Establishing Forster's Tern (*Sterna forsteri*) Nesting Sites at Pond A16 Using Social Attraction for the South Bay Salt Pond Restoration Project

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)

Abbreviations

CI   confidence intervals

DENWR   Don Edwards San Francisco Bay National Wildlife Refuge

SBSP   South Bay Salt Pond

SE   standard error

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Abstract

Forster's terns (*Sterna forsteri*), historically one of the most numerous colonial-breeding waterbirds in South San Francisco Bay, California, have experienced recent decreases in the number of nesting colonies and overall breeding population size. The South Bay Salt Pond Restoration Project aims to restore 50–90 percent of former salt evaporation ponds to tidal marsh habitat in South San Francisco Bay. During phase 1 of the South Bay Salt Pond Restoration Project, the breaching of several pond levees to begin the process of tidal marsh restoration inundated island nesting habitat that had been used by Forster's terns, American avocets (*Recurvirostra americana*), and other waterbirds. Additional nesting habitat could be lost as more managed ponds are converted to tidal marsh in the future. To address this issue, the South Bay Salt Pond Restoration Project organized the construction of new nesting islands in managed ponds that will not be restored to tidal marsh, thereby providing enduring island nesting habitat for waterbirds. In 2012, 16 new islands were constructed in Pond A16 in the Alviso complex of the Don Edwards San Francisco Bay National Wildlife Refuge, which increased the number of islands in this pond from 4 to 20. However, despite a long history of nesting on the four islands in Pond A16 before the 2012 construction activities, no Forster's terns have nested in Pond A16 during the 7-year period (2012–18) after island construction.

During the 2017 and 2019 breeding seasons, we used social attraction measures (decoys and colony call playback systems) to attract Forster's terns to islands within Pond A16 to re-establish nesting colonies. We maintained these systems from March through August in each year. To evaluate the effect of these social attraction measures, we completed surveys (between April and August) where we recorded the number and location of all Forster's terns and other waterbirds using Pond A16, and we monitored waterbird nests. We compared bird survey and nest monitoring data collected in 2017 and 2019 to data collected in 2015 and 2016, prior to the implementation of social attraction measures, allowing for direct evaluation of the effect of social attraction efforts on Forster's terns.

To increase the visibility and stakeholder involvement of this project, we engaged in multiple outreach activities in 2017, 2019, and 2020, including the development of a project website and educational video; publication of popular articles in 2017 and 2020; the development of outreach materials describing the project to the general public; and public presentations to relay findings to managers, stakeholders, and the general public.

The relative abundance of Forster's terns in Pond A16, after adjusting for the overall South San Francisco Bay breeding population each year, was higher during the nesting period in 2017 and 2019 (when social attraction was used) than in 2015 and 2016 (before social attraction was used). Furthermore, more Forster's terns were observed during the pre-nesting and nesting periods in the areas of Pond A16 where decoys and call systems were deployed. Although no Forster's tern nests were observed in Pond A16 before social attraction was implemented (2015, 2016), or during the first-year social attraction was implemented (2017), 35 Forster's tern nests were recorded during the second year of social attraction implementation in 2019. These 35 nests represent a re-establishment of a Forster's tern nesting colony to Pond A16 for the first time in 8 years. As social attraction efforts often benefit from multiple years of decoy and call system deployment, results from 2017 and 2019 suggest that continued implementation of social attraction measures could help to ensure Forster's tern breeding colonies persist in Pond A16 and other areas of South San Francisco Bay.

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Introduction

The South Bay Salt Pond (SBSP) Restoration Project aims to restore 50–90 percent of former salt evaporation ponds to tidal marsh habitat in South San Francisco Bay, California, including many wetlands within Santa Clara County (Goals Project, 1999). This restoration is expected to benefit the South San Francisco Bay ecosystem, including improved water quality, fish habitat, and flood protection. However, many waterbirds use these former salt ponds for nesting and foraging, and islands within these ponds are important nesting habitat (Strong and others, 2004; Ackerman and others, 2014a; Hartman and others, 2016a, b). For this reason, the SBSP Restoration Project is enhancing some of the remaining 10–50 percent of former salt ponds that are not being restored to tidal marsh habitat to support breeding, migratory, and wintering waterbirds.

The primary pond enhancement feature has been the construction of islands to attract and support nesting birds. Previous work has established the preferred location, size, shape, slope, and other features of islands that are well suited for nesting terns and shorebirds (Ackerman and others, 2014a; Hartman and others, 2016a, b). In 2010, pond enhancements (including 30 new islands) were constructed at Ravenswood Pond SF2 (near the west end of the Dumbarton Bridge) at a cost of $9 million, and in 2012, pond enhancements (including 16 new islands) were constructed at Alviso Pond A16 at a cost of $4 million. However, nesting waterbirds have been slow to colonize these new islands. At Pond A16, after an initial increase in nesting in 2013 (*n*=139 nests), the first year after island construction, American avocet *(Recurvirostra americana)* annual nest numbers declined, reaching a low of four nests in 2015. In 2016, 4 years after island construction, American avocets again began nesting in large numbers in Pond A16. The Forster's tern (*Sterna forsteri*) is an at-risk species in San Francisco Bay and was one of the species expected to benefit from the construction of island nesting habitat in managed ponds. Yet, no Forster's terns nested at Pond A16 between 2012 and 2018, despite the fact that before new island construction in 2012, Pond A16 often supported hundreds of nesting Forster's terns annually (Ackerman and Herzog, 2012).

Project Goals

Social attraction is a wildlife restoration technique whereby decoys of nesting birds, along with bird sound recordings, are deployed to look and sound like a real nesting colony in order to attract birds to nest at specific sites (Arnold and others, 2011; Jones and Kress, 2012; Hartman and others, 2019). Because of their colonial nature, terns and many other seabirds are attracted to nesting sites by the presence of conspecifics, making the deployment of decoys and colony

sound recordings a promising method for establishing new breeding colonies and re-establishing historical breeding colonies (Kress, 1983; Roby and others, 2002; Hartman and others, 2019). We previously showed the effectiveness of social attraction measures in establishing Caspian tern (*Hydroprogne caspia*) breeding colonies at two locations in South San Francisco Bay where they had never bred previously (Hartman and others, 2018, 2019). In just 3 years, we increased the number of Caspian tern nests between these two sites on the Don Edwards San Francisco Bay National Wildlife Refuge (DENWR) from 0 to at least 664 nests following implementation of social attraction measures. The objective of this project was to implement similar social attraction measures targeting Forster's terns to re-establish the historically large breeding colony at Pond A16.

In recent years, the breeding population of Forster's terns in South San Francisco Bay has decreased from 1,259 nests in 2006 to 604 nests in 2019 (J.T. Ackerman, M.P. Herzog, and C.A. Hartman, U.S. Geological Survey, unpub. data, 2020). Moreover, the number of large Forster's tern breeding colonies (greater than or equal to 40 nests) in South San Francisco Bay has decreased from an average of 7.3 annually between 2005 and 2010, to only 4 colonies in 2019 (J.T. Ackerman, M.P. Herzog, and C.A. Hartman, U.S. Geological Survey, unpub. data, 2020). Some of these losses can be traced to loss of historical island nesting habitat due to changes in pond management associated with the SBSP Restoration Project. For example, large colonies of Forster's terns previously nested in Ponds A7 and A8 of the Alviso pond complex, but the islands in these ponds are now flooded, which prevents nesting. Pond A16, also in the Alviso pond complex, supported hundreds of Forster's tern nests annually between 2005 and 2010 (Ackerman and Herzog, 2012). However, in 2012, Pond A16 was temporarily drained to construct 16 new nesting islands, and no Forster's terns nested in the pond between 2012 and 2018. Instead, Forster's terns have been nesting in New Chicago Marsh, which is directly south of Pond A16 (fig. 1). However, New Chicago Marsh is a shallow-water marsh habitat that does not afford the same protection from terrestrial predators as islands within deep-water ponds, and waterbird nest success in New Chicago Marsh typically is low (Ackerman and others, 2014b).

The colonial nature of Forster's terns, the fact that Pond A16 has previously supported large numbers of breeding terns, and the large potential source population of terns in adjacent New Chicago Marsh make social attraction a viable option for re-establishing Forster's tern breeding colonies in Pond A16. After nesting is established, these colony sites could be used by breeding Forster's terns for decades. Additionally, because the presence of nesting Forster's terns can attract other nesting waterbirds such as American avocets (Hartman and others, 2016b), re-establishing Forster's tern breeding colonies to Pond A16 also could increase use of Pond A16 by other nesting waterbirds.

Figure 1. New Chicago Marsh and Alviso Pond 16, where 50 Forster's tern decoys and 1 colony call playback system were deployed on each of 6 islands (Islands 14–18 and 20, shown in blue), Don Edwards San Francisco Bay National Wildlife Refuge, California, 2017 and 2019 breeding seasons. Decoys and call systems for Caspian terns were deployed on Islands 11 and 12 (shown in orange) and for western snowy plovers were deployed on Island 3 (shown in brown), 2015–17 (Hartman and others, 2018).

In 2017 and 2019, we implemented Forster's tern social attraction measures (decoys and call systems) in Pond A16 to re-establish breeding colonies. The objectives of this project were to:

1. Deploy and maintain social attraction measures (decoys and call systems) for Forster's terns on six islands within Pond A16;

2. Monitor and evaluate prospecting and nesting by Forster's terns and other waterbird species in Pond A16; and

3. Conduct outreach activities to advertise the project and promote social attraction efforts as a tool for waterbird management in South San Francisco Bay, and to relay findings to managers, stakeholders, and the general public.

Methods

Social Attraction Measures for Forster's Terns

In early March 2017 and 2019, we deployed Forster's tern social attraction measures (decoys and call systems) on six islands at the south end of Pond A16 of the DENWR (fig. 1). Funding was not available to implement social attraction measures in 2018. We chose these six islands based on their nearness to New Chicago Marsh, a site that in recent years has had numerous nesting Forster's terns but where nest success has been low because of easy access to nest sites by terrestrial predators. Thus, by placing decoys and call systems close to the adjacent New Chicago Marsh, Forster's terns may be attracted to nest instead in Pond A16, where waterbird nest success typically is higher (Ackerman and others, 2014b). In addition to their nearness to New Chicago Marsh, we selected islands based on their size and shape. Forster's terns prefer linear-shaped and elongated islands to more rounded islands (Hartman and others, 2016a). Five of the six islands in which we deployed decoys and call systems were elongated and highly linear, and four of the six islands were historical islands that existed before new island construction and on which Forster's terns had nested before 2012 (fig. 1).

We arranged 50 Forster's tern decoys spaced 1–1.5 meters (m) apart on each of the six islands (300 total decoys, figs. 2–4). Decoys (Duck Trap Woodworking, Lincolnville, Maine) were carved of wood and painted to resemble Forster's terns in an incubation posture. We installed a call system (Murremaid Music Boxes, South Bristol, Maine) on each of the six islands with decoys and broadcasted Forster's tern colony calls continuously through two omni-directional outdoor speakers. Each call system was powered by two 6-volt Optima® AGM batteries and charged by a 135 W Kyocera© solar panel, enabling it to broadcast continuously throughout the breeding season. Call boxes and solar panels were deployed about 20 m from the decoy arrangements. The two omni-directional speakers were deployed amongst the decoys and connected to the call box by speaker wire. We used a 30-minute recording of a Forster's tern colony recorded at Pond A16 in 2009 (Borker and others, 2014). Decoys and call systems, broadcasting on a continuous loop, remained on each island until they were retrieved in August.

In 2015, 2016, and 2017, we also deployed Caspian tern and western snowy plover (*Charadrius nivosus nivosus*) decoys and call systems on three islands on the north end of Pond A16 (fig. 1; Hartman and others, 2018).

Evaluating Forster's Tern Response to Social Attraction Implementation

Bird Surveys

We did weekly bird surveys at Pond A16 beginning in early March 2017 and 2019 (shortly after decoy and call system deployment) and continuing through August 2017 and 2019. Surveys were done in the early morning or early afternoon. Each survey consisted of driving around the levee surrounding Pond A16 and stopping at five set vantage points (fig. 5) to record the number and location of all Forster's terns and other prominent waterbirds known to nest in South San Francisco Bay. Surveys were done by using binoculars and a 20–60× spotting scope. We recorded bird locations by assigning each observation to 1 of 26, 250- by 250-m grid cells within Pond A16 (fig. 5). Each survey was completed within 60 minutes to limit double-counting of individuals and avoid biasing abundance estimates.

Nest Monitoring

We visited 18 of the 20 islands in Pond A16 weekly during the nesting season (April–June 2017 and 2019) to record nesting activity of Forster's terns, American avocets, and other waterbirds. These data were compared to similar nest monitoring efforts conducted in 2015 and 2016, prior to social attraction implementation. We did not visit two islands (Islands 11 and 12) at the north end of the pond in 2017 owing to our ongoing study of Caspian terns on these islands (Hartman and others, 2019). During each island visit, we systematically searched for nests. We also searched for nests on raised mudflat areas between islands that remained above water and where some birds nested. For each new nest found, we recorded Universal Transverse Mercator coordinates and marked the nest with a uniquely numbered aluminum tag held in place just outside the nest bowl with a garden staple and a 40-centimeter (cm) flag placed 2 m north of the nest. We then revisited nests weekly until failure or hatch and documented if the nest was active or inactive (abandoned or depredated), recorded the number of eggs in the nest, floated eggs to determine the stage of development (Ackerman and Eagles-Smith, 2010), and determined overall nest fate (hatched versus failed).

Figure 2.   Forster's tern decoys deployed on Island 15 in Pond A16 (see fig. 1 for location), Don Edwards San Francisco Bay National Wildlife Refuge, California, 2017 and 2019. Photographs by Jeanne Fasan, U.S. Geological Survey, March 15, 2019.

We modeled daily nest survival from nest initiation to hatch by using the logistic exposure method (Shaffer, 2004). We then estimated the overall nest success rate from the product of the individual nest daily survival rates during the 28-day nest interval for Forster's terns and 26-day nest interval for American avocets. Unlike apparent nest success (ratio of successful nests to total nests found), the logistic exposure method accounts for nests that failed before they could be discovered, thereby providing a more accurate estimate of nest success. We calculated 95-percent confidence intervals (CI) around the mean nest success rate by using the delta method (Seber, 1982).

Figure 3.   Forster's tern decoys and call system with solar panel array deployed on Island 16 in Pond A16 (see fig. 1 for location), Don Edwards San Francisco Bay National Wildlife Refuge, California, 2017 and 2019. Photographs by Jeanne Fasan, U.S. Geological Survey, March 15, 2019.

Statistical Analyses

Forster's Tern Use of Pond A16 Before and During Social Attraction Implementation

For all analyses, we compared 2 years of data collected prior to implementation of Forster's tern social attraction measures (2015, 2016) to 2 years of data collected during implementation of Forster's tern social attraction measures (2017, 2019). From our bird-survey data, we calculated Forster's tern and American avocet abundance in Pond A16 during each week of the breeding season (April–August) of 2015, 2016, 2017, and 2019. We then used general linear models to examine the fixed effects of month (April, May, June, July, and August) and year (2015, 2016, 2017, and 2019) on Forster's tern or American avocet abundance in Pond A16. However, we observed a substantial decrease in the total number of Forster's tern nests in South San Francisco Bay in 2017 and 2019 relative to 2015 and 2016 (see the "Results and Discussion" section). Because the number of birds using Pond A16 in any given year is dependent on the total number of birds present in the entire South San Francisco Bay, we needed to account for the overall decrease in the

Forster's tern population in South San Francisco Bay. We, therefore, adjusted the number of Forster's terns observed during each survey by multiplying this value by the number of Forster's tern nests in South San Francisco Bay in 2017 divided by the total number of nests observed in South San Francisco Bay in each year. Nest searching and monitoring effort throughout South San Francisco Bay was equal among years. By making this adjustment, we examined the relative abundance of Forster's terns in Pond A16 after accounting for annual differences in the overall breeding population in South San Francisco Bay. As American avocet populations have similarly declined in South San Francisco Bay, we adjusted the number of American avocets observed during each survey in the same way as we adjusted tern numbers. We then evaluated the fixed effects of month, year, and a month×year interaction on the adjusted Forster's tern and American avocet abundance in Pond A16. Additionally, we compared adjusted Forster's tern and American avocet abundances during each month (April–August) before (2015, 2016) and during (2017, 2019) implementation of social attraction measures. Adjusted Forster's tern and American avocet abundance were not normally distributed, so we used a natural log data transformation to meet the assumption of normality.

Figure 4. Forster's tern decoys and call system deployed on Island 17 in Pond A16 (see fig. 1 for location), Don Edwards San Francisco Bay National Wildlife Refuge, California, 2017 and 2019. Photograph by Jeanne Fasan, U.S. Geological Survey, March 15, 2019.

Forster's Tern Locations within Pond A16 in Relation to Distance to Social Attraction

We did a second analysis in which we examined if Forster's tern use of the eight 250- by 250-m grid cells within Pond A16 with decoys and call systems (fig. 5) varied before (2015, 2016) versus during (2017, 2019) implementation of social attraction measures. First, we assigned each grid cell in Pond A16 to one of two treatments: (1) with social attraction (grid cell included one or more islands with decoys and call systems deployed in 2017 and 2019) or (2) without social attraction (grid cell did not include islands with decoys and call systems in 2017 and 2019). We then tested whether Forster's tern abundance within grid cells varied by year (2015, 2016, 2017, or 2019), treatment (with or without social attraction in 2017 and 2019), and a year by treatment interaction. For this analysis, we only included April–June survey data, because this represents the pre-nesting and

nesting periods for Forster's terns and other waterbirds in San Francisco Bay. We again adjusted the number of Forster's terns observed during a survey by the nesting population for that year. We also included two individual covariates (pond area and island area) that we hypothesized could influence Forster's tern use of an individual grid cell, but we could not control for it in our experimental design. Although each grid cell was 250- by 250-m, not all grid cells were solely within Pond A16 (fig. 5). Because we did not count Forster's terns outside Pond A16, grid cells with little area within Pond A16 could be expected to have fewer Forster's terns within them than grid cells completely within Pond A16. Additionally, the amount of island area may influence Forster's tern use of a particular grid cell because cells with more island area may offer more nesting and roosting opportunities for terns. By including the pond area and island area of each grid as covariates, we accounted statistically for these differences.
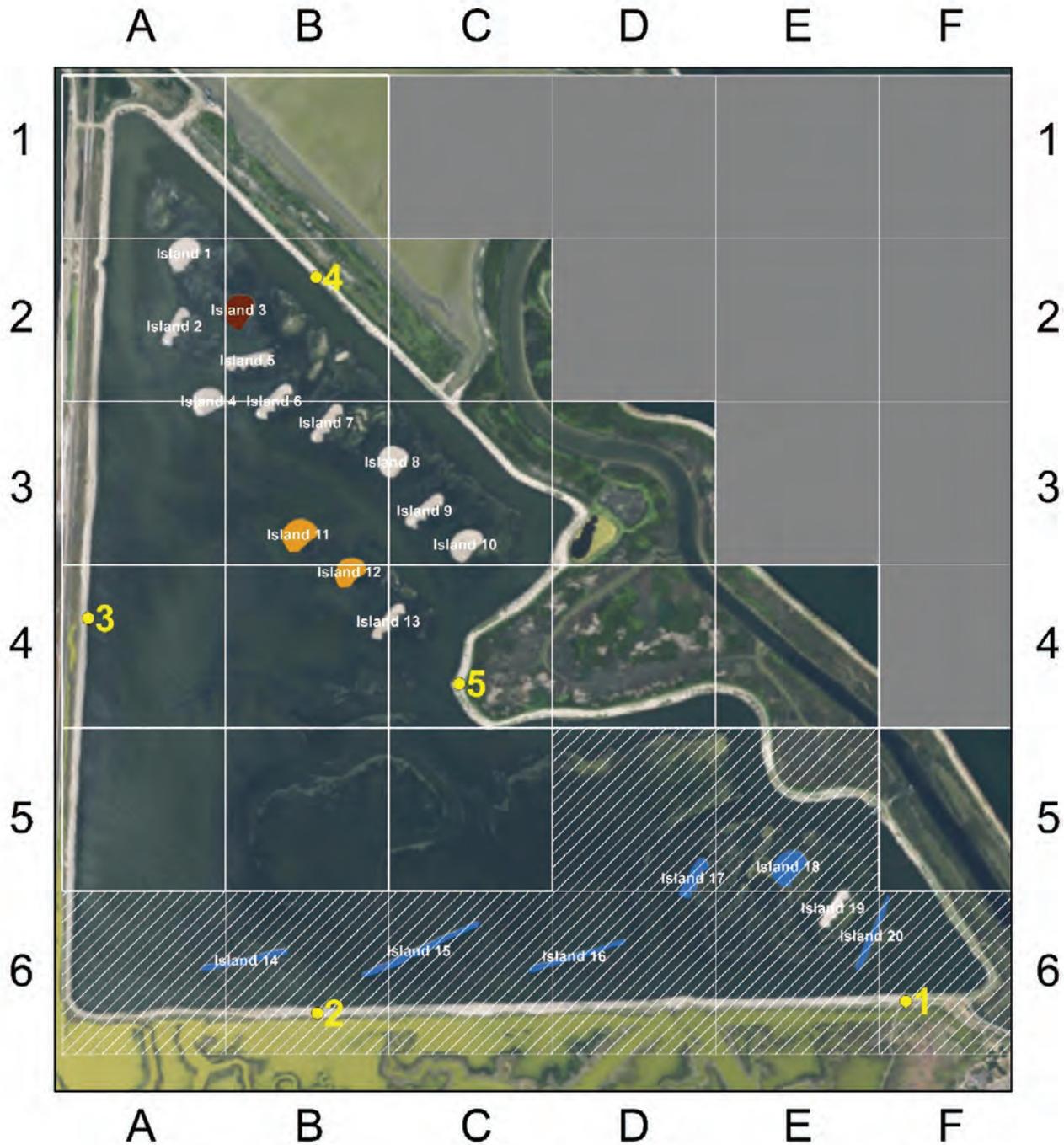
Figure 5. Location of five vantage points (numbered yellow dots) used to count number and location of Forster's terns during pond surveys in Pond A16, Don Edwards San Francisco Bay National Wildlife Refuge, California, 2017 and 2019 breeding seasons. Square grid cells are 250- by 250 meters. Islands 11 and 12 (shown in orange) were used for Caspian tern social attraction and island 3 (shown in brown) was used for western snowy plover social attraction in 2015–17 (Hartman and others, 2018). Grid cells with white hatching indicate those containing islands with Forster's tern decoys and call systems in 2017 and 2019. Observations in grid cells completely outside Pond A16 (shown in gray, upper right side) were not included.

Grid cell survey data were not normally distributed and data transformation was not possible because of the large number of zeros. Good visibility during surveys and conspicuous study species meant that zeroes likely reflected a genuine absence of birds within grid cells rather than an inability to detect birds. We, therefore, used a generalized linear mixed model with a Poisson distribution with the adjusted Forster's tern abundance as the response variable, year, treatment, a year by treatment interaction, and pond area (continuous covariate) and island area (continuous covariate) as fixed effects and the individual grid cell as a random effect. We did a separate, identical analysis with the adjusted American avocet abundance as the response variable. All analyses were done using SAS/STAT software (release 9.4, SAS Institute, Cary, North Carolina). We report back-transformed least squares means and estimated standard errors using the delta method (Seber, 1982).

Spatial Distribution of Forster's Tern Observations within Pond A16

We summed the total number of Forster's terns observed within each grid cell in Pond A16 during April through June (pre-nesting and nesting periods). We then calculated the proportion of all observations (April–June) that occurred within each grid cell and plotted these proportions using ArcGIS™ 10.4.1 (Environmental Research Systems Institute, Redlands, California) to create maps of Forster's tern activity. In this way, we could ascertain whether Forster's tern distribution within Pond A16 during the pre-nesting and nesting periods was affected by the location of social attraction measures.

Outreach to Stakeholders and the General Public

We conducted multiple outreach activities to promote our social attraction efforts as a tool for waterbird management in South San Francisco Bay and to relay findings to managers, stakeholders, and the general public. These activities included the development of a project website hosted by the U.S. Geological Survey (updated in spring 2020 with results from the 2019 effort), four public presentations, publication of two popular articles in local outlets highlighting project activities, the development of outreach materials and posters describing the project to the public, and two visits with local elementary school classes to explain the project and enlist students in painting tern decoys.

Results and Discussion

Forster's Tern Use of Pond A16 Before and During Social Attraction Implementation

We completed a total of 21 bird surveys at Pond A16 between April and August of 2019 and compared these data to surveys done during the same period in 2015, 2016, and 2017. Adjusted weekly Forster's tern abundance in Pond A16 varied significantly by month ($F_{4, 72} = 3.73$, $p = 0.01$) and by the month by year interaction ($F_{12, 72} = 3.42$, $p = 0.001$). Adjusted Forster's tern abundance was greater during implementation of social attraction measures (2017, 2019) than before implementation (2015, 2016) in May ($F_{1, 72} = 6.87$, $p = 0.01$) and June ($F_{1, 72} = 4.25$, $p = 0.04$; fig. 6), the primary nesting period. Adjusted Forster's tern abundance also was higher during the pre-nesting period in April during social attraction implementation (fig. 6), but this difference was not statistically significant ($F_{1, 72} = 3.22$, $p = 0.08$). In contrast, adjusted Forster's tern abundance was lower during social attraction implementation during the post-nesting period (fig. 6) in July ($F_{1, 72} = 3.87$, $p = 0.05$) and August ($F_{1, 72} = 8.14$, $p = 0.01$). The greater tern abundance during the post-nesting period, before the social attraction project started, was likely due to the substantially smaller South San Francisco Bay nesting population in 2017 (471 nests) and 2019 (604 nests) producing fewer juvenile terns compared to 2015 (997 nests) and 2016 (1,258 nests). Thus, fewer juveniles produced in 2017 and 2019 meant smaller tern populations during the post-nesting period (regardless of any added benefit of social attraction to Pond A16).

The adjusted weekly American avocet abundance in Pond A16 varied by month ($F_{4, 67} = 16.53$, $p < 0.0001$), year ($F_{3, 67} = 10.24$, $p < 0.0001$), and by the month by year interaction term ($F_{12, 67} = 2.46$, $p = 0.01$). Adjusted American avocet abundance was similar before and during implementation of Forster's tern social attraction measures except during May, when American avocet abundance was higher in the years before social attraction measures were implemented ($F_{1, 67} = 16.29$, $p = 0.0001$; fig. 7).
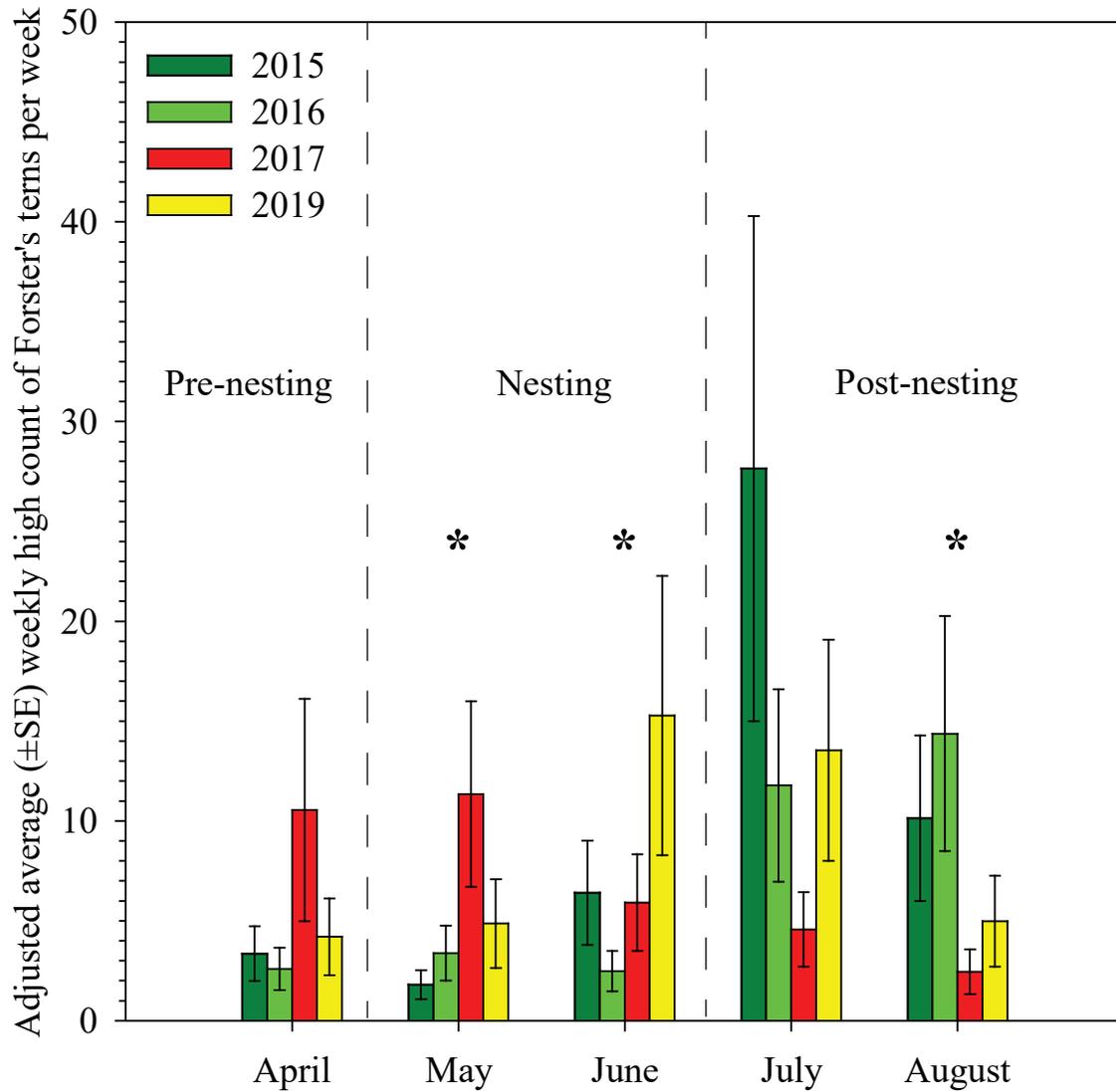
Figure 6. Adjusted average (plus or minus standard error [±SE]) weekly Forster's tern abundance at Pond A16 before (2015, 2016) and during (2017, 2019) implementation of social attraction measures (Forster's tern decoys and calls) by month during the pre-nesting, nesting, and post-nesting periods, Don Edwards San Francisco Bay National Wildlife Refuge, California. Asterisks denote months in which Forster's tern abundance differed significantly before versus during implementation of social attraction measures.
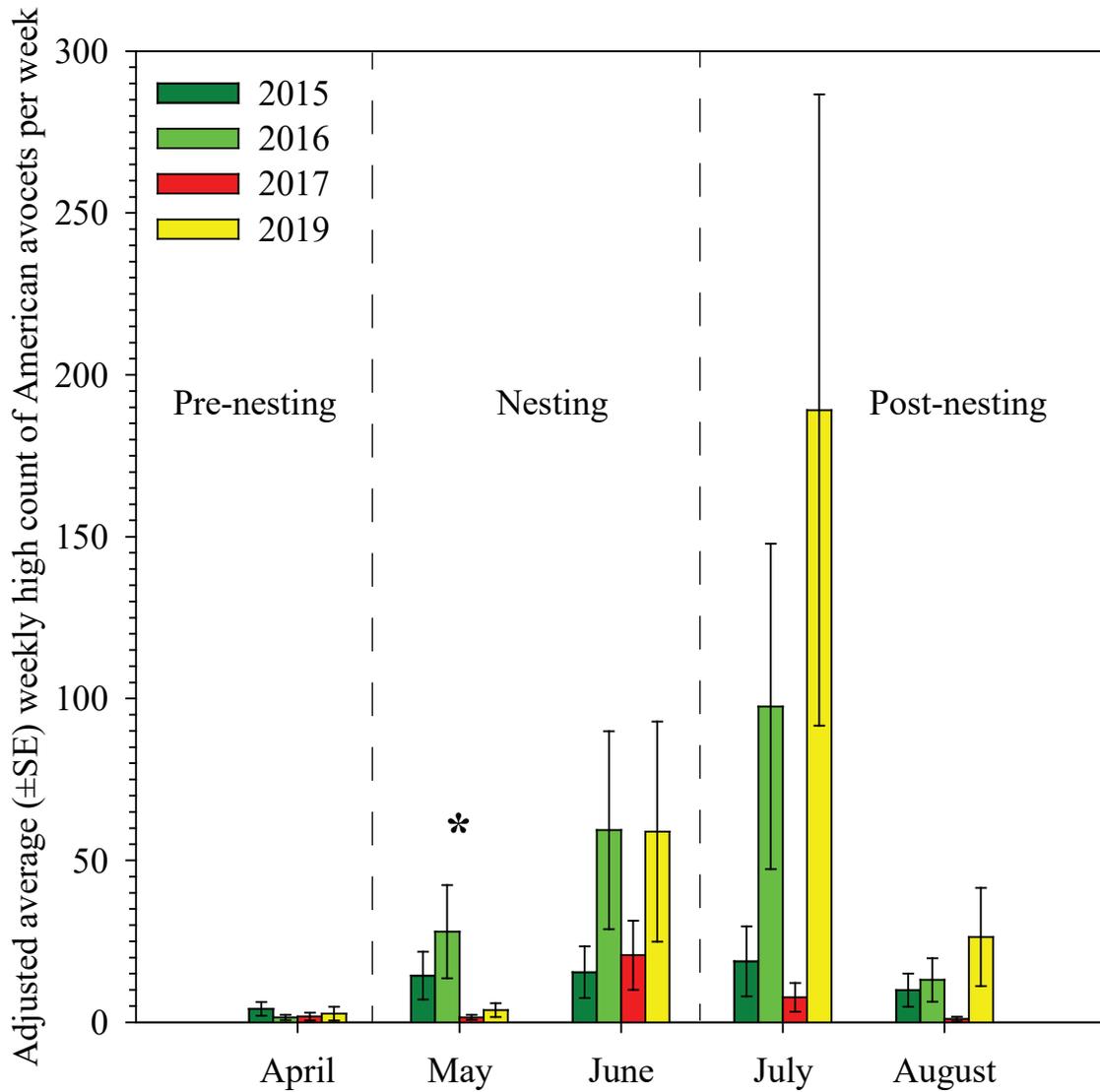
Figure 7.   Adjusted average (plus or minus standard error [±SE]) weekly American avocet abundance at Pond A16 before (2015, 2016) and during (2017, 2019) implementation of social attraction measures (Forster's tern decoys and calls) by month during the pre-nesting, nesting, and post-nesting periods, Don Edwards San Francisco Bay National Wildlife Refuge, California. Asterisks denote months in which American avocet abundance differed significantly before versus during implementation of social attraction measures.

Forster's Tern Locations within Pond A16 in Relation to Distance to Social Attraction

Adjusted Forster's tern abundance within individual 250- by 250-m grid cells of Pond A16 during the pre-nesting and nesting periods varied by treatment (with or without social attraction in 2017 and 2019, $F_{1, 67} = 5.80$, $p = 0.02$) and by year ($F_{3, 67} = 4.09$, $p = 0.01$), while accounting for the amount of pond area within the grid cell ($F_{1, 67} = 9.90$, $p = 0.003$), the amount of island area within the grid cell ($F_{1, 67} = 0.36$, $p = 0.55$), and the year by treatment interaction ($F_{3, 67} = 2.12$, $p = 0.11$). Least squares mean comparisons indicated that in 2017, Forster's tern abundance was significantly greater in grid cells where social attraction measures were implemented than in grid cells where they were not implemented ($F_{1, 67} = 8.12$, $p = 0.01$) but this difference was not significant in 2019 ($F_{1, 67} = 1.79$, $p = 0.19$; table 1; fig. 8). Forster's terns also were more abundant during 2015 in grid cells where social attraction would be implemented in 2017 and 2019 ($F_{1, 67} = 4.97$, $p = 0.03$) but were not more abundant in those grid cells during 2016 ($F_{1, 67} = 0.00$, $p = 0.97$; table 1; fig. 8). Overall, when comparing grid cell use before (2015, 2016) to during (2017, 2019) social attraction implementation, Forster's tern abundance was significantly greater in grid cells with social attraction measures during implementation ($F_{1, 67} = 13.36$, $p = 0.0005$). A comparison of the spatial distribution of Forster's tern observations among years showed that birds occupied a smaller area closer to islands with social attraction measures in 2017 than they did in years prior to social attraction implementation (fig. 9). However, in 2019, the second year of social attraction efforts, Forster's tern observations were again spread out throughout the pond, with local concentrations within and adjacent to grid cells containing islands with social attraction measures (fig. 9).

Adjusted American avocet abundance within individual grid cells of Pond A16 during the pre-nesting and nesting periods varied by year ($F_{3, 65} = 21.42$, $p < 0.0001$), treatment ($F_{1, 65} = 7.03$, $p = 0.01$), and the year by treatment interaction ($F_{3, 65} = 3.45$, $p = 0.02$), while accounting for the amount of island area within the grid cell ($F_{1, 65} = 16.78$, $p = 0.0001$) and the amount of pond area within the grid cell ($F_{1, 65} = 0.38$, $p = 0.54$). As with Forster's terns, least squares mean comparisons indicated that in 2017, American avocet abundance was significantly greater in grid cells where Forster's tern social attraction measures were implemented than in grid cells where they were not implemented ($F_{1, 65} = 4.61$, $p = 0.04$) but this difference was not significant in 2019 ($F_{1, 65} = 2.85$, $p = 0.10$; table 1; fig. 10). American avocets also were more abundant during 2015 in grid cells where social attraction would be implemented in 2017 and 2019 ($F_{1, 65} = 13.18$, $p = 0.001$) but were not more abundant in those grid cells during 2016 ($F_{1, 65} = 2.40$, $p = 0.13$; table 1; fig. 10). Overall, when comparing grid cell use before (2015, 2016) to during (2017, 2019) social attraction implementation, American avocet abundance was significantly greater in grid cells with social attraction measures during implementation ($F_{1, 65} = 12.13$, $p = 0.0009$).

Table 1. Back-transformed least squares mean number of Forster's terns, adjusted number of Forster's terns, number of American avocets, and adjusted number of American avocets observed April–June per 250- by 250-meter grid cell in Pond A16, Don Edwards San Francisco Bay National Wildlife Refuge, California, before (2015, 2016) and during (2017, 2019) implementation of Forster's tern social attraction measures.

	Before social attraction implementation				During social attraction implementation			
	2015		2016		2017		2019	
Per grid cell	Social attraction grid cells	No social attraction grid cells	Social attraction grid cells	No social attraction grid cells	Social attraction grid cells	No social attraction grid cells	Social attraction grid cells	No social attraction grid cells
Number of Forster's terns	0.87	0.07	0.49	0.39	0.92	0.12	1.02	0.40
Adjusted number of Forster's terns	0.43	0.04	0.20	0.19	0.99	0.16	0.85	0.40
Number of American avocets	1.22	0.09	2.28	0.78	1.59	0.36	2.87	0.98
Adjusted number of American avocets	1.20	0.10	1.25	0.49	0.97	0.24	2.82	1.09
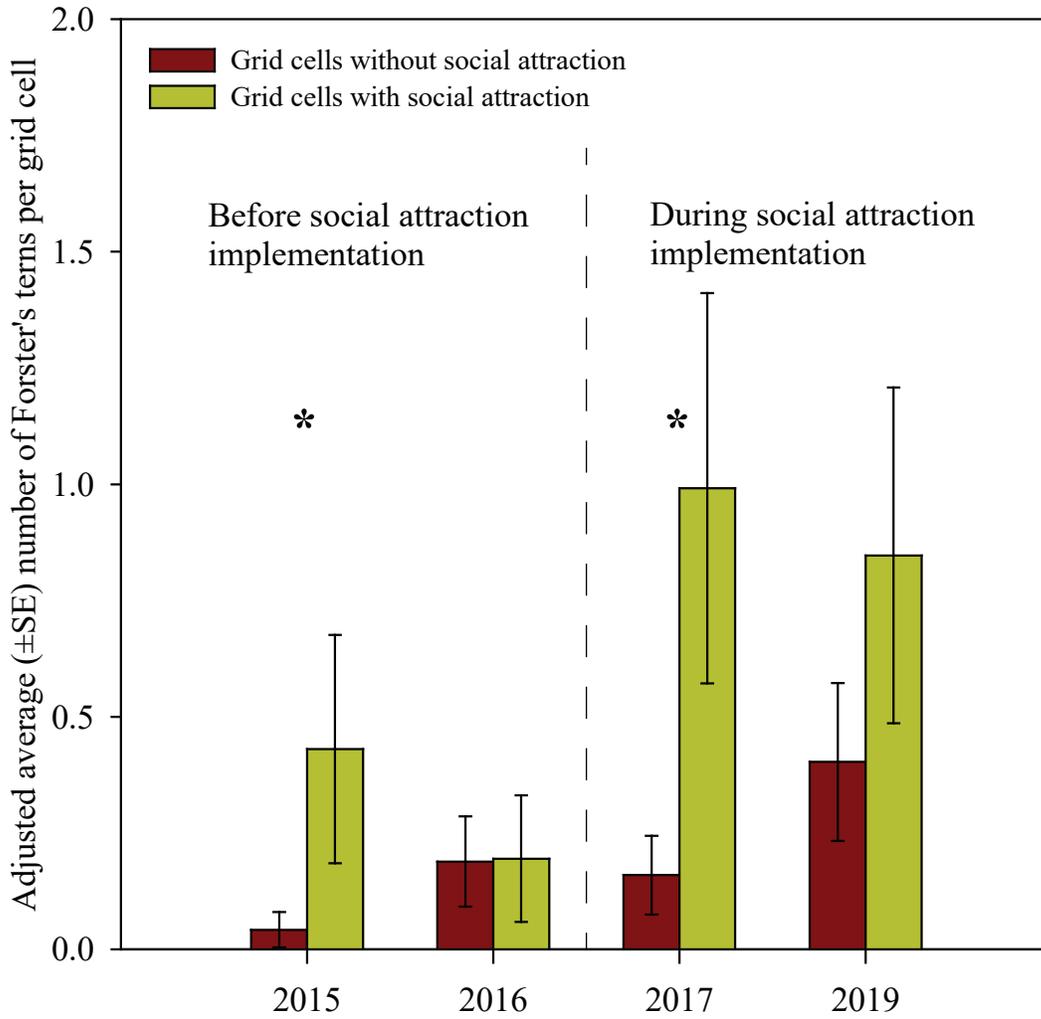
Figure 8.   Adjusted average (plus or minus standard error [±SE]) Forster's tern abundance per grid cell per survey at Pond A16 before (2015, 2016) and during (2017, 2019) implementation of social attraction measures (Forster's tern decoys and calls) during the pre-nesting and nesting periods (April–June), Don Edwards San Francisco Bay National Wildlife Refuge, California. Asterisks denote years in which Forster's tern abundance in grid cells that received social attraction measures in 2017 and 2019 was significantly different from grid cells that did not.
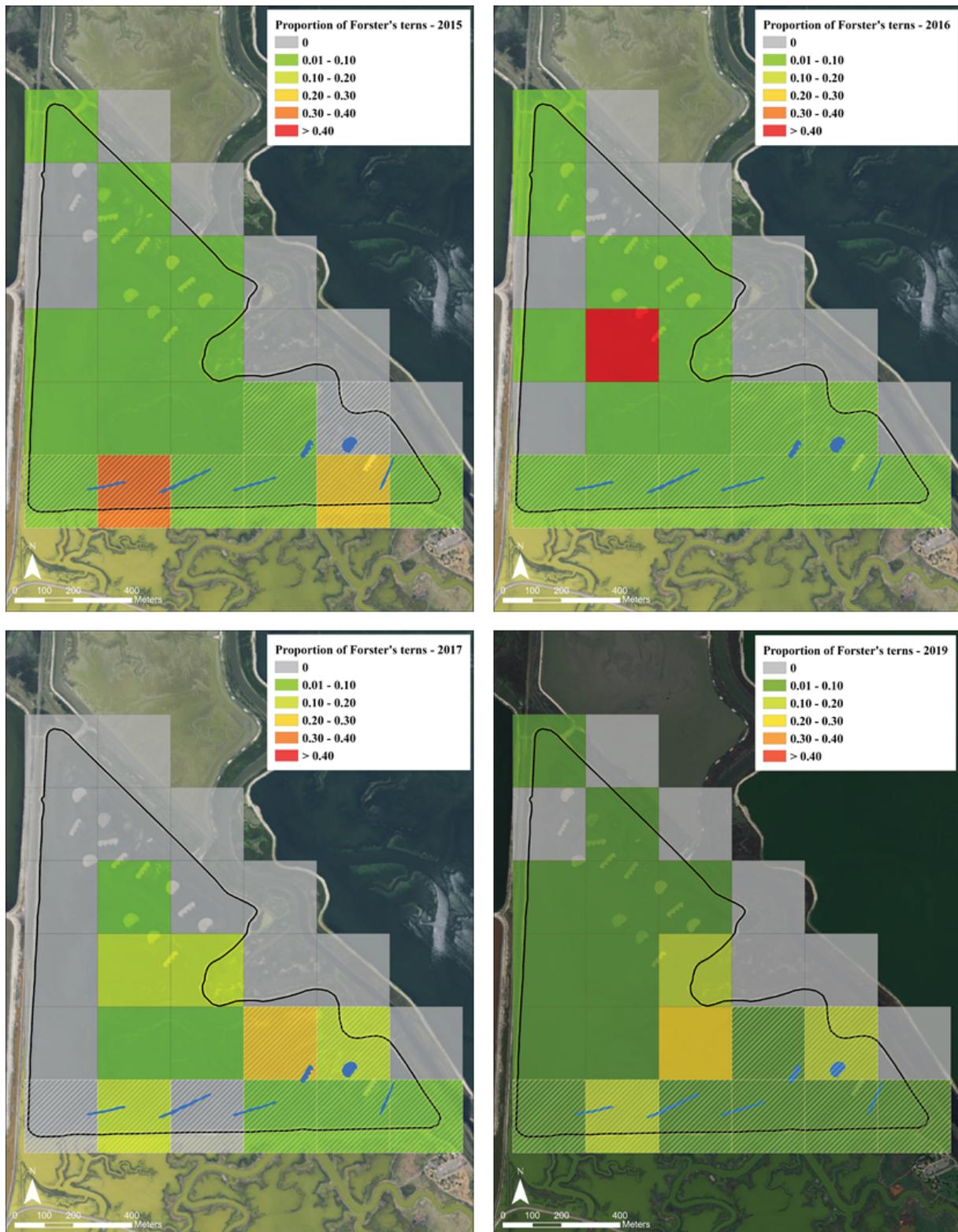
Figure 9.   Proportion of all Forster's terns observed within each individual 250- by 250-meter grid cell in Pond A16 during the pre-nesting and nesting periods (April–June) before (2015, 2016; top panels) and during (2017, 2019; bottom panels) implementation of Forster's tern social attraction measures (decoys and calls) on six islands (shown at bottom of each image in blue), Don Edwards San Francisco Bay National Wildlife Refuge, California. The black line denotes the Pond A16 boundary. Grid cells with white hatching (at south end of the pond) denote those cells containing islands where Forster's tern social attraction measures were implemented in 2017 and 2019.
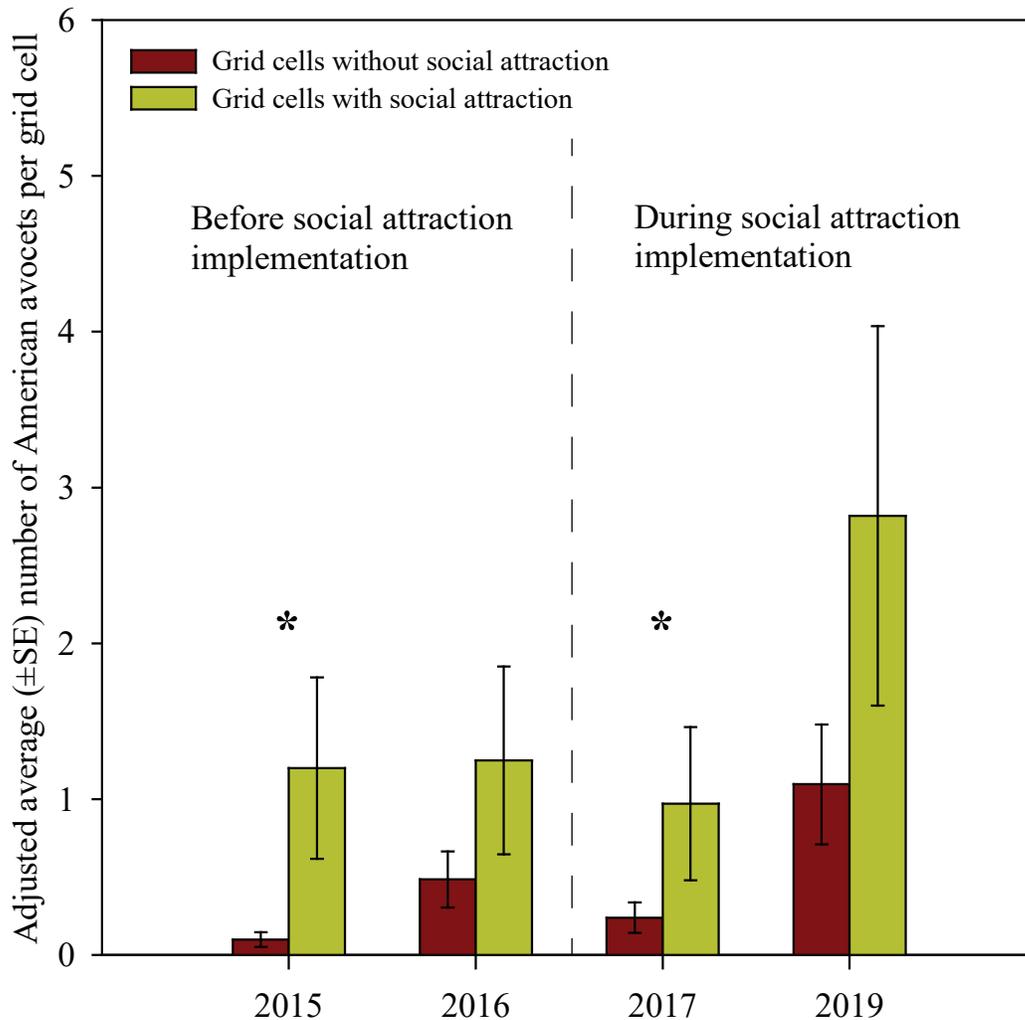
Figure 10.   Adjusted average (plus or minus standard error [±SE]) American avocet abundance per grid cell per survey at Pond A16 before (2015, 2016) and during (2017, 2019) implementation of social attraction measures (Forster's tern decoys and calls) during the pre-nesting and nesting periods (April–June), Don Edwards San Francisco Bay National Wildlife Refuge, California. Asterisks denote years in which American avocet abundance in grid cells that received social attraction measures in 2017 and 2019 was significantly different from grid cells that did not.

Waterbird Nests in Pond A16

We recorded 35 Forster's tern nests in Pond A16 in 2019 (figs. 11, 12). These 35 nests were the first Forster's tern nests observed at Pond A16 since island construction occurred in 2012 (fig. 13). Forster's tern nests were observed in the northern and southern portions of the pond. Six nests were found at the southern end, with three nests on Island 15 and one nest adjacent to Island 18, both of which were islands that were enhanced with tern decoys and call systems; the other two nests at the southern end were on exposed mudflats. The remaining 29 Forster's tern nests were found on exposed mudflats at the north end of the pond between constructed islands and the northeast levee (fig. 11). We also recorded 156 American avocet nests in Pond A16 in 2019, which was the highest number of nests observed for this species in Pond A16 since new islands were constructed in 2012, and more than the 35 American avocet nests observed in Pond A16 in 2018. Annual American avocet nest abundance in Pond A16 increased from an average of 46.5 nests before implementation of social attraction measures (average of 2015 and 2016) to 117.5 nests during implementation (average of 2017 and 2019; fig. 14). Likewise, on islands that received Forster's tern social attraction measures in 2017 and 2019, annual American avocet nest abundance increased from an average of 23.5 before implementation of social attraction measures to 41.0 nests during implementation.
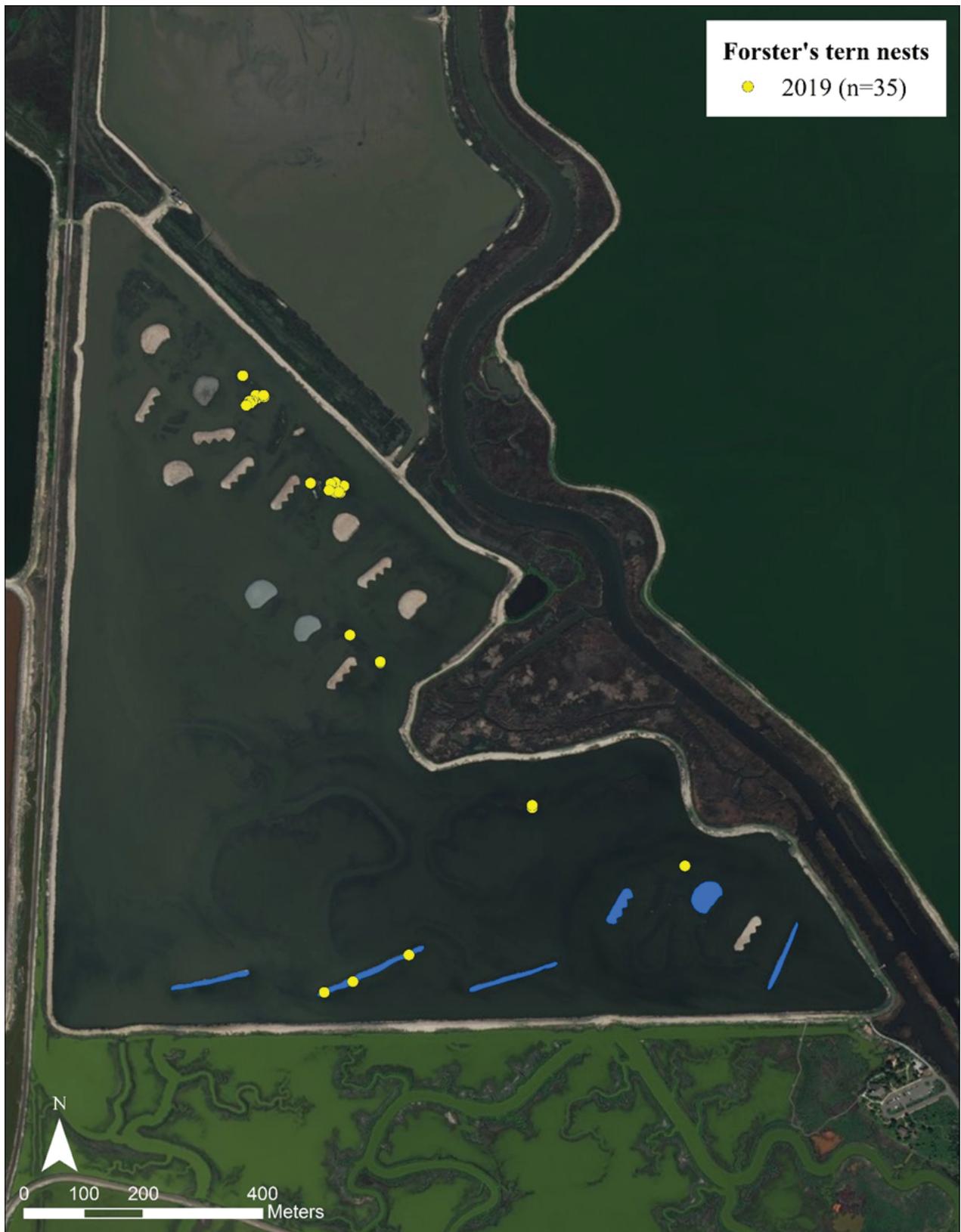
Figure 11.   Forster's tern nest locations in Pond A16 in 2019 during implementation of Forster's tern social attraction measures (decoys and calls), Don Edwards San Francisco Bay National Wildlife Refuge, California. Prior to 2019, no Forster's tern nests had been observed in Pond A16 since 2011. Islands highlighted in blue denote islands on which social attraction measures were implemented in 2017 and 2019.

Figure 12.   Forster's tern nesting on Island 15 of Pond A16 (see fig. 1 for location), Don Edwards San Francisco Bay National Wildlife Refuge, California, 2019. Photographs by Jeanne Fasan, U.S. Geological Survey, June 2019.
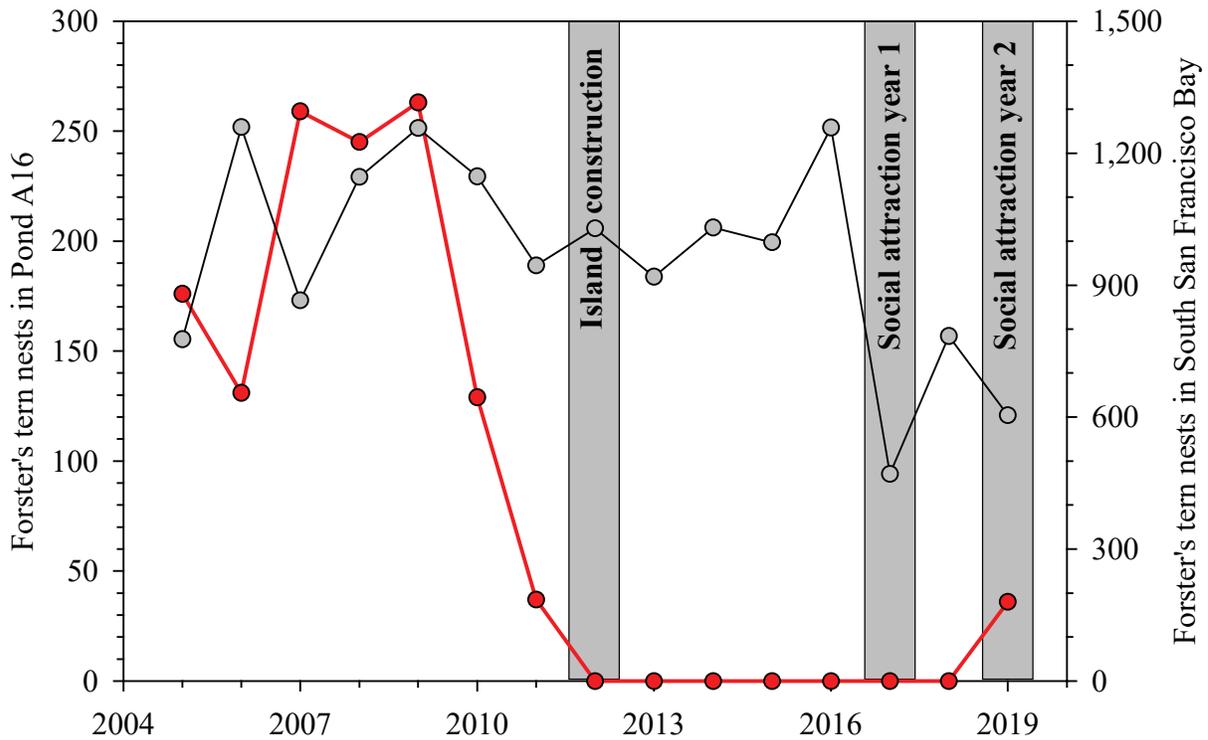
Figure 13.   The number of Forster's tern nests observed in Pond A16 (red line), relative to the number of Forster's tern nests throughout the entire South San Francisco Bay (black line) before and during social attraction efforts to re-establish the Forster's tern nesting colony at Pond A16, Don Edwards San Francisco Bay National Wildlife Refuge, California, 2005–19.

In 2019, 16 of the 35 (46 percent) Forster's tern nests successfully hatched young; 9 were depredated, 8 were abandoned, and 2 survived until their hatch date but contained unviable eggs. Nest success estimated by using the logistic exposure method was 45 percent (95-percent CI: 18 percent, 67 percent), which was greater than the overall nest success of 27 percent (95-percent CI: 21 percent, 33 percent) estimated for the entire South San Francisco Bay in 2019. Importantly, Forster's tern nest success in Pond A16 was much greater than the nest success of 15 percent (95-percent CI: 7 percent, 26 percent) estimated for the approximately 200 Forster's tern nests in adjacent New Chicago Marsh in 2019, which does not afford the same protection from terrestrial predators as islands do within Pond A16. Similarly, American avocet nest success in Pond A16 was 38 percent (95-percent CI: 26 percent, 50 percent) in 2019, which was greater than the 28 percent (95-percent CI: 5 percent, 58 percent) estimated for New Chicago Marsh in 2019 but slightly lower than the overall estimate of 48 percent (95-percent CI: 39 percent, 57 percent) for the entire South San Francisco Bay in 2019.

Social Attraction Efforts Take Time to Establish Long-Term Colonies

Establishment of waterbird breeding colonies using social attraction often benefits from multiple years of effort (Kress, 1983; Jones and Kress, 2012). For example, in coastal Maine, social attraction measures (decoys and calls) were first deployed in 1978 in an attempt to re-establish arctic tern (*Sterna paradisaea*), as well as common tern (*S. hirundo*), nesting colonies on Eastern Egg Rock, a major historical nesting site on which terns had not bred since the 1930s (Kress, 1983). In the first year of the effort, tern sightings on Eastern Egg Rock nearly doubled, but the first nests were not recorded until 1980, the third year of the effort. By 1983, 5 years after the project started, more than 1,000 terns were nesting on Eastern Egg Rock, making it the largest common tern breeding colony in Maine (Kress, 1983). The fact that Forster's tern nesting was successfully re-established to Pond A16 after only 2 years of social attraction effort is encouraging and suggests that continued social attraction efforts at Pond A16 and other sites will help to increase nesting opportunities for Forster's tern and maintain breeding populations in South San Francisco Bay.
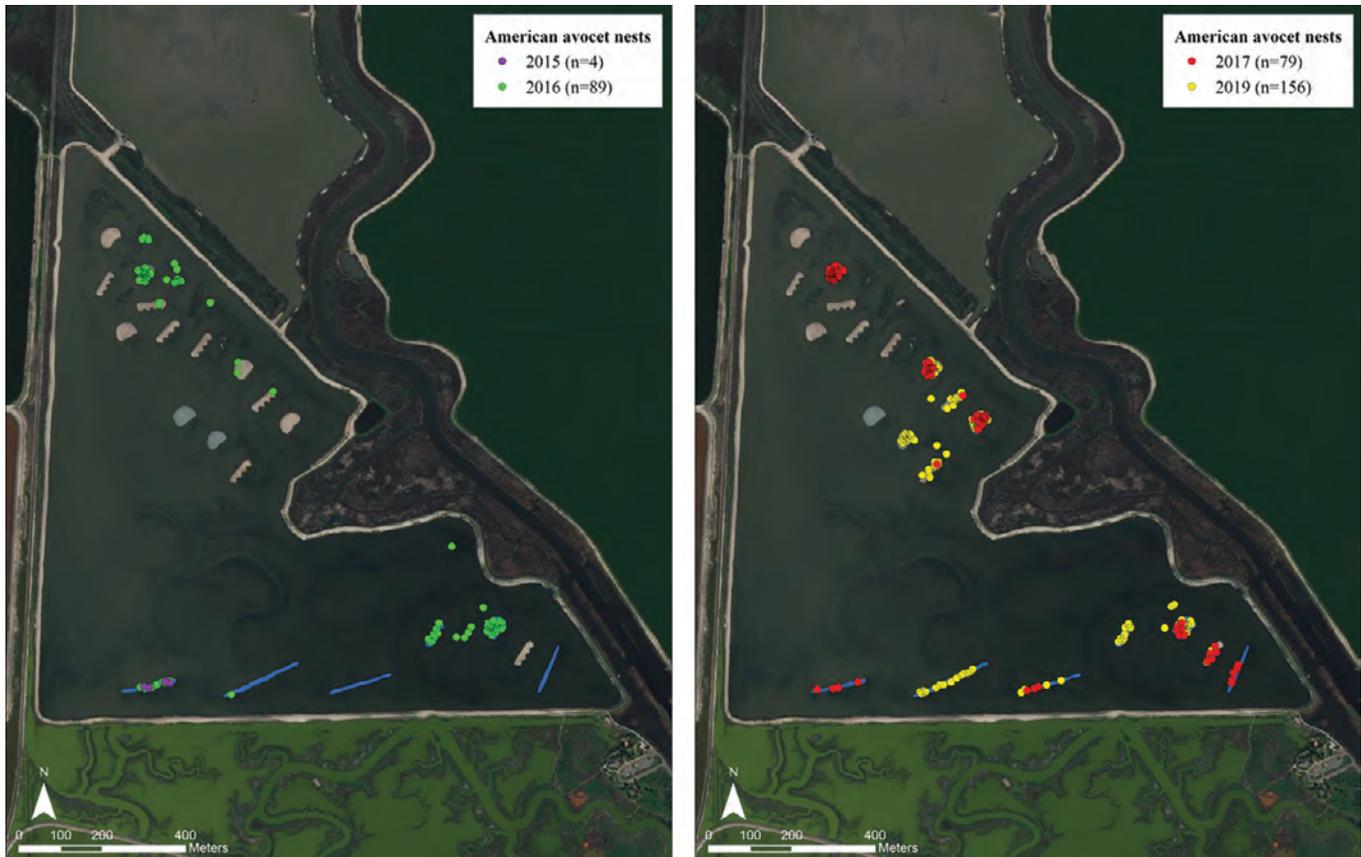
Figure 14.   American avocet nest locations in Pond A16 before (2015, 2016; left panel) and during (2017, 2019; right panel) implementation of Forster's tern social attraction measures (decoys and calls), Don Edwards San Francisco Bay National Wildlife Refuge, California. Islands highlighted in blue denote islands on which social attraction measures were implemented in 2017 and 2019.

In 2017, we observed a substantial decrease in the number of large Forster's tern breeding colonies (from an average of 7 in the 2000s to only 4 in 2017) and the overall Forster's tern breeding population (from more than 1,000 nests annually in previous years to fewer than 500 nests in 2017) in South San Francisco Bay. These declines in Forster's tern colonies and nest abundance continued in 2019 (4 large nesting colonies, 604 nests). Some of this decrease could be linked to the loss of historical island nesting habitat due to the conversion of managed ponds to tidal action as part of the SBSP Restoration Project. As future phases of the SBSP Restoration Project convert more managed ponds to tidal action, and the islands within these ponds are lost,

Forster's tern nesting opportunities could become more limited, potentially reducing the breeding population further. The decreasing Forster's tern breeding population and the projected loss of additional nesting habitat highlights the urgency in establishing or re-establishing colonies in managed ponds (such as Pond A16) that will continue to provide nesting habitat into the future. The successful re-establishment of nesting Forster's terns to Pond A16 after only 2 years of social attraction effort, as well as the successful establishment of Caspian tern breeding colonies in a related effort (Hartman and others, 2019), suggests that social attraction is a viable means for re-establishing tern breeding colonies in South San Francisco Bay.

Outreach to Stakeholders and the General Public

We engaged in multiple outreach activities for this project, including development of a website and an outreach video, four public presentations, two publications of a popular article, posting of outreach materials for the general public, and two visits with local elementary school classes.

In June 2017, the story map website entitled "Re-establishing Waterbird Breeding Colonies in San Francisco Bay" was published and is accessible to the general public (https://apps.usgs.gov/shorebirds/; fig. 15).
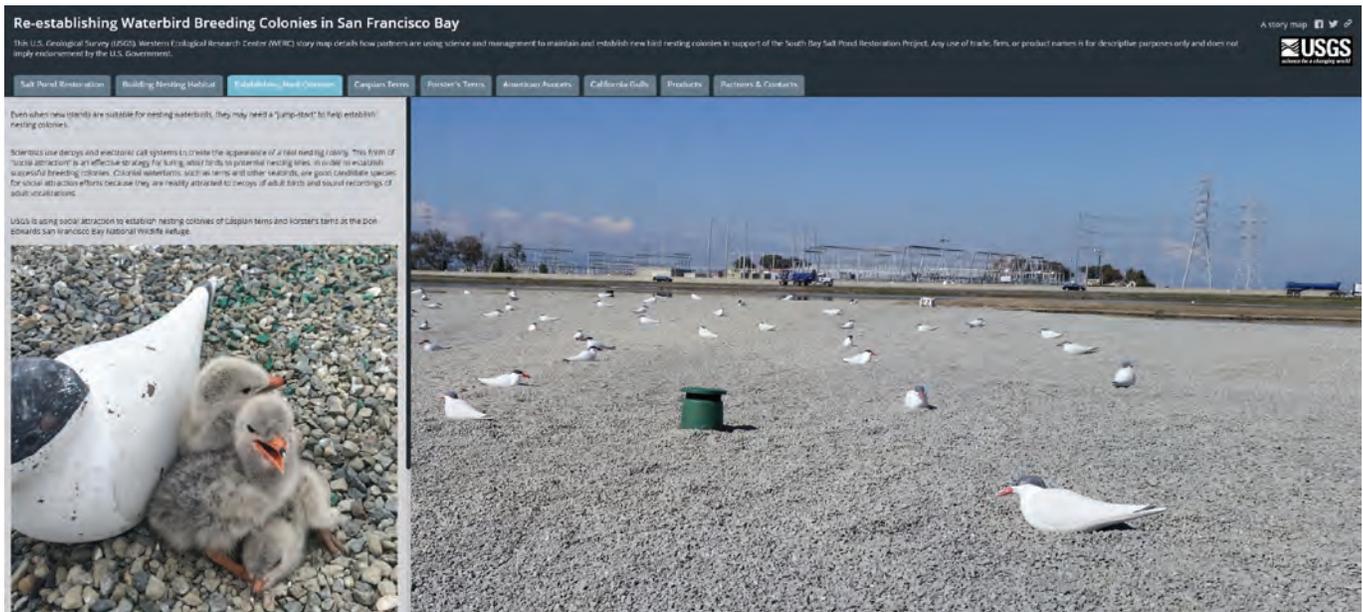

Figure 15. U.S. Geological Survey story map website (https://apps.usgs.gov/shorebirds/) and imbedded video documentary detailing the Forster's tern social attraction project in the broader context of breeding waterbird research and management in South San Francisco Bay, California.

The project website was updated in the spring of 2020 with results from the 2019 social attraction effort. In addition to a detailed description of the Forster's tern social attraction project at Pond A16, the website serves to place those efforts in the broader context of waterbird research, conservation, and management in South San Francisco Bay and the SBSP Restoration Project. The story map includes an overview of the benefits and challenges of the SBSP Restoration Project to breeding waterbirds, recommendations for the construction of nesting islands, descriptions and results of our social attraction efforts for Forster's terns and Caspian terns, as well as population changes and management of American avocets and California gulls (*Larus californicus*). Included in the Forster's tern social attraction component of the website is an educational outreach video describing the need for the project and how it was implemented (https://www.youtube.com/watch?v=-IaZD0YlAvM&feature=youtu.be).

We gave four presentations associated with our tern social attraction efforts in South San Francisco Bay. On March 23, 2017, we presented at the SBSP Restoration Project researchers and management team meeting at the DENWR where we gave updates on ongoing efforts to promote nesting by waterbirds in the SBSP Restoration Project area. On October 11, 2017, we presented an invited talk at the 13th Biennial State of the San Francisco Estuary Conference, entitled "Waterbird Nesting Ecology and Management in San Francisco Bay." This conference focused on management and health of the San Francisco Bay-Delta Estuary and was attended by more than 800 people. Our presentation focused on the declining populations of waterbirds nesting in San Francisco Bay, the importance of island nesting habitat to waterbirds, and how social attraction can be an effective tool for establishing nesting colonies. On November 16, 2017, we presented a talk entitled "Using Social Attraction to Establish Tern Breeding Colonies in South San Francisco Bay" at the San Francisco Bay Bird Observatory Science Talk forum. This forum was attended by San Francisco Bay Bird Observatory staff, members, and the general public. Our presentation focused on our efforts in establishing Forster's tern and Caspian tern breeding colonies on the DENWR. On April 16, 2020, we presented a webinar hosted by the San Francisco Bay Bird Observatory entitled "Return of the Terns! Using Social Attraction to Establish Tern Nesting Colonies in South San Francisco Bay." This webinar was attended by more than 100 people and detailed our social attraction efforts in South San Francisco Bay, and in particular, our successful re-establishment of nesting Forster's tern to Pond A16 in 2019.

In February 2017, we visited two elementary schools to talk to students about waterbird conservation in San Francisco Bay and how social attraction can be used to attract birds to nest. We then worked with students in a hands-on activity of repainting tern decoys that were used in our social attraction efforts in 2017. This outreach effort gave young students a unique opportunity to contribute to waterbird conservation efforts close to home.

In June 2017, the article "Caspian Push and Pull" was published in Estuary News, a publication of the San Francisco Estuary Partnership (http://www.sfestuary.org/estuary-news-caspian-push-and-pull/). This article focused on our successful efforts using social attraction to establish tern nesting colonies in South San Francisco Bay and our engagement of local schoolchildren in repainting decoys for our social attraction efforts. In April 2020, we published a popular article titled "Return of the Terns! Social Attraction Helps Forster's Terns Return to a Key Nesting Area in South San Francisco Bay" in Tide Rising, a quarterly newsletter from the San Francisco Bay Wildlife Society (http://sfbws.com/tide-rising/volume-1-issue-3-spring-2020). This article detailed the successful re-establishment of nesting Forster's terns to Pond A16 in 2019.

In spring of 2019, we posted outreach materials describing the Forster's tern social attraction project to the general public. These outreach materials included a link on the Don Edwards San Francisco Bay National Wildlife Refuge website (https://www.fws.gov/refuge/Don_Edwards_San_Francisco_Bay/), a poster displayed at the Don Edwards San Francisco Bay National Wildlife Refuge's Environmental Education Center, and a poster displayed along the walking trail on the Pond A16 levee adjacent to the islands with decoys and call systems (appendices 1–3). These materials were displayed prominently throughout the spring and summer of 2019. Finally, on April 15, 2019, we toured the Pond A16 project site with representatives from Valley Water, U.S. Geological Survey, San Francisco Bay Bird Observatory, and U.S. Fish and Wildlife Service to view the deployed decoys and call systems.

Conclusions

Social attraction efforts implemented in 2017 and 2019 were successful in altering Forster's tern and American avocet use of, and distribution within, Pond A16 and ultimately in re-establishing a nesting Forster's tern colony in 2019. During the primary nesting period (May–June), the relative abundance of Forster's terns at Pond A16 was higher during implementation of social attraction measures (2017, 2019) than before implementation of social attraction measures (2015, 2016). Moreover, Forster's terns and American avocets were much more prevalent in the areas of Pond A16 where social attraction measures were implemented during the pre-nesting and nesting periods in 2017 and 2019 than in areas where it was not implemented.

During the 2019 breeding season, we recorded 35 Forster's tern nests at Pond A16. These nests represent a return to nesting by Forster's terns to Pond A16 for the first time in the 8 years since the construction of 16 new nesting islands in 2012. In addition, social attraction efforts that target Forster's terns can benefit other nesting waterbird species, such as American avocets, because avocets and tern often co-locate nests (Hartman and others, 2016b). We documented 156 American avocet nests in Pond A16 during the 2019 breeding season, which is among the highest annual number of American avocet nests recorded in Pond A16 during the past 15 years (2005–19) of nest monitoring efforts by the U.S. Geological Survey in South San Francisco Bay. Moreover, more total American avocet nests were recorded in Pond A16 during implementation of social attraction measures in 2017 and 2019 (n=235) than before implementation in 2015 and 2016 (n=93), and avocets nested on all six islands where Forster's tern social attraction measures were implemented, but avocets nested on only four of these islands before implementation of social attraction measures. Yet, the proportion of American avocet nests in Pond A16 that were on islands with social attraction measures was actually lower during social attraction implementation (31 percent) than before (51 percent). These results indicated that although social attraction was successful in attracting nesting Forster's terns and American avocets to Pond A16, birds distributed themselves throughout the pond and were not limited to just those islands with decoys and call systems.

Both Forster's terns and American avocets experienced relatively high nest success in Pond A16 in 2019, 45 percent and 38 percent, respectively. Importantly, nest success rates in Pond A16 were greater than those in adjacent New Chicago Marsh, a large shallow-water marsh that lacks nesting islands that can reduce access by terrestrial nest predators. Altogether, the re-establishment of nesting Forster's terns, the increase in American avocet nest abundance, and the higher nest success within Pond A16 during implementation of social attraction measures likely will benefit efforts to maintain breeding waterbird populations in South San Francisco Bay as future phases of the SBSP Restoration Project continue.

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Appendix 1. Project link on the Don Edwards San Francisco Bay National Wildlife Refuge website

(https://www.fws.gov/refuge/Don_Edwards_San_Francisco_Bay/).

WHAT'S NEW?!

Establishing Forster's Tern Nesting Colonies at Pond A16

Project Overview

In 2012, the South Bay Salt Pond Restoration Project constructed 16 new nesting islands in Pond A16 to provide nesting habitat for waterbirds. Forster's Terns, once abundant nesters in Pond A16, have not returned to nest there since the construction of the new islands. The U.S. Geological Survey (USGS), San Francisco Bay Bird Observatory, and U.S. Fish and Wildlife Service, with funding from Valley Water, are using social attraction on six islands to help re-establish Forster's tern breeding colonies at Pond A16.
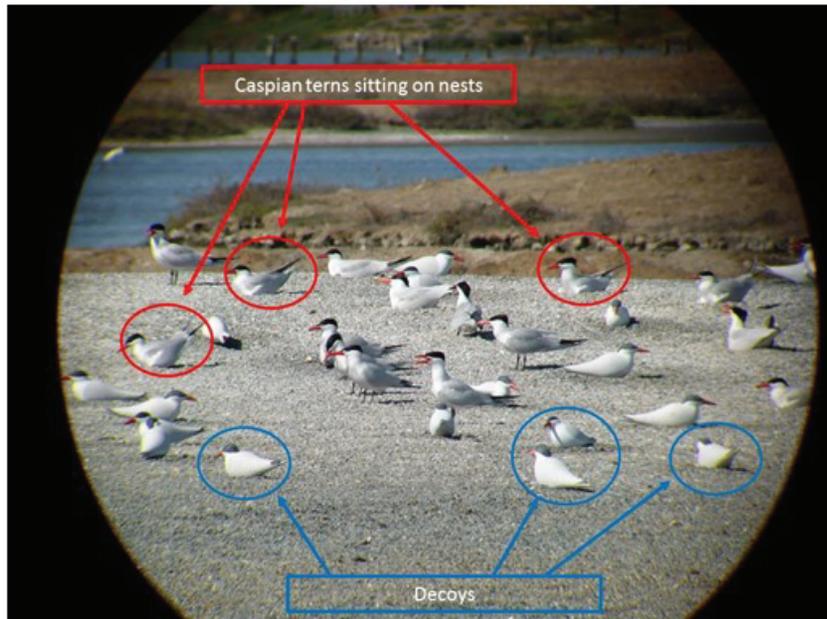
Forster's Terns (*Sterna forsteri*):

Forster's Terns prefer wetland habitats where they forage for fish and arthropods. They forage by hovering and then plunging into the water to catch a meal. Forster's Terns historically nested on islands at Pond A16. Compared to some marsh habitat, island nesting can be advantageous as it is more difficult for terrestrial predators to get to the nest. Forster's Terns are migratory birds, breeding in the Bay Area from April to August and wintering along the coasts of California and Mexico. Forster's Terns are an at- risk species in the San Francisco Bay Area and a target species for The South Bay Salt Pond Restoration Project.

What is Social Attraction?

Social attraction is an important conservation technique whereby visual (bird decoys) and auditory (colony sound recordings) cues are used to mimic a real, established waterbird nesting colony and attract individuals to nest in prefered habitats and restored sites. Social attraction has been used successfully to establish breeding colonies of many waterbird species around the world, including Caspian Terns (Hydroprogne caspia) right here at the north end of Pond A16. Can you see any of the 50 decoys (pictured right) or hear the colony sound recordings on the islands in front of you?

For more information on this project please visit: https://apps.usgs.gov/shorebirds/.

Sponsored by: US Geological Survey, San Francisco Bay Bird Observatory, U.S. Fish and Wildlife Service, and Valley Water.

Forster's terns are eat fish from the surrounding bay waters. Photo Credit: USGS, SFBBO.

Forster's tern decoys on an island in Pond A16. Photo Credit: Ken Phenicie, SFBBO, USGS.

This satellite picture of Alviso Pond A16 shows the islands that can host the tern colonies.

Appendix 2. Outreach poster displayed along the Pond A16 walking trail (April–August 2019) with a description of the project

Appendix 3.   Outreach poster displayed at the Don Edwards San Francisco Bay National Wildlife Refuge Environmental Education Center (April–August 2019) with a description of the project

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Establishing Forster's Tern Nesting Sites at Pond A16 Using Social Attraction for the South Bay Salt Pond Restoration Project

USGS
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SAN FRANCISCO BAY
BIRD OBSERVATORY

Establishing Forster's Tern Nesting Colonies at Pond A16

Valley Water

Project Overview:
The U.S. Geological Survey (USGS), San Francisco Bay Bird Observatory, and U.S. Fish and Wildlife Service, with funding from Valley Water, are using social attraction on six islands during the 2019 breeding season to help re-establish Forster's Tern breeding colonies at Pond A16.

Alviso Pond A16

New Chicago Marsh

Forster's Terns (*Sterna forsteri*):
Found in wetlands, Forster's Terns forage for fish by hovering above then diving into the water. Forster's Terns nest in colonies from April to August and are attracted to breeding sites by the presence of other terns. Pond A16 historically hosted a large breeding colony of Forster's Terns. Scientists are working to re- establish this colony through social attraction methods.

What is social attraction?:
Social attraction is a conservation technique that uses audio and visual cues to attract colonial species, like Forster's Terns, to a breeding site. Researchers have placed 50 decoy birds on each of six islands in Pond A16 (marked in red above), as well as electronic call systems that broadcast recorded calls of Forster's Terns.

For more information on this project please visit: https://apps.usgs.gov/shorebirds/   Photo Credit: USGS, SFBBO

USGS