Age at banding |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Top | Middle | Bottom | Top | Middle | Bottom | Band color | Code color | Alphanumeric code | | | | | | |
| 1 | Red | Orange | Dark Green | Yellow | Light Green | Metal | – | – | – | 1 | A16/11 | No | East Sand Island | 2004 | Chick |
| 2 | Orange | Dark blue | Metal | – | – | – | Yellow | Black | J677 | 4 | A16/11 | No | East Sand Island | 2010 | Chick |
| 3 | Dark green | Yellow | Metal | – | – | – | Yellow | Black | K400 | 1 | A16/11 | No | Sheepy Lake | 2012 | Chick |
| 4 | X | Yellow | Orange | X | Metal | Dark Green | – | – | – | 1 | SF2/21 | No | Unknown | Unknown | Unknown |
| 5 | Dark blue | Orange | White | Light Green | Metal | White | – | – | – | 2 | SF2/21 | No | Knight Island | 2003 | Chick |
| 6 | Dark blue | Dark blue | Dark blue | Dark Green | Light Blue | Metal | – | – | – | 7 | SF2/21 | Yes | Brooks Island | 2005 | Chick |
| 7 | Red | Dark blue | Yellow | Yellow | White | Metal | – | – | – | 9 | SF2/21 | Yes | Brooks Island | 2004 | Chick |
| 8 | Orange | Light green | Dark blue | Yellow | White | Metal | – | – | – | 6 | SF2/21 | Yes | Brooks Island | 2004 | Chick |
| 9 | Dark blue | Light green | Yellow | Dark Green | Light Blue | Metal | – | – | – | 1 | SF2/21 | No | Brooks Island | 2005 | Chick |
| 10 | Dark blue | Red | Dark green | Dark Green | Light Blue | Metal | – | – | – | 1 | SF2/21 | No | Brooks Island | 2005 | Chick |
| 11 | Orange | Light green | Metal | – | – | – | Yellow | Black | J731 | 3 | SF2/21 | Yes | Port of Bellingham | 2010 | Chick |
| 12 | Orange | Light green | Metal | – | – | – | Yellow | Black | J520 | 1 | SF2/21 | No | Port of Bellingham | 2010 | Chick |
| 13 | White | Light blue | Metal | – | – | – | Yellow | Black | F108 | 1 | SF2/21 | No | Goose Island | 2011 | Chick |
| 14 | Dark blue | Orange | Metal | – | – | – | Yellow | Black | E380 | 6 | SF2/17&21 | Yes | Eden Landing | 2009 | Chick |

| Tern | Left leg color band combination | | | Right leg color band combination | | | Right leg alphanumeric band | | | Number of days observed | Pond/island | Breeding behavior observed? | Banding location | Banding year | Age at banding |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Top | Middle | Bottom | Top | Middle | Bottom | Band color | Code color | Alphanumeric code | | | | | | |
| 15 | Dark green | Yellow | Metal | – | – | – | Yellow | Black | K320 | 5 | SF2/21 | Yes | Sheepy Lake | 2012 | Chick |
| 16 | Red | Orange | Metal | – | – | – | Yellow | Black | C548 | 2 | SF2/21 | Yes | Brooks Island | 2008 | Chick |
| 17 | Dark blue | Orange | Metal | – | – | – | Yellow | Black | E240 | 2 | SF2/17&21 | No | Brooks Island | 2009 | Adult |
| 18 | Red | Orange | Metal | – | – | – | Yellow | Black | C379 | 3 | SF2/21 | Yes | Brooks Island | 2008 | Adult |
| 19 | White | Yellow | Metal | – | – | – | Yellow | Black | F274 | 1 | SF2/17 | No | Sheepy Lake | 2011 | Chick |
| 20 | White | Light blue | Metal | – | – | – | Yellow | Black | F118 | 1 | SF2/21 | No | Goose Island | 2011 | Chick |
| 21 | Red | Orange | Metal | – | – | – | Yellow | Black | C629 | 2 | SF2/17&21 | No | Brooks Island | 2008 | Chick |
| 22 | Dark blue | Dark blue | Metal | – | – | – | Yellow | Black | E858 | 3 | SF2/17&21 | No | East Sand Island | 2009 | Chick |
| 23 | Red | Dark blue | Metal | – | – | – | Yellow | Black | C881 | 1 | SF2/21 | No | East Sand Island | 2008 | Chick |
| 24 | Red | Orange | Metal | – | – | – | Yellow | Black | C670 | 2 | SF2/21 | No | Brooks Island | 2008 | Chick |
| 25 | Dark blue | Orange | Metal | – | – | – | Yellow | Black | E399 | 2 | SF2/21 | No | Brooks Island | 2009 | Chick |
| 26 | Orange | White | Metal | – | – | – | Red | White | A123 | 1 | SF2/21 | No | East Sand Island | 2010 | Adult |

## Nesting of Snowy Plovers and other Waterbirds

At Pond A16, snowy plovers were observed on nine occasions between April and August, with a high count of 15 birds recorded on July 11. At Pond SF2, snowy plovers were observed on five occasions in March and early April, with a high count of 155 birds recorded on April 1. Almost all snowy plovers were observed on mudflats or along the pond levees. At Pond A16, only two snowy plovers were observed on an island; one on Island 2 on May 2 and one on Island 3 (snowy plover social attraction island) on July 26. At Pond SF2, no snowy plovers were observed on an island. No snowy plovers nested in Pond A16, and snowy plovers only nested in the salt panne part of Pond SF2 west of the constructed islands.

At Pond A16, 89 American avocet and 5 black-necked stilt nests were observed on islands or on mudflat habitat in 2016. Fifty (56 percent) of the American avocet nests and none of the black-necked stilt nests successfully hatched young. Twenty-three American avocet nests were observed on Island 3 in Pond A16 (snowy plover social attraction island) and 13 (57 percent) of these nests successfully hatched young.

At Pond SF2, 121 American avocet and 8 Forster's tern nests were recorded on islands or on mudflat habitat in 2016. Eighty-three (69 percent) of the American avocet nests and 6 (75 percent) of the Forster's tern nests successfully hatched young. American avocet nests were observed on Island 10 (n=1), Island 17 (n=1), and Island 21 (n=2). The nest on Island 10 (snowy plover social attraction island) was depredated, the nest on Island 17 (Caspian tern social attraction island) hatched, and the two nests on Island 21 (Caspian tern social attraction island) were not monitored to determine fate because of the presence of the active Caspian tern nesting colony on the island.

## Gull Dissuasion

California gull numbers at Pond A16 were lower in 2016 compared to 2015. In 2015, the average ±1 standard deviation number of California gulls at Pond A16 was 710±875 over the course of the study and 519±781 during March through July. In 2016, the average number of California gulls at Pond A16 was 536±690 over the course of the study and only 188±147 between March and July. At Pond SF2, numbers of California gulls were slightly greater in 2016; however, this was mostly the result of large numbers of gulls moving through in late August. In 2015, the average number of California gulls at Pond SF2 was 38±41 over the course of the study and 21±20 during March through July. In 2016, the average number of California gulls at Pond SF2 was 126±238 over the course of the study and only 28±51 between March and July. Gulls roosted on the modified islands less often than on other islands. This, coupled with the much lower numbers of gulls relative to 2015, made gull hazing largely unnecessary in 2016. We never observed gulls prospecting for nest sites, building nests, or engaging in other nesting behaviors at either Ponds A16 or SF2.

The greater number of gulls at Pond A16 compared to Pond SF2 likely is due, in part, to the greater distance of Pond SF2 to the nearest breeding gull colony and to the nearest landfill, which attracts large numbers of gulls (J.T. Ackerman, U.S. Geological Survey, unpub. data, 2009). The distance from modified islands in Pond A16 to the nearest gull colony is less than 3 km, whereas the distance from modified islands in Pond SF2 to the nearest gull colony is more than 5 km (fig. 1). Additionally, the density of breeding gulls is much greater around Pond A16 than around Pond SF2 (fig. 1). Furthermore, the distance from modified islands in Pond A16 to the nearest landfill (Newby Island) is about 2 km, whereas the distance from modified islands in Pond SF2 to the nearest landfill (Tri Cities) is more than 11 km. Finally, gulls likely were attracted to Pond A16 because it lies almost directly between the large A9/A10 gull colony and the Newby Island Landfill (fig. 1).

## Factors Influencing Overall Success of Caspian Tern Colonies

Potential egg or chick predators observed at Ponds A16 and SF2 included California gulls, ring-billed gulls, western gulls (*Larus occidentalis*), Bonaparte's gulls (*Chroicocephalus philadelphia*), American crows (*Corvus brachyrhynchos*), and common ravens (table 2). Of these predators, California gulls were by far the most numerous, and are well-documented predators of waterbird eggs and chicks in south San Francisco Bay (Herring and others, 2011; Ackerman, Herzog, Hartman, and Herring, 2014; Ackerman, Herzog, Hartman, and Takekawa, 2014). California gulls were particularly abundant at Pond A16, making up 56 percent of the surveyed birds observed. However, numbers of California gulls at Pond A16 were lower in 2016 than in 2015, and weekly high counts only exceeded 500 individuals after late July (figs. 9 and 10). Gulls in Pond A16 typically were observed roosting on islands and the surrounding pond levees, and there was little evidence that California gulls had a large negative influence on nesting Caspian terns. On June 2, a California gull was observed depredating an abandoned Caspian tern nest at the edge of the colony on Island 11 in Pond A16. On July 1, a California gull unsuccessfully attempted to steal a fish from a Caspian tern chick. On September 18, a peregrine falcon (*Falco peregrinus*) was observed eating a Caspian tern fledgling on Island 11 in Pond A16. At Pond SF2, there were fewer gulls than at Pond A16, and gulls were largely absent from the pond between mid-April and mid-July (fig. 11). Gulls rarely roosted on SF2 islands modified for Caspian terns, and were never observed harassing terns.

Although the number of Caspian terns observed at Pond A16 was about one-half the number observed at Pond SF2, the proportion of terns that bred was similar between the two ponds. It is possible that the relatively larger number of gulls at Pond A16 compared to Pond SF2 dissuaded additional Caspian terns from visiting Pond A16 and ultimately nesting. However, the difference in overall Caspian tern numbers also could have been due to the locations of the two ponds and the likelihood that they would be visited by Caspian terns.

In late September, at the time decoys and call systems were removed, we observed several dead Caspian terns at both Caspian tern nesting islands, which is typical among colonial waterbird nesting colonies. This included 6 fledglings and 7 pre-fledged chicks on Island 11 in Pond A16 and 50 pre-fledged chicks on Island 21 in Pond SF2. This represents a large decrease from the 2 fledglings and 26 pre-fledged chicks observed dead on Island 11 in Pond A16 in late September of 2015, but a substantial increase from the 5 fledglings and 21 pre-fledged chicks observed dead on Island 21 in Pond SF2 in late September 2015. Causes of mortality for chicks and fledglings in 2016 is unknown, but there were no obvious signs of trauma, suggesting that these individuals died because of abandonment, starvation, exposure, and (or) other natural causes. Because the number of breeding pairs was greater in 2016, and overall chick production also appeared to be greater in 2016 than in 2015, the large number of dead pre-fledged chicks observed on Island 21 in Pond SF2 suggests that low chick survival may have limited Caspian tern productivity in 2016.

## Conclusions and Management Implications

Results from the 2016 nesting season continue to demonstrate the success of island modifications and social attraction measures for establishing Caspian tern (*Hydroprogne caspia*) breeding colonies at Ponds A16 and SF2 of the Don Edwards San Francisco Bay National Wildlife Refuge (DENWR), south San Francisco Bay, California. Moreover, 2016 results indicate that these new Caspian tern breeding colonies are expanding relative to 2015, the first year of the study. Overall, we estimated that at least 317 Caspian tern breeding pairs nested at Ponds A16 and SF2, and at least 158 chicks fledged, for a breeding success rate (fledglings per breeding pair) of 0.50. This represents a 42 percent increase from the 224 breeding pairs estimated in 2015, but a 9 percent decrease from the 174 chicks fledged and a 36 percent decrease from the 0.78 fledglings per breeding pair observed in 2015. Although fledglings per breeding pair was lower in 2016 than in 2015, 0.50 chicks fledged per breeding pair is only slightly lower than the long-term average on East Sand Island (about 0.62), similar to the long-term average on Crescent Island (0.53) in the mid-Columbia River, and greater than the average among several sites in south San Francisco Bay. Nest density (nests per square meter of colony area) in Ponds A16 and SF2 also was lower in 2016 (0.42) compared to 2015 (0.61), and was lower than densities observed at other San Francisco Bay sites including Brooks Island (0.9), Eden Landing (1.0), and Steven's Creek (0.5). However, the proportion of modified island area occupied by Caspian tern nesting colonies more than doubled in 2016 (747 $m^2$) compared to 2015 (366 $m^2$), encompassing 17 and 28 percent of the available nesting habitat on Island 11 in Pond A16 and Island 21 in Pond SF2, respectively. Even with the increase in island area used by Caspian terns in 2016, the complete lack of nesting on three of the five modified islands resulted in use of only 10 percent (747 $m^2$) of the 7,903 $m^2$ area modified for nesting Caspian terns in Ponds A16 and SF2. This suggests that there is considerable opportunity for Caspian tern breeding colonies to expand at each pond in future years.

Of the 26 banded Caspian terns observed at Ponds A16 and SF2 in 2016, only 8 were observed to be engaged in breeding behaviors. The other 18 were mostly observed in early spring and (or) late summer, suggesting that they bred at other locations and only passed through Ponds A16 and SF2 before and after the breeding period. Six of the 8 terns that were suspected or confirmed to have bred on modified islands in Ponds A16 and SF2 were banded at other Caspian tern breeding sites in San Francisco Bay (Brooks Island or Eden Landing). The other 2 terns were banded as chicks at Sheepy Lake, California, and the Port of Bellingham, Washington. Thus, whereas 5 of the 26 banded Caspian terns that we observed originated from East Sand Island in the Columbia River estuary, none of these terns bred in Ponds A16 or SF2 in 2016. Therefore, band resighting efforts to date do not provide evidence that modified islands on DENWR have provided breeding habitat for terns from the Columbia River Basin. However, pre- and post-breeding observations of 5 terns that were banded on East Sand Island suggest that there is potential for use of modified islands on the DENWR by Columbia River Basin terns in the future.

We found little evidence that the large population of California gulls in south San Francisco Bay had a negative effect on nesting Caspian terns. In fact, numbers of California gulls in 2016 were markedly lower at Pond A16 than in 2015, and numbers of gulls at Ponds A16 and SF2 were relatively low throughout most of the breeding season, only increasing in August and September. However, as the islands in Pond SF2 and especially Pond A16 are relatively new, continued monitoring, as well as hazing, may be necessary to ensure that this attractive nesting habitat is not overtaken by nesting gulls.

Snowy plovers did not nest on the two islands modified for them, and they also did not nest nor were they observed on any of the five islands modified for Caspian terns. In contrast, Caspian terns were observed on the two islands modified for snowy plovers on two occasions between March 18 and September 12. Thus, there were no signs of conflict between Caspian terns and snowy plovers associated with island modifications in Ponds A16 and SF2.

Successful establishment of Caspian tern colonies in Ponds A16 and SF2 in 2015, and increases in colony sizes in 2016, demonstrate the potential of social attraction measures to help establish waterbird nesting colonies in San Francisco Bay. To offset the loss of managed pond habitat from tidal marsh restoration, the South Bay Salt Pond Restoration Project has constructed 46 new islands (16 in Pond A16, 30 in Pond SF2) over the past 5 years to provide nesting and roosting habitat for waterbirds (7 of these islands were further modified for nesting Caspian terns and snowy plovers in 2015 and are the focus of the current study). However, these other recently constructed islands thus far have been used relatively little by nesting waterbirds, particularly Forster's terns (*Sterna forsteri*), one of the most abundant colonial-breeding waterbirds in south San Francisco Bay. Continued social attraction measures similar to those used in this study may help to establish breeding colonies of several species at targeted wetlands enhanced by the South Bay Salt Pond Restoration Project.

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