



Black Rail Inventory at Cape Lookout and Cape Hatteras National Seashores



Marsh habitat on Bodie Island in Cape Hatteras National Seashore.
NPS

Black rail inventory at Cape Lookout and Cape Hatteras national seashores

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Abstract

The black rail (*Laterallus jamaicensis*) is the most secretive of the secretive marsh birds and one of the least understood species in North America. On the east coast, eastern black rails historically bred in tidal and freshwater marshes along the Atlantic coast from Massachusetts, south to Florida. Within the mid-Atlantic region suitable black rail habitat is concentrated in the high marsh along the upper elevational zone of salt marshes. This zone is dominated by salt meadow hay (*Spartina patens*), saltgrass (*Distichlis spicata*), and is often interspersed with shrubs such as marsh elder (*Iva frutescens*) or saltbush (*Baccharis hamifolia*).

North Carolina has been a stronghold for eastern black rails within the mid-Atlantic region, with the marsh complexes associated with the lower Pamlico sound supporting one of largest concentrations and highest densities of eastern black rails throughout their range. However, even within these marshes, eastern black rail populations have experienced declines marked by reductions in occupied sites and decline in numbers within historic strongholds. Evidenced by increasing confinement to the highest portions of the high marsh in recent years, sea-level rise and increased rates of high marsh inundation are likely a major contributing factor to declines. With the population of eastern black rails declining over 75% in the last 10–20 years, the U. S. Fish and Wildlife Service formally listed the eastern black rail as threatened under the endangered species act on 9 November 2020 (USFWS 2020).

To fulfill the need for information to guide management decisions on projects at Cape Lookout and Cape Hatteras National Seashores and to aide in (potential?) future designations of critical habitat, we conducted widespread, systematic surveys for black rails and other secretive marsh birds within the parks during the breeding seasons of 2022 and 2023.

A total of 1,222 surveys were conducted at 431 points over the course of 2 years. In addition to recording detections of all focal species, we recorded detections of 6 eastern black rails on North Core Banks where they were not previously known to occur. The population of black rails occupying the high marsh habitat on North Core Banks could account for 5–10% of the North Carolina black rail population and increase the known sites occupied within the state.

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Background

The black rail (*Laterallus jamaicensis*) is the most secretive of the secretive marsh birds and one of the least understood species in North America. Black rails are the smallest member of the rail (Rallidae) family. Adult eastern black rail (*Laterallus jamaicensis jamaicensis*), measure 10–15 centimeters (cm) in total length, have a mass averaging 35 grams (g) and have a wingspan that ranges from 22–28 cm. Adults of both sexes are similar in size. Both sexes exhibit plumage that is pale to blackish gray, with a chestnut-colored nape. Upper tail coverts and flight feathers are dark gray to blackish with small white spots. Flanks, under tail coverts, and lower abdomen are dark gray to blackish and show thin white and gray barring that is washed with chestnut. Males typically exhibit darker plumage overall with gray throats while females are paler overall and have pale gray to white throats. The bill is small and black (Eddleman et al. 1994). Leg color can range from brownish gray to blackish brown (Meanley and Stewart 1960).

Eastern black rails make several vocalizations. The most commonly heard call is advertising call of adult males which has been described as “kic-kic-kerr”, “kickee-doo” and “ki-ki-krrr” (Kellogg 1962, Davidson 1992). The “ki-ki-krrr” call can be quite loud and heard for some distance given calm conditions. Other vocalizations used as contact calls and alarm calls include the growl or “grrr” and “churt” (Conway 2011). The growl and churt are lower decibel calls and are not as detectable at longer distances as the classic “ki-ki-krrr”. Both sexes of black rails have been shown to respond to playback calls with a variety of vocalizations (Legare et al. 1999).

Eastern black rails historically bred in tidal and freshwater marshes along the Atlantic coast from Massachusetts, south to Florida, west along the gulf coast to South Texas and scattered locations across the mid-continent from Texas to the Great Lakes, west to Colorado and east of the Appalachian Mountains (Eddleman et al. 1994). The ideal nesting habitat is grassy vegetation that forms dense cover with an open understory and water levels not exceeding 6cm (Eddleman et al. 2020, Flores and Eddleman 1995, Legare and Eddleman 2001). Within the mid-Atlantic region suitable black rail habitat is concentrated in the high marsh along the upper elevational zone of salt marshes (Davidson 1992, Eddleman et al. 1994). This zone is dominated by salt meadow hay (*Spartina patens*), saltgrass (*Distichlis spicata*), and is often interspersed with shrubs such as marsh elder (*Iva frutescens*) or saltbush (*Baccharis hamifolia*). Historically the upper high marsh was only inundated during extreme high tide events (Cowardin 1977). If the high marsh habitat is prone to frequent inundation of over 6cm, vegetated refuges of higher elevation must be available and accessible.

In general, the character of the high marsh is a short-grass savannah. The high marsh forms as isolated hummocks on elevated portions within marshes or more frequently, along the upland-marsh edge. The ecotone between the upland and marsh sometimes includes stunted pine trees (*Pinus* spp.) and eastern red cedar (*Juniperus virginiana*). Additional features of Black Rail habitats may include the presence of salt pannes (higher saline patches dominated by *Salicornia* sp.) and patches of needle rushes (*Juncus* spp.) in wetter zones. In lower salinity marshes and non-tidal marshes, Black Rails are found in vegetation communities that are a mix of rushes (*Juncus* spp.), sedges (*Carex* spp.),

sawgrass (*Cladium* sp.), and cattails (*Typha* spp.) (Wilson, Watts and Poulton 2016). Marsh patch size is very important, with black rail occupancy increasing as the patch size of the high marsh habitat increases (Roach and Barret 2015).

North Carolina has been a stronghold for eastern black rails within the mid-Atlantic region, with the marsh complexes associated with the lower Pamlico sound supporting one of largest concentrations and highest densities of eastern black rails throughout their range (Watts 2016). However, even within these marshes, eastern black rail populations have experienced declines marked by reductions in occupied sites and decline in numbers within historic strongholds. This trend is analogous to declines in other regions of the mid-Atlantic. Most sites on the outer coast of North Carolina, that were regularly occupied from the 1980s to the early 2000s, have not had detections of black rails during the breeding season in recent years (Watts 2016).

Based on widescale surveys of the outer coast in 2014–2016, a soft population estimate of breeding black rails in North Carolina would be 40–60 pairs. However, due to the lack of complete coverage, the remoteness and inaccessibility of some extensive marsh systems and the difficulty in accurately surveying this secretive species, there is a level of uncertainty to this estimation (Watts 2016, Wilson, Watts and Poulton 2016).

The reasons for significant declines in the numbers of black rails are not definitive, but stressors such as habitat loss and degradation, predation, low reproductive rates, low survival, and environmental contaminants could be contributing factors (Wilson, Watts and Poulton 2016). Evidenced by increasing confinement to the highest portions of the high marsh in recent years, sea-level rise and increased rates of high marsh inundation are likely a major contributing factor to declines (Watts 2016). With the population of eastern black rails declining over 75% in the last 10–20 years, the U. S. Fish and Wildlife Service formally listed the eastern black rail as threatened under the Endangered Species Act on 9 November 2020 (USFWS 2020).

Prior to these surveys, conducted in 2022 and 2023, no widespread, systematic surveys for Black Rail had been conducted at Cape Lookout (CALO) and Cape Hatteras (CAHA) National Seashores. Given the secretive nature of this marsh dwelling bird, and associated bird species, little is known about its occurrence, distribution, and abundance at CALO and CAHA. An inventory of secretive marsh birds was required to inform management decisions on park projects including a cabin relocation project (demolition and construction), road/trail construction, dock construction, and dredging projects associated with hurricane recovery in a near marsh habitat. In addition, accurate population surveys for the eastern black rail would benefit both Seashore's management of potential future critical habitat designations.

Objectives

Our objectives for conducting widespread, systematic surveys for black rails and other secretive marsh birds was to fulfill the need for information to guide management decisions on park projects, including those associated with hurricane recovery, and to aide in potential future designations of critical habitat. Specific projects related to hurricane recovery include but are not limited to cabin relocation projects (demolition and construction), road/trail construction, dock construction, and dredging projects associated with hurricane recovery in a near marsh habitat.

Specific goals were:

1. Conduct widespread, systematic surveys for black rails and other secretive marsh birds within the study area over two breeding seasons (2022 at CALO and 2023 at CAHA).
2. Analyze observation data to determine abundance, occupancy, and predicted distribution of black rails in the study area.
3. Given sufficient data, analyses of observation data of other species of secretive marsh birds (to include clapper rail, Virginia rail, seaside sparrow, marsh wren and sedge wren).
4. Given sufficient data, develop a habitat suitability model for black rails within CALO and CAHA to inform park management of habitat where black rails are most likely to occur.

Study Area

The study for the 2022 and 2023 black rail and secretive marsh bird surveys was in Cape Lookout (CALO) and Cape Hatteras (CAHA) National Seashores. Surveys in 2022 were conducted on all portions of CALO with the exception of the northern most 2.3 miles of North Core Banks. CALO consists of 3 islands (Shackleford Banks, South Core Banks and North Core Banks) between Ocracoke Inlet to the north and Beaufort Inlet to the south. The park encompasses over 28,000 acres of beach, marsh, water, and maritime forest along 56 miles of barrier islands within Carteret County, North Carolina (Figure 1). Surveys in 2023 were focused at CAHA and the northern most 2.3 miles of North Core Banks. CAHA is comprised of portions of 2 islands (Ocracoke Island and Hatteras Island) and the Bodie Island district and stretches over 70 miles from Ocracoke Inlet on the southern end to Nags Head to the north. CAHA contains over 30,000 acres of beach, marsh, water, and maritime forest in the counties of Hyde and Dare in coastal North Carolina (Figure 2).



Figure 1. Map of Cape Lookout (CALO) National Seashore with red polygon indicating the approximate boundary of the park.



Figure 2. Map of Cape Hatteras (CAHA) National Seashore with red polygon indicating the approximate boundary of the park.

Methods

Survey Point Selection

Data from the vegetation mapping inventory of CALO and CAHA was used to identify possible black rail habitat (NPS 2014a and NPS 2014b). For these surveys, possible black rail habitat was any non-regularly inundated non-forested wetland, forest, shrub thicket, dune swale, and especially high marsh, if they contained or were associated with a *Spartina* sp. or *Juncus roemerianus* component. Survey points were situated as close as possible to the high marsh/forested wetland and upland ecotone, within marsh habitat patches, and along the shoreline of habitat patches with approximately 400m between the closest adjacent points. Survey points at CALO were situated within all possible black rail habitat patches that were reasonably and safely accessible by vehicle, foot, or kayak at CALO. At CAHA priority was given to larger patches of *Spartina* or *Juncus roemerianus* associated with larger marsh complexes that were reasonably and safely accessible by vehicle, foot, or kayak.

Survey Protocol

Crepuscular surveys were conducted during both the morning and evening on days without steady rain and winds of less than 20 mph. Morning surveys were conducted from 2 hours before sunrise to 2 hours after sunrise, and evening surveys from 2 hours before sunset to 2 hours after sunset. Efforts were made to survey each point once during each of 3 survey periods. Survey periods were: 1 (May 2-May 24), 2 (May 25-June 19) and 3 (June 20-July 15). Observers navigated to survey points using handheld GPS devices loaded with coordinates of the survey points. Upon arriving at the survey point, a digital audio file of black rail calls was initiated on the FoxPro game callers. Game callers were placed on 4-foot garden shepherd hooks, sunk in the ground with the primary speaker directed into the habitat patch. Caller volume was set to approximately 80 db and broadcast a 10-minute sequence of alternating silent listening periods and black rail vocalizations. Vocalizations included a combination of ki-ki-kerr, churt, growl and eek-eek calls that are consistent with broader surveys effort throughout the east coast. Surveyors stood approximately 5 m away from the caller to facilitate detections of all responses.

Following the standardized marsh bird data collection methods recommended by Conway (2011), aural and visual detections of all focal species (black rail, Virginia rail, clapper rail, seaside sparrow, marsh wren, and sedge wren) were recorded on separate lines of the data sheet with estimation of distance and direction. Distances, directions, and timing of calls were used to discriminate multiple individuals of the same species. Multiple detections of the same individual during the survey were tracked on a minute-by-minute basis. Environmental and temporal variables were collected at each point that may have influenced detection including date, time, wind speed (Beaufort Wind Scale), sky conditions (U.S. Weather Bureau scale 0–5, clear/<25% cloud cover, 25–75% cloud cover, 75–99% cloud cover, overcast, fog, and drizzle), and background noise (scale 0–4, no noise, faint noise, moderate noise that limits detection to 100m, loud noise that limits detection to 50m, and , intense noise that limits detection to 25m). In addition to the focal species, efforts were made to record tallies of both common nighthawk and chuck-wills-widows detected during surveys.

Statistical Analysis

We extracted the composition of vegetation alliances from the vegetation mapping inventory of CALO and CAHA for 50m, 100m and 200m buffers surrounding each survey point using Esri ArcPro (NPS 2014a and NPS 2014b). To simplify analyses, we grouped similar alliances into broad groups including open water, dune vegetation, high marsh, brackish marsh, low marsh, and *Phragmites australis*-dominated, shrub scrub, upland forest, and other upland (Table 1).

Table 1. Vegetation alliances and other habitat types that were grouped into broad habitat categories used for occupancy analyses. Broad categories include high marsh (HM), low marsh (LM), brackish marsh (BM), phragmites, shrub, dune, forest, open water, other upland. Table includes the number of points that each alliance appeared within 50, 100, and 200 m of each survey point (n_50, n_100, and n_200 respectively) as well as the percentage of each within 50, 100, and 200 m of each survey point (%50, %100, and %200 respectively).

New Vegetation Group	Alliance	n50	n100	n200	%50	%100	%200
BM	Cladium mariscus ssp. jamaicense Tidal Temperate Herbaceous Alliance	2	5	11	0%	0%	0%
BM	Typha domingensis Seasonally Flooded Temperate Herbaceous Alliance	1	5	11	0%	0%	0%
BM	Cladium mariscus ssp. jamaicense Tidal Herbaceous Alliance	3	7	15	0%	0%	0%
BM	Juncus roemerianus Tidal Herbaceous Alliance	156	301	722	7%	9%	11%
Dune	Muhlenbergia filipes Herbaceous Alliance	2	7	20	0%	0%	0%
Dune	Uniola paniculata Temperate Herbaceous Alliance/Spartina patens - (Schoenoplectus pungens/ Eremochloa ophiuroides Herbaceous Alliance	67	122	292	6%	6%	6%
Dune	Uniola paniculata Temperate Herbaceous Alliance/Muhlenbergia filipes Herbaceous Alliance/Spartina patens - (Schoenoplectus pungens) Herbaceous Alliance	215	317	635	18%	18%	14%
Forest	Quercus virginiana-Ilex vomitoria-(Morella cerifera) Shrubland Alliance	3	5	6	0%	0%	0%
Forest	Quercus virginiana-(Sabal palmetto) Forest Alliance	9	9	14	0%	1%	1%
Forest	Quercus virginiana-(Sabal palmetto) Forest Alliance / Quercus virginiana-Ilex vomitoria-(Morella cerifera) Shrubland Alliance	4	7	20	0%	0%	0%
Forest	Pinus taeda-Quercus nigra Forest Alliance / Pinus elliotii Planted Forest Alliance	5	12	28	0%	0%	0%
Forest	Pinus elliotii Planted Forest Alliance / Pinus taeda - Quercus nigra Forest Alliance	12	21	74	1%	1%	1%
HM	Sarcocornia perennis-(Distichlis spicata, Salicornia spp.) Tidal Herbaceous Alliance	1	1	2	0%	0%	0%
HM	Spartina patens-(Distichlis spicata) Tidal Herbaceous Alliance	102	156	396	7%	7%	6%
HM	Spartina patens-(Distichlis spicata) Tidal Herbaceous Alliance / Fimbristylis castanea-Schoenoplectus pungens/ Typha domingensis Flooded Herbaceous Alliance	158	217	510	10%	11%	10%
LM	Spartina alterniflora Tidal Herbaceous Alliance	39	108	385	1%	2%	3%
Open Water	Streams and Canals	1	4	4	0%	0%	0%
Open Water	NA	16	32	90	1%	2%	3%
Open Water	Water	38	77	214	2%	2%	3%

Table 1 (continued). Vegetation alliances and other habitat types that were grouped into broad habitat categories used for occupancy analyses. Broad categories include high marsh (HM), low marsh (LM), brackish marsh (BM), phragmites, shrub, dune, forest, open water, other upland. Table includes the number of points that each alliance appeared within 50, 100, and 200 m of each survey point (n_50, n_100, and n_200 respectively) as well as the percentage of each within 50, 100, and 200 m of each survey point (%50, %100, and %200 respectively).

New Vegetation Group	Alliance	n50	n100	n200	%50	%100	%200
Open Water	Bays and Estuaries	91	143	343	8%	7%	7%
Phrag	Phragmites australis Tidal Herbaceous Alliance	12	23	80	1%	1%	1%
Shrub	Morella cerifera / Saturated Shrubland Alliance	6	12	31	0%	0%	0%
Shrub	Baccharis halimifolia-Iva frutescens Tidal Shrubland Alliance / Borrchia frutescens Tidal Herbaceous Alliance	6	9	32	0%	0%	0%
Shrub	Baccharis halimifolia-Iva frutescens Tidal Shrubland Alliance / Borrchia frutescens Tidal Shrubland Alliance	16	31	82	1%	1%	1%

We constructed single-season occupancy models using bird detections with the package ‘unmarked’ (Fiske and Chandler 2011) in Program R (R Core Team 2023) for black rail, clapper rail, Virginia rail, chuck-wills-widow, common nighthawk, seaside sparrow, and marsh wren. We first evaluated whether the inclusion of environmental predictors within the detection function improved model while using only the intercept (zero predictors) within the occupancy function. Environmental factors that we compared included wind (scale 0–5), temperature (°F), sky (0–5), background noise (scale 0–4), day of year, a polynomial factor for day of year to account for the possibility greater or poorer detection during the middle of the survey season, time (hr) before sunrise or after sunset (whichever was nearest), absolute time (hr) relative to sunrise and sunset (whichever was nearest), and whether the survey occurred when the sun was above or below the horizon (day/night). We also compared models with interactions between time and absolute time relative to sunset/sunrise and whether the surveyed occurred during day/night. We then selected the best model according to Akaike information criterion (AICc)scores. If competing models were within 2 AICc points of each other, we created an additive model that included predictors from both models and chose the model with the lowest AICc score. After selecting the predictors to be included in the detection function, we compared two model sets, one that included a term for park identity (CAHA or CALO) and one without a park identity term. Each model set included a model with one other predictor for percent cover high marsh, low marsh, brackish marsh, and Phragmites dominated habitat within 50, 100, and 200 m of each survey point. We then selected the best model according to AICc scores. If competing models were within 2 AIC points of each other, we created an additive model that included predictors from the top competing models and then determined whether any of those predictors were uninformative (Leroux 2019). If all predictors were informative, we chose the model with the lowest AICc score. All continuous predictors were scaled prior to analysis.

Results

Black Rail and Focal Species Survey

A total of 1,222 surveys were conducted at 431 survey points during the 2022 and 2023 seasons (Appendix A). Surveys at CALO in 2022, and single surveys at 5 points near Portsmouth Village in 2023, were comprised of 613 surveys at 224 survey points (Appendix B). In 2023 surveys at CAHA consisted of 609 surveys at 207 survey points (Appendix C). The vast majority (86.8% N=369) of survey points were surveyed at least three separate times during the breeding season, with a small subset of points on Ocracoke Island having a fourth round of surveys conducted at the end of last survey period. Due to a combination of factors such as inclement weather, flooding of interior marsh points, underestimating difficulty of access, and expansion of bird nesting closures, several points (13.2% N=49) were only surveyed once or twice. The occupancy model we used had no difficulty processing unbalanced sampling schedules. The result of fewer visits to any particular site is that the error of for predictors associated with the site will be higher, and additional visits refine error for predictors associated with those sites.

Surveys in 2022, at CALO, resulted in the detection of least one individual of each of the focal species, except sedge wren. During surveys conducted at CAHO in 2023, at least one individual of each of the focal species was encountered with the exception of black rail. Detection numbers ranged from a single sedge wren detected at point 'O9' on Ocracoke to 248 clapper rails encountered throughout both parks.

Black Rails

We observed zero black rails at CAHA and recorded six black rail observations at three locations in CALO. Four observations occurred at point 'P71' including two on 21 May 2021 and two on 23 June 2022. The other black rail observations included a single bird at points 'P72' and 'P73' on 23 June 2022 (Figure 3 and Figure 4). Based on the timing of calls, recorded direction and distance, it is possible the two detections recorded at point 'P71' on 23 June 2022 was a single black rail. During the 23 June 2022 survey at 'P71' a single black rail was vocalizing the "ki-ki-krrr" call during minutes 1 through 8 of the 10-minute survey period at an estimated distance of 51–100m and a bearing of 115 degrees. No calling was recorded for minutes 9 and 10. After the survey was completed, a bird started vocalizing the "ki-ki-krrr" call at an estimated distance of 26–50m and a bearing of 140 degrees. It is possible that the black rail recorded after the end of the survey is the same bird recorded during the survey and was moving toward the caller. The two black rails observations recorded on 21 May 2022 were believed to have been separate individuals based on call timing and direction and distance of calls. Due to two black rails detections at 'P71' on 21 May 2022 and the inability to confirm only a single black rail on 23 June 2022, we used both 23 June 2022 detections in analyses.



Figure 3. Map of points on North Core Banks with black rail detections displayed as average number of detections per survey.

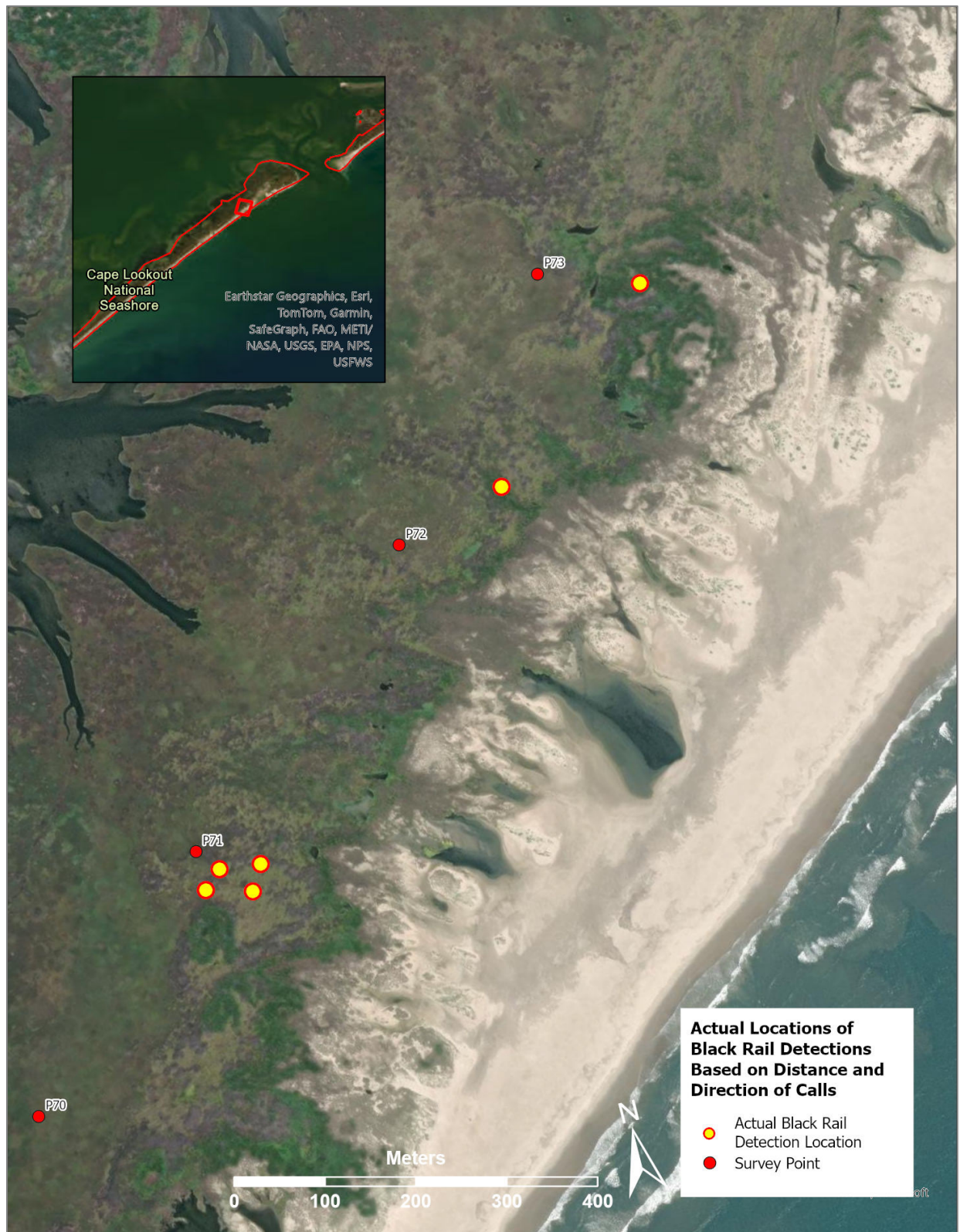


Figure 4. Map of actual black rail detection locations based on calculations of detection distances and directions.

Four black rail observations occurred during morning daylight hours and two occurred during evening nighttime hours. Data for this species was particularly sparse (detected at 0.7% of survey locations) and many of the models were unable converge and estimate error for predictors. Therefore, we used the intercept-only model and estimated detection at 0.27 ± 0.21 and occupancy at $1.2 \pm 0.09\%$.

Clapper Rail

We recorded 45 clapper rail observations at 35 locations in CAHA and 203 clapper rail observation at 92 survey points at CALO (Figures 5–11). The top occupancy model for clapper rail (Appendix D) included time relative to sunrise/sunset ($\beta = 0.23 \pm 0.10$, $p = 0.005$), whether the survey occurred during day or night ($\beta_{\text{night}} = -1.27 \pm 0.25$, $p < 0.001$) and an interaction between those terms ($\beta_{\text{crepXnight}} = -0.72 \pm 0.28$, $p < 0.010$) in the detection function. Our model predicted detection to be 0.49 ± 0.04 at sunrise and 0.21 ± 0.04 at sunset. The top model included park identity ($\beta_{\text{CALO}} = 1.41 \pm 0.32$, $p < 0.001$), low marsh cover within 200 m ($\beta = 0.63 \pm 0.30$, $p = 0.039$), and open water cover within 100 m ($\beta = 0.90 \pm 0.1$, $p < 0.001$) within the occupancy function. Our model predicted occupancy to be 0.24 ± 0.05 at Cape Hatteras and 0.56 ± 0.06 at Cape Lookout using mean cover of low marsh within 200 m and open water within 100 m of a survey point.

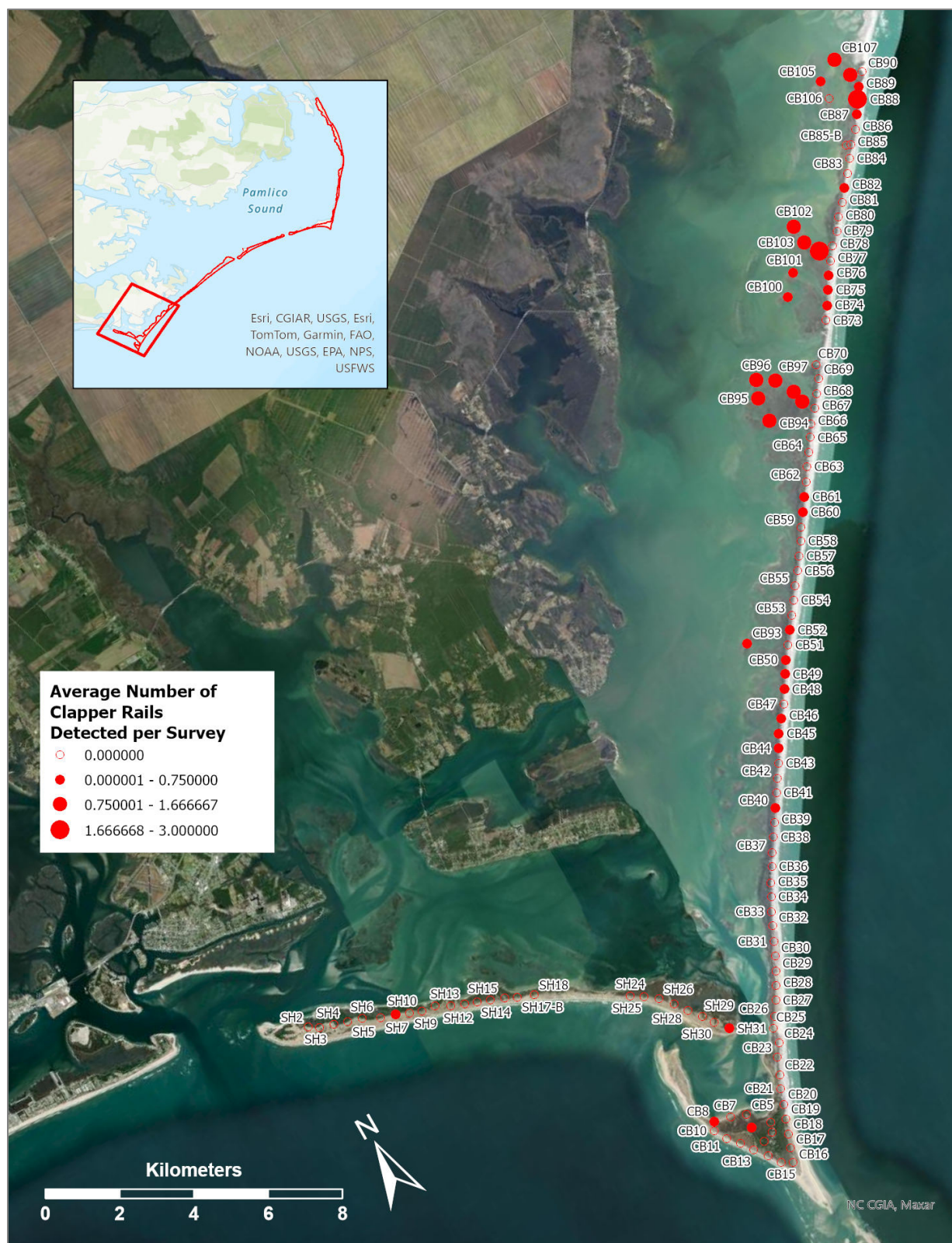


Figure 5. Map of points on Shackleford Banks and South Core Banks (CALO) with clapper rail detections displayed as average number of detections per survey.



Figure 6. Map of points on North Core Banks (CALO) with clapper rail detections displayed as average number of detections per survey.



Figure 7. Map of points on Ocracoke Island (CAHA) with clapper rail detections displayed as average number of detections per survey.



Figure 8. Map of points on south Hatteras Island and Avon area (CAHA) with clapper rail detections displayed as average number of detections per survey.



Figure 9. Map of points near Salvo (CAHA) with clapper rail detections displayed as average number of detections per survey.



Figure 10. Map of clapper rail detections at Pea Island NWR.



Figure 11. Map of points at Bodie Island (CAHA) with clapper rail detections displayed as average number of detections per survey.

Virginia Rail

We recorded 7 Virginia rail observations at seven locations in CAHA and two Virginia rail observations at two survey points at CALO (Fig 12, 13, and 14). Eight of the nine observations occurred between 02 and 07 May with the other detection occurring 07 June. The top occupancy model for Virginia rail (Appendix E) included day of year ($\beta = -2.70 \pm 1.08$, $p = 0.012$) in the detection function. Predicted detection rate was approximately zero (at 0.002 ± 0.002). The top model included low marsh cover within 100 m ($\beta = 16.6 \pm 83.9$, $p = 0.795$), open water cover within 50 m ($\beta = -70.7 \pm 201.9$, $p = 0.726$) of the survey point and park identity ($\beta_{\text{CALO}} = -17.9 \pm 47.9$, $p = 0.708$) in the occupancy function. Our model predicted occupancy at nearly zero at both CAHA and CALO (2.13×10^{-13} and 3.49×10^{-21} , respectively). The model predictions are a product of all detections occurring at only a single location. These locations were almost all during the early portion of the survey season when Virginia rails are migrating (Figure 15).

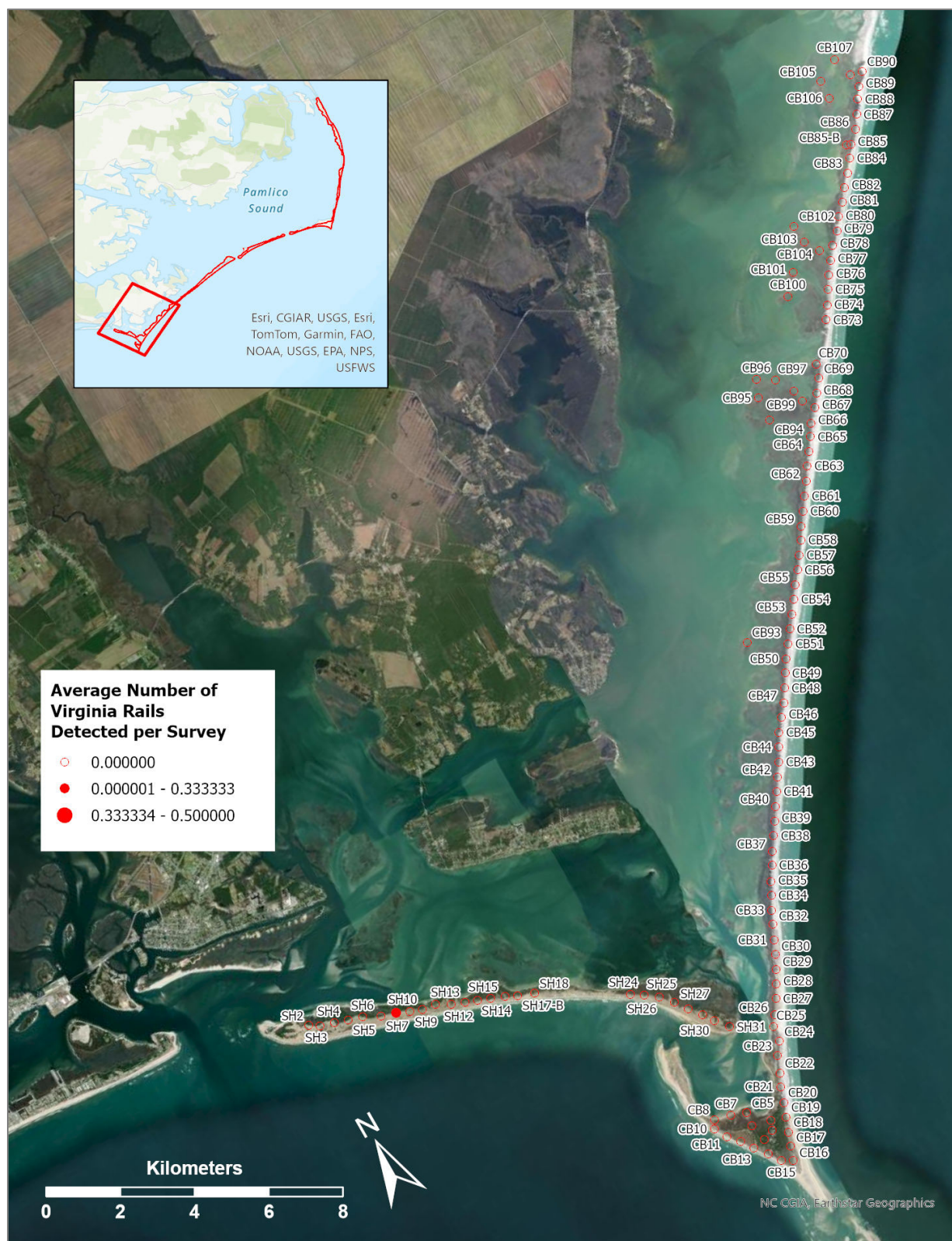


Figure 12. Map of points on Shackleford Banks and South Core Banks (CALO) with Virginia rail detections displayed as average number of detections per survey.





Figure 14. Map of points at Bodie Island (CAHA) with Virginia rail detections displayed as average number of detections per survey.

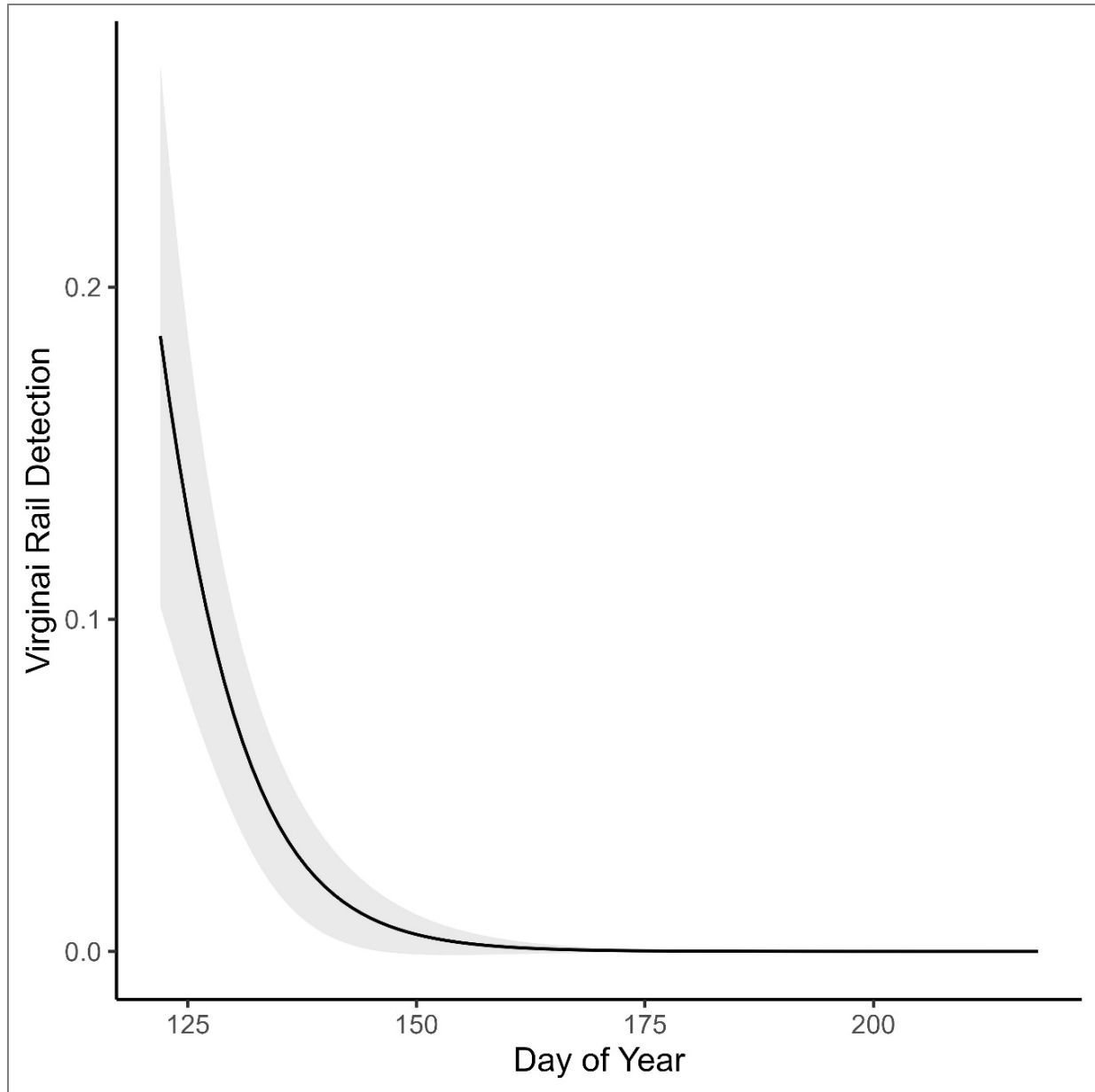


Figure 15. Plot of Virginia rail detections by day of year. Most detections occurred early in the breeding season and are likely late migrants that have yet to move north.

Marsh Wren

We recorded three marsh wren observations at three locations in CAHA and one marsh wren at a single location at CALO (Figure 16, Figure 17, and Figure 18). Three observations occurred between 02 May and 04 May with the fourth bird occurring on 06 July. Data for this species was extremely sparse and intercept-only models failed to converge. We estimate raw occupancy at 0.009(4/431 survey points). As with Virginia rails, most marsh wren detections occurred early in the breeding season and are believed to be migrant birds that have yet to move north.

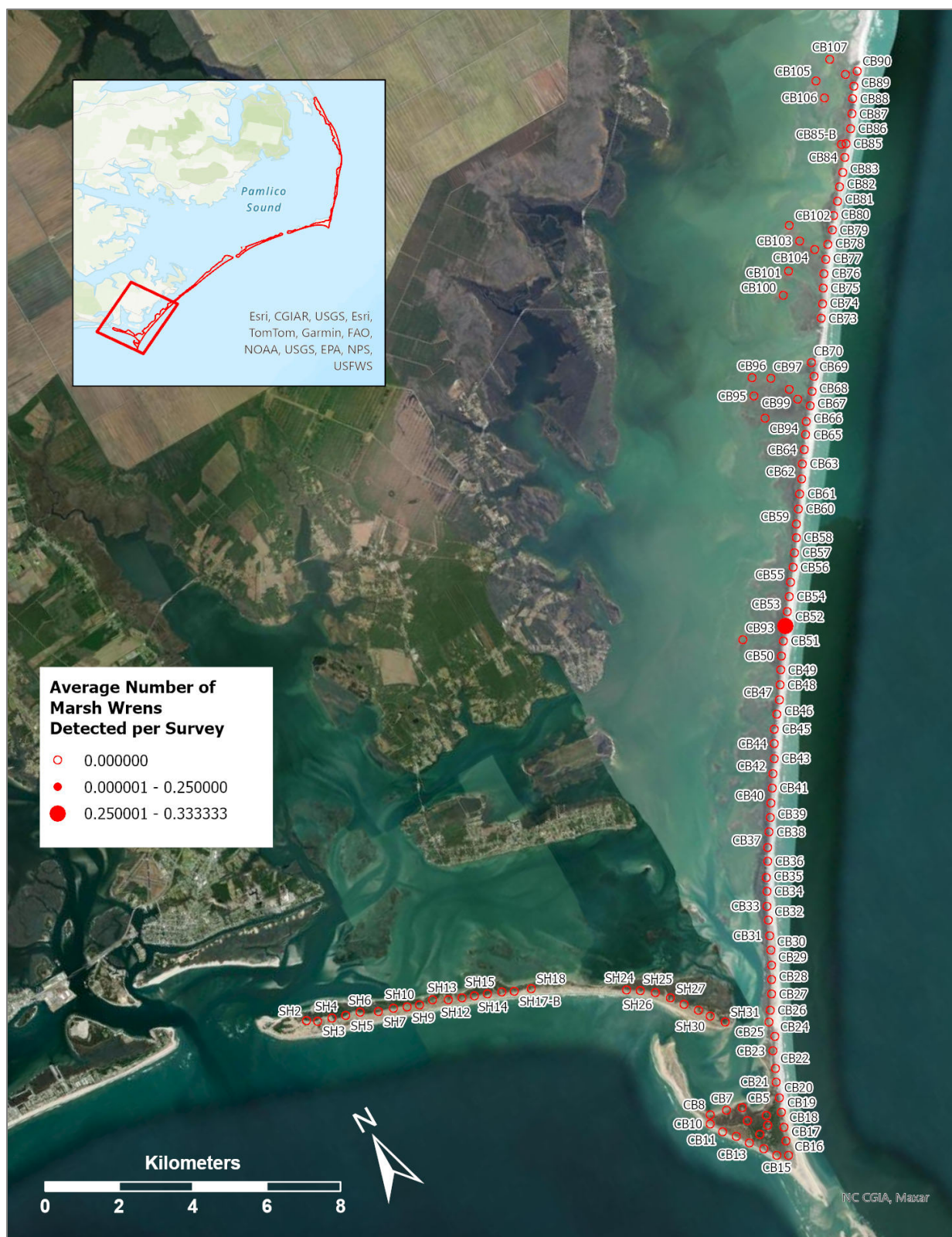


Figure 16. Map of points at Shackleford Banks and South Core Banks (CALO) with marsh wren detections displayed as average number of detections per survey.



Figure 17. Map of points on Ocracoke Island (CAHA) with marsh wren detections displayed as average number of detections per survey.



Figure 18. Map of points at Bodie Island (CAHA) with marsh wren detections displayed as average number of detections per survey.

Sedge Wren

We recorded one sedge wren at a single location in CAHA and observed zero sedge wrens at CALO (Figure 19). This bird was recorded at 'O9' on 05 May 2023. Data for this species was extremely sparse and intercept only models failed to converge. We estimate raw occupancy at 0.002 (1/441 survey points). This individual was detected early in the breeding season and is believed to be a migrant.



Figure 19. Map of points on Ocracoke Island (CAHA) with sedge wren detections displayed as average number of detections per survey.

Seaside Sparrow

We recorded 38 seaside sparrow observations at 23 locations in CAHA and 147 seaside sparrow observations at 58 survey points at CALO (Figures 20–26). The top occupancy model for seaside sparrows (Appendix F) included time relative to sunrise ($\beta=0.13\pm0.11$, $p = 0.235$), whether the survey occurred during day or night ($\beta_{\text{night}}=-1.38\pm0.34$, $p<0.001$) and an interaction between those terms ($\beta_{\text{crepXnight}}=-0.62\pm0.38$, $p=0.105$) in the detection function. Detection was estimated at 0.45 ± 0.04 at sunrise and 0.17 ± 0.05 at sunset. The top model included low marsh cover within 200 m ($\beta=1.59\pm0.40$, $p<0.001$) and open water cover within 50 m ($\beta=1.00\pm0.19$, $p<0.001$) of the survey point within the occupancy function. Occupancy was estimated at 0.26 ± 0.05 using mean low marsh cover within 200 m and open water cover within 50 m of survey point.

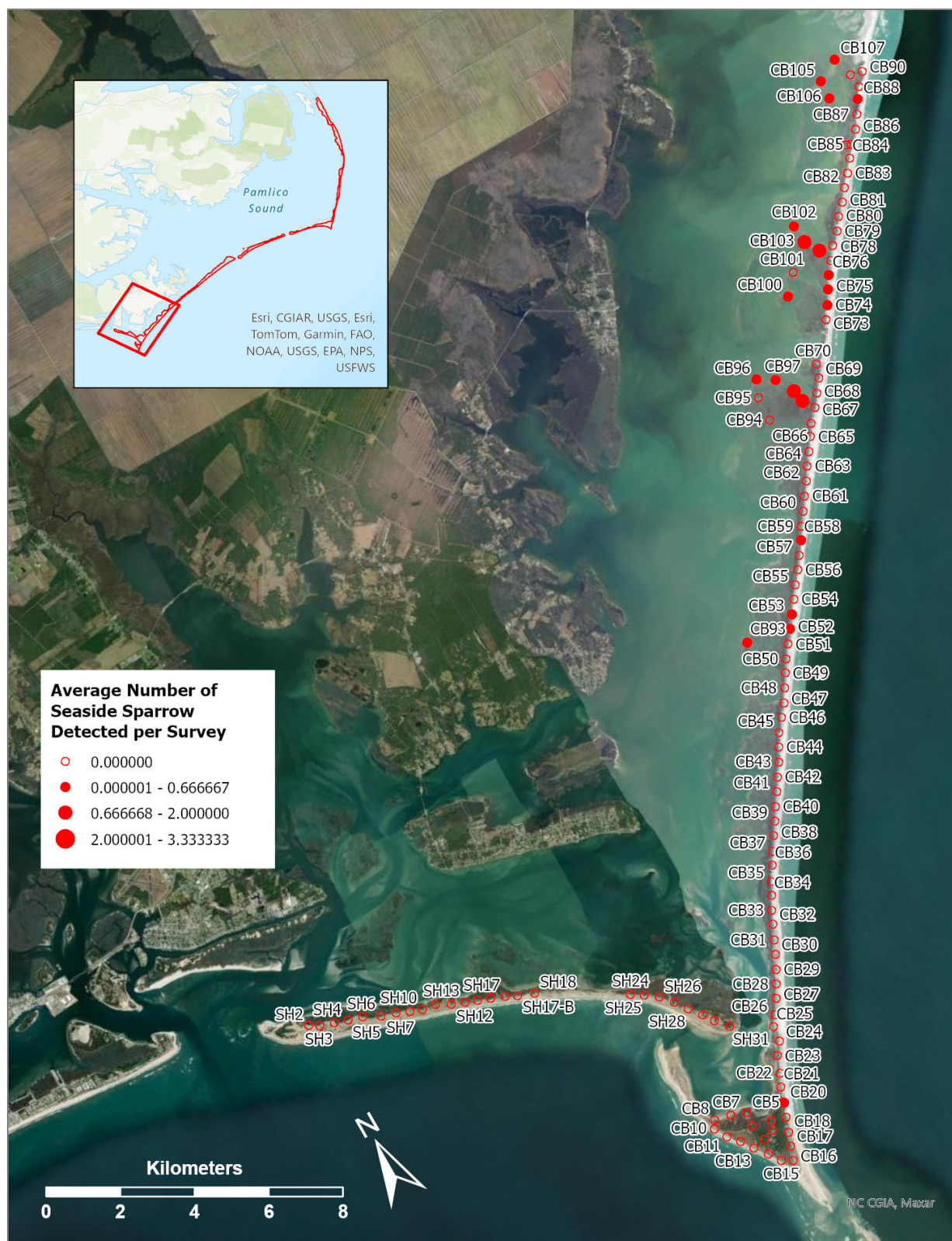


Figure 20. Map of points on Shackleford Banks and South Core Banks (CALO) with seaside sparrow detections displayed as average number of detections per survey.



Figure 21. Map of points on North Core Banks (CALO) with seaside sparrow detections displayed as average number of detections per survey.



Figure 22. Map of points on Ocracoke Island (CAHA) with seaside sparrow detections displayed as average number of detections per survey.



Figure 23. Map of points on south Hatteras Island and Avon area (CAHA) with seaside sparrow detections displayed as average number of detections per survey.



Figure 24. Map of points near Salvo (CAHA) with seaside sparrow detections displayed as average number of detections per survey.



Figure 25. Map of points at Pea Island NWR (CAHA) with seaside sparrow detections displayed as average number of detections per survey.



Figure 26. Map of points at Bodie Island (CAHA) with seaside sparrow detections displayed as average number of detections per survey.

Other Species of Interest

In addition to the focal species, detections were recorded for several other species of interest including American bittern, Nelson's sparrow, Chuck-will's-widow, and common night hawk. We recorded one American bittern at a single location in CAHA and observed zero American bitterns at CALO. This bird was recorded at 'B25' on 06 May 2023. Data for this species was extremely sparse and intercept-only models failed to converge. We estimate raw occupancy at 0.002 (1/431 survey points). We detected 3 Nelson's sparrows at 3 locations in CALO (CB48, CB49, and CB94), and a single Nelson's sparrow at 'O48' in CAHA. We estimate raw occupancy at 0.009 (4/431 survey points). All observations of both the American bittern and Nelson's sparrow occurred on or before 15 May and are considered observations of migrant birds.

Chuck-will's-widow

We observed nine chuck-will's-widows at five survey points in CAHA and 20 chuck-will's widow observations at nine survey points at CALO (Figure 27 and Figure 28). The top occupancy model for chuck-will's-widow (Appendix G) included whether the survey occurred during day or night ($\beta_{\text{night}}=4.04\pm0.97$, $p<0.001$) in the detection function. The model estimated detection at 0.76 ± 0.13 during night and 0.05 ± 0.03 during day. The top model included park identity ($\beta_{\text{CALO}}=1.04\pm0.60$, $p=0.083$) and brackish marsh cover within 50 m of the survey point ($\beta=0.44\pm0.21$, $p=0.038$). The model estimated occupancy at approximately 0.03 ± 0.02 at CAHA and 0.09 ± 0.03 at CALO. While one of the top models was brackish marsh cover within 50m, all Chuck-will's widow detections were birds calling in maritime forest habitat. Calling Chuck-will's-widow can be detected at distances greater than a kilometer away and the brackish marsh cover within 50m model should not factor into preferred habitat.

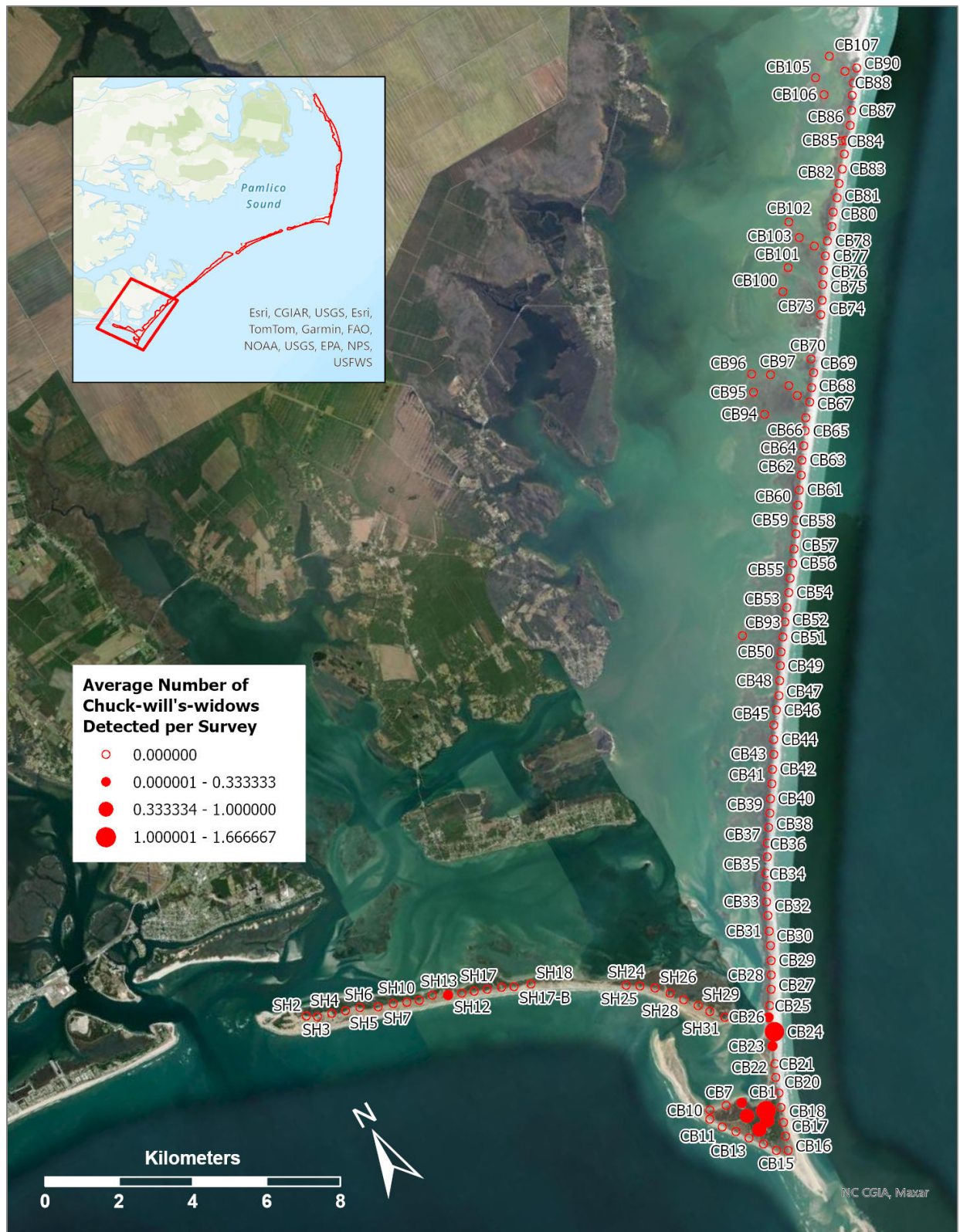


Figure 27. Map of points on Shackleford Banks and South Core Banks (CALO) with Chuck-wills-widow detections displayed as average number of detections per survey.



Figure 28. Map of points at Bodie Island (CAHA) with Chuck-wills-widow detections displayed as average number of detections per survey.

Common Nighthawk

We recorded 43 common nighthawk observations at 28 locations in CAHA and 434 common nighthawk observations at 83 survey points at CALO (Figures 29–33). The top occupancy model for common nighthawk (Appendix H) included the absolute time relative to sunset and sunrise ($\beta = -0.72 \pm 0.10$, $p < 0.001$) and whether the survey occurred during night or day ($\beta_{\text{night}} = 0.52 \pm 0.17$, $p = 0.002$) within the detection function. Detection was estimated at 0.54 ± 0.04 at sunrise and 0.66 ± 0.04 at sunset. The top model included park identity ($\beta_{\text{CALO}} = 12.03 \pm 25.85$, $p = 0.642$) and high marsh cover within 200 m of the survey point ($\beta = 0.69 \pm 0.22$, $p = 0.002$) within the occupancy function and estimated occupancy at 0.14 ± 0.03 at CAHA and 1.00 ± 0.001 at CALO.

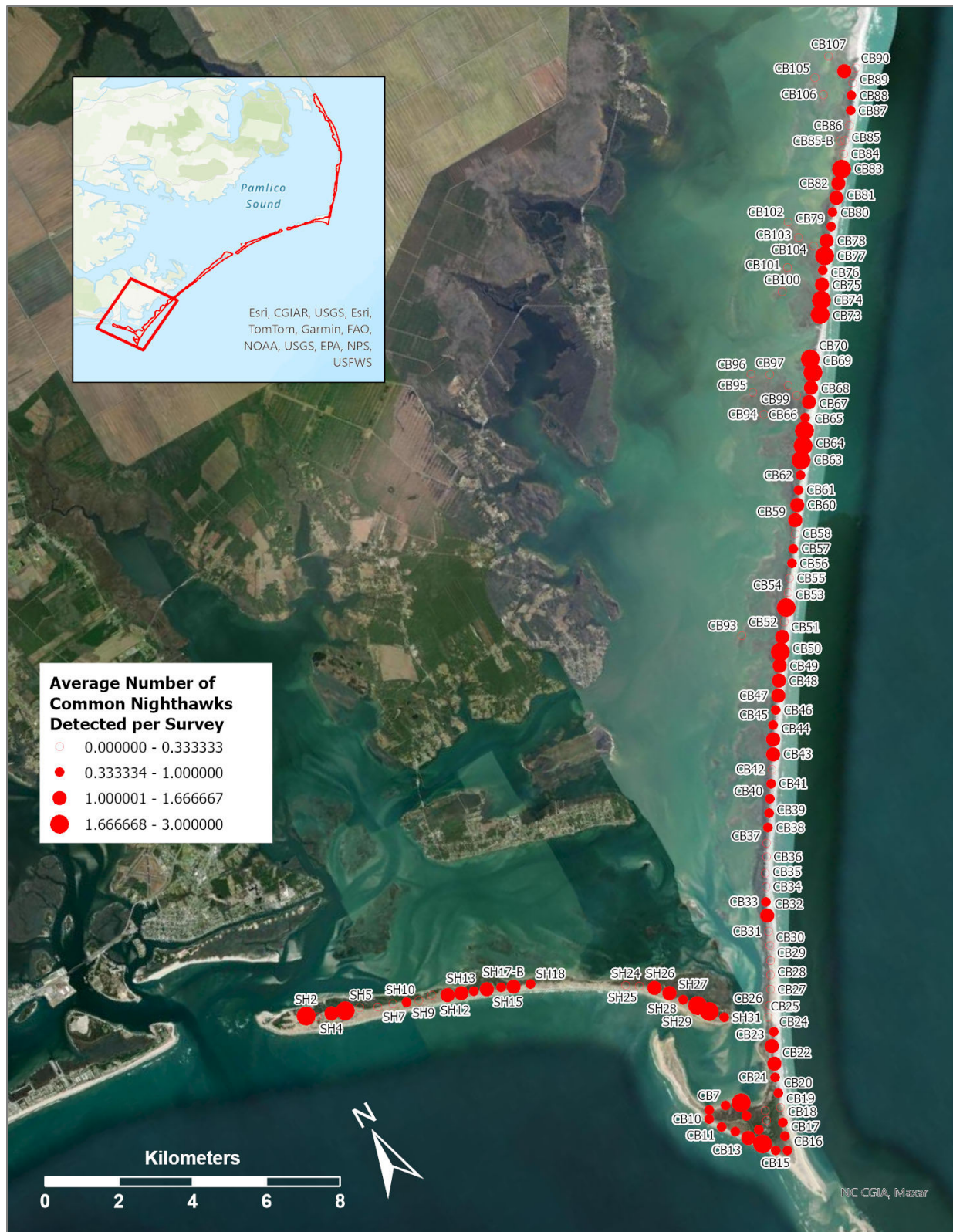


Figure 29. Map of points on Shackleford Banks and South Core Banks (CALO) with common nighthawk detections displayed as average number of detections per survey.



Figure 30. Map of points on North Core Banks (CALO) with common nighthawk detections displayed as average number of detections per survey.



Figure 31. Map of points on Ocracoke Island (CAHA) with common nighthawk detections displayed as average number of detections per survey.



Figure 32. Map of points on south Hatteras Island and Avon area (CAHA) with common nighthawk detections displayed as average number of detections per survey.



Figure 33. Map of points at Pea Island NWR (CAHA) with common nighthawk detections displayed as average number of detections per survey.

Discussion

Coastal North Carolina is an important stronghold for the eastern black rail. The region has the distinction of having more recent observations during the breeding season than any state to the north. The marshes associated with the lower Pamlico Sound, which include Cedar Island and Piney Island, support one of the largest concentrations and highest densities of black rails throughout their range (Watts 2016).

Despite their location in the lower Pamlico sound, and their proximity to other known locations for eastern black rails, no large-scale systematic survey had been conducted on the properties of Cape Lookout (CALO) and Cape Hatteras (CAHA) National Seashores. The marsh habitats of CALO and CAHA are ranked very highly for eastern black rails by Stevens and Conway (2021) due to the proportion of high-quality habitat, location on protected federal lands, and low level of development. These qualities are not only important for eastern black rails, but for other species such as clapper rails, and salt marsh sparrows that rely on these habitats for breeding.

Surveys for eastern black rails and other secretive marsh birds at CALO and CAHA in 2022 and 2023 resulted in at least one detection of all the focal species (eastern black rail, Virginia rail, clapper rail, seaside sparrow, marsh wren, and sedge wren). Virginia rails, marsh wrens, and a single sedge wren were detected in low numbers, primarily during surveys in early May. These species were not expected to be found breeding and are most likely winter residents or migrants that had not yet migrated north. Due to both low numbers of detections and no repeated detections at specific points, detection rates were unable to be estimated (Welsh et al 2013).

Clapper rails detections (N=137) were common and widespread throughout both parks. Over twice as many clapper rails were detected at CALO when compared with CAHA. This disparity is attributed to the affinity of clapper rails to low marsh (*Spartina alterniflora*) habitats in proximity to open water and the greater amount of this habitat available at CALO. Seaside sparrow detections (N=185) were also widespread and common throughout both parks, however 79% of detections occurred at CALO. While seaside sparrows are typically detected in high marsh habitats, models showed a strong correlation to proximity of low marsh (*Spartina alterniflora*) habitat and open water. Marshes at CAHA do not have the expansive low marsh habitat that is present at CALO.

While conducting these surveys we also recorded observations of other bird species of interest, including Chuck-will's widow and common night hawk. While most survey points were not associated with appropriate Chuck-will's-widow habitat, this species was detected regularly from forested habitats early in the seasons during dark hours. Common nighthawks were the most frequently detected species (N=477). Common nighthawk detections were widespread south of Bodie Island, and common especially on the southern most points at Shackleford banks and South Core Banks. Detections of common nighthawks on these islands accounted for over 55% of all detections. While models predicted a high correlation to high marsh habitat within 200m, common nighthawks, nests, and chicks were often encountered in dune/scrub habitat while traveling to survey site. Breeding densities on Shackleford Banks and South Core Banks are likely very high.

Data for black rails detected during these surveys was particularly sparse (detected at 0.7% of survey locations) and many of the models were unable to converge and estimate error for predictors (Welsh et al 2013). However, these detections were associated with one of the largest high marsh patches available at the parks and within habitat that is consistent with other observations in the mid-Atlantic and northern south Atlantic states.

Both CALO and CAHA have a large amount of high marsh habitat that possess vegetative composition and structure that is attractive to black rails. However, frequent inundation is likely one of the limiting factors preventing this species from occupying these habitats. Coastal North Carolina is highly susceptible to increasing rates of sea-level-rise and land subsidence, with the habitats black rails rely on the most at risk (Johnston et al 2021). Not only are black rails being displaced by frequent inundation, but sea-level-rise and land subsidence is resulting in a conversion of high marsh habitat into low marsh (Wilson and Turrin 2014). Extreme levels of high marsh inundation were confirmed while conducting these surveys at both Bodie Island and Ocracoke Island. The large high marsh patches on the south end of Ocracoke and the large high marsh patches on the north end of Bodie Island were observed inundated with over 6 cm of water on multiple occasions.

Both CALO and CAHA possess habitat that may be suitable for breeding black rails. The most likely black rail habitat is the high marsh habitat behind the dunes on the northern half of North Core Banks. This area has some of the largest patches of *S. patens* high marsh, vegetated high elevation refuge, and was not observed to be as prone to frequent inundation during surveys. This habitat was responsible for all black rail detections during these surveys. Other possible areas within the parks where black rail could occur are the large high marsh patches on the south end of Ocracoke and the large high marsh patches on the north end of Bodie Island. While these marshes were observed inundated on several occasions, there are forested hummocks and ridges that could provide refuge from inundation. The large high marsh patch south of Cape Hatteras lighthouse is of sufficient size and appears to have high elevation refuge within the shrubland and on the edge of the forest to the north. Finally, while the high marsh patches are not as large or contiguous as other sites, the areas around the dikes at Pea Island provide elevational refuge.

The six black rail detections made a CALO represent a new unknown probable breeding location for 3, possibly 4, eastern black rails. With a soft population estimate, based on other recent surveys and observations, of eastern black rails in North Carolina of 40–60, these new detections may account for 5–10% of North Carolina's black rail population (Watts 2016). It is recommended that the new occurrences of eastern black rails discovered on North Core Banks be monitored or resurveyed at somewhat regular intervals to track their status in future years.

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Appendix A: List of Points Surveyed

Table 2. List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
AN1	CAHA	Avon North	3	35.43994	-75.48943
AN2	CAHA	Avon North	3	35.43665	-75.49015
AN3	CAHA	Avon North	3	35.43178	-75.49055
AN4	CAHA	Avon North	3	35.42805	-75.49126
AN5	CAHA	Avon North	3	35.42178	-75.49234
AN6	CAHA	Avon North	3	35.41716	-75.49226
AN7	CAHA	Avon North	3	35.41259	-75.49247
AN8	CAHA	Avon North	3	35.40904	-75.49442
AS1	CAHA	Avon South	3	35.31279	-75.51129
AS2	CAHA	Avon South	3	35.30903	-75.51193
AS3	CAHA	Avon South	3	35.30565	-75.51297
AS4	CAHA	Avon South	3	35.31559	-75.51359
AS5	CAHA	Avon South	3	35.31388	-75.51393
AS6	CAHA	Avon South	3	35.31048	-75.51466
AS7	CAHA	Avon South	3	35.30732	-75.51478
B1	CAHA	Bodie Island	3	35.89160	-75.59364
B10	CAHA	Bodie Island	3	35.86208	-75.57766
B11	CAHA	Bodie Island	3	35.85860	-75.57650
B12	CAHA	Bodie Island	3	35.85522	-75.57497
B13	CAHA	Bodie Island	3	35.85197	-75.57306
B14	CAHA	Bodie Island	3	35.84887	-75.57080
B15	CAHA	Bodie Island	3	35.84592	-75.56824
B16	CAHA	Bodie Island	3	35.88120	-75.59127
B17	CAHA	Bodie Island	3	35.87756	-75.59026
B18	CAHA	Bodie Island	3	35.87478	-75.58997
B19	CAHA	Bodie Island	3	35.86751	-75.58590
B2	CAHA	Bodie Island	3	35.88834	-75.59175
B20	CAHA	Bodie Island	3	35.86499	-75.58626
B21	CAHA	Bodie Island	2	35.86156	-75.58203
B22	CAHA	Bodie Island	3	35.86080	-75.58584
B23	CAHA	Bodie Island	3	35.85918	-75.58454
B24B	CAHA	Bodie Island	2	35.84716	-75.57080
B25	CAHA	Bodie Island	3	35.84173	-75.56982
B26	CAHA	Bodie Island	3	35.83964	-75.56777

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
B27	CAHA	Bodie Island	3	35.85395	-75.57791
B28	CAHA	Bodie Island	3	35.85225	-75.57637
B29	CAHA	Bodie Island	3	35.83378	-75.56072
B3	CAHA	Bodie Island	3	35.88527	-75.58942
B30	CAHA	Bodie Island	3	35.83065	-75.55924
B31	CAHA	Bodie Island	3	35.82809	-75.56016
B32	CAHA	Bodie Island	3	35.82626	-75.56302
B33	CAHA	Bodie Island	3	35.82345	-75.56508
B34	CAHA	Bodie Island	3	35.81917	-75.56417
B35	CAHA	Bodie Island	3	35.82156	-75.56420
B36	CAHA	Bodie Island	3	35.82460	-75.56273
B37	CAHA	Bodie Island	3	35.82634	-75.56037
B38	CAHA	Bodie Island	3	35.82566	-75.55656
B39	CAHA	Bodie Island	3	35.82282	-75.55514
B4	CAHA	Bodie Island	3	35.88221	-75.58708
B40	CAHA	Bodie Island	3	35.81938	-75.55371
B41	CAHA	Bodie Island	3	35.81602	-75.55245
B42	CAHA	Bodie Island	3	35.81314	-75.55154
B43	CAHA	Bodie Island	3	35.81028	-75.55068
B44	CAHA	Bodie Island	3	35.81016	-75.55385
B45	CAHA	Bodie Island	3	35.81154	-75.55807
B46	CAHA	Bodie Island	3	35.81378	-75.56322
B47	CAHA	Bodie Island	3	35.81733	-75.56339
B48	CAHA	Bodie Island	3	35.82346	-75.56871
B49	CAHA	Bodie Island	3	35.82686	-75.56963
B5	CAHA	Bodie Island	3	35.87904	-75.58496
B6	CAHA	Bodie Island	3	35.87580	-75.58304
B7	CAHA	Bodie Island	3	35.87245	-75.58138
B8	CAHA	Bodie Island	3	35.86905	-75.57991
B9	CAHA	Bodie Island	3	35.86559	-75.57866
CB1	CALO	Core Banks South	3	34.60710	-76.53523
CB10	CALO	Core Banks South	3	34.61212	-76.55102
CB100	CALO	Core Banks South	3	34.77887	-76.41077
CB101	CALO	Core Banks South	3	34.78328	-76.40583
CB102	CALO	Core Banks South	3	34.79294	-76.39889

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
CB103	CALO	Core Banks South	3	34.78833	-76.39865
CB104	CALO	Core Banks South	3	34.78463	-76.39599
CB105	CALO	Core Banks South	3	34.82022	-76.37099
CB106	CALO	Core Banks South	3	34.81564	-76.37110
CB107	CALO	Core Banks South	3	34.82318	-76.36414
CB11	CALO	Core Banks South	3	34.60896	-76.54891
CB12	CALO	Core Banks South	3	34.60629	-76.54603
CB13	CALO	Core Banks South	3	34.60334	-76.54375
CB14	CALO	Core Banks South	3	34.60043	-76.54086
CB15	CALO	Core Banks South	3	34.59742	-76.53848
CB16	CALO	Core Banks South	3	34.59601	-76.53543
CB17	CALO	Core Banks South	3	34.59927	-76.53404
CB18	CALO	Core Banks South	3	34.60254	-76.53248
CB19	CALO	Core Banks South	3	34.60598	-76.53092
CB2	CALO	Core Banks South	3	34.60484	-76.53653
CB20	CALO	Core Banks South	3	34.60930	-76.52943
CB21	CALO	Core Banks South	3	34.61302	-76.52784
CB22	CALO	Core Banks South	3	34.61605	-76.52611
CB23	CALO	Core Banks South	3	34.61998	-76.52425
CB24	CALO	Core Banks South	3	34.62277	-76.52160
CB25	CALO	Core Banks South	3	34.62655	-76.52091
CB26	CALO	Core Banks South	3	34.62895	-76.51900
CB27	CALO	Core Banks South	3	34.63220	-76.51627
CB28	CALO	Core Banks South	3	34.63523	-76.51415
CB29	CALO	Core Banks South	3	34.63832	-76.51193
CB3	CALO	Core Banks South	3	34.60388	-76.53970
CB30	CALO	Core Banks South	3	34.64155	-76.50999
CB31	CALO	Core Banks South	3	34.64481	-76.50824
CB32	CALO	Core Banks South	3	34.64821	-76.50621
CB33	CALO	Core Banks South	3	34.65137	-76.50447
CB34	CALO	Core Banks South	3	34.65454	-76.50240
CB35	CALO	Core Banks South	3	34.65754	-76.50042
CB36	CALO	Core Banks South	3	34.66083	-76.49783
CB37	CALO	Core Banks South	3	34.66366	-76.49573
CB38	CALO	Core Banks South	3	34.66685	-76.49312

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
CB39	CALO	Core Banks South	3	34.66978	-76.49075
CB4	CALO	Core Banks South	3	34.60828	-76.54097
CB40	CALO	Core Banks South	3	34.67278	-76.48840
CB41	CALO	Core Banks South	3	34.67584	-76.48590
CB42	CALO	Core Banks South	3	34.67882	-76.48363
CB43	CALO	Core Banks South	3	34.68183	-76.48103
CB44	CALO	Core Banks South	3	34.68490	-76.47887
CB45	CALO	Core Banks South	3	34.68801	-76.47667
CB46	CALO	Core Banks South	3	34.69082	-76.47388
CB47	CALO	Core Banks South	3	34.69363	-76.47118
CB48	CALO	Core Banks South	3	34.69670	-76.46882
CB49	CALO	Core Banks South	3	34.69978	-76.46650
CB5	CALO	Core Banks South	3	34.61164	-76.54037
CB50	CALO	Core Banks South	3	34.70269	-76.46423
CB51	CALO	Core Banks South	3	34.70559	-76.46143
CB52	CALO	Core Banks South	3	34.70852	-76.45883
CB53	CALO	Core Banks South	3	34.71132	-76.45617
CB54	CALO	Core Banks South	3	34.71429	-76.45345
CB55	CALO	Core Banks South	3	34.71715	-76.45096
CB56	CALO	Core Banks South	3	34.72004	-76.44824
CB57	CALO	Core Banks South	2	34.72286	-76.44565
CB58	CALO	Core Banks South	3	34.72590	-76.44296
CB59	CALO	Core Banks South	3	34.72880	-76.44100
CB60	CALO	Core Banks South	3	34.73179	-76.43823
CB61	CALO	Core Banks South	3	34.73477	-76.43562
CB62	CALO	Core Banks South	3	34.73769	-76.43303
CB63	CALO	Core Banks South	3	34.74080	-76.43058
CB64	CALO	Core Banks South	3	34.74357	-76.42810
CB65	CALO	Core Banks South	2	34.74655	-76.42548
CB66	CALO	Core Banks South	3	34.74937	-76.42336
CB67	CALO	Core Banks South	3	34.75210	-76.42014
CB68	CALO	Core Banks South	3	34.75495	-76.41761
CB69	CALO	Core Banks South	3	34.75784	-76.41478
CB7	CALO	Core Banks South	3	34.61300	-76.54488
CB70	CALO	Core Banks South	3	34.76119	-76.41346

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
CB73	CALO	Core Banks South	3	34.76933	-76.40443
CB74	CALO	Core Banks South	3	34.77229	-76.40199
CB75	CALO	Core Banks South	3	34.77551	-76.39946
CB76	CALO	Core Banks South	3	34.77844	-76.39713
CB77	CALO	Core Banks South	3	34.78126	-76.39458
CB78	CALO	Core Banks South	3	34.78420	-76.39181
CB79	CALO	Core Banks South	3	34.78669	-76.38868
CB8	CALO	Core Banks South	3	34.61407	-76.54959
CB80	CALO	Core Banks South	3	34.78961	-76.38612
CB81	CALO	Core Banks South	2	34.79213	-76.38305
CB82	CALO	Core Banks South	3	34.79499	-76.38040
CB83	CALO	Core Banks South	3	34.79767	-76.37749
CB84	CALO	Core Banks South	3	34.80055	-76.37473
CB85	CALO	Core Banks South	3	34.80335	-76.37243
CB85-B	CALO	Core Banks South	3	34.80371	-76.37365
CB86	CALO	Core Banks South	3	34.80592	-76.36899
CB87	CALO	Core Banks South	3	34.80894	-76.36656
CB88	CALO	Core Banks South	2	34.81204	-76.36406
CB89	CALO	Core Banks South	2	34.81458	-76.36194
CB90	CALO	Core Banks South	1	34.81736	-76.35883
CB92	CALO	Core Banks South	3	34.81811	-76.36243
CB93	CALO	Core Banks South	3	34.71083	-76.47167
CB94	CALO	Core Banks South	3	34.75504	-76.43348
CB95	CALO	Core Banks South	3	34.76101	-76.43311
CB96	CALO	Core Banks South	3	34.76513	-76.43100
CB97	CALO	Core Banks South	3	34.76275	-76.42619
CB98	CALO	Core Banks South	3	34.75812	-76.42306
CB99	CALO	Core Banks South	3	34.75501	-76.42235
H1	CAHA	Hatteras South	3	35.24398	-75.53249
H10	CAHA	Hatteras South	3	35.23139	-75.53828
H11	CAHA	Hatteras South	3	35.22830	-75.53595
H12	CAHA	Hatteras South	3	35.22722	-75.52926
H13	CAHA	Hatteras South	3	35.23197	-75.54222
H14	CAHA	Hatteras South	3	35.23348	-75.54564
H15	CAHA	Hatteras South	3	35.23507	-75.54950

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
H16	CAHA	Hatteras South	3	35.23538	-75.55355
H17	CAHA	Hatteras South	3	35.23584	-75.55792
H18	CAHA	Hatteras South	3	35.23621	-75.56217
H19	CAHA	Hatteras South	3	35.23663	-75.56641
H2	CAHA	Hatteras South	3	35.23619	-75.53108
H20	CAHA	Hatteras South	3	35.23646	-75.57079
H21	CAHA	Hatteras South	3	35.23703	-75.57502
H22	CAHA	Hatteras South	3	35.23684	-75.57892
H23	CAHA	Hatteras South	3	35.23688	-75.58116
H3	CAHA	Hatteras South	3	35.23834	-75.52769
H4	CAHA	Hatteras South	3	35.24175	-75.52676
H5	CAHA	Hatteras South	3	35.24506	-75.52592
H6	CAHA	Hatteras South	3	35.24864	-75.52485
H7	CAHA	Hatteras South	3	35.24169	-75.53010
H8	CAHA	Hatteras South	3	35.23274	-75.52975
H9	CAHA	Hatteras South	3	35.23327	-75.53438
O1	CAHA	Ocracoke Island	3	35.18504	-75.78201
O10B	CAHA	Ocracoke Island	3	35.16969	-75.81674
O11	CAHA	Ocracoke Island	3	35.16845	-75.81973
O12B	CAHA	Ocracoke Island	3	35.16685	-75.82281
O13	CAHA	Ocracoke Island	3	35.16598	-75.82694
O14	CAHA	Ocracoke Island	3	35.16350	-75.83218
O15	CAHA	Ocracoke Island	3	35.16220	-75.83643
O16	CAHA	Ocracoke Island	3	35.16106	-75.84021
O17	CAHA	Ocracoke Island	3	35.15819	-75.84803
O18	CAHA	Ocracoke Island	3	35.15657	-75.85156
O19	CAHA	Ocracoke Island	3	35.15489	-75.85540
O2	CAHA	Ocracoke Island	3	35.18184	-75.78367
O20	CAHA	Ocracoke Island	3	35.15345	-75.85938
O21	CAHA	Ocracoke Island	3	35.15188	-75.86318
O22	CAHA	Ocracoke Island	3	35.15034	-75.86690
O25	CAHA	Ocracoke Island	3	35.14412	-75.88293
O26	CAHA	Ocracoke Island	3	35.14128	-75.89100
O27B	CAHA	Ocracoke Island	3	35.13648	-75.90260
O28B	CAHA	Ocracoke Island	3	35.13370	-75.90945

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
O3	CAHA	Ocracoke Island	3	35.18010	-75.78713
O32	CAHA	Ocracoke Island	3	35.12751	-75.92121
O33	CAHA	Ocracoke Island	3	35.12496	-75.92424
O34	CAHA	Ocracoke Island	3	35.12296	-75.92790
O35	CAHA	Ocracoke Island	3	35.12097	-75.93155
O36	CAHA	Ocracoke Island	3	35.11901	-75.93524
O37	CAHA	Ocracoke Island	3	35.11716	-75.93901
O38	CAHA	Ocracoke Island	3	35.11519	-75.94268
O39	CAHA	Ocracoke Island	3	35.11316	-75.94631
O40	CAHA	Ocracoke Island	3	35.11117	-75.94997
O41	CAHA	Ocracoke Island	3	35.10920	-75.95364
O42	CAHA	Ocracoke Island	3	35.10728	-75.95736
O43	CAHA	Ocracoke Island	3	35.10586	-75.96135
O44	CAHA	Ocracoke Island	3	35.10561	-75.96571
O45	CAHA	Ocracoke Island	3	35.10638	-75.96986
O46	CAHA	Ocracoke Island	3	35.10371	-75.97280
O47	CAHA	Ocracoke Island	4	35.10049	-75.97475
O48	CAHA	Ocracoke Island	4	35.09770	-75.97743
O49	CAHA	Ocracoke Island	4	35.09525	-75.98065
O4B	CAHA	Ocracoke Island	3	35.17866	-75.79168
O5	CAHA	Ocracoke Island	3	35.17739	-75.79589
O50	CAHA	Ocracoke Island	4	35.09267	-75.98372
O51	CAHA	Ocracoke Island	3	35.08988	-75.98648
O53B	CAHA	Ocracoke Island	3	35.18701	-75.77889
O54	CAHA	Ocracoke Island	3	35.18792	-75.78204
O55B	CAHA	Ocracoke Island	4	35.09637	-75.98343
O56	CAHA	Ocracoke Island	3	35.12783	-75.92675
O63B	CAHA	Ocracoke Island	3	35.08502	-75.99120
O64	CAHA	Ocracoke Island	3	35.08280	-75.99358
O6B	CAHA	Ocracoke Island	3	35.17578	-75.79991
O7B	CAHA	Ocracoke Island	3	35.17439	-75.80463
O8B	CAHA	Ocracoke Island	3	35.17277	-75.80916
O9	CAHA	Ocracoke Island	3	35.17126	-75.81260
O98	CAHA	Ocracoke Island	2	35.10785	-75.96277
O99	CAHA	Ocracoke Island	2	35.10982	-75.96024

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
P100	CALO	North Core Banks	3	34.97664	-76.17530
P101	CALO	North Core Banks	3	34.97519	-76.17060
P102-A	CALO	North Core Banks	1	34.99031	-76.14957
P102-BA	CALO	North Core Banks	1	34.98749	-76.15220
P104-A	CALO	North Core Banks	1	34.99657	-76.14375
P105-A	CALO	North Core Banks	1	34.99991	-76.14026
P107-A	CALO	North Core Banks	2	35.00444	-76.13588
P108	CALO	North Core Banks	1	35.00006	-76.14306
P109	CALO	North Core Banks	2	35.00220	-76.14127
P110	CALO	North Core Banks	1	35.00550	-76.13926
P111	CALO	North Core Banks	3	35.01929	-76.11611
P112	CALO	North Core Banks	3	35.02423	-76.10898
P113	CALO	North Core Banks	3	35.03194	-76.10748
P114	CALO	North Core Banks	3	35.03499	-76.10153
P114-B	CALO	North Core Banks	3	35.03996	-76.09472
P12	CALO	North Core Banks	2	34.88637	-76.27523
P13	CALO	North Core Banks	3	34.88746	-76.27281
P14	CALO	North Core Banks	3	34.88983	-76.26984
P15	CALO	North Core Banks	2	34.89225	-76.26628
P16	CALO	North Core Banks	3	34.89458	-76.26291
P17	CALO	North Core Banks	3	34.89673	-76.25942
P18	CALO	North Core Banks	3	34.89957	-76.25638
P19	CALO	North Core Banks	3	34.90180	-76.25314
P20	CALO	North Core Banks	3	34.90416	-76.25025
P200	CALO	North Core Banks	1	35.04658	-76.06865
P201	CALO	North Core Banks	1	35.04774	-76.06758
P202	CALO	North Core Banks	1	35.04875	-76.06329
P203	CALO	North Core Banks	1	35.04981	-76.06069
P204	CALO	North Core Banks	1	35.05148	-76.05546
P21	CALO	North Core Banks	3	34.90636	-76.24672
P22	CALO	North Core Banks	3	34.90915	-76.24359
P23	CALO	North Core Banks	3	34.91151	-76.24092
P24	CALO	North Core Banks	2	34.91405	-76.23746
P25	CALO	North Core Banks	2	34.91689	-76.23396
P26	CALO	North Core Banks	3	34.91990	-76.23014

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
P27	CALO	North Core Banks	3	34.92190	-76.22806
P28	CALO	North Core Banks	3	34.92453	-76.22524
P29	CALO	North Core Banks	3	34.92696	-76.22200
P30	CALO	North Core Banks	3	34.92967	-76.21879
P31	CALO	North Core Banks	3	34.93225	-76.21609
P32	CALO	North Core Banks	3	34.93487	-76.21309
P33	CALO	North Core Banks	3	34.93709	-76.20952
P34	CALO	North Core Banks	3	34.93969	-76.20649
P35	CALO	North Core Banks	3	34.94278	-76.20378
P36	CALO	North Core Banks	3	34.94505	-76.20052
P37	CALO	North Core Banks	3	34.94770	-76.19731
P38	CALO	North Core Banks	3	34.95039	-76.19460
P39	CALO	North Core Banks	3	34.95296	-76.19154
P40	CALO	North Core Banks	3	34.95567	-76.18841
P41	CALO	North Core Banks	3	34.95792	-76.18558
P42	CALO	North Core Banks	3	34.96063	-76.18212
P43	CALO	North Core Banks	1	34.96277	-76.17873
P44	CALO	North Core Banks	1	34.96499	-76.17615
P45	CALO	North Core Banks	1	34.96762	-76.17268
P46	CALO	North Core Banks	2	34.96996	-76.16931
P47	CALO	North Core Banks	3	34.97242	-76.16585
P48	CALO	North Core Banks	3	34.97453	-76.16229
P49	CALO	North Core Banks	2	34.97881	-76.16468
P50	CALO	North Core Banks	1	34.98148	-76.16170
P51	CALO	North Core Banks	3	34.98220	-76.15287
P52	CALO	North Core Banks	3	34.98437	-76.14956
P53	CALO	North Core Banks	3	34.98712	-76.14663
P54	CALO	North Core Banks	3	34.98944	-76.14334
P55	CALO	North Core Banks	3	34.99203	-76.14036
P56	CALO	North Core Banks	3	34.99420	-76.13723
P57	CALO	North Core Banks	3	34.99693	-76.13389
P58	CALO	North Core Banks	3	34.99932	-76.13073
P6	CALO	North Core Banks	3	34.87332	-76.29579
P60	CALO	North Core Banks	1	35.00561	-76.12958
P61	CALO	North Core Banks	1	35.01090	-76.13112

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
P61-B	CALO	North Core Banks	2	35.00796	-76.12785
P62	CALO	North Core Banks	2	35.01233	-76.12770
P62-B	CALO	North Core Banks	2	35.00943	-76.12580
P62-C	CALO	North Core Banks	2	35.01349	-76.12283
P63	CALO	North Core Banks	1	35.01284	-76.11532
P64	CALO	North Core Banks	2	35.01407	-76.11196
P65	CALO	North Core Banks	3	35.01611	-76.10841
P66	CALO	North Core Banks	3	35.01867	-76.10533
P67	CALO	North Core Banks	2	35.02117	-76.10217
P68	CALO	North Core Banks	2	35.02357	-76.10039
P69	CALO	North Core Banks	3	35.02666	-76.09805
P7	CALO	North Core Banks	3	34.87825	-76.29432
P70	CALO	North Core Banks	3	35.02913	-76.09534
P71	CALO	North Core Banks	3	35.03129	-76.09272
P72	CALO	North Core Banks	3	35.03375	-76.08944
P73	CALO	North Core Banks	3	35.03603	-76.08703
P74	CALO	North Core Banks	3	35.03857	-76.08421
P75	CALO	North Core Banks	3	35.04144	-76.08186
P7-B	CALO	North Core Banks	3	34.88053	-76.28946
P8	CALO	North Core Banks	3	34.88238	-76.29321
P9	CALO	North Core Banks	3	34.88586	-76.28882
P95	CALO	North Core Banks	3	34.95574	-76.19581
P96	CALO	North Core Banks	3	34.95988	-76.19366
P97	CALO	North Core Banks	3	34.96404	-76.18679
P98	CALO	North Core Banks	3	34.96607	-76.18462
P99	CALO	North Core Banks	3	34.96933	-76.17873
PI1	CAHA	Pea Island	3	35.76167	-75.51797
PI10	CAHA	Pea Island	3	35.73550	-75.50548
PI11	CAHA	Pea Island	3	35.73278	-75.50820
PI12	CAHA	Pea Island	3	35.72929	-75.50821
PI13	CAHA	Pea Island	3	35.72585	-75.50687
PI14	CAHA	Pea Island	3	35.72240	-75.50560
PI15	CAHA	Pea Island	3	35.71897	-75.50425
PI16	CAHA	Pea Island	3	35.71539	-75.50372
PI17	CAHA	Pea Island	3	35.71197	-75.50240

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
PI18	CAHA	Pea Island	3	35.70847	-75.50134
PI19	CAHA	Pea Island	3	35.70529	-75.49947
PI2	CAHA	Pea Island	3	35.75959	-75.51589
PI20	CAHA	Pea Island	3	35.70253	-75.49662
PI21	CAHA	Pea Island	3	35.70006	-75.49596
PI22	CAHA	Pea Island	3	35.69653	-75.49591
PI23	CAHA	Pea Island	3	35.69293	-75.49565
PI24	CAHA	Pea Island	3	35.68976	-75.49389
PI25	CAHA	Pea Island	3	35.68840	-75.48988
PI26	CAHA	Pea Island	3	35.68806	-75.48582
PI27	CAHA	Pea Island	3	35.69074	-75.48485
PI28	CAHA	Pea Island	3	35.69426	-75.48577
PI29	CAHA	Pea Island	3	35.69777	-75.48681
PI3	CAHA	Pea Island	3	35.75685	-75.51371
PI30	CAHA	Pea Island	3	35.70123	-75.48802
PI31	CAHA	Pea Island	3	35.70464	-75.48946
PI32	CAHA	Pea Island	3	35.70807	-75.49084
PI33	CAHA	Pea Island	3	35.71154	-75.49202
PI34	CAHA	Pea Island	3	35.71508	-75.49276
PI35	CAHA	Pea Island	3	35.71800	-75.49438
PI36	CAHA	Pea Island	3	35.72182	-75.49590
PI37	CAHA	Pea Island	3	35.72522	-75.49739
PI38	CAHA	Pea Island	3	35.72865	-75.49875
PI39	CAHA	Pea Island	3	35.67304	-75.48025
PI4	CAHA	Pea Island	3	35.75423	-75.51116
PI40	CAHA	Pea Island	3	35.66952	-75.47962
PI41	CAHA	Pea Island	3	35.66646	-75.48047
PI42	CAHA	Pea Island	3	35.66227	-75.47946
PI43	CAHA	Pea Island	3	35.65870	-75.47888
PI44	CAHA	Pea Island	3	35.65528	-75.47816
PI45	CAHA	Pea Island	3	35.65164	-75.47707
PI46	CAHA	Pea Island	3	35.64812	-75.47653
PI47	CAHA	Pea Island	3	35.64453	-75.47539
PI48	CAHA	Pea Island	3	35.64107	-75.47425
PI49	CAHA	Pea Island	3	35.63756	-75.47361

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
PI5	CAHA	Pea Island	3	35.75079	-75.50992
PI50	CAHA	Pea Island	3	35.63401	-75.47275
PI51	CAHA	Pea Island	3	35.75618	-75.51700
PI52	CAHA	Pea Island	3	35.74960	-75.51325
PI53	CAHA	Pea Island	3	35.74377	-75.51041
PI6	CAHA	Pea Island	3	35.74752	-75.50777
PI7	CAHA	Pea Island	3	35.74420	-75.50630
PI8	CAHA	Pea Island	3	35.74044	-75.50508
PI9	CAHA	Pea Island	3	35.73714	-75.50277
SAL1	CAHA	Salvo	2	35.52830	-75.47933
SAL10	CAHA	Salvo	2	35.50477	-75.48629
SAL11	CAHA	Salvo	2	35.50215	-75.48388
SAL12	CAHA	Salvo	2	35.49947	-75.48424
SAL13	CAHA	Salvo	2	35.49283	-75.48372
SAL2	CAHA	Salvo	2	35.52644	-75.48262
SAL3	CAHA	Salvo	2	35.52399	-75.48174
SAL4	CAHA	Salvo	2	35.52268	-75.48623
SAL5	CAHA	Salvo	2	35.51910	-75.48620
SAL6	CAHA	Salvo	2	35.51592	-75.48306
SAL7	CAHA	Salvo	2	35.51358	-75.48159
SAL8	CAHA	Salvo	2	35.51086	-75.48309
SAL9	CAHA	Salvo	2	35.50832	-75.48574
SH10	CALO	Shackleford Banks	3	34.67252	-76.60823
SH11	CALO	Shackleford Banks	3	34.67189	-76.60406
SH12	CALO	Shackleford Banks	3	34.67002	-76.60001
SH13	CALO	Shackleford Banks	3	34.66889	-76.59626
SH14	CALO	Shackleford Banks	3	34.66776	-76.59277
SH15	CALO	Shackleford Banks	3	34.66655	-76.58917
SH17	CALO	Shackleford Banks	3	34.66527	-76.58519
SH17-B	CALO	Shackleford Banks	3	34.66394	-76.58188
SH18	CALO	Shackleford Banks	3	34.66243	-76.57710
SH2	CALO	Shackleford Banks	3	34.68271	-76.63954
SH24	CALO	Shackleford Banks	3	34.65062	-76.55275
SH25	CALO	Shackleford Banks	3	34.64876	-76.54934
SH26	CALO	Shackleford Banks	2	34.64653	-76.54591

Table 2 (continued). List of points surveyed at CALO and CAHA in 2022 and 2023, with park designation, general location within park, number of survey rounds conducted at each point and WGS 1984 coordinates.

Survey Point	Park	Island/Area	Number of Surveys	Latitude	Longitude
SH27	CALO	Shackleford Banks	3	34.64365	-76.54275
SH28	CALO	Shackleford Banks	3	34.64061	-76.54015
SH29	CALO	Shackleford Banks	3	34.63762	-76.53746
SH3	CALO	Shackleford Banks	3	34.68136	-76.63669
SH30	CALO	Shackleford Banks	3	34.63491	-76.53520
SH31	CALO	Shackleford Banks	3	34.63185	-76.53221
SH4	CALO	Shackleford Banks	3	34.68022	-76.63268
SH5	CALO	Shackleford Banks	3	34.67910	-76.62875
SH6	CALO	Shackleford Banks	3	34.67805	-76.62456
SH7	CALO	Shackleford Banks	3	34.67599	-76.61970
SH8	CALO	Shackleford Banks	3	34.67490	-76.61544
SH9	CALO	Shackleford Banks	3	34.67346	-76.61159

Appendix B: Maps with Locations Surveyed in CALO

Figure 34 and Figure 35 show maps of locations surveyed at CALO in 2022 and 2023.



Figure 34. Map of points on Shackleford Banks and South Core Banks (CALO) surveyed during the 2022 season.



Figure 35. Map of points on North Core Banks (CALO) surveyed during the 2022 and 2023 seasons.

Appendix C: Maps of Locations Surveyed at CAHA

Figures 36–40 show maps with locations of point surveyed at CAHA in 2023.



Figure 36. Map of points on Ocracoke Island (CAHA) surveyed during the 2023 season.



Figure 37. Map of points on south Hatteras Island and near Avon (CAHA) surveyed during the 2023 season.



Figure 38. Map of points near Salvo (CAHA) surveyed during the 2023 season.



Figure 39. Map of points at Pea Island NWR (CAHA) surveyed during the 2023 season.



Figure 40. Map of points at Bodie Island (CAHA) surveyed during the 2023 season.

Appendix D: Model Selection Table for Clapper Rail

Table 3. Model Selection Table for Clapper Rail including all predictors for detection (ρ) and occupancy (ψ) including the number of parameters (K), log-likelihood (log-lik), AICc score, Δ AICc, and model weight (wt).

Model Parameters	K	Log-lik	AICc	Δ AICc	wt
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+LM200+OW100})$	9	-414.05	846.52	0.00	0.76
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+LM200+OW200})$	9	-415.27	848.98	2.46	0.22
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+LM200+OW50})$	9	-417.76	853.94	7.42	0.02
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+LM200})$	7	-429.71	873.68	27.16	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+LM100+LM200})$	8	-429.56	875.46	28.94	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+LM100})$	7	-434.50	883.26	36.74	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+HM50})$	6	-436.35	884.90	38.38	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+LM50})$	7	-435.64	885.54	39.02	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+HM100})$	7	-437.40	889.06	42.54	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+HM200})$	7	-438.18	890.63	44.11	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{LM200})$	6	-439.58	891.35	44.83	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{LM100})$	7	-438.68	891.62	45.10	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park})$	7	-439.19	892.64	46.12	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+Phrag200})$	7	-439.20	892.66	46.14	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+Phrag50})$	7	-439.30	892.87	46.35	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+BM100})$	7	-439.43	893.13	46.61	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+BM200})$	7	-439.46	893.19	46.67	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+Phrag100})$	7	-439.53	893.32	46.80	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+BM50})$	6	-452.72	917.63	71.12	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{LM50})$	6	-456.18	924.56	78.04	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{HM50})$	6	-456.58	925.36	78.84	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{HM100})$	6	-457.43	927.06	80.54	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{Phrag200})$	5	-458.72	927.58	81.06	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{HM200})$	5	-458.72	927.58	81.06	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(.)$	6	-458.09	928.38	81.86	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(.)$	6	-458.41	929.03	82.51	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{Phrag50})$	6	-458.56	929.32	82.80	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{Phrag100})$	6	-458.61	929.42	82.90	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{BM50})$	6	-458.63	929.45	82.93	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{BM100})$	6	-458.72	929.64	83.12	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{BM200})$	6	-458.72	929.64	83.12	0.00
$\rho(\text{day/night+crepuscular}), \psi(.)$	4	-461.19	930.47	83.95	0.00
$\rho(\text{day/night+absolute crepuscular time}), \psi(.)$	4	-461.87	931.84	85.32	0.00

Table 3 (continued). Model Selection Table for Clapper Rail including all predictors for detection (ρ) and occupancy (ψ) including the number of parameters (K), log-likelihood (log-lik), AICc score, Δ AICc, and model weight (wt).

Model Parameters	K	Log-lik	AICc	Δ AICc	wt
$\rho(\text{day/night}), \psi(.)$	3	-463.53	933.11	86.59	0.00
$\rho(\text{absolute crepuscular time}), \psi(.)$	3	-478.10	962.26	115.74	0.00
$\rho(\text{sky}), \psi(.)$	3	-478.86	963.77	117.25	0.00
$\rho(\text{day of year}), \psi(.)$	3	-480.62	967.29	120.77	0.00
$\rho(\text{crepuscular time}), \psi(.)$	3	-481.03	968.12	121.60	0.00
$\rho(.), \psi(.)$	2	-482.72	969.46	122.94	0.00
$\rho(\text{moon}), \psi(.)$	3	-481.80	969.66	123.14	0.00
$\rho(\text{crepuscular time+am/pm}), \psi(.)$	4	-480.87	969.83	123.31	0.00
$\rho(\text{am/pm}), \psi(.)$	3	-482.57	971.19	124.67	0.00
$\rho(\text{noise}), \psi(.)$	3	-482.57	971.19	124.67	0.00
$\rho(\text{wind}), \psi(.)$	3	-482.66	971.38	124.86	0.00

Appendix E: Model Selection Table for Virginia Rail

Table 4. Model Selection Table for Virginia Rail including all predictors for detection (ρ) and occupancy (ψ) including the number of parameters (K), log-likelihood (log-lik), AICc score, Δ AICc, and model weight (wt).

Model Parameters	K	Log-lik	AICc	Δ AICc	wt
ρ (day of year), ψ (park+LM100+OW50)	6	-34.58	81.36	0.00	0.28
ρ (day of year), ψ (park+LM100+OW200)	6	-34.64	81.48	0.12	0.26
ρ (day of year), ψ (park+LM100+OW100)	6	-34.93	82.05	0.69	0.20
ρ (day of year), ψ (park+LM100)	5	-36.69	83.51	2.15	0.10
ρ (day of year), ψ (LM200)	4	-38.81	85.71	4.35	0.03
ρ (day of year), ψ (park+LM200)	5	-38.10	86.33	4.97	0.02
ρ (day of year), ψ (BM50+LM200)	5	-38.13	86.40	5.04	0.02
ρ (day of year), ψ (park+BM100)	5	-39.23	88.59	7.23	0.01
ρ (day of year), ψ (HM50)	4	-40.34	88.77	7.40	0.01
ρ (day of year), ψ (park+Phrag50)	5	-39.40	88.95	7.59	0.01
ρ (day of year), ψ (park)	4	-40.57	89.22	7.86	0.01
ρ (day of year), ψ (HM100)	4	-40.66	89.41	8.05	0.01
ρ (day of year), ψ (Phrag50)	4	-40.90	89.89	8.53	0.00
ρ (day of year), ψ (park+Phrag100)	5	-39.90	89.93	8.57	0.00
ρ (day of year), ψ (Phrag100)	4	-40.96	90.02	8.66	0.00
ρ (day of year), ψ (.)	3	-41.99	90.03	8.67	0.00
ρ (day of year), ψ (park+BM200)	5	-40.01	90.16	8.80	0.00
ρ (day of year), ψ (park+HM100)	5	-40.18	90.50	9.14	0.00
ρ (day of year), ψ (park+HM200)	5	-40.32	90.78	9.42	0.00
ρ (day of year), ψ (park+LM50)	5	-40.33	90.81	9.45	0.00
ρ (day of year), ψ (park+BM50)	5	-40.35	90.84	9.48	0.00
ρ (day of year), ψ (BM200)	4	-41.38	90.86	9.50	0.00
ρ (day of year), ψ (park+Phrag200)	5	-40.41	90.95	9.59	0.00
ρ (day of year), ψ (Phrag200)	4	-41.43	90.95	9.59	0.00
ρ (day of year), ψ (park+HM50)	5	-40.45	91.04	9.67	0.00
ρ (day of year), ψ (BM100)	4	-41.53	91.15	9.79	0.00
ρ (day of year), ψ (BM50)	4	-41.54	91.17	9.80	0.00
ρ (day of year), ψ (LM50)	4	-41.54	91.18	9.82	0.00
ρ (day of year), ψ (LM100)	4	-41.66	91.42	10.06	0.00
ρ (day of year), ψ (HM200)	4	-41.91	91.91	10.55	0.00
ρ (noise), ψ (.)	3	-46.95	98.59	17.23	0.00
ρ (moon), ψ (.)	3	-51.31	108.67	27.31	0.00
ρ (am/pm), ψ (.)	3	-51.78	109.61	28.25	0.00

Table 4 (continued). Model Selection Table for Virginia Rail including all predictors for detection (ρ) and occupancy (ψ) including the number of parameters (K), log-likelihood (log-lik), AICc score, Δ AICc, and model weight (wt).

Model Parameters	K	Log-lik	AICc	Δ AICc	wt
$\rho(\cdot), \psi(\cdot)$	2	-53.17	110.36	29.00	0.00
$\rho(\text{crepuscular timeam/pm}), \psi(\cdot)$	4	-51.57	111.23	29.87	0.00
$\rho(\text{sky}), \psi(\cdot)$	3	-52.81	111.68	30.32	0.00
$\rho(p(\text{wind})), \psi(\cdot)$	3	-53.04	112.14	30.78	0.00
$\rho(\text{day/night}), \psi(\cdot)$	3	-53.05	112.15	30.79	0.00
$\rho(\text{crepuscular time}), \psi(\cdot)$	3	-53.07	112.19	30.83	0.00
$\rho(\text{absolute crepuscular time}), \psi(\cdot)$	3	-53.07	112.20	30.84	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\cdot)$	5	-51.83	113.79	32.43	0.00
$\rho(\text{day/night+absolute crepuscular time}), \psi(\cdot)$	4	-52.91	113.92	32.56	0.00
$\rho(\text{day/night+crepuscular}), \psi(\cdot)$	4	-52.95	114.00	32.64	0.00

Appendix F: Model Selection Table for Seaside Sparrow

Table 5. Model Selection Table for Seaside Sparrow including all predictors for detection (ρ) and occupancy (ψ) including the number of parameters (K), log-likelihood (log-lik), AICc score, Δ AICc, and model weight (wt).

Model Parameters	K	Log-lik	AICc	Δ AICc	wt
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{LM200+OW50})$	7	-285.69	585.65	0.00	0.72
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{LM200+OW100})$	7	-286.94	588.14	2.49	0.21
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{LM200+OW200})$	7	-288.03	590.33	4.68	0.07
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{LM200})$	6	-306.86	625.92	40.27	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+LM200})$	7	-305.93	626.12	40.47	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{HM200})$	7	-306.21	626.69	41.05	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+HM200})$	6	-322.31	656.82	71.17	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+HM100})$	7	-323.28	660.83	75.18	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+HM50})$	7	-324.51	663.28	77.63	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+Phrag200})$	7	-324.67	663.61	77.96	0.00
$\rho(\text{day/night+80repuscular+d/nXcrep}), \psi(\text{park+LM100})$	7	-324.75	663.76	78.11	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park})$	6	-325.82	663.83	78.19	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+LM50})$	7	-325.01	664.28	78.63	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+BM100})$	7	-325.02	664.30	78.65	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+Phrag100})$	7	-325.12	664.51	78.87	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+BM50})$	7	-325.36	664.98	79.34	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+Phrag50})$	7	-325.70	665.67	80.02	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+BM200})$	7	-325.78	665.82	80.18	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+HM100})$	6	-331.75	675.69	90.05	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{park+Phrag200})$	6	-332.12	676.43	90.79	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(.)$	5	-335.19	680.53	94.88	0.00
$\rho(\text{day/night+crepuscular2}), \psi(.)$	5	-335.19	680.53	94.88	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{LM100})$	6	-334.26	680.71	95.07	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{HM50})$	6	-334.40	681.00	95.36	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{BM100})$	6	-334.42	681.03	95.38	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{Phrag50})$	6	-334.86	681.91	96.26	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{LM50})$	6	-334.95	682.10	96.45	0.00
$\rho(\text{day/night}), \psi(.)$	3	-338.07	682.19	96.55	0.00
$\rho(\text{day/night+crepuscular}), \psi(.)$	4	-337.06	682.22	96.58	0.00

Table 5 (continued). Model Selection Table for Seaside Sparrow including all predictors for detection (ρ) and occupancy (ψ) including the number of parameters (K), log-likelihood (log-lik), AICc score, Δ AICc, and model weight (wt).

Model Parameters	K	Log-lik	AICc	Δ AICc	wt
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{BM200})$	6	-335.02	682.24	96.59	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{Phrag100})$	6	-335.07	682.33	96.68	0.00
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(\text{BM50})$	6	-335.09	682.37	96.73	0.00
$\rho(\text{day/night+absolute crepuscular time}), \psi(.)$	4	-337.20	682.49	96.84	0.00
$\rho(\text{sky}), \psi(.)$	3	-347.14	700.34	114.69	0.00
$\rho(\text{absolute crepuscular time}), \psi(.)$	3	-347.46	700.98	115.34	0.00
$\rho(.), \psi(.)$	2	-348.98	701.99	116.34	0.00
$\rho(\text{crepuscular time}), \psi(.)$	3	-348.33	702.72	117.08	0.00
$\rho(\text{moon}), \psi(.)$	3	-348.54	703.13	117.48	0.00
$\rho(\text{day of year}), \psi(.)$	3	-348.78	703.62	117.97	0.00
$\rho(\text{noise}), \psi(.)$	3	-348.89	703.83	117.18	0.00
$\rho(\text{wind}), \psi(.)$	3	-348.94	703.93	118.28	0.00
$\rho(\text{am/pm}), \psi(.)$	3	-348.95	703.96	118.32	0.00
$\rho(\text{crepuscular timeam/pm}), \psi(.)$	4	-348.31	704.71	119.06	0.00

Appendix G: Model Selection Table for Chuck-will's-widow

Table 6. Model Selection Table for Chuck-will's-widow including all predictors for detection (ρ) and occupancy (ψ) including the number of parameters (K), log-likelihood (log-lik), AICc score, Δ AICc, and model weight (wt).

Model Parameters	K	Log-lik	AICc	Δ AICc	wt
$\rho(\text{day/night}), \psi(\text{park+BM50})$	5	-68.99	148.11	0.00	0.13
$\rho(\text{day/night}), \psi(\text{BM50})$	4	-70.59	149.28	1.16	0.07
$\rho(\text{day/night}), \psi(\text{park})$	4	-70.87	149.84	1.72	0.05
$\rho(\text{day/night}), \psi(\text{parkBM100})$	5	-69.87	149.89	1.77	0.05
$\rho(\text{day/night}), \psi(.)$	3	-72.00	150.06	1.95	0.05
$\rho(\text{day/night}), \psi(.)$	3	-72.00	150.06	1.95	0.05
$\rho(\text{day/night}), \psi(\text{HM50})$	4	-71.16	150.41	2.29	0.04
$\rho(\text{day/night}), \psi(\text{parkPhrag200})$	5	-70.21	150.56	2.44	0.04
$\rho(\text{day/night}), \psi(\text{BM100})$	4	-71.26	150.62	2.50	0.04
$\rho(\text{day/night}), \psi(\text{LM200})$	4	-71.41	150.92	2.80	0.03
$\rho(\text{day/night}), \psi(\text{park+HM50})$	5	-70.45	151.05	2.94	0.03
$\rho(\text{day/night}), \psi(\text{LM100})$	4	-71.48	151.06	2.95	0.03
$\rho(\text{day/night}), \psi(\text{parkLM200})$	5	-70.50	151.15	3.04	0.03
$\rho(\text{day/night+absolute crepuscular time}), \psi(.)$	4	-71.54	151.16	3.05	0.03
$\rho(\text{day/night}), \psi(\text{park+LM100})$	5	-70.52	151.18	3.07	0.03
$\rho(\text{day/night}), \psi(\text{HM100})$	4	-71.56	151.22	3.11	0.03
$\rho(\text{day/night}), \psi(\text{LM50})$	4	-71.61	151.32	3.21	0.03
$\rho(\text{day/night}), \psi(\text{parkLM50})$	5	-70.61	151.36	3.25	0.02
$\rho(\text{day/night}), \psi(\text{Phrag200})$	4	-71.71	151.51	3.40	0.02
$\rho(\text{day/night}), \psi(\text{HM200})$	4	-71.77	151.63	3.52	0.02
$\rho(\text{day/night}), \psi(\text{parkHM100})$	5	-70.78	151.70	3.58	0.02
$\rho(\text{day/night}), \psi(\text{park+BM200})$	5	-70.78	151.70	3.58	0.02
$\rho(\text{day/night+crepuscular}), \psi(.)$	4	-71.82	151.74	3.63	0.02
$\rho(\text{day/night}), \psi(\text{parkPhrag50})$	5	-70.84	151.83	3.71	0.02
$\rho(\text{day/night}), \psi(\text{park+Phrag100})$	5	-70.85	151.85	3.73	0.02
$\rho(\text{day/night}), \psi(\text{park+HM200})$	5	-70.86	151.86	3.75	0.02
$\rho(\text{day/night}), \psi(\text{BM200})$	4	-71.90	151.90	3.79	0.02
$\rho(\text{day/night}), \psi(\text{Phrag50})$	4	-71.93	151.96	3.84	0.02
$\rho(\text{day/night}), \psi(\text{Phrag100})$	4	-72.00	152.10	3.99	0.02
$\rho(\text{day/night+crepuscular+d/nXcrep}), \psi(.)$	5	-71.02	152.18	4.07	0.02
$\rho(\text{sky}), \psi(.)$	3	-77.03	160.12	12.00	0.00
$\rho(\text{day of year}), \psi(.)$	3	-77.22	160.49	12.37	0.00
$\rho(\text{p(wind)}), \psi(.)$	3	-81.72	169.49	21.38	0.00

Table 6 (continued). Model Selection Table for Chuck-will's-widow including all predictors for detection (ρ) and occupancy (ψ) including the number of parameters (K), log-likelihood (log-lik), AICc score, Δ AICc, and model weight (wt).

Model Parameters	K	Log-lik	AICc	Δ AICc	wt
$\rho(\cdot), \psi(\cdot)$	2	-86.32	176.67	28.55	0.00
$\rho(\text{am/pm}), \psi(\cdot)$	3	-85.88	177.82	29.70	0.00
$\rho(\text{noise}), \psi(\cdot)$	3	-86.09	178.23	30.12	0.00
$\rho(\text{moon}), \psi(\cdot)$	3	-86.13	178.31	30.20	0.00
$\rho(\text{crepuscular time}), \psi(\cdot)$	3	-86.21	178.47	30.35	0.00
$\rho(\text{absolute crepuscular time}), \psi(\cdot)$	3	-86.32	178.69	30.58	0.00
$\rho(\text{crepuscular timeam/pm}), \psi(\cdot)$	4	-85.86	179.82	31.70	0.00

Appendix H: Model Selection Table for Common Nighthawk

Table 7. Model Selection Table for Common Nighthawk including all predictors for detection (ρ) and occupancy (ψ) including the number of parameters (K), log-likelihood (log-lik), AICc score, Δ AICc, and model weight (wt).

Model Parameters	K	Log-lik	AICc	Δ AICc	wt
ρ (day/night+absolute crepuscular time), ψ (park+HM200)	6	-481.75	975.70	0.00	0.47
ρ (day/night+absolute crepuscular time), ψ (park+BM200)	6	-482.16	976.52	0.82	0.31
ρ (day/night+absolute crepuscular time), ψ (park+HM100)	6	-483.33	978.85	3.15	0.10
ρ (day/night+absolute crepuscular time), ψ (park+HM50)	6	-484.00	980.19	4.49	0.05
ρ (day/night+absolute crepuscular time), ψ (park+Phrag200)	6	-484.33	980.85	5.15	0.04
ρ (day/night+absolute crepuscular time), ψ (park+Phrag100)	6	-485.74	983.69	7.99	0.01
ρ (day/night+absolute crepuscular time), ψ (park+BM100)	6	-486.20	984.59	8.89	0.01
ρ (day/night+absolute crepuscular time), ψ (park+LM200)	6	-486.23	984.67	8.96	0.01
ρ (day/night+absolute crepuscular time), ψ (park+Phrag50)	6	-486.51	985.22	9.52	0.00
ρ (day/night+absolute crepuscular time), ψ (park)	5	-487.93	985.99	10.29	0.00
ρ (day/night+absolute crepuscular time), ψ (park+LM50)	6	-487.15	986.51	10.80	0.00
ρ (day/night+absolute crepuscular time), ψ (park+LM100)	6	-487.40	986.99	11.29	0.00
ρ (day/night+absolute crepuscular time), ψ (park+BM50)	6	-487.75	987.71	12.00	0.00
ρ (day/night+absolute crepuscular time), ψ (Phrag200)	5	-557.50	1125.14	149.44	0.00
ρ (day/night+absolute crepuscular time), ψ (HM100)	5	-559.72	1129.58	153.88	0.00
ρ (day/night+absolute crepuscular time), ψ (HM50)	5	-561.46	1133.06	157.35	0.00
ρ (day/night+absolute crepuscular time), ψ (HM200)	5	-562.74	1135.63	159.93	0.00
ρ (day/night+absolute crepuscular time), ψ (Phrag100)	5	-565.51	1141.17	165.47	0.00
ρ (day/night+absolute crepuscular time), ψ (Phrag50)	5	-566.40	1142.94	167.24	0.00
ρ (day/night+absolute crepuscular time), ψ (BM200)	5	-567.57	1145.28	169.58	0.00
ρ (day/night+absolute crepuscular time), ψ (.)	4	-568.63	1145.36	169.66	0.00
ρ (day/night+absolute crepuscular time), ψ (.)	4	-568.63	1145.36	169.66	0.00
ρ (day/night+absolute crepuscular time), ψ (BM100)	5	-567.65	1145.45	169.75	0.00
ρ (day/night+absolute crepuscular time), ψ (BM50)	5	-568.03	1146.20	170.50	0.00
ρ (absolute crepuscular time), ψ (.)	3	-570.08	1146.21	170.51	0.00
ρ (day/night+absolute crepuscular time), ψ (LM50)	5	-568.42	1146.98	171.28	0.00

Table 7 (continued). Model Selection Table for Common Nighthawk including all predictors for detection (ρ) and occupancy (ψ) including the number of parameters (K), log-likelihood (log-lik), AICc score, Δ AICc, and model weight (wt).

Model Parameters	K	Log-lik	AICc	Δ AICc	wt
$\rho(\text{day/night} + \text{absolute crepuscular time}), \psi(\text{LM200})$	5	-568.62	1147.38	171.68	0.00
$\rho(\text{day/night} + \text{absolute crepuscular time}), \psi(\text{LM100})$	5	-568.62	1147.39	171.69	0.00
$\rho(\text{crepuscular time} + \text{am/pm}), \psi(.)$	4	-573.89	1155.87	180.17	0.00
$\rho(\text{day/night} + \text{crepuscular time} + d/nX_{\text{crep}}), \psi(.)$	5	-578.12	1166.37	190.67	0.00
$\rho(\text{am/pm}), \psi(.)$	3	-581.83	1169.71	194.01	0.00
$\rho(\text{day/night} + \text{crepuscular}), \psi(.)$	4	-582.03	1172.15	196.45	0.00
$\rho(\text{sky}), \psi(.)$	3	-583.61	1173.28	197.58	0.00
$\rho(\text{crepuscular time}), \psi(.)$	3	-587.31	1180.67	204.97	0.00
$\rho(\text{noise}), \psi(.)$	3	-590.23	1186.51	210.81	0.00
$\rho(\text{day/night}), \psi(.)$	3	-590.76	1187.57	211.87	0.00
$\rho(\text{moon}), \psi(.)$	3	-592.65	1191.36	215.66	0.00
$\rho(p(\text{wind})), \psi(.)$	3	-593.58	1193.22	217.52	0.00
$\rho(\text{day of year}), \psi(.)$	3	-593.64	1193.34	217.64	0.00

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