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Implications for the South Bay Salt Pond Restoration Project

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U. S. GEOLOGICAL SURVEY & SAN FRANCISCO BAY BIRD OBSERVATORY

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Prepared for:

South Bay Salt Pond Restoration Project
State Coastal Conservancy
USFWS Coastal Program in San Francisco Bay
Don Edwards San Francisco Bay National Wildlife Refuge
Eden Landing Ecological Reserve
U. S. Fish and Wildlife Service
California Department of Fish and Game
U. S. Geological Survey
San Francisco Bay Bird Observatory

Davis, California
[2009]

U.S. DEPARTMENT OF THE INTERIOR
Ken Salazar, Secretary

U.S. GEOLOGICAL SURVEY
Suzette Kimball, Acting Director

Suggested citation:
Ackerman, J. T., C. A. Eagles-Smith, J. Y. Takekawa, J Bluso-Demers, D Tsao, and D Le Fer. 2009. California Gull Movements in Relation to Nesting Waterbirds and Landfills: Implications for the South Bay Salt Pond Restoration Project. Data Summary, U. S. Geological Survey, Western Ecological Research Center, Davis, CA 64 pp.

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Acknowledgments:
This research was funded by the State Coastal Conservancy, South Bay Salt Pond Restoration Project, U. S. Fish and Wildlife Service Coastal Program in San Francisco Bay, U. S. Geological Survey Western Ecological Research Center, San Francisco Bay Bird Observatory, and the efforts of Ann Buell, Lynne Trulio, and Rick Morat. We thank Cheryl Strong, Eric Mruz, Clyde Morris, Joy Albertson, Joelle Buffa, Mendel Stewart, Marge Kolar, the staff at the Don Edwards San Francisco Bay National Wildlife Refuge, John Krause and staff at the Eden Landing Ecological Reserve, Cargill, Newby Island Landfill, and Tri-Cities Landfill for logistical access and project support. We thank Dena Spatz, Erik Nass, Angela Rex, Sara Snyder, Naghma Malik, Sarah Stoner-Duncan, Leslie Yen, and Lindsay Dembosz for fieldwork. We thank Cheryl Strong, Ann Buell, Lynne Trulio, Meghan Moda, and John Krause for comments on earlier drafts.

Cover Photo generously provided of Ken Phenicie

EXECUTIVE SUMMARY

Problem Statement

- The California gull (*Larus californicus*) population in the South San Francisco Bay has increased from fewer than 200 breeding gulls in 1982 to over 46,800 in 2008.
- The exponential increase of gulls in San Francisco Bay may be closely related to their use of landfills.
- The South Bay Salt Pond Restoration Project is initiating plans to restore 15,100 acres of salt ponds into tidal marsh and managed ponds, including restoring tidal action to pond A6. This may cause some of the 46,800 breeding gulls to move to new nesting sites and negatively effect current populations of ground-nesting waterbirds through harassment, encroachment on nesting sites, and predation on eggs and chicks.

Study Objectives

- In this study, we radio-marked and tracked California gulls during a two year period to determine movements, home ranges, and their relative use of landfills and waterbird nesting colonies.
- We monitored the abundance of California gulls in A6 and other locally breeding waterbirds in the immediate vicinity of the A6 gull colony to establish a prior baseline for waterbird nesting distribution in 2008.

Study Results

Objective 1. Determine nest abundance at the A6 California gull colony by coarse identifiable habitat feature in 2008, before A6 is breached.

- In 2008, there were 13,183 California gull nests within pond A6. Assuming each nest represents two adults, more than 26,366 adult gulls used A6 as a nesting colony with potentially several thousand more immature gulls present.
- Gull nests were most abundant near the center of pond A6, with the northeastern sections having the highest gull nest densities.
- Overall, 28% (3,727) of nests were located on raised islands, 24% (3,221) were located within 10 m of canals, 22% (2,945) were located on the dry bed panne, 16% (2,147) were

located on the internal road, 8% (1,090) were located near small dewatered channels, <1% (48) were located on islands surrounded by water, and <1% (5) were located on the external levee that borders pond A6.

Objective 2. Radio-mark and track California gulls at two breeding colonies (A6 and Coyote Hills) to determine movements, home ranges, and relative use of landfills and waterbird nesting sites in 2008.

- We radio-marked and tracked 113 California gulls (63 in 2007 and 50 in 2008) and obtained >8,000 telemetry locations.
- Gull home range and core use area sizes differed among breeding stages, breeding colony locations, and between years, but not sexes.
- In general, most gulls were located in close proximity (<7 km) to landfills throughout the breeding season.
- Core-use areas of radio-marked gulls encompassed the A6 and Coyote Hills breeding colonies, as well as the Newby Island and Tri Cities Landfills and several salt ponds adjacent to the landfills where gulls presumably roosted between meals.
- The proportion of time gulls spent on colony during the pre-breeding season was variable (20-40% of the day), and generally increased over time up to the start of the breeding season (1 May), when it reached a maximum. Time spent on colony was highest (approximately 60% of the day) during the breeding season (1 May to 15 July) and lowest (<20% of the day) during the post-breeding season. Over the course of the breeding season, the proportion of the day spent on colony declined substantially towards the post-breeding season.
- Colony attendance was strongly influenced by the time of day, especially during the breeding season when gulls were present at their colonies about 65% of the time from 20:00 to 05:00. Conversely, gulls tended to be present at their colonies from 06:00 to 18:00 about 40% of their time. This pattern of colony attendance was in direct contrast to landfill attendance patterns.
- Gulls generally arrived at landfills at 06:00 in the morning and left at 18:00 when the landfills were closed and the exposed refuse was covered.

Objective 3. Monitor the abundance of other locally breeding waterbirds in the immediate vicinity of the A6 gull colony to establish a prior baseline for waterbird nesting distributions in 2008, before A6 is breached and gulls are dispersed.

- We monitored American avocet (*Recurvirostra americana*), black-necked stilt (*Himantopus mexicanus*), and Forster's tern (*Sterna forsteri*) nesting at locations in close proximity to the A6 gull colony, including ponds A1, AB1, A2W, A7, A8, A12, A16, N4A, R1, and New Chicago Marsh. In total, we monitored 1,856 waterbird nests in 2008: 919 Forster's tern, 847 avocet, and 90 stilt nests.
- We found 450 waterbird nests in A7 and A8, which are scheduled to be flooded/breached for tidal marsh restoration in spring 2010. Thus, habitat for 24% of all the nests found in the South Bay will be made unavailable due to the implementation of the A8 restoration plan. In order to maintain breeding waterbird numbers in the South Bay, mitigation likely will be needed to create new nesting habitat in other ponds, such as the Refuge's proactive water manipulations and island creation in pond A12.
- The gull population's home range encompassed known waterbird nesting colonies in A8, A12, A13, A16, A17, and portions of New Chicago Marsh. These ponds accounted for 58% (1,074 nests) of all the waterbird nests monitored in the South Bay in 2008. Therefore, the majority of suitable nesting habitats for waterbirds are exposed to gulls based on their current movements.
- Waterbird nest success in ponds that were encompassed by the 2008 gull population's home range tended to be lower than in ponds that were little used by gulls. For example, the ponds with the lowest nest success for avocets were A8 (29%) and A12 (29%) and for Forster's terns were A8 (16%) and A12 (38%).

Conclusions and Management Implications

- We documented that the California gull population in the South San Francisco Bay continued to expand in 2008, and their movements were largely dictated by the locations of landfills, their reproductive stage, and time of day. Although landfills appeared to have the over-riding importance on gull movements, gulls were located closer to and spent more time at their colonies during the breeding season when gulls were presumably incubating eggs and caring for young chicks.

- The South Bay Salt Pond Restoration Project will implement plans to breach pond A6 (Knapp) in 2010 to begin this former salt pond's restoration to tidal marsh. This will cause most or all of the 26,366 California gulls currently nesting in this dry pond to move elsewhere to breed. It is unclear where these gulls will move to breed, but it is likely that gulls will move to islands and protected levees that are either close to their current nesting site at A6, such as A7 or A16, or closer to the Newby Island and Tri-Cities Landfills. Redistribution of California gulls could impact other nesting birds in the South Bay through harassment, encroachment on nesting sites, and predation on eggs and chicks.
- Regardless of where California gull colonies are located, gulls have large home range sizes with core use areas averaging 6 km and other nesting waterbirds will continue to be at risk to predation. The gull population's home range encompassed 58% (1,074 nests) of all the waterbird nests monitored in the South Bay. Nest success tended to be lower in these ponds, however more directed studies of gull predation on waterbird eggs and chicks will be necessary to clearly understand the impact of California gulls on waterbird reproductive success.
- The South Bay Salt Pond Restoration Project will implement plans to breach pond A8 in 2009, as well as open it to A5 and A7 resulting in one larger, deeper-flooded pond system. This management action will submerge current waterbird nesting habitat in A8, and potentially A7, and waterbirds will be forced to move elsewhere. This loss in nesting habitat for nearly one-fourth (450 nests) of all the waterbird nests in the South Bay could be mitigated by creation of new nesting islands in the remaining salt ponds. It will be critical to concurrently monitor waterbird reproductive success (both nest success and chick survival) and the production and bioaccumulation of methyl mercury into waterbirds associated with these management activities.

CALIFORNIA GULL MOVEMENTS IN RELATION TO NESTING WATERBIRDS AND LANDFILLS: IMPLICATIONS FOR THE SOUTH BAY SALT POND RESTORATION PROJECT

Data Summary

By Josh Ackerman, Collin Eagles-Smith, John Takekawa, Jill Bluso-Demers, Danika Tsao, & Danielle Le Fer

INTRODUCTION & OBJECTIVES

The California gull (*Larus californicus*) population in the South San Francisco Bay (hereafter South Bay) has increased from fewer than 200 breeding gulls in 1982 to over 46,800 in 2008 (Strong et al. 2004; San Francisco Bay Bird Observatory, unpublished data; Figure 1A). Yet breeding populations of California gulls at other areas in the State, such as Mono Lake, have not increased over the same time period (Wrege et al. 2006). The exponential increase in San Francisco Bay may be closely related to their use of landfills and other anthropogenic sources of food associated with a highly urbanized environment, as there are at least three landfills within short flight distance of the main breeding colonies (Figure 2). Unfortunately, the expanding California gull population may negatively affect other ground nesting birds in the South Bay through harassment (Kakouros 2006), encroachment on nesting sites (Strong et al. 2004), and predation on eggs and chicks (Ackerman et al. 2006a). For example, in 2005 and 2006, we documented that California gulls depredated at least 61% of avocet (*Recurvirostra americana*) and 23% of stilt chicks (*Himantopus mexicaus*; Ackerman et al. 2006a), and 12% of avocet nests (Herring et al., submitted A). In addition, there is concern that California gulls may displace other breeding waterbirds from preferred nesting sites as their population grows or the current nesting sites are lost to tidal marsh restoration.

The South Bay Salt Pond Restoration Project is initiating plans to restore 15,100 acres of salt ponds into tidal marsh and managed pond habitats, and may cause a portion of the 46,800 breeding gulls to move to new nesting sites, displacing other nesting waterbirds and potentially increasing predation rates. Of immediate concern is displacement of the largest California gull breeding colony in A6 (Figure 1B). In 2008, there were 26,366 California gulls nesting within the dry pond bed of A6 (see Results). Current restoration plans include breaching pond A6 in 2010, or shortly thereafter. As a result, A6 will become flooded during the gull breeding season and force gulls to move elsewhere to breed. It is unknown where gulls that occupy A6 will disperse to breed after restoration in A6 commences, but it is likely that many gulls will nest in nearby salt ponds that contain suitable island nesting sites and also are close to landfills, such as pond A16. However, pond A16 currently provides nesting habitat for one of the largest breeding populations of avocets and Forster's terns (*Sterna forsteri*) in San Francisco Bay (Ackerman et al. 2006a). Understanding California gull movements and habitat use will be critical to predicting their response to South Bay Salt Pond Restoration Project.

In this report, we addressed three main objectives:

Objective 1: Determine nest abundance at the A6 California gull colony by coarse identifiable habitat feature in 2008, before A6 is breached.

Objective 2: Radio-mark and track California gulls at two breeding colonies (A6 and Coyote Hills) to determine movements, home ranges, and relative use of landfills and waterbird nesting sites in 2008.

Objective 3: Monitor the abundance of other locally breeding waterbirds in the immediate vicinity of the A6 gull colony to establish a prior baseline for waterbird nesting distributions in 2008, before A6 is breached and gulls are dispersed.

OBJECTIVE 1: *Determine nest abundance at the A6 California gull colony by coarse identifiable habitat feature in 2008, before A6 is breached.*

Methods

Please refer to Figure 2 for a study area map. We counted all nests at the A6 gull colony on 13 May 2008, when nesting was well underway. Before we entered the colony, we used aerial photographs and geographic information system (GIS) to identify 14 clearly demarcated sections (using roads, canals, and the PG&E boardwalks) within pond A6 so that we could calculate nesting densities for each section. For each nest we recorded whether it was a nest bowl with no eggs, nest with eggs present, or a nest with chicks present. For those nests with offspring present, we counted the number of eggs and/or chicks. In addition, we identified the primary coarse habitat feature associated with each nest, including the A6 internal road, external pond levee, panne, near canals (<10 m), near dewatered channels (<5 m), islands (surrounded by water), and raised islands (not currently surrounded by water).

Results and Discussion

In 2008, there were 13,183 California gull nests within the dry pond bed of A6. Assuming each nest represents two adults, more than 26,366 adult gulls used A6 as a nesting colony with potentially several thousand more immature gulls present. Of those nests, 48% (6,366) were 3-egg nests, 40% (5,334) were 2-egg nests, 7% (987) were 1-egg nests, 3% (379) were empty nest bowls, <1% (46) had chicks in the nest, <1% (35) were 4-egg nests, <1% (2) were 5-egg nests, and <1% (34) were previously abandoned nests. Gull nests were most abundant near the center of A6 (Figure 3A), with the northeastern sections having the highest gull nest densities (Figure 3B). In particular, sections 8 and 9 had the highest nest densities, followed by sections 5, 10, and 6. Sections 1 and 11-14 did not have any gull nests, likely due to the fact that these areas are often flooded in late winter and early spring. Overall, 28% (3,727) of nests were located on raised islands, 24% (3,221) were located within 10 m of canals, 22% (2,945) were located on the dry bed panne, 16% (2,147) were located on the internal road, 8% (1,090) were located near small dewatered channels, <1% (48) were located on islands surrounded by water, and <1% (5) were located on the external levee that borders A6. We emphasize that this was merely where nests were located, and should not be interpreted as nest site selection since we did not measure the availability of the different habitats, which was beyond the scope of this study. Additional work to gain insight into nest habitat selection by quantifying availability of habitats relative to their use may be beneficial for managing gull nesting in the future.

OBJECTIVE 2: ***Radio-mark and track California gulls at two breeding colonies (A6 and Coyote Hills) to determine movements, home ranges, and relative use of landfills and waterbird nesting sites in 2008.***

Methods

Capture and Marking---During the pre-breeding season, we captured California gulls at the A6 and Coyote Hills colonies using remotely detonated net-launchers (Coda Enterprises, Mesa, Arizona) and rocket nets (Dill and Thornsberry 1950). We marked adult gulls with a radio transmitter attached to their back with a backpack harness made of 3/16 inch Teflon ribbon (Model A1135, Advanced Telemetry Systems Inc. [ATS], Isanti, Minnesota). Each knot was secured with cyanoacrylic glue (Loctite 422, Henkel Corp., Rocky Hill, Connecticut). Transmitter packages weighed about 18 g or <3% of the gull's body mass. During 2007, 13 gulls were radio-marked by affixing transmitters to leg bands. However, most of these gulls went missing by the end of the breeding season and we were often unable to locate them because these smaller transmitters had limited range. Instead, we had good success with the back-pack style radio transmitter package. Gulls were captured and marked under State Scientific Collection Permits (SC-000009), Federal Bird Banding Permits (23564, 22911), and Federal Fish and Wildlife Permits (MB173904, MB102896).

Gull Measurements---We measured culmen length, bill depth at the gonys, head-to-bill length, tarsus length (tarsometatarsus bone), flattened wing length (carpal joint to the end of the longest straightened primary), length of rectrices R1 and R6 (R1 was the central most rectrix on the right side, R6 was the outer most rectrix on the right side), and body mass for each gull. We measured gull morphology to the nearest 0.01 mm with digital calipers (Fisher Scientific, Hampton, NH), except wing length and tail measurements, which were measured to the nearest 1.0 mm with a stopped wing rule. We measured body mass to the nearest 1.0 g with a 1-kg Pesola spring scale (Pesola AG, Baar, Switzerland). A drop of blood was collected from each gull for sex determination using the chromo-helicase-DNA binding protein gene by Zoogen Services Inc., Davis, California. We held birds during marking operations in shaded and screen-lined poultry cages (model 5KTC, Murray McMurray Hatchery, Webster City, Iowa) and released gulls at the capture site. Using discriminant function analysis and DNA verification, we developed a model to determine a California gull's sex based on their morphometrics (Herring et al., submitted B).

California gull with (unattached) back-pack style radio transmitter shown.

Radio-tracking---We tracked radio-marked gulls (pictured here) from trucks equipped with dual 4-element Yagi antennas (Advanced Telemetry Systems, Isanti, Minnesota) with null-peak systems (AVM Instrument, Livermore, California) to accurately determine bearings (e.g., Takekawa et al. 2002, Ackerman et al. 2006b). In 2007, we also tracked gulls from fixed-wing aircraft with dual side-view 4-element Yagi antennas and a left-right control box (Advanced Telemetry Systems Inc., Isanti, Minnesota) so transmitter signals could be located on either side of the plane (Gilmer et al. 1981). We attempted to locate gulls daily by truck and every month by aircraft from their date of capture until mid September. To ensure coverage throughout the South San Francisco Bay, we used fixed tracking routes through all main salt pond systems (includes Alviso, Moffett, Mowry, Newark, and Eden Landing), bay edges, and the two largest landfills that are open to residential waste (Newby Island Landfill and Tri-Cities Landfill). Gull use of the Palo Alto Landfill is limited since this landfill receives only residential waste and most waste for the city is transferred elsewhere (Ackerman et al. 2006a). For each location by truck, we obtained at least two azimuths within several minutes to minimize movement error. Transmitter signals could easily be heard at distances >5 km when flying and >2 km when on the ground, so only some gull locations in the middle of the bay might have been missed and it is unlikely that any gulls were missed within most salt ponds due to their distance from truck tracking locations. One exception might be the Mowry salt ponds, especially M1 and M2, where we recorded fewer gull locations by truck due to limited access during levee and salt pond maintenance by Cargill. In South San Francisco Bay, Warnock and Takekawa (1995) reported average error rates of 1.5 degrees for bearings, 58 ± 35 (SE) m for distances between true and calculated locations, and 1.1 ha for error-polygon size with similar truck systems and location distances (e.g., <3 km). We used triangulation program software (LOAS, version 3.0.1, Ecological Software Solutions, Schwägalpstrasse 2, 9107 Urnäsch, Switzerland) to calculate Universal Transverse Mercator (UTM) coordinates for each location. We overlaid Bay Area EcoAtlas habitat coverages (version 1.50b, San Francisco Estuary Institute 1998) to depict locations versus habitat features in the Bay.

Automated Data Logging Stations---In addition, we established automated telemetry data logger systems to continuously monitor gull presence or absence at each of the three main gull breeding colonies (A6, Coyote Hills, and Mowry) and the two main landfill sites (Newby Island and Tri-cities). The automated telemetry system (pictured here) consisted of a data logging telemetry receiver (model R4500S, Advanced Telemetry Systems Inc., Isanti, Minnesota) linked to an omni-directional dipole or H-antenna (Advanced Telemetry Systems Inc., Isanti, Minnesota) and was powered by a 12-volt marine battery. The receiver system continuously scanned all gull frequencies with an approximate cycle of 20 minutes. During normal system operation, we interpreted a lack of detection as an absence from the colony or landfill. The range of the receiving system was manipulated so that only gulls within the specified site could be recorded. At the Coyote Hills and Mowry gull colonies, we used two automated telemetry data logger systems to cover the entire colony. We used reference transmitters placed within the sites of interest to ensure that the receiving system functioned properly and manually confirmed correct function at least once every two weeks. On some occasions, the system failed to function properly due to loss of battery power; we omitted data from those time periods from our analyses.

Automated data logging station at Coyote Hills California gull colony.

Automated Data Logging Station Analyses---We analyzed patterns of gull colony and landfill attendance by examining presence/absence data at two temporal scales. First, to evaluate daily patterns of attendance, we calculated the proportion of each day that a gull attended the colony or landfill by dividing the number of data logger cycles that the gull was detected on a given day by the number of data logger cycles completed that day. For this analysis, we only used data when we had complete records for the entire 24 hrs in a day; that is, all 72 data logger receiver cycles (20 min each) were functioning appropriately and there was no reason for data omission (e.g., due to battery failure). Each radio-marked gull contributed one data point per day, unless it was censored (removed). Second, to investigate hourly patterns of attendance, we divided the data into 24 one-hour time intervals for each gull. For each hour of the day, we considered a gull present (1) if it was detected at least once during that hour and absent (0) if it was not detected during that hour. We also determined each gull's breeding colony with the automated data logger system data using two conservative criteria: (1) if a gull spent >50% of their nighttime hours (20:00 to 0500) during the breeding season (1 May to 15 July, 2008) at a colony or (2) if a gull spent >4× more time at a colony than any other potential breeding colony and if their time at this colony was >25% of the total possible nighttime hours during the breeding season. Few other studies have conducted similar studies, but those that have assume known breeding colonies based on average attendance patterns.

Home Range Size Analyses---We used ArcGIS 9.2 (ESRI 2006) to map all truck and aerial telemetry locations. For the rare occasions when consecutive observations on an individual gull were obtained <90 min apart, we randomly selected only one observation to include in analyses. We also excluded any locations with error-polygon sizes ≥50 ha, which were calculated for each triangulation by assuming a constant variance (two standard deviations; LOAS). Using the fixed-kernel method (Seaman and Powell 1996), we calculated home ranges and core-use areas for each individual gull, which we defined as the areas encompassing 95% and 50% of the utilization distributions, respectively, by season (pre-breeding [capture to 1 May], breeding [1 May to 15 July], or post-breeding [15 July to 15 September]). We selected likelihood-cross-validation (CVh) as the smoothing parameter because it generally produces home range estimates with better fit and less variability with small sample sizes than other smoothing parameters, such as least-squares-cross-validation (Horne and Garton 2006). We used Animal Space Use 1.2 (Horne and Garton 2007) to calculate CVh and Home Range Tools for ArcGIS (Rodgers et al. 2005), with the CVh value as the smoothing parameter selection, to calculate home-range and core-use area sizes for gulls with ≥10 locations.

We used analysis of variance (ANOVA) to test whether gull home range and core use area size differed among variables using JMP® version 5.0 software (SAS Institute, Cary, North Carolina). We used a backward elimination procedure (Zar 1999), with alpha >0.05 to remove interactions, to test our expanded global model that included breeding stage (pre-breed, breed, and post-breed), year (2007 and 2008), sex, and colony as main effects, and year × breeding stage, year × colony, and breeding stage × colony as 2-way interactions. We found significant interactions between breeding stage × capture colony, but not breeding colony (see Results), therefore we conducted separate ANOVAs for each capture colony to test the effects of breeding stage, year, and sex. We used Tukey HSD multiple pairwise comparisons to test differences between categories for significant ($P<0.05$) variables. All data were $\log_e$-transformed for analysis and we only included data for the year the gull was radio-marked in order to avoid pseudoreplication between years for returning gulls. We back-transformed data for graphical presentation using the delta method for standard errors (Williams et al. 2002).

Results and Discussion

During the pre-breeding season from 6 March 2007 to 26 April 2007 and 6 March 2008 to 15 April 2008, we radio-marked 113 California gulls (Table 1). In 2007, we radio-marked 63 gulls of which 50 transmitters were attached via backpack harness and 13 transmitters were attached to leg bands (Table 2). In 2008, 50 gulls were radio-marked using backpack harnesses (Tables 3 & 4). Of these, 32 gulls were radio-marked at the A6 colony and 18 gulls were radio-marked at the Coyote Hills colony.

Twenty-nine of the 50 (58%) gulls radio-marked using back-pack harnesses in 2007 returned with working transmitters and we continued to track them in 2008 (Table 5). We identified the breeding colony for 25 of the 29 returning gulls in 2008. Of those 25 gulls, 12 (48%) remained at the same breeding colony used in 2007 and 10 (40%) gulls switched breeding colonies (we could not identify breeding colonies in both years for 7 gulls). Three of the 4 (75%) returning gulls that nested at Coyote Hills in 2007, also nested at Coyote Hills in 2008. In contrast, of the 18 returning gulls that nested at A6 in 2007, 50% remained at A6, 44% switched to the Mowry colony, and 6% switched to the Coyote Hills colony.

In total we recorded 8,061 useable telemetry locations based on truck and aerial tracking, and several hundred thousand locations using the automatic data logging stations placed at the colonies and landfills.

Gull Home Range Size: Capture Colony---We began our analyses using all the data, and compared home range sizes between the two colonies where we captured the gulls (A6 and Coyote Hills). This is different from the (below) analyses which categorizes gulls by their breeding colonies (A6, Coyote Hills, or Mowry), which were determined post hoc by examining the data (see Methods). We feel the breeding colony analyses are more robust, but that the capture colony results also are useful especially for understanding gull space use and exchange among colonies.

The final model indicated that there was a significant interaction between breeding stage × capture colony for both home range size (ANOVA: year: $F_{1,210}$=4.13, P=0.04; breeding stage: $F_{2,210}$=3.58, P=0.03; capture colony: $F_{1,210}$=24.21, P<0.0001; sex: $F_{1,210}$=0.52, P=0.47; breeding stage × capture colony: $F_{2,210}$=3.77, P=0.02) and core use area size (ANOVA: year: $F_{1,210}$=4.24, P=0.04; breeding stage: $F_{2,210}$=8.85, P=0.001; capture colony: $F_{1,210}$=20.91, P<0.0001; sex: $F_{1,210}$=1.77, P=0.18; breeding stage × capture colony: $F_{2,210}$=4.82, P=0.01). We therefore conducted separate ANOVAs for each capture colony to remove the interaction terms.

At the A6 capture colony, home range size differed among breeding stages (ANOVA: $F_{2,144}$=10.84, P<0.0001), but not between years ($F_{1,144}$=1.85, P=0.18), or sexes ($F_{1,144}$=0.61, P=0.44). Tukey-Kramer pairwise tests revealed that home range sizes were greater during the post-breeding time period than either the pre-breeding or breeding time periods, which did not differ (Figure 4). In contrast, home range sizes did not differ among breeding stages ($F_{2,64}$=0.24, P=0.79), between years ($F_{1,64}$=2.51, P=0.12), or sexes ($F_{1,64}$=0.02, P=0.88) at the Coyote Hills colony (Figure 4).

Gull Home Range Size: Breeding Colony---Even though we captured gulls at a particular colony during the pre-breeding season, this did not necessarily mean that the gulls actually nested at that colony. Therefore, we used our smaller dataset with known breeding sites in these additional analyses. We re-ran the same statistical tests as described above, except that we used the breeding colony location as the main effect instead of using the capture colony location. The main difference in the results was that the breeding stage × colony interaction was not significant and therefore we did not separate the analyses by breeding colony like we did for capture colonies.

Gull home range size differed among breeding stages (ANOVA: $F_{2,161}$=12.00, P<0.0001), breeding colony locations ($F_{2,161}$=9.60, P<0.001), and between years ($F_{1,161}$=6.46, P=0.01), but not sexes ($F_{1,161}$=0.48, P=0.49). Similarly, we found that gull core use areas differed among breeding stages (ANOVA: $F_{2,161}$=22.18, P<0.0001), breeding colony locations ($F_{2,161}$=7.12, P=0.001), and between years ($F_{1,161}$=6.99, P=0.01), but not sexes ($F_{1,161}$=1.58, P=0.21). Tukey-Kramer pairwise tests revealed that home range and core use area sizes both differed between colonies A6 and Coyote Hills, and between pre-breeding and post-breeding, and breeding and post-breeding time periods (Figure 5). Overall, home range sizes and core use areas were smaller in 2008 than in 2007; this might have been partially due to increased sample sizes (number of telemetry locations) near colonies and landfills in 2008 which concentrated the fixed-kernel home range estimators. Alternatively, there may have been differences in resource availability between years, though there is no available data to test this explanation.

Gull Proximity to Colonies and Landfills---In general, most gulls were located within 7 km of landfills throughout the breeding season (Figures 6-8). The distance between colony locations and landfill locations appeared to influence the distance that gulls were located from their colony. The Mowry colony is closest to the landfills (6 km from Newby Island and 5 km from Tri-Cities), followed by the A6 colony (7 km from Newby Island and 6 km from Tri-Cities), then the Coyote Hills colony (14 km from Newby Island and 13 km from Tri-Cities). Gulls breeding at Mowry were almost always within 3 km of their colony, whereas A6 breeding gulls were typically located within 5 km of their colony, and Coyote Hills breeding gulls were mainly located within 12 km of their colony (Figures 6-8).

The distance breeding gulls were located from their colonies tended to change with the calendar date in the form of a weak quadratic function, such that gulls were located farther from their colonies during the pre-breeding and post-breeding season, and closer to their colony during the breeding season (Figures 9-11). Conversely, the opposite was observed at landfills; gulls were located closer to the landfills during the pre-breeding and post-breeding season and farther from the landfills during the breeding season (Figures 9-11). This is likely due to gulls spending more time at colonies during the breeding season when incubating eggs and raising chicks. However, these relationships were weak and partly driven by increased power associated with very large sample sizes. Several other factors, such as the abundance and distribution of more natural prey, likely influenced gull distance from landfills and colonies and should be considered in the future.

Gull Space Use---Home range of California gulls clearly centered around gull breeding colonies and the two largest landfills within the South Bay (Figure 12). Core-use areas of radio-marked gulls in 2007 and 2008 encompassed the A6 and Coyote Hills breeding colonies, as well as the Newby Island and Tri-Cities Landfills and several adjacent salt ponds where gulls presumably roosted between meals (Figure 12). For gulls breeding at both A6 and Coyote Hills, core use areas tended to encompass more of the landfill areas during the post-breeding season (Figures 13-15) when parents were presumably less attached to their breeding sites. However, our results were remarkably consistent among years and throughout the breeding season indicating the importance of landfill locations in dictating the daily movements of California gulls.

Gull Activity---Our movement data showing the importance of landfills to gulls was supported by our automated data logging station data (Figures 16-17). The overall time spent on colony by gulls was highest (approximately 60% of the day) during the breeding season (1 May to 15 July) and lowest (<20% of the day) during the post-breeding season. The proportion of time spent on colony during the pre-breeding season was variable (20-40% of the day), and generally increased over time up to the start of the breeding season (1 May), when it reached a maximum. Over the course of the breeding season, the proportion of the day spent on colony declined substantially toward the post-breeding time period.

In addition to date, colony attendance was strongly influenced by the time of day, especially during the breeding season (Figures 18-19). During the breeding season, gulls tended to be present at their colonies from 20:00 to 05:00 about 65% of the time. Conversely, gulls tended to be present at their colonies from 06:00 to 18:00 about 40% of their time. This pattern of colony attendance is in direct contrast to landfill attendance patterns. Gulls seemed to arrive at landfills at 06:00 in the morning and leave at 18:00 when the landfills were closed and the exposed refuse was covered. Detailed attendance patterns for each colony and landfill are shown in Figures 20-24 for 2007 and Figures 25-29 for 2008.

OBJECTIVE 3: ***Monitor the abundance of other locally breeding waterbirds in the immediate vicinity of the A6 gull colony to establish a prior baseline for waterbird nesting distributions in 2008, before A6 is breached and gulls are dispersed.***

Methods

Each colony was entered on a weekly basis and new nests were located and marked with a uniquely numbered anodized aluminum tag (Ben Meadows Company, Janesville, Wisconsin) placed at the nest and a colored pin flag placed 2 m from the nest. We recorded UTM coordinates for each nest site with a GPS. During nest visits, the stage of embryo development was estimated by floating (Hays and LeCroy 1971; Alberico 1995; Ackerman and Eagles-Smith, submitted), and clutch size and nest fate (hatched, failed, or depredated) was determined. We calculated nest abundance and nest success for each pond and species using Mayfield (1961, 1975) techniques. Mayfield nest success is defined as the number of successful nests out of those that were attempted, and is different from apparent nest success which is defined as the number of successful nests divided by the number of nests that were found. A nest is considered successful if at least one egg successfully hatches in the clutch.

Results and Discussion

We monitored American avocet, black-necked stilt, and Forster's tern nesting at colonies in the South Bay, including ponds A1, AB1, A2W, A7, A8, A12, A16, N4A, R1, and New Chicago Marsh (Figure 2). In total, we monitored 1,860 waterbird nests in 2008; 919 Forster's terns, 847 avocets, 90 stilts, and 4 black skimmer nests (Table 6). The largest nesting abundances were in pond A12 (405 nests) - a new nesting habitat created by the Refuge for the first time in 2008 by drawing down water levels and exposing islands suitable for nesting. The largest avocet colony occurred in A12 (328 nests) and A8 (205 nests). However, the next largest avocet colony was only 62 nests in A2W. The largest Forster's tern colonies were in ponds AB1 (250 nests) and A16 (248 nests), followed by A7 (152 nests) and A1 (105 nests). The largest number of stilt nests were located in New Chicago Marsh (33 nests), as they traditionally nest here at high densities (Ackerman et al. 2006a), but we did not conduct a comprehensive survey at this site in 2008 due to a lack of funds. For comparison, we had a much larger nest searching effort in 2007 and found 537 nests in New Chicago Marsh.

In total, we found 450 waterbird nests in A7 and A8, which are scheduled to be flooded/breached for tidal marsh restoration in spring 2009. We did not search all wetlands in the South Bay for waterbird nests, but we did search most wetlands and especially those areas that are known to have the largest colonies. Thus, habitat for potentially 24% of all the nests found in the South Bay will be made unavailable due to the implementation of the A8 restoration plan. This loss in nesting habitat could be mitigated by creation of new nesting habitat in other ponds; such as the Refuge's proactive water manipulations and island creation in pond A12.

Nest success was highly variable among ponds and species (Table 6). In general, Forster's terns had higher nest success than avocets at most sites where they co-occurred. Forster's tern nest success ranged from a high of 99% in pond A1 to a low of 16% in pond A8. Avocet nest success was highest in pond R1 (93%) and lowest in ponds A8 (29%) and A12 (29%). Sample sizes of stilt nests were too low for accurate estimates of nest success at most sites, but stilt nest success in New Chicago Marsh was 26%.

We overlaid the home range and core use areas for the California gull population in 2008 on the waterbird nesting distributions in 2008 (Figure 30). Gull core use areas did not overlap any waterbird nesting colonies, but the home range of gulls overlapped several waterbird colonies. In particular, gull home range encompassed known nesting colonies in A8, A12, A13, A16, A17, and portions of New Chicago Marsh. These ponds accounted for 58% (1,074 nests) of all the waterbird nests monitored in the South San Francisco Bay. Therefore, the majority of suitable nesting habitat for waterbirds is exposed to gulls based on their current movements. We did not find nests in A17 in 2008, although there was a large avocet colony (92 nests) there in 2007. We did not monitor nests in A13 in 2008, though we counted more than 30 nests in this pond during preliminary surveys.

Nest success in ponds that were encompassed by the 2008 gull population's home range tended to be lower than in ponds that were little used by gulls (Figure 31). For example, the ponds with the lowest nest success for avocets were A8 (29%) and A12 (29%) and for Forster's terns were A8 (16%) and A12 (38%). This is not to suggest that nest success is mainly influenced by gull predation. Indeed, pond A8 likely has lower nest success than most ponds because waterbirds in that pond typically nest on peninsulas that sometimes can be accessed by terrestrial predators depending on water levels (e.g., skunks and coyotes). However, nests in pond A12 are almost entirely on islands that terrestrial predators cannot easily access. We often observed gulls within pond A12 and suspected gull predation on eggs. Pond A16 also was encompassed in the gull population's home range, and nest success was intermediate among colonies at this site (avocets: 74%, Forster's terns: 82%). Nests within pond A16 are entirely on islands and well protected from most terrestrial predators, thus aerial predators are mainly responsible for nest depredations in this pond. We emphasize that although nest success tended to be lower in ponds used by gulls, these results should be interpreted cautiously. More directed studies of gull predation on waterbird eggs and chicks will be necessary to clearly understand the impact of California gulls on waterbird reproductive success.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

The South Bay Salt Pond Restoration Project will implement plans to breach pond A6 (Knapp) in 2010, thus initiating this former salt pond's restoration to tidal marsh. This will cause most or all of the 26,366 California gulls currently nesting in this dry pond to move elsewhere to breed. It is unclear where these gulls will move to breed, but it is likely that gulls will move to islands and protected levees that are either close to their current nesting site at A6, such as A7 or A16, or closer to the Newby Island and Tri-Cities Landfills. Currently, besides A6, the fastest growing California gull colonies over the past 5 years have been at the Mowry M1/M2, Mowry M4/M5, and Coyote Hills breeding colonies. There appears to be some additional nesting sites (space) still available at these colonies and it is possible that displaced A6 gulls will choose to move to these colonies to breed. We did find that of the 22 returning gulls in 2008 that were radio-marked in 2007, 48% remained at the same breeding colony and 40% switched breeding colonies (we could not identify breeding colonies in both years for 12% of gulls). On a colony specific basis, 75% of gulls (N=4) breeding at Coyote Hills remained at this colony. In contrast, of the 18 returning gulls that bred at A6 in 2007, 50% remained at A6, 44% switched to the Mowry colony, and 6% switched to the Coyote Hills colony in 2008. This suggests that there was some colony exchange between years and could indicate the potential for successful redistribution of gulls to different nesting sites. We emphasize that these sample sizes were extremely small for such a comparison, so we recommend caution in interpretation.

Another potential outcome of dislocating the A6 gull colony, and perhaps more likely, is that many of the displaced gulls will move onto nesting islands in the salt ponds near A6 and the landfills, such as A7 and A16. Currently, most suitable islands within the Alviso salt pond complex are occupied by nesting populations of avocets, stilts, and Forster's terns, as well as smaller numbers of nesting black skimmers, Caspian terns, and snowy plovers. Thus, redistribution of California gulls could impact other nesting birds in the South Bay through harassment (Kakouros 2006), encroachment on nesting sites (Strong et al. 2004), and predation on eggs and chicks (Ackerman et al. 2006a). Avocets and stilts begin nesting in late March and early April (Ackerman et al. 2007), before California gulls typically begin nesting in late April (Winkler 1996). Forster's terns tend to nest in early May, slightly after gulls (J. T. Ackerman, unpublished data). Thus, relocated California gulls might displace terns and increase predation pressure on avocets and stilts.

One potential solution to reduce disruption of the current nesting distributions of waterbirds in the South Bay is to try to maintain as much gull nesting habitat in A6 as possible. This could potentially be accomplished by increasing the height of key raised areas within A6 (such as in section 9 in Figure 3), so they would remain as islands after A6 is breached with Alviso Slough. Our results indicated that the raised portions of A6 were already used heavily by California gulls, accounting for 28% of all nest locations despite this habitat type being relatively sparse in A6.

Importantly, we documented that 450 waterbird nests were located in A7 and A8 in 2008, accounting for potentially one-fourth of all the nests in the South Bay. In 2009, the South Bay Salt Pond Restoration Project will implement plans to restore A8 into a muted tidal marsh. This management action will include breaching the levee between A8 and Alviso Slough. Additionally, A8 will be connected with A5 and A7, resulting in a single large, deeply-flooded pond system. Suitable nesting islands that currently exist in A8, and potentially A7, will be submerged and waterbirds will be forced to move elsewhere to nest. This lost nesting habitat for a significant portion of the waterbirds breeding in the South Bay could be mitigated by creation of new nesting habitat in other ponds.

One example of this is the Refuge's proactive water manipulations and island creation in pond A12. By lowering water levels in A12 to expose submerged islands, the Refuge created nesting habitat for an additional 405 nests. This very positive benefit for waterbirds, however, was mediated by the unintended production and bioaccumulation of methyl mercury, the most bioavailable and toxic form to humans and wildlife. In fact, Forster's tern and stilt eggs in pond A12 had higher mercury concentrations than any other site monitored in 2008, and avocet eggs in pond A12 contained the second highest concentrations of mercury (Ackerman and Eagles-Smith, unpublished data). Elsewhere we have shown that mercury concentrations in eggs at these levels are currently causing reduced hatching success in waterbirds on the Refuge (Ackerman and Eagles-Smith 2008). Thus, although the continued creation of islands in the remaining salt ponds will likely provide substantial benefit to waterbirds for use as nesting, roosting, and foraging habitat, concurrent monitoring of nesting densities, nest success, and methyl mercury bioaccumulation into waterbird eggs should be conducted.

Regardless of where California gull colonies are located, gulls have large home range sizes with core use areas averaging 6 km in size, thus other nesting waterbirds will continue to be at risk to predation. We found that the California gull population's home range encompassed 58% (1,074 nests) of all the waterbird nests monitored in the South Bay. Nest success tended to be lower in these ponds; however, more directed studies of gull predation on waterbird eggs and chicks will be necessary to clearly understand the impact of California gulls on waterbird reproductive success. For example, we found that California gulls depredated at least 61% of avocet and 23% of stilt chicks in the South Bay (Ackerman et al. 2006a), and it is suspected that similar predation pressures exist for Forster's terns (Ackerman et al. 2006a) and snowy plovers (Robinson et al. 2007), although no detailed studies have been done. Furthermore, gulls are likely to depredate bird eggs as well, though few studies have examined this. Using a limited number of remote infra-red video cameras, we documented that 12% of avocet nest depredations were caused by California gulls (Herring et al., submitted A). Therefore, the majority of suitable nesting habitat for waterbirds was exposed to California gulls based on their current movements, and existing evidence suggests that they are predominant predators of several of the most abundant nesting waterbirds.

In a recent review, Shuford (2008) suggested that California gulls had little effect on the distribution and numbers of several common nesting waterbirds in the South Bay, including Caspian terns, Forster's terns, blacked-necked stilts, and American avocets. However, broad impacts to populations, such as declining numbers, may not be the appropriate yard-stick for measuring the effect of California gulls on breeding waterbirds. Even when populations are truly declining, it is difficult to detect at this large scale, and declines may not be evident for several years. Instead, robust and clear examples of high predation rates or disturbance by gulls on breeding waterbirds are more realistic examples of the effect California gulls are presently having on nesting birds, and could provide evidence of population-level effects before they are propagated.

To conclude, our results concur with simultaneous landfill surveys (Ackerman et al. 2006a, Hudson and LeFer 2007, Robinson et al. 2008) showing the importance of landfills to California gulls. Although there have been no similar studies conducted on California gulls at other locales, landfills are known to be an important diet source for other gull species, such as herring gulls (*Larus argentatus*; Belant et al. 1993) and yellow-legged gulls (*Larus michahellis*; Duhem et al. 2005). Whereas landfill abatement programs may result in site-specific control of gulls during the actual abatement activity (Robinson et al. 2008), uncoordinated abatement efforts among landfills and those that are sporadic or short-term in duration are unlikely to control gulls for any meaningful duration of time and not at the scale of the South Bay landscape (Belant 1997). In fact, short-term abatement may have a negative effect on other waterbirds if large gull populations supported by landfills temporarily shift predation during abatement activities to other local food sources such as waterbird eggs and chicks, invertebrates, and fish. Belant (1997) and Shuford (2008) summarize potential management options to control gulls, but few options other than lethal control have been successful at large temporal and spatial scales. Lethal control is an unlikely option in the San Francisco Bay because of the ethical considerations and the fact that, as migratory birds, they are protected in most cases. Instead, California gulls should become part of a long-term management plan together with other locally breeding waterbirds, where an adaptive management feed-back process of applied research, habitat manipulation, waterbird monitoring, and habitat redesign could curtail some of the effects of

California gulls on other waterbirds. In fact, enhancing nesting habitat for shorebirds, terns, and other nesting waterbirds, such as the widespread creation of nesting islands, may have more of a positive benefit for breeding waterbirds than trying to directly control California gulls.

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TABLES

Table 1. Number of California gulls radio-marked during the 2007 and 2008 pre-breeding seasons, and the distribution of breeding colony locations for those radio-marked gulls. A breeding colony was determined by using automated data logger systems stationed at each colony using two criteria: (1) if a gull spent >50% of their nighttime hours (20:00 to 0500) during the breeding season (1 May to 15 July, 2008) at a colony or (2) if a gull spent >4× more time at a colony than any other potential breeding colony and if their time at this colony was >25% of the total possible nighttime hours during the breeding season.

	Capture Colony			Breeding Colony			
Year	A6	Coyote Hills	Total	A6	Coyote Hills	Mowry	Total
2007	40	23	**63**	33	5	1	**39**
2008 [1]	32	18	**50**	34	13	12	**59**
Total	**72**	**41**	***113***	**67**	**18**	**13**	***98***

[1] 2008 breeding colony tally includes gulls radio-marked in 2007 that returned in 2008

Table 2. Capture location and breeding colony for California gulls that were radio-marked and tracked during the 2007 breeding season in South San Francisco Bay. A dashed line indicates that the breeding colony could not be determined.

2007 Tracking Year					
Frequency ID	Radio Type	Sex[1]	Year Captured	Capture Colony	Breeding Colony
4263	leg	Male	2007	A6	A6
4315	leg	Female	2007	A6	---
4338	leg	Male	2007	A6	---
4355	leg	Male	2007	A6	A6
4365	leg	Male	2007	Coyote Hills	---
4384	leg	Female	2007	A6	A6
4415	leg	Female	2007	A6	---
4437	leg	Male	2007	A6	A6
4457	leg	Female	2007	A6	---
4486	leg	Female	2007	Coyote Hills	A6
4495	leg	Female	2007	A6	---
4946	leg	Female	2007	A6	A6
6333	harness	Female	2007	Coyote Hills	Coyote Hills
6345	harness	Male	2007	Coyote Hills	Coyote Hills
6358	harness	Male	2007	A6	---
6395	harness	Female	2007	A6	---
6409	harness	Male	2007	Coyote Hills	---
6435	harness	Male	2007	A6	A6
6445	harness	Male	2007	A6	A6
6458	harness	Female	2007	Coyote Hills	Coyote Hills
6484	harness	Female	2007	Coyote Hills	---
6758	harness	Male	2007	A6	A6
6767	harness	Female	2007	Coyote Hills	---
6871	harness	Male	2007	Coyote Hills	---
7020	harness	Male	2007	Coyote Hills	---
7120	harness	Male	2007	Coyote Hills	A6
7145	harness	Male	2007	Coyote Hills	A6
7157	harness	Male	2007	Coyote Hills	Coyote Hills
7171	harness	Female	2007	A6	A6
7320	harness	Female	2007	A6	A6
7332	harness	Male	2007	A6	---
7334	leg	Male	2007	A6	---
7345	harness	Female	2007	Coyote Hills	---
7371	harness	Male	2007	A6	A6
7622	harness	Female	2007	A6	A6
7633	harness	Male	2007	A6	A6
7645	harness	Female	2007	A6	A6
7658	harness	Male	2007	A6	A6
7670	harness	Male	2007	Coyote Hills	---
7683	harness	Female	2007	A6	A6
7695	harness	Female	2007	A6	A6
7708	harness	Male	2007	Coyote Hills	---
7720	harness	Female	2007	Coyote Hills	Coyote Hills
7734	harness	Female	2007	A6	A6
7746	harness	Female	2007	A6	A6
7759	harness	Male	2007	A6	---
7771	harness	Male	2007	A6	A6
7783	harness	Female	2007	A6	A6
7796	harness	Male	2007	Coyote Hills	---
7807	harness	Female	2007	Coyote Hills	A6
7821	harness	Female	2007	A6	A6
7835	harness	Male	2007	Coyote Hills	Mowry
7846	harness	Male	2007	A6	---
7859	harness	Male	2007	A6	A6
7872	harness	Female	2007	A6	A6
7883	harness	Male	2007	A6	A6
7896	harness	Female	2007	Coyote Hills	---
7908	harness	Male	2007	Coyote Hills	---
7932	harness	Female	2007	A6	A6
7945	harness	Female	2007	Coyote Hills	A6
7973	harness	Female	2007	A6	---
7982	harness	Male	2007	A6	A6
7995	harness	Male	2007	A6	A6

[1] Sex was mostly determined via DNA, but some were sexed using morphometrics and discriminant function analysis (Herring et al., submitted B).

Table 3. Capture location and breeding colony for California gulls that were radio-marked and tracked during the 2008 breeding season in South San Francisco Bay. A dashed line indicates that the breeding colony could not be determined.

2008 Tracking Year: 2008 Marked Gulls Only

Frequency ID	Radio Type	Sex[1]	Year Captured	Capture Colony	Breeding Colony
4036	harness	Female	2008	A6	A6
4104	harness	Male	2008	Coyote Hills	---
4133	harness	Male	2008	Coyote Hills	Coyote Hills
4144	harness	Male	2008	A6	A6
4176	harness	Male	2008	Coyote Hills	Coyote Hills
4184	harness	Male	2008	Coyote Hills	A6
4224	harness	Female	2008	A6	Mowry
4234	harness	Male	2008	Coyote Hills	Coyote Hills
4244	harness	Female	2008	Coyote Hills	---
4403	harness	Male	2008	A6	Mowry
4704	harness	Female	2008	A6	A6
4719	harness	Female	2008	A6	A6
4919	harness	Female	2008	A6	Coyote Hills
4934	harness	Male	2008	A6	A6
5094	harness	Male	2008	A6	A6
5209	harness	Male	2008	A6	---
5251	harness	Male	2008	A6	A6
5294	harness	Female	2008	A6	A6
5382	harness	Female	2008	A6	A6
5523	harness	Male	2008	A6	A6
5607	harness	Female	2008	A6	A6
5621	harness	Male	2008	Coyote Hills	---
5647	harness	Female	2008	A6	---
5671	harness	Male	2008	A6	A6
5681	harness	Female	2008	Coyote Hills	---
5710	harness	Male	2008	Coyote Hills	---
5722	harness	Female	2008	Coyote Hills	A6
5732	harness	Female	2008	Coyote Hills	Coyote Hills
5747	harness	Male	2008	Coyote Hills	Coyote Hills
5758	harness	Male	2008	Coyote Hills	---
5780	harness	Female	2008	Coyote Hills	---
5833	harness	Female	2008	Coyote Hills	Coyote Hills
5857	harness	Male	2008	A6	A6
5886	harness	Female	2008	Coyote Hills	Coyote Hills
5965	harness	Female	2008	A6	A6
5980	harness	Female	2008	Coyote Hills	---
6283	harness	Male	2008	Coyote Hills	Coyote Hills
6296	harness	Male	2008	A6	Mowry
6992	harness	Female	2008	A6	A6
7207	harness	Female	2008	A6	---
7220	harness	Female	2008	A6	A6
7233	harness	Female	2008	A6	A6
7245	harness	Male	2008	A6	A6
7257	harness	Male	2008	A6	---
7270	harness	Female	2008	A6	---
7283	harness	Male	2008	A6	A6
7297	harness	Male	2008	A6	A6
7307	harness	Male	2008	A6	A6
7356	harness	Female	2008	A6	---
7707	harness	Male	2008	A6	---

[1] Sex was mostly determined via DNA, but some were sexed using morphometrics and discriminant function analysis (Herring et al., submitted B).

Table 4. Capture location and breeding colony for <u>all California gulls that were marked in 2007 or 2008 and tracked during the 2008</u> breeding season in South San Francisco Bay. A dashed line indicates that the breeding colony could not be determined.

2008 Tracking Year: All Gulls

Frequency ID	Radio Type	Sex[1]	Year Captured	Capture Colony	Breeding Colony
6333	harness	Female	2007	Coyote Hills	---
6345	harness	Male	2007	Coyote Hills	Coyote Hills
6358	harness	Male	2007	A6	A6
6395	harness	Female	2007	A6	---
6409	harness	Male	2007	Coyote Hills	---
6435	harness	Male	2007	A6	---
6445	harness	Male	2007	A6	A6
6458	harness	Female	2007	Coyote Hills	A6
6484	harness	Female	2007	Coyote Hills	---
6758	harness	Male	2007	A6	Mowry
6767	harness	Female	2007	Coyote Hills	Mowry
6871	harness	Male	2007	Coyote Hills	---
7020	harness	Male	2007	Coyote Hills	---
7120	harness	Male	2007	Coyote Hills	A6
7145	harness	Male	2007	Coyote Hills	Mowry
7157	harness	Male	2007	Coyote Hills	Coyote Hills
7171	harness	Female	2007	A6	A6
7320	harness	Female	2007	A6	---
7332	harness	Male	2007	A6	Mowry
7345	harness	Female	2007	Coyote Hills	---
7371	harness	Male	2007	A6	Mowry
7622	harness	Female	2007	A6	---
7633	harness	Male	2007	A6	Mowry
7645	harness	Female	2007	A6	A6
7658	harness	Male	2007	A6	---
7670	harness	Male	2007	Coyote Hills	---
7683	harness	Female	2007	A6	---
7695	harness	Female	2007	A6	A6
7708	harness	Male	2007	Coyote Hills	---
7720	harness	Female	2007	Coyote Hills	Coyote Hills
7734	harness	Female	2007	A6	Mowry
7746	harness	Female	2007	A6	---
7759	harness	Male	2007	A6	---
7771	harness	Male	2007	A6	A6
7789	harness	Female	2007	Coyote Hills	---
7796	harness	Male	2007	Coyote Hills	---
7807	harness	Female	2007	Coyote Hills	Coyote Hills
7821	harness	Female	2007	A6	Mowry
7835	harness	Male	2007	Coyote Hills	---
7846	harness	Male	2007	A6	---
7859	harness	Male	2007	A6	Mowry
7872	harness	Female	2007	A6	Mowry
7883	harness	Male	2007	A6	---
7896	harness	Female	2007	Coyote Hills	---
7908	harness	Male	2007	Coyote Hills	---
7932	harness	Female	2007	A6	A6
7945	harness	Female	2007	Coyote Hills	A6
7973	harness	Female	2007	A6	---
7982	harness	Male	2007	A6	---
7995	harness	Male	2007	A6	A6
4036	harness	Female	2008	A6	A6
4104	harness	Male	2008	Coyote Hills	---
4133	harness	Male	2008	Coyote Hills	Coyote Hills
4144	harness	Male	2008	A6	A6
4176	harness	Male	2008	Coyote Hills	Coyote Hills
4184	harness	Male	2008	Coyote Hills	A6
4224	harness	Female	2008	A6	Mowry
4234	harness	Male	2008	Coyote Hills	Coyote Hills
4244	harness	Female	2008	Coyote Hills	---
4403	harness	Male	2008	A6	Mowry
4704	harness	Female	2008	A6	A6
4719	harness	Female	2008	A6	A6
4919	harness	Female	2008	A6	Coyote Hills
4934	harness	Male	2008	A6	A6
5094	harness	Male	2008	A6	A6
5209	harness	Male	2008	A6	---
5251	harness	Male	2008	A6	A6
5294	harness	Female	2008	A6	A6
5382	harness	Female	2008	A6	A6
5523	harness	Male	2008	A6	A6
5607	harness	Female	2008	A6	A6
5621	harness	Male	2008	Coyote Hills	---
5647	harness	Female	2008	A6	---
5671	harness	Male	2008	A6	A6
5681	harness	Female	2008	Coyote Hills	---
5710	harness	Male	2008	Coyote Hills	---
5722	harness	Female	2008	Coyote Hills	A6
5732	harness	Female	2008	Coyote Hills	Coyote Hills
5747	harness	Male	2008	Coyote Hills	Coyote Hills
5758	harness	Male	2008	Coyote Hills	---
5780	harness	Female	2008	Coyote Hills	---
5833	harness	Female	2008	Coyote Hills	Coyote Hills
5857	harness	Male	2008	A6	A6
5886	harness	Female	2008	Coyote Hills	Coyote Hills
5965	harness	Female	2008	A6	A6
5980	harness	Female	2008	Coyote Hills	---
6283	harness	Male	2008	Coyote Hills	Coyote Hills
6296	harness	Male	2008	A6	Mowry
6992	harness	Female	2008	A6	A6
7207	harness	Female	2008	A6	---
7220	harness	Female	2008	A6	A6
7233	harness	Female	2008	A6	A6
7245	harness	Male	2008	A6	A6
7257	harness	Male	2008	A6	---
7270	harness	Female	2008	A6	---
7283	harness	Male	2008	A6	A6
7297	harness	Male	2008	A6	A6
7307	harness	Male	2008	A6	A6
7356	harness	Female	2008	A6	---
7707	harness	Male	2008	A6	---

[1] Sex was mostly determined via DNA, but some were sexed using morphometrics and discriminant function analysis (Herring et al., submitted B).

Table 5. Breeding colony location of California gulls radio-marked in 2007 that returned to breed in 2008. A dashed line indicates that the breeding colony could not be determined.

2008 Tracking Year: Returning Gulls Tracked for 2 Years					
Frequency ID	Radio Type	Sex[1]	Capture Colony 2007	Breeding Colony 2007	Breeding Colony 2008
6333	harness	Female	Coyote Hills	Coyote Hills	---
6345	harness	Male	Coyote Hills	Coyote Hills	Coyote Hills
6358	harness	Male	A6	---	A6
6445	harness	Male	A6	A6	A6
6458	harness	Female	Coyote Hills	Coyote Hills	A6
6758	harness	Male	A6	A6	Mowry
6767	harness	Female	Coyote Hills	---	Mowry
7120	harness	Male	Coyote Hills	A6	A6
7145	harness	Male	Coyote Hills	A6	Mowry
7157	harness	Male	Coyote Hills	Coyote Hills	Coyote Hills
7171	harness	Female	A6	A6	A6
7332	harness	Male	A6	---	Mowry
7371	harness	Male	A6	A6	Mowry
7633	harness	Male	A6	A6	Mowry
7645	harness	Female	A6	A6	A6
7683	harness	Female	A6	A6	---
7695	harness	Female	A6	A6	A6
7708	harness	Male	Coyote Hills	---	---
7720	harness	Female	Coyote Hills	Coyote Hills	Coyote Hills
7734	harness	Female	A6	A6	Mowry
7771	harness	Male	A6	A6	A6
7796	harness	Male	Coyote Hills	---	---
7807	harness	Female	Coyote Hills	A6	Coyote Hills
7821	harness	Female	A6	A6	Mowry
7859	harness	Male	A6	A6	Mowry
7872	harness	Female	A6	A6	Mowry
7932	harness	Female	A6	A6	A6
7945	harness	Female	Coyote Hills	A6	A6
7995	harness	Male	A6	A6	A6

[1] Sex was mostly determined via DNA, but some were sexed using morphometrics and discriminant function analysis (Herring et al., submitted B).

Table 6. The number of avocet, stilt, and Forster's tern nests monitored and their nest success during 2008 breeding season in South San Francisco Bay salt ponds and marshes.

	Avocet		Stilt		Forster's Tern		*Total*
Site	*N*	*Nest Success* [1]	*N*	*Nest Success* [1]	*N*	*Nest Success* [1]	*N*
A1	28	54%	2	---	105	99%	*135*
AB1	31	63%	8	72%	250	97%	*289*
A2W	62	81%	12	100%	14	83%	*88*
A7	13	53%	0	---	152	79%	*165*
A8	205	29%	5	1%	75	16%	*285*
A12	328	29%	7	71%	70	38%	*405*
A16	53	74%	14	57%	248	82%	*315*
N4A	48	71%	9	100%	5	50%	*62*
R1	43	93%	0	---	0	---	*43*
New Chicago Marsh[1]	36	33%	33	26%	0	---	*69*
Total	*847*		*90*		*919*		*1856*

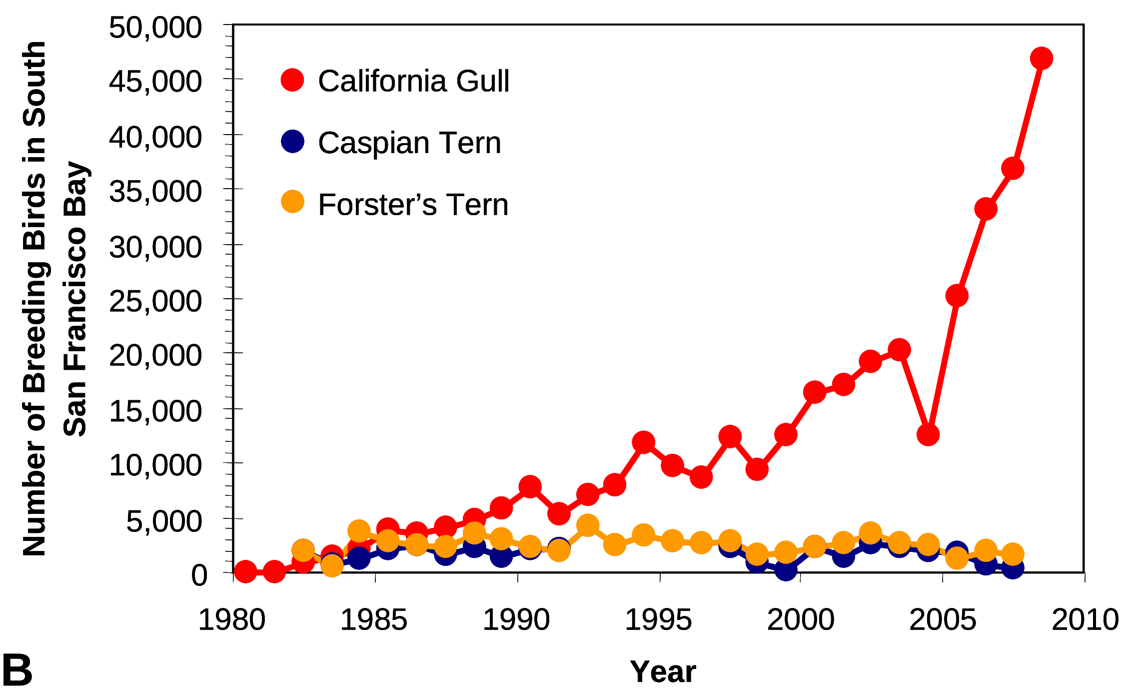
[1] Nest success estimated using the Mayfield (1961, 1975) method.

[2] New Chicago Marsh was not completely searched in 2008 due to a lack of funds, so the number of nests should not be interpreted as nesting effort at this site.

FIGURES

Figure 1. A) California gull breeding populations in the South San Francisco Bay have increased rapidly over the past two decades while Caspian tern and Forster's tern populations have declined slightly. B) Growth of several California gull colonies in the South San Francisco Bay since 1982.

A



B

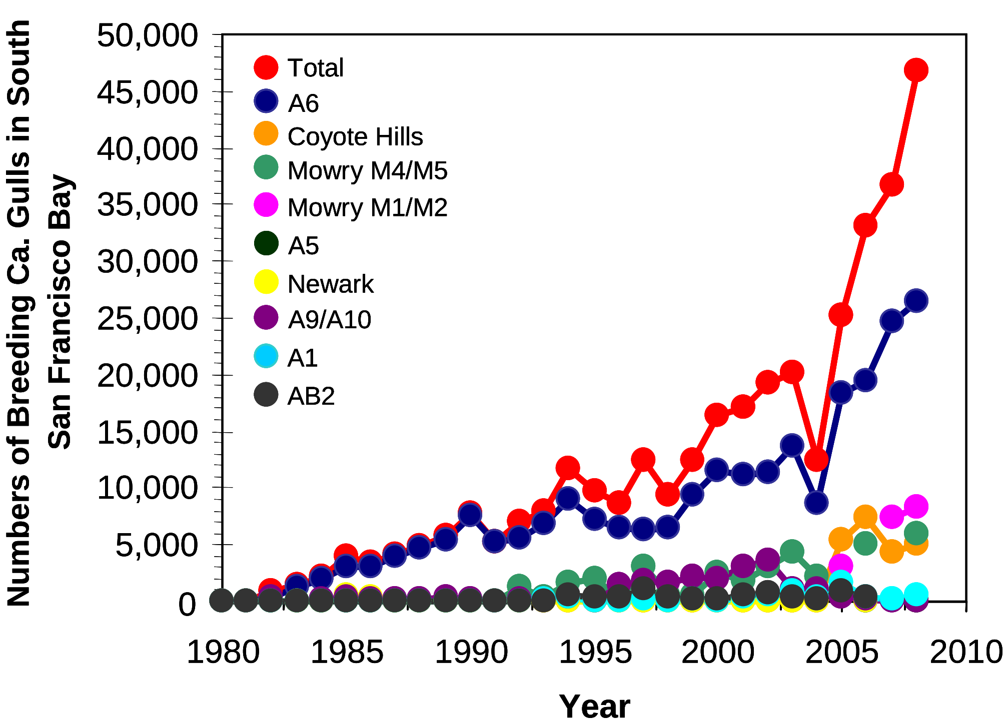


Figure 2. Study area map of the South San Francisco Bay. Main gull colonies are shown with red circles and landfills are shown with black circles. The two main gull colonies that were studied nested within A6 and Coyote Hills ponds (N1A, N2A, N3A, and N4AB).

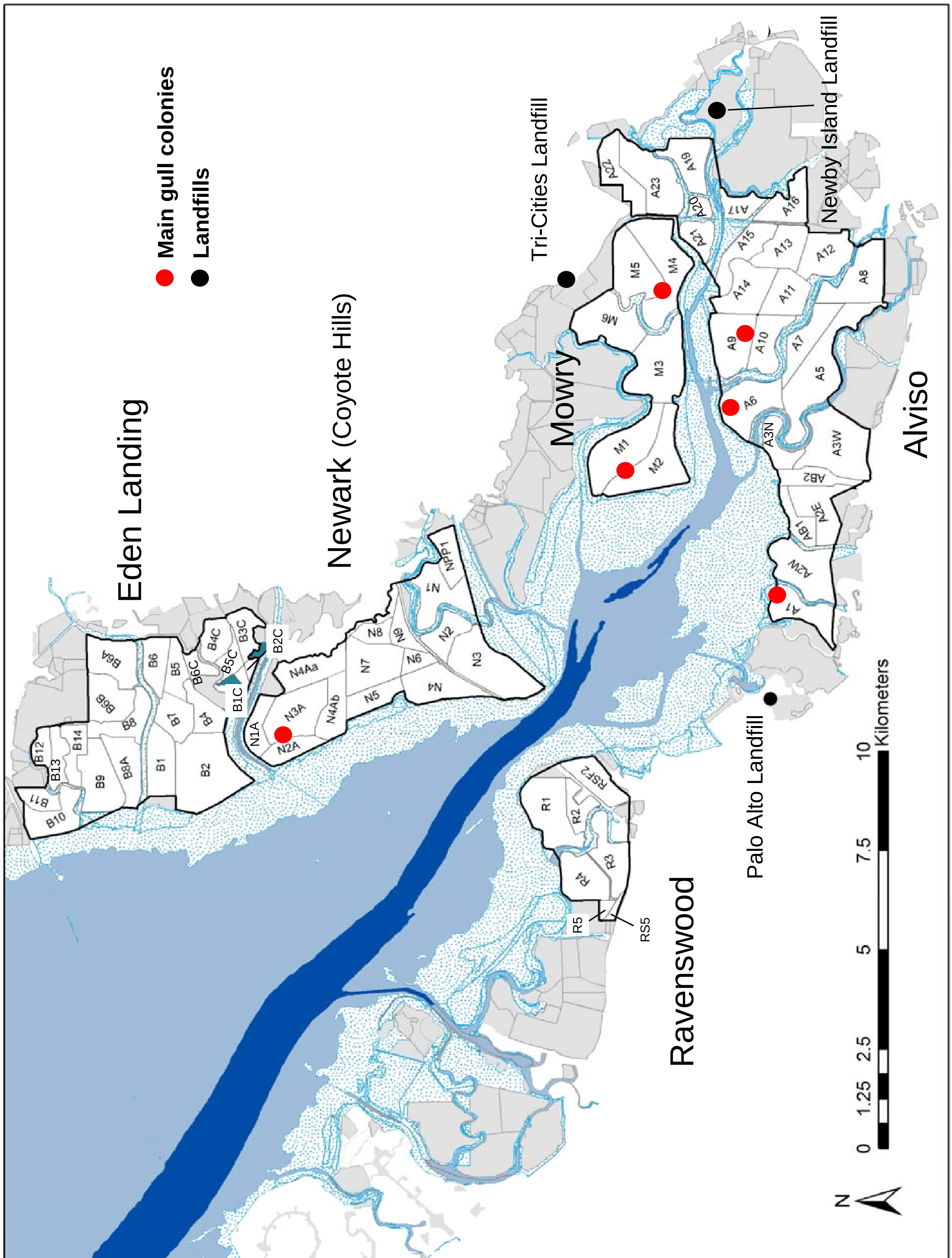


Figure 3. Distribution, abundance (A), and density (B) of California gull nests at Pond A6 in 2008. Colors indicating abundance and density are on a sliding scale.

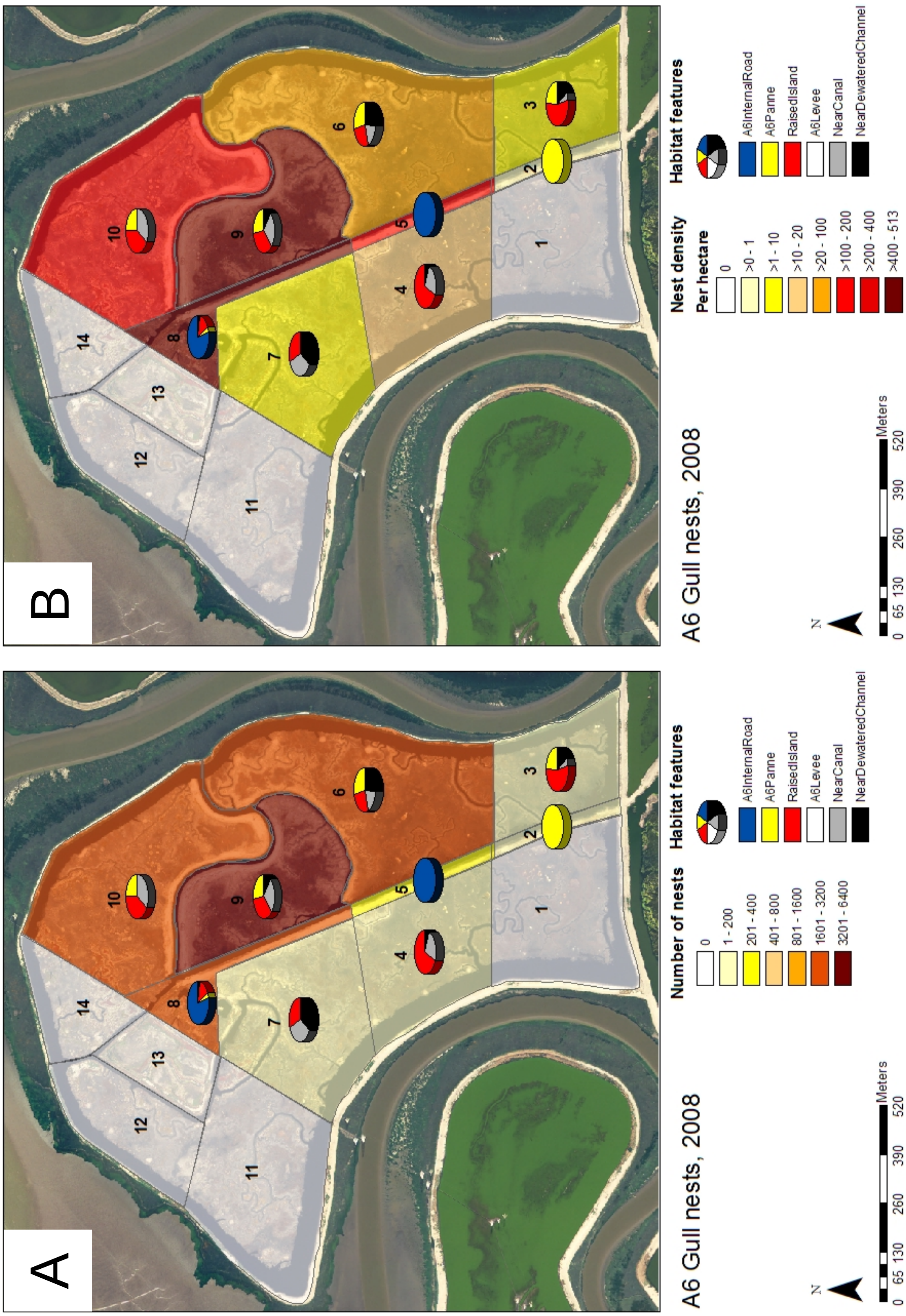


Figure 4. Home range and core use area sizes (mean ± SE) of radio-marked California gulls based on capture colony, which includes the A6 and Coyote Hills colony during the 2007 and 2008 breeding seasons in the South San Francisco Bay.

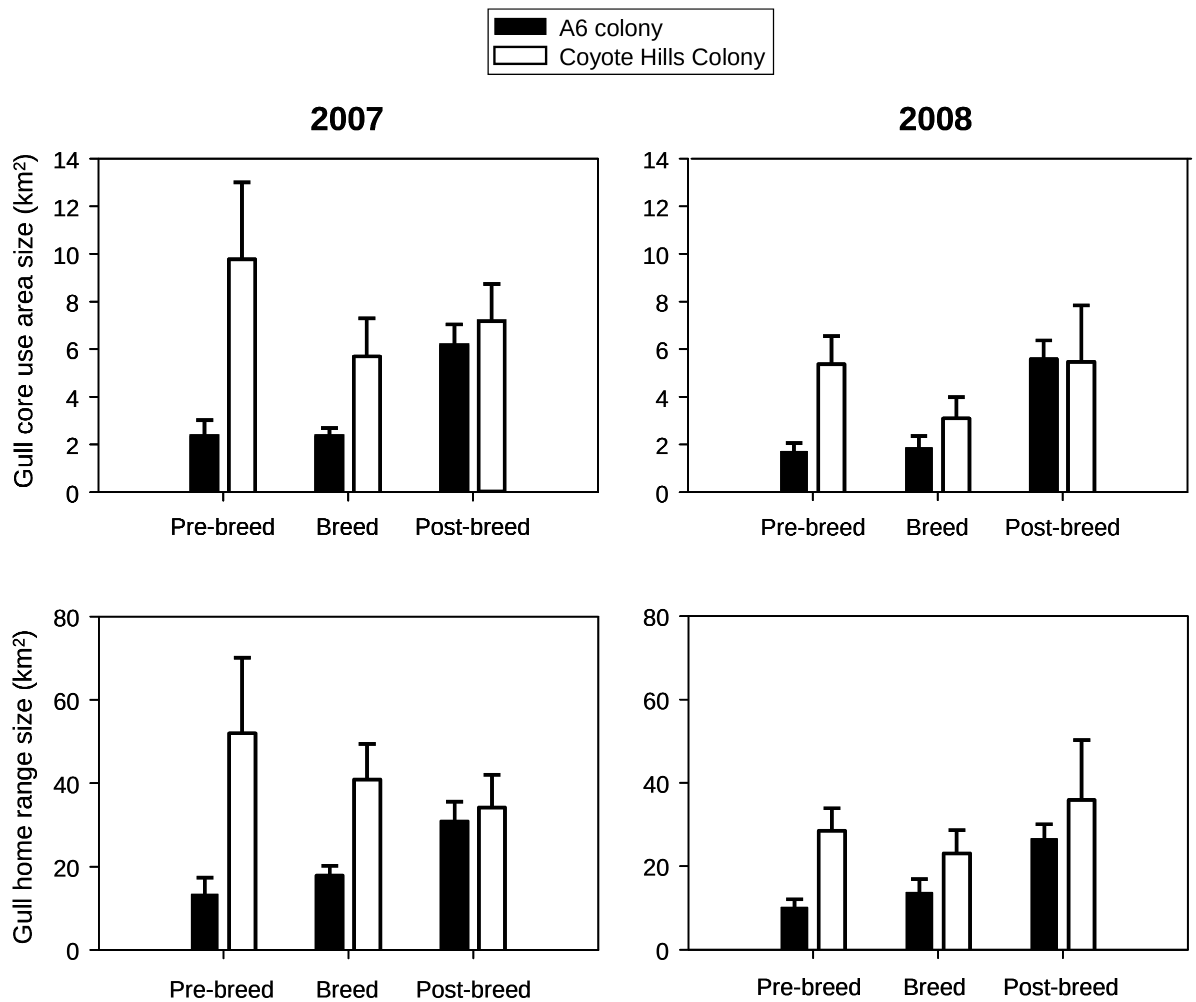


Figure 5. Home range and core use area sizes (mean ± SE) of radio-marked California gulls based on breeding colony, which includes the A6 and Coyote Hills colony during the 2007 and 2008 breeding seasons in the South San Francisco Bay.

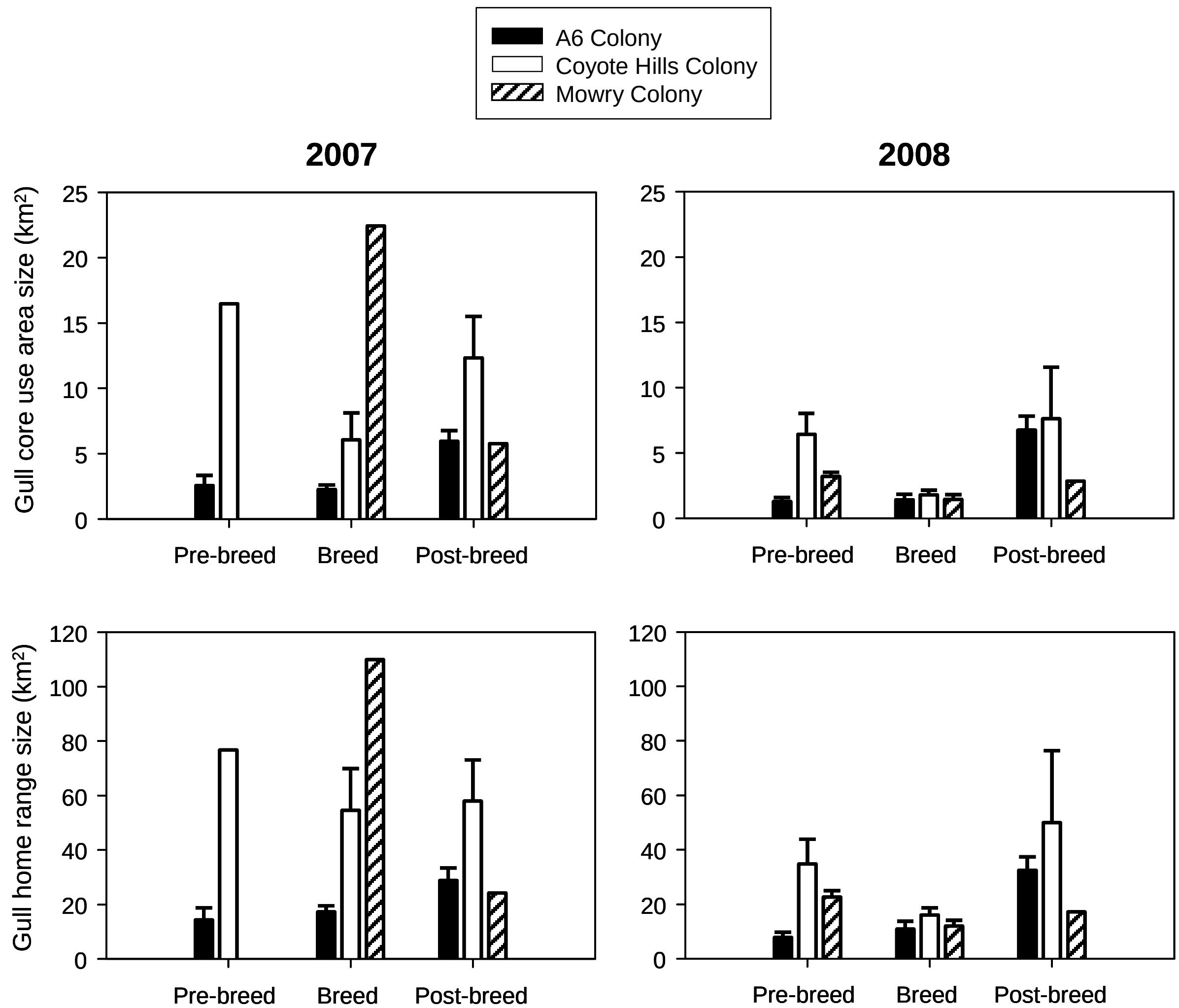


Figure 6. The cumulative proportion of radio-marked California gulls within a specified distance from the breeding colonies or landfills during the 2007 breeding season in the South San Francisco Bay.

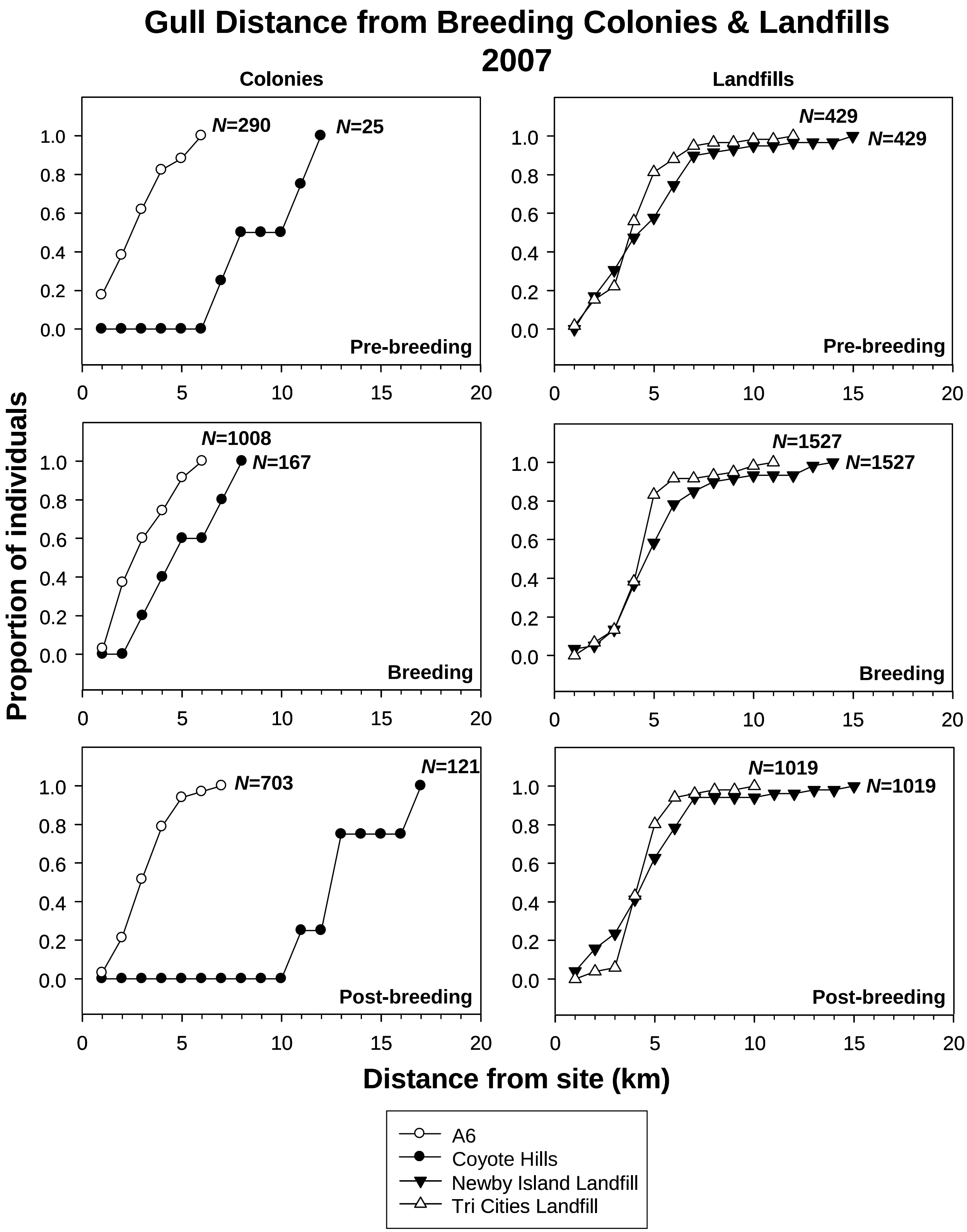


Figure 7. The cumulative proportion of radio-marked California gulls within a specified distance from the breeding colonies or landfills during the 2008 breeding season in the South San Francisco Bay.

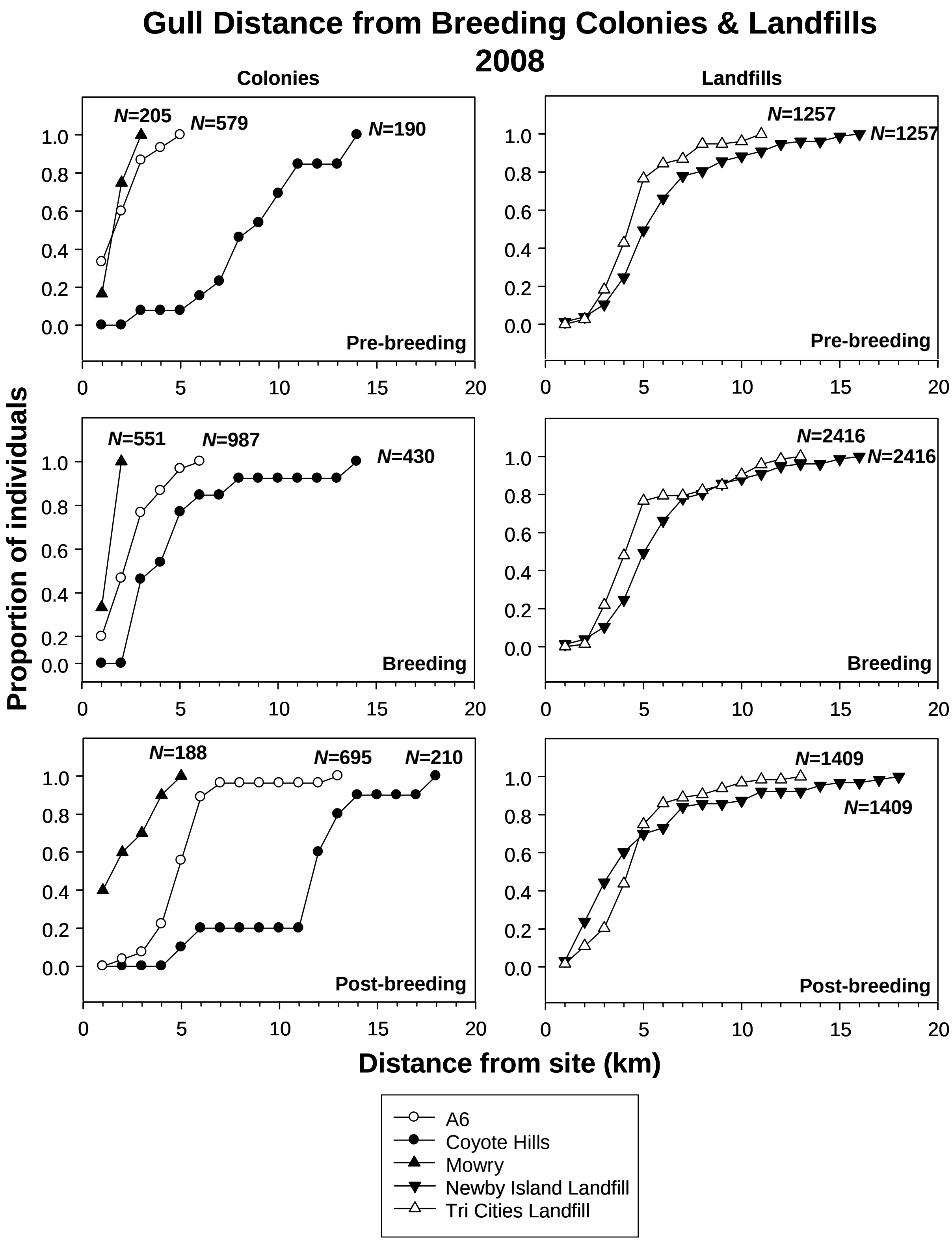


Figure 8. The cumulative proportion of radio-marked California gulls within a specified distance from the breeding colonies or landfills during the 2007 and 2008 breeding season combined in the South San Francisco Bay.

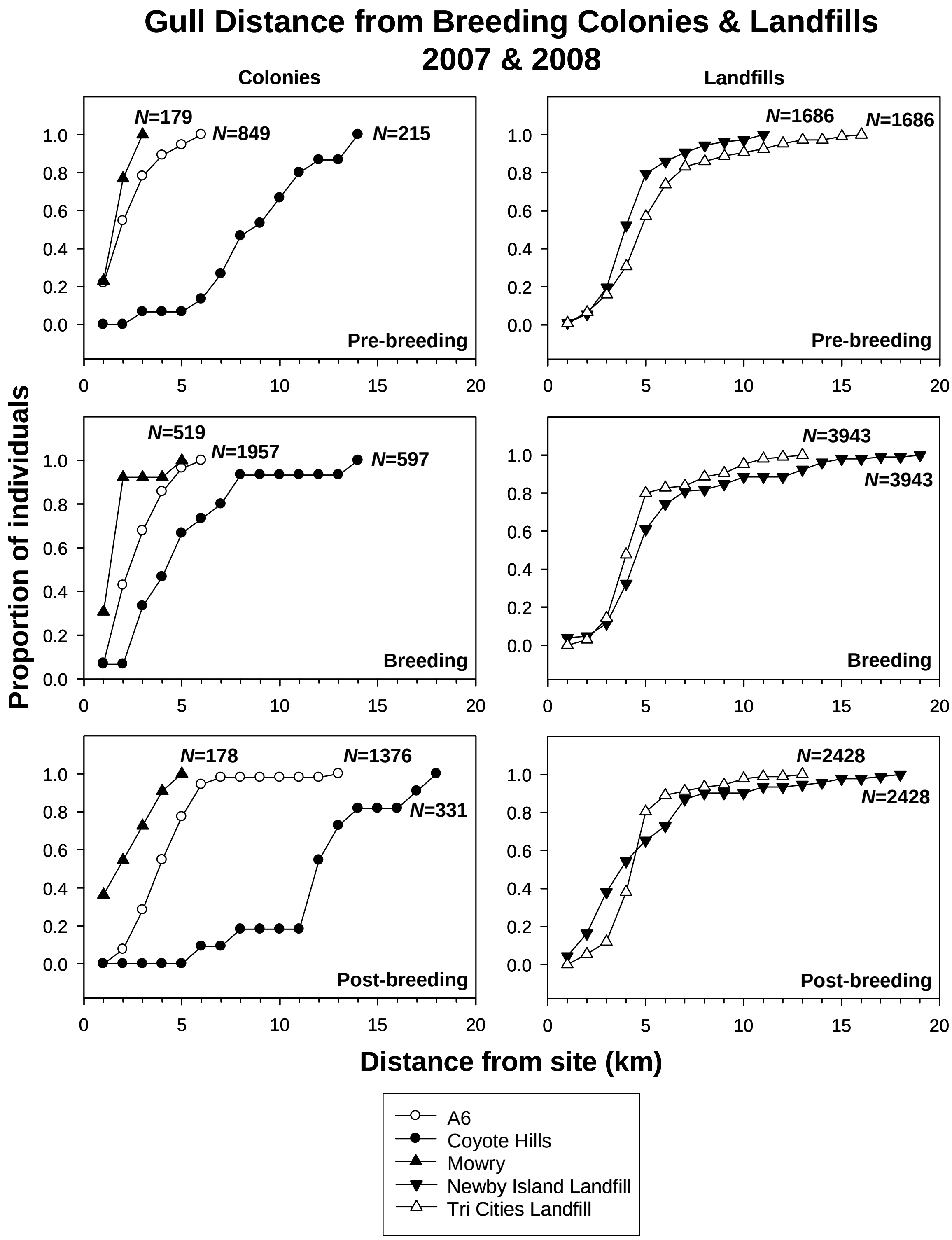


Figure 9. The distance radio-marked California gulls were located from breeding colonies and landfills by calendar date during the 2007 breeding season in the South San Francisco Bay.

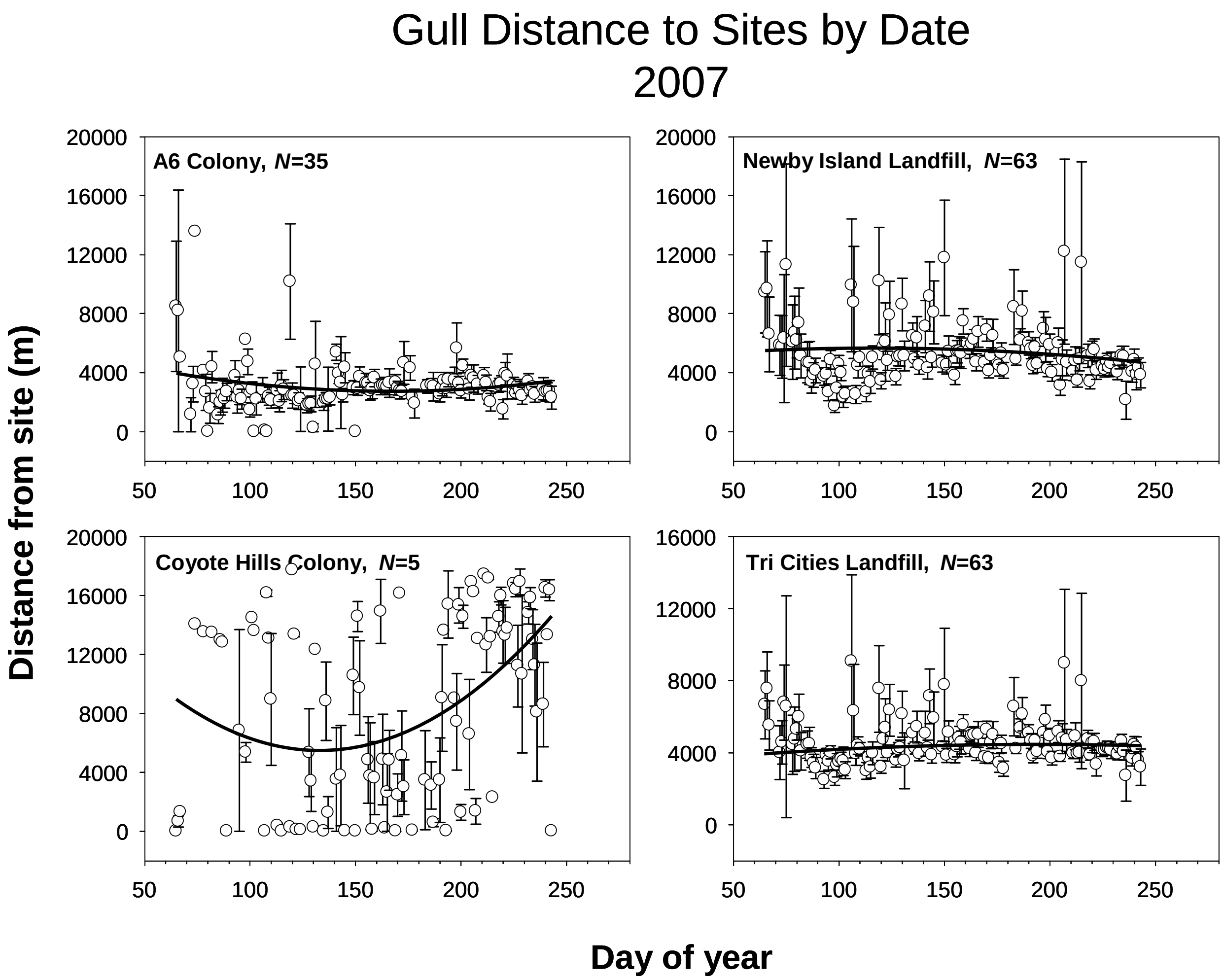


Figure 10. The distance radio-marked California gulls were located from breeding colonies and landfills by calendar date during the 2008 breeding season in the South San Francisco Bay.

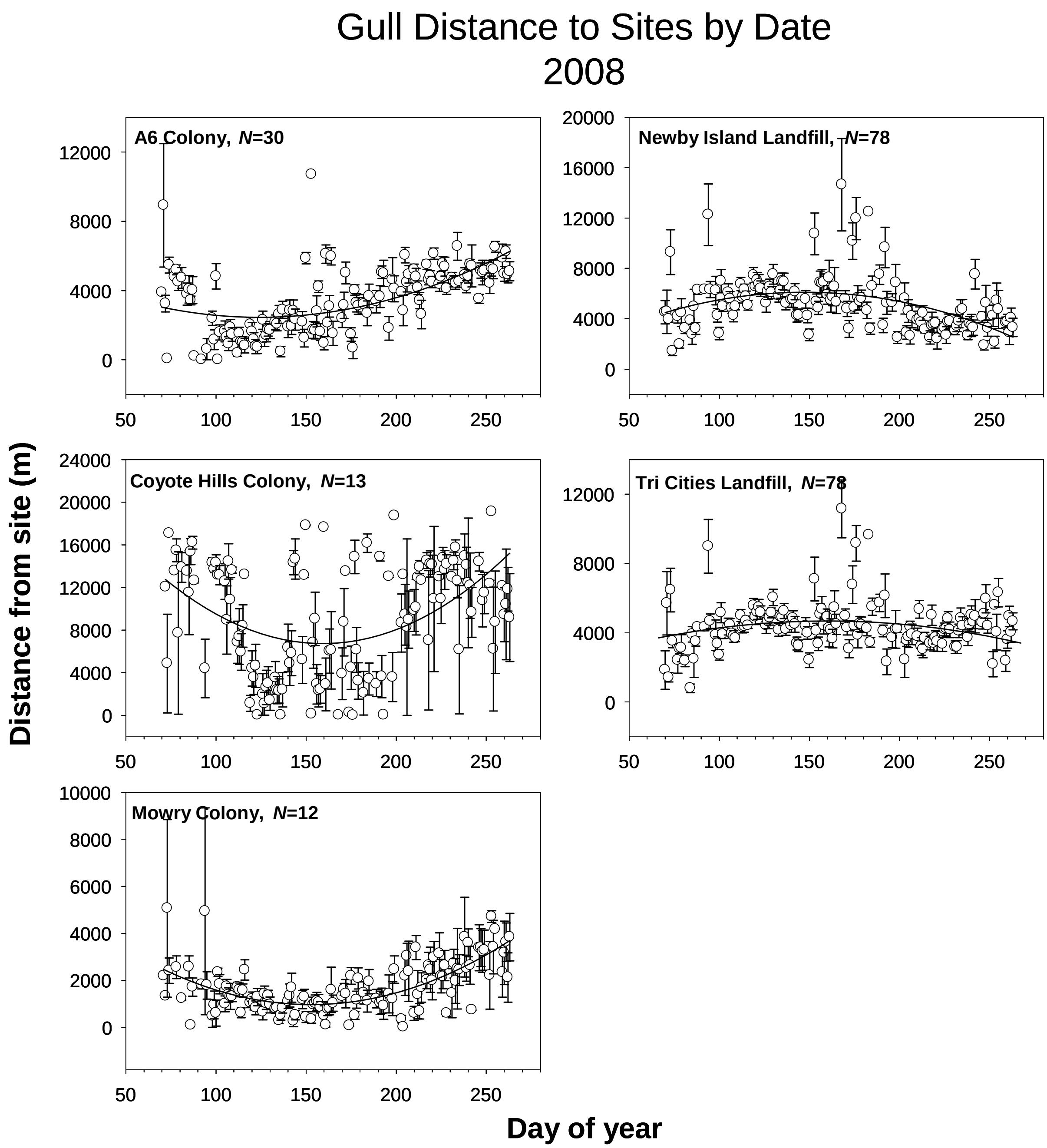


Figure 11. The distance radio-marked California gulls were located from breeding colonies and landfills by calendar date during the 2007 and 2008 breeding seasons combined in the South San Francisco Bay.

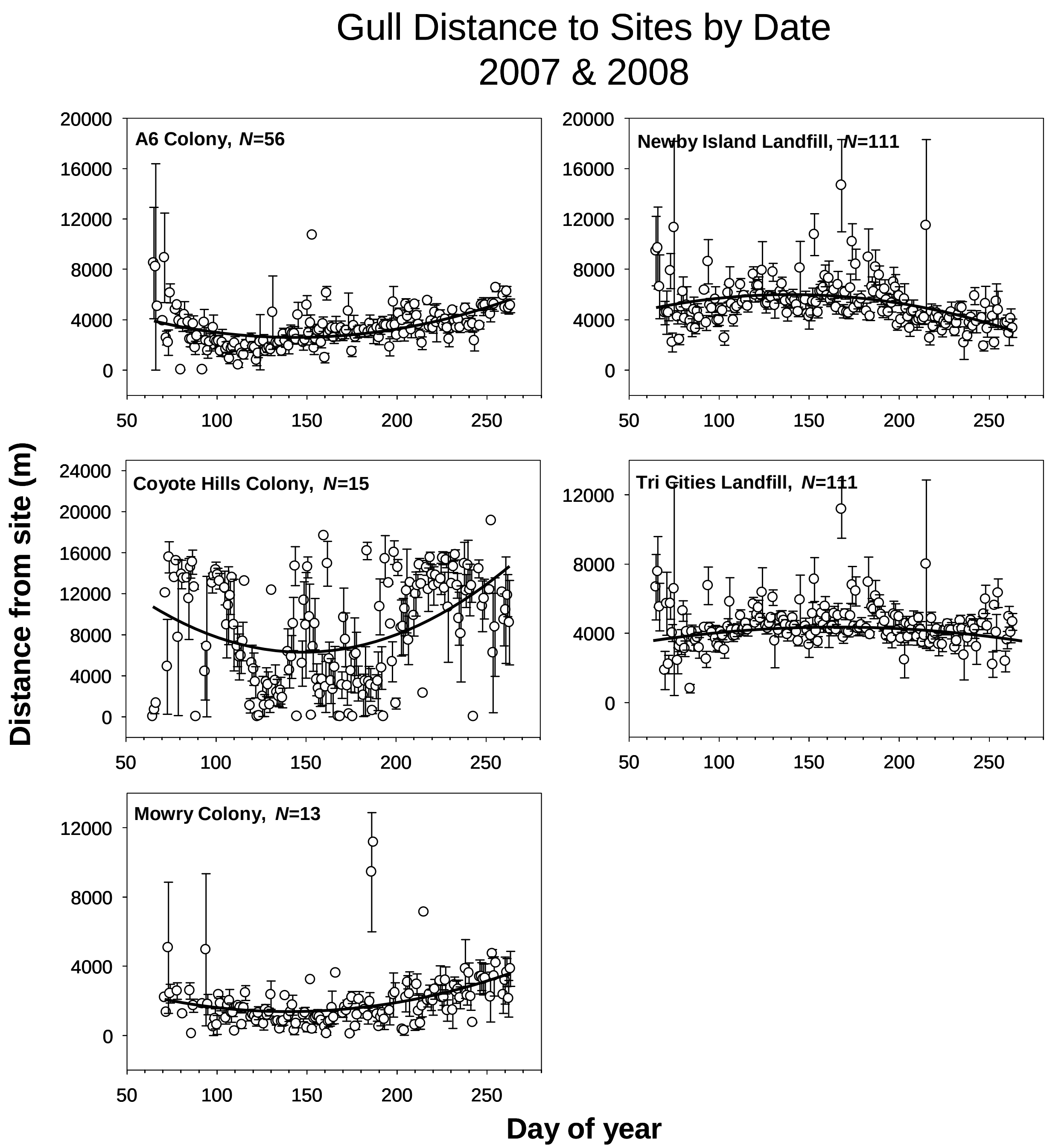
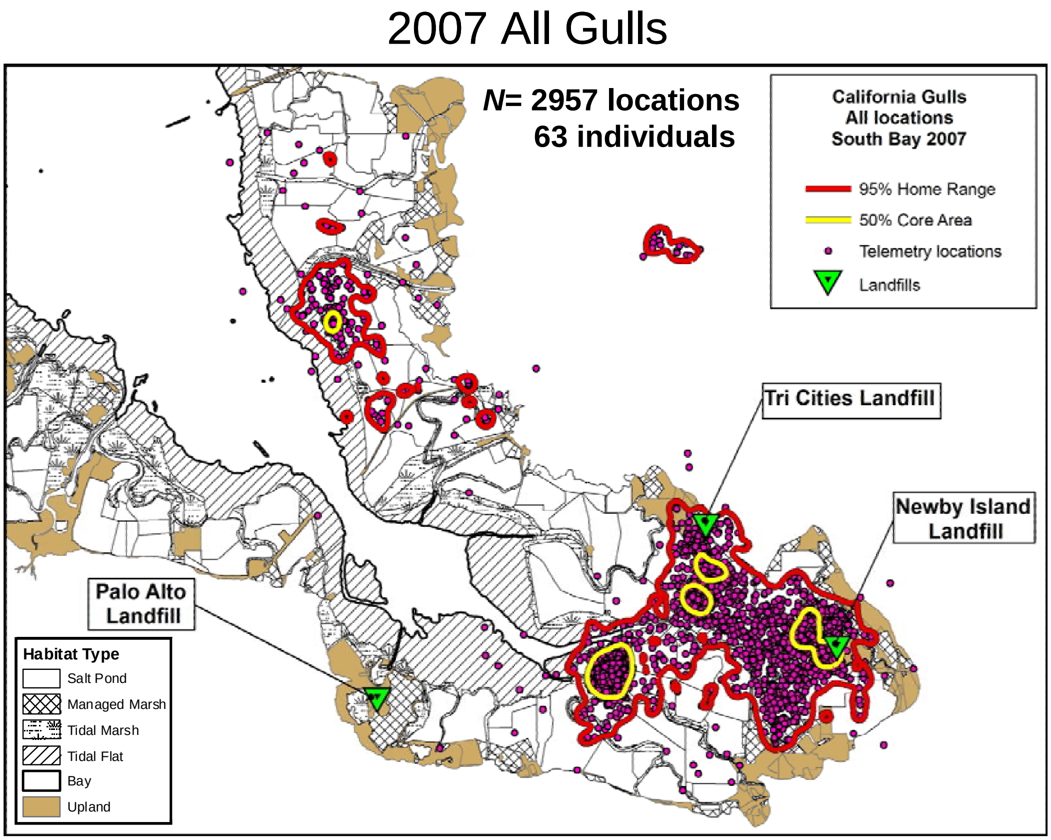


Figure 12. Radio-telemetry locations of all California gulls tracked during 2007 and 2008 in South San Francisco Bay.



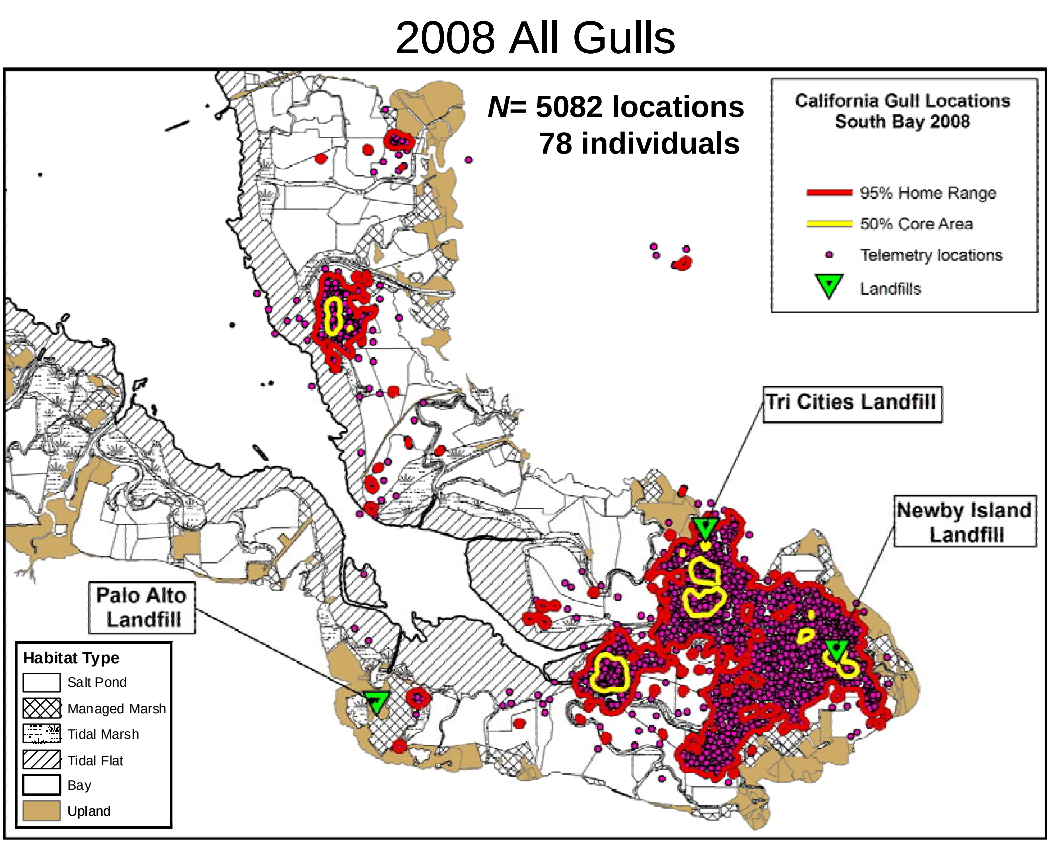


Figure 13. Radio-telemetry locations of California gulls breeding at the A6 colony in 2007 and 2008 in the South San Francisco Bay. Each panel represents either the pre-breeding, breeding, or post-breeding time frame.

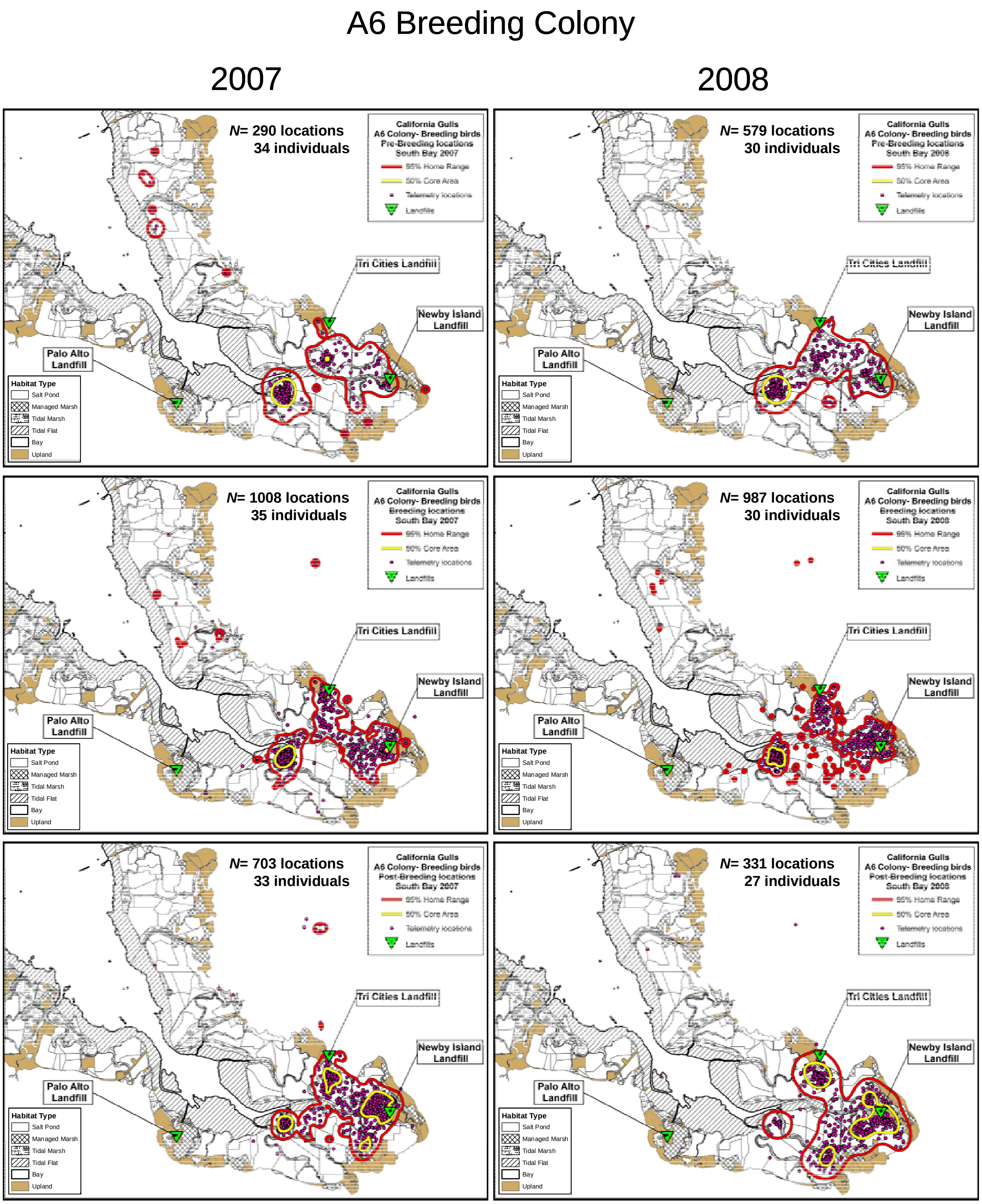


Figure 14. Radio-telemetry locations of California gulls breeding at the Coyote Hills colony in 2007 and 2008 in the South San Francisco Bay. Each panel represents either the pre-breeding, breeding, or post-breeding time frame.

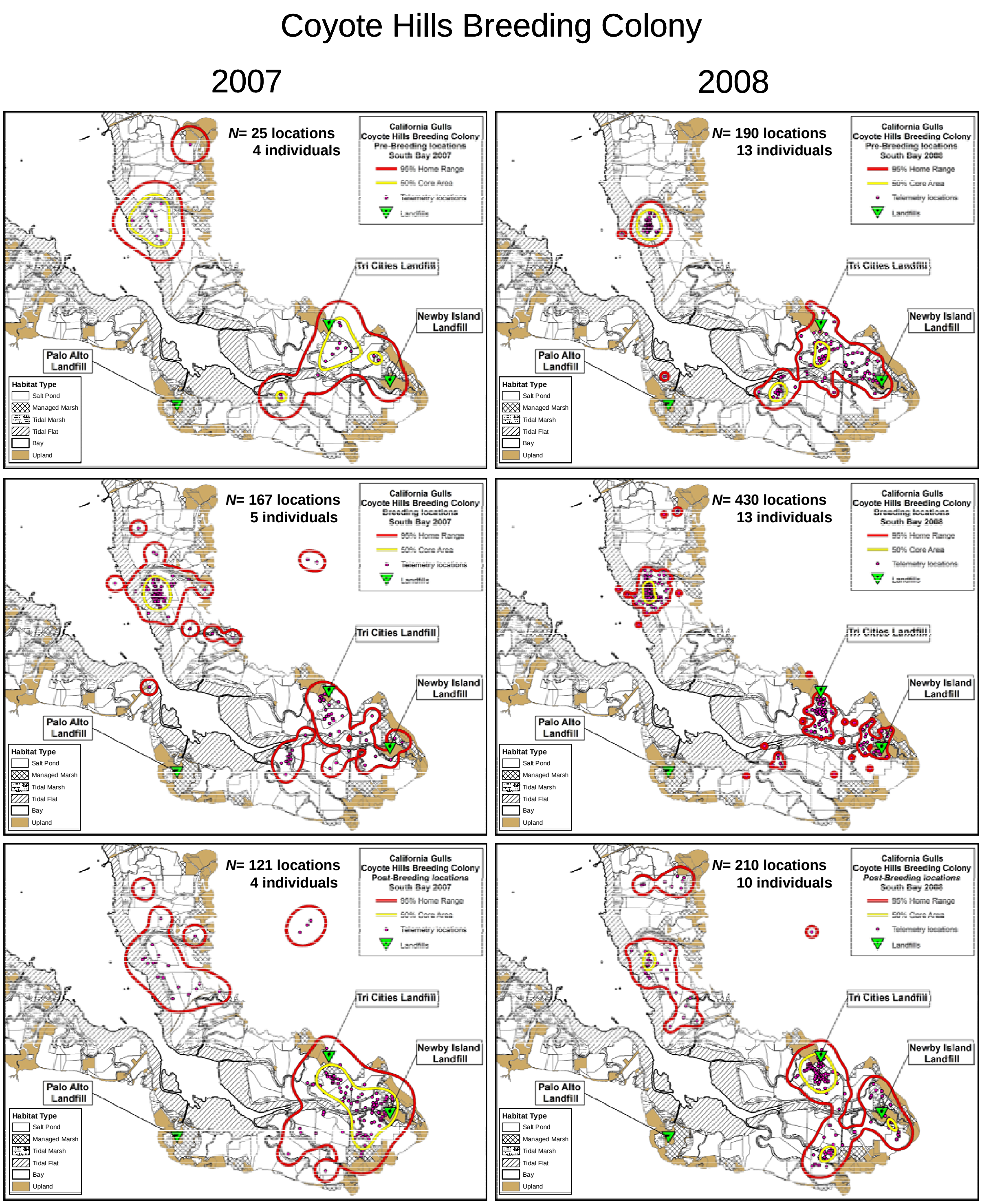


Figure 15. Radio-telemetry locations of California gulls breeding at the Mowry colony in 2007 and 2008 in the South San Francisco Bay. Each panel represents either the pre-breeding, breeding, or post-breeding time frame.

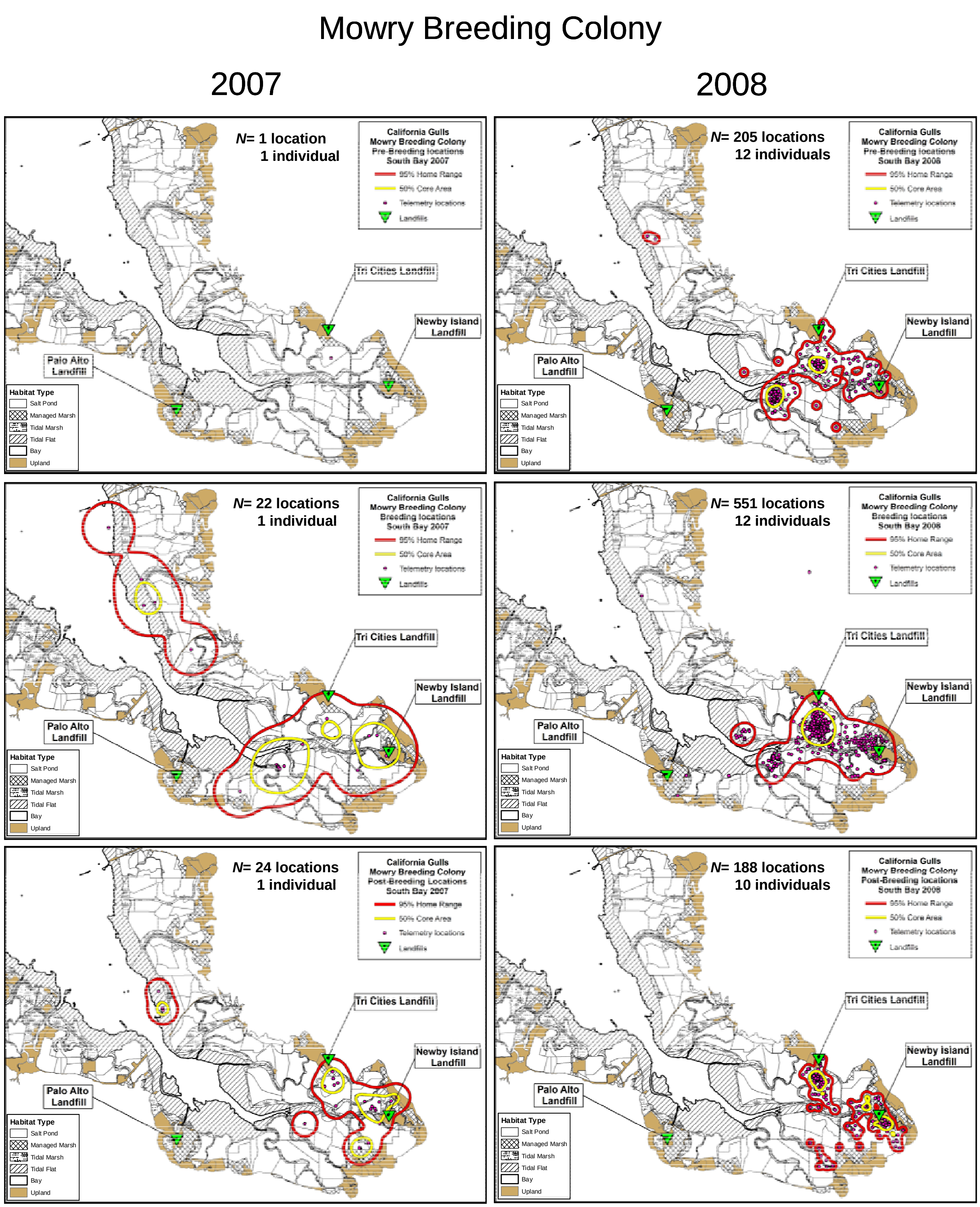


Figure 16. The proportion of each day radio-marked California gulls spent at breeding colonies and landfills throughout the breeding season during 2007 in the South San Francisco Bay. Arrows indicate the last date that gulls were radio-marked.

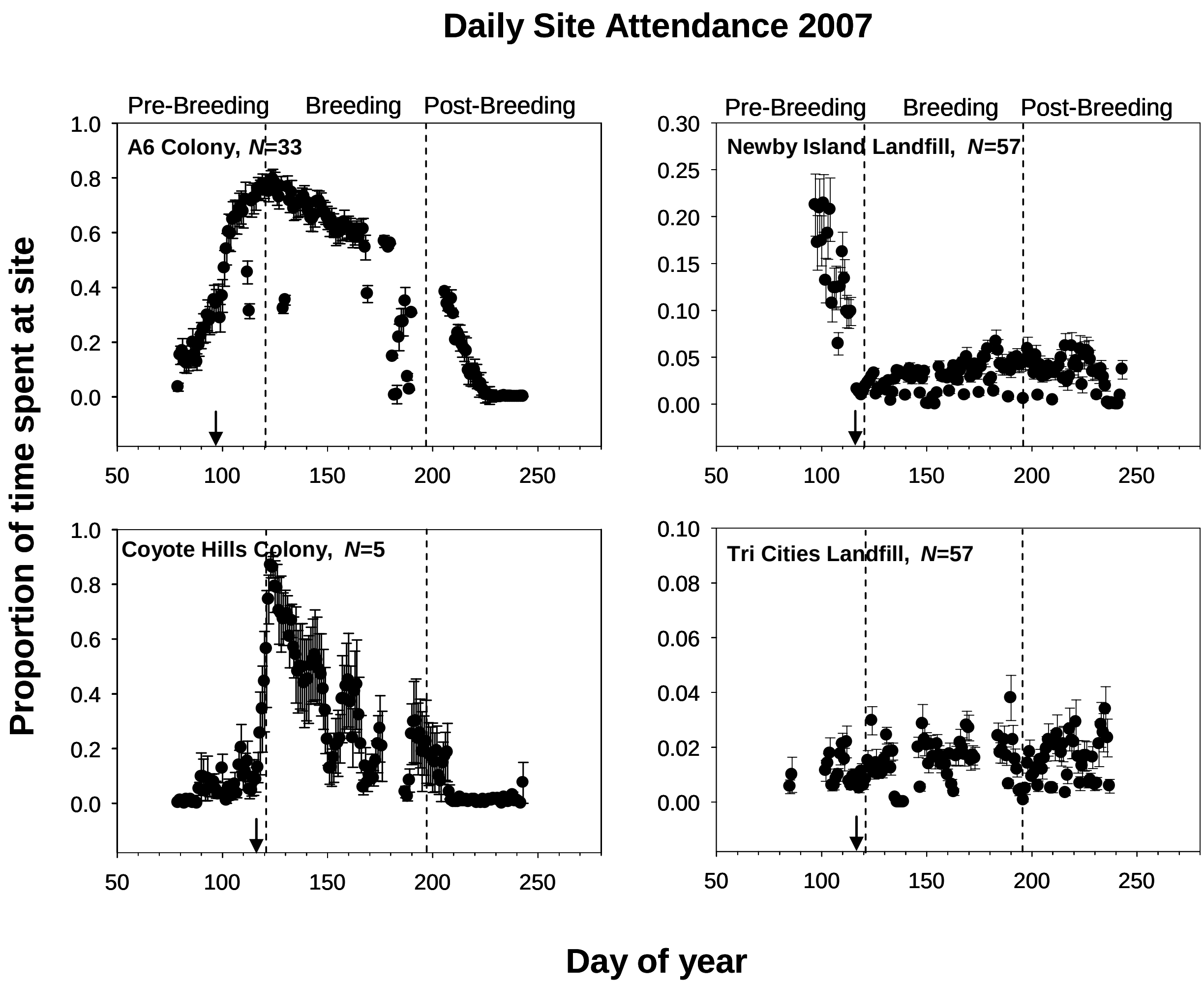


Figure 17. The proportion of each day radio-marked California gulls spent at breeding colonies and landfills throughout the breeding season during 2008 in the South San Francisco Bay. Arrows indicate the last date that gulls were radio-marked.

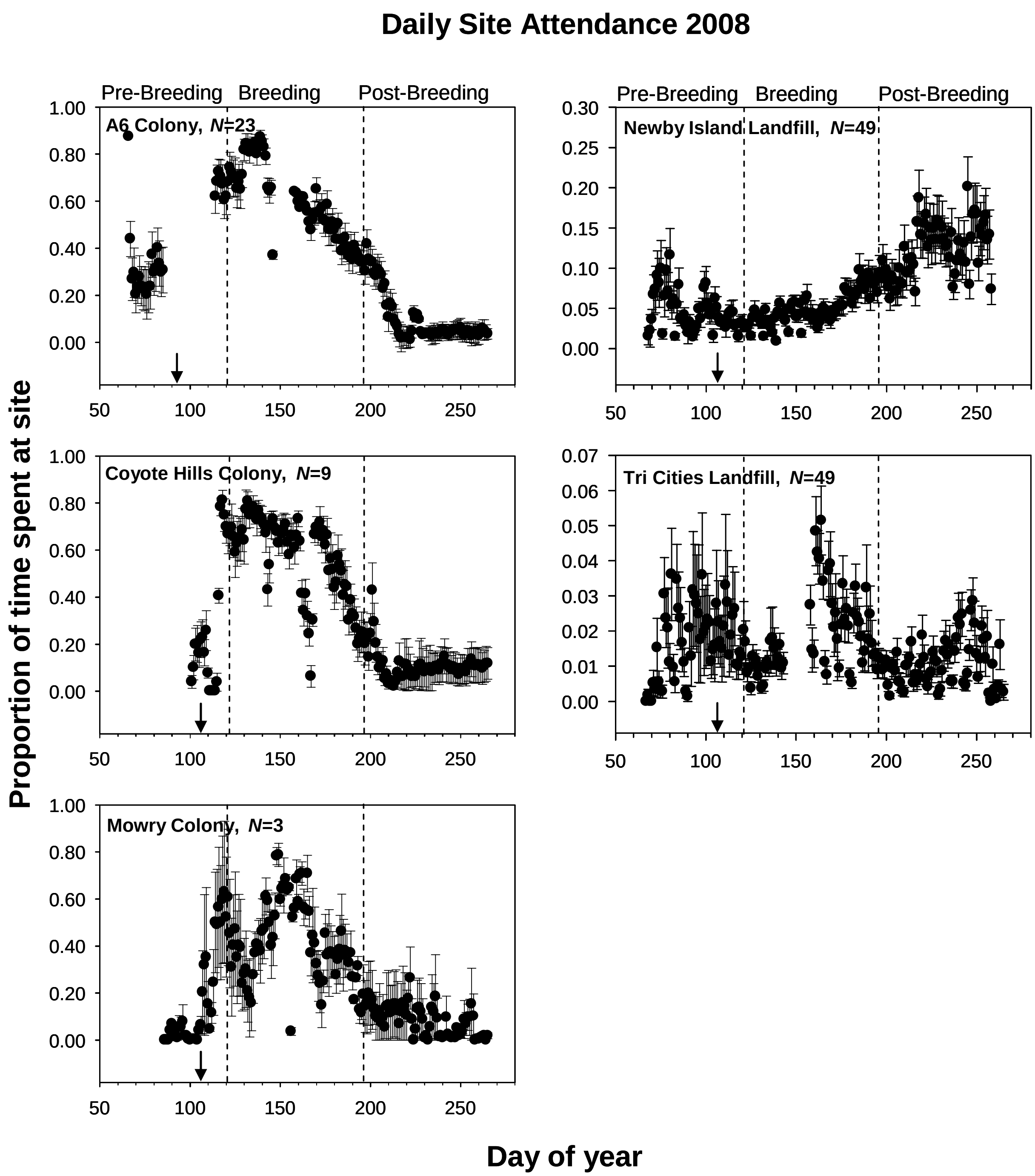


Figure 18. The proportion of time radio-marked California gulls spent at breeding colonies and landfills throughout the day during 2007 in the South San Francisco Bay.

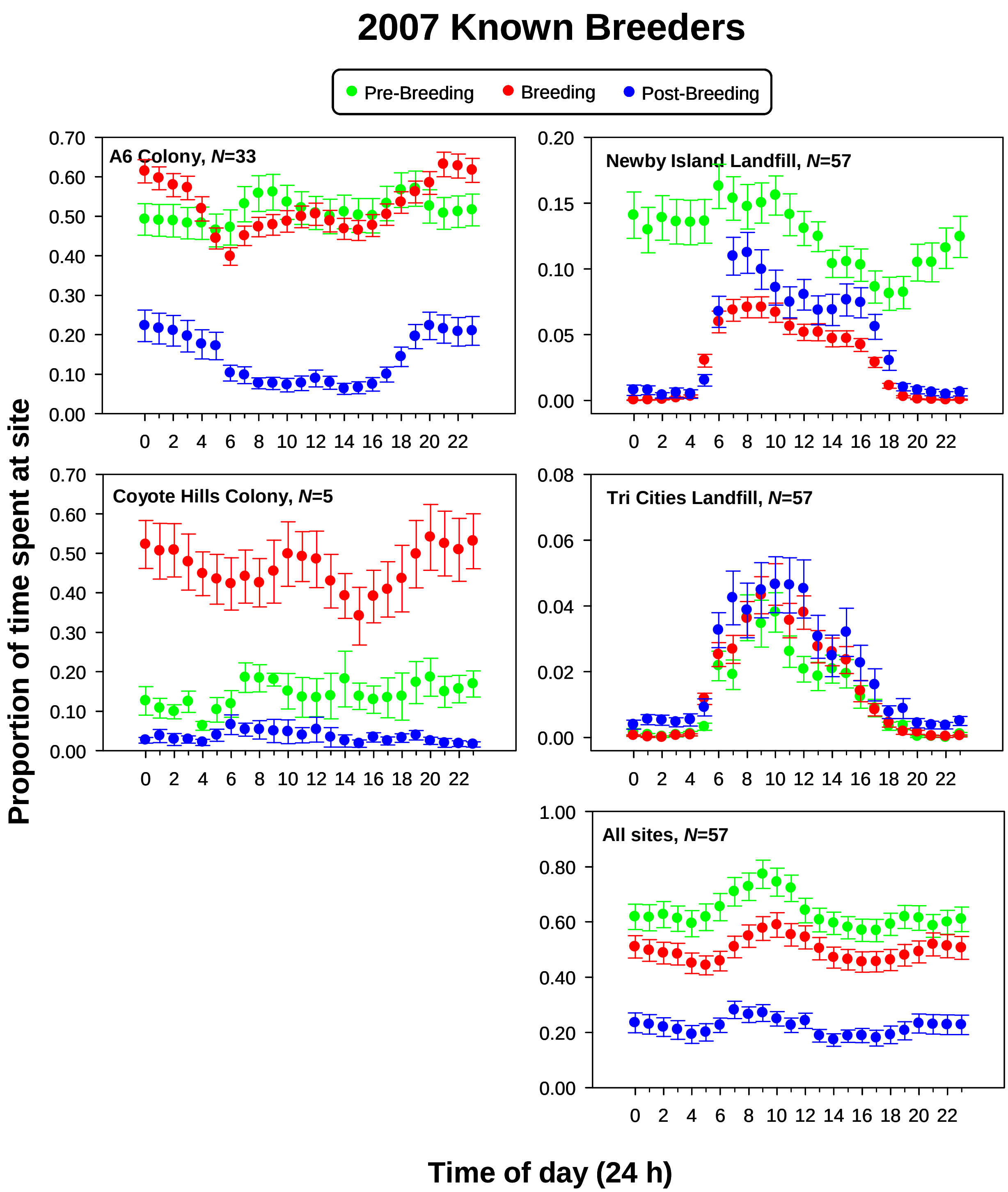


Figure 19. The proportion of time radio-marked California gulls spent at breeding colonies and landfills throughout the day during 2008 in the South San Francisco Bay.

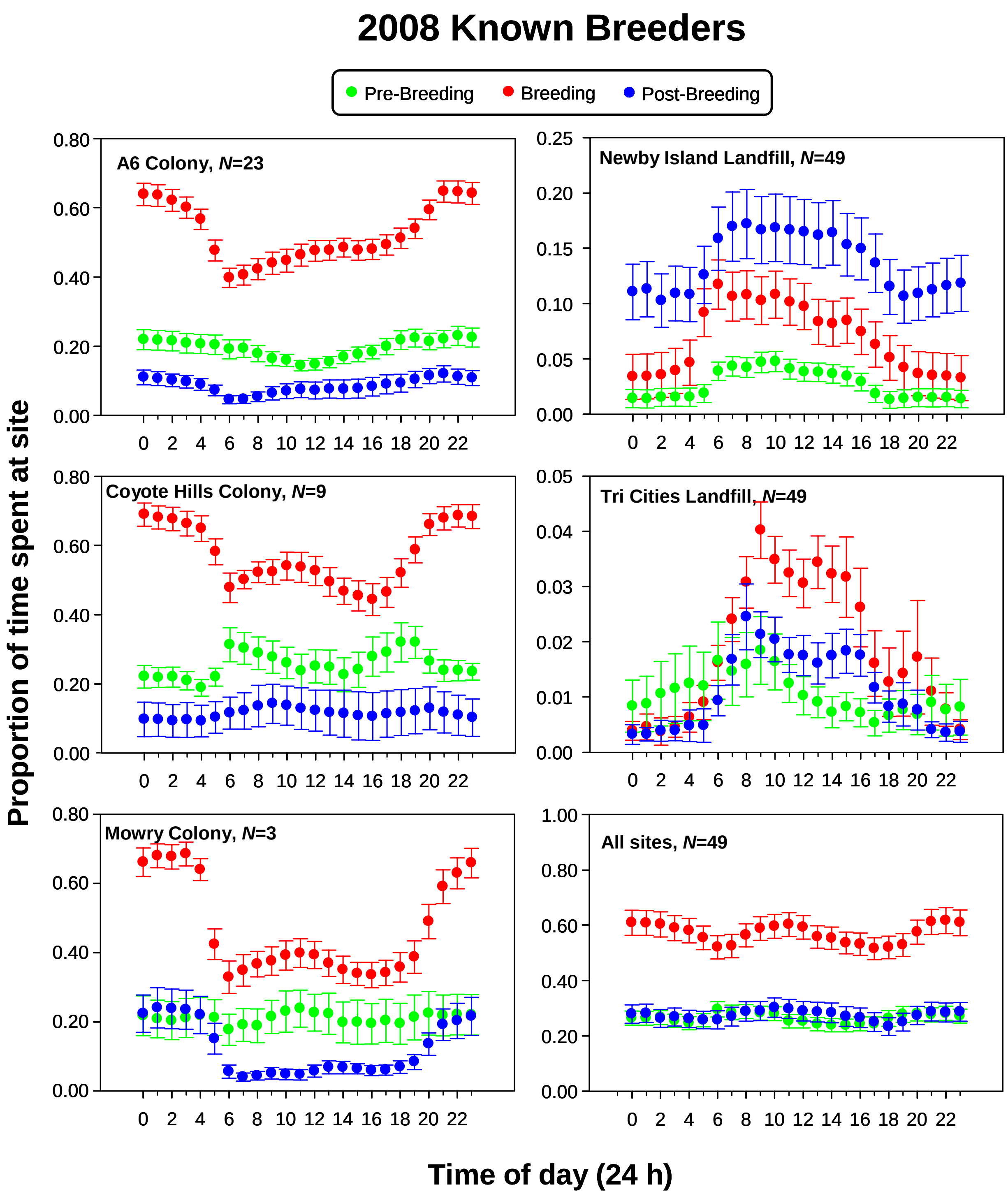


Figure 20. The proportion of time radio-marked California gulls spent at the A6 colony during the day in 2007, South San Francisco Bay.

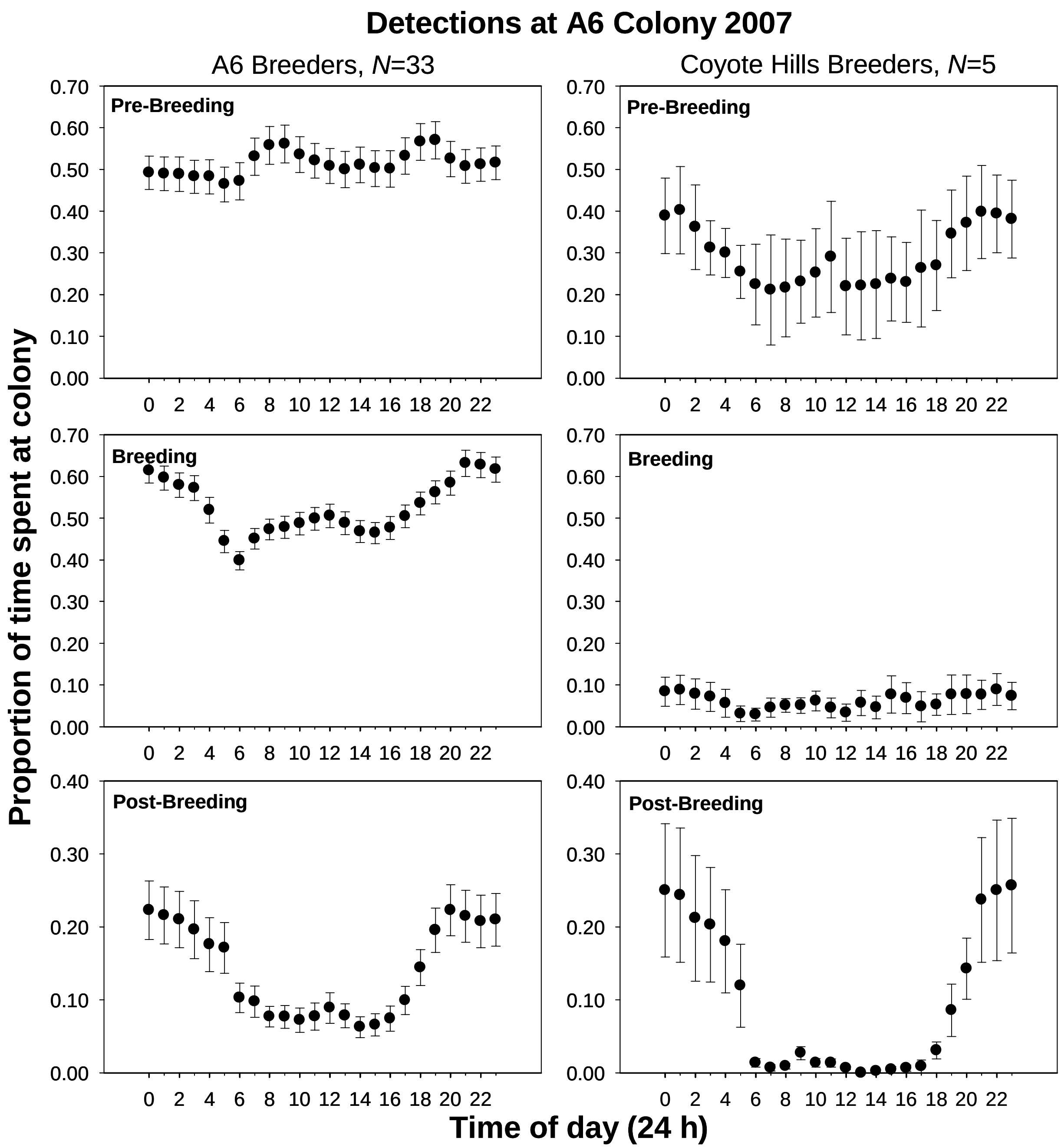


Figure 21. The proportion of time radio-marked California gulls spent at the Coyote Hills colony during the day in 2007, South San Francisco Bay.

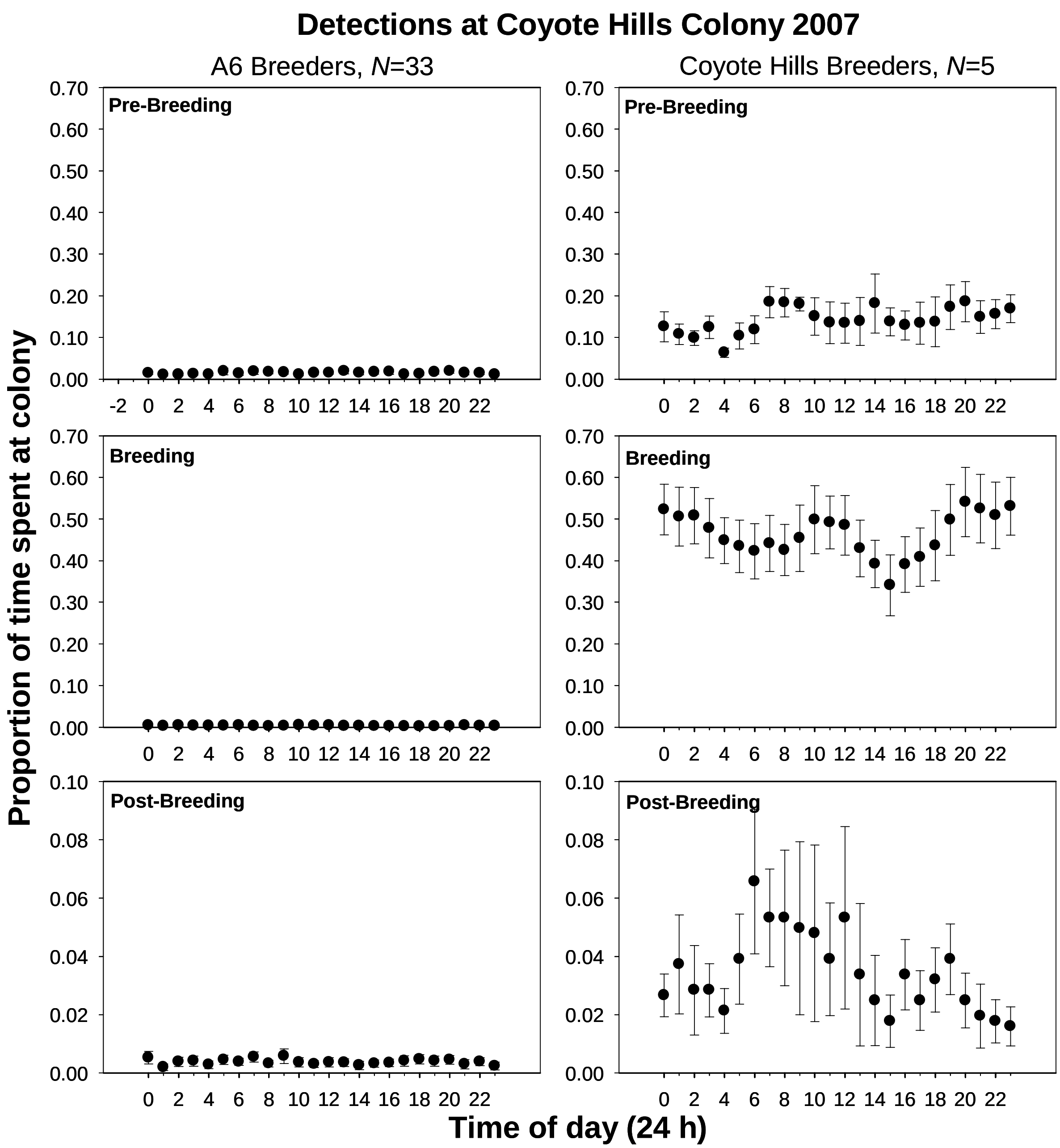


Figure 22. The proportion of time radio-marked California gulls spent at the Mowry colony during the day in 2007, South San Francisco Bay.

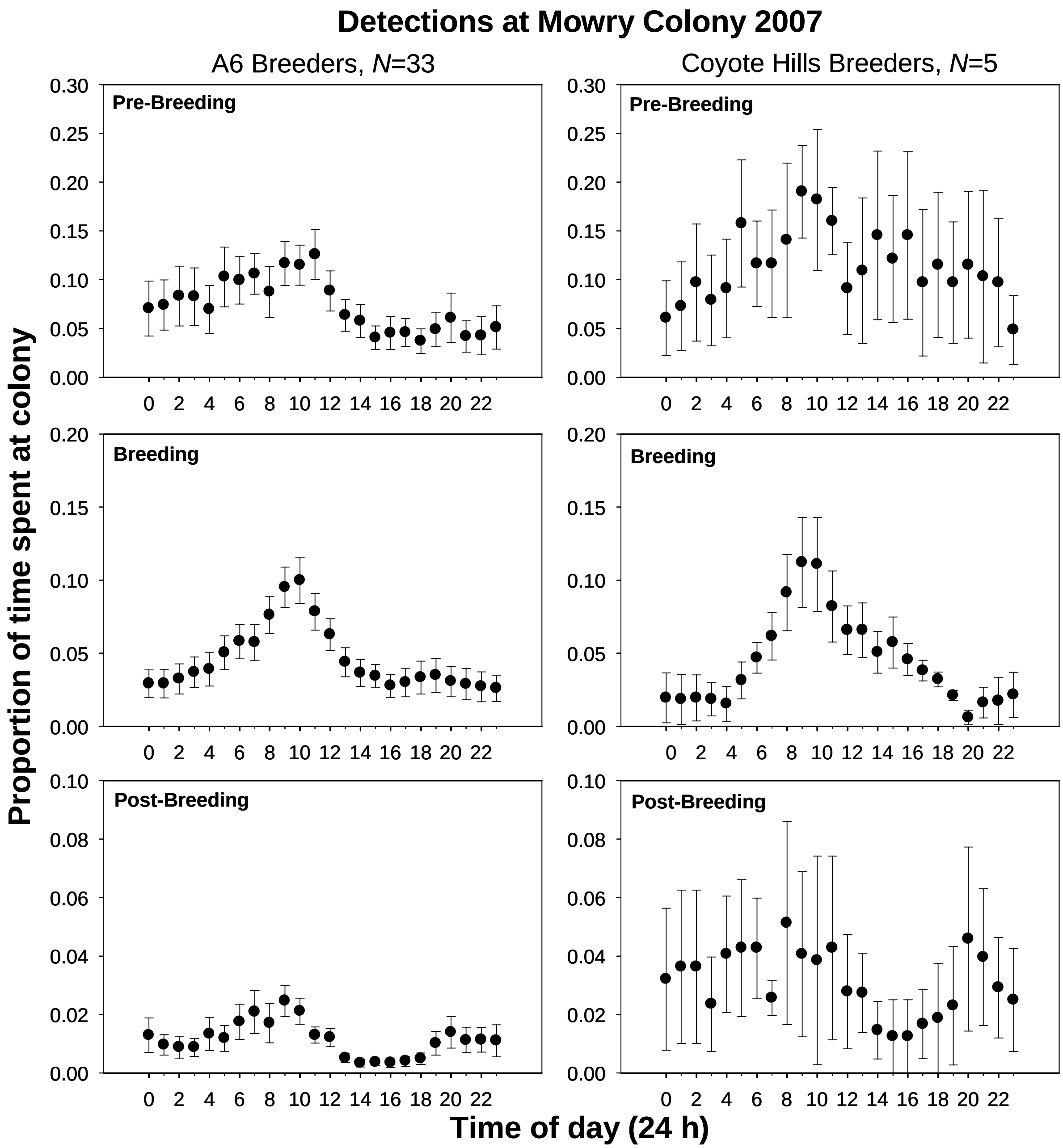


Figure 23. The proportion of time radio-marked California gulls spent at the Newby Island Landfill during the day in 2007, South San Francisco Bay.

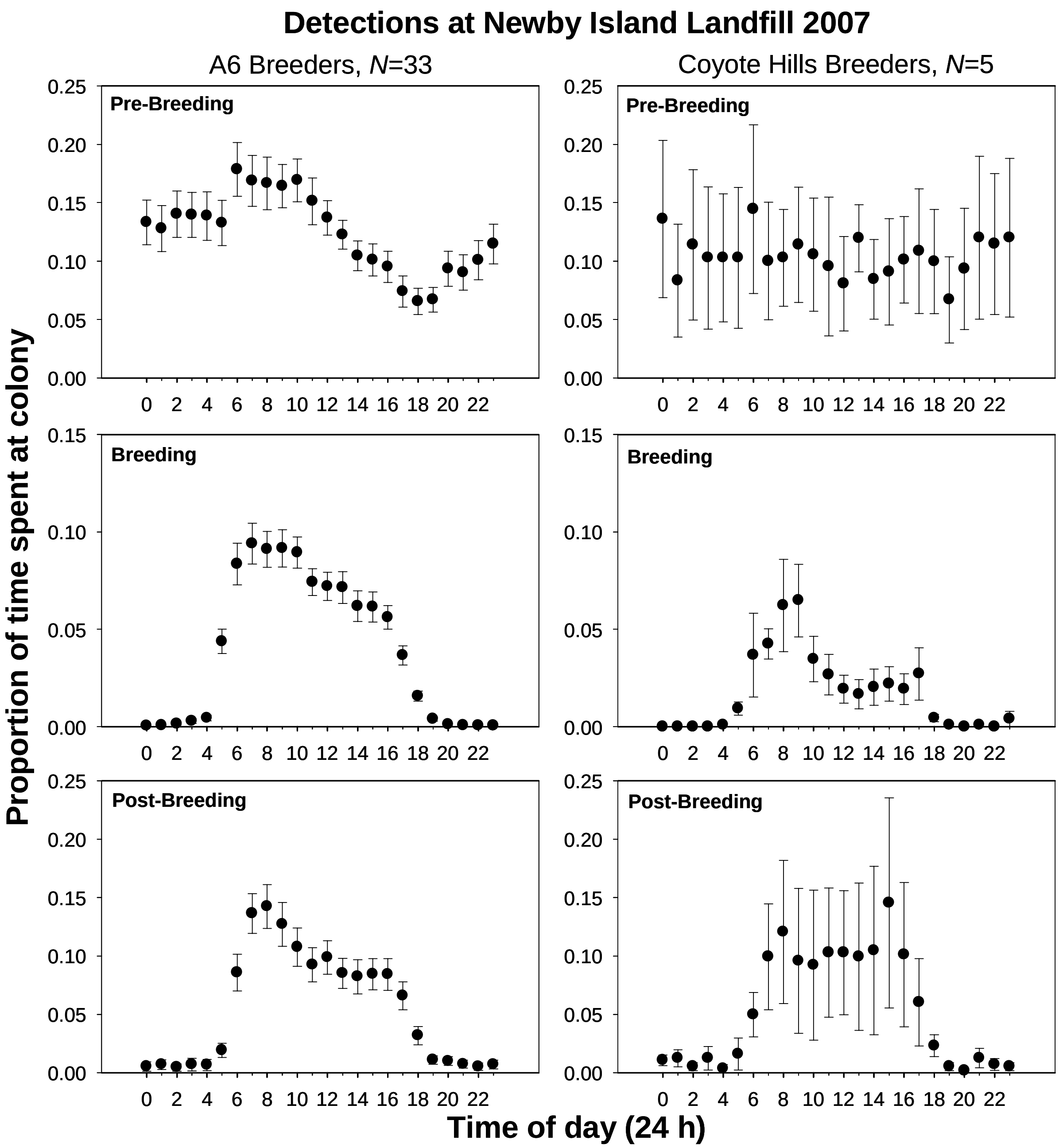


Figure 24. The proportion of time radio-marked California gulls spent at the Tri-Cities Landfill during the day in 2007, South San Francisco Bay.

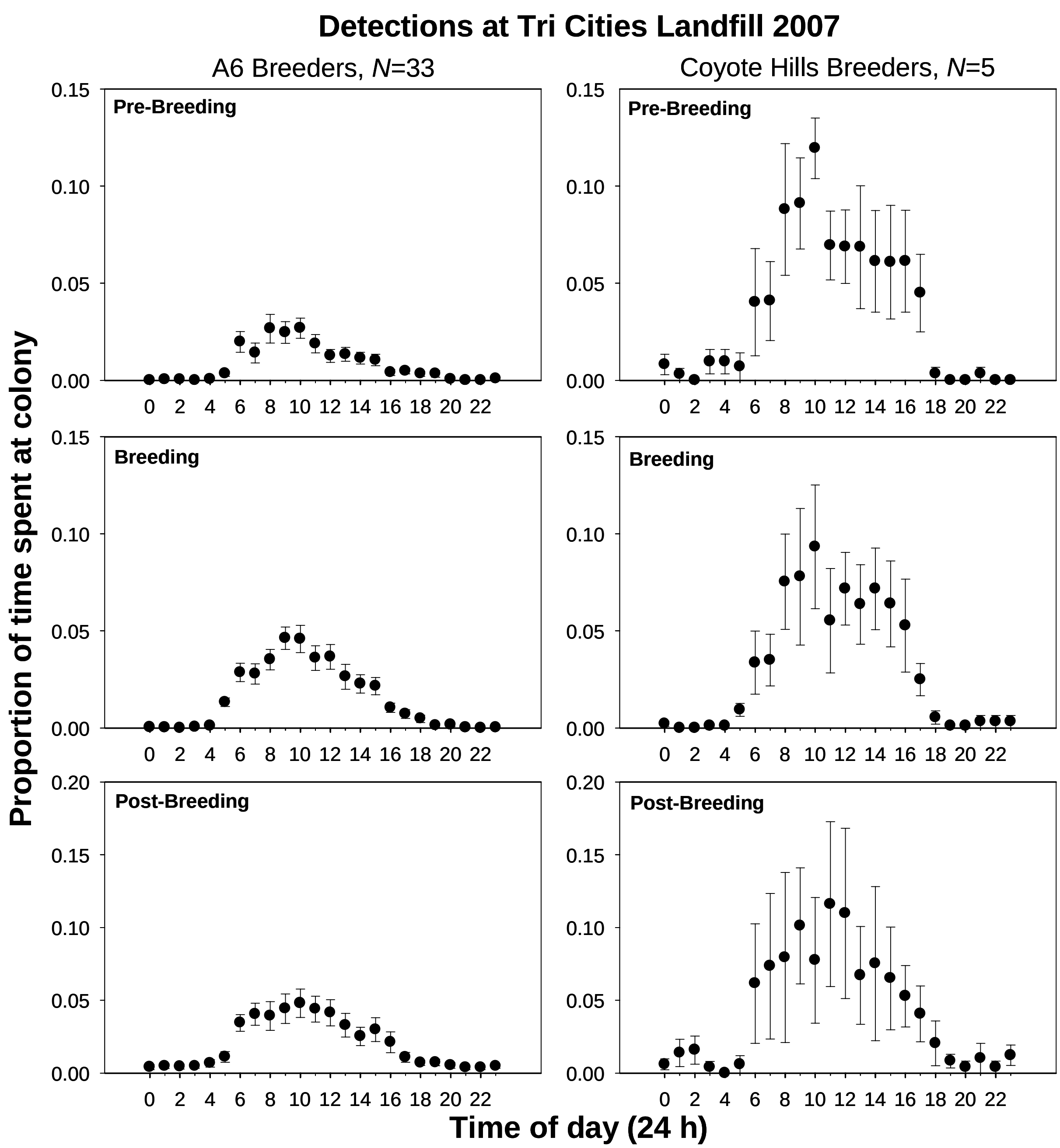


Figure 25. The proportion of time radio-marked California gulls spent at the A6 colony during the day in 2008, South San Francisco Bay.

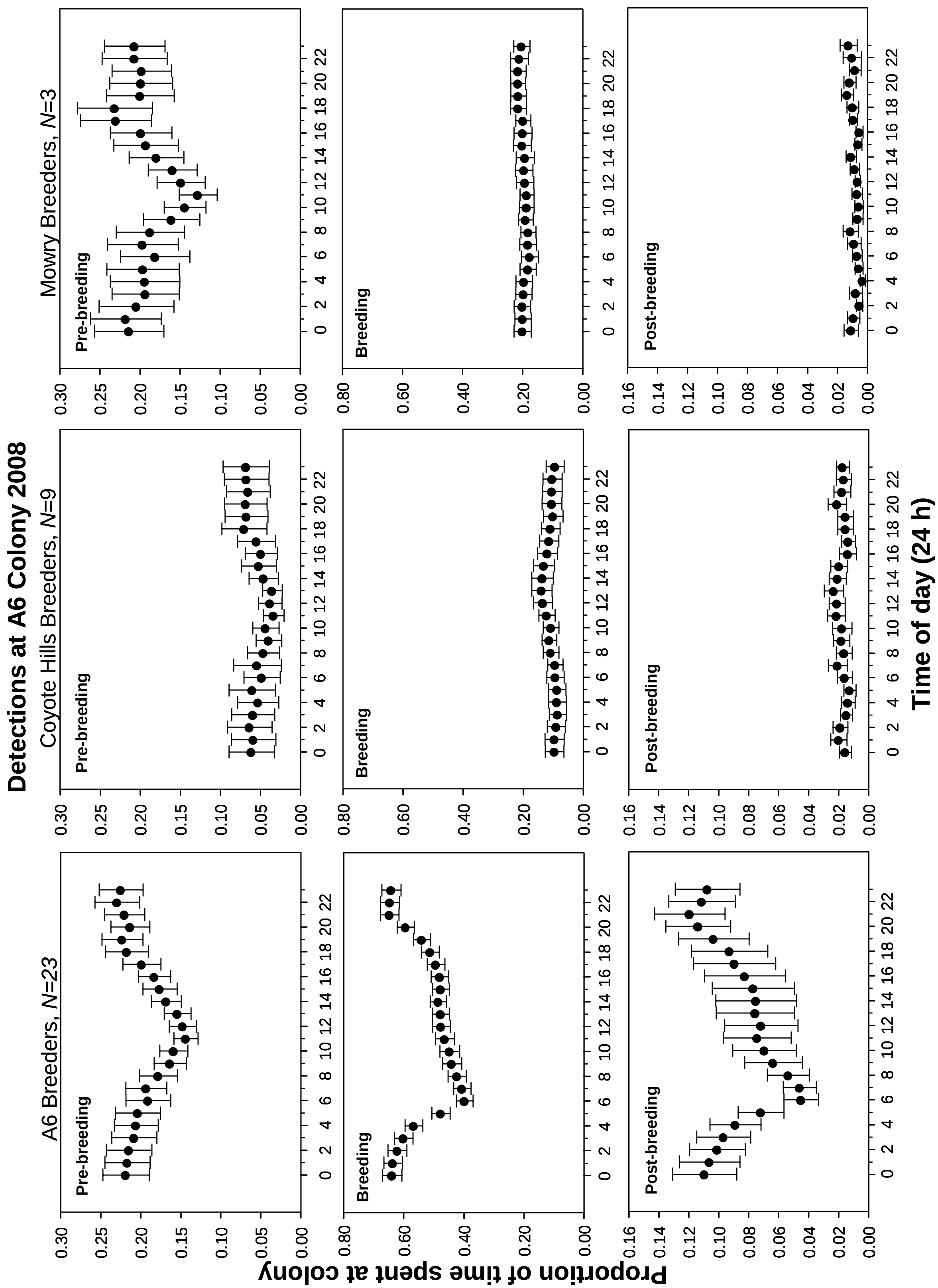


Figure 26. The proportion of time radio-marked California gulls spent at the Coyote Hills colony during the day in 2008, South San Francisco Bay.

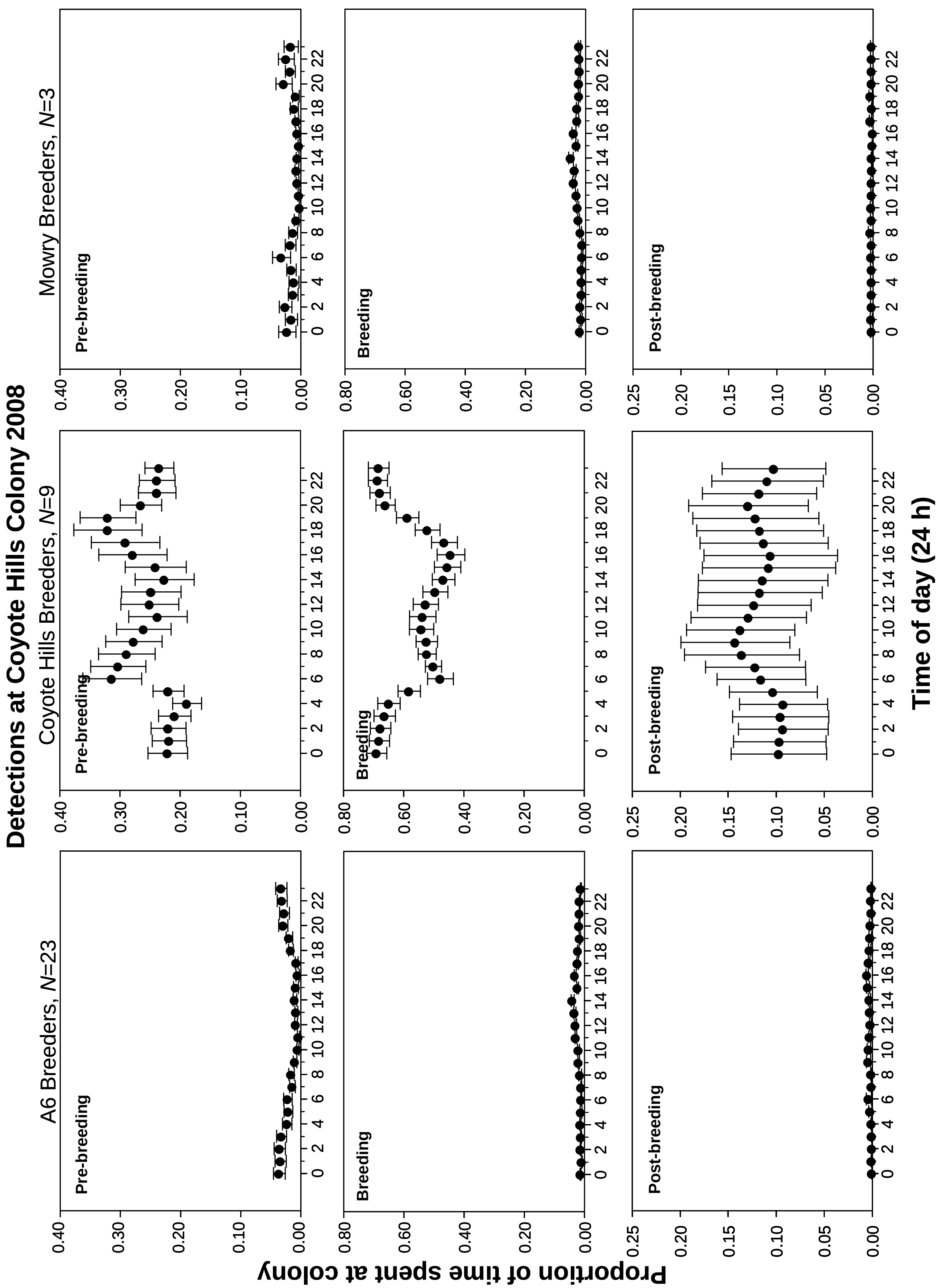


Figure 27. The proportion of time radio-marked California gulls spent at the Mowry colony during the day in 2008, South San Francisco Bay.

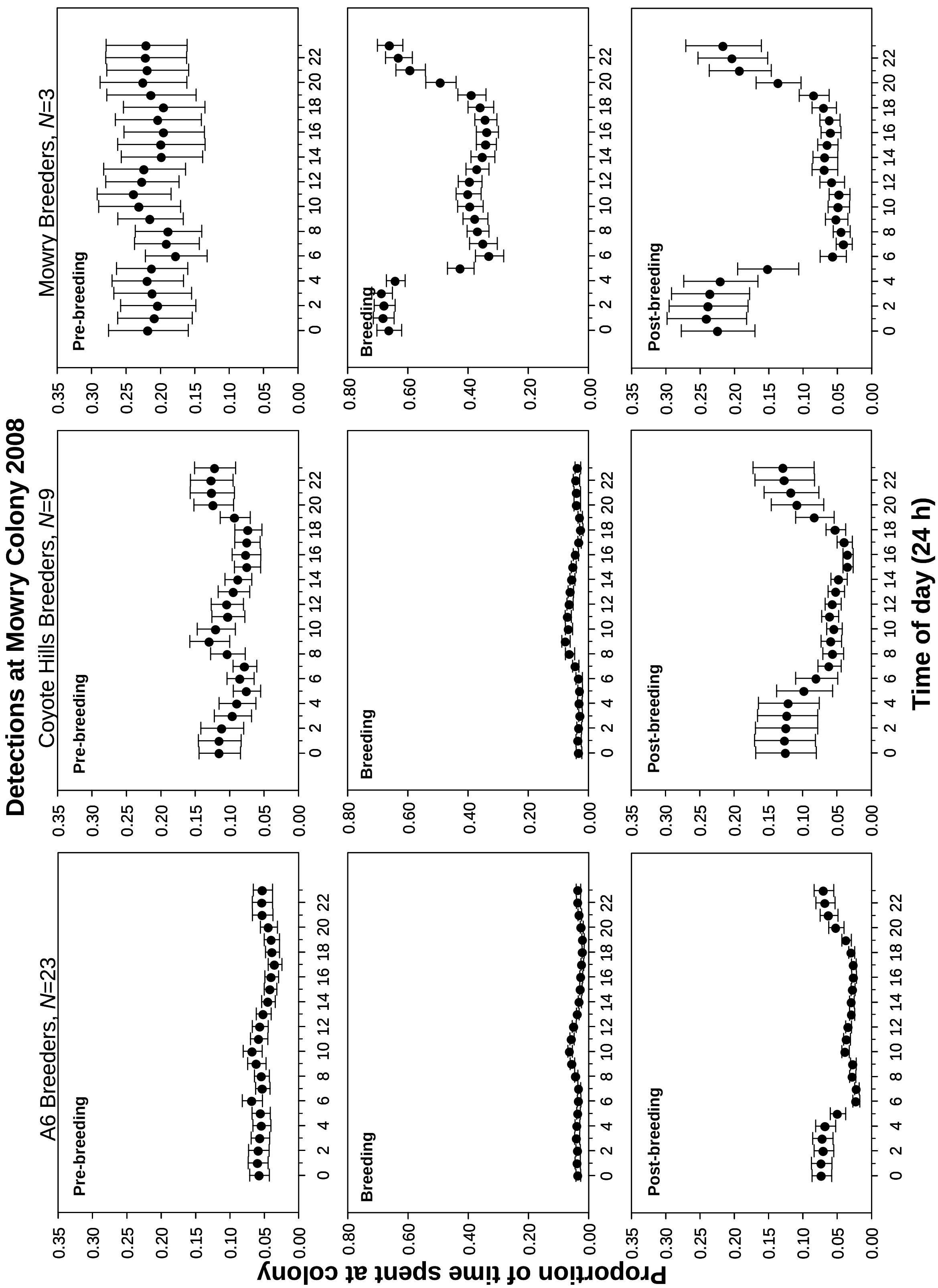


Figure 28. The proportion of time radio-marked California gulls spent at the Newby Island Landfill during the day in 2008, South San Francisco Bay.

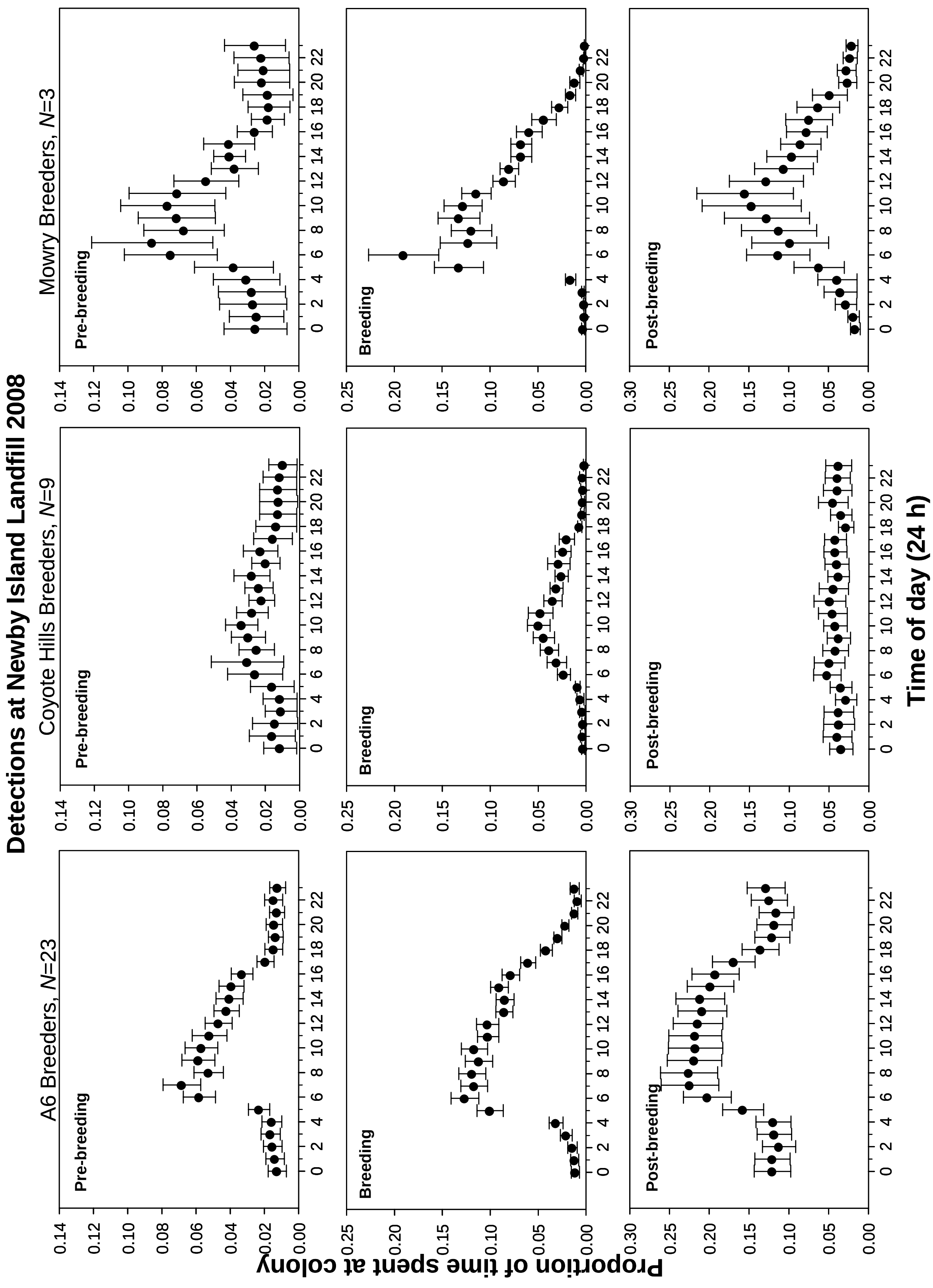


Figure 29. The proportion of time radio-marked California gulls spent at the Tri-Cities Landfill during the day in 2008, South San Francisco Bay.

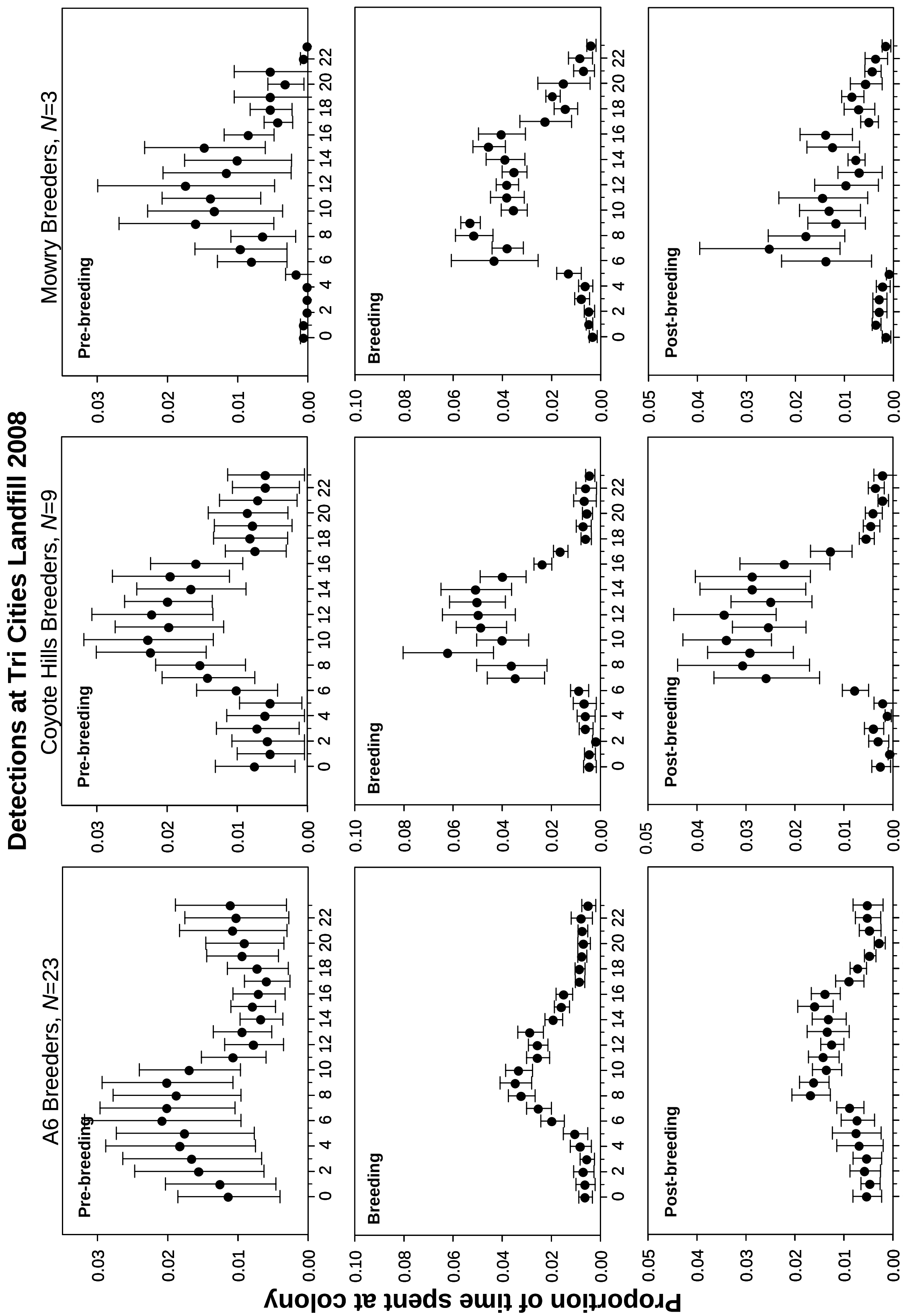


Figure 30. Home range (95% utilization distribution; red) and core use (50% utilization distribution; yellow) areas for the entire population of radio-marked California gulls in 2008, overlaid on the abundance and distribution of avocet, stilt, and Forster's tern nests in South San Francisco Bay.

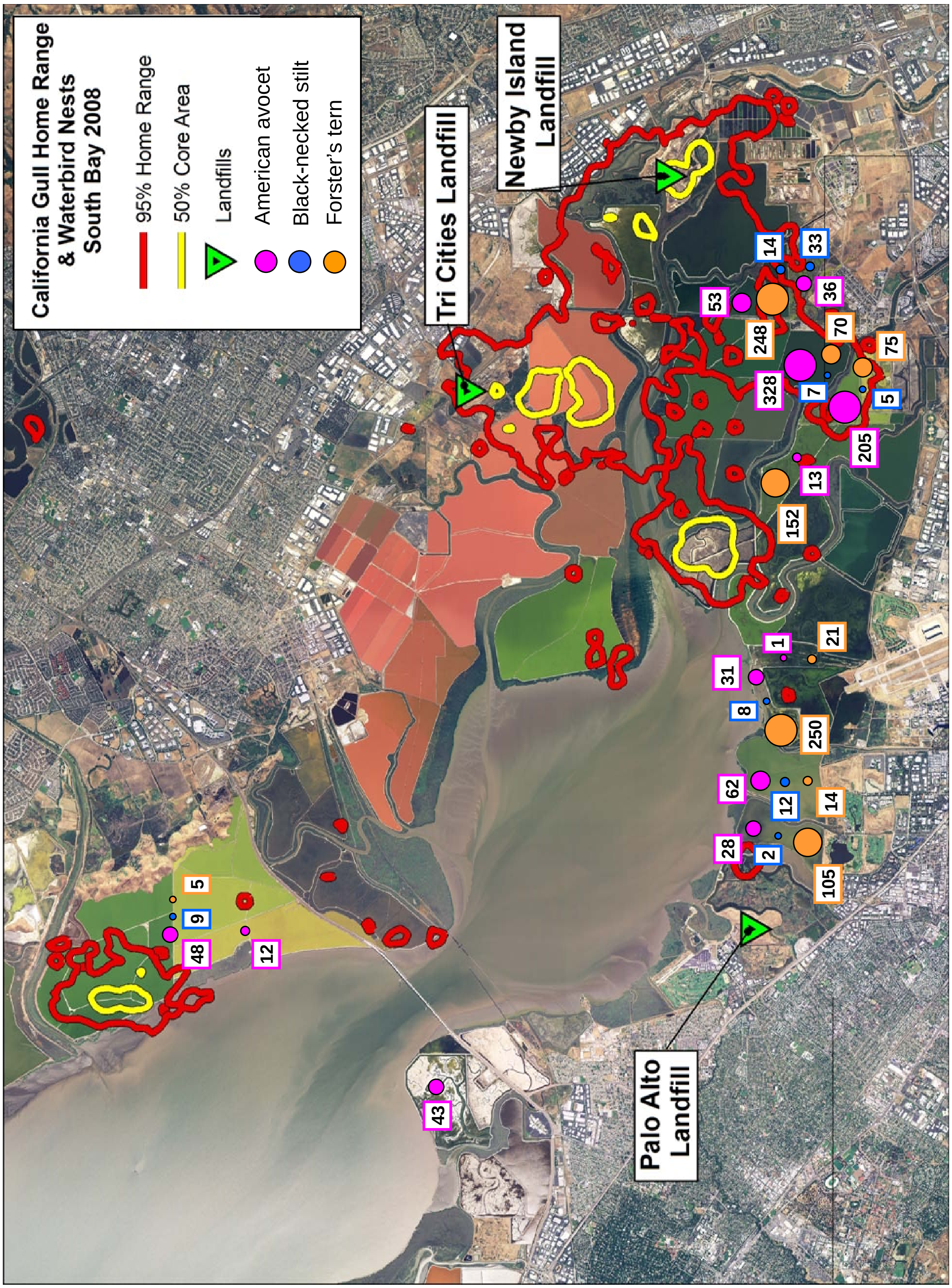


Figure 31. Home range (95% utilization distribution; red) and core use (50% utilization distribution; yellow) areas for the entire population of radio-marked California gulls in 2008, overlaid on the nest success for each colony of avocets, stilts, and Forster's terns in South San Francisco Bay.