California Gull Intrusions on Breeding Waterbird Colonies and Impacts to Reproductive Success:

Implications for the South Bay Salt Pond Restoration Project

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Introduction

In 2009, we initiated a study to assess the impact that California Gull (*Larus californicus*) predation had on daily survival rates and nest success for breeding waterbirds in Pond A16 (**Figure 1**). From May 5, 2009 to August 5, 2009, we monitored nests of Forster's Terns (*Sterna forsteri*; hereafter terns*)*, American Avocets (*Recurvirostra americana;* hereafter avocets*)*, and Black-necked Stilts (*Himantopus mexicanus;* hereafter stilts*)* at Pond A16 (**Table 1**), using standard USGS South Bay nest monitoring protocol. Briefly, nests in Pond A16 were found and checked weekly. Data on all new nests and the weekly fate of current nests (survived, depredated, abandoned, or unknown fate) were recorded. Simultaneously, we monitored California Gull intrusions within Pond A16, using a novel surveillance technique. We placed radio telemetry data loggers on 2 waterbird nesting islands in Pond A16 to detect gull intrusion events near the nesting colony. Fifty California Gulls were radio-marked the previous year in Spring of 2008, with transmitters that lasted for an estimated 18 month period. Thus, the recorded intrusions depended on previously radio-marked California Gulls returning to San Francisco Bay to breed, that the transmitters survived >1 year, and that radio-marked gulls actually used Pond A16. The data loggers continuously scanned for radio-marked gulls once every 15-20 minutes. To ensure we did not have any intervals where data was not recorded, we divided each hour of each day into three 20 minute bins. An intrusion event was defined by a positive identification of a radio-marked California Gull within Pond A16 during a 20 min interval. Intrusion events were then used as an index of California Gull use within Pond A16. For this report, we present the results of our

analyses on nest survival of terns and avocets (stilt sample size was too small), summarize the California Gull nest intrusions, and assess the potential impact that California Gulls had on tern and avocet nest survival.

Figure 1. Study area map of Pond A16 (within San Francisco Bay National Wildlife Refuge). Data loggers and waterbird nesting colonies were located on Island 1 and Island 2.

Nest Survival Results

We monitored a total of 309 nests (243 tern nests, 56 avocet nests, and 10 stilt nests). After data proofing and censoring for unknown fates, we used a total of 299 nests (237 tern, 52 avocet, and 10 stilt nests) in our analysis. Using the logistic-exposure method (Shaffer 2004), we estimated daily nest survival for terns and avocets. Rather than running separate model sets for each species, we have included species as a factor in a single model set. The small sample size of stilt nests did not allow

estimation of unique daily survival rates over the 27 day period. Instead, results for stilts are based on an intercept-only model using only the stilt data.

Table 1. Summary nest statistics for Pond A16 (within San Francisco Bay National Wildlife Refuge) during 2009 breeding season.

Species Name	Nest hatched?		Total Nests
	Yes	No	
American Avocet	43	13	56
Black-necked Stilt	8	2	10
Forster's Tern	185	58	243
Black Skimmer	1	0	1
Total	**237**	**73**	**310**

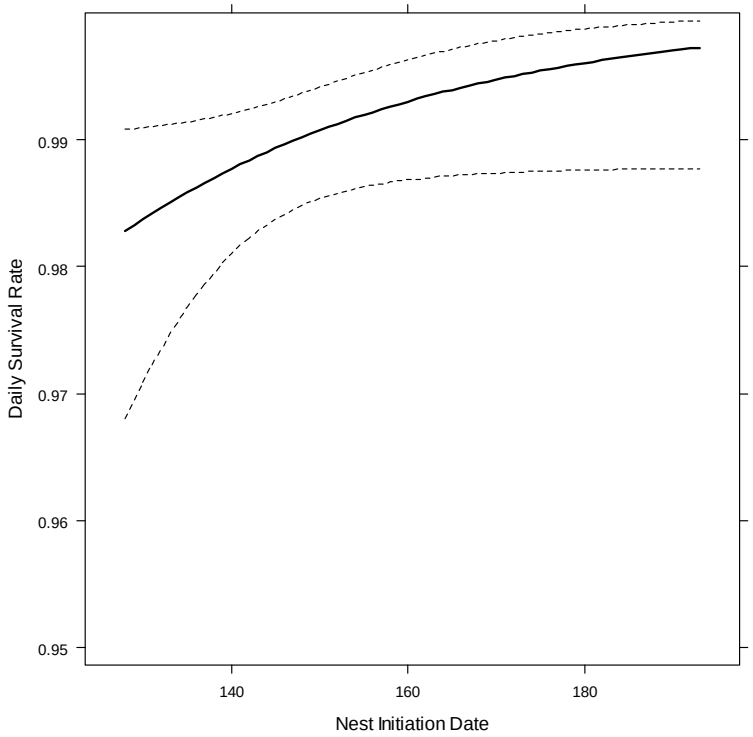
In addition to the potential impact from gulls, we also were interested in understanding the major factors that influenced nest success of waterbirds nesting at Pond A16. Thus, we included factors such as age of nest when it was found (as determined by the average egg age from floating), nest initiation date (back calculated from the date the nest was found minus the age of the nest), presence/absence of vegetation at the nest site, clutch size of the nest, and species. The complete set of models and model selection results are provided in **Table 2**.

Table 2. Model selection diagnostics for logistic exposure analysis of nest survival for American Avocets and Forster's Terns at Pond A16 (within San Francisco Bay National Wildlife Refuge). The model with nest initiation date and clutch size was the most parsimonious. Only top 15 models are displayed in table.

Model	K	AICc	ΔAIC_c	Model Weight
initiation.date + clutch.size	3	368.98	0	0.264
initiation.date*clutch.size	4	370.10	1.20	0.144
initiation.date + clutch.size + age	4	370.55	1.65	0.115
initiation.date	2	370.75	1.85	0.104
initiation.date + age	3	371.52	2.61	0.071
initiation.date*clutch.size*age	8	371.79	2.88	0.062
initiation.date + veg.presence	3	372.25	3.35	0.04
initiation.date + clutch.size + age + species	6	372.36	3.45	0.046
initiation.date*clutch.size*species	12	372.95	4.04	0.034
initiation.date*age	4	373.46	4.55	0.027
clutch.size*age	4	373.52	4.61	0.026
initiation.date + species	4	374.61	5.70	0.015
clutch.size	2	375.58	6.67	0.009
Intercept only	1	375.91	7.01	0.007
veg.presence	2	377.06	8.16	0.004

Not surprisingly, our results indicated that nests found later in incubation survived at a higher daily rate than nests found earlier in laying and incubation (0.9900 vs. 0.9927 for newly initiated versus 27-day old nests, respectively). We also found a very slight increase in a nest's daily survival rate (DSR) with clutch size (increase in DSR between 2 and 3 eggs for terns and 3 and 4 eggs for avocets). Importantly, we found that nest survival rates increased with nest initiation date (**Figure 2**), which is opposite to most nest survival studies which typically find that nest survival rates decline throughout the breeding season. Indeed, this raises the question as to whether there is a substantial impact on nest survival (such as gull predation) that occurs early in the breeding season but diminishes over time in Pond A16. **Figure 3** displays the results of high mortality early in the breeding season. During early June, a major depredation event occurred on "Island 4", which caused the entire colony on that island to abandon. This event is visible in the nesting results (**Figure 3)**, however the radio data-loggers were not put out until just after this event.

1A)



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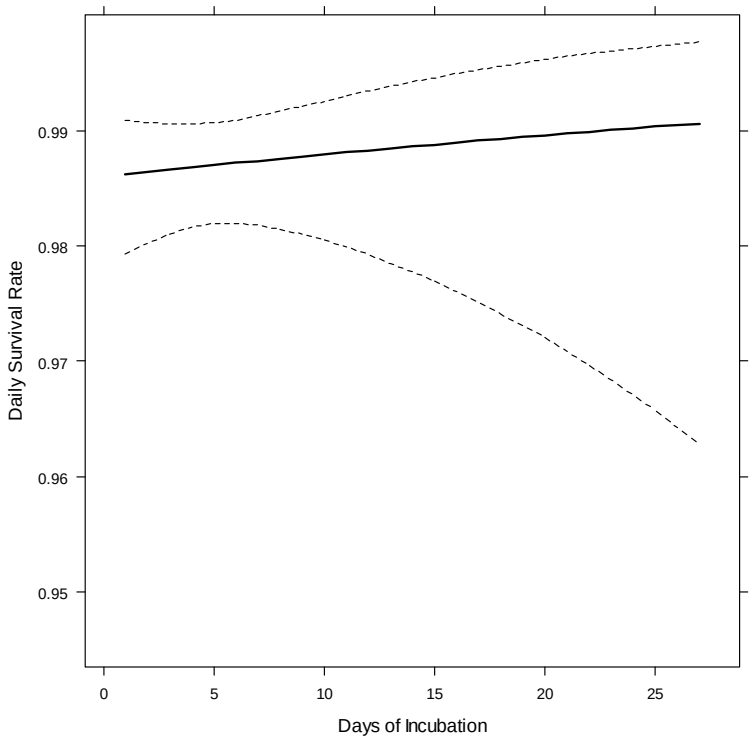

Figure 2. Model average predicted daily survival rate for all waterbird nests in Pond A16 (within San Francisco Bay National Wildlife Refuge) by 1A) Julian date and 1B) days of incubation in 2009. 1A) Model predictions are based on a nest found at 9 days of age with a clutch size of 3 eggs and shows daily survival rates throughout the season. 1B) Model predictions are based on a nest that initiated on May 20, 2009 with a clutch size of 3 eggs and shows daily survival rate through a complete incubation period.

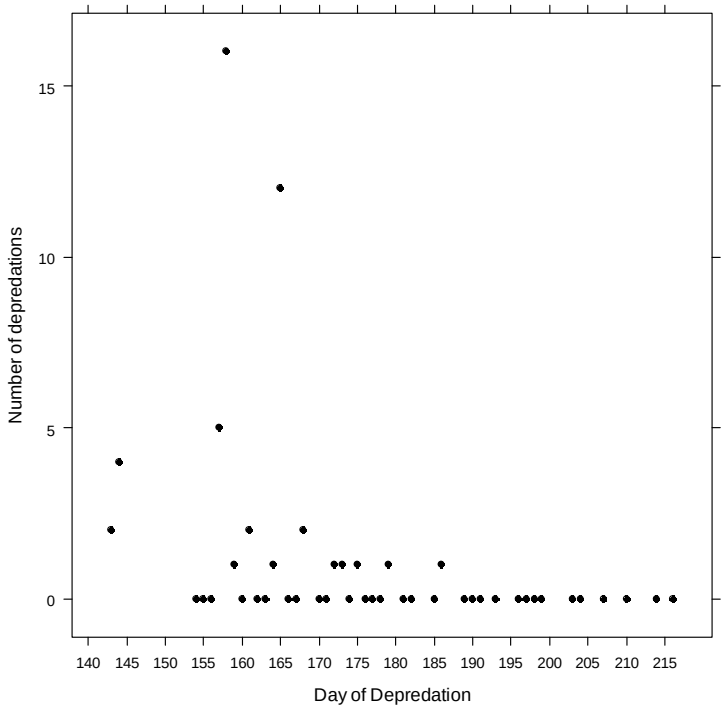

Figure 3. Distribution of nest depredation events of waterbird nests at Pond A16 (within San Francisco Bay National Wildlife Refuge) in relation to date. (June 1, 2009 = Day 151).

Nest Success Estimates

Using the model averaged results of daily survival, we found that overall nest success (estimated as the probability of surviving from laying to hatch) was similar for all three waterbird species (**Table 3**). However, sample sizes were so small for stilts, that nest survival estimates are very poor.

Table 3. Model averaged nest success predictions by species nesting at Pond A16 (within San Francisco Bay National Wildlife Refuge), assuming an average 27 day period between date the first egg was laid to when the nest hatches. These predictions were based on an average nest initiation date of June 1, 2009, and a clutch size of 3 eggs for Forster's Terns (observed mean = 2.8), and 4 eggs for American Avocets (observed mean = 3.9).

Species Name	Nest Success	Lower 95% CI	Upper 95% CI	Sample Size
American Avocet	0.837	0.559	0.942	52
Black-necked Stilt*	0.747	0.290	0.934	10
Forster's Tern	0.800	0.608	0.895	237
Black Skimmer**	1.00	NA	NA	NA

*Black-necked stilt estimate is based on an "Intercept-only" model using only black-necked stilt nests.
**We only observed and monitored 1 black skimmer nest, thus no models were run, and no variance was estimated.

Gull Intrusion Results

Between mid-June and mid-August, we recorded the presence or absence of radio-marked gulls in Pond A16 for a total of 1495 hours of surveillance. During this survey period, the data loggers completed 5980 scan cycles and recorded 8854 positive intrusion events (**Figure 4**). The data loggers recorded the presence of 18 individual California Gulls during the study period. We found high variation in the total number of intrusion events for each gull (**Figure 5**). However, our data suggests that there was little variation in the proportion of gulls visiting (e.g. at least 1 intrusion by one of the 18 radio-marked gulls) the colony on any given day throughout the study period, with a radio-marked California Gull present at Pond A16 approximately 40-60% of the time. (**Figure 6**). Thus, it appears that many gulls visit Pond A16 each day, but that specific gulls spend significantly more time within the tern colonies than others.

There appeared to be a slight seasonal effect on gull activity. We found that the mean average number of intrusion events per gull slowly increased through the season, until late July (~215th day of year), where gull activity decreased until the end of the breeding season (**Figure 7)**. These results also are supported by the findings that the amount of time that at least one gull was detected in Pond A16 followed a very similar pattern (**Figure 8)**. It is possible that these results could be an artifact of declining radio transmitter performance, as these transmitters were approaching their expected lifespan. However, we did not observe any obvious drop outs of individual gulls as might be expected when a transmitter battery dies. Instead, these results would only be expected from transmitters where failure was not catastrophic, but instead transmitter performance weakened over time. We do not believe this to be the norm for failing transmitters, and thus we believe the decline in gull activity is the correct interpretation.

In addition to seasonal patterns, we also examined daily use patterns of California Gulls at A16. Gull activity was generally highest at Pond A16 during the daylight hours from 0600 to 1800 (**Figure 9, Figure 10**). These results corroborate our findings from our previous study on California Gull movement patterns where gulls spent most of their time at the nearby Newby Island landfill from 0600 to 1800 when the landfill was open and refuse was uncovered (Ackerman et al. 2009).

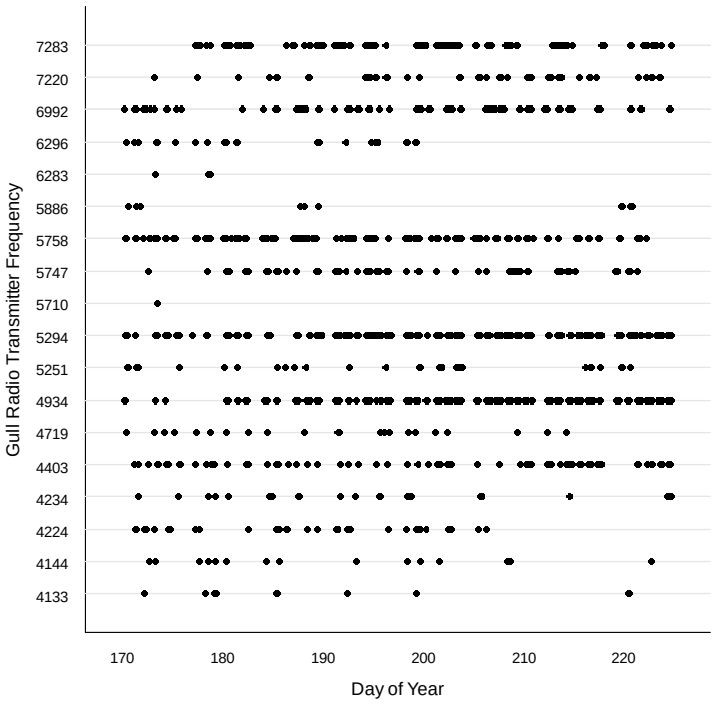

Figure 4. Visualization of all intrusion events for each California Gull at Pond A16 (within San Francisco Bay National Wildlife Refuge) throughout the 2009 breeding season. Each solid dot represents a detection within a 20 minute scan interval.

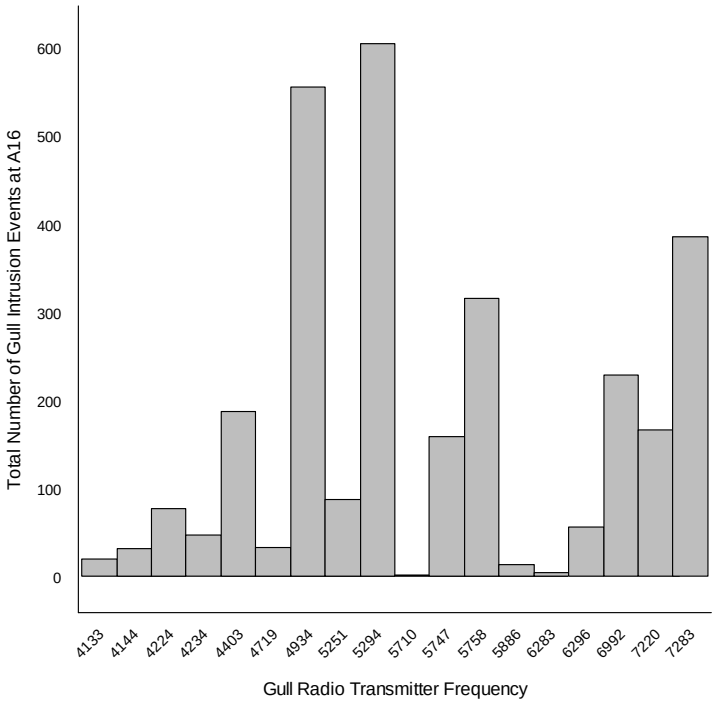

Figure 5. Variation in the number of intrusion events by individual California Gulls at Pond A16 (within San Francisco Bay National Wildlife Refuge) during the 2009 breeding season.

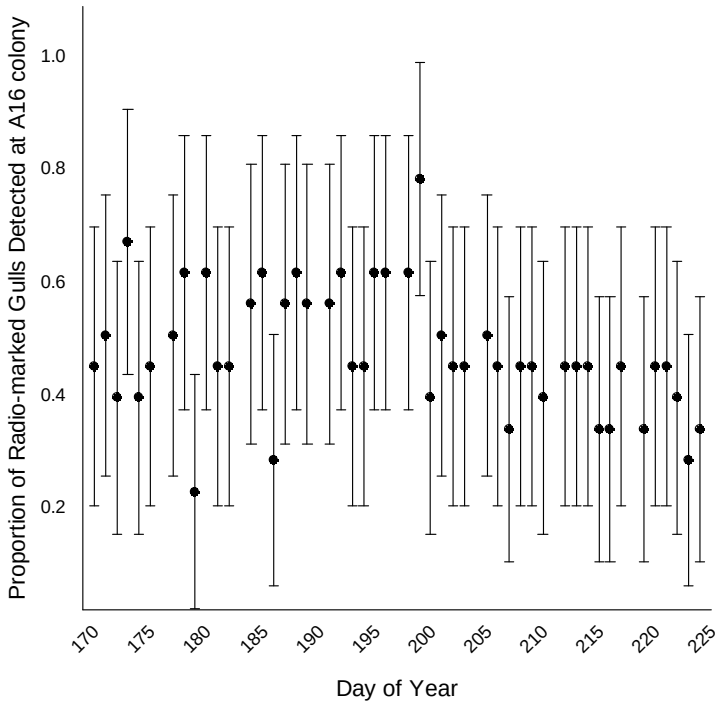

Figure 6. The proportion of radio-marked California Gulls (N=18), that were detected at Pond A16 (within San Francisco National Wildlife Refuge) at least once on a given day of the 2009 breeding season.

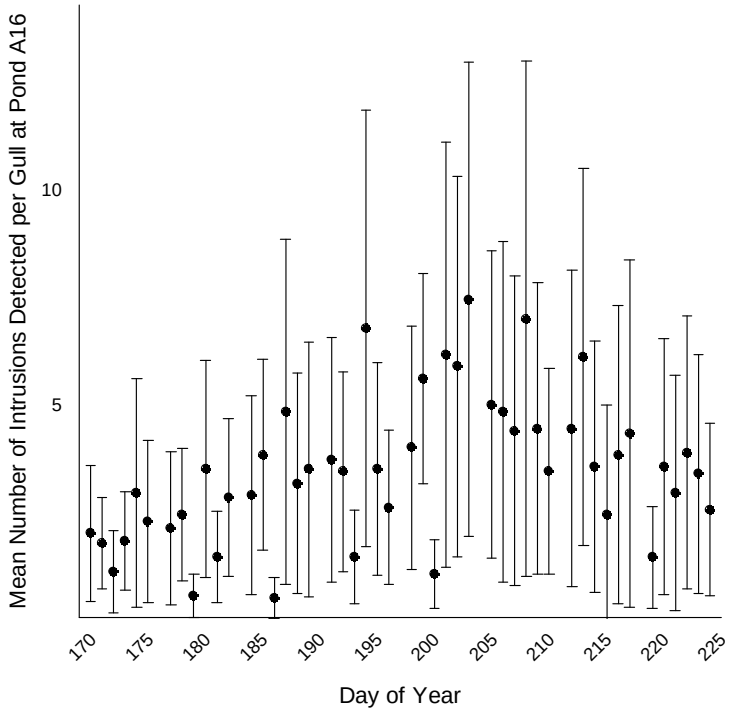

Figure 7. Mean number of intrusion events per California Gull on a given day of the season at Pond A16 (within San Francisco Bay National Wildlife Refuge). Metric is calculated as the total number of intrusions per day per gull, and then averaged across all gulls.

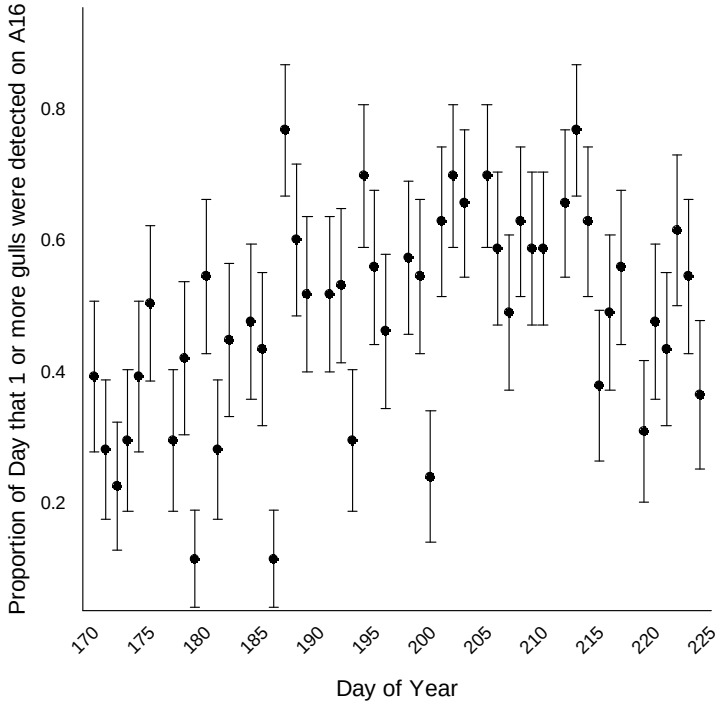

Figure 8. Proportion of a day where at least one California Gull was detected on Pond A16 (within San Francisco Bay National Wildlife Refuge). Metric is calculated by tallying the number of 20 min scan intervals on any given day where at least 1 unique gull was detected and then divided by the total number of possible 20 min scan intervals in a day (72).

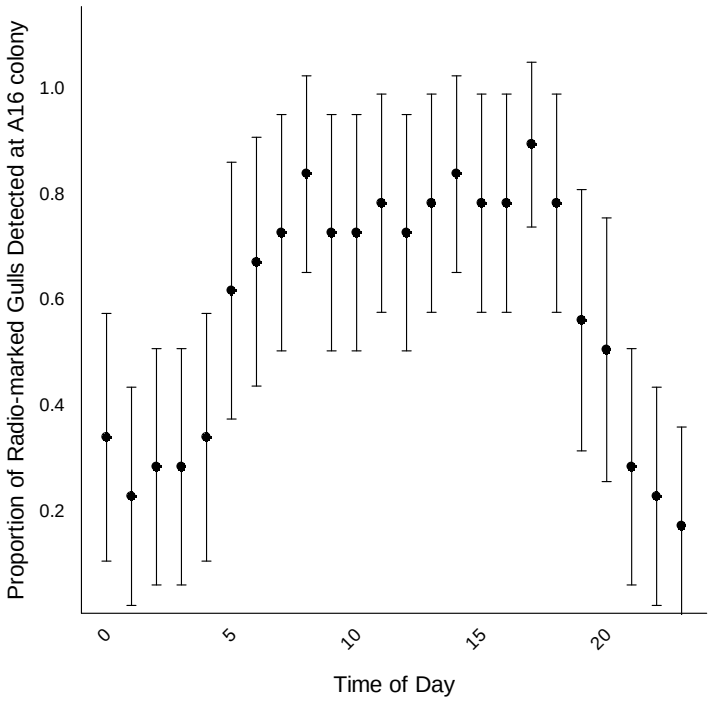

Figure 9. Proportion of radio-marked California Gulls (N=18) detected (at least once, over the 2009 season) at a specific time of day at Pond A16 (within San Francisco Bay National Wildlife Refuge). Metric is calculated by summing the number of gulls ever detected at Pond A16 within a specific hour of the data and dividing by the total number of radio-marked gulls (18).

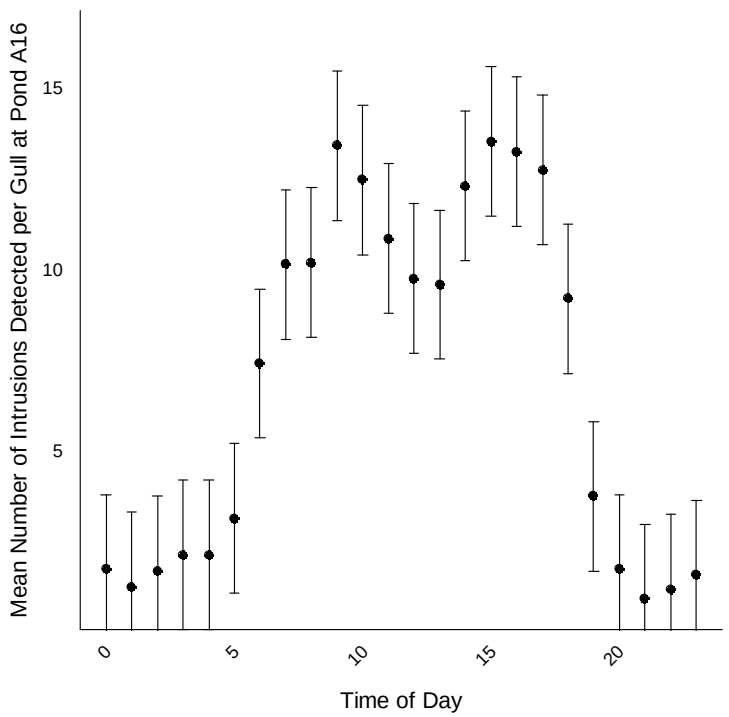

Figure 10. Mean number of intrusions over the entire season by a California Gull at a specific time of day at Pond A16 (within San Francisco Bay National Wildlife Refuge) in 2009. Metric is calculated as the total number of intrusions per hour per gull (over the entire season), and then averaged across all gulls.

Potential Impact of California Gull Intrusions on Reproductive Success

In 2009, peak nest initiation for avocets, stilts, and terns occurred in late May and consequently peak hatch in mid-late June. Unfortunately, due to the late date of the contract award, radio data-loggers were not placed on the islands until peak hatch had already occurred (**Figure 11**). Thus, our gull activity results should be interpreted as potential impacts to chick survival. The overall patterns suggest that Pond A16 nesting colonies also experienced significant pressure from California Gulls during nest initiation as well.

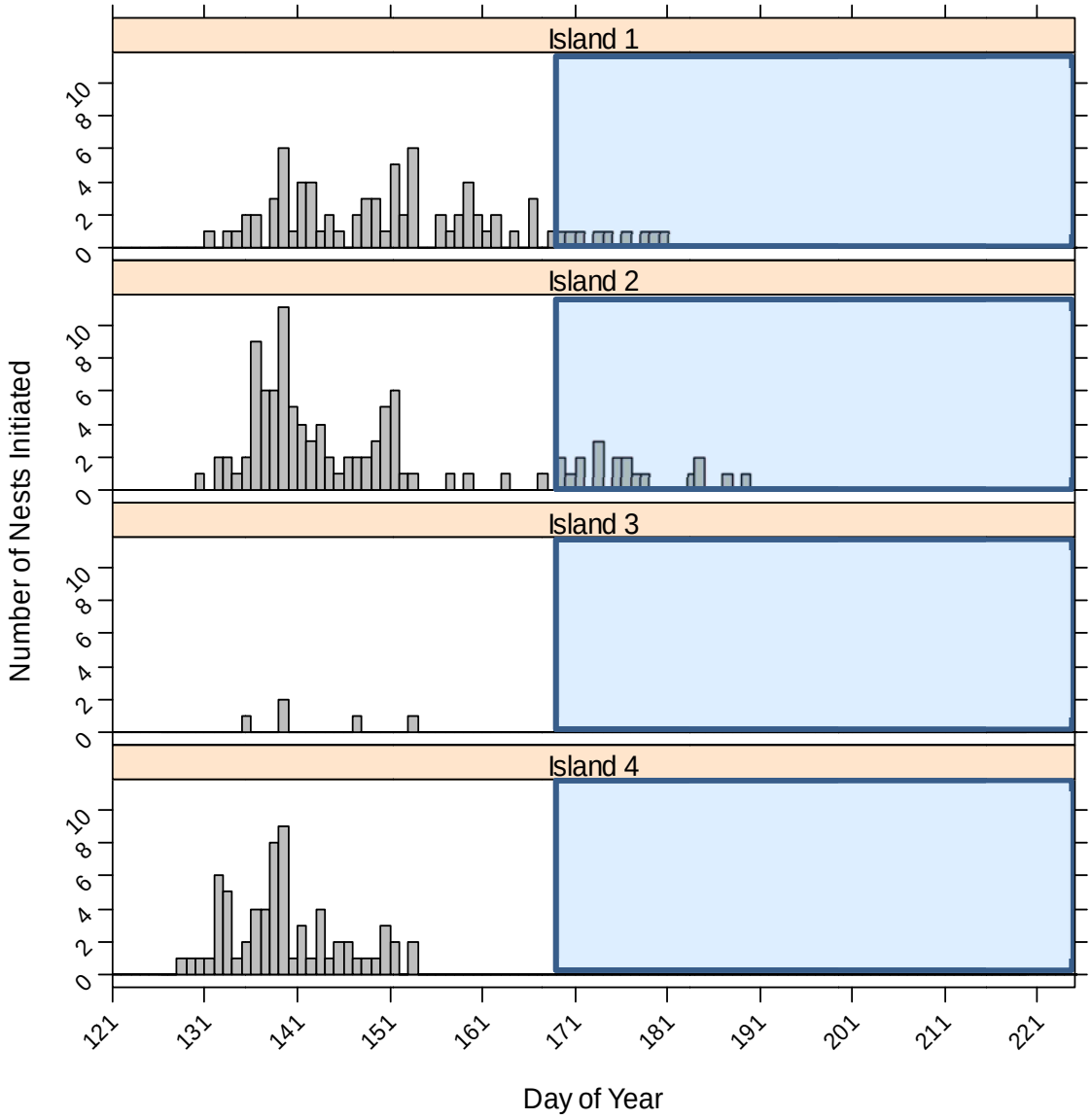

Figure 11. Distribution of waterbird nest initiation dates in 2009 at Pond A16 (within San Francisco Bay National Wildlife Refuge). The shaded box indicates the period of time the radio data-loggers were active.

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