Application of Ground-truth for Classification and Quantification of Bird Movements on Migratory Bird Habitat Initiative Sites in Southwest Louisiana

Final Report

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EXECUTIVE SUMMARY

This project was initiated to assess migrating and wintering bird use of lands enrolled in the Natural Resources Conservation Service's (NRCS) Migratory Bird Habitat Initiative (MBHI). The MBHI program was developed in response to the Deepwater Horizon oil spill in 2010, with the goal of improving/creating habitat for waterbirds affected by the spill. In collaboration with the University of Delaware (UDEL), we used weather surveillance radar data (Sieges 2014), portable marine radar data, thermal infrared images, and visual observations to assess bird use of MBHI easements. Migrating and wintering birds routinely make synchronous flights near dusk (e.g., departure during migration, feeding flights during winter). Weather radars readily detect birds at the onset of these flights and have proven to be useful remote sensing tools for assessing bird-habitat relations during migration and determining the response of wintering waterfowl to wetland restoration (e.g., Wetlands Reserve Program lands). However, ground-truthing is required to identify radar echoes to species or species group. We designed a field study to ground-truth a larger-scale, weather radar assessment of bird use of MBHI sites in southwest Louisiana. We examined seasonal bird use of MBHI fields in fall, winter, and spring of 2011-2012. To assess diurnal use, we conducted total area surveys of MBHI sites in the afternoon, collecting data on bird species composition, abundance, behavior, and habitat use. In the evenings, we quantified bird activity at the MBHI easements and described flight behavior (i.e., birds landing in, departing from, circling, or flying over the MBHI tract). Our field sampling captured the onset of evening flights and spanned the period of collection of the weather radar data analyzed. Pre- and post-dusk surveys were conducted using a portable radar system and a thermal infrared camera.

Landbirds, shorebirds, and wading birds were commonly found on MBHI fields during diurnal surveys in the fall. Ducks (breeding and early migrating species) were also detected on diurnal surveys, but were less abundant than the previously mentioned taxa. Wading birds were the most abundant taxa observed during evening surveys up to 5 min before dusk when their numbers declined and duck densities increased. Ducks accounted for 64.0% of all birds detected from 0-5 min before dusk. Most ducks observed at that

time were flyovers (71.4%), but circling (9.2%), departing (12.1%), and landing birds (7.4%) were also detected.

In fall, the portable radar system detected two peaks in bird movement: one shortly before sunset and a second shortly after dusk. The later movement began just before dusk, peaked approximately 9 min after dusk, and concluded within 20 min after dusk. The flight headings of birds changed in relation to time from dusk. In general, the majority of targets flew towards the southwest before dusk and towards the northeast after dusk. The change in flight direction pre- and post-dusk may be related to movements dominated by migratory versus local flight.

In winter, ducks, shorebirds, wading birds, and landbirds were the most abundant taxa in diurnal surveys. Geese were abundant at times, but their frequency of occurrence and densities were highly variable. The majority of ducks, shorebirds, and wading birds were observed feeding in MBHI fields. Landbirds and geese were more commonly seen resting. Overwintering ducks and geese dominated the movements near dusk (95.9% of all birds ≤ 5 min pre-dusk). Ducks were more frequently observed landing in (40.8%) and flying over (33.5%) MBHI fields while geese were mainly observed circling (54.7%) and flying over (38.9%) sites. Most of the shorebirds detected ≤ 5 min before dusk (74.6% of all shorebirds) were departing the MBHI fields. Portable radar and thermal infrared camera data indicate that large northeastward movements of waterfowl (99.9% of birds identified to taxa) occurred after dusk (~10 min post-dusk). Most birds observed on radar during this peak were flyovers and did not use the MBHI fields (78.9%); however, birds were detected landing in (10.9%) and departing from (2.9%) MBHI fields. The post-dusk movements may have been waterfowl feeding flights that routinely occur in southwest Louisiana between roost sites in coastal marsh and foraging sites in agricultural fields to the north. After the conclusion of these movements ca. 30 min post-dusk, portable radar data showed little activity through the night until approximately 0.5 to 1.5 hr pre-dawn. Radar data within 30 min pre-dawn indicate that most birds departed MBHI fields on flight headings toward the southwest. The pre-dawn movements were likely waterfowl departing from their foraging sites and returning to roosting areas in coastal marshes to the south.

Shorebirds, ducks, and wading birds were the most abundant taxa during diurnal surveys of MBHI fields in spring, and the majority of individuals were observed actively foraging rather than resting. Breeding, overwintering, and transient migrant species were all detected on MBHI fields. Near dusk, the majority of birds in flight were ducks (67.7 % of all birds) that were flying over (38.2%), departing from (34.2%), or landing in (22.9%) MBHI fields. These results contrast with our winter observations when 40.8% of ducks landed in MBHI fields and 9.1% departed from fields. Portable radar and thermal camera data documented a peak in bird movements shortly after dusk; however, the peak was of lower magnitude than observed in winter. Thermal camera data identified the birds as mostly shorebirds (57.3%) and waterfowl (40.4%). Flight headings were more variable than winter and lacked a unidirectional flow. After the post-dusk movement had concluded, bird activity remained low throughout the night until approximately 30 min before dawn when a small peak in activity was observed. Flight headings during the pre-dawn movement were variable and multidirectional.

We compared bird abundance data collected by each of our three sampling techniques (portable radar, thermal infrared camera, and direct visual observation) for the 45-min observation period immediately preceding dusk; the period when all three survey methods were used simultaneously. Abundance data from the three methods were significantly correlated at $P \leq 0.05$.

We documented diurnal and nocturnal bird use of MBHI fields. Most observations near dusk in winter, when weather radar data were sampled, were of ducks and geese, and in spring, shorebirds and ducks. Our winter observations show large synchronous movements of waterfowl occurring near dusk. These birds were moving to the NE and feeding in agricultural fields at night. Portable radar data suggest that birds stay in these fields through the night and make return flights near dawn.

INTRODUCTION

The intent of this report is to describe field data gathered in support of a radar-based study to assess migrating and wintering bird use of lands enrolled in the Natural Resources Conservation Service's (NRCS) Migratory Bird Habitat Initiative (MBHI). The MBHI program was developed in response to the Deepwater Horizon oil spill in 2010, with the goal of improving/creating habitat for water birds affected by the spill. In the fall of 2010, southwest Louisiana landowners enrolled in the MBHI began managing their farm land for waterfowl, shorebirds, and wading birds by creating mudflats and/or shallow water flooded fields.

This report is part of an ongoing research partnership formed in 2006 among the USGS National Wetlands Research Center, University of Delaware (UDEL) and NRCS, that has been using weather surveillance radars (WSR-88D, also known as NEXRAD) to assess the response of migrating and wintering birds to Wetlands Reserve Program (WRP) lands in support of the Wildlife Component of the Conservation Effects Assessment Project (CEAP) (Buler et al. 2010, Buler et al. 2011, Buler et al. 2012a, Buler et al. 2012b). The national NEXRAD network readily detects birds aloft and has proven to be a useful remote-sensing tool for assessing the response of wintering waterfowl to WRP lands (Buler et al. 2012a). This is possible because wintering waterfowl initiate nocturnal feeding flights en masse in an abrupt exodus that is closely synchronized to the angle of the sun near dusk (i.e., the end of civil twilight when solar angle equals -6°). In order to assess the accuracy and precision of mapping waterfowl distributions with NEXRAD data, collection of ground-truthing data is required. For instance, in the Central Valley of California, we mapped wintering waterfowl distributions using NEXRAD data that was ground-truthed with a radio-telemetry dataset (Buler et al. 2012b). Because the telemetry data were not designed or collected for the purpose of ground-truthing radar observations, we concluded that future radar studies should collect more robust ground-truthing data by sampling replicate areas stratified throughout radar coverage areas (Buler et al. 2012b, p. 8). Ground-truthing, often lacking in radar ornithology studies, can also provide empirical evidence that radar reflectivity at the onset of nocturnal feeding flights, or onset of migration in the case of shorebirds and landbirds, is quantitatively related to the density of birds on the ground (Buler and Diehl 2009). This is especially important when the goal of a radar-based study is to assess bird response to "on the ground" changes in habitat conditions, like with the MBHI.

Methodologies used to ground-truth NEXRAD data vary depending on study objectives. Studies focused on migrant-habitat relations require radar data collected during synchronized, en masse movements, such as evening exodus. During migration, nocturnal migrants rest and feed in stopover habitat during the day, then resume migration just after sunset. By using radar data collected at the point of evening exodus, it is possible to determine bird distributions during stopover. Transect survey and mist-net data have identified targets in radar studies that quantified bird stopover distributions during spring and autumn migration (DiGaudio et al. 2008, Buler and Moore 2011). NEXRAD data have also been used to study the movements and distribution of migrating and wintering waterfowl. Ground-based counts, radio-telemetry, and thermal imaging data have all been used to identify waterfowl during the evening exodus of migrating birds and at the onset of evening feeding flights of overwintering birds (O'Neal et al. 2010, Randall et al. 2011, Buler et al. 2012b). The goal of our study was to classify and quantify bird movements on selected MBHI sites in southwestern Louisiana to identify the source of radar echoes detected during evening liftoff (i.e., evening departure during migration, evening feeding flight during winter). We used direct visual counts, thermal infrared imaging, and portable marine radar data to identify birds prior to and during evening liftoff and to describe spatial and temporal patterns of movement.

METHODS

Study Area and Site Selection

Information on MBHI tract boundaries and associated management activities were obtained from the NRCS Louisiana office for all MBHI easements within 80 km of the NEXRAD station in Lake Charles, LA (KLCH). This range limit was selected because of radar beam geometry. NEXRAD samples the airspace by rotating 360° through a series of 5-14 tilt angles over a period of 5-10 min. Typically, the lowest tilt angle of 0.5° is used for studies of bird-habitat relations. With increasing distance from the radar, the radar beam increases in height and begins to pass above low flying birds at distances beyond 80 km (Buler and Diehl 2009).

A total of 122 potential study sites were within 80 km of KLCH. We eliminated sites if their contracts were not multi-year and multi-season. Multi-year contracts (i.e., EQIP contracts, n=44) were required because all 1-year contracts (i.e., WHIP contracts, n=78) were completed by the summer of 2011. Single-season contracts (i.e., fall or winter only) were avoided to better capture both shorebird and waterfowl migration. One site was eliminated because it was located in an area with poor NEXRAD coverage. These steps reduced the number of available contracts to 39. We then dropped from consideration sites smaller than a radar pulse volume (0.5° by 250 m), <4 km from another study site (to ensure spatial independence, Buler et al. 2012b), or > 71 km from KLCH (because of concerns about radar beam height). This narrowed the list of potential study sites to 25 MBHI contracts. After contact was made with the landowners and sites were evaluated, the list was reduced to 12 contracts/sites (Figure 1), primarily due to landowner concern that the proposed activities might be incompatible with hunting, withdrawal from the program, or disinterest in being involved for unspecified reasons. Each study site was a field or group of fields within close proximity to each other. Number of fields per site ranged from 1 to 12 for a total of 55 fields located 20 to 71 km from KLCH. Fields ranged from 16.1 to 121.6 ha, with the majority in rice and/or crawfish production (Table 1).

As part of our collaboration with UDEL, we also obtained information on MBHI tracts within an 80-km radius of four additional NEXRAD stations: Houston, TX (KHGX), Little Rock, AR (KLZK), Memphis, TN (KNQA), and Paducah, KY (KPAH). All MBHI tract data (boundaries and management activities for fields) were sent to UDEL for analyses (i.e., assessment of migratory bird use of agricultural fields pre- and post-enrollment in the MBHI program).

Use of MBHI Fields

To measure diurnal bird use of the MBHI easements, we conducted total area surveys from August 2011 through May 2012. Each of the 55 fields was sampled on average once every 9-10 days. We used a modified version of the Integrated Waterbird Management and Monitoring Program protocol (IWMM 2010) to estimate bird densities. Surveys occurred in the afternoon and continued up to 1 hr before sunset. All birds detected within a known area were recorded. The area surveyed for each count was delineated using aerial photography so that bird densities could be calculated. For each count, we recorded weather conditions, habitat cover type, water level, number of birds by species, and data on bird behavior, specifically whether birds were actively foraging or resting. Bird density (number of birds per hectare) was summarized by bird taxa (i.e., ducks, geese, shorebirds, wading birds, landbirds, seabirds, and waterbirds; see Appendix A for taxa classification by species) and behavior, and by season: fall (August–October), winter (November–February), and spring (March–May).

MBHI management practices were not consistently applied to all sites during the study. Some sites were only actively managed in the fall and winter, whereas others were active in winter and spring, and still others were active in fall, winter, and spring. The number of seasons of active management depended on the MBHI activity the landowners enrolled in. To avoid unequal sampling among sites, we chose not to limit our sampling to periods of active management and sampled each site for the entire length of the study.

Evening Movements

Ground surveys were conducted to quantify birds in the air space above the study sites at evening liftoff. These observations served as ground verification for radar data collected by the KLCH station and interpolated to a sun angle of 5.5° below horizon (i.e., approximately 2.5 min before dusk or a solar angle of -6°). Sampling began in August 2011 and continued through May 2012. Each site was sampled every 22-23 days on average. Surveys began 30 min before sunset and continued until visual counts were no longer possible, usually at or shortly after the end of civil twilight, the time period (approximately 25 min) between sunset (solar angle = -0.833°) and dusk (solar angle = -6.0°). Our sampling period captured the onset of evening flights and spanned the period of collection of the NEXRAD data analyzed. Data were recorded on weather conditions, observation time, species, number of individuals, flight direction, and flight activity (on the ground, landing, departing, circling, or flying over the study site). Bird density was summarized by date and taxa (i.e., ducks, geese, shorebirds, wading birds, landbirds, and seabirds). For the 45 min preceding dusk, bird density per minute was summarized by season, flight behavior, and taxa.

Portable Radar

Waterfowl and shorebirds are known to move between roosting and feeding sites at night when visibility is limited. We used a portable radar system to complement evening ground survey data and to quantify movements after dusk. The radar system was deployed the week of August 22, 2011 and surveyed one site per week through May 2012. The system was operated from 1 hr pre-sunset until at least 30 min post-dusk, but usually past sunrise of the following morning, to collect data on movement patterns (e.g., direction, speed, quantity, altitude) of birds in the study area. The radar system (Detect, Inc.) included two radars: one scanning horizontally (S-band), the other scanning vertically (X-band). The horizontal-scanning radar (JRC model JMA-5330-12; scanner model NKE-1075) used a 3.7 m slotted antenna with a transmitted power of 30 kW and beam width of 1.9° x 30°. We operated at 2.8 km range with a rotation speed of 26 rpm, transmitting frequency of 3050 MHz (10 cm wavelength), pulse width of 0.07 µs, and a repetition frequency of 1900 Hz. We reduced ground clutter interference using a radar fence constructed with radar absorbing foam (Laird Technologies) and an aluminum shield. The fence was attached in front of the rotating antenna so that the lower edge of the beam was blocked. The vertical-scanning radar (JRC model JMA-5320-7, scanner model NKE-2252) used a 2.1 m slotted antenna with a transmitted power of 25 kW, a beam width of 1.0° x 20°, and a rotation speed of 24 rpm. We scanned a range of 1.4 km with a transmitting frequency of 9410 MHz (3 cm wavelength), pulse width of 0.07 µs, and repetition frequency of 2200 Hz.

All radar data were digitally recorded using a radar interface card (Sigma Engineering, Ltd., model Rsi4000-RT-8/12) and SeaScan Processor (Sigma Engineering, Ltd.). These raw radar files were later analyzed to extract bird targets using Program radR (Taylor et al. 2010), an open source platform designed for marine radar systems. Various plugins are available within radR for analyzing radar data. The 'SeaScan archive reader' plugin was used to read-in the raw radar files. Persistent ground clutter was removed with the 'declutter' plugin. The 'zone' plugin was used to truncate the horizontal radar data to <1.59 km, the greatest distance between the radar unit and the outer boundary of a study site. We used the 'tracker' plugin with the multi-frame correspondence method to plot and measure the number of targets in the airspace. The 'track summarizer' script was used to calculate each track's speed and distance traveled in the radar beam. Tracks with speeds less than 6 m/sec were excluded to minimize insect contamination. Both the horizontal- and the vertical-scanning radars had difficulty distinguishing between individual birds and flocks of birds. Consequently, the number of targets detected by the portable radar often under estimated the true number of individuals in the airspace when flocks were present.

We calculated the number of targets per minute within 1.59 km of the radar unit and compared these results to the evening ground survey data and thermal infrared camera data (see following methods). Flight altitudes and flight headings were summarized for radar targets in 10-min intervals from 50 min pre-dusk to 30 min post-dusk and 50 min pre-dawn to 60 min post-dawn. Altitude data are only presented for winter due to heavy insect contamination in fall and spring. Using the horizontal portable radar data, we quantified winter bird use of MBHI fields in the evenings from 5 min pre-dusk to 30 min post-dusk and in the mornings from 30 min pre-dawn to dawn. These time periods were selected to capture the large waterfowl movements that typically occur near dusk and dawn. The radar data were manually scanned in 1-min increments and targets detected over the MBHI were classified as landing in, departing from, or flying over the MBHI fields. Targets that could not be classified into one of these categories were classified as unknowns.

Because we were interested in comparing portable radar data to NEXRAD reflectivity data (analyzed by UDEL), we extracted radar intensity values from data collected near dusk. The intensity values were measured within radR using the 'saveblips' plugin. Radar intensity values from each portable radar scan are on a log scale. The anti-log (e) was calculated, summed across each sweep, and then averaged across sweeps per site. Intensity values from eleven radar sweeps spaced 1 min apart and centered on dusk (one at dusk, 5 before, and 5 after) were averaged for comparison with NEXRAD data.

Thermal Infrared Camera

Beginning in December 2011, we used a thermal infrared camera (FLIR Systems, Inc., model T-620 with 25° lens) in conjunction with the portable radar surveys to identify radar targets and estimate bird densities in low-light conditions. The camera was mounted to a tripod to record birds flying through a portion of the radar beam from 1 hr prior to sunset to ca. 30 min post-dusk. The camera had a resolution of 640 x 480 (307,200 pixels), a frame rate of 30 Hz, and a field of view of 25° x 19°. Video files were recorded in mpeg4 format to a SD card on the camera and scanned for birds at a later date. The camera readily detected birds and insects, but not all objects could be easily identified. We classified detections as bird, insect, other (e.g., airplane), or unknown. For bird detections, we recorded the number of individuals and identified targets to taxa (e.g., wading birds, waterfowl, shorebirds, landbirds, seabirds, or unknown).

Data Analysis

Using winter and spring data, we compared results of the portable radar, evening visual, and thermal infrared camera surveys for the 45-min observation period immediately preceding dusk. This was the only time period when the three survey methods were used simultaneously. Data were clustered into 5-min intervals and the mean numbers of targets per minute were compared. We used Spearman's correlation coefficient (Proc CORR, SAS Institute Inc. 2008) to test for similarities among the portable radar, evening visual-counts, and thermal infrared camera detections, and report significant correlations at $P \leq 0.05$.

The data were also made available to UDEL for ground-truth analysis of NEXRAD data in southwest Louisiana (Sieges 2014).

RESULTS AND DISCUSSION

Fall Observations

Use of MBHI Fields

Bird phenology and potential target densities — Ducks, shorebirds, wading birds, and landbirds were all commonly detected on MBHI fields in the fall (Figure 2). Ducks included breeding species, such as Mottled Duck (*Anas fulvigula*) and whistling-ducks (*Dendrocygna* spp.), and early migrants such as Blue-winged Teal (*Anas discors*) and Northern Pintail (*Anas acuta*) (See Appendix A for a list of all species detected and Appendices B–E for species-specific bird densities grouped by taxa). The densities of shorebirds and waders in MBHI fields were greatest in the fall when a mix of resident, migrating, and overwintering species were detected. The most common shorebirds were 'peep' sandpipers (*Calidris* spp.), dowitchers (*Limnodromus* spp.), and yellowlegs (*Tringa* spp.). White Ibis (*Eudocimus albus*) and *Plegadis* spp. (White-faced Ibis and Glossy Ibis) were the most abundant wading birds observed. Blackbirds (*Agelaius phoeniceus*, *Molothrus ater*) and grackles (*Quiscalus* spp.) comprised the majority of landbirds. Waterbirds and geese were uncommon and no seabirds were observed using MBHI fields in the fall. Bird densities were unevenly distributed among the study sites (Figure 3). With the exception of site 11, bird densities were generally higher at the southern sites (sites 1-6). The largest densities of ducks, wading birds, and landbirds were observed at the southern sites. Site 11 had the highest densities of shorebirds.

Feeding vs. resting — Bird activity (i.e., actively foraging or resting) varied among taxa (Figure 4). The majority of ducks (69.2%), wading birds (81.6%), and landbirds (86.5%) were observed resting, whereas a larger number of shorebirds (74.8%) and waterbirds (73.5%) tended to use MBHI fields for foraging. By late fall, most ducks were using MBHI fields for active foraging. The few geese detected in the fall were all resting.

Evening Movements

Direct visual observations — We examined densities of all birds in the airspace above the MBHI fields during the 45-min period leading up to dusk. Wading birds were the most abundant taxa during this period (Figure 5), primarily *Plegadis* spp. and White Ibis (See Appendices F–I for species-specific bird densities). Ducks (mainly Blue-winged Teal and whistling-duck spp.) were the second most abundant taxa followed by shorebirds and landbirds (mostly blackbirds). No seabirds or waterbirds were detected in the fall.

Bird abundance varied temporally as the surveys progressed towards dusk (Figure 6). Wading birds were the most common taxa throughout most surveys up to 5 min pre-dusk at which point their densities declined to low levels (99.5% of all observations occurred >5 min before dusk). Ducks were present throughout the 45-min period, but were most abundant near dusk and were the most abundant taxa detected near dusk (64.0% of all bird detections ≤5 min pre-dusk when solar angle was -5° to -6°). Shorebirds were most abundant before sunset (67.2%) and not common near dusk (5.8% within 5 min of dusk). Geese were detected in late fall, and 40% of their detections came near dusk. Landbirds were also observed, but most detections (95.2%) occurred prior to sunset.

We categorized the evening flight activities for each taxon based on whether birds were landing, departing, circling, or flying over the MBHI fields. The majority of ducks observed were flyovers (60.8%) and did not use the MBHI fields (Figure 7). There was a relatively large number of ducks observed circling (22.5%), which were birds that likely landed in the study area. Detections of ducks departing from (8.6%) and landing in (8.1%) MBHI fields were less frequently observed. Of ducks detected near dusk (≤5 min before dusk), 71.4% were flyovers, 12.1% were departures, 9.2% were circling, and 7.4% were landing. Shorebirds were infrequently seen landing in the MBHI fields (5.1% of all shorebirds) (Figure 8). Circling birds and flyovers were observed throughout the observation period, but most departing shorebirds were observed between 20-45 min before dusk (92.9% of departures). Only 6.4% of shorebirds were observed near dusk (≤ 5 min from dusk) and these birds were mostly flyovers (50.8%) and departures (43.0%).

Most wading bird detections were flyovers (79.6% of all waders) (Figure 9) and relatively few were observed landing in (1.4%) or circling (3.3%) the MBHI fields. Wading bird flights had primarily ceased within 5 min of dusk (0.5% of wading birds detected ≤ 5 min from dusk) and were mostly flyovers (98.3%). Landbird observations near dusk (2.5% ≤ 5 min from dusk) were primarily birds landing in (96.9%) (Figure 10) MBHI fields.

Thermal infrared detections — Thermal infrared camera data were only collected in winter and spring.

Portable marine radar — In the fall, the horizontal-scanning radar detected two peaks in bird movement: one shortly before sunset and a second shortly after dusk (Figure 11). The later movement began shortly before dusk, peaked about 9 min post-dusk and concluded within 20 min after dusk. Flight headings of radar targets changed in relation to time from dusk (Figure 12). In general, targets flew towards the southwest during the 50 to 10 min preceding dusk. In the first 10 min after dusk, the radar observed a strong movement of targets flying towards the northeast. This pattern continued to a lesser degree in the 10-20 min after dusk. The northeastward flow coincided with the post-dusk peak in number of targets (Figure 11). The change in flight direction pre- and post-dusk may be related to movements dominated by migratory versus local flight.

We measured flight altitudes of radar targets with the vertical-scanning radar; however, heavy insect contamination on 70% of the fall surveys prevented accurate estimates. Most of the contamination occurred near dusk and masked the peak movement detected by the horizontal-scanning radar. Insects were not an issue with the horizontal-scanning radar because of the longer wavelength used by this radar.

<u>*Morning Movements*</u>

Portable marine radar — Continuous radar sampling from sunset through sunrise was not initiated until late fall. Therefore, these data are only presented for winter and spring.

Winter Observations

<u>*Use of MBHI Fields*</u>

Bird phenology and potential target densities — Ducks, shorebirds, wading birds, and landbirds were present at the MBHI sites throughout the winter (Figure 2). Dabbling ducks (e.g., Gadwall [*Anas strepera*], Northern Shoveler [*Anas clypeata*], Green-winged Teal [*Anas carolinensis*]) were routinely found on MBHI fields, and diving ducks (e.g., Canvasback [*Aythya valisineria*]) were occasionally detected. Geese were abundant at times, but their frequency of occurrence (0.094) and densities were highly variable ranging from a few individuals to 15,000 Snow Geese (*Chen caerulescens*) in one field. At least eleven shorebird species and eight wading bird species used the fields during winter. Dowitchers were the most common shorebird observed. Similar to fall, *Plegadis* spp. and White Ibis were the most abundant wading birds. Red-winged Blackbird (*Agelaius phoeniceus*) was the most common landbird species. Waterbirds and seabirds were detected but at low densities. American Coot (*Fulica americana*) and Ring-billed Gulls (*Larus delawarensis*) were the most abundant waterbird and seabird, respectively.

The density of ducks on MBHI lands fluctuated over the winter. Duck hunting was known to occur on at least 9 of 12 study sites, and the variation in bird density may be a result of hunting pressure. There were three hunting periods during our study: teal season (Sept. 10-25), duck season - 1st split (Nov. 12 – Dec. 4), and duck season - 2nd split (Dec. 17 – Jan. 22). We observed a decline in duck use of MBHI sites during each of these three periods (Figure 13). In each case, duck density increased after the season was over. A similar hunting response by geese was not observed; however, goose hunting occurred over a longer period (Nov. 12 – Mar. 11 for Snow Geese and Ross' Geese [*C. rossii*]), thus making it more difficult to detect a response.

Similar to fall, bird densities varied among the study sites (Figure 14). Duck, landbird, and waterbird densities were higher at sites that were closer to coastal marshes and conservation areas (e.g., Lacassine National Wildlife Refuge [NWR], Cameron Prairie NWR, and White Lake Wetlands Conservation Area). Geese were most abundant on MBHI fields that were just north of the White Lake Wetlands Conservation Area.

Feeding vs. resting — Bird activity (i.e., actively foraging or resting) varied among taxa and season (Figure 4). Nearly all geese (99.9%) and landbirds (96.7%) used the fields for resting, whereas ducks (80.8%), shorebirds (84.6%), wading birds (65.1%), and waterbirds (85.2%) routinely used MBHI fields for foraging. Seabirds were feeding (50.4%) and resting (49.6%) with equal frequency.

<u>*Evening Movements*</u>

Direct visual observations — Geese, landbirds, and wading birds dominated the bird movement during the 45-min period leading up to dusk (Figure 5). Snow Geese were more abundant in early winter, and then their numbers dropped considerably in December. Landbirds, primarily blackbirds, were most abundant from mid-December through mid-January, whereas wading birds were detected throughout the winter. Ducks and shorebirds were common, but at lower densities than geese, blackbirds, and wading birds. Mallard (*Anas platyrhynchos*) and Northern Shoveler were common ducks throughout the winter. Shorebirds were primarily comprised of yellowlegs spp., dowitcher spp. (most likely Long-billed Dowitcher [*Limnodromus scolopaceus*], based on Dittman and Cardiff [2009]), and Wilson's Snipe (*Gallinago delicata*). Seabirds (mainly Ring-billed Gull) were observed sporadically and were not abundant. Few waterbirds were detected and all were American Coots.

When considering the proximity of bird movements to dusk (i.e., when the NEXRAD data were sampled), ducks and geese were the most abundant taxa (95.9% of all detections) in the 5 min preceding dusk (Figure 15). Although common in much of the survey, very few wading birds (1.5% of all detections)) and no landbirds were observed in the last 5 min before dusk. Shorebirds were infrequently detected during the counts and not abundant near dusk (7.8% of all detections ≤ 5 min before dusk). Seabird densities were also low and most observations occurred before sunset (95.9% of all detections). Waterbirds were rare and only detected before sunset.

We categorized the evening flight activities for each taxon based on whether birds were landing, departing, circling, or flying over the MBHI fields. For ducks, activity was highest near dusk (39.7% of all ducks observed ≤ 5 min from dusk) and most of these birds were flyovers (33.5%) or birds landing (40.8%) in MBHI fields (Figure 16). There was also a relatively large number of ducks observed circling MBHI fields (16.6% of ducks observed ≤ 5 min from dusk), which in most instances were birds that landed in the study area. Birds leaving MBHI sites near dusk were observed, but were less common (9.1% of detections ≤ 5 min from dusk). Geese were detected erratically, but when observed, were often in large numbers. Near dusk (≤ 5 min from dusk), few geese were observed landing (3.4%) and most were flyovers (38.9%) and circling (54.7%) birds (Figure 17). Shorebirds detected near dusk (7.7% of all shorebirds ≤ 5 min before dusk) were not directly observed landing in the MBHI fields, but 21.2% were observed circling the fields (Figure 18). Shorebirds were most often seen departing (74.6%) the MBHI fields during this time. For wading birds, most detections during the 45-min survey were of flyovers (75.5%) (Figure 19). Only 1.5% of wading bird observations occurred within 5 min of dusk. During this period, most waders were departing (65.8%) or flying over (33.6%) the study sites. Nearly all landbirds (99.3%) and most seabirds (81.9%) observed during the 45-min surveys were flyovers and most occurred well before dusk (Figure 20, Figure 21). Only 0.003% of landbirds and 0.1% of seabirds were detected ≤ 5 min from dusk. Waterbirds were rare and only observed departing the MBHI fields (Figure 21). No waterbirds were detected near dusk.

Thermal infrared detections — We began thermal infrared camera surveys in mid-December. During these surveys (N = 9 in winter), we recorded 8,511 birds in the airspace above the MBHI fields between 45 min pre- to 30 min post-dusk (approximate solar angle of 3° to -12°). On average, the camera recorded 13.4 birds/min. We identified 71.9% of observations to taxa. In winter, landbirds (79.9% of all taxa) and wading birds (14.1%) were the dominant taxa flying before sunset (Figure 22). Waterfowl (i.e., ducks and geese) were the dominant taxa flying after dusk (99.9% of birds identified to taxa). The waterfowl movement was characterized by a bimodal peak in activity after dusk. The first of the peaks occurred 2 min post-dusk (solar angle = -6.3°); the second, larger peak occurred at 11 min after dusk (solar angle = -8.1°). In general, the peak waterfowl movements began approximately 5 min post-dusk (solar angle = °-6.9) and were finished around 20 min after dusk (solar angle = -9.8°) although some movements were detected out to 30 min post dusk.

Portable marine radar — Our winter radar data clearly illustrate that a large movement of birds occurred before sunset, followed by a second larger movement peaking shortly after dusk (Figure 11). Thermal infrared camera observations indicated that the pre-sunset movements were primarily landbirds and wading birds, and the second movement was dominated by waterfowl. The later movement on radar began approximately 10 min pre-dusk, peaked about 10 min post-dusk and concluded about 30 min post-dusk. These observations were in general agreement with the thermal infrared detections. Once the post-dusk movements had ceased, bird activity on radar remained low throughout the night.

We compared data from the three sampling techniques (portable radar, thermal infrared camera, and direct visual observation) for the 45-min observation period immediately preceding dusk. This window was the only period when all three survey methods were employed simultaneously. Abundance data from the three survey methods were significantly correlated at $P \leq 0.05$ (Table 2).

We tracked 10,772 targets detected by the horizontal-scanning radar from 5 min pre-dusk through 30 min post-dusk, and classified them as landing, departing, or flying over the fields. Bird activity during this period was dominated by flyovers (78.9% of all birds) (Figure 23). Most birds that used MBHI sites were landing (10.9%) in the fields rather than departing (2.9%). We were unable to classify the movements of the remaining 7.4% of targets.

The direction of flight for bird targets detected by the horizontal-scanning radar varied with proximity to dusk (Figure 24). From 20 to 50 min preceding dusk, most birds were observed flying towards the SSW. This trend dissipated after sunset and began to shift direction in the final 10 min before dusk. In the 20 min following dusk, we observed a strong northeastward bird movement, which corresponded with the peak in bird activity detected on radar and with the thermal infrared camera. The unidirectional flow weakened substantially in the 20 to 30 min period after dusk when birds ceased flight activity. The post-dusk movements may have been waterfowl feeding flights that routinely occur in southwest Louisiana between roost sites in coastal marsh (e.g., Lacassine NWR, Cameron Prairie NWR, and White Lake Wetlands Conservation Area) and foraging sites in agricultural fields to the north.

Flight altitudes were measured with the vertical-scanning radar and summarized into 10-min blocks from 50 min pre-dusk to 30 min post-dusk (Figure 25). We detected targets as high as 1800 m above ground level (AGL), but most targets (89.8%) were detected below 500 m AGL. We detected the greatest number of targets during the first 20 min after dusk (50.6% of all targets detected during the 80-min survey), which was consistent with our observations collected with the horizontal-scanning radar and thermal camera.

<u>*Morning Movements*</u>

Portable marine radar — Bird activity remained low 60 min post-dusk to 2 hr pre-dawn, after which activity began to increase (Figure 11, Figure 26). The flight activity near dawn was characterized by two peaks in activity: the first 30 min pre-dawn, and a second peaking approximately 10 min after sunrise. The pre-dawn bird movements in winter were distinct from the post-dusk movements in that they occurred further from twilight, exhibited a less defined peak in activity, and occurred over a longer time span. Flight directions during the pre- and post-dawn movements were opposite the observed evening movements (Figure 27). Pre-dawn movements were primarily at a southwestward heading, whereas post-dawn observations were at a NNE heading. The pre-dawn movements were likely waterfowl returning from their feeding areas to the north and heading to roost areas in the marshes to the south (e.g., Lacassine NWR, Cameron Prairie NWR, and White Lake Wetlands Conservation Area).

Flight altitudes measured with the vertical-scanning radar were summarized into 10-min blocks from 60 min pre-dawn to 60 min post-dawn (Figure 28). Birds were detected up to 1800 m AGL, but were primarily found below 500 m AGL (86.8%). Differences in flight altitudes were observed during pre- and post-dawn periods. In general, pre-dawn flights occurred at higher altitudes (69.5% of targets at ≤ 400 m AGL) than post-dawn flights (89.4% of targets at ≤ 400 m AGL).

During the time period from 30 to 0 min pre-dawn (solar angle ~ -12° to -6°), we tracked 4,509 targets (N = 13 days) detected by the horizontal-scanning radar. Flyovers were the most common (72.8%) followed by departures (15.7%) (Figure 23), with landings accounting for only 3.6% of all targets detected. We were unable to classify 6.5% of the targets. Based on these observations and our observations of bird movements throughout the night (Figure 11 and Figure 26), it is likely that most birds that landed in the MBHI fields near dusk stayed on these fields until near dawn before returning to their roosting areas.

Spring Observations

<u>*Use of MBHI Fields*</u>

Bird phenology and potential target densities — Ducks, shorebirds, and wading birds were the most abundant taxa using MBHI fields in the spring (Figure 2). Breeding (e.g., Fulvous Whistling-Duck), overwintering (e.g., Northern Shoveler), and transient migrant (e.g., Semipalmated Sandpiper [*Calidris pusilla*]) species were all detected on MBHI fields. Dowitchers and Black-necked Stilts (*Himantopus mexicanus*) were common shorebirds. *Plegadis* spp. were the most abundant wading birds. Geese were only present in early spring and at low numbers. Landbirds were present throughout spring, but at much lower levels than observed in the fall and winter. Seabirds and waterbirds were also present, but were not common. Laughing Gull (*Leucophaeus atricilla*) was the most abundant seabird and American Coot was the most abundant waterbird.

Spring bird densities were variable across study sites; however, in contrast to winter, duck abundance exhibited less variability among sites and the north-south gradient was much less pronounced (Figure 29). This may be a result of lack of hunting pressure in the spring and/or differential stopover use during migration. In spring, the relative distribution of each taxon was more uniform within and among sites when compared to fall and winter. Shorebirds were most abundant at sites 1 and 2. Wading birds were uniformly distributed across the study sites. Seabirds were most abundant at site 10 and waterbirds were most abundant at site 8. Landbirds were less common than during winter, but were still more abundant at the southern sites.

Feeding vs. resting — In spring, the majority of ducks (88.0%), shorebirds (98.2%), wading birds (69.2%), seabirds (92.2%), and waterbirds (98.3%) were observed foraging rather than resting in MBHI fields (Figure 4). Landbirds were the only taxon with larger numbers resting (72.1%). Geese were equally observed foraging and resting (45.8% and 54.2%, respectively).

<u>*Evening Movements*</u>

Direct visual observations — During the 45-min pre-dusk surveys, ducks (primarily whistling-ducks and Blue-winged Teal), shorebirds (mostly dowitchers and yellowlegs), and wading birds were the most abundant taxa observed (Figure 5). Geese were uncommon and only observed in early spring. Landbirds were present (primarily Red-winged Blackbird, grackles, and swallows [Hirundinidae]) but at much lower levels than recorded in the winter. Seabirds (e.g., Laughing Gull) and waterbirds (e.g., American Coot) were occasionally seen during this period.

The temporal phenology of bird abundance varied as the surveys progressed towards dusk (Figure 30). Ducks were the most abundant taxa in the last 5 min pre-dusk (67.7 % of all bird taxa); however, relative duck abundance was less during this time (21.7% of ducks observed ≤ 5 min pre-dusk) than in winter (38.1% of ducks). Shorebirds (93.9% of detections during this period), wading birds (89.7%), and landbirds (97.2%) were most abundant between 45 and 15 min before dusk. Geese were rare, accounting for <1% of all birds, and were not detected near dusk. Seabirds were uncommon and primarily observed before or near sunset (93.0 % of detections >15 min before dusk). Waterbirds were most abundant after sunset (68.5% of observations).

We categorized the flight activities for ducks, geese, shorebirds, and wading birds based on whether birds were landing, departing, circling, or flying over the MBHI fields. Duck use of MBHI fields in spring was different than observed during winter. Flyovers were still the most common observation (50.5% of ducks); however, departures (28.0%) were more abundant than landing (12.9%) and circling (8.6%) birds (Figure 31). The opposite pattern was observed in the winter with fewer ducks leaving the MBHI near dusk, than were landing and circling. Near dusk (≤ 5 min before dusk), this pattern remained, with flyovers (38.2%) and departures (34.2%) being more frequent than landings (22.9%) and circling birds (4.7%). This change in flight activity may be due to a shift from nocturnal feeding flights to initiation of migratory flight. For shorebirds, flyovers were most common (80.3% with 62.1% ≤ 5 min pre-dusk) followed by departures (15.3% with 37.9% ≤ 5 min pre-dusk) (Figure 32). Few shorebirds were observed landing (2.1% with 0.0% ≤ 5 min pre-dusk) or circling (2.4% with 0.0% ≤ 5 min pre-dusk) the MBHI fields. Wading birds were more frequently seen as flyovers (82.4%) and relatively few waders were detected near dusk (3.8% of sightings ≤ 5 min from dusk); however, departures (63.6%) were more common near dusk than flyovers (29.9%) (Figure 33). Flyovers were more abundant for both landbirds (87.2%) (Figure 34) and seabirds (96.5%) (Figure 35) and most sightings (86.9% and 66.1%, respectively) were pre-sunset. For landbirds, 0.1% was detected ≤ 5 min pre-dusk and only 1.3% of seabirds was detected during this period. Landbirds detected near dusk were all circling, and seabirds near dusk were all flyovers. Waterbirds were rarely detected; however, 55.9% of their observations were ≤5 min from dusk. Of the birds observed during this period, 83.3% circled and 16.7% departed from MBHI fields (Figure 36).

Thermal infrared detections — In the spring, we detected 1,228 birds (1.7 birds/min) on 10 surveys with the thermal camera and identified 57.6% of bird observations to taxa. The majority of pre-sunset activity was comprised of landbirds (44.5%), wading birds (34.4%), and shorebirds (16.1%) (Figure 37). Shorebirds (57.3%) and waterfowl (40.4%) were the most abundant taxa after dusk. A peak in bird activity was observed 9 min after dusk, similar to the timing in winter, but of lower magnitude and different taxa composition.

Portable marine radar — Similar to winter, we observed two peaks in bird movements: one shortly before sunset (~32 min pre-dusk) and a second after dusk (~8 min post-dusk) (Figure 11); however, the magnitude of these peaks was much less pronounced. Our thermal camera data indicated that the pre-sunset movements were primarily landbirds, waders, and shorebirds whereas the second movement was dominated by shorebirds and waterfowl. After the later peak concluded, bird activity remained low throughout the night. The direction of flight for bird targets was similar to winter during the pre-sunset periods (30-50 min pre-dusk) with a general southwestward movement (Figure 38). However, the post-dusk movements were more variable and flight headings lacked a unidirectional flow. We would expect to see more of a northerly flight heading as birds initiate migratory flight; however, local flights may have dominated the movement. We measured flight altitudes of radar targets with the vertical-scanning radar; however, heavy insect contamination prevented accurate estimates.

Spearman's correlation coefficients indicate that the portable radar, direct visual observation, and thermal infrared camera data were significantly correlated in spring (Table 2). We also examined winter and spring data combined, and data from the three survey methods were significantly correlated.

Morning Movements

Portable marine radar — Bird activity remained low throughout most of the night (Figure 26). A small movement of birds occurred approximately 30 min before dawn. This movement was of smaller magnitude than observed in winter and exhibited a more defined peak. A second, much larger bird movement occurred near sunrise. Flight directions during the post-dawn peak were similar to winter, primarily at a NE heading (Figure 39). Pre-dawn movements contrasted with the winter movements in that they were of low magnitude and did not exhibit a strong directional pattern.

CONCLUSION

Our combined approach of using direct visual counts, portable marine radar data, and a thermal imaging camera was valuable for classifying and quantifying migrating and wintering bird use of MBHI sites in southwest Louisiana. Results of direct observations indicate that MBHI fields provided diurnal foraging habitat for shorebirds during fall migration and for multiple taxa in winter and spring. MBHI fields were also used as diurnal resting sites in fall, winter, and spring by ducks, geese, wading birds, and landbirds. During evening surveys, the portable marine radar and thermal camera recorded distinct peaks of movement in fall, winter, and spring between 8-10 min post dusk. The targets were not identified in fall; however, ducks dominated the movement in winter. A mixture of shorebirds and ducks comprised the peak movement in spring.

Most wintering ducks during the peak evening movement (the period of NEXRAD data analysis) flew over MBHI fields (78.9%) in a NE direction, and 10.9% landed in MBHI fields. Our findings confirm observations by Cox and Afton (1996) and Randall et al. (2011) who found that many ducks in southwest Louisiana make routine feeding flights from large diurnal roosts in coastal marshes (where hunting is prohibited) northward to the agricultural landscape where they feed throughout the night before making pre-dawn return flights. Data from the marine radar found a shift in direction of movement consistent with nocturnal feeding flights oriented SW–NE and morning return flights to roosting sites in an opposite orientation (NE–SW). Furthermore, morning flight behavior of birds aloft was predominantly birds flying over (72.8%) or departing from (15.7%) MBHI fields towards the SW. The morning flight occurred about 30 min before dawn and was ca. 1 hr prior to a second morning peak movement just after sunrise. The flight had a less defined peak than the post-dusk exodus and occurred over a longer time span. If combined with thermal imagery for target identification, it may be possible to quantify morning return flights of waterfowl with NEXRAD data. Given that the majority of ducks flew over MBHI fields during evening flights, an analysis of morning exodus may be more informative for assessing waterfowl response to MBHI management activities, especially where the MBHI goal is to provide foraging habitat for waterfowl (versus roosting habitat).

During migration and in contrast to winter, fewer ducks were present on MBHI fields. Ducks dominated the air space just prior to dusk (64-67% of all detections) and in fall were mostly flying over MBHI sites (71.4%). During spring migration, shorebirds

(57.3%) and ducks (40.4%) were observed flying over, departing, and landing in MBHI fields in nearly equal proportions. Flight headings did not suggest flights were dominated by any one behavior (e.g., feeding flights, migratory flights, local flights, etc.).

NEXRAD is a broad-scale instrument and the echoes from waterfowl, landbirds, shorebirds, and wading birds in southwest Louisiana often overlap. The detailed data that we obtained on the phenology of bird taxa, the behavior of birds on the ground and aloft, and the exact timing and orientation of their routine movements (e.g., flights between roosting and feeding sites, migratory flights) provide empirical evidence for use in ground-truthing NEXRAD radar reflectivity at the onset of large synchronized, nocturnal flights.

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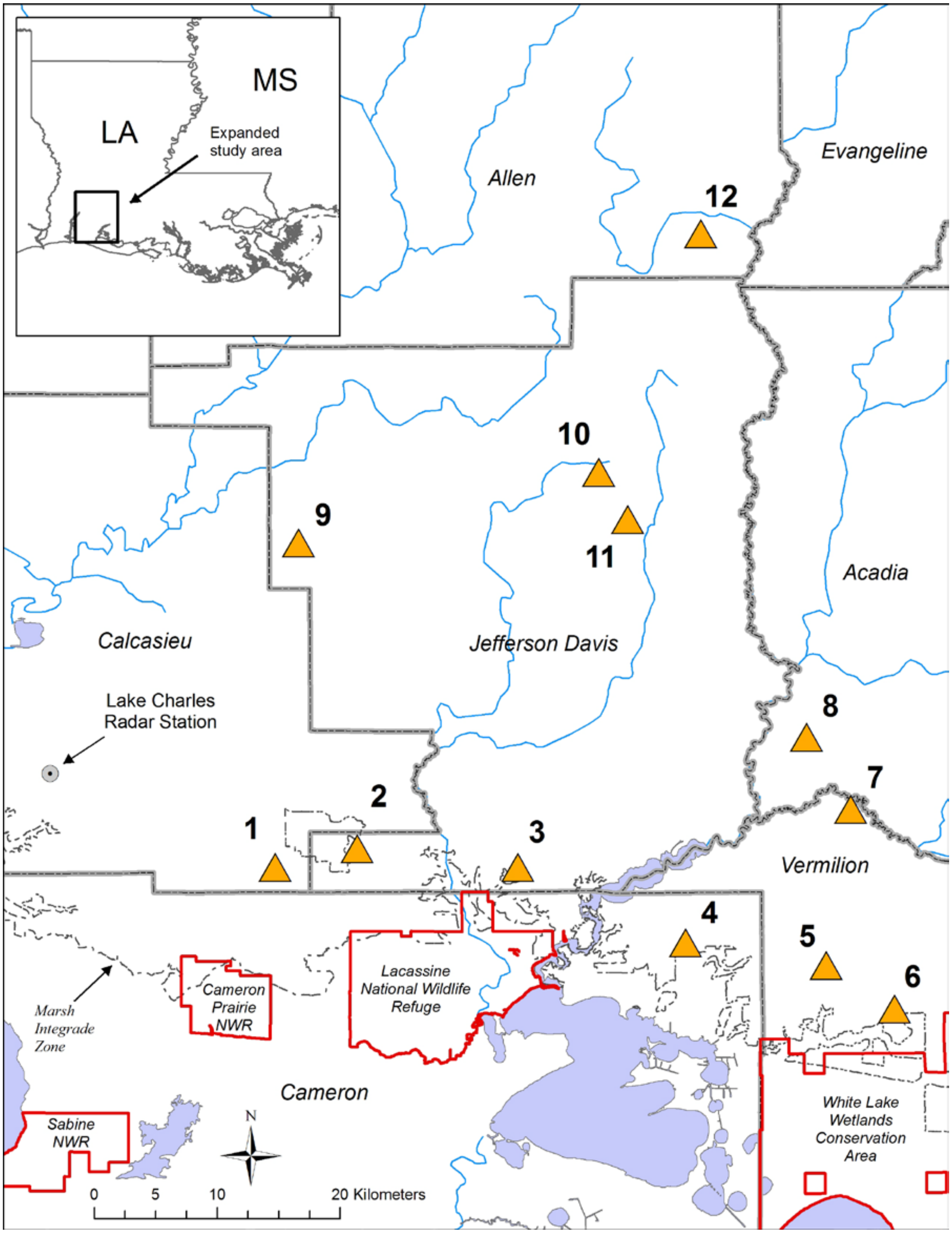


Figure 1. MBHI study site locations in southwest Louisiana.

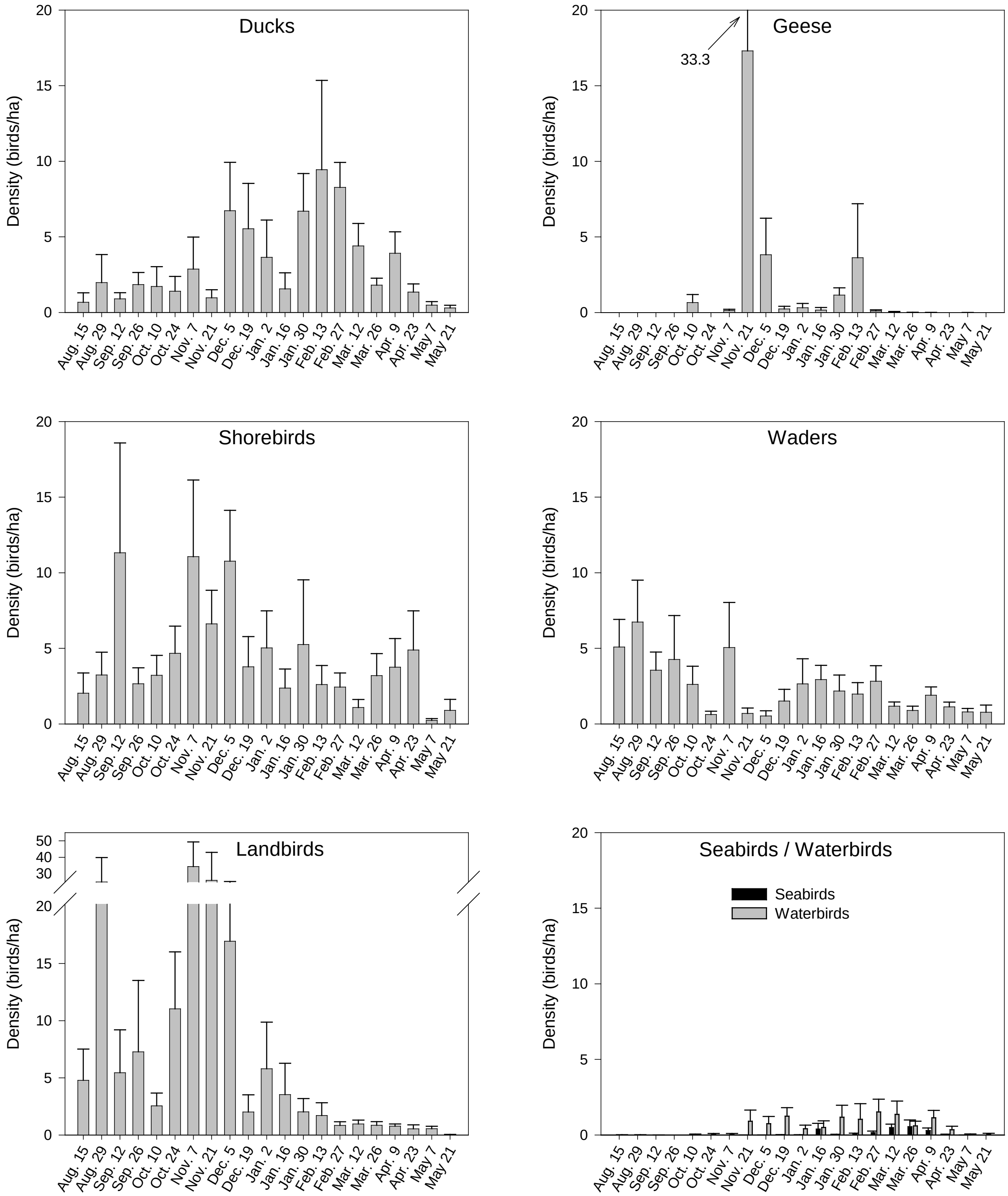


Figure 2. Biweekly bird use of MBHI fields (# of birds/ha) by taxa: ducks, geese, shorebirds, wading birds, landbirds, seabirds, and waterbirds.

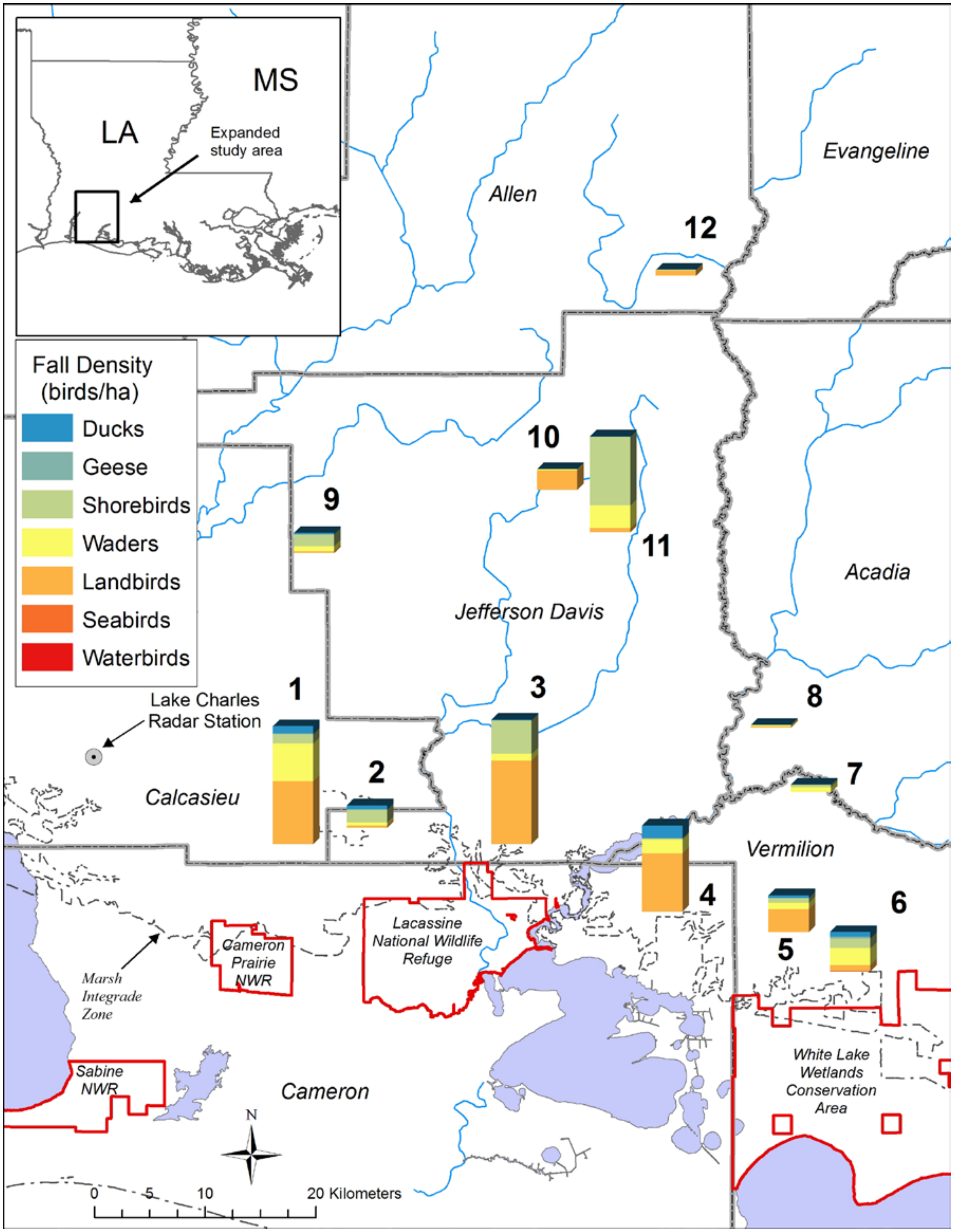


Figure 3. The relative densities (birds/ha) of each taxon in the fall by study site. Total bird densities and within-taxa densities varied among study sites.

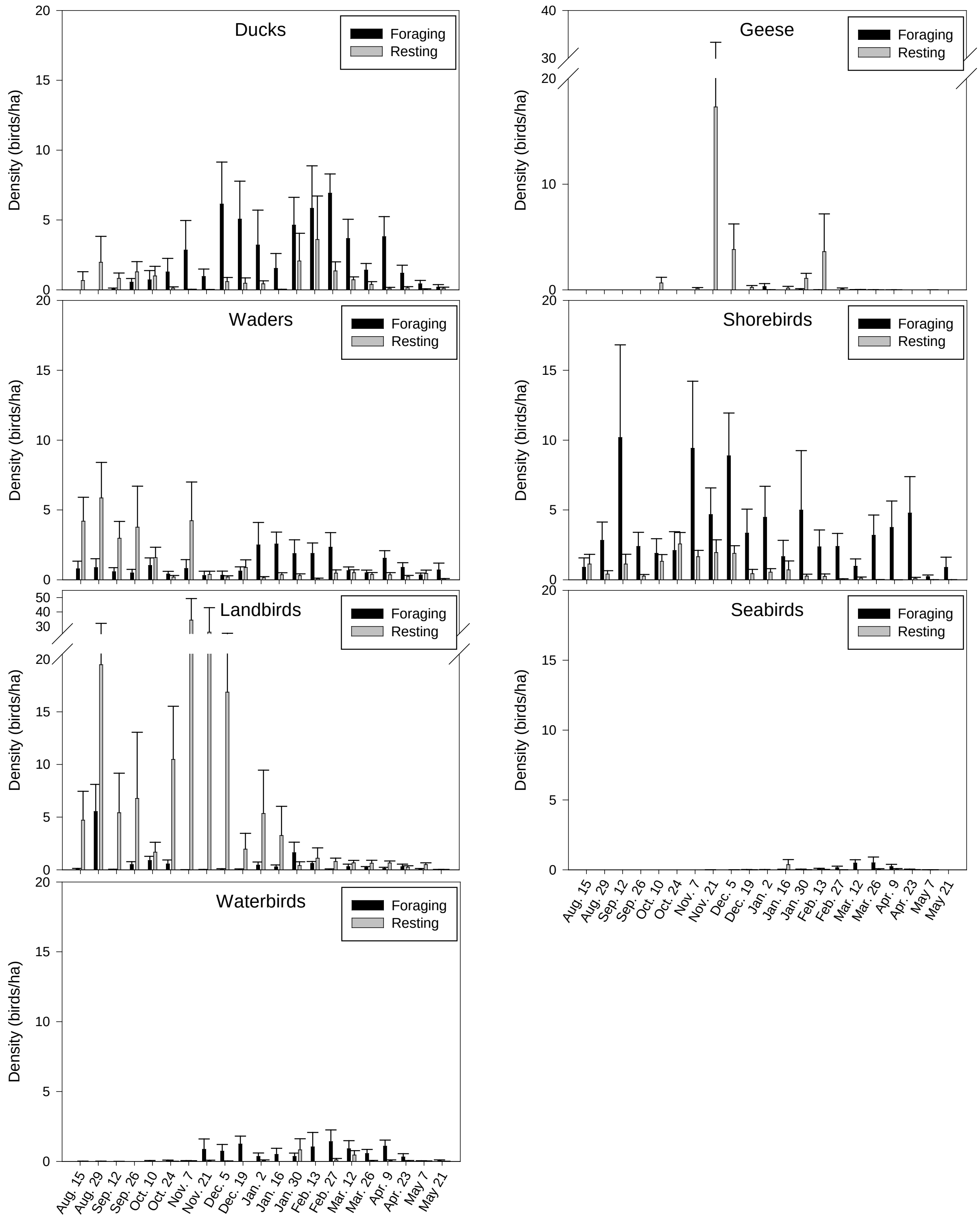


Figure 4. Biweekly bird use of MBHI fields (# of birds/ha) categorized by taxa and bird behavior: actively foraging or resting.

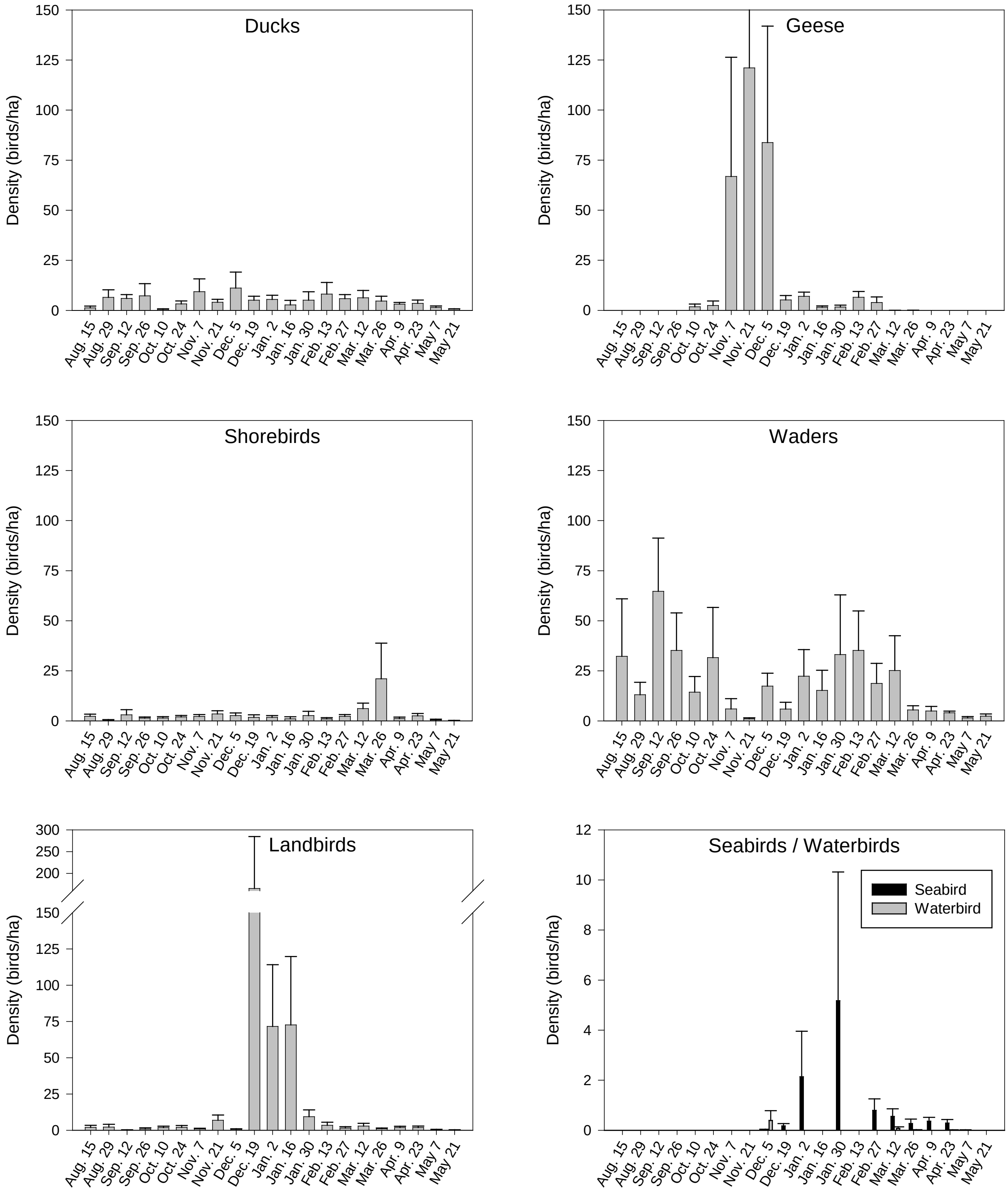


Figure 5. Biweekly evening bird movements observed during the direct visual surveys. Figures only include observations from the 45 min preceding dusk.

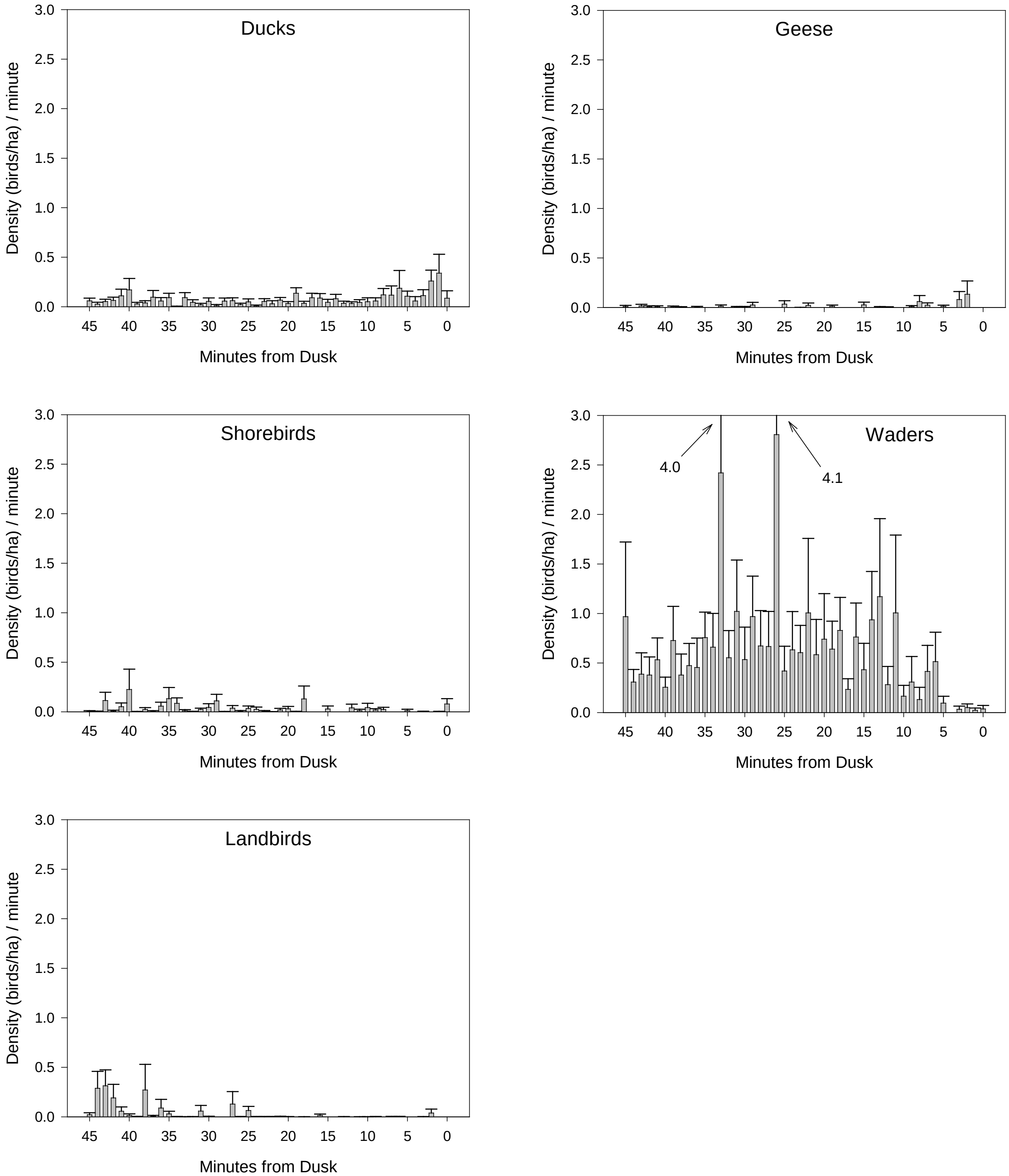


Figure 6. Temporal phenology of birds (birds/ha) in the fall detected during the direct visual observations. Data are presented per taxon as density per minute during the 45-min period leading up to dusk (n = 43 days). These data do not include birds on the ground, only birds landing, departing, circling, or flying over the MBHI fields. Seabirds and waterbirds were not detected in the fall during this period.

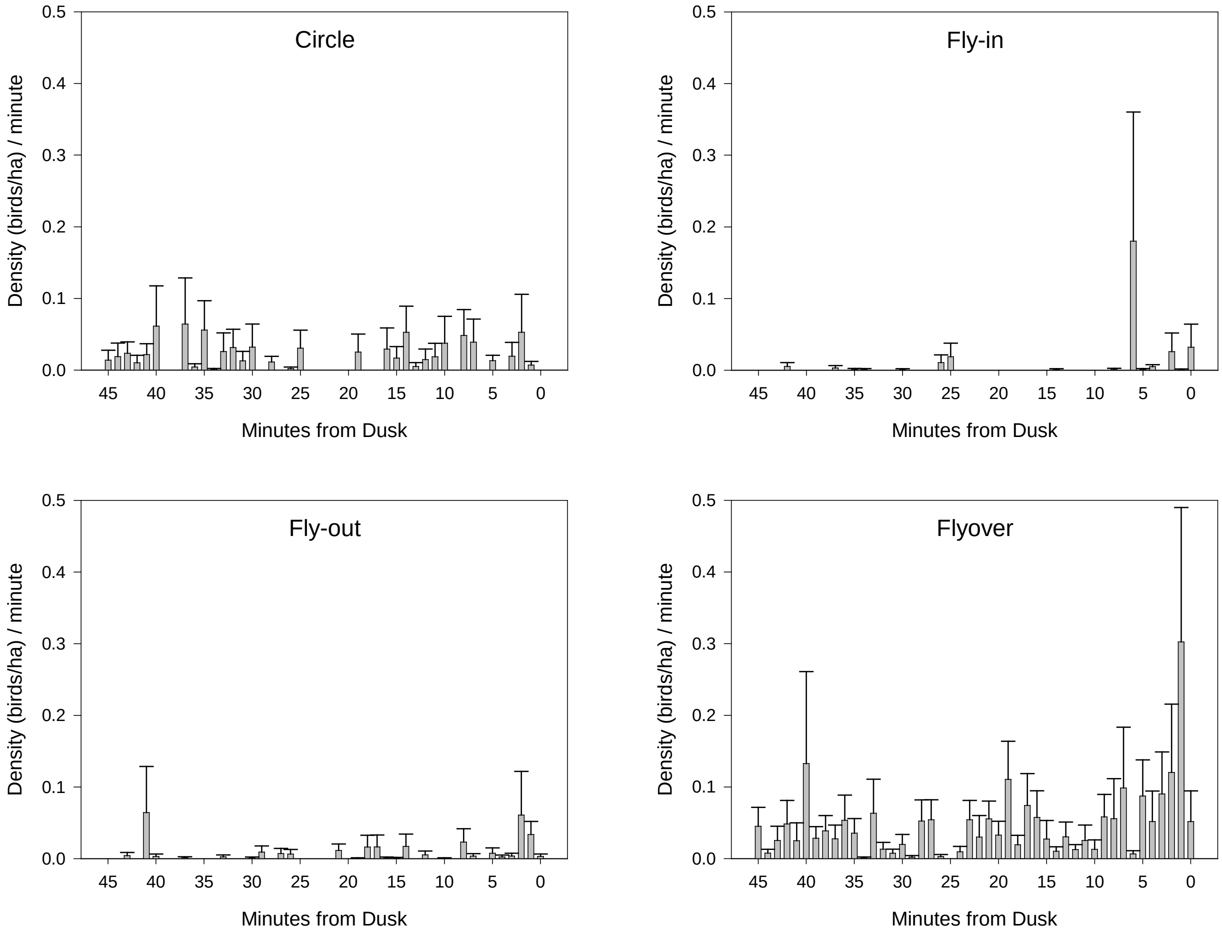


Figure 7. Evening flight activity of ducks observed in fall during the direct visual observation surveys. Figures depict mean duck densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 43 days).

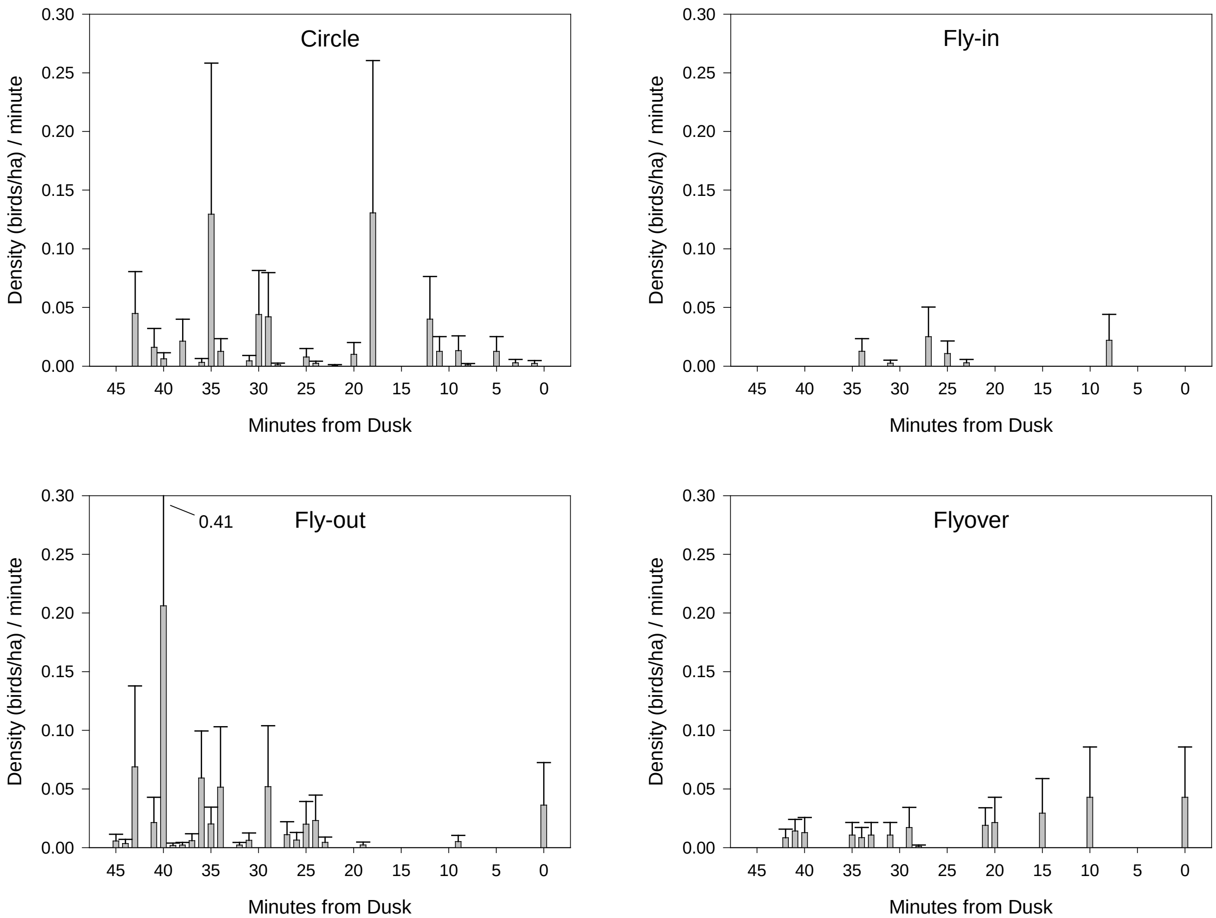


Figure 8. Evening flight activity of shorebirds observed in fall during the direct visual observation surveys. Figures depict mean shorebird densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 43 days).

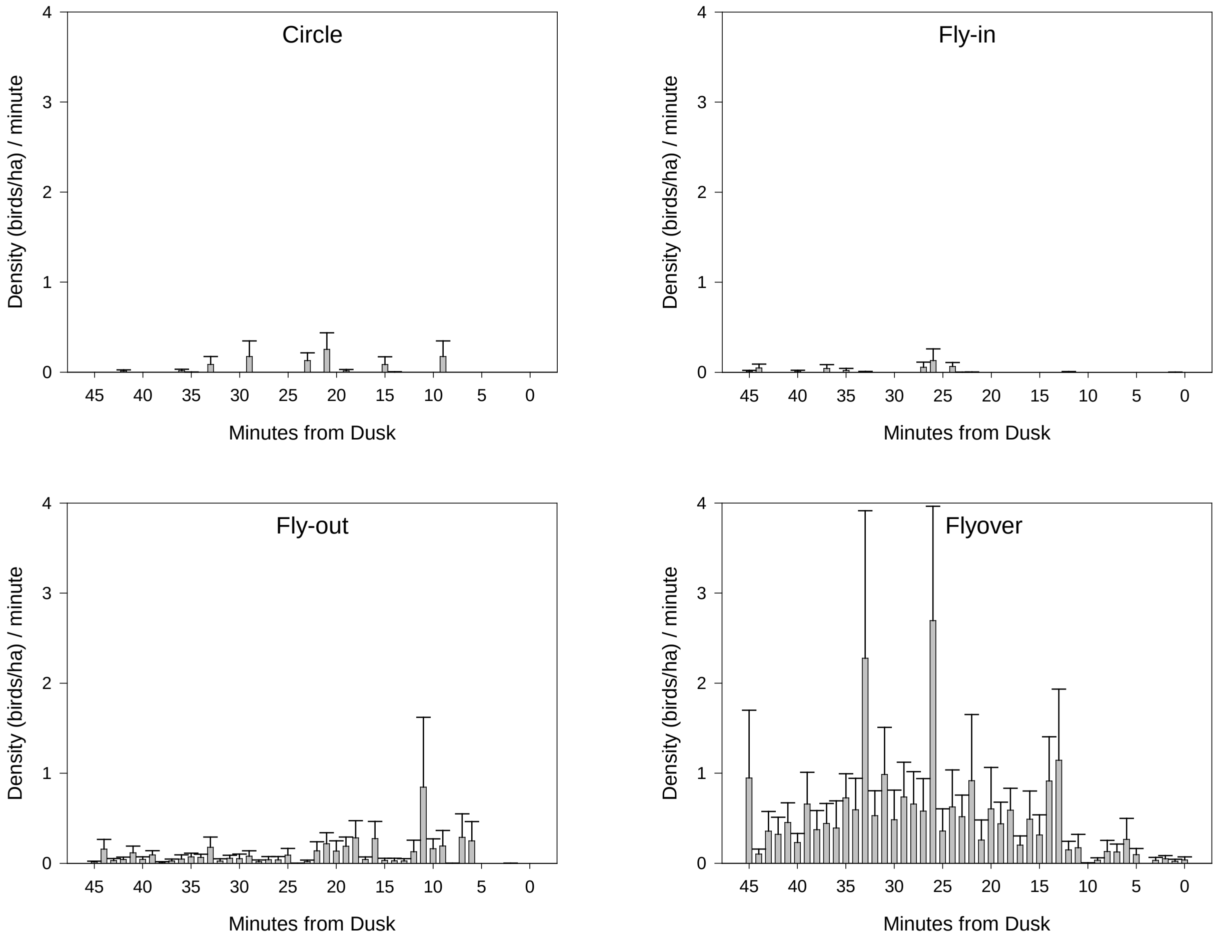


Figure 9. Evening flight activity of wading birds observed in fall during the direct visual observation surveys. Figures depict mean wader densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 43 days).

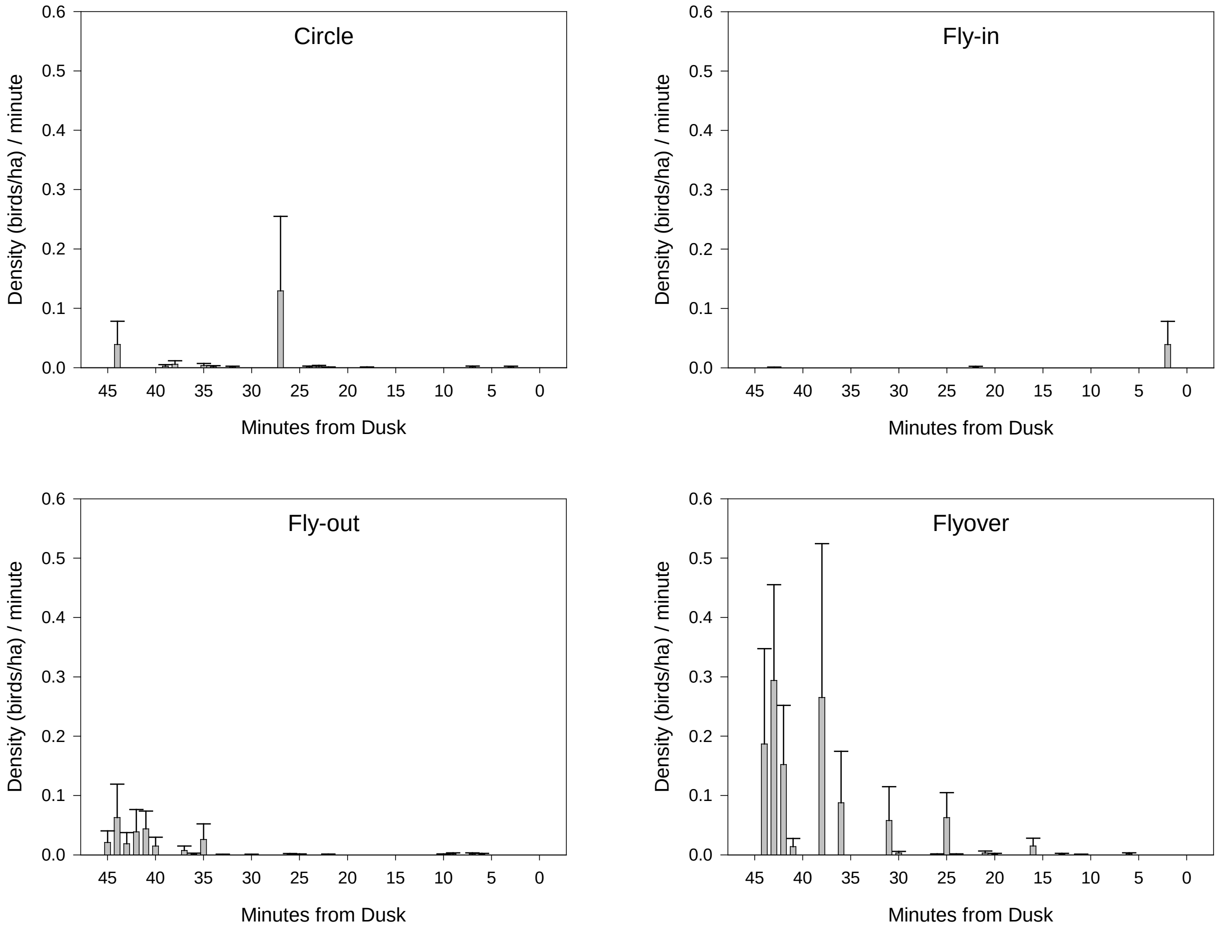


Figure 10. Evening flight activity of landbirds observed in fall during the direct visual observation surveys. Figures depict mean densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 43 days).

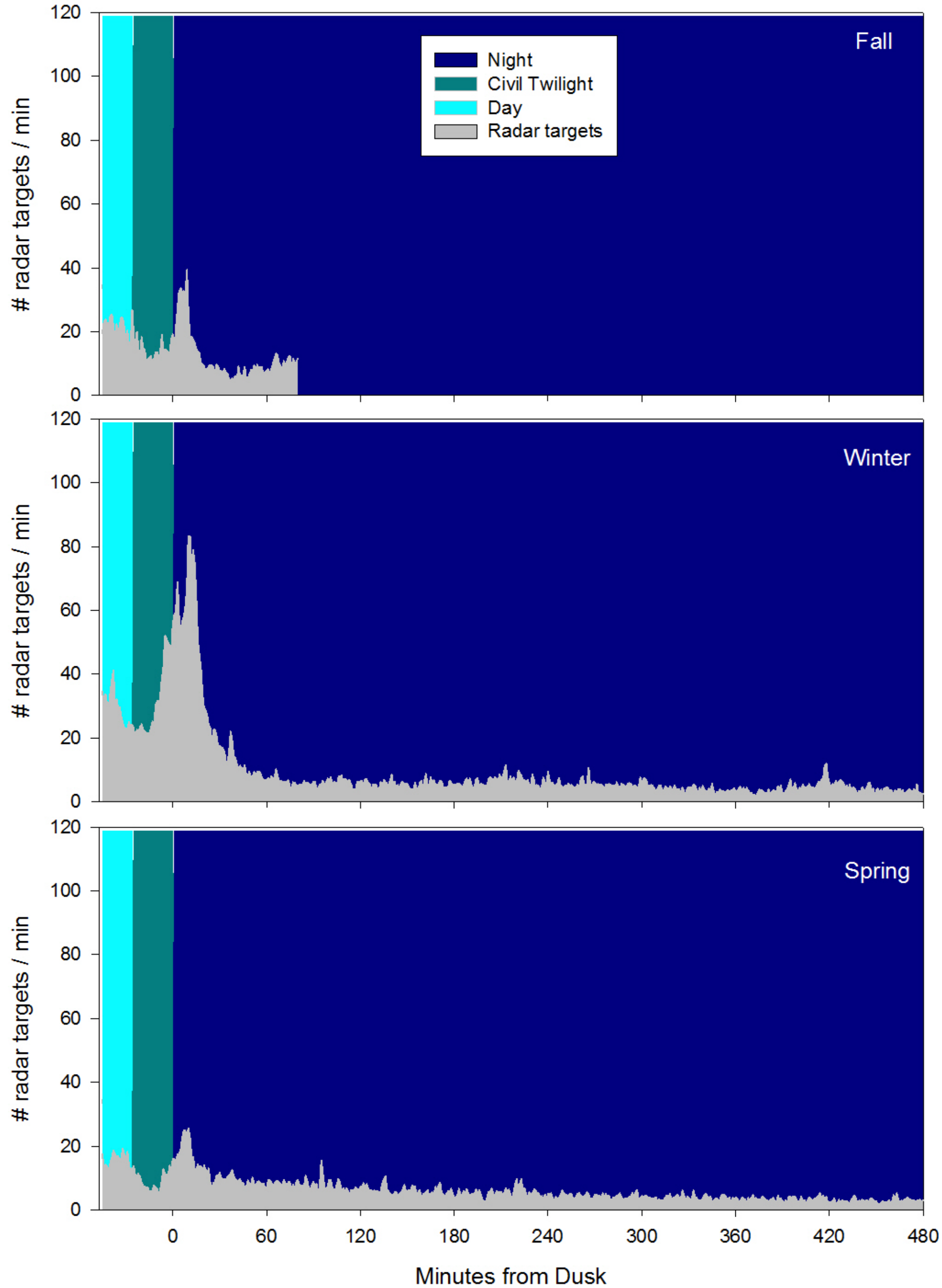


Figure 11. Portable radar bird activity from 45 min before dusk through the first 6 hr post-dusk. Continuous radar sampling throughout the night was not started until late fall, so fall data were truncated (fall: n=10; winter: n=16; spring: n=10). After the peak bird movement immediately post-dusk, bird activity was consistently low for the remaining observation period. Values <10 targets/min are primarily background noise.

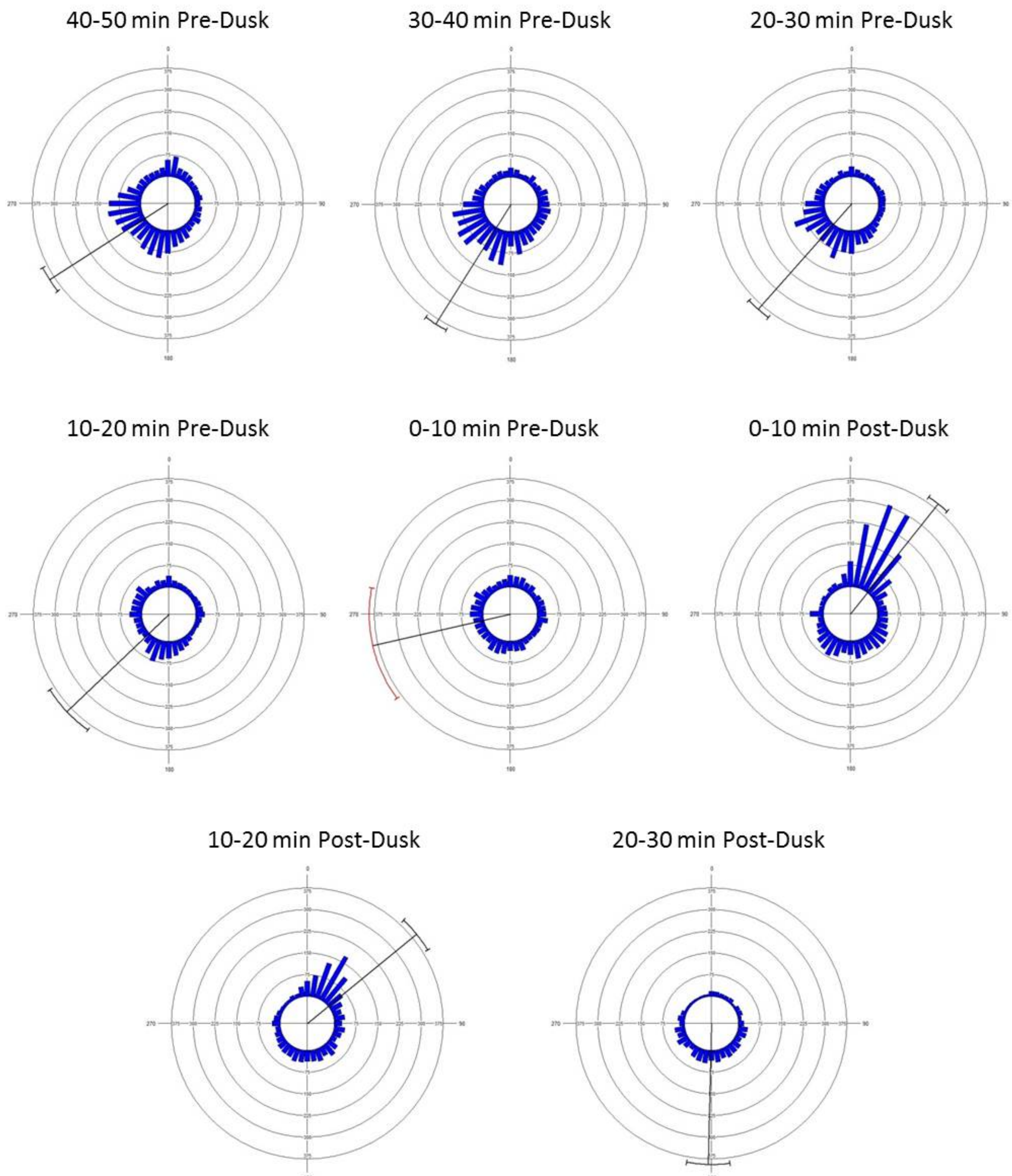


Figure 12. Circular histograms representing flight headings for fall bird targets detected with the horizontal scanning radar (Note: North is up, the straight black line represents the mean, the shorter line perpendicular to the mean with brackets depicts the 95% confidence intervals, all figures were set to the same scale). Targets were categorized into 10-min blocks relative to dusk (sunset occurred ~25 min before dusk) (n = 10 days).

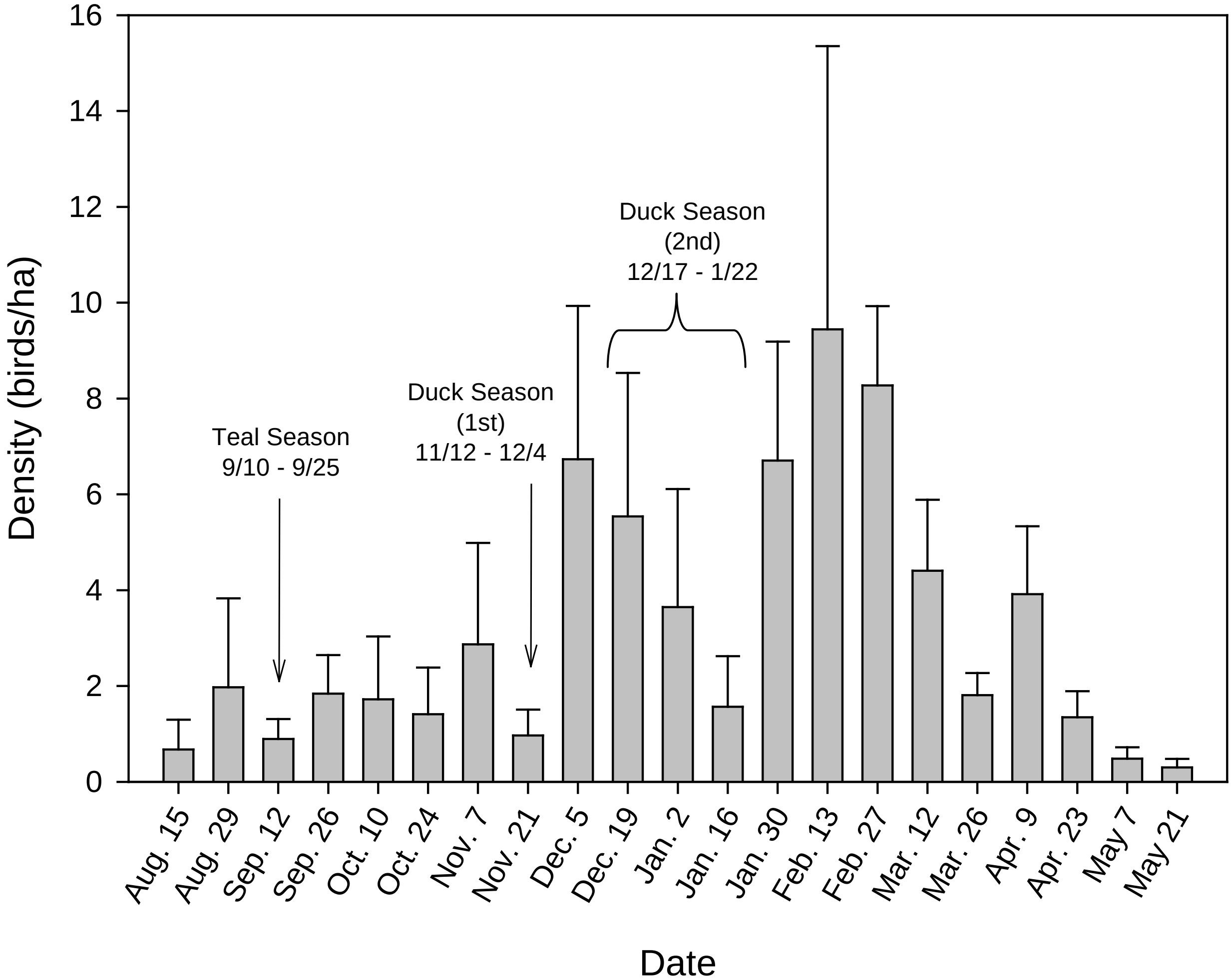


Figure 13. Biweekly duck densities (# of birds/ha) on all MBHI lands surveyed. Most MBHI properties were hunted during waterfowl season and hunting pressure appears to have affected waterfowl use/abundance.

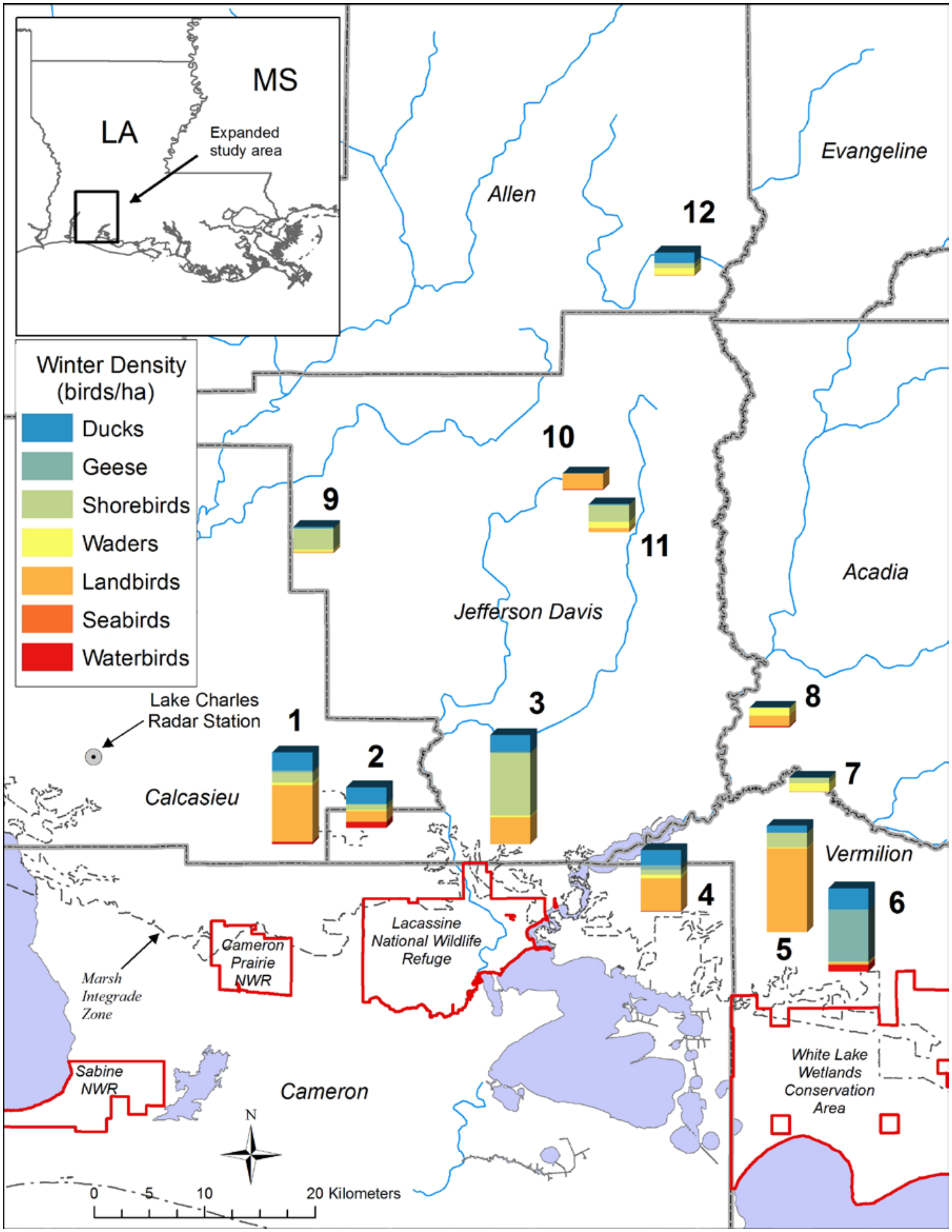


Figure 14.The relative densities (birds/ha) of each taxon in winter by study site. Total bird densities and within-taxa densities varied among study sites. Bird abundance was higher in the southern-most study sites.

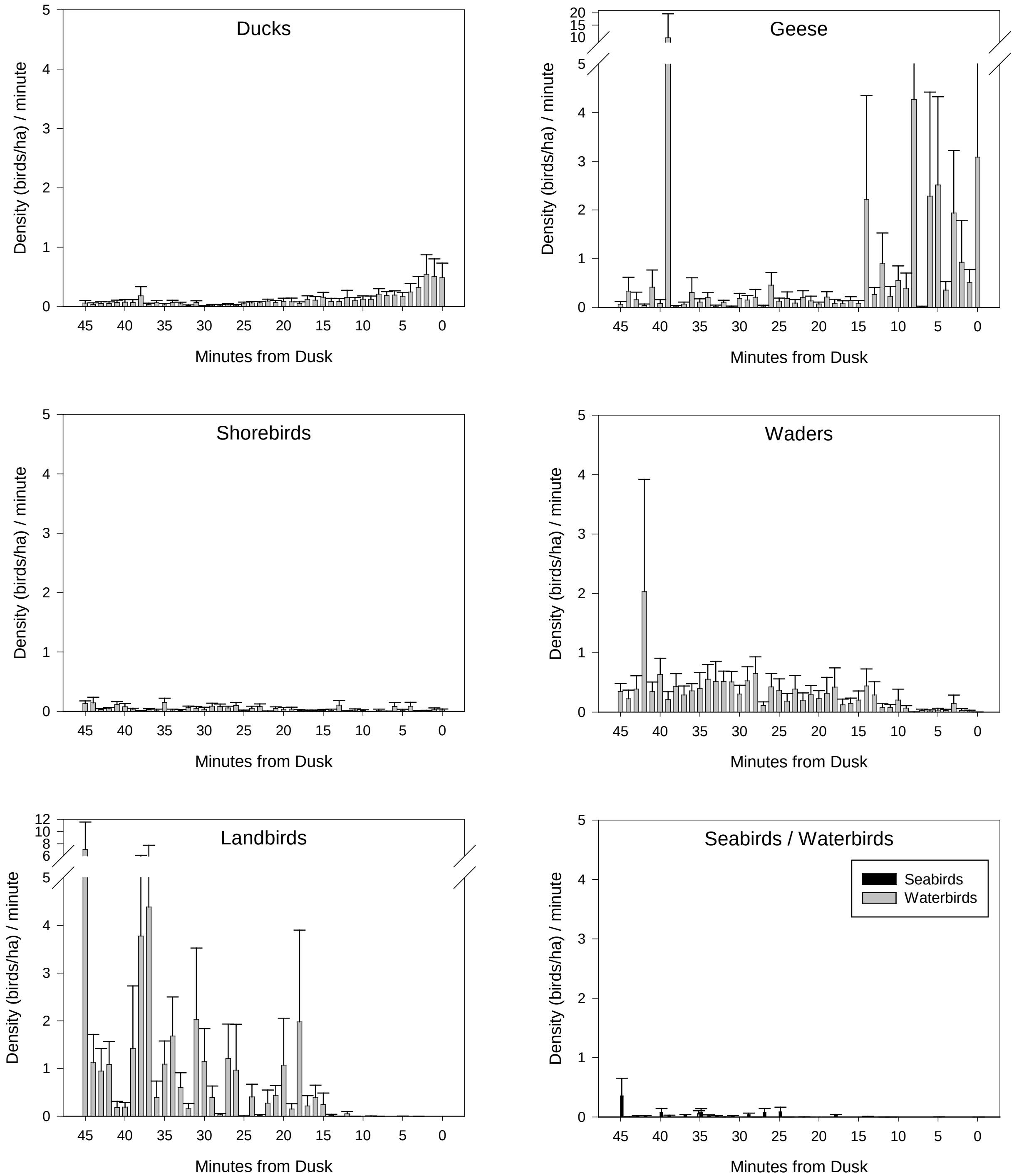


Figure 15. Temporal phenology of birds (birds/ha) in the winter detected during the direct visual observations. Data are presented per taxon as density per minute during the 45-min period leading up to dusk (n = 62 days). These data do not include birds on the ground, only birds landing, departing, circling, or flying over the MBHI fields.

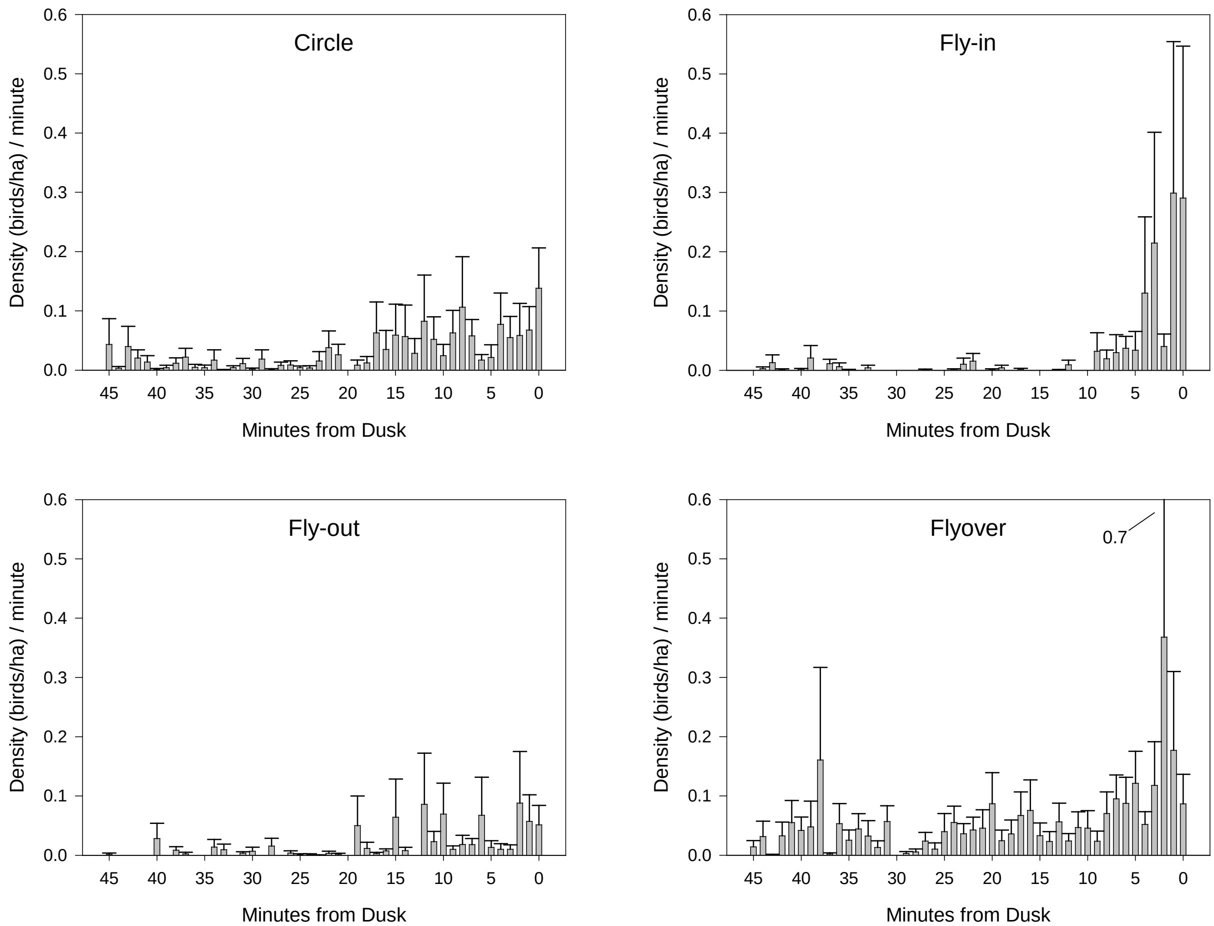


Figure 16. Evening flight activity of ducks observed in winter during the direct visual observation surveys. Figures depict mean duck densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 62 days).

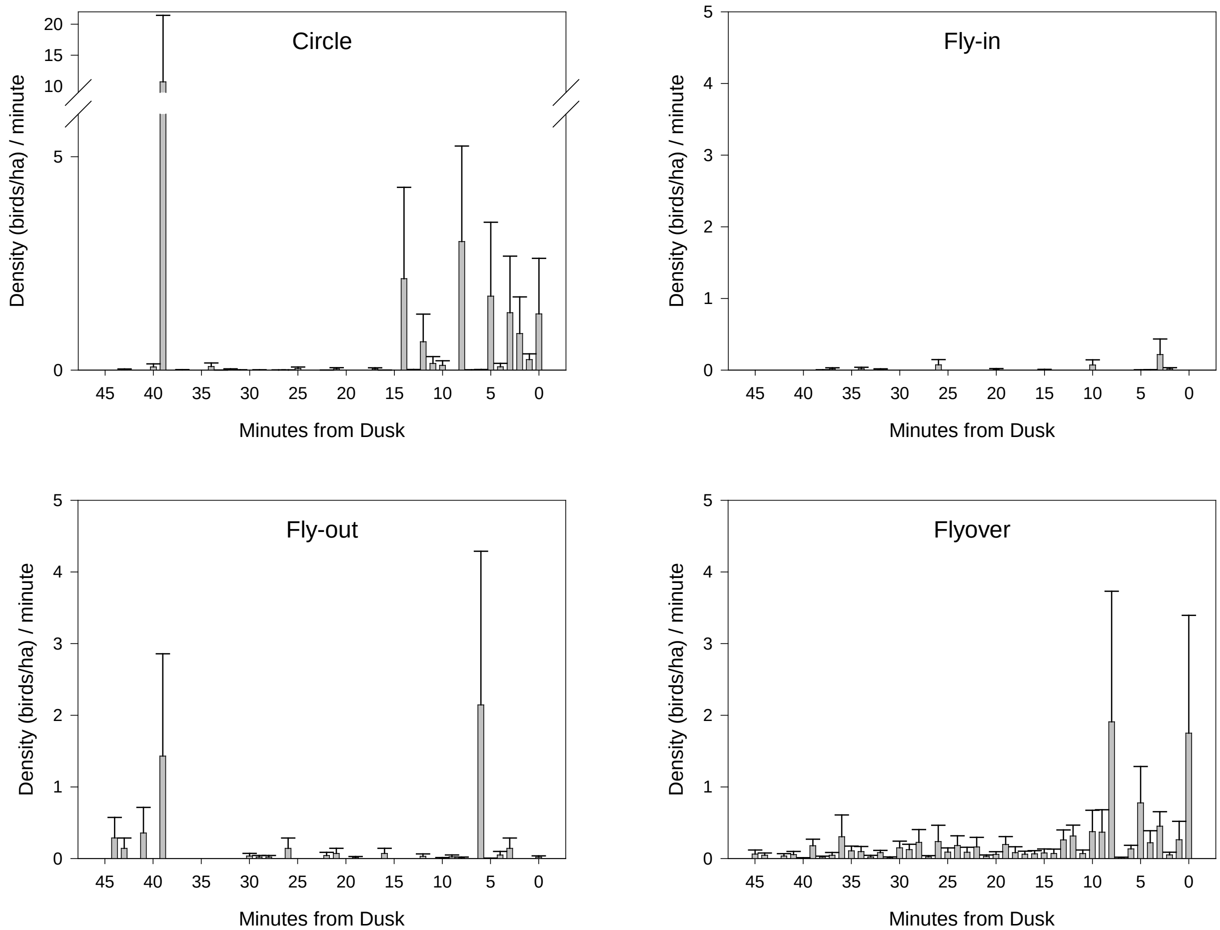


Figure 17. Evening flight activity of geese observed in winter during the direct visual observation surveys. Figures depict mean goose densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 62 days).

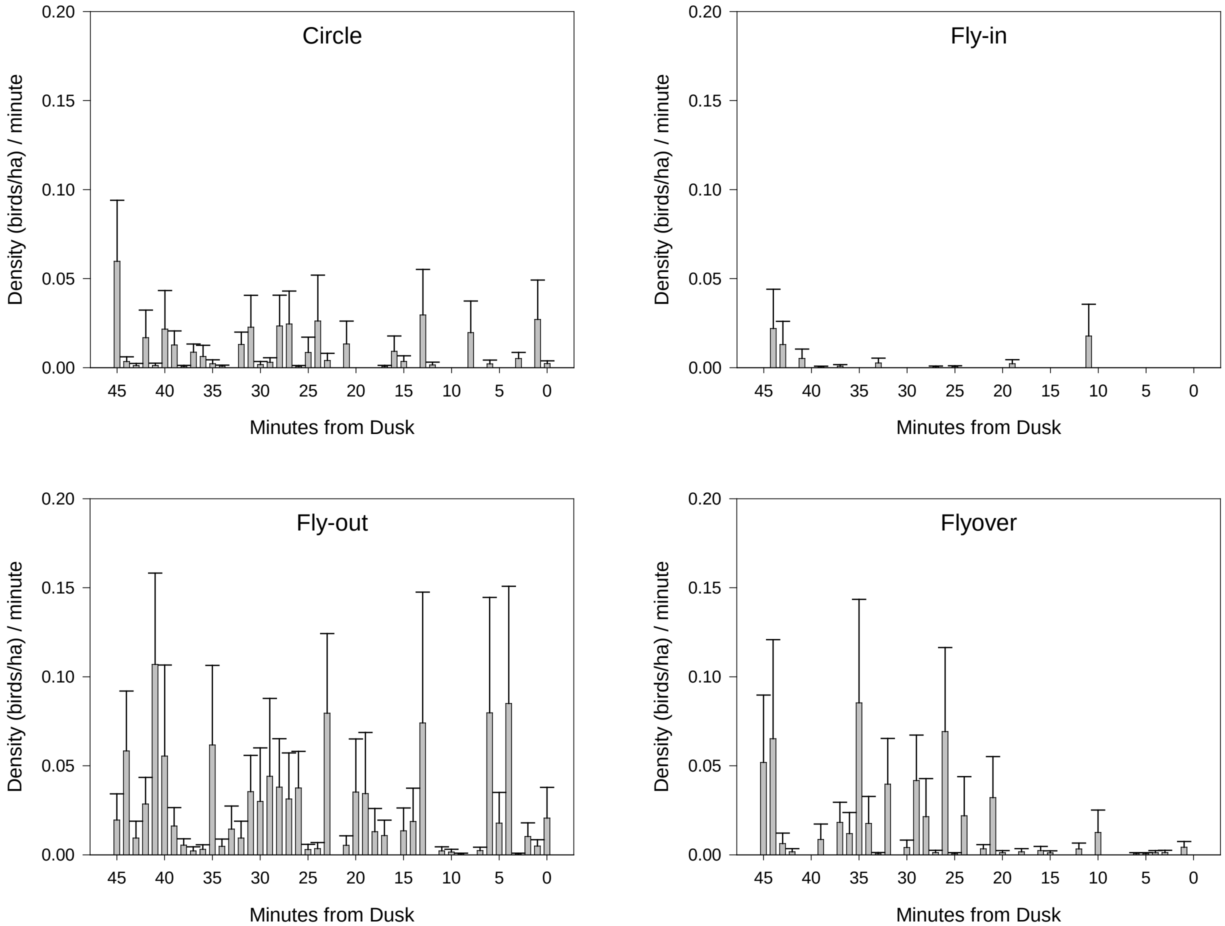


Figure 18. Evening flight activity of shorebirds observed in winter during the direct visual observation surveys. Figures depict mean shorebird densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 62 days).

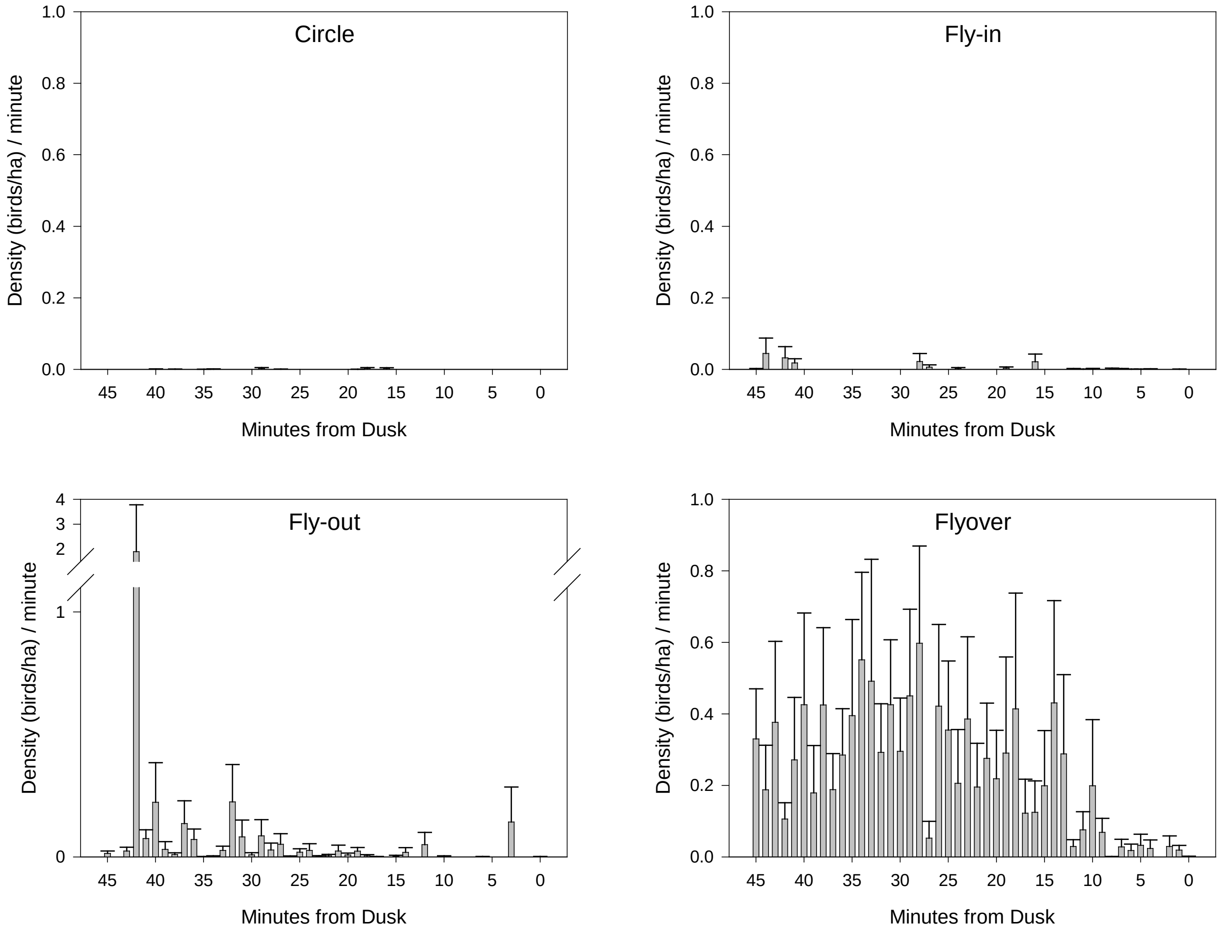


Figure 19. Evening flight activity of wading birds observed in winter during the direct visual observation surveys. Figures depict mean wader densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 62 days).

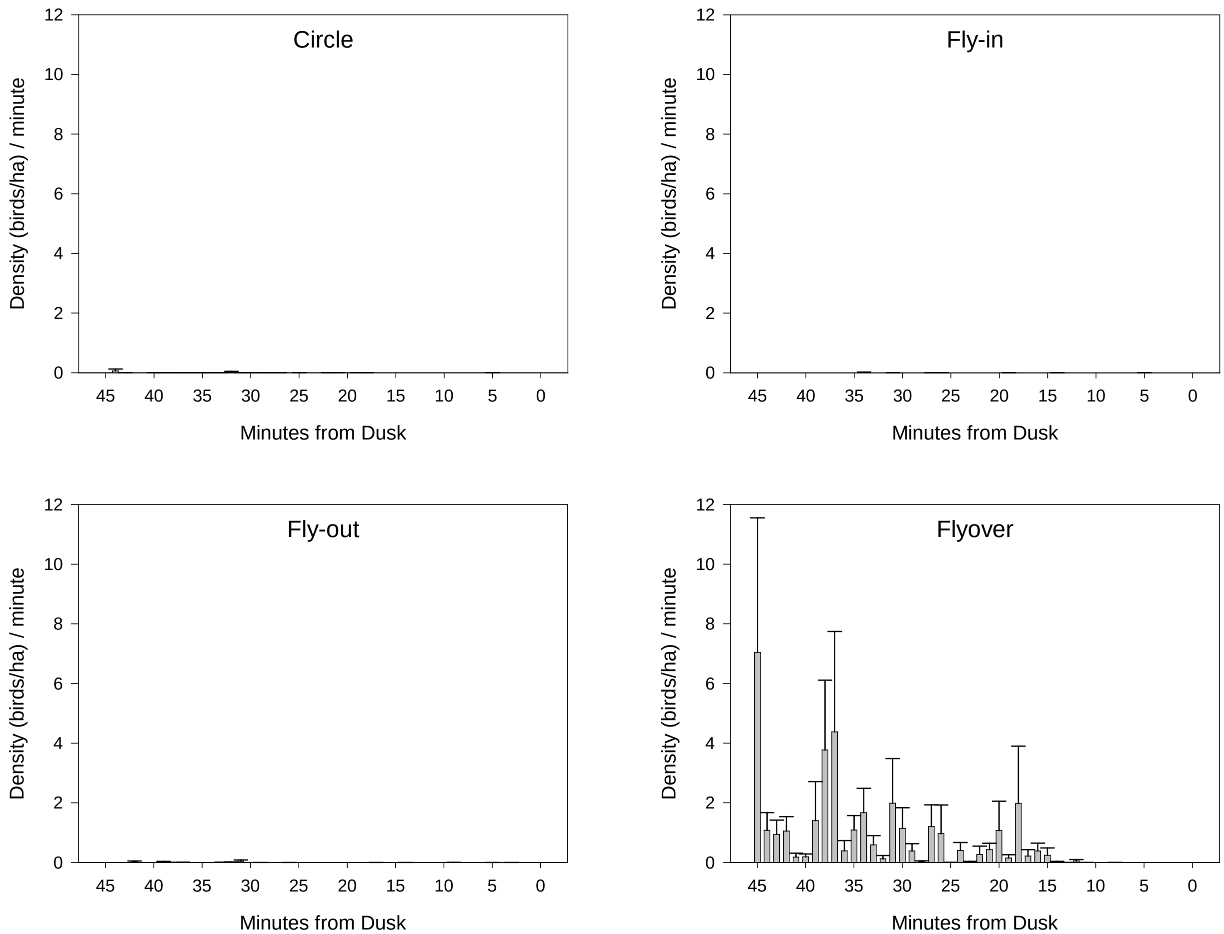


Figure 20. Evening flight activity of landbirds observed in winter during the direct visual observation surveys. Figures depict mean densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 62 days).

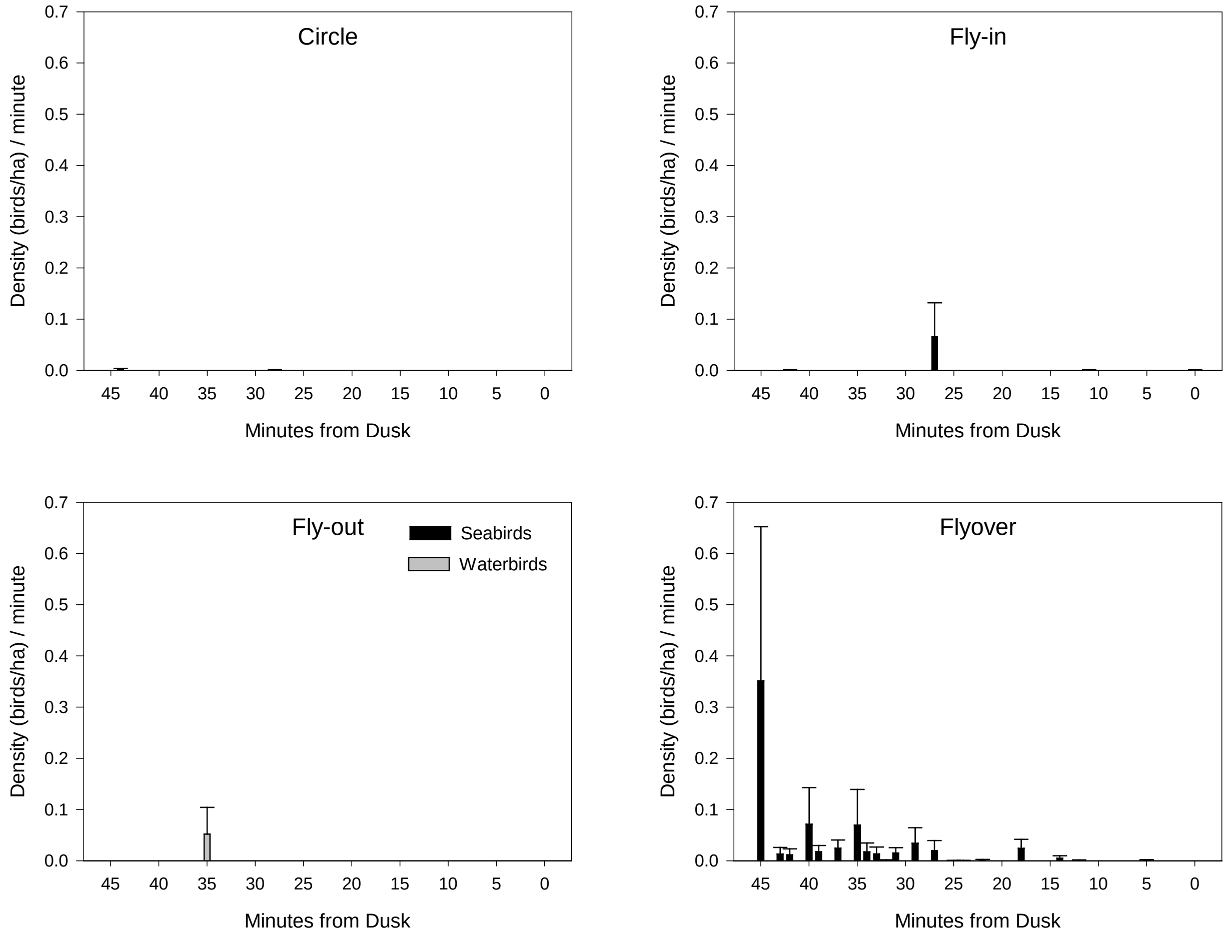


Figure 21. Evening flight activity of seabirds (black bars) and waterbirds (gray bar) observed in winter during the direct visual observation surveys. Figures depict mean densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 62 days).

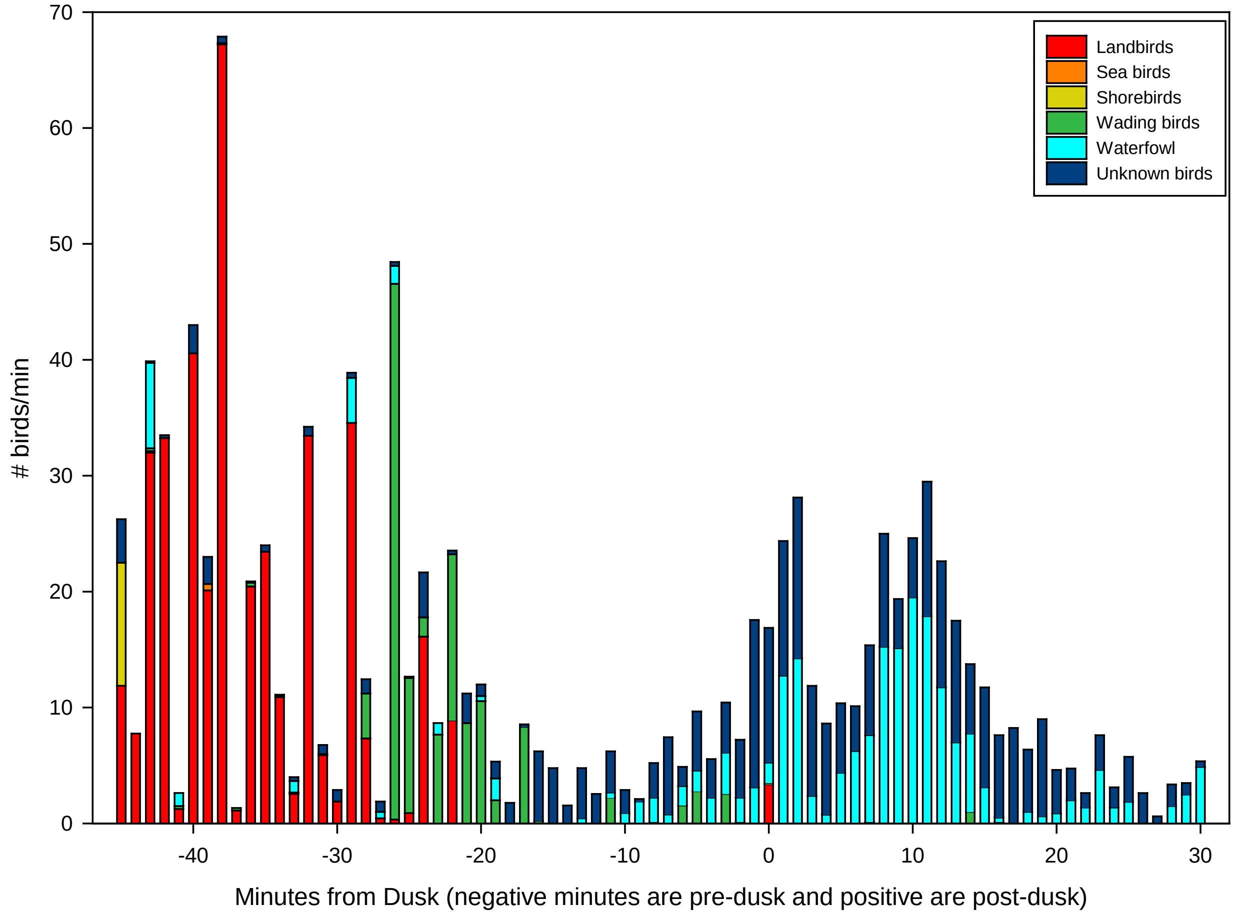


Figure 22. Thermal camera bird detections by taxa in winter (n = 9 days). Observations were from 45 min pre- to 30 min post-dusk. Dusk occurs at 0 min on the x-axis and sunset occurs at approximately -25 min. Most landbird movements had ceased by sunset. Wading bird movements were concentrated around sunset, whereas waterfowl peaked post-dusk. Birds that we were unable to identify to taxa were called unknowns.

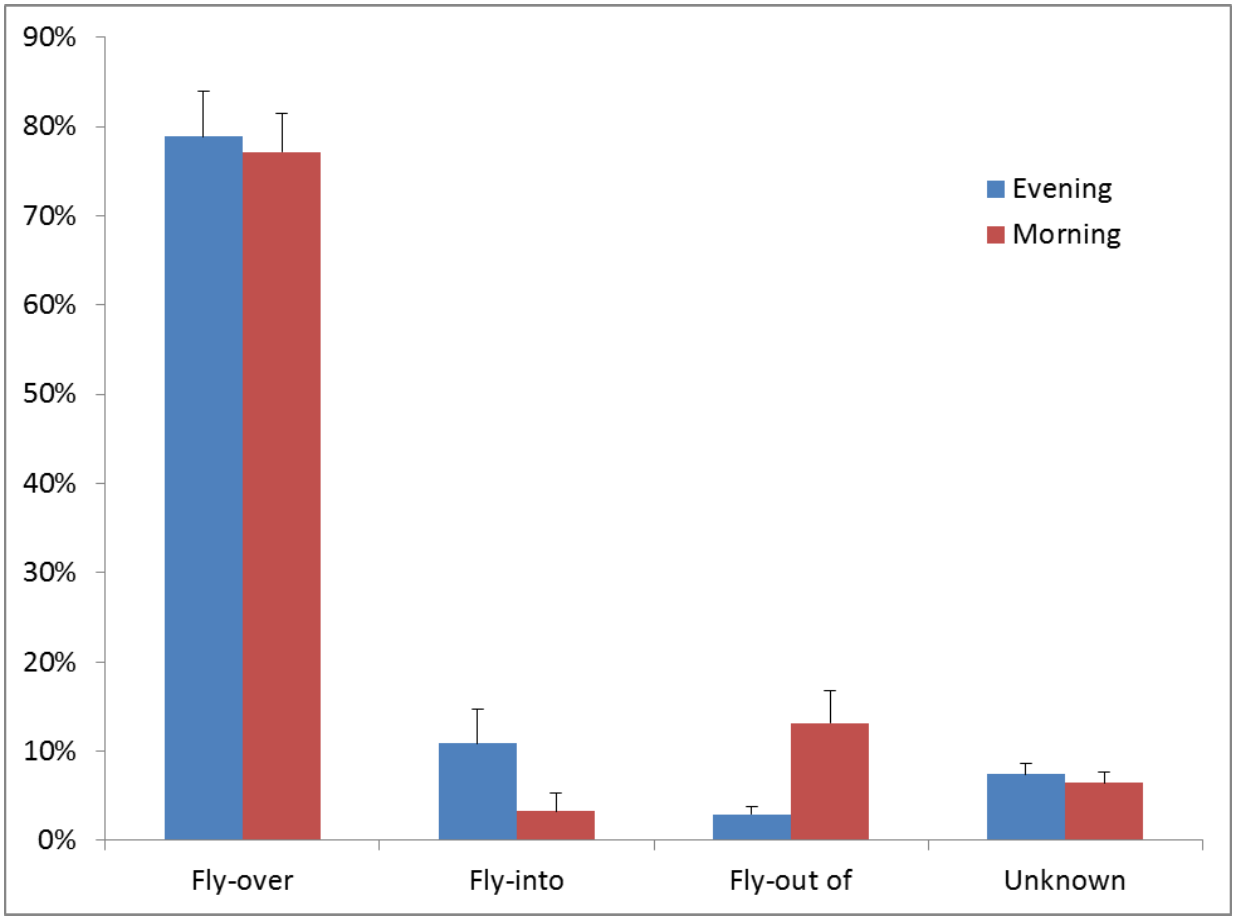


Figure 23. Summary of winter bird activity in the evening (5 min pre-dusk through 30 min post-dusk; n = 16 days) and the morning (30 min pre-dawn; n = 13 days) as determined by radar. The horizontal portable radar data were manually scanned during these periods and targets detected over the MBHI were classified as landing, departing, or flying over. Targets that could not be classified into one of these categories were classified as unknowns.

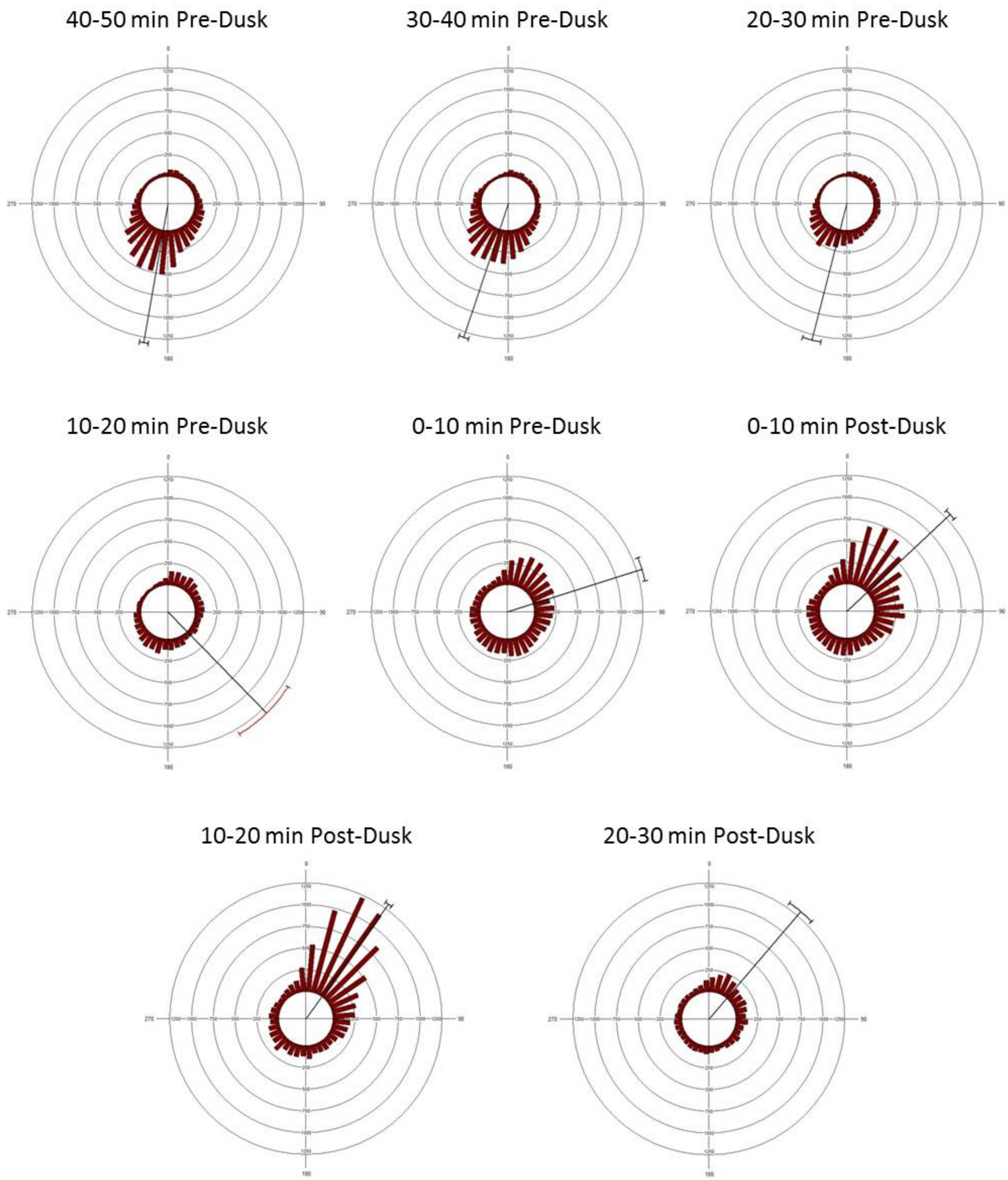


Figure 24. Circular histograms representing flight headings for winter bird targets detected with the horizontal scanning radar (Note: North is up, the straight black line represents the mean, the shorter line perpendicular to the mean with brackets depicts the 95% confidence intervals, all figures were set to the same scale). Targets were categorized into 10-min blocks relative to dusk (sunset occurred ~25 min before dusk) (n = 16 days). Before and during sunset, most birds flew at a SSW heading. After dusk, most targets were flying in a NNE–NE direction.

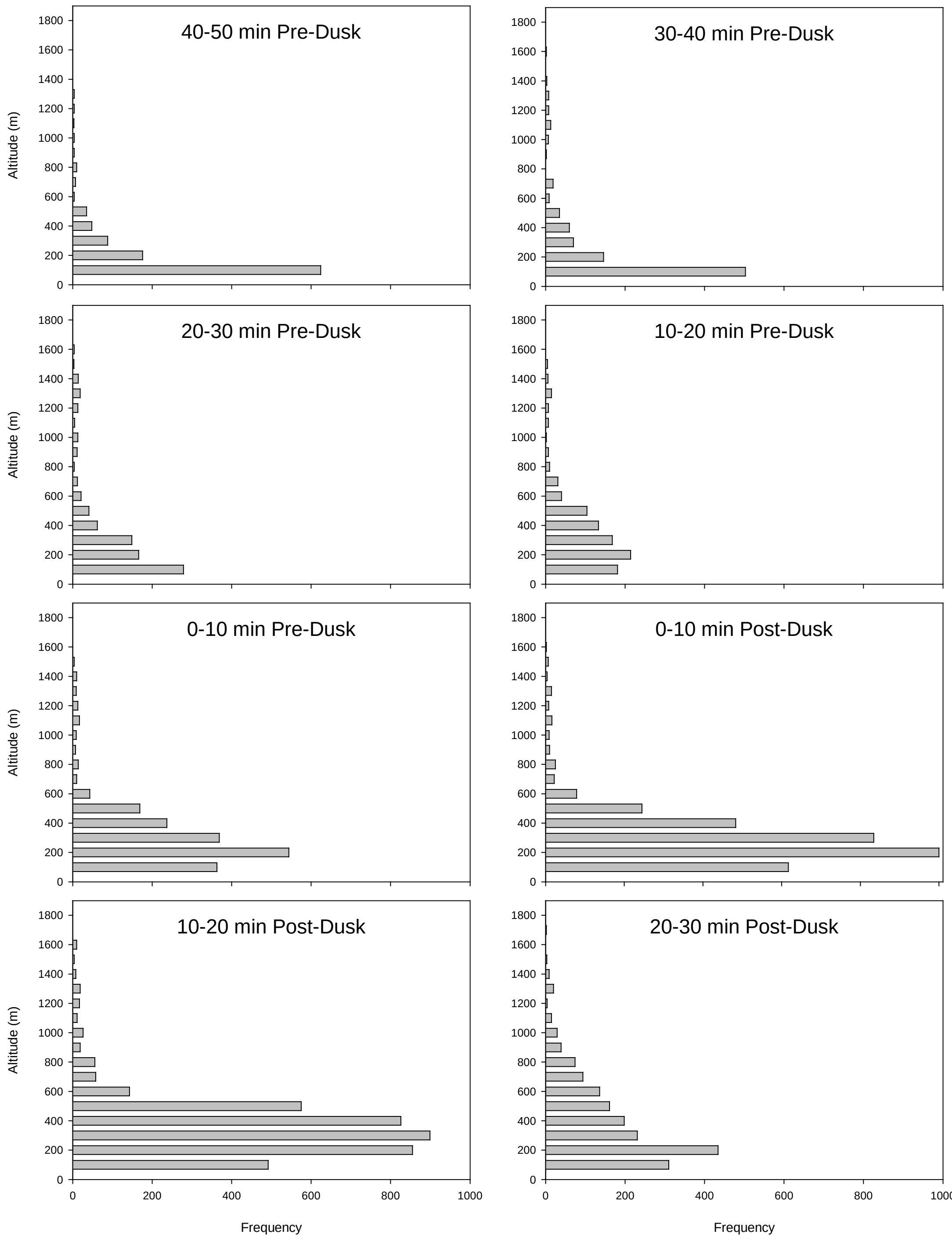


Figure 25. Flight altitudes (meters above ground level) in winter for birds detected with the vertical scanning radar (n = 15 days: 1 day excluded because of insect contamination). Altitudes organized in 10-min blocks relative to dusk (Note: sunset occurred ~25 min before dusk).

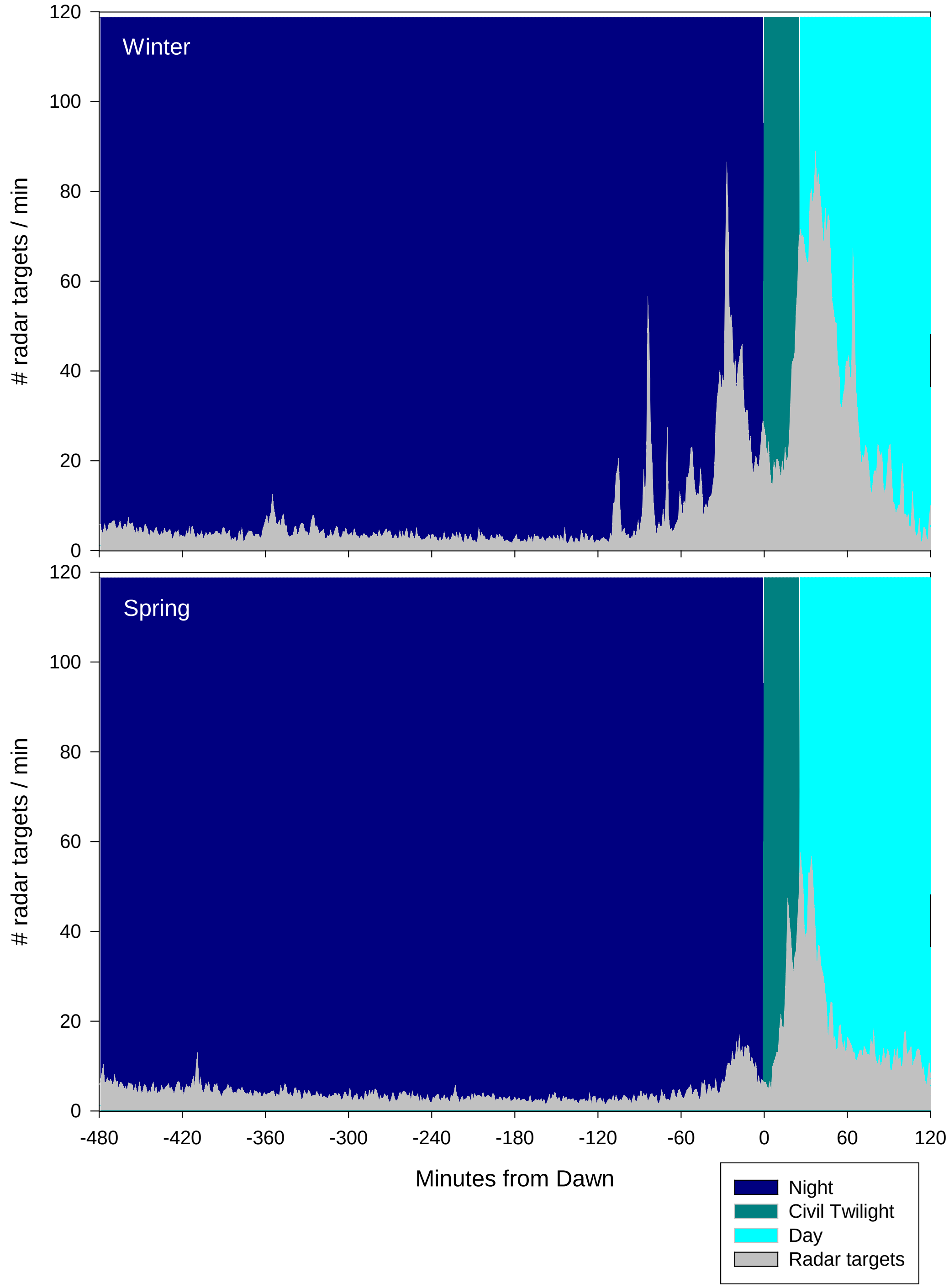
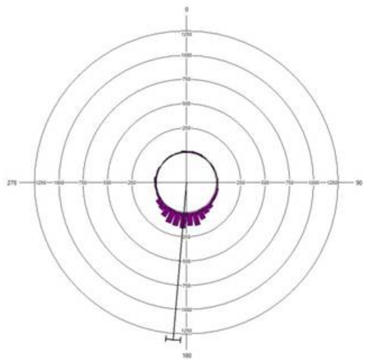
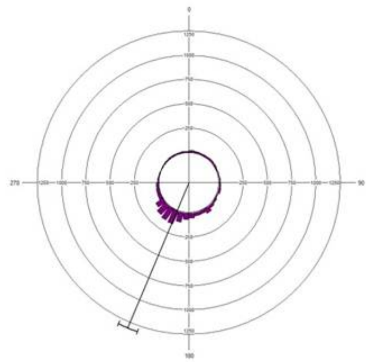


Figure 26. The number of targets detected by portable surveillance radar in the 4 hr pre- and 2 hr post-dawn in winter and spring. Continuous radar sampling throughout the night was not started until late fall, so fall data were not included (winter: n=13; spring: n=10). Values <10 targets/min are primarily background noise.

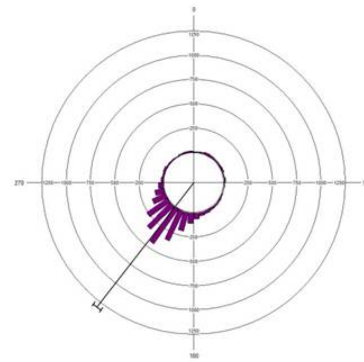
50-60 min Pre-Dawn



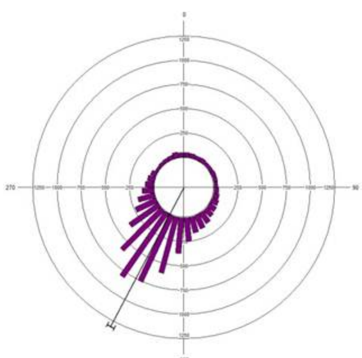
40-50 min Pre-Dawn



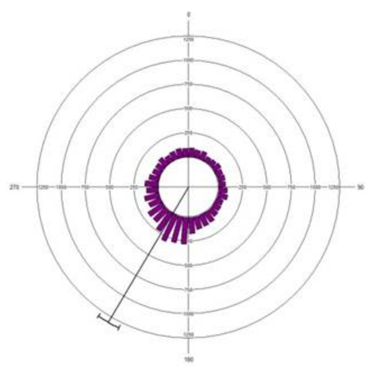
30-40 min Pre-Dawn



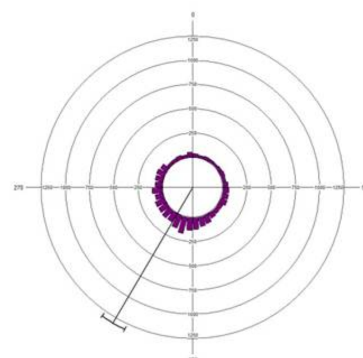
20-30 min Pre-Dawn



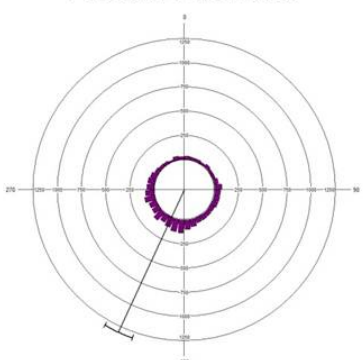
10-20 min Pre-Dawn



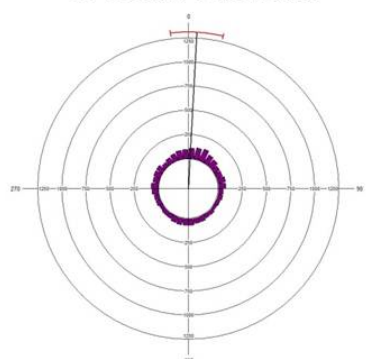
0-10 min Pre-Dawn



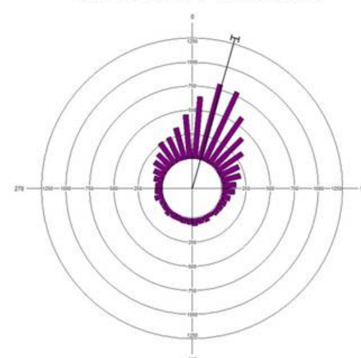
0-10 min Post-Dawn



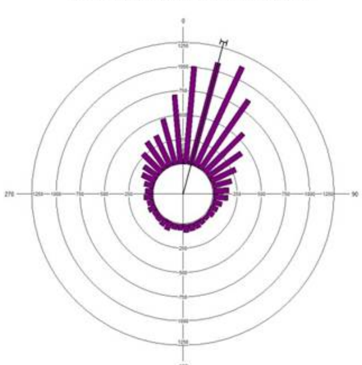
10-20 min Post-Dawn



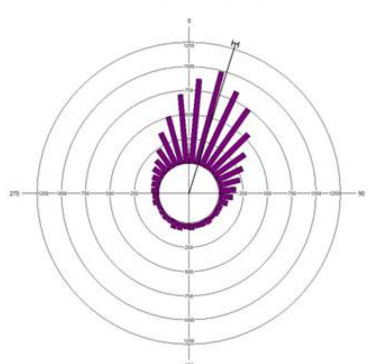
20-30 min Post-Dawn



30-40 min Post-Dawn



40-50 min Post-Dawn



50-60 min Post-Dawn

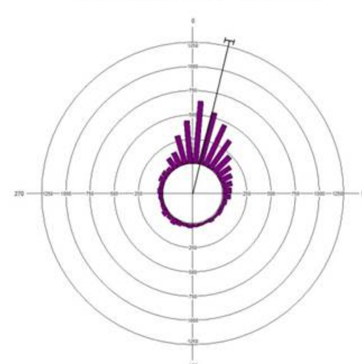


Figure 27. Circular histograms representing flight headings for winter bird targets detected with the horizontal scanning radar during the pre- and post-dawn period (Note: North is up, the straight black line represents the mean, the shorter line perpendicular to the mean with brackets depicts the 95% confidence intervals, all figures were set to the same scale). Targets were categorized into 10-min blocks relative to dawn (sunrise occurred ~25 min after dawn) (n = 13 days). Prior to dawn, most birds flew at a SSW heading. This pattern shifted near sunrise, with most targets observed flying in a NNE–NE direction.

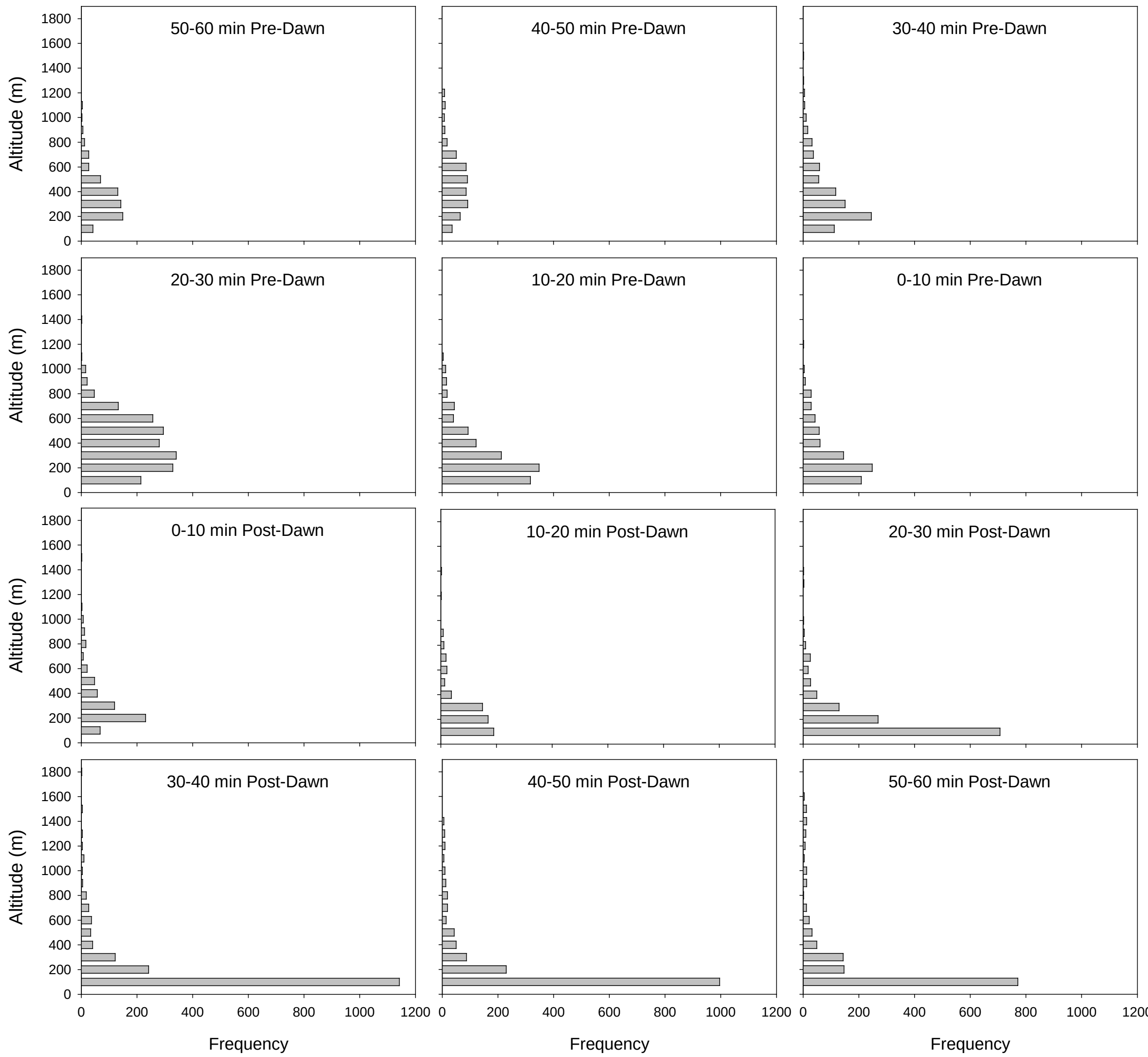


Figure 28. Winter flight altitudes (meters above ground level) for birds detected with the vertical scanning radar during the pre- and post-dawn period (n = 11 days: 2 days excluded because of contamination). Altitudes categorized into 10-min blocks relative to dawn (sunrise occurred ~25 min after dawn).

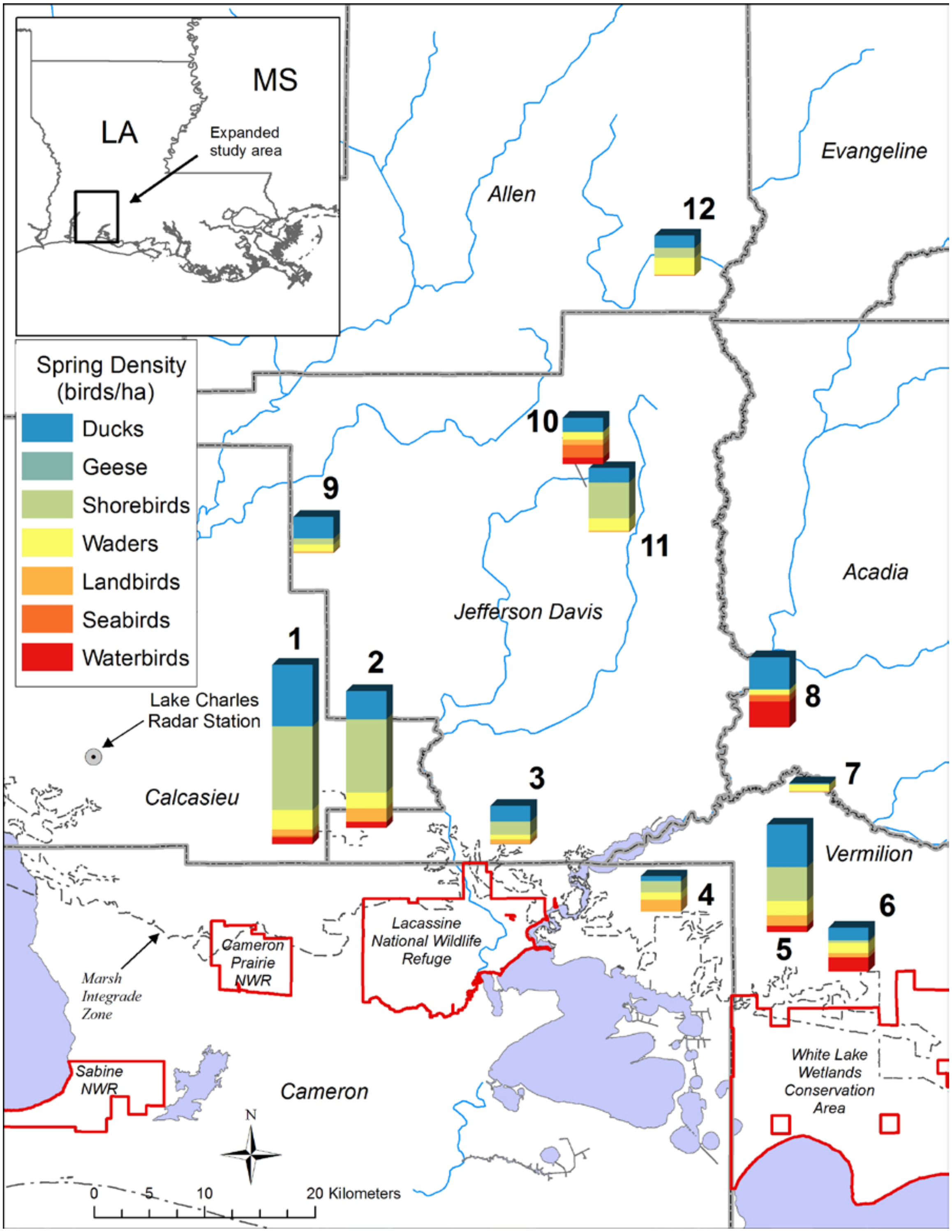


Figure 29.The relative densities (birds/ha) of each taxon in spring by study site. Total bird densities and within-taxa densities varied among study sites.

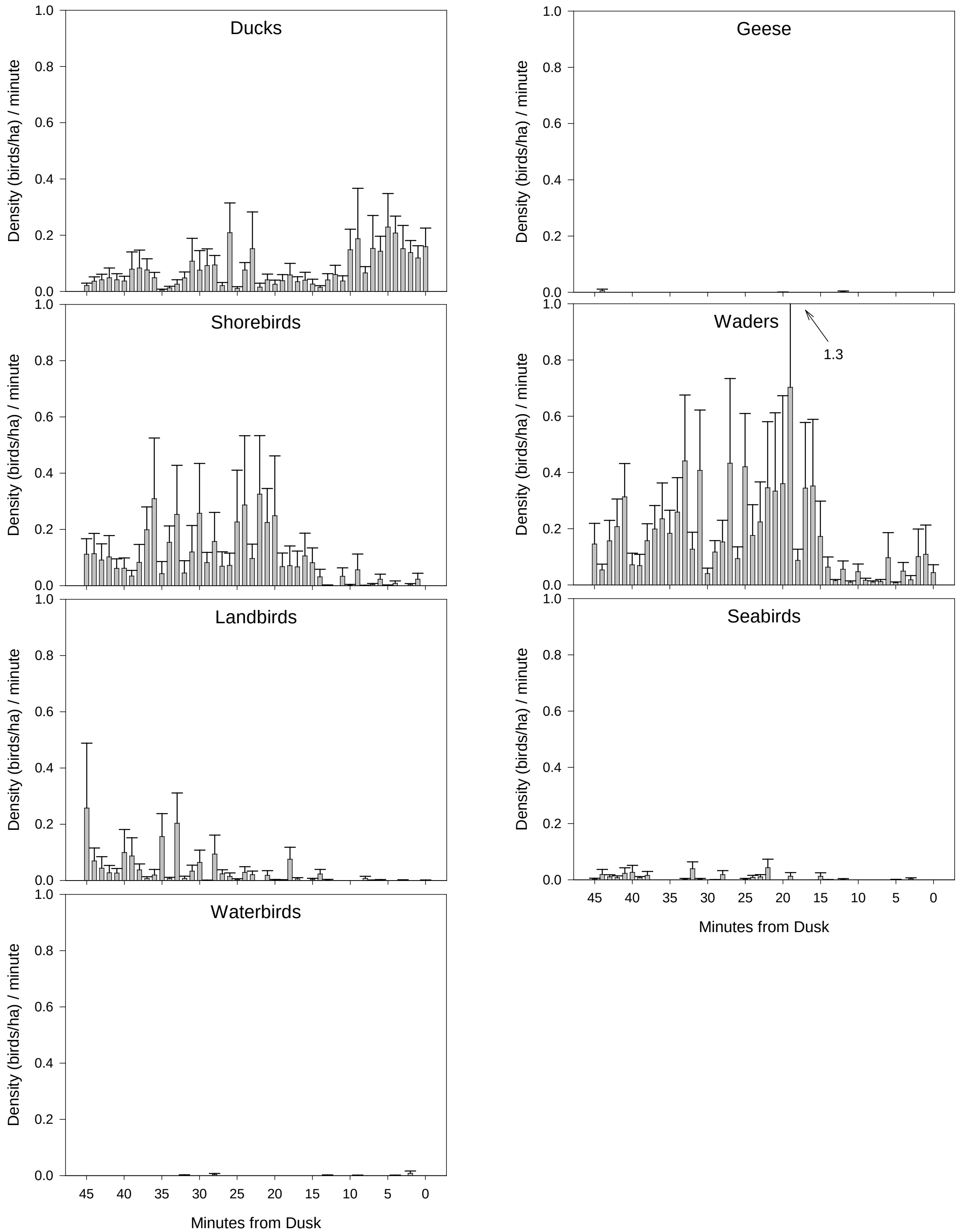


Figure 30. Temporal phenology of birds (birds/ha) in the spring detected during the direct visual observations. Data are presented per taxon as density per minute during the 45-min period leading up to dusk (n = 45 days). These data do not include birds on the ground, only birds landing, departing, circling, or flying over the MBHI fields.

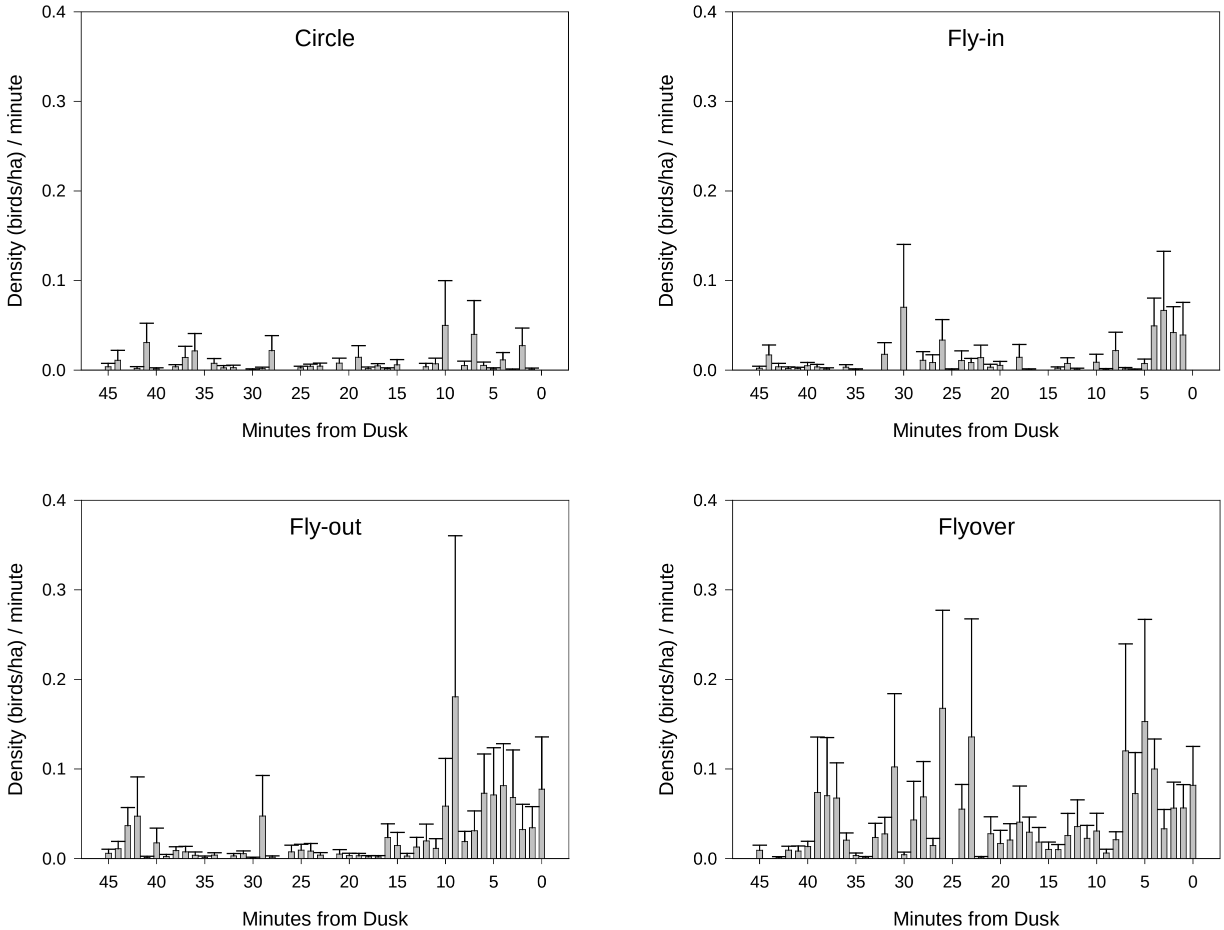


Figure 31. Evening flight activity of ducks observed in spring during the direct visual observation surveys. Figures depict mean duck densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 45 days).

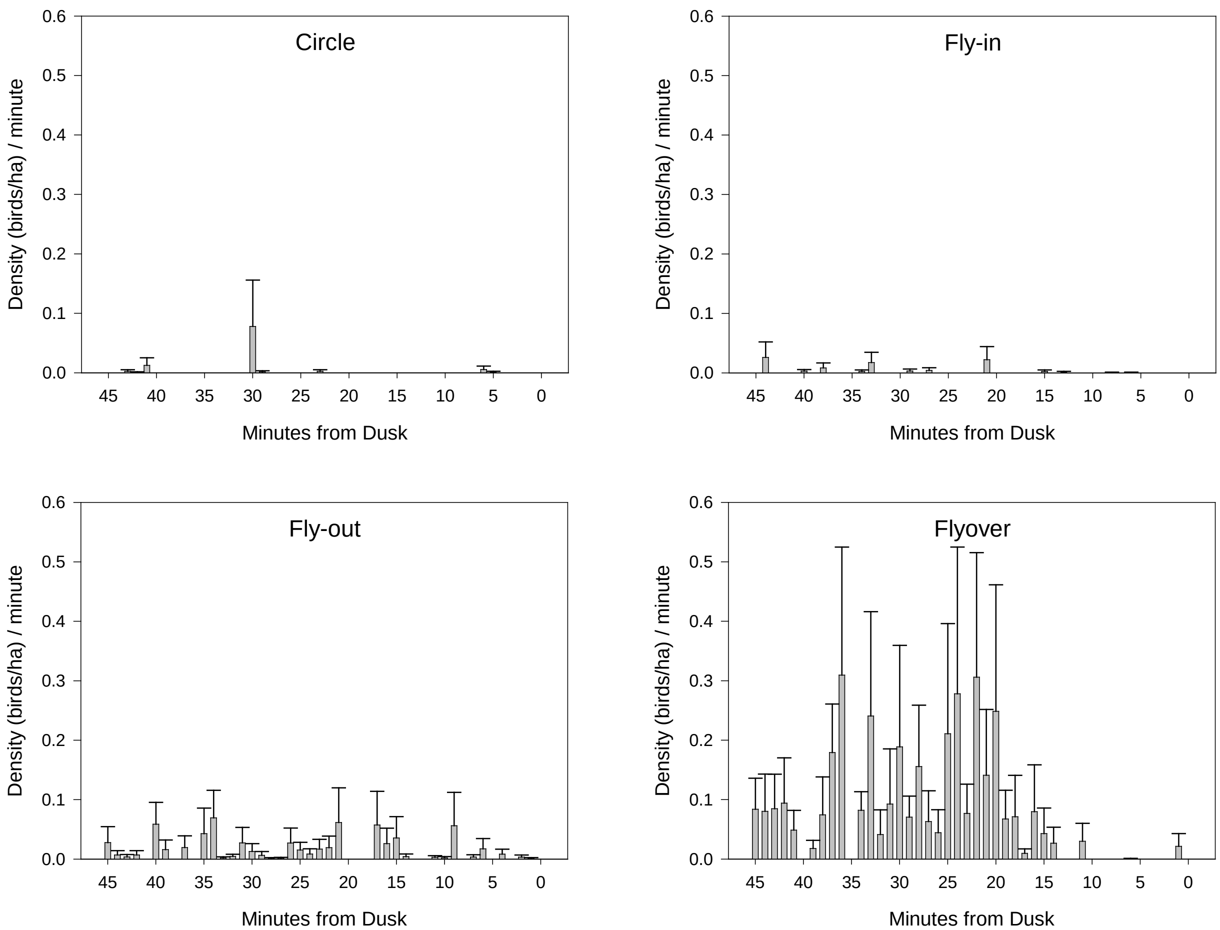


Figure 32. Evening flight activity of shorebirds observed in spring during the direct visual observation surveys. Figures depict mean shorebird densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 45 days).

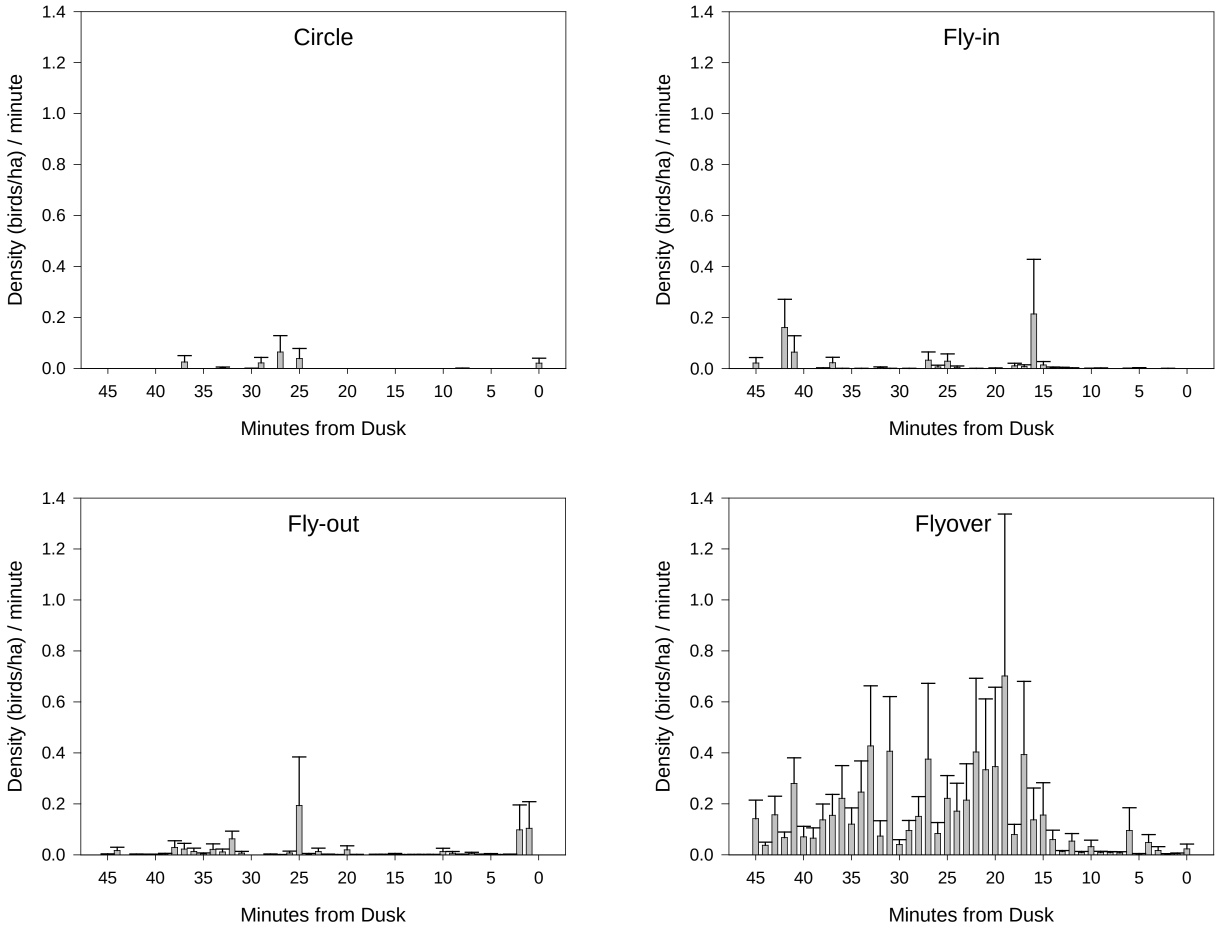


Figure 33. Evening flight activity of wading birds observed in spring during the direct visual observation surveys. Figures depict mean wader densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 45 days).

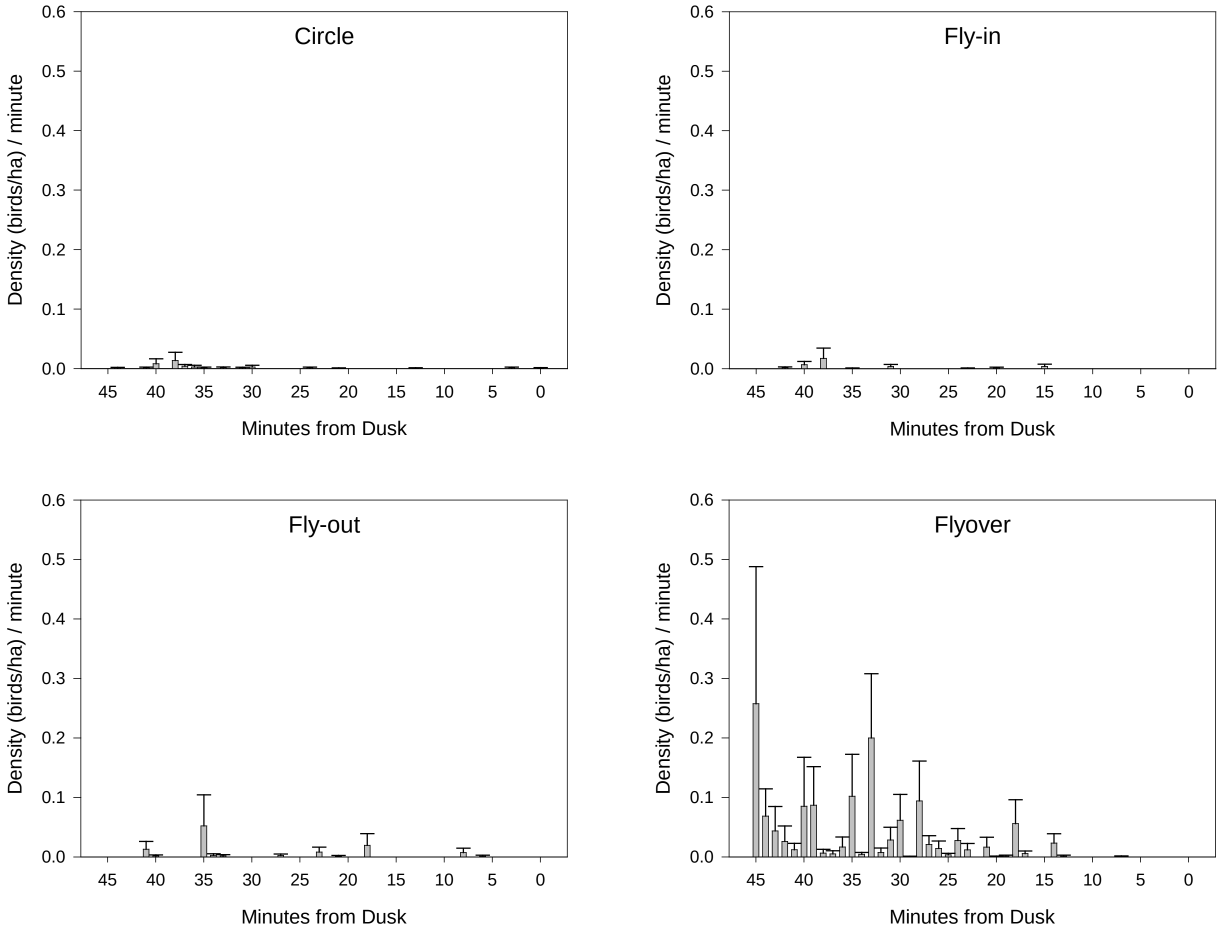


Figure 34. Evening flight activity of landbirds observed in spring during the direct visual observation surveys. Figures depict mean densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 45 days).

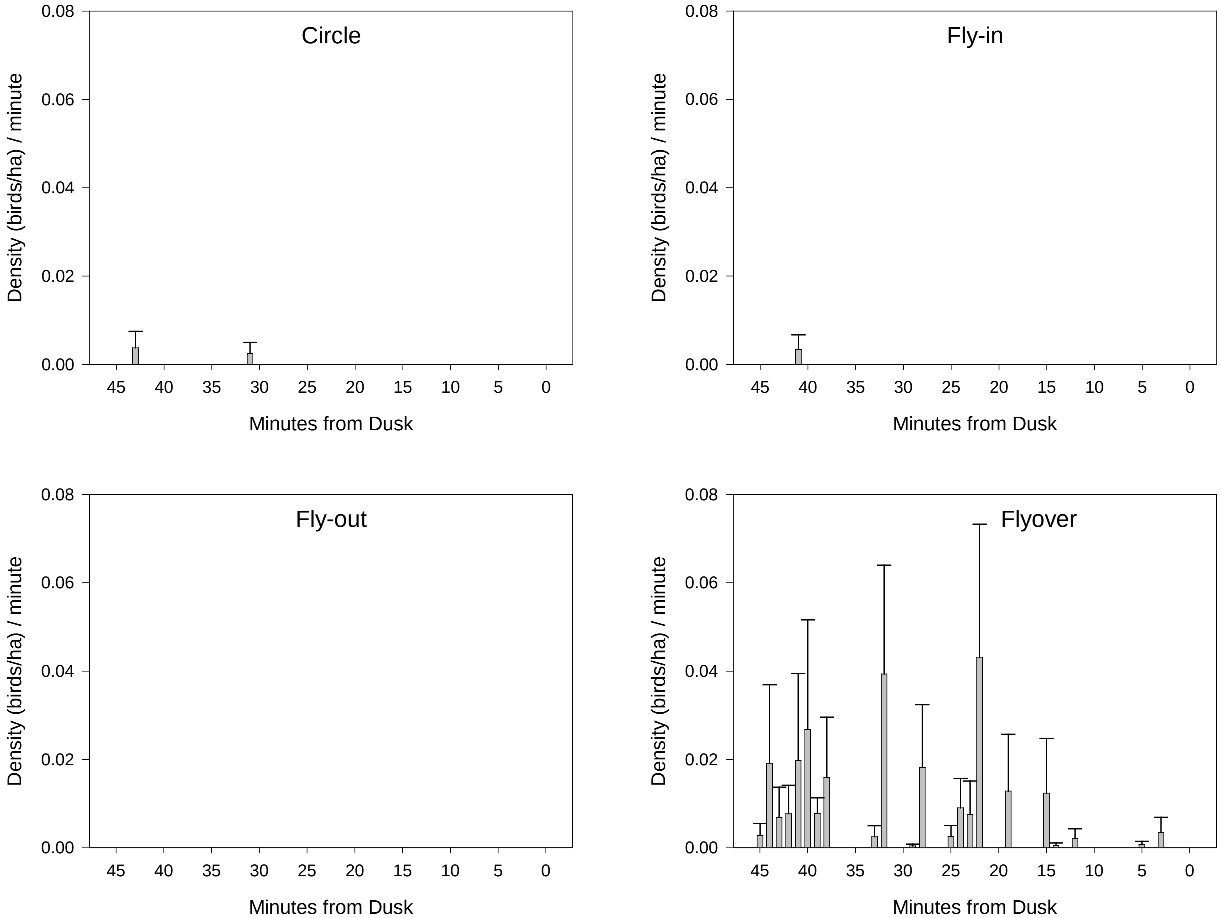


Figure 35. Evening flight activity of seabirds observed in spring during the direct visual observation surveys. Figures depict mean densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 45 days).

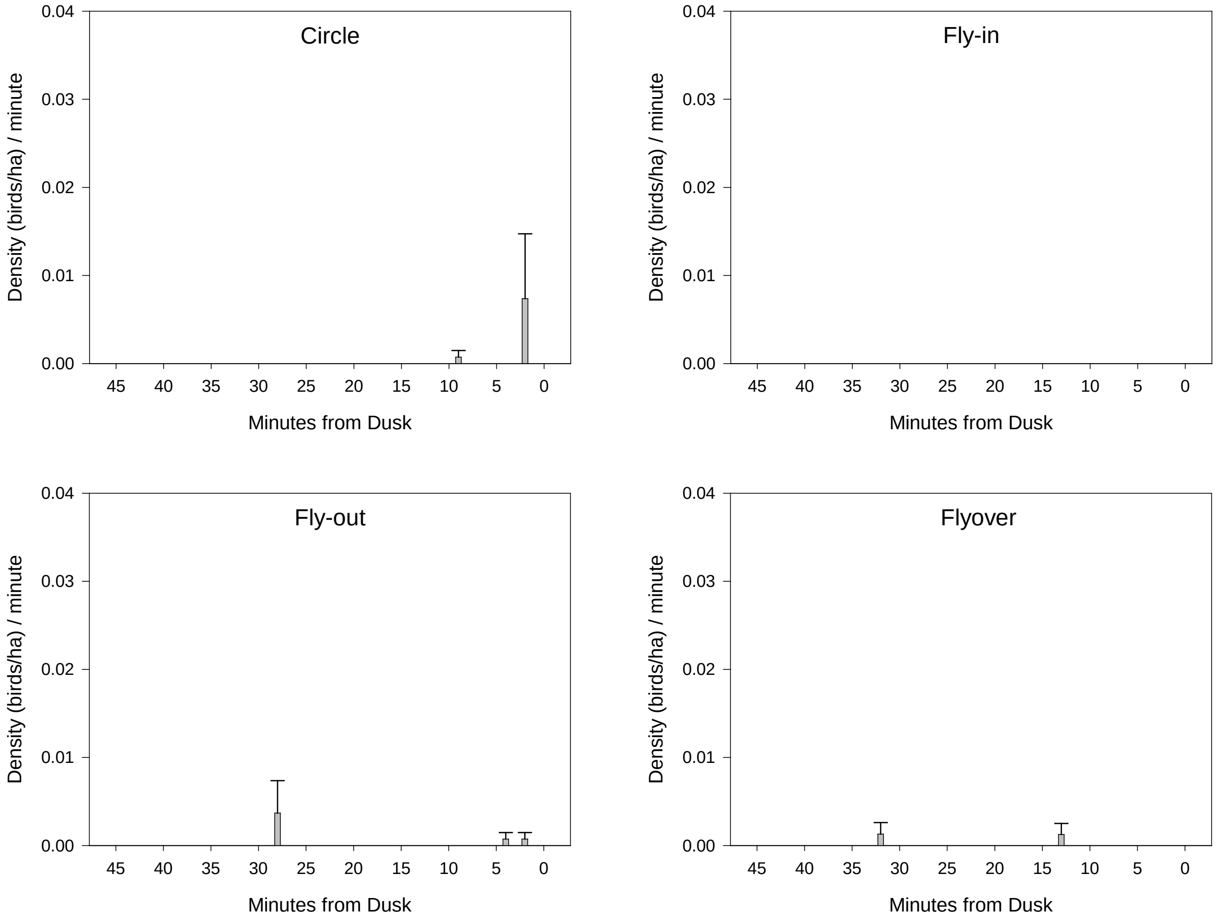


Figure 36. Evening flight activity of waterbirds observed in spring during the direct visual observation surveys. Figures depict mean densities (birds/ha) per minute by flight activity: circling, landing, departing, or flying over the study site (n = 45 days).

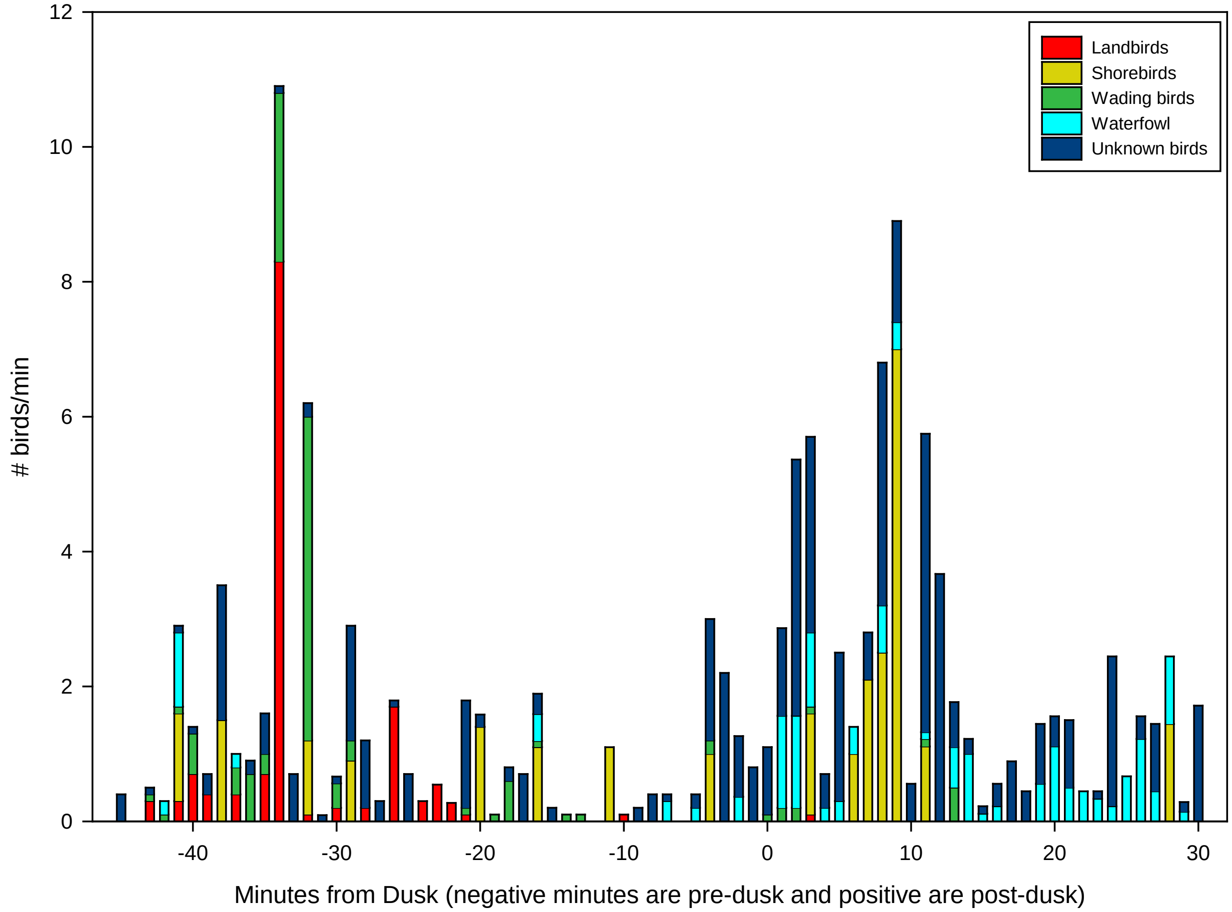


Figure 37. Thermal camera bird detections by taxa during spring (n = 10 days). Observations were from 45 min pre- to 30 min post-dusk. Dusk occurs at 0 min on the x-axis and sunset occurs at approximately -25 min. Landbird and wading bird movements peaked before sunset, whereas shorebirds and waterfowl were most abundant after dusk. Birds that we were unable to identify to taxa were called unknowns.

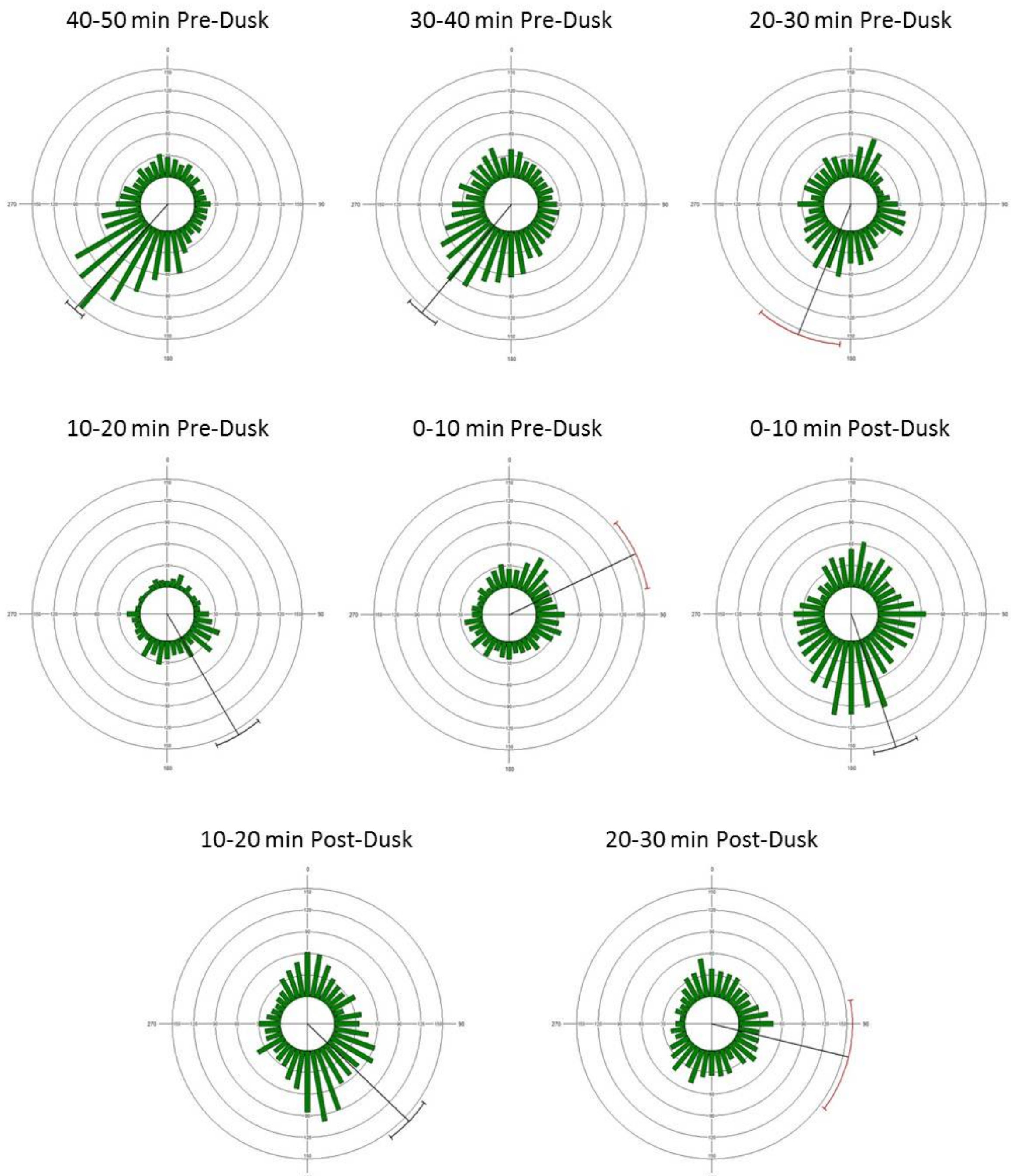


Figure 38. Circular histograms representing flight headings for spring bird targets detected with the horizontal scanning radar (Note: North is up, the straight black line represents the mean, the shorter line perpendicular to the mean with brackets depicts the 95% confidence intervals, all figures were set to the same scale). Targets were categorized into 10-min blocks relative to dusk (sunset occurred ~25 min before dusk) (n = 10 days).

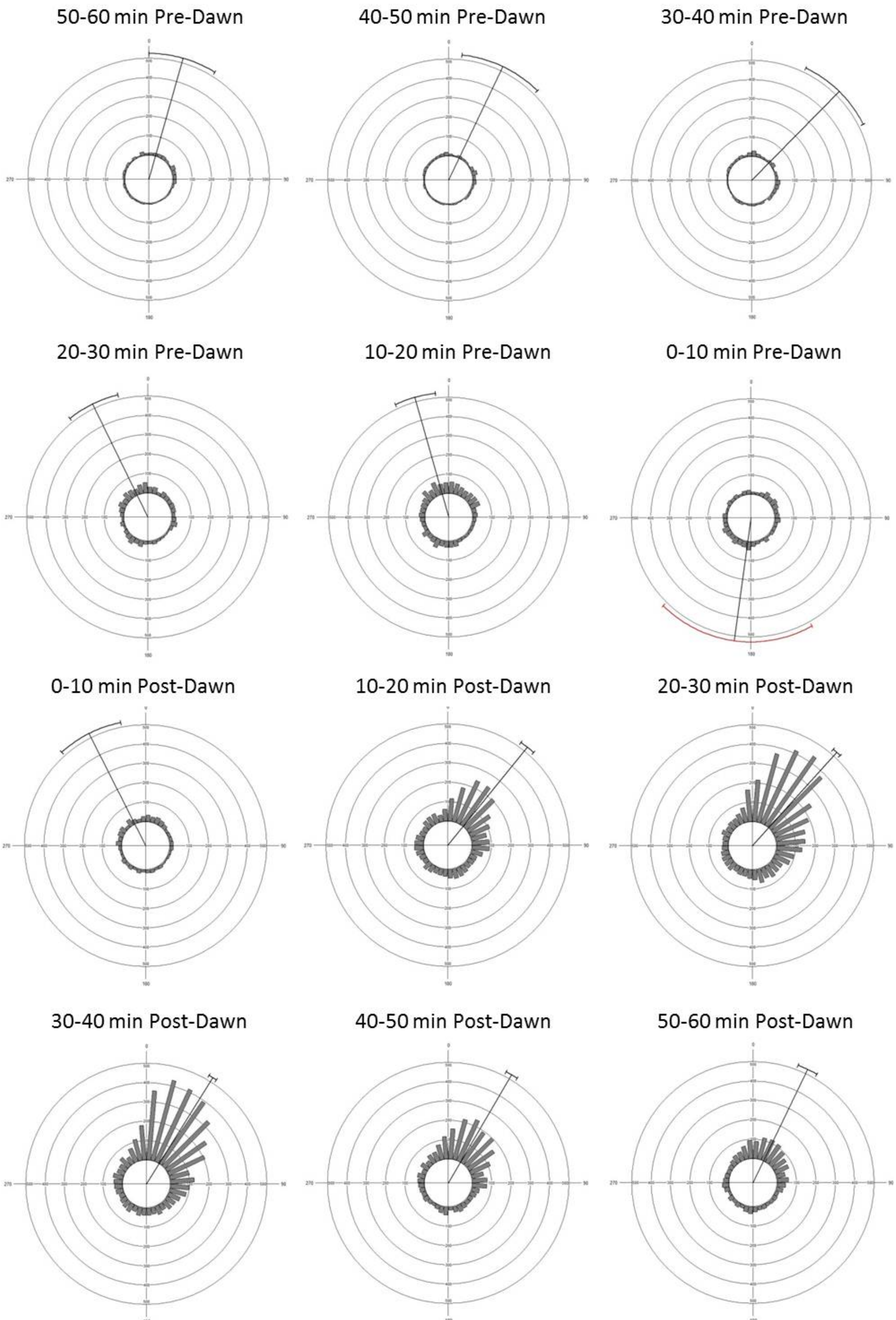

50-60 min Pre-Dawn
40-50 min Pre-Dawn
30-40 min Pre-Dawn
20-30 min Pre-Dawn
10-20 min Pre-Dawn
0-10 min Pre-Dawn
0-10 min Post-Dawn
10-20 min Post-Dawn
20-30 min Post-Dawn
30-40 min Post-Dawn
40-50 min Post-Dawn
50-60 min Post-Dawn

Figure 39. Circular histograms representing flight headings for spring bird targets detected with the horizontal scanning radar during the pre- and post-dawn period (Note: North is up, the straight black line represents the mean, the shorter line perpendicular to the mean with brackets depicts the 95% confidence intervals, all figures were set to the same scale). Targets were categorized into 10-min blocks relative to dawn (sunrise occurred ~25 min after dawn) (n = 10 days).

Table 1. MBHI area surveyed during two sampling periods: diurnal MBHI use and evening movements. Site numbers correspond to the identifiers used in Figure 1.

		Surveys: Diurnal Use of MBHI Fields				**Surveys: Evening Movements, Direct Visual Observations**			
Site #	**USGS ID**	**# of Fields**	**Dates Surveyed**	**Area (ac)**	**Area (ha)**	**# of Fields**	**Dates Surveyed**	**Area (ac)**	**Area (ha)**
1	C2	5	8/16 - 10/20/2011	151.7	61.4	2	8/25/2011-5/2/2012	54.6	22.1
		5	11/1/2011 - 5/21/2012	143.0	57.9				
2	C3	3	8/16/2011	40.9	49.7	1	8/16/2011-5/21/2012	78.9	31.9
		2	8/25/2011 - 5/21/2012	93.2	37.7				
3	C4	12	8/17 - 9/29/2011	267.5	108.3	3	8/29/2011-5/3/2012	79.3	32.1
		6	10/24/2011	104.4	42.3				
		7	11/2 - 12/15/2011	265.8	107.6				
		11	12/29/2011	266.5	107.8				
		10	1/10 - 3/13/2012	232.2	93.9				
		12	3/23 - 5/14/2012	300.5	121.6				
4	C5	4	8/15 - 10/11/2011	115.8	46.9	2	8/17/2011-5/14/2012	48.0	19.4
		4	10/12 - 11/2/2011	84.2	34.1				
		4	11/17/2011 - 5/14/2012	100.6	40.7				
5	C6	5	8/24 - 10/31/2011	64.0	25.9	3	9/16/2011-5/1/2012	55.0	22.3
		5	11/9/2011 - 1/10/2012	107.4	43.5				
		5	1/19/2012	113.5	45.9				
		5	2/2 - 3/26/2012	107.4	43.5				
		4	4/11 - 5/17/2012	53.4	21.6				
6	C20	4	8/15 - 11/21/2011	109.7	44.4	2	8/15/2011-5/17/2012	72.1	29.2
		4	12/1/2011 - 5/17/2012	129.3	52.3				
7	C11	3	8/18/2011 - 5/23/2012	57.3	23.2	4	8/11/2011-5/23/2012	37.5	15.2
8	C10	5	8/18 - 12/21/2011	216.6	87.7	3	8/30/2011-5/7/2012	124.8	50.5
		5	12/30/2011 - 1/13/2012	179.9	72.8				
		5	1/27/2012	216.6	87.7				
		2	2/1/2012	39.7	16.1				
		5	2/23 - 5/23/2012	216.6	87.7				
9	C12	2	8/22 - 9/1/2011	47.0	19.0	2	9/1/2011-9/26/2011	58.2	23.5
		4	9/15/2011 - 5/22/2012	133.2	53.9	3	10/18/2011-5/10/2012	92.5	37.4
10	C18	4	8/23 - 10/5/2011	181.6	73.5	2	8/23/2011-5/22/2012	69.9	28.3
		4	10/18/2011 - 5/22/2012	185.0	74.9				
11	C21	1	8/22 - 10/26/2011	53.0	21.5	1	8/22/2011-5/15/2012	79.9	32.3
		1	11/7/2011 - 3/26/2012	70.8	28.6				
		1	4/4 - 5/15/2012	63.5	25.7				
12	C19	5	8/23/2011 - 4/4/2012	171.9	69.6	1	8/31/2011	78.9	31.9
		4	4/18 - 5/15/2012	156.8	63.4	4	9/22/2011-5/9/2012	96.0	38.9
Total		55				30			

Table 2. Comparison of the three bird survey methods employed in this study: direct visual observations, thermal camera surveys, and portable radar surveys. Spearman's correlation coefficient was used to make comparisons. These comparisons only include data from dates and times (0 to 45 min pre-dusk) where all three methods were employed (winter: n=9 days; spring: n=10 days). *P*-values < 0.05 are in bold. The volume of airspace sampled by each method was not equal with the thermal camera sampling the smallest area and the radar the largest; nonetheless, all three methods were in general agreement.

	Winter (n=9)			**Spring (n=10)**			**Winter and Spring Combined (n=19)**		
	Thermal	**Radar**	**Visual**	**Thermal**	**Radar**	**Visual**	**Thermal**	**Radar**	**Visual**
Thermal	1.000	.	.	1.000	.	.	1.000	.	.
Radar	0.400 **<.0001**	1.000	.	0. 370 **<.0001**	1.000	.	0. 416 **<.0001**	1.000	.
Visual	0.519 **<.0001**	0.495 **<.0001**	1.000	0. 221 **0.038**	0.501 **<.0001**	1.000	0. 407 **<.0001**	0. 523 **<.0001**	1.000

Appendix A. Species detected during the diurnal total area surveys and/or the evening direct visual surveys (X = detected). Taxa classification used in this report is also provided. A total of 122 species were detected.

Common Name	Scientific Name	Diurnal Total Area Surveys	Evening Direct Visual Surveys
DUCKS			
Black-bellied Whistling-Duck	*Dendrocygna autumnalis*	X	X
Fulvous Whistling-Duck	*Dendrocygna bicolor*	X	X
Wood Duck	*Aix sponsa*	X	X
Gadwall	*Anas strepera*	X	X
American Wigeon	*Anas americana*	X	
Mallard	*Anas platyrhynchos*	X	X
Mottled Duck	*Anas fulvigula*	X	X
Blue-winged Teal	*Anas discors*	X	X
Northern Shoveler	*Anas clypeata*	X	X
Northern Pintail	*Anas acuta*	X	X
American Green-winged Teal	*Anas crecca*	X	X
Canvasback	*Aythya valisineria*	X	
Redhead	*Aythya americana*	X	
Ring-necked Duck	*Aythya collaris*	X	
Lesser Scaup	*Aythya affinis*	X	
Common Goldeneye	*Bucephala clangula*	X	
Hooded Merganser	*Lophodytes cucullatus*	X	
Ruddy Duck	*Oxyura jamaicensis*	X	
GEESE			
Greater White-fronted Goose	*Anser albifrons*	X	X
Snow Goose	*Chen caerulescens*	X	X
Ross' Goose	*Chen rossii*		X
Cackling Goose	*Branta hutchinsii*	X	
SEABIRDS			
Neotropic Cormorant	*Phalacrocorax brasilianus*	X	X
Double-crested Cormorant	*Phalacrocorax auritus*	X	
Anhinga	*Anhinga anhinga*		X
Laughing Gull	*Leucophaeus atricilla*	X	X
Ring-billed Gull	*Larus delawarensis*	X	X
Gull-billed Tern	*Gelochelidon nilotica*	X	
Caspian Tern	*Hydroprogne caspia*	X	X
Forster's Tern	*Sterna forsteri*	X	
WADERS			
Wood Stork	*Mycteria americana*	X	
* American Bittern	*Botaurus lentiginosus*		X
Great Blue Heron	*Ardea herodias*	X	X
Great Egret	*Ardea alba*	X	X
Snowy Egret	*Egretta thula*	X	X
Little Blue Heron	*Egretta caerulea*	X	X
Tricolored Heron	*Egretta tricolor*	X	X
Cattle Egret	*Bubulcus ibis*	X	X
Green Heron	*Butorides virescens*	X	X

Appendix A - continued.

Common Name	Scientific Name	Diurnal Total Area Surveys	Evening Direct Visual Surveys
WADERS – cont.			
Black-crowned Night-Heron	*Nycticorax nycticorax*	X	X
Yellow-crowned Night-Heron	*Nyctanassa violacea*	X	X
White Ibis	*Eudocimus albus*	X	X
Glossy Ibis	*Plegadis falcinellus*	X	
White-faced Ibis	*Plegadis chihi*	X	X
Roseate Spoonbill	*Platalea ajaja*	X	X
WATERBIRDS			
Pied-billed Grebe	*Podilymbus podiceps*	X	
Rail sp.	*Rallus sp.*	X	
Sora	*Porzana carolina*	X	
Purple Gallinule	*Porphyrio martinica*	X	
Common Gallinule	*Gallinula galeata*	X	
American Coot	*Fulica americana*	X	X
SHOREBIRDS			
Black-bellied Plover	*Pluvialis squatarola*	X	
American Golden-Plover	*Pluvialis dominica*	X	
Semipalmated Plover	*Charadrius semipalmatus*	X	
Killdeer	*Charadrius vociferus*	X	X
Black-necked Stilt	*Himantopus mexicanus*	X	X
American Avocet	*Recurvirostra americana*	X	X
Spotted Sandpiper	*Actitis macularius*	X	
Solitary Sandpiper	*Tringa solitaria*	X	X
Greater Yellowlegs	*Tringa melanoleuca*	X	X
Lesser Yellowlegs	*Tringa flavipes*	X	X
Upland Sandpiper	*Bartramia longicauda*	X	
Marbled Godwit	*Limosa fedoa*	X	
Ruddy Turnstone	*Arenaria interpres*	X	
Semipalmated Sandpiper	*Calidris pusilla*	X	
Western Sandpiper	*Calidris mauri*	X	X
Least Sandpiper	*Calidris minutilla*	X	X
Baird’s Sandpiper	*Calidris bairdii*	X	
Pectoral Sandpiper	*Calidris melanotos*	X	
Dunlin	*Calidris alpina*	X	X
Stilt Sandpiper	*Calidris himantopus*	X	
Short-billed Dowitcher	*Limnodromus griseus*	X	X
Long-billed Dowitcher	*Limnodromus scolopaceus*	X	
Wilson's Snipe	*Gallinago delicata*	X	X
Wilson's Phalarope	*Phalaropus tricolor*	X	
LANDBIRDS			
Turkey Vulture	*Cathartes aura*	X	
Northern Harrier	*Circus cyaneus*	X	X
Red-shouldered Hawk	*Buteo lineatus*	X	X
Red-tailed Hawk	*Buteo jamaicensis*	X	X
Crested Caracara	*Caracara cheriway*	X	
American Kestrel	*Falco sparverius*	X	X

Appendix A - continued.

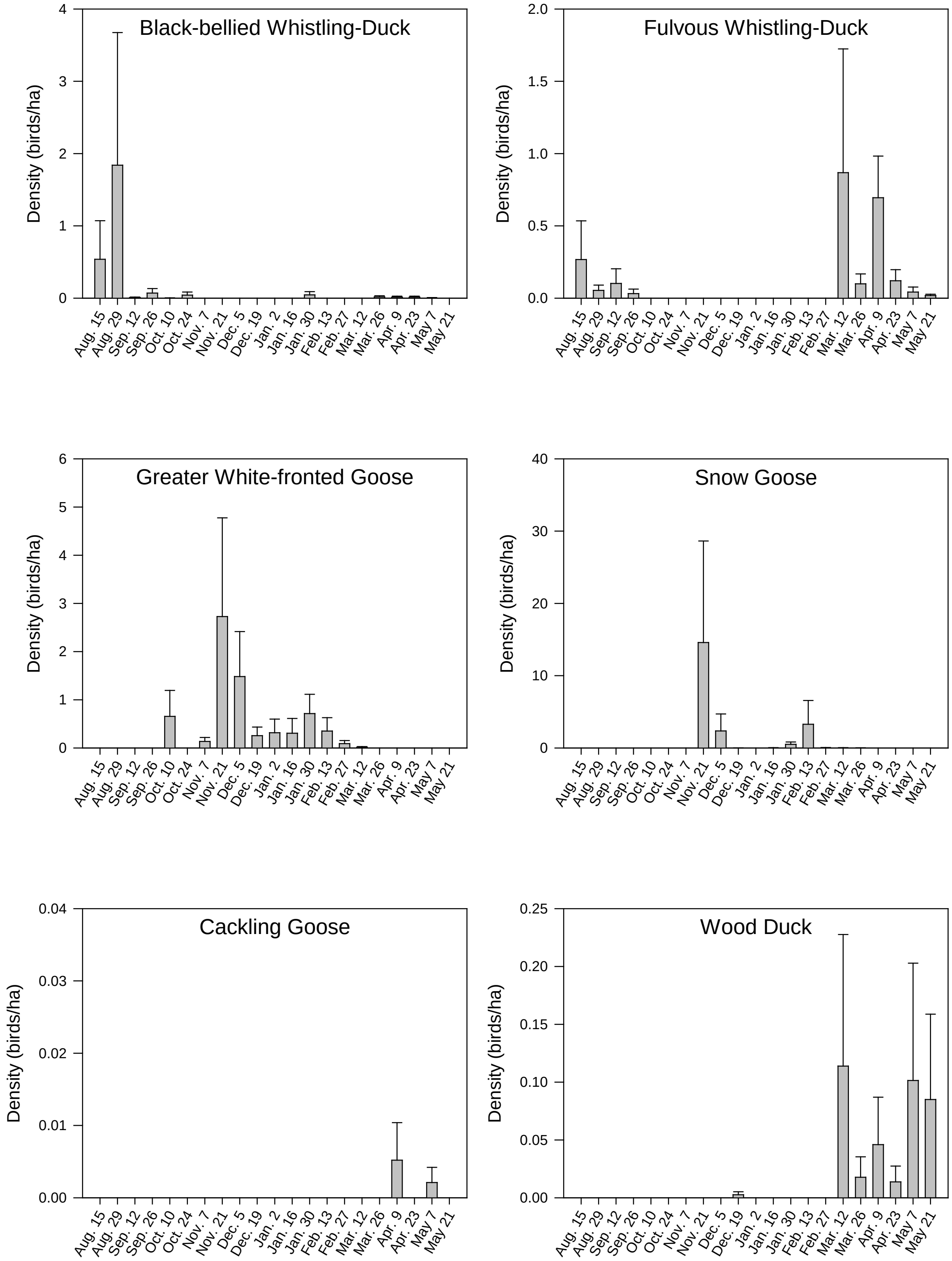
Common Name	Scientific Name	Diurnal Total Area Surveys	Evening Direct Visual Surveys
LANDBIRDS – cont.			
Rock Pigeon	*Columba livia*	X	
Eurasian Collared-Dove	*Streptopelia decaocto*	X	
Mourning Dove	*Zenaida macroura*	X	X
Inca Dove	*Columbina inca*	X	
Barn Owl	*Tyto alba*		X
Great Horned Owl	*Bubo virginianus*		X
Barred Owl	*Strix varia*		X
Common Nighthawk	*Chordeiles minor*	X	X
Belted Kingfisher	*Megaceryle alcyon*	X	
Eastern Phoebe	*Sayornis phoebe*	X	
Eastern Kingbird	*Tyrannus tyrannus*	X	
Scissor-tailed Flycatcher	*Tyrannus forficatus*		X
Loggerhead Shrike	*Lanius ludovicianus*	X	X
American Crow	*Corvus brachyrhynchos*	X	X
Fish Crow	*Corvus ossifragus*	X	
Purple Martin	*Progne subis*	X	X
Tree Swallow	*Tachycineta bicolor*	X	X
Cliff Swallow	*Petrochelidon pyrrhonota*		X
Barn Swallow	*Hirundo rustica*	X	X
Marsh Wren	*Cistothorus palustris*	X	X
Northern Mockingbird	*Mimus polyglottos*	X	
European Starling	*Sturnus vulgaris*	X	
American Pipit	*Anthus rubescens*	X	
Orange-crowned Warbler	*Oreothlypis celata*	X	
Common Yellowthroat	*Geothlypis trichas*	X	X
Palm Warbler	*Setophaga palmarum*	X	
Yellow-rumped Warbler	*Setophaga coronata*	X	
Field Sparrow	*Spizella pusilla*	X	
Savannah Sparrow	*Passerculus sandwichensis*	X	X
Grasshopper Sparrow	*Ammodramus savannarum*	X	
Song Sparrow	*Melospiza melodia*		X
Northern Cardinal	*Cardinalis cardinalis*	X	X
Indigo Bunting	*Passerina cyanea*		X
Painted Bunting	*Passerina ciris*	X	
Dickcissel	*Spiza americana*	X	
Red-winged Blackbird	*Agelaius phoeniceus*	X	X
Eastern Meadowlark	*Sturnella magna*	X	X
Western Meadowlark	*Sturnella neglecta*	X	
Common Grackle	*Quiscalus quiscula*	X	X
Boat-tailed Grackle	*Quiscalus major*	X	
Brown-headed Cowbird	*Molothrus ater*	X	

* Detected during portable radar survey only

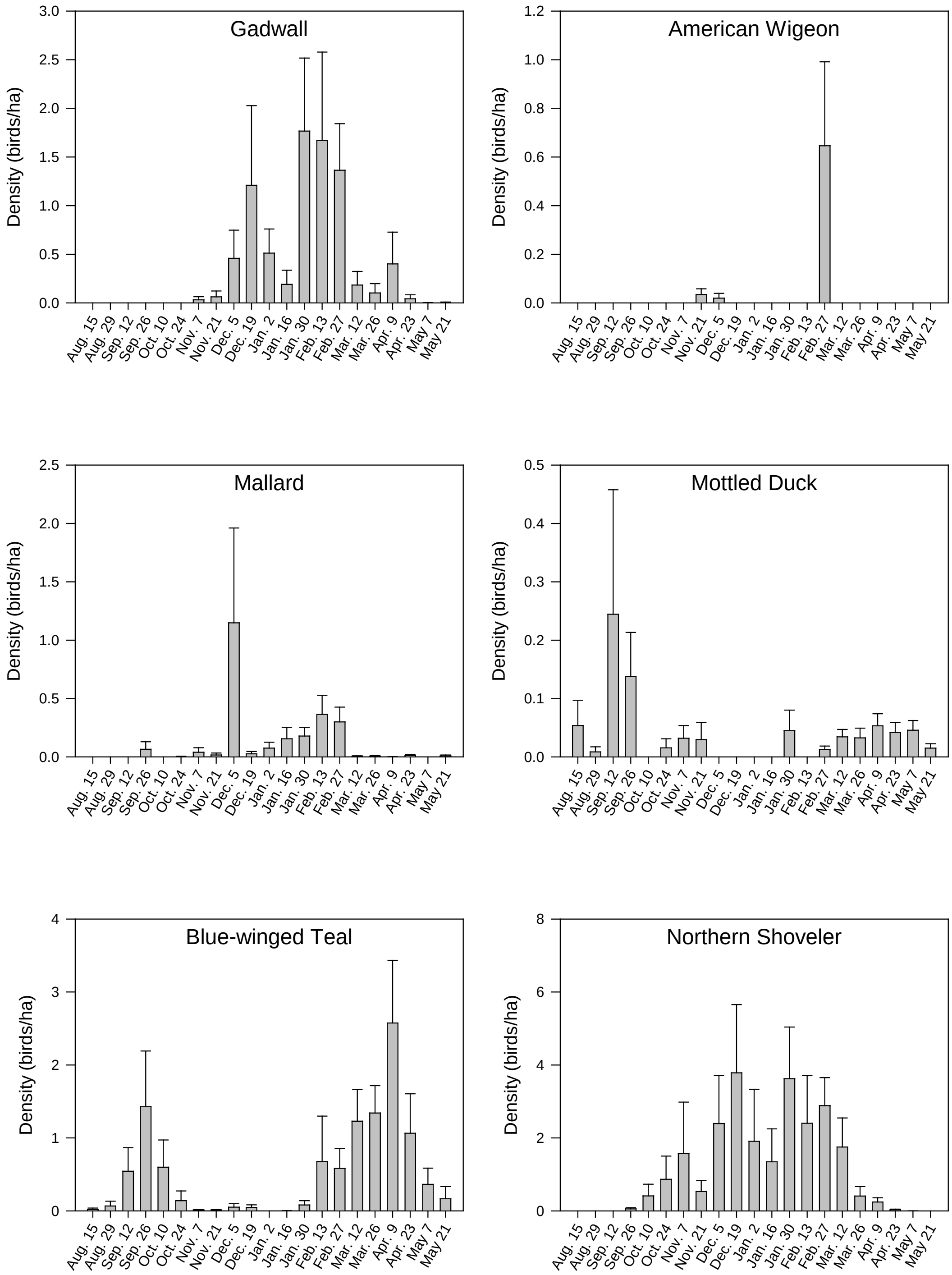
Other species detected on MBHI fields, but not during official survey periods:

Virginia Rail (*Rallus limicola*)
Sedge Wren (*Cistothorus platensis*)

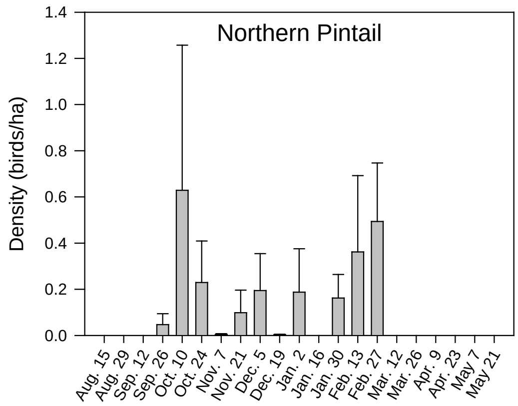
Appendix B. Biweekly waterfowl densities (# of birds/ha) recorded on MBHI easements during the diurnal use surveys.

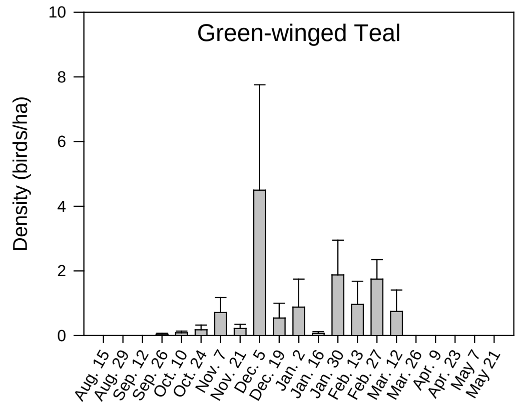


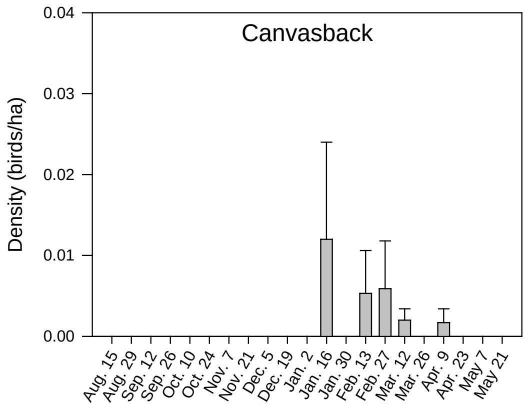
Appendix B - continued.

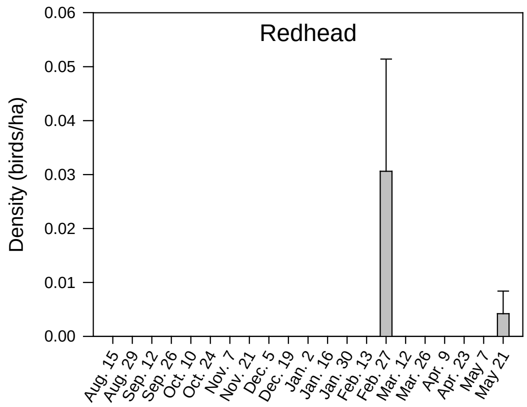


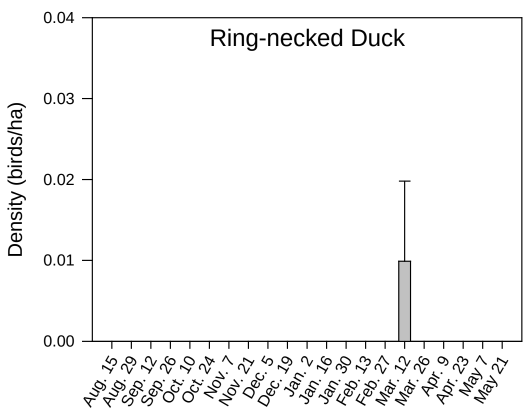
Appendix B - continued.

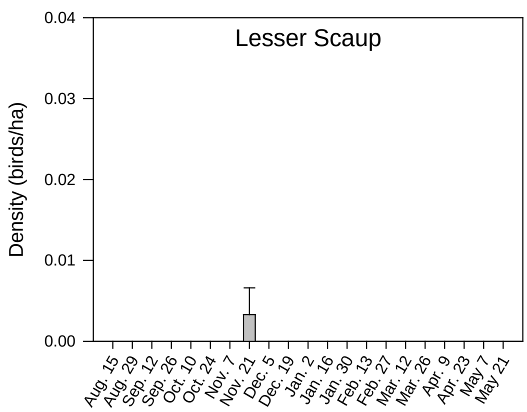




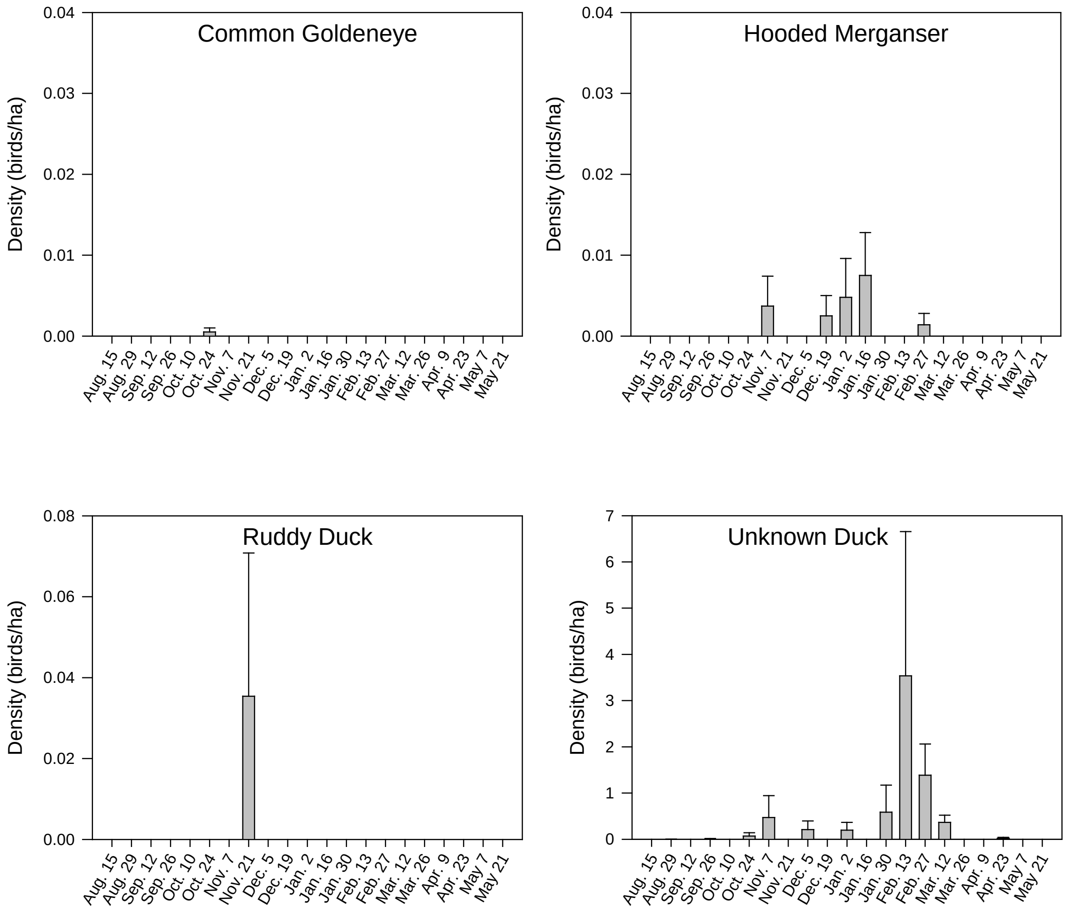




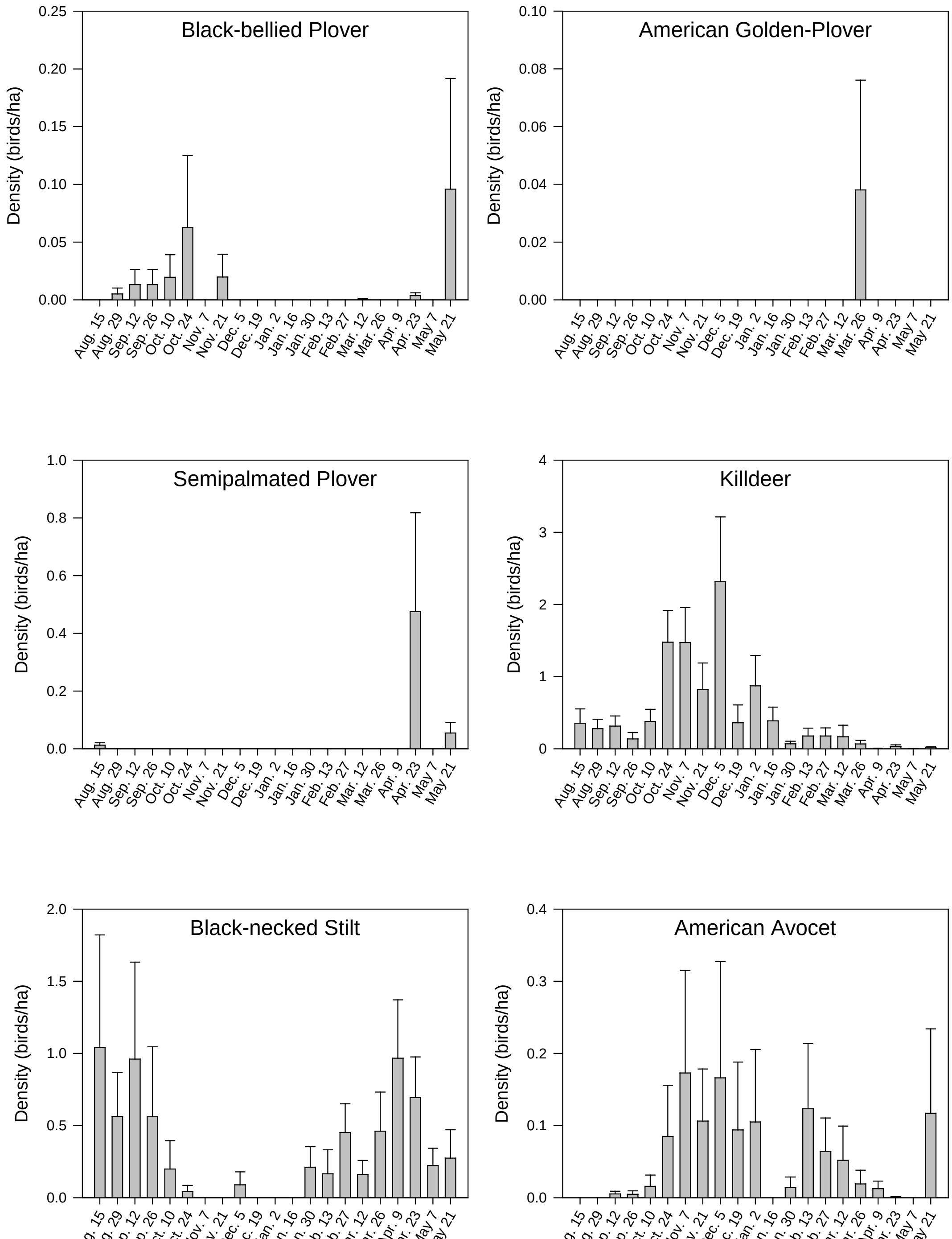




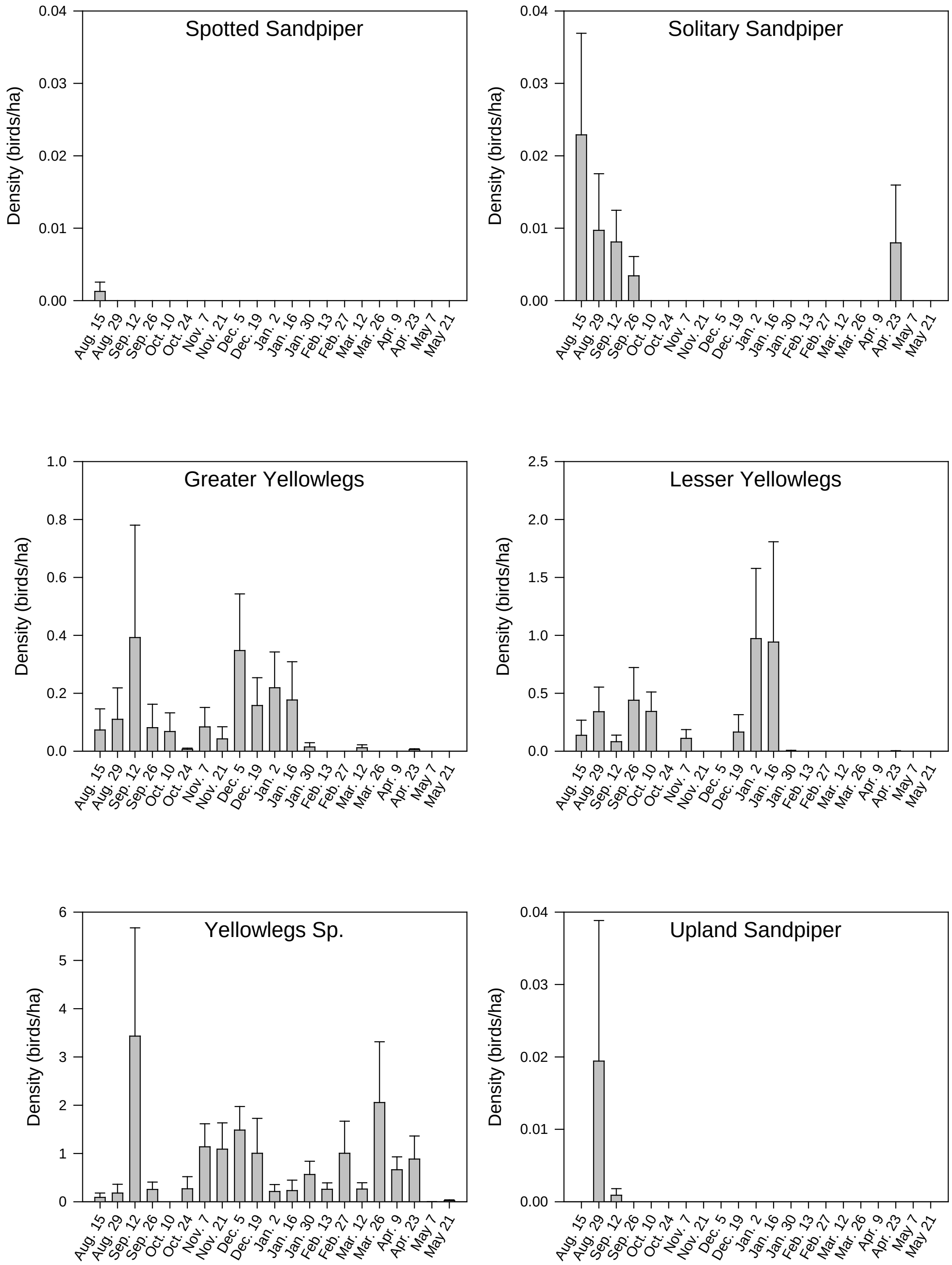
Appendix B - continued.



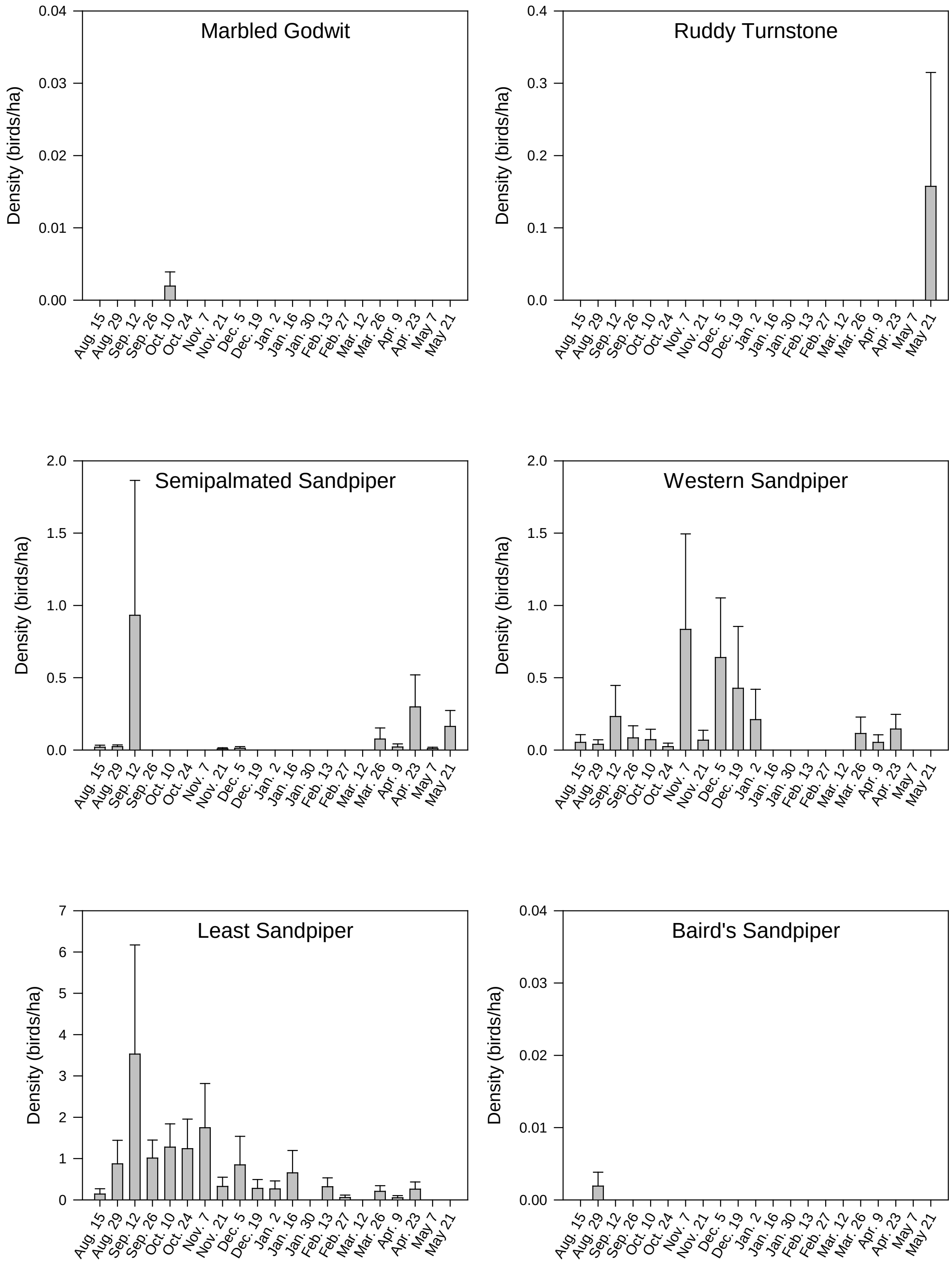
Appendix C. Biweekly shorebird densities (# of birds/ha) recorded on MBHI easements during the diurnal use surveys.



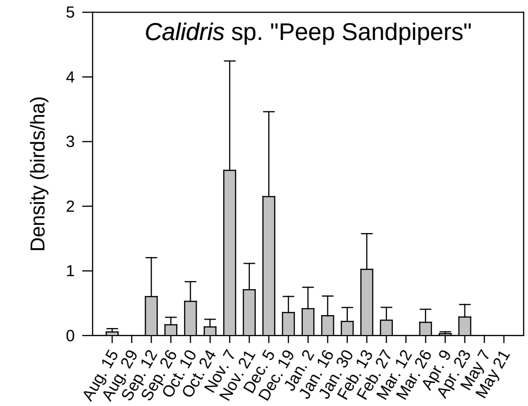
Appendix C - continued.

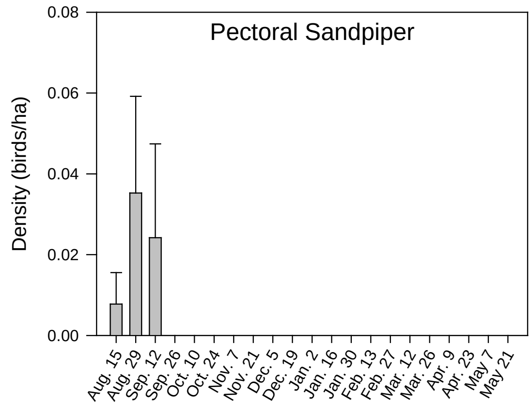


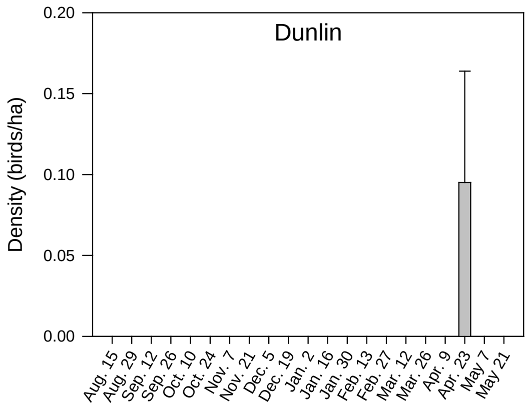
Appendix C - continued.

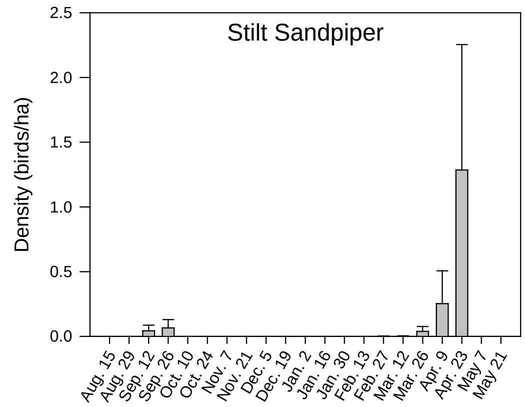


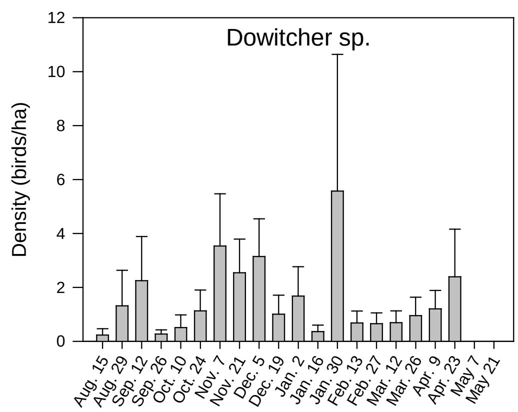
Appendix C - continued.

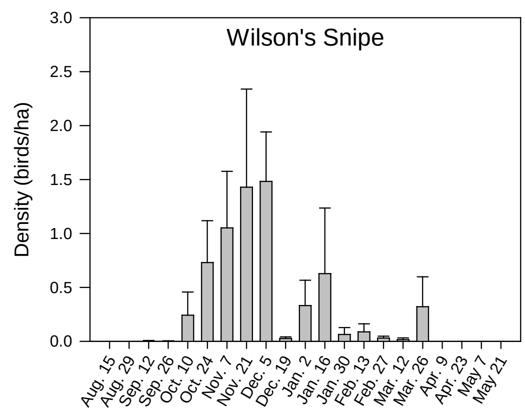




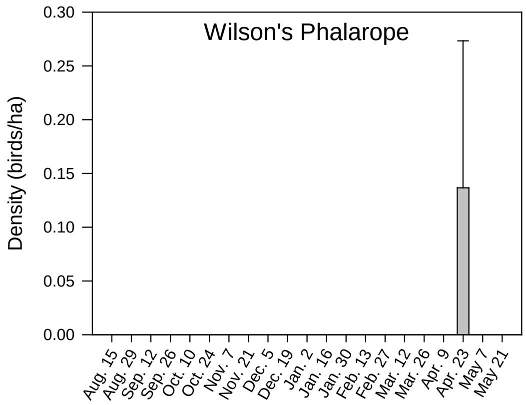


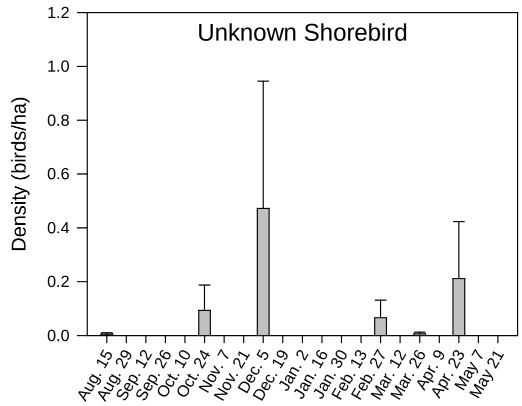




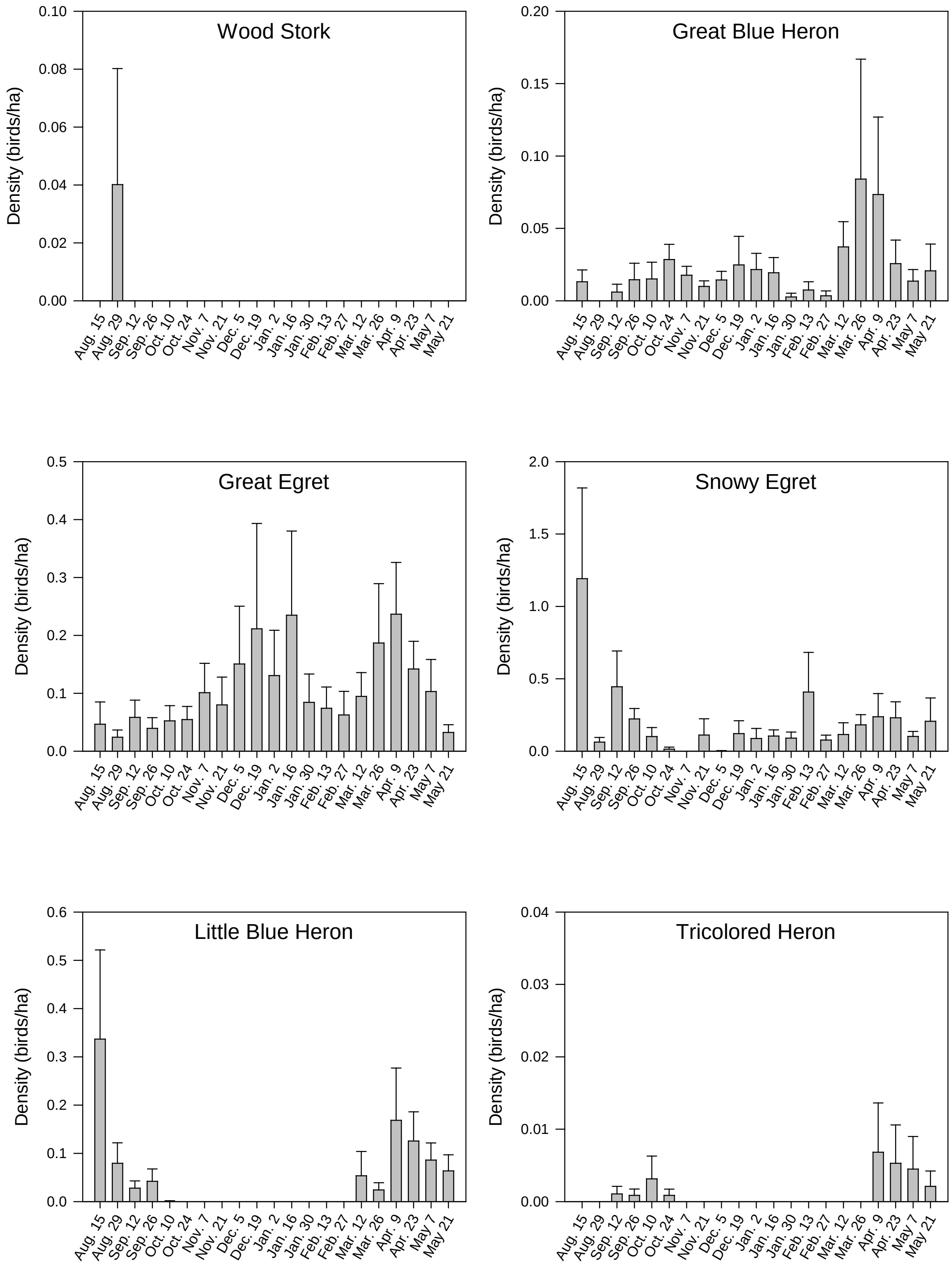


Appendix C - continued.

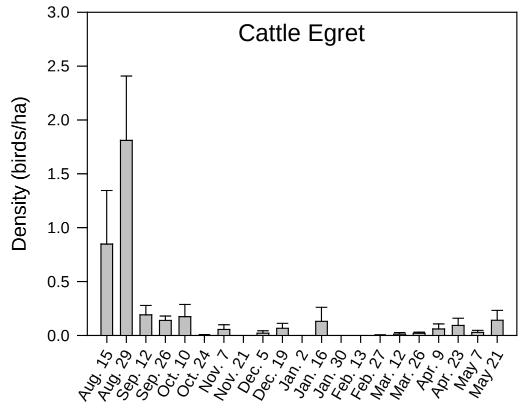


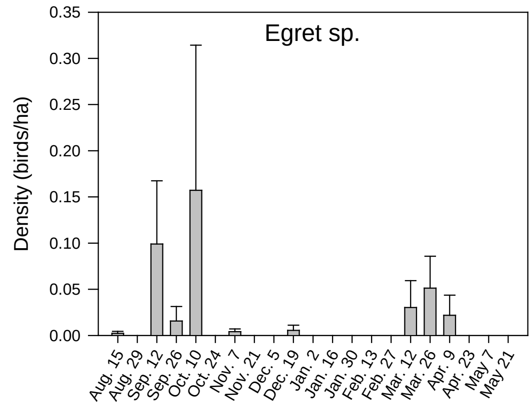


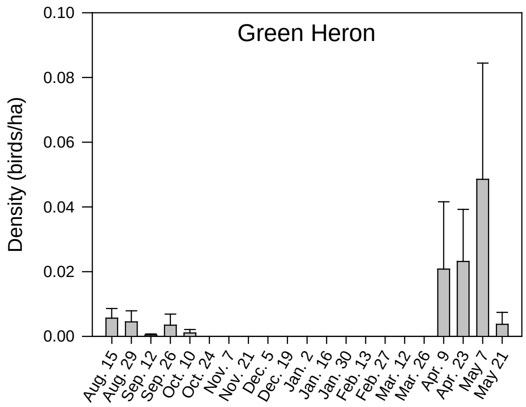
Appendix D. Biweekly wading bird densities (# of birds/ha) recorded on MBHI easements during the diurnal use surveys.

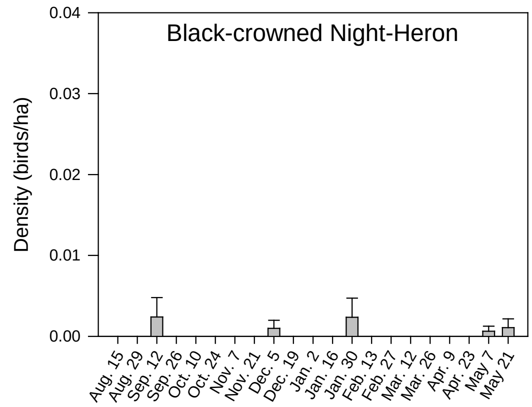


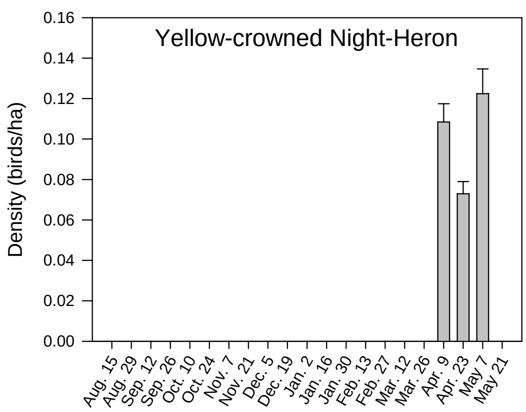
Appendix D - continued.

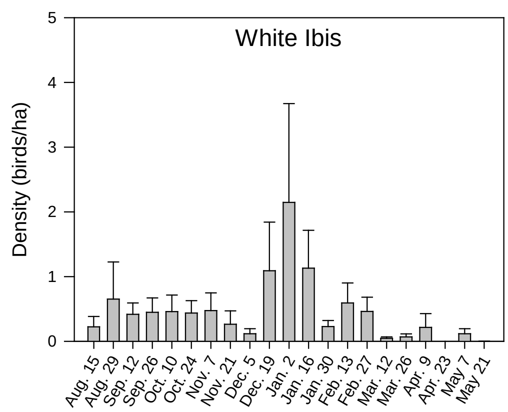




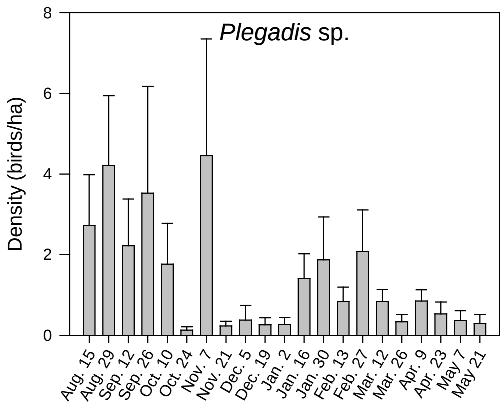


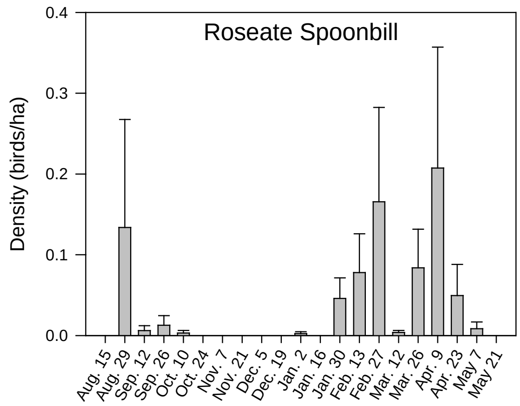




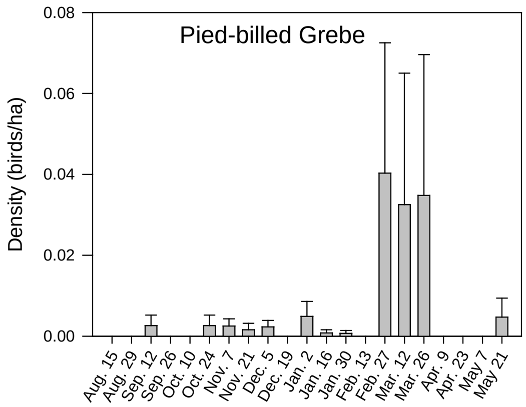


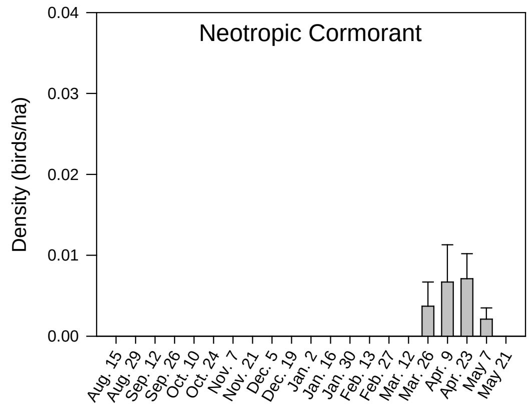
Appendix D - continued.

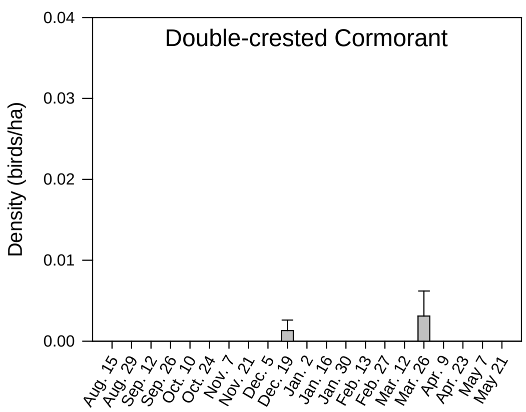


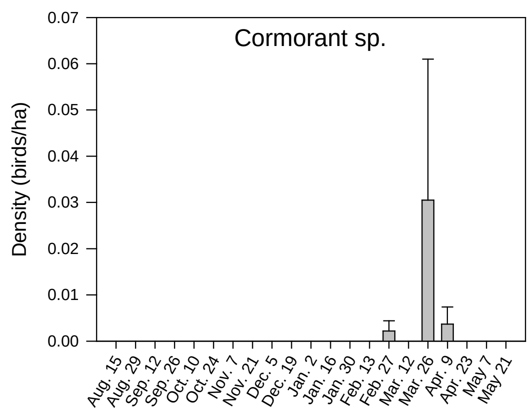


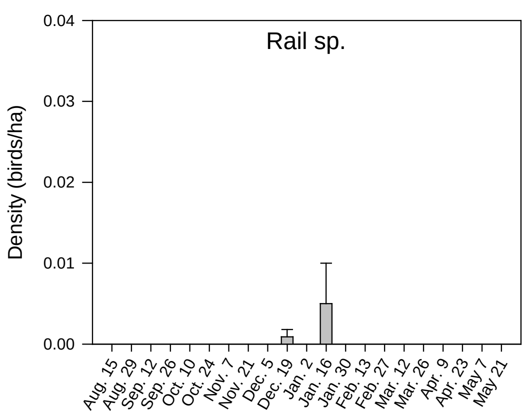
Appendix E. Biweekly densities (# of birds/ha) for seabirds, waterbirds, and the most common landbirds recorded on MBHI easements during the diurnal use surveys.

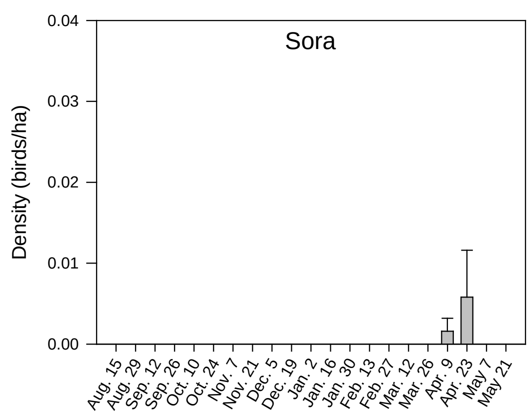




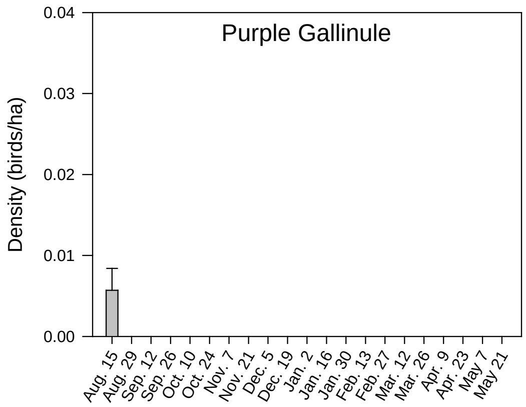


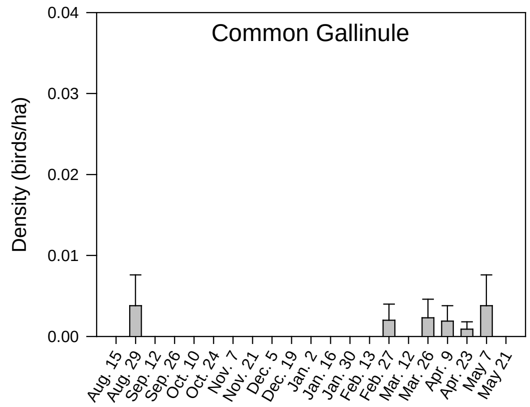


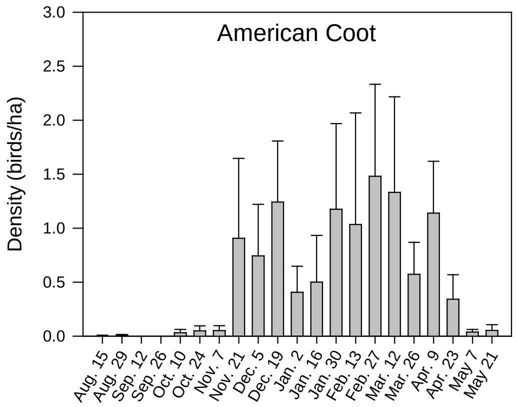


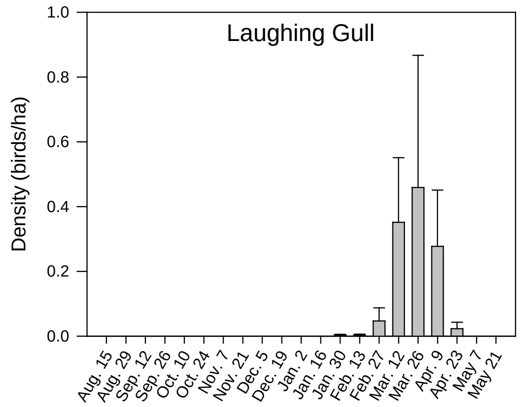


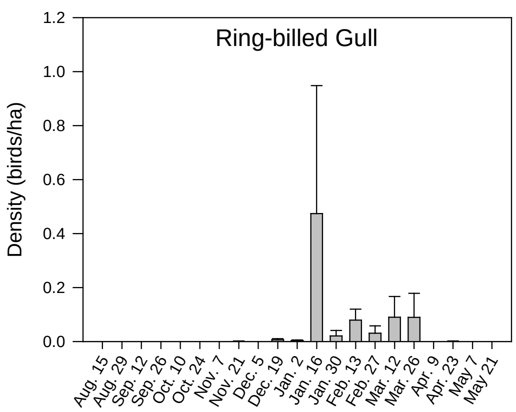
Appendix E - continued.

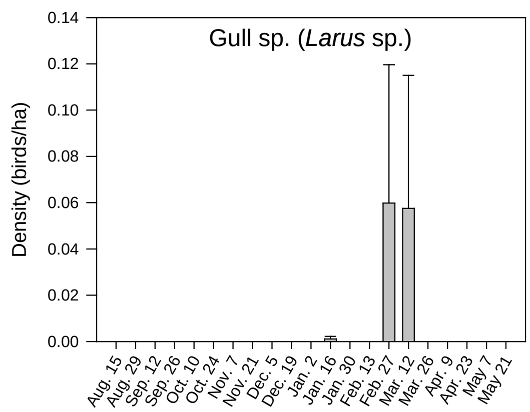




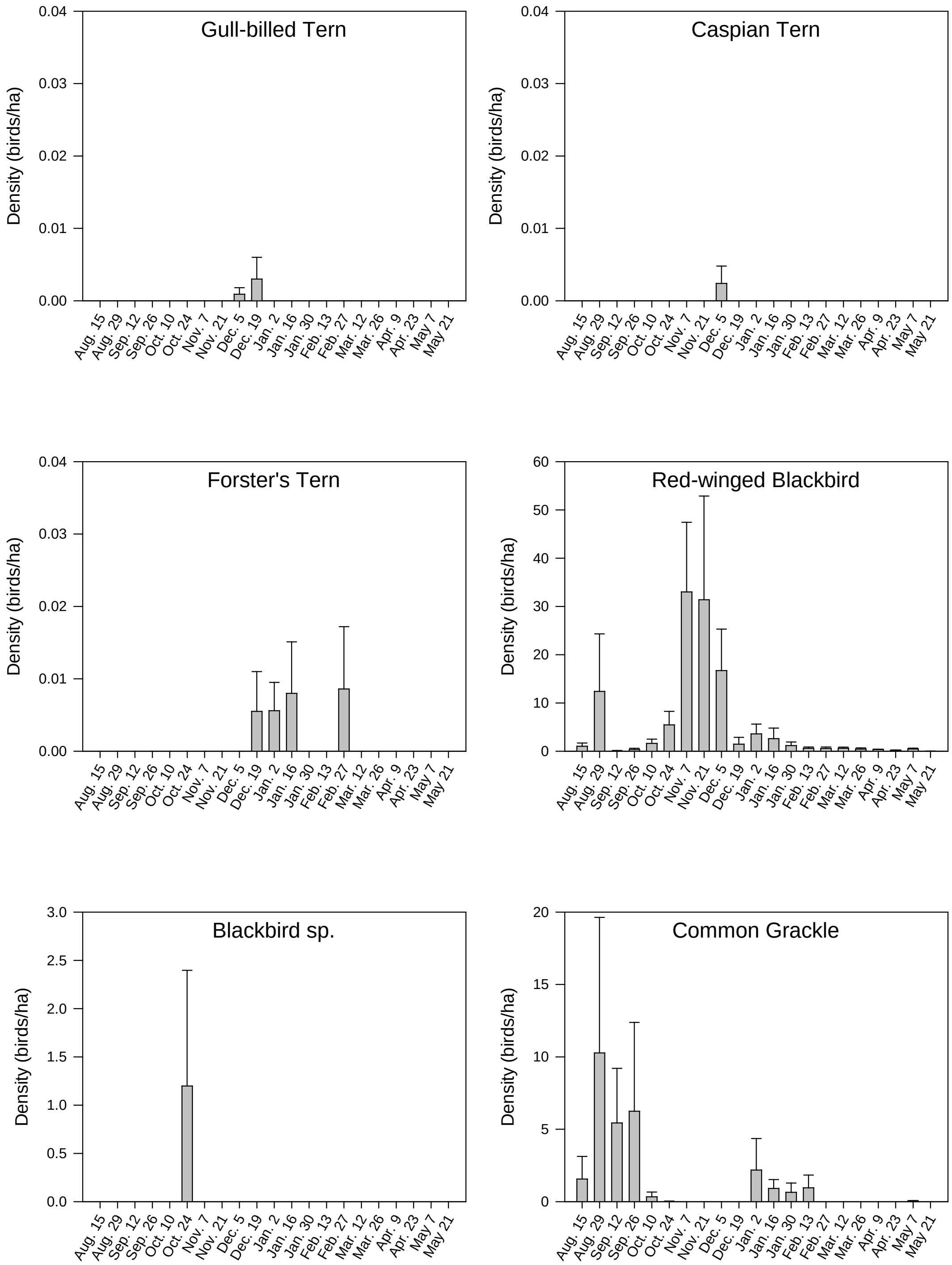




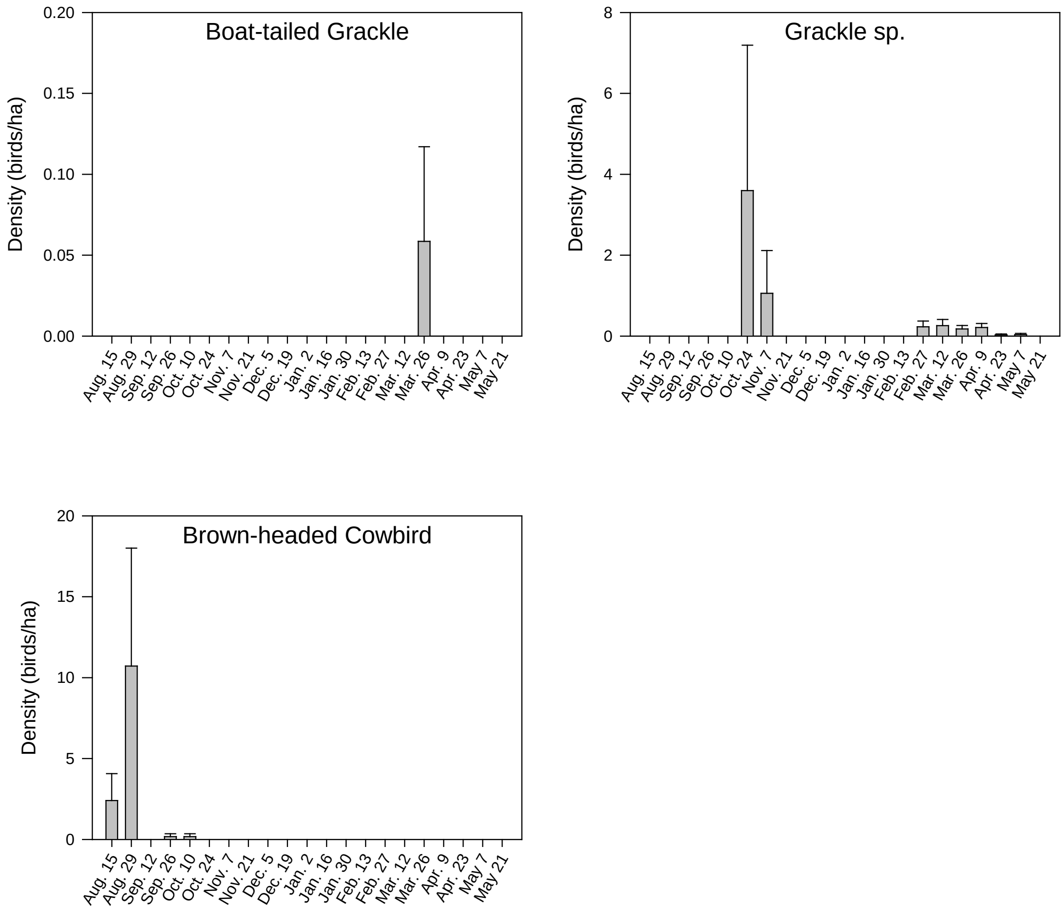




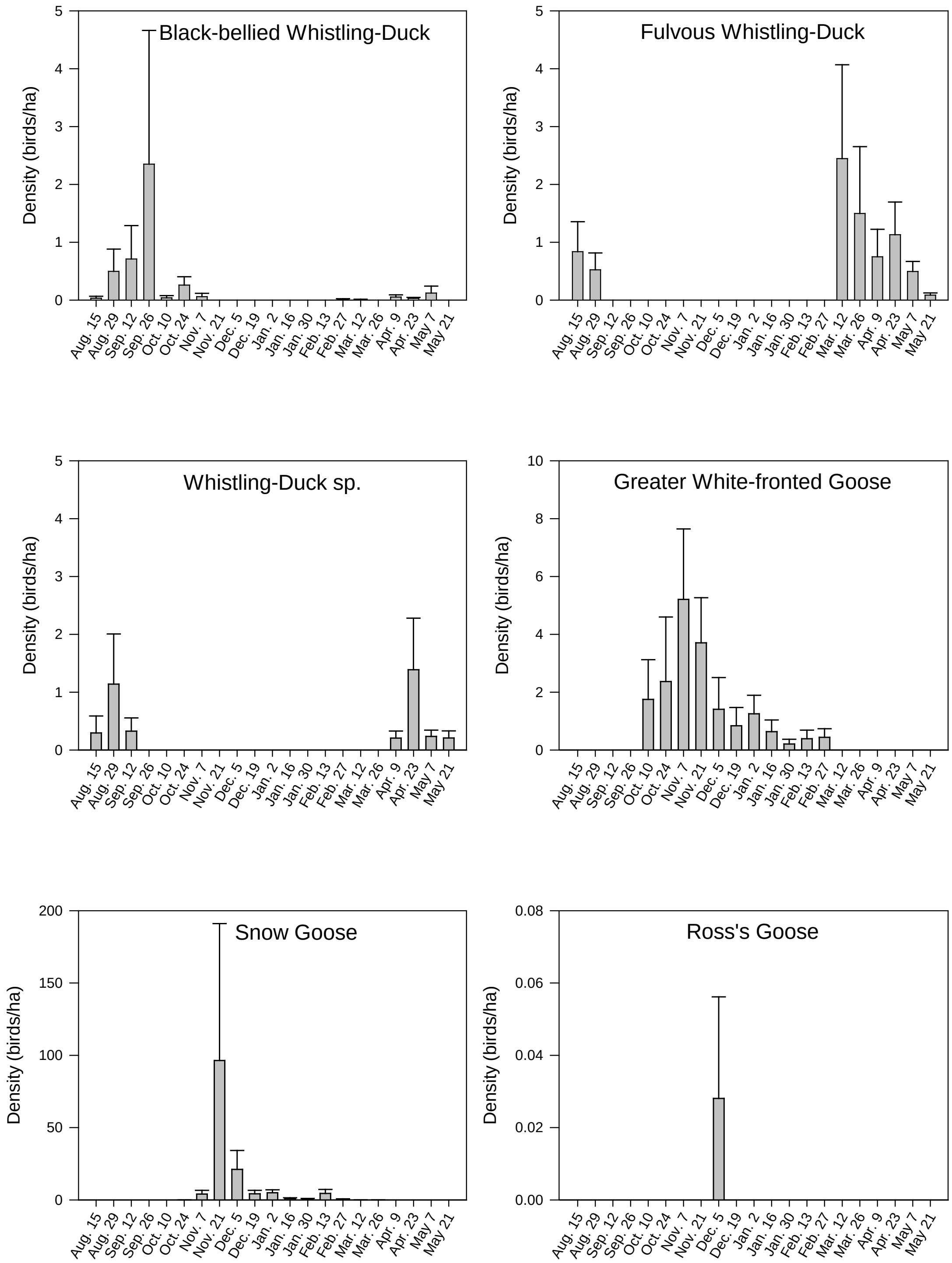
Appendix E - continued.



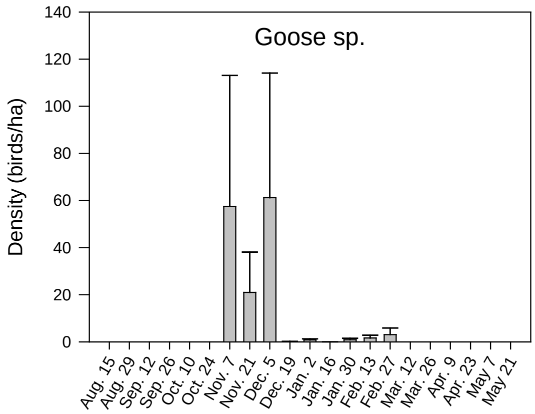
Appendix E - continued.

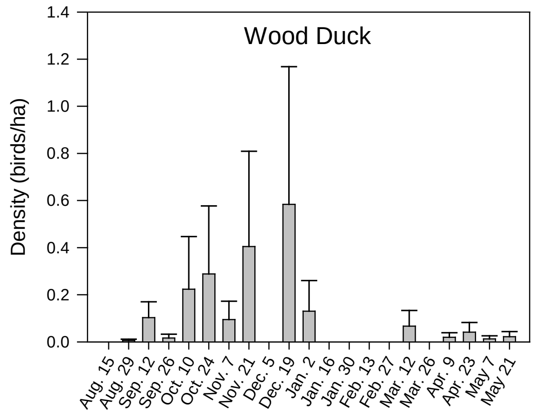


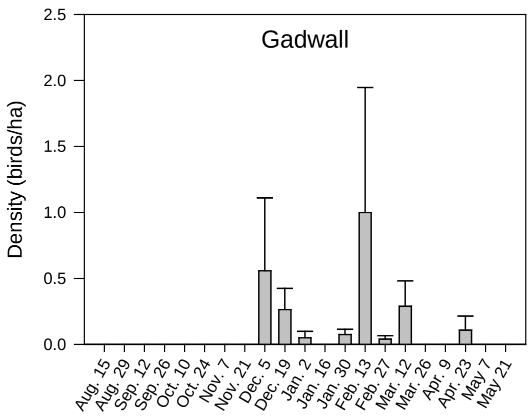
Appendix F. Biweekly summary of evening movements of waterfowl (# of birds/ha) detected during the direct visual observation surveys. Only birds detected in the airspace above the MBHI easements during the 45-min period leading up to dusk are included.

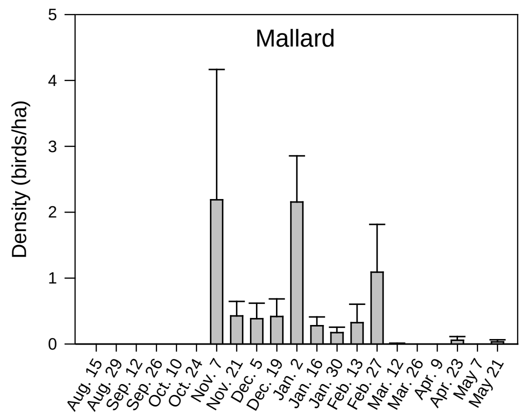


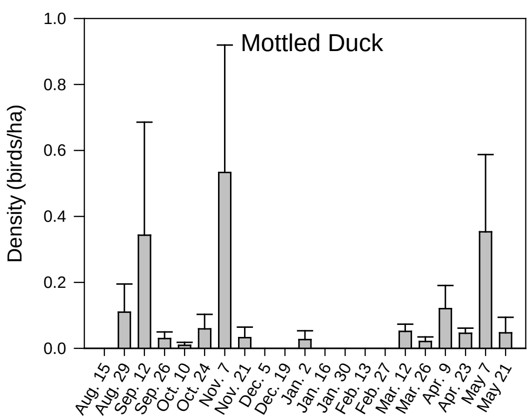
Appendix F - continued.

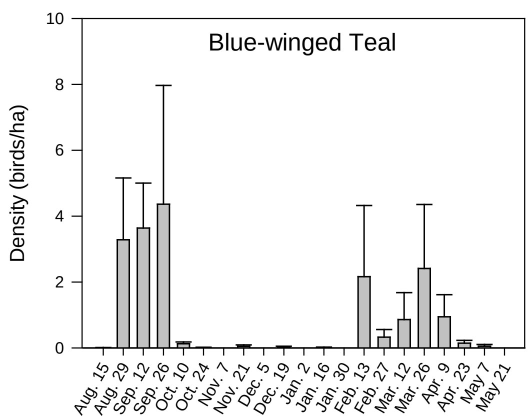




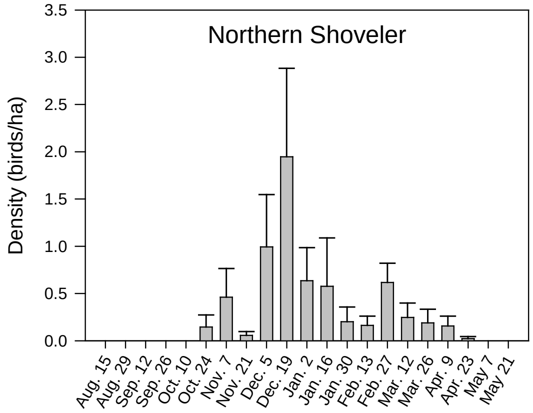


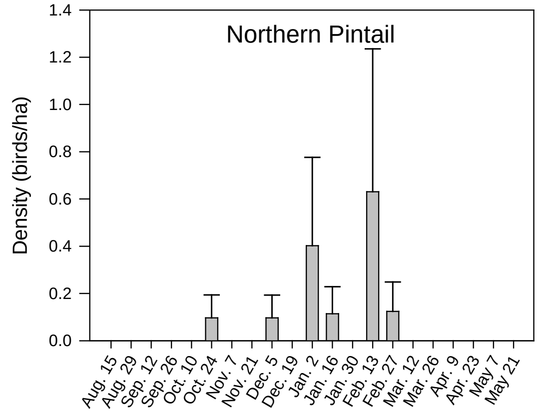


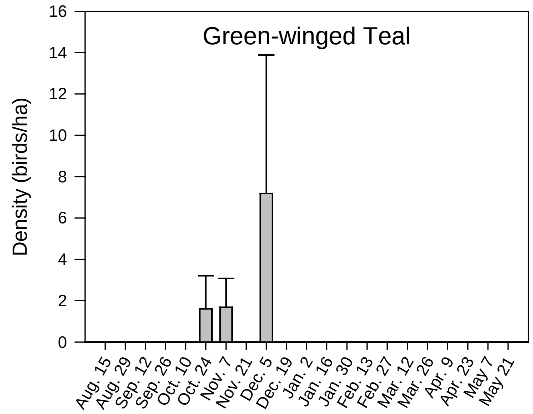


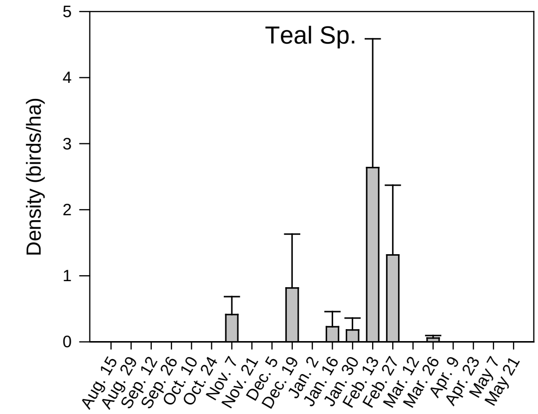


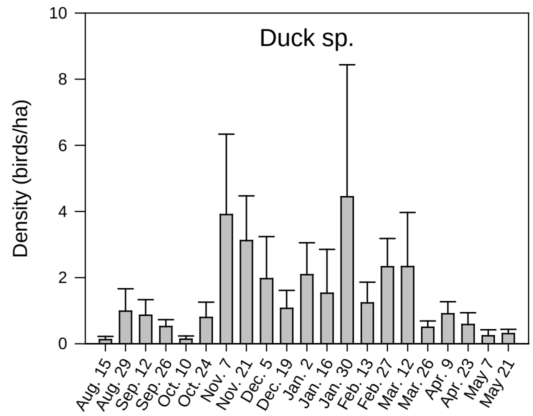
Appendix F - continued.



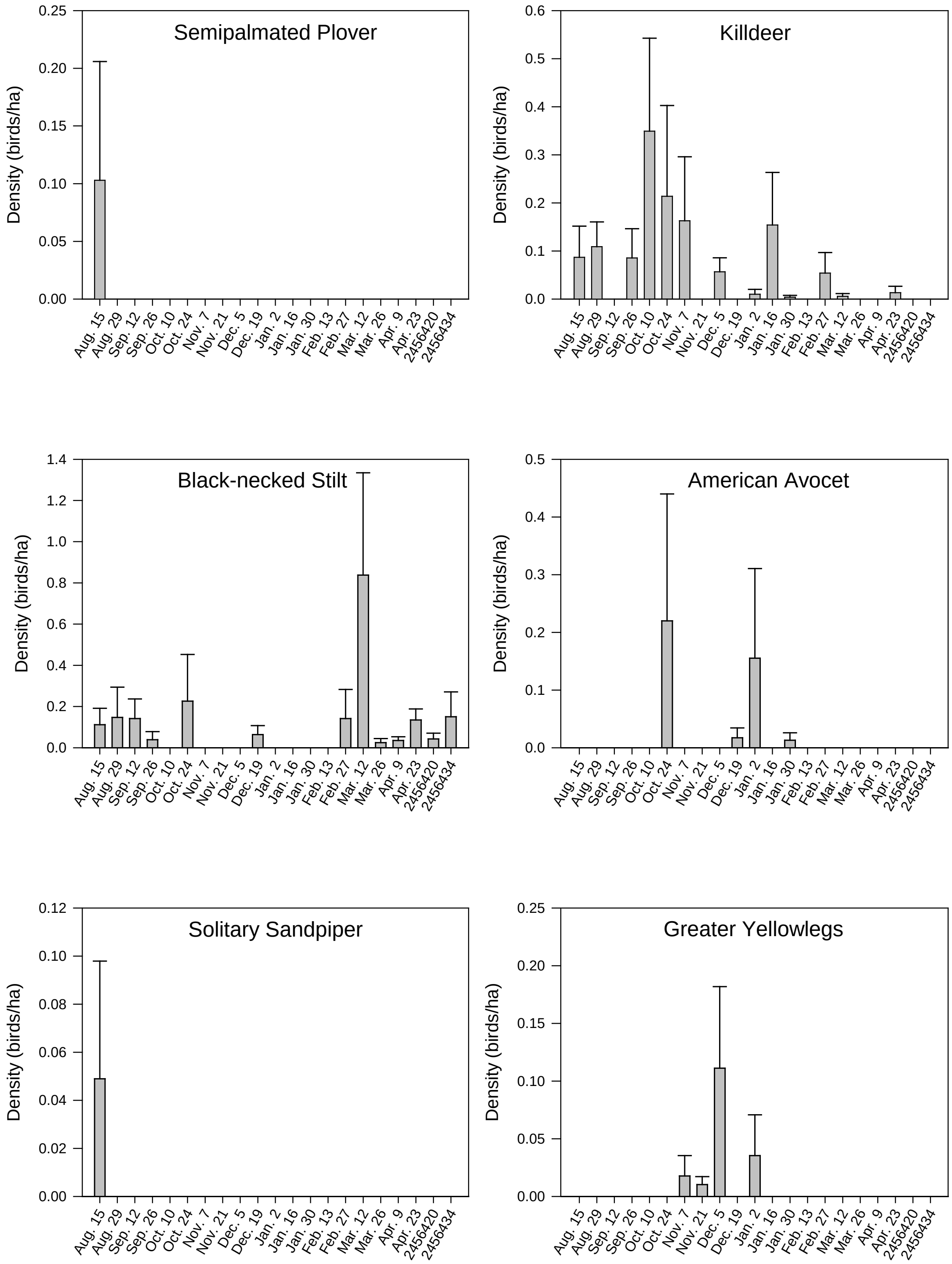




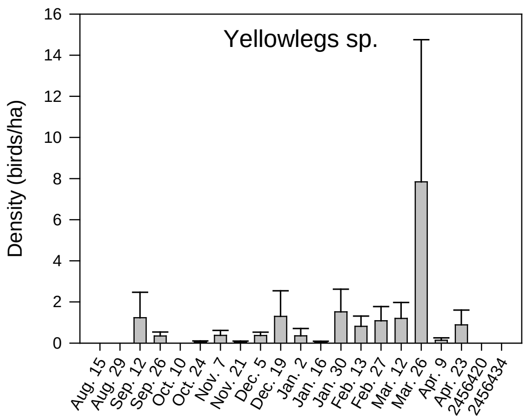


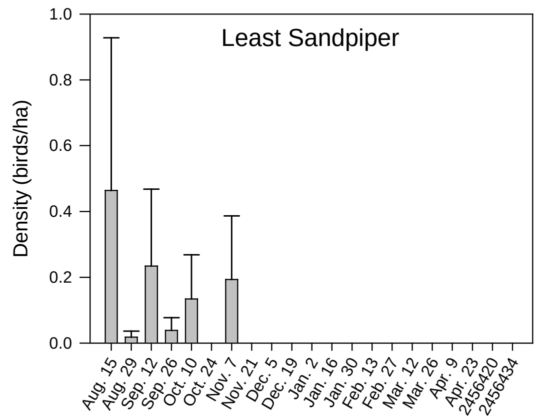


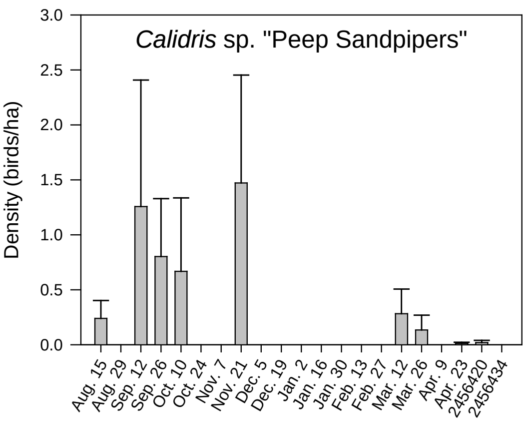
Appendix G. Biweekly summary of evening movements of shorebirds (# of birds/ha) detected during the direct visual observation surveys. Only birds detected in the airspace above the MBHI easements during the 45-min period leading up to dusk are included.

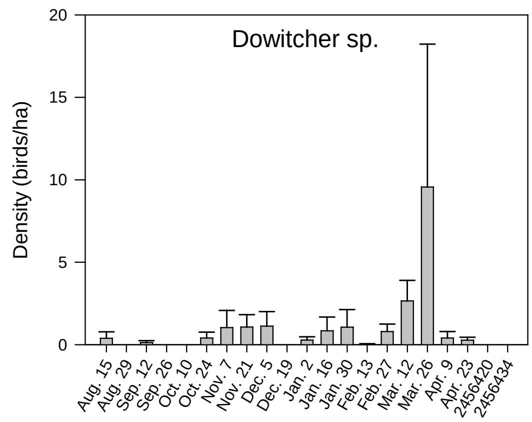


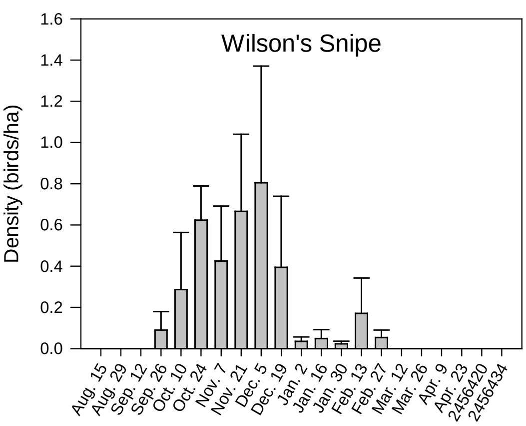
Appendix G - continued.

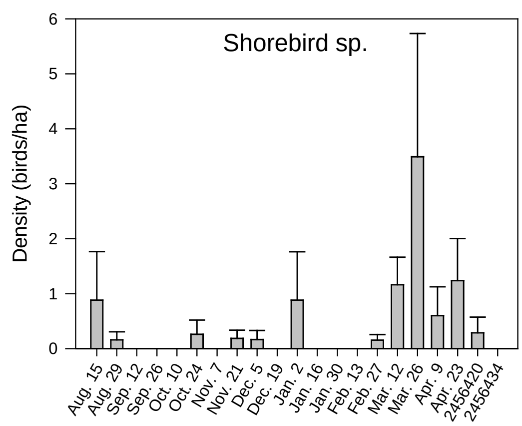




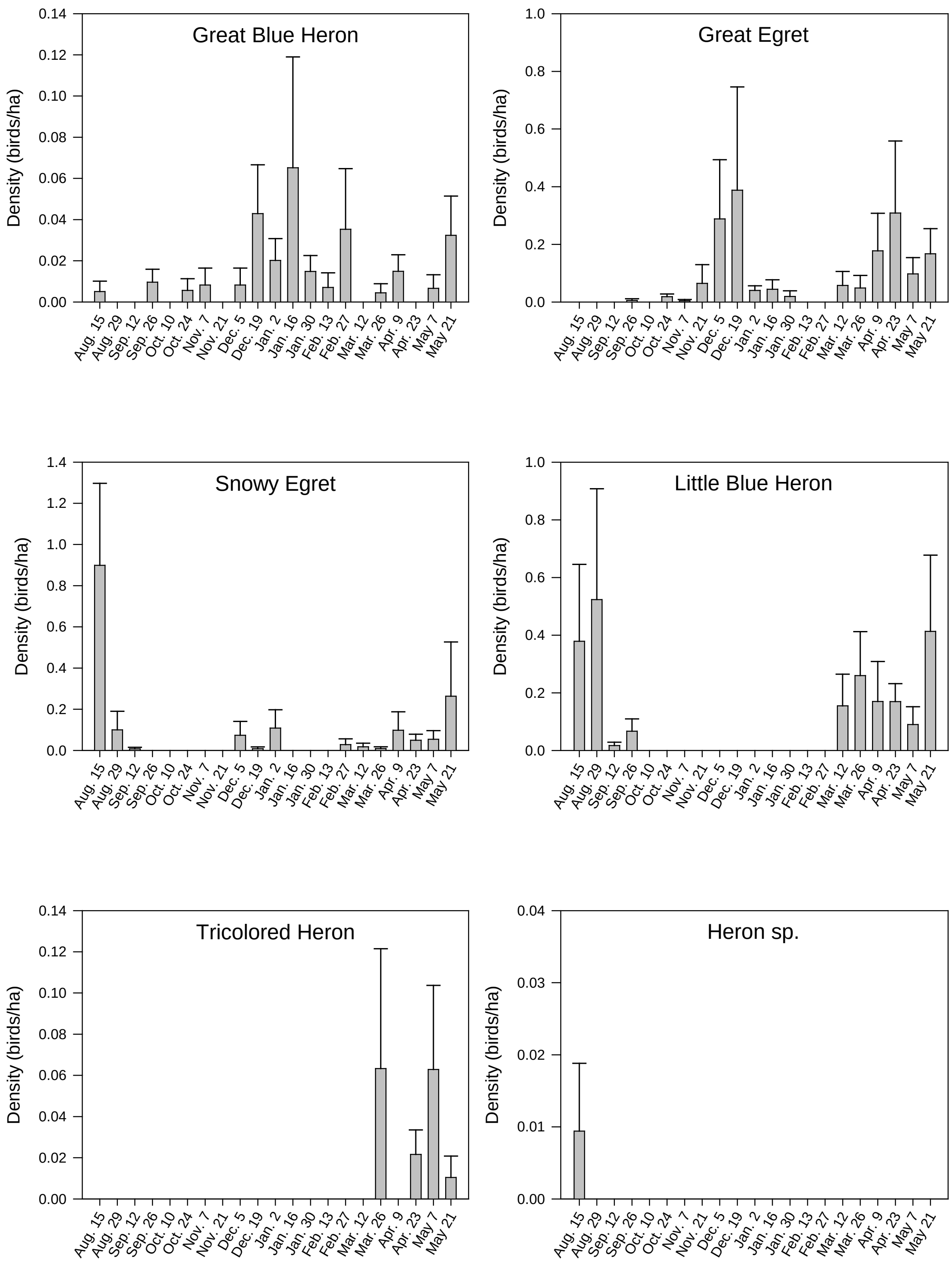




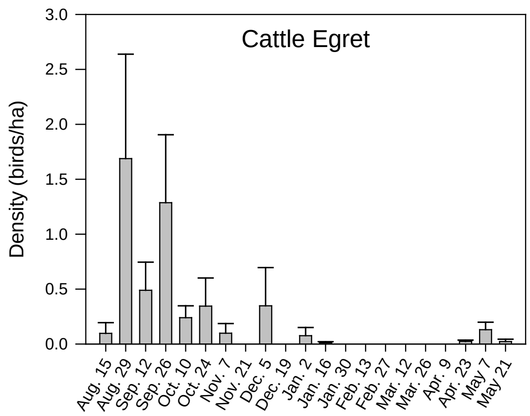


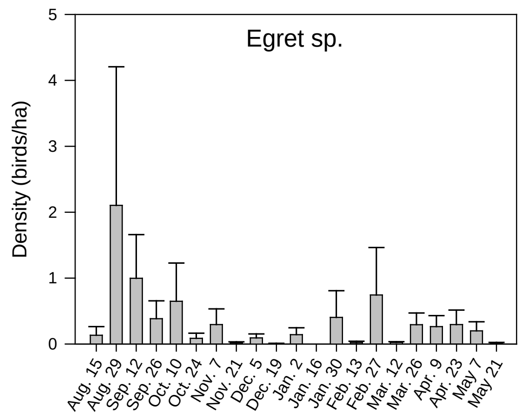


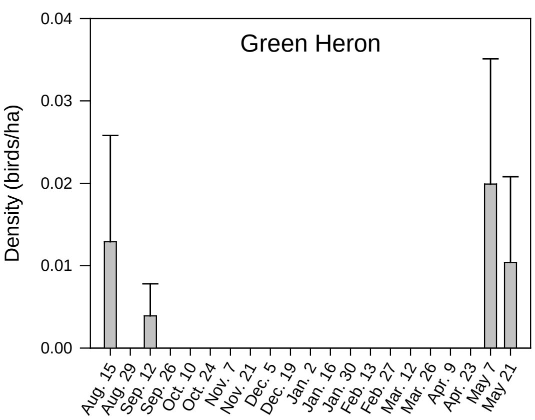
Appendix H. Biweekly summary of evening movements of wading birds (# of birds/ha) detected during the direct visual observation surveys. Only birds detected in the airspace above the MBHI easements during the 45-min period leading up to dusk are included.

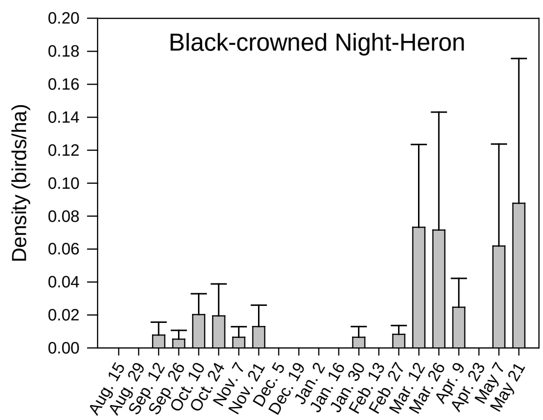


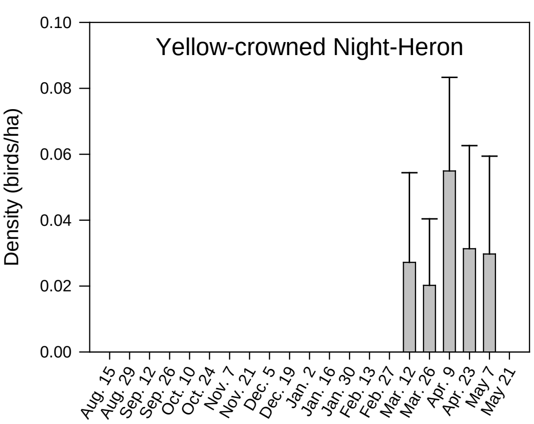
Appendix H - continued.

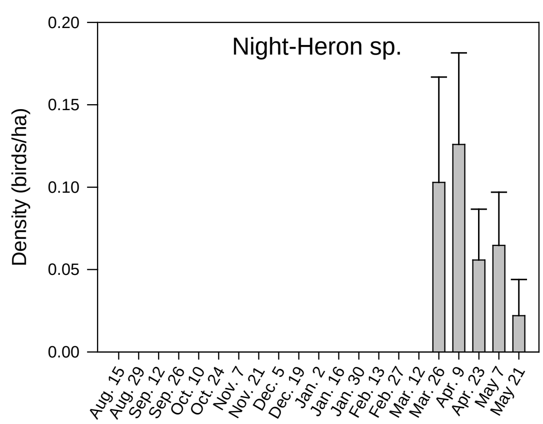




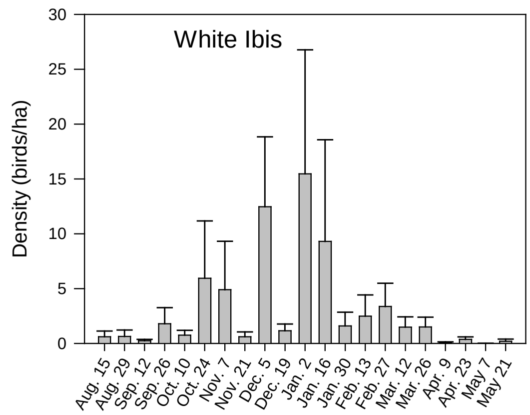


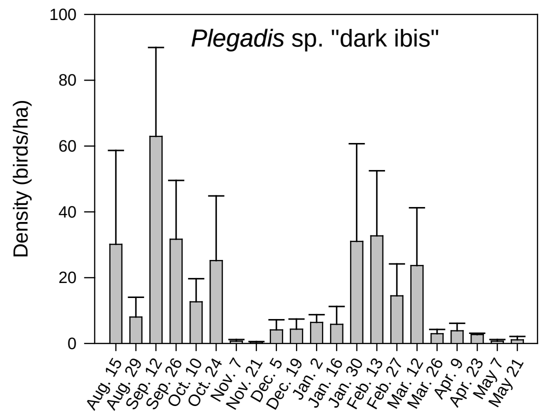


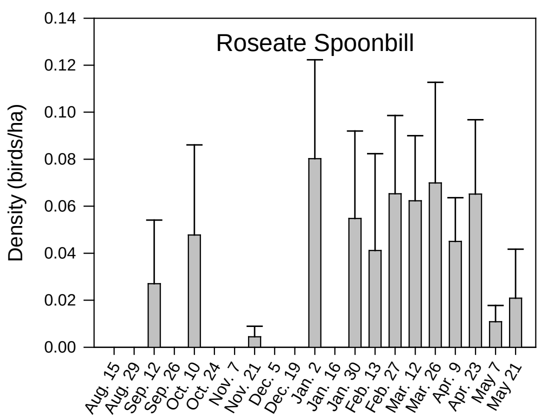


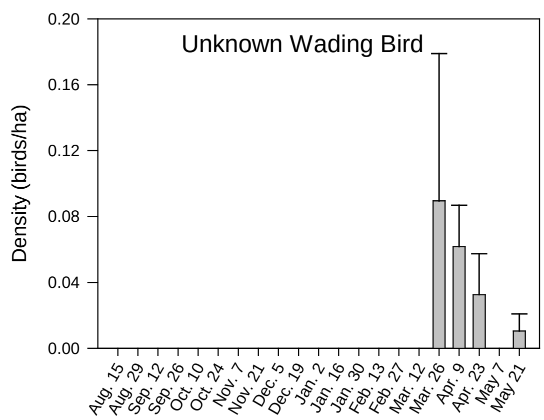


Appendix H - continued.

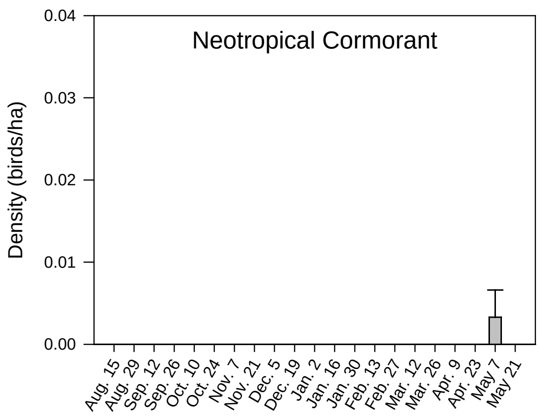


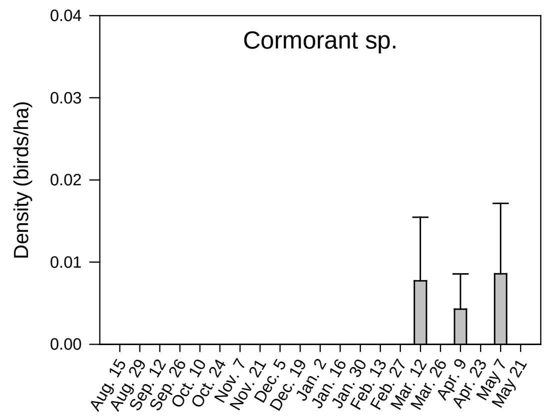


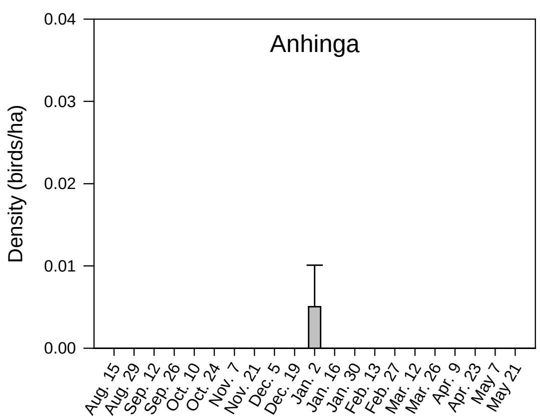


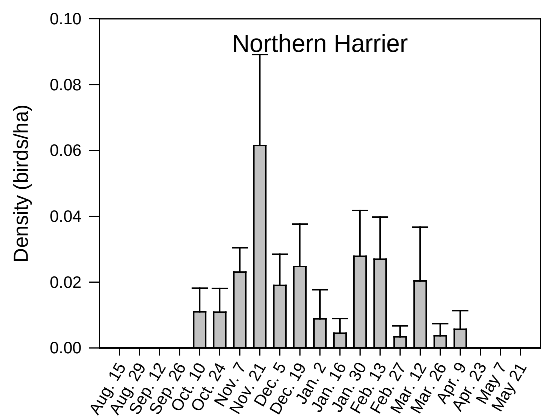


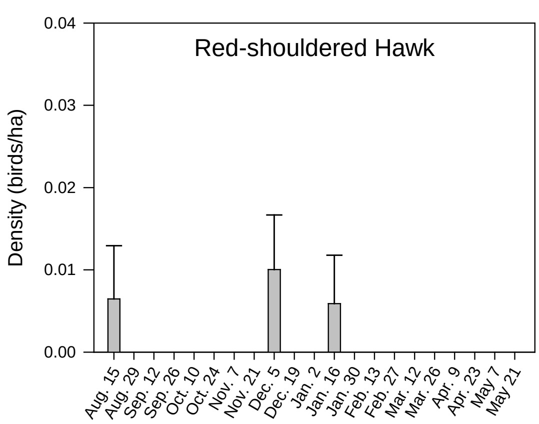
Appendix I. Biweekly summary of evening movements of other bird taxa (# of birds/ha) detected during the direct visual observation surveys. Only birds detected in the airspace above the MBHI easements during the 45-min period leading up to dusk are included.

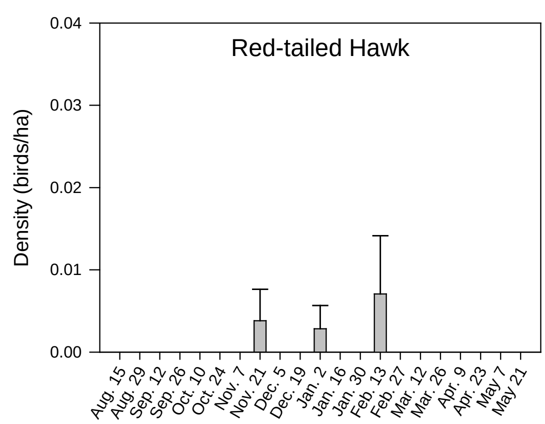




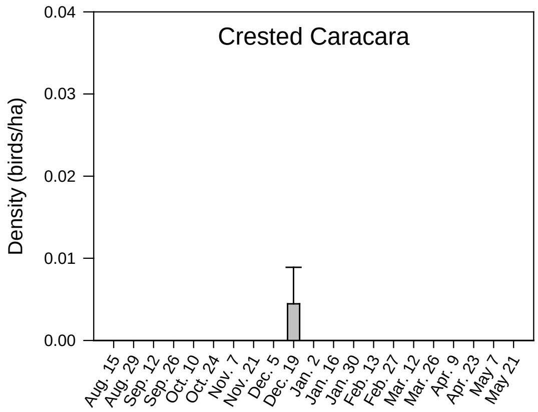


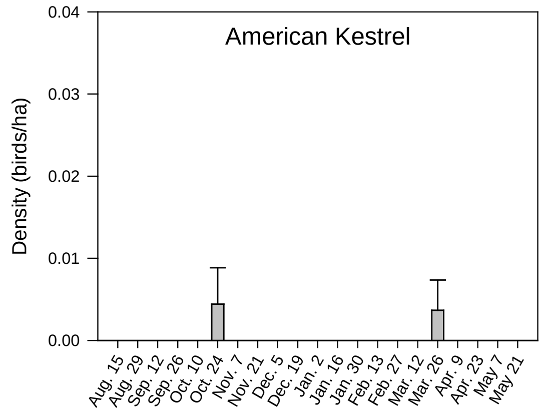


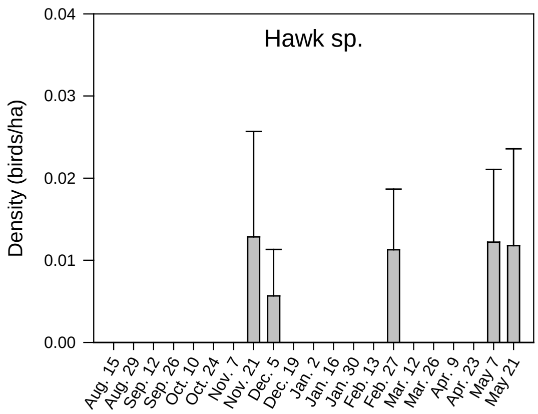


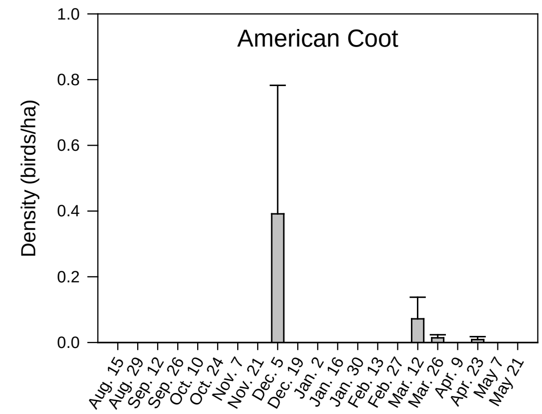


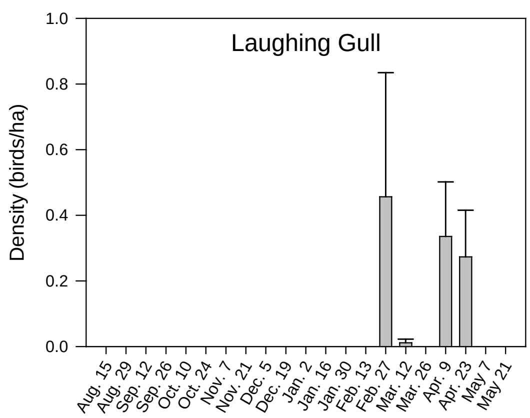
Appendix I - continued.

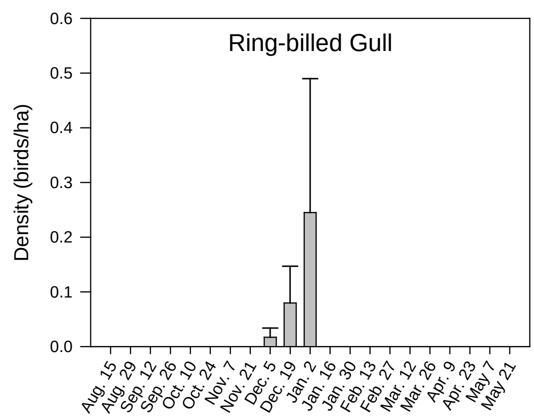




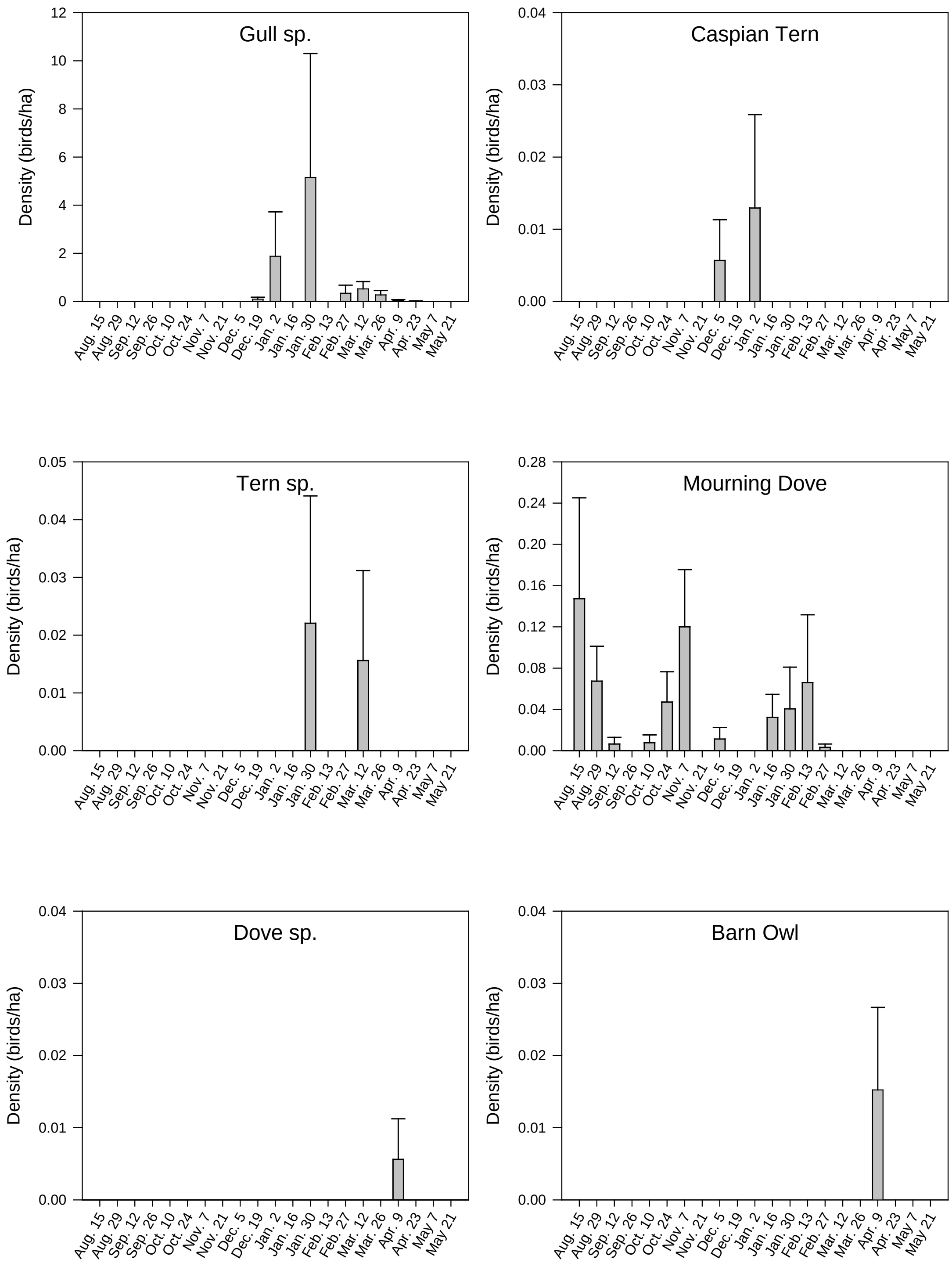




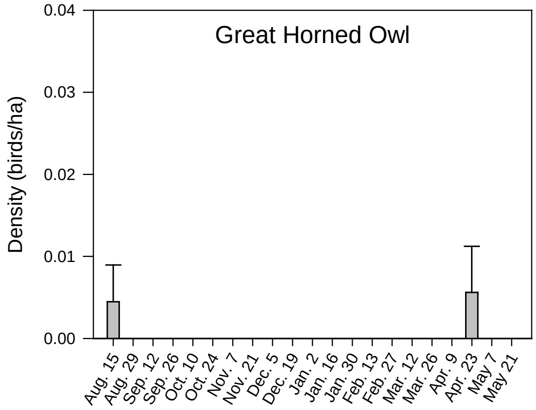


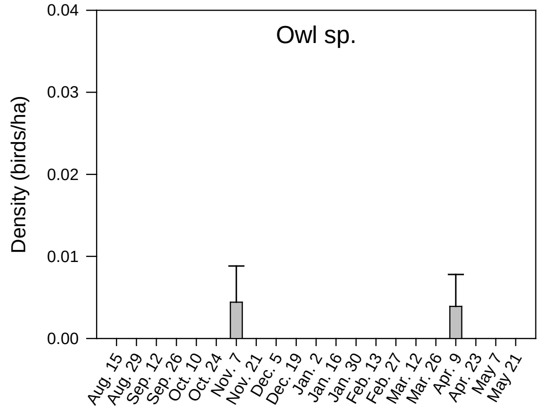


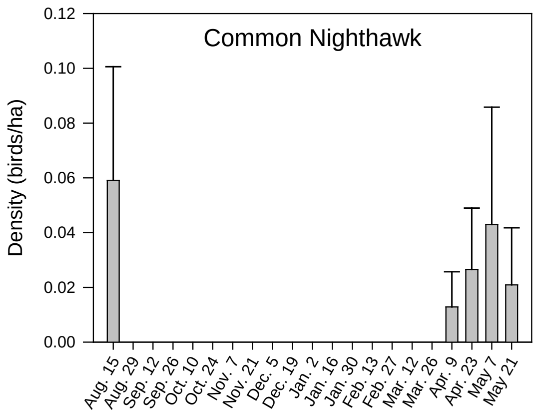
Appendix I - continued.

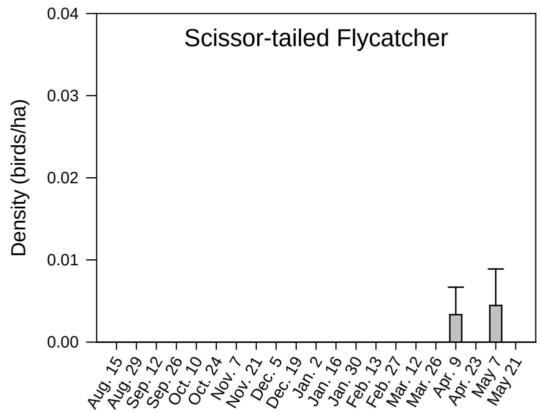


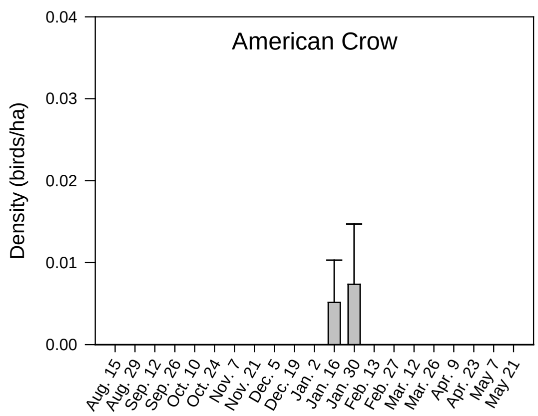
Appendix I - continued.

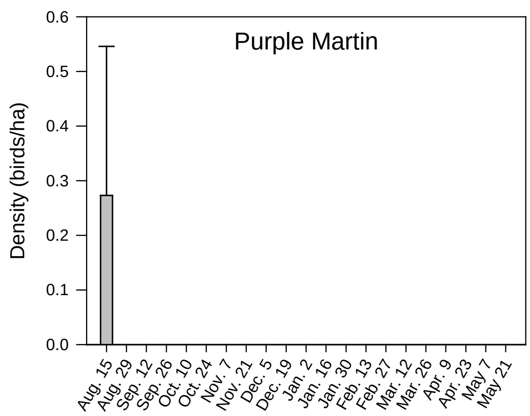




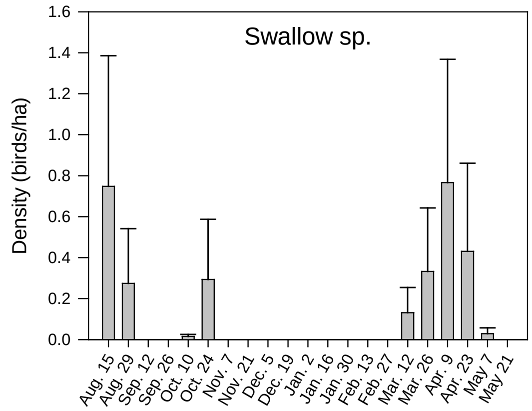


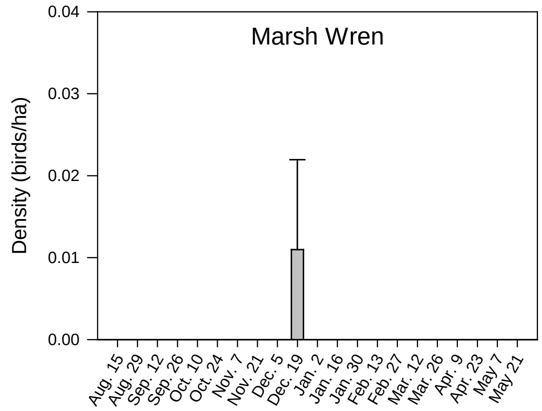


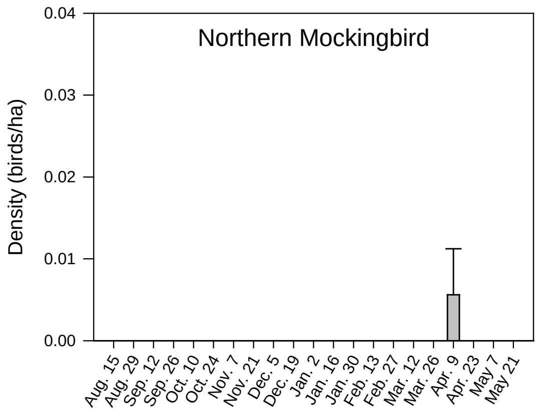


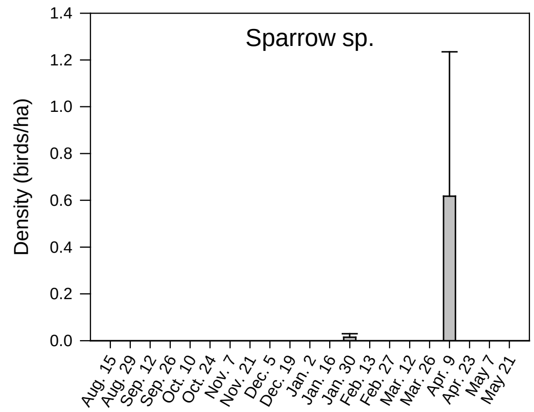


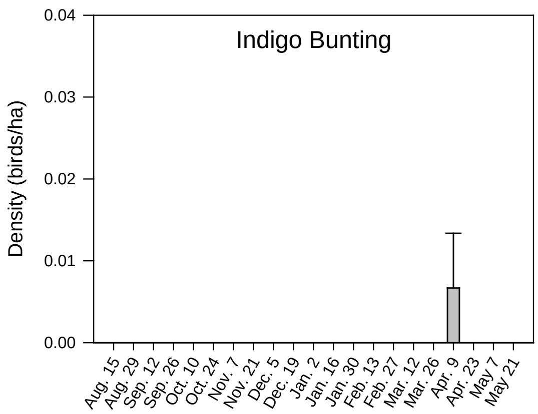
Appendix I - continued.

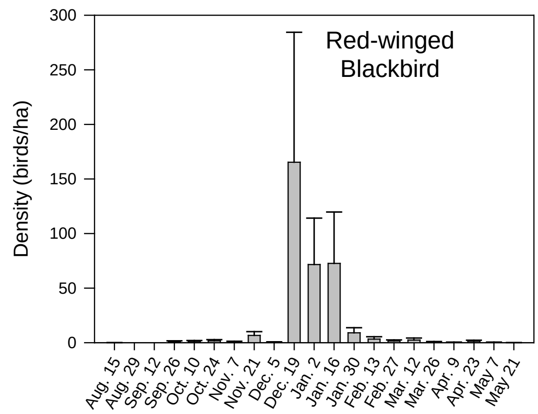












Appendix I - continued.