New York State
Marsh Bird Monitoring Program Pilot Study
2009 - 2011

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SUMMARY

Population status and trends remain uncertain for many marsh bird species due to their elusive behavior, infrequent vocalizations, and affinity for inaccessible emergent wetlands. These traits make it difficult to detect marsh birds during traditional surveys, limiting the ability of existing long-term, wide-scale bird monitoring programs to estimate marsh bird trends. A targeted marsh bird survey protocol has been developed to increase detection rates, however, inconsistencies among sampling designs precludes pooling of data from multiple locations which is necessary to understand marsh birds at regional or continental scales. To address this issue, New York State Department of Environmental Conservation (NYSDEC) was one of seven other states that participated in the U.S. Fish and Wildlife Service's (USFWS) National Marsh Bird Monitoring Program Pilot Study, which integrated a statistically rigorous sampling design with the Standardized North American Marsh Bird Monitoring Protocols to assess the population status of secretive marsh birds. Focal species included Virginia rail, sora, king rail, American bittern, least bittern and pied-billed grebe. Primary objectives of the three-year pilot study in NY included: (1) to estimate temporal trends in marsh bird occupancy and abundance to inform management decisions regarding population health; (2) to determine change in annual occupancy and abundance to inform regulatory decisions for harvested species; and (3) to document species-specific habitat associations at multiple scales.

From 2009 to 2011, NYSDEC conducted nearly 1,500 call-broadcast surveys at 417 survey points in freshwater wetlands throughout upstate NY and one freshwater wetland on Long Island. Survey points included random points from the pilot study sampling design (n=366) as well as non-random long-term monitoring points (n=51) previously established by NYSDEC. We calculated species-specific weighted model averages of maximum likelihood estimates (MLEs) of site occupancy probability as an index of population status, and compared habitat characteristics at detection and non-detection sites. Including both pilot study and long-term monitoring points, Virginia rail was the most frequently observed focal species with detections at 23% of the survey points (n=94). Occupancy MLEs were 0.133 in 2009, 0.305 in 2010, and 0.317 in 2011. Virginia rail were detected at sites with more emergent and floating vegetation, more open water, and less shrubs and upland habitat than nondetection sites. American bittern were detected at 10% of survey points (n=42). Occupancy MLEs were 0.042 in 2009, 0.198 in 2010, and 0.293 in 2011 and top-supported models indicated that detection probability was survey-dependent. American bittern were detected at sites with greater water depth, more open water and floating vegetation, less shrub cover, less upland habitat than nondetection sites. Pied-billed grebe were detected at 9% of points (n=39) and occupancy MLEs were 0.006 in 2009, 0.170 in 2010, and 0.159 in 2011. Detection sites had less emergent vegetation and more open water than nondetection sites. Least bittern were detected at 8% of points (n=33) and occupancy MLEs were 0.078 in 2009, 0.149 in 2010, and 0.175 in 2011. Detection sites had deeper and more open water than nondetection sites. Sora were detected at 7% of points (n=30). Occupancy MLEs were 0.136 in 2009, 0.268 in 2010, and 0.215 in 2011 and detection points had slightly more floating vegetation than nondetection sites. King rail were detected at <1% of points (n=3) with a naïve site occupancy of ≤ 0.01 in all years; estimates of occupancy and detection probabilities could not be modeled with such sparse detection histories. In order to gain a better understanding of statewide marsh bird trends, a sustained or increased intensity of future survey efforts will be required.

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WILDLIFE RESTORATION

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INTRODUCTION

Conservation and management of marsh birds, a group of waterbirds including rails, bitterns, grebes, gallinules and snipe, are limited by a lack of knowledge about population status and trends, species-specific distributions and habitat associations, and is further complicated by the fact that several species are state-regulated migratory game birds while others are listed as endangered, threatened, or species of special concern (Conway & Nadeau 2006; Conway 2009, 2011). It is difficult to estimate population status and trends because these species are elusive in nature, vocalize infrequently, and inhabit inaccessible, dense emergent wetlands - traits which all preclude surveying with traditional methods. For this reason, continent-wide monitoring programs like the North American Breeding Bird Surveys (BBS) do not detect sufficient numbers of marsh birds to reliably estimate long-term population trends (Sauer 1999). Management implications of these uncertainties include difficulties in determining need for protection (with state/federal listing), assessing efficacy of conservation initiatives and habitat management, and setting responsible harvest limits (Bart 2006).

To date, the most comprehensive information on statewide marsh bird distribution is provided by the Second Atlas of Breeding Birds in New York State (BBA). The number of occupied survey blocks (with possible, probable, or confirmed breeding) declined for several marsh birds between the first (1980-1985) and second (2000-2005) atlas periods. Common moorhen (*Gallinula chloropus*) declined by 33% (Medler 2008a), American bittern (*Botaurus lentiginosus*) declined by 10% (McGowan 2008a), least bittern (*Ixobrychus exilis*) by 9% (Kennedy 2008), and clapper rail (*Rallus longirostris*) by 3% (Medler 2008b). The number of occupied blocks did not change for either king rail (*Rallus elegans*) (Medler 2008c) or black rail (*Laterallus jamaicensis*) (Medler 2008d), with only five blocks for the former and one block for the latter, indicating the rarity of these species. Distribution increased for five species: pied-billed grebe (*Podilymbus podiceps*) by 47% (McGowan 2008b), Virginia rail (*Rallus limicola*) by 21% (Medler 2008e), sora (*Porzana carolina*) by 15% (Medler 2008f), American coot (*Fulica americana*) by 10% (Medler 2008g), and Wilson's snipe (*Gallinago delicata*) by 2% (McGowan 2008c). A recurring theme in the majority of marsh bird BBA narratives is the need for targeted survey efforts to monitor these secretive species.

Targeted marsh bird surveys were developed by the North American Marsh Bird Monitoring Program, which was established in 1998 with the goal of providing wildlife managers with information about the population status of secretive marsh birds (Ribic et al. 1999). The Standardized North American Marsh Bird Monitoring Protocols were specifically developed to increase detections with a call-broadcast technique, providing an effective method to document the presence and distribution of focal species (Conway 2009, 2011). Data sharing for regional or continental analysis is facilitated by an online database managed by the U.S. Geological Survey (USGS) Patuxent Wildlife Research Center and partners (USGS et al. 2007). Following these standardized procedures, New York State Department of Environmental Conservation (NYSDEC) conducted targeted marsh bird surveys from 2004-2006, providing a comprehensive analysis of marsh bird distribution, probability of occupancy and detection, and habitat associations from targeted marsh bird surveys in New York State (Osborne et al. 2011). However, the study area focused on large, state-owned wetlands and sites were not randomly selected. Remaining challenges for marsh bird monitoring programs include the development of a standardized, statistically robust sampling design to ensure collection, analysis and interpretation of statistically sound data, and the inclusion of surveys on small wetlands and private lands.

To address these issues, NYSDEC collaborated with U.S. Fish & Wildlife Service (USFWS) Division of Migratory Bird Management as one of seven states to participate in the National Marsh Bird Monitoring Program Pilot Study. The pilot study explored the feasibility of integrating a probabilistic sampling design developed by Johnson et al. (2009) with the existing standardized survey protocols (Conway 2009, 2011). NYSDEC participated in the pilot study from 2009 to 2011 with overarching goals of field testing the random sampling design, contributing to the national collaborative effort to obtain population trend data, and further developing a long-term, statewide marsh bird monitoring program. Specific objectives in NY included: (1) to estimate temporal trends in marsh bird occupancy and abundance to inform management decisions regarding population health, e.g., determine if a species is of special concern, threatened or endangered; (2) to determine changes in annual occupancy and abundance to guide regulatory decisions for harvested species, such as rails, gallinules and snipe; and (3) to document species-specific habitat associations at multiple scales. Surveys targeted two classes of focal species, primarily focusing on rails, bitterns, and grebe while also surveying for gallinules, snipe, terns, and other wetland-obligate species (Table 1).

Table 1. Primary and secondary focal species of the Marsh Bird Monitoring Program in New York State, 2009-2011.

Species	Common Name	Alpha Code	Status in New York State
Primary			
Botaurus lentiginosus	American bittern	AMBI	Species of Special Concern
Ixobrychus exilis	least bittern	LEBI	Threatened
Laterallus jamaicensis	black rail	BLRA	Endangered
Podilymbus podiceps	pied-billed grebe	PBGR	Threatened
Porzana carolina	sora	SORA	State-regulated migratory game bird
Rallus elegans	king rail	KIRA	Threatened
Rallus limicola	Virginia rail	VIRA	State-regulated migratory game bird
Rallus longirostrus	clapper rail	CLRA	State-regulated migratory game bird, closed season
Secondary			
Chlidonias niger	black tern	BLTE	Endangered
Cistothorus palustris	marsh wren	MAWR	
Empidonax traillii	willow flycatcher	WIFL	Species of greatest conservation need
Fulica americana	American coot	AMCO	State-regulated migratory game bird
Gallinago delicata	Wilson’s snipe	WISN	State-regulated migratory game bird
Gallinula chloropus	common moorhen	COMO	State-regulated migratory game bird
Melospiza georgiana	swamp sparrow	SWSP	
Sterna hirundo	common tern	COTE	Threatened

METHODS

Sampling design

Survey routes were selected according to a random sampling design that was developed to ensure that the survey points were statistically sound, logistically feasible, and allowed for data collected across state lines by multiple observers to be combined for analysis (Johnson et al. 2009). Survey points were generated with a two-stage cluster sample for each state participating in the pilot study. The "sampling universe" (i.e., all potential marsh bird breeding habitat) was first divided into primary sampling units (PSUs); these were 40-km^2 hexagons containing small (≤ 3 ha) and large (>3 ha) wetlands from existing wetlands maps like the National Wetlands Inventory. A random order in which to survey PSUs was assigned. Within each PSU, secondary sampling units (SSUs), the actual survey point locations, were randomly selected using a generalized random tessellation sampling (GRTS) method. The GRTS method allowed for flexibility in the site selection process; for example, points could be added if habitat suitability increased or removed if landowner permission status changed, without compromising the statistical rigor of the sampling design. Each SSU was given a unique identifier indicating both wetland size and the random order in which to survey. In 2009, SSUs were classified as either National Wildlife Refuge (NWR) or General NYS. In 2010, the sampling design was modified to stratify SSUs into four classes: NWR, public land, private land, and estuarine. In practice, SSUs were chosen by a combination of the predefined random sampling order, preliminary assessment of aerial imagery, and the process of ground-truthing. Surveyors visited SSUs to assess habitat and access suitability, with the option of moving the survey point within 100m of the original random point location. If a SSU was inaccessible, fell in unsuitable habitat, or was located on private land for which access could not be obtained, it was omitted and the surveyor then visited the next random point until a minimum of four points were chosen. Within each PSU, a "survey route" was defined as a cluster of four to ten SSUs each spaced ≥ 400m to several kilometers apart and easily visited in a single morning or evening by walking, canoe, or motor boat.

Study area

From 2009 to 2011, NYSDEC surveyed a total of 417 points throughout the state in freshwater emergent and freshwater tidal wetlands ranging from <0.1 ha to 247.6 ha ($\bar{x}$=16.8) (Figure 1). Of these, 366 (88%) were SSUs from the pilot study's random sampling design and 51 (12%) were long-term monitoring points established by NYSDEC (Appendix A). In 2009, staff surveyed 188 points, including 180 SSUs within 29 PSUs in Regions 3-5 and eight long-term monitoring points in Regions 7-8. None of the 2009 SSUs were revisited. In 2010, staff surveyed 174 points comprising 33 routes in Regions 3-9. These points included 141 new SSUs within 27 PSUs and 33 long-term monitoring points. Excluding the long-term points, 101 SSUs (72%) were on public land and 40 SSUs (28%) were on private land. In 2011, staff surveyed 190 points comprising 34 survey routes; 152 were SSUs within 29 PSUs and 38 were long-term monitoring points. Staff surveyed 59 new points (including SSUs and new long-term points), revisited 111 points that were established in 2010 (including SSUs and long-term points), and revisited 20 long-term points that were established from 2004-2008. Excluding long-term points, the pilot study included 109 SSUs (72%) that were on public land and 43 SSUs (28%) that were on private land. (In a separate but complementary study, the Saltmarsh Habitat and Avian Research Program [SHARP] initiated marsh bird surveys in 2011 in salt marsh habitat on Long Island [Regions 1 and 2] providing coverage of this critical habitat [SHARP 2011]).

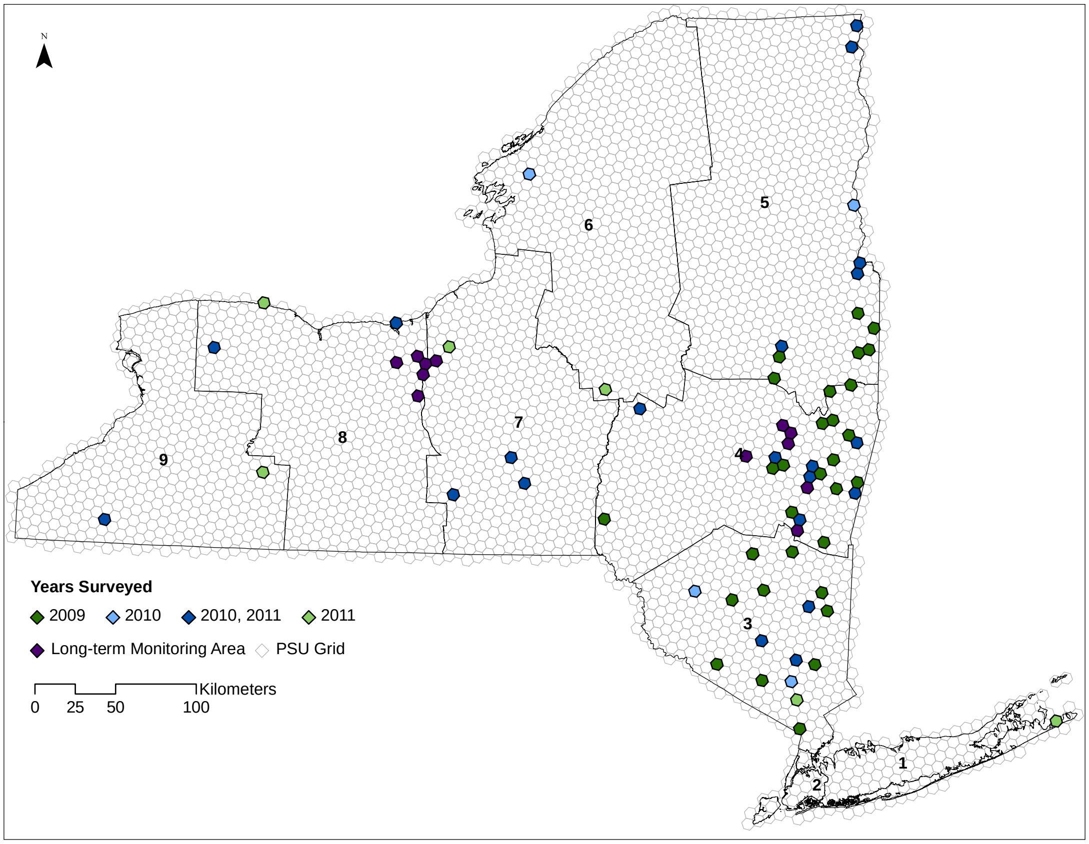

Figure 1. Survey route locations by NYSDEC Region, including pilot study PSUs and areas with long-term monitoring points. New York State Marsh Bird Monitoring Program, 2009-2011.

Survey protocols

Marsh bird surveys.—Reconnaissance occurred in April and surveys were conducted in May and June each year. Each route was surveyed once in each of three survey windows (1-14 May, 15-31 May, and 1-15 June), separating visits by about ten days. In the Adirondack and Catskill Parks and other high elevation areas, survey windows were 15-31 May, 1-15 June and 15-30 June. Rarely, surveys were delayed so that the last replicate fell in early July (e.g., Lake Champlain flooding in 2011). Survey replication ensured that marsh bird calls were broadcast during each species' peak-response period (Lor 2000), and three survey replicates have been found to determine species presence or absence with 90% certainty (Gibbs & Melvin 1993). Surveys were conducted either in the morning (30 minutes before to three hours after sunrise) or evening (three hours before to 30 minutes after sunset). For each route, SSUs were ideally visited in the same order and all SSUs were surveyed on the same day, although time of day could differ among replicates. Surveys interrupted by inclement weather were cancelled and all SSUs were revisited on another day unless it was logistically unreasonable to do so.

Marsh bird survey methods followed the Standardized North American Marsh Bird Monitoring Protocols (Conway 2009, 2011). Surveyors used a call-broadcast technique to elicit responses from focal species during unlimited radius point counts; the 2004-2006 NYSDEC marsh bird surveys successfully used this method (Osborne et al. 2011). Five minutes of passive listening were followed by six minutes of call-broadcasts, in which the observer used a CD/MP3 player and speaker or MP3 game caller to play 30 seconds of species-specific vocalizations followed by 30 seconds of silence for each focal species (broadcast sequence: least bittern, sora, Virginia rail, king rail, American bittern, pied-billed grebe). A single observer recorded all primary and secondary species detected (heard, seen, or heard and seen) during each minute. For primary focal species, call type and a distance estimate (with range finder or distance band maps) were recorded for each individual bird. For secondary species, the surveyor noted species, number of individuals and distance band (0-50m, 51-100m, >100m). Common species were not recorded, although species of conservation interest (e.g., waders, raptors) were tallied.

Habitat surveys.—In early May 2010 and 2011, habitat characteristics within a 50m radius of each survey point were documented. Surveyors measured water depth (cm) and vegetation height (0-1m, 1-3m, 3-6m, >6m), estimated percent cover of habitat covariates (emergent vegetation, shrubs, open water, floating vegetation, trees, snags, mudflats, upland), determined vegetation density (none, sparse, moderate, rank), and designated a wetland cover class according to Stuart and Kantrud (1971). The top three dominant plants (>25% cover) and percent cover of any invasive plants were recorded. Surveyors indicated edge type (roadside, ditch or berm, upland, open water, interior) and method of access (canoe, motor boat, walk, wade). Habitat data from 2009 were not analyzed because the protocol was not yet finalized.

Statistical analysis

Occupancy and detection modeling.—Occupancy estimates can be used as an index of population abundance. Primary focal species detection histories at all 2009-2011 points (including long-term monitoring points) were used to estimate probability of site occupancy (ψ) while accounting for imperfect detection probability (p) (MacKenzie et al. 2003, MacKenzie 2005). Maximum likelihood estimates (MLEs) of ψ and p were calculated with multi-season models in Program PRESENCE v.3.1 (Hines 2006) which assumes an open population between seasons. MLEs for each species were generated using the first model parameterization, with directly estimated initial ψ and derived ψ in subsequent years, constant or year-dependent colonization (γ) and persistence (ε), and constant, year- or survey-specific p. ψ and p were not modeled as a function of habitat covariates. When numerical convergence of a model was not reached, parameter estimates from the simplest model were supplied as initial values. Models were ranked by Akaike's Information Criterion (AIC_c) adjusted for small sample size and the model with the smallest AIC_c value was considered the top-ranked model (MacKenzie 2006). Species-specific weighted model-averaged estimates were generated by summing the product of each model's ψ estimate and model weight.

Habitat surveys.—Habitat covariates (water depth, percent cover of emergent vegetation, shrubs, open water, floating vegetation, trees/snags, mudflats, upland) were compared for focal species detection/non-detection points (Osborne et al. 2011). Shapiro-Wilk W tests indicated that data were not normally distributed, data transformations failed to improve normality and most samples had unequal variance; thus, nonparametric two-sample Mann-Whitney U tests were used to compare median ranks. Box plots illustrated descriptive statistics (median, upper/lower quartiles, range) comparing covariates at detection and non-detection sites. Chi-square analysis compared frequency of focal species detection/non-detection among difference vegetation height and density classes. Analyses were performed with program PAST, a statistical freeware (Hammer et al. 2001), and results were considered significant at α=0.05.

RESULTS AND DISCUSSION

Focal species detections

During nearly 1,500 surveys at 417 points from 2009-2011, surveyors detected Virginia rail at about 25% of survey points, American bittern, pied-billed grebe, least bittern, and sora at about 10% of points, and king rail at <1% of points (Table 2). During 498 surveys at 188 points from 10 May to 7 July 2009, there were 32 Virginia rail at 21 points, four least bittern at two points, four sora at two points, two pied-billed grebe at one point, one American bittern at one point, and no king rail. From 3 May to 29 June 2010, 448 surveys were conducted at 174 points, yielding 84 Virginia rail at 47 points, 55 pied-billed grebe at 27 points, 32 American bittern at 23 points, 22 least bittern at 17 points, 26 sora at 19 points, and two king rail at two points. During 504 surveys at 190 points from 2 May and 11 July 2011, there were 76 Virginia rail at 47 points, 51 pied-billed grebe at 27 points, 34 American bittern at 29 points, 25 least bittern at 22 points, 13 sora at 11 points, and one king rail (Figure 2). No clapper or black rail were detected on Long Island.

Secondary species were detected at <50% of all survey points. Swamp sparrow were detected at 38% of points (n=71) in 2009, 14% (n=25) in 2010, and 31% (n=58) in 2011. Marsh wren were detected at <1% of points (n=1) in 2009, 23% (n=40) in 2010, and 23% (n=43) in 2011. Willow flycatcher were at 15% of points (n=28) in 2009, 6% (n=11) in 2010, and 13% (n=25) in 2011. Common moorhen were detected at 2% of points (n=4) in 2009, 11% (n=20) in 2010, and 9% (n=17) in 2011. American coot were observed at 3% of points (n=5) in 2010 and 4% (n=8) in 2011. Terns (black, common, and Caspian) and snipe were detected at <1% of points in 2010 and 2011 (Figure 3). Additional species of interest included: trumpeter swan (*Cygnus buccinators*), sandhill crane (*Grus canadensis*), bald eagle (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), great blue heron (*Ardea herodias*), great egret (*Ardea alba*), green heron (*Butorides virescens*), alder flycatcher (*Empidonax alnorum*), cerulean warbler (*Dendroica cerulea*) and blue-winged warbler (*Vermivora pinus*).

Table 2. Focal species counts during the New York State Marsh Bird Monitoring Program, 2009-2011.

2009	VIRA	AMBI	PBGR	LEBI	SORA	KIRA
# Individuals[a]	32	1	2	4	4	0
# Detections[b]	99	6	4	20	25	0
# Points (% Points)	21 (11.2%)	1 (0.5%)	1 (0.5%)	2 (1.1%)	2 (1.1%)	0 (0%)
2010						
# Individuals	84	32	55	22	26	2
# Detections	283	193	187	135	59	3
# Points (% Points)	47 (27.0%)	23 (13.2%)	27 (15.5%)	17 (9.8%)	19 (10.9%)	2 (1.1%)
2011						
# Individuals	76	34	51	25	13	1
# Detections	229	122	189	121	23	1
# Points (% Points)	47 (24.7%)	29 (15.3%)	27 (14.2%)	22 (11.6%)	11 (5.8%)	1 (0.5%)
Total # Points	94	42	39	33	30	3
Total % Points	22.5%	10.1%	9.4%	7.9%	7.2%	0.7%

[a] # individuals = the sum of high counts per species at each survey point.

[b] # detections = number of times a species was detected during passive and broadcast periods of all surveys.

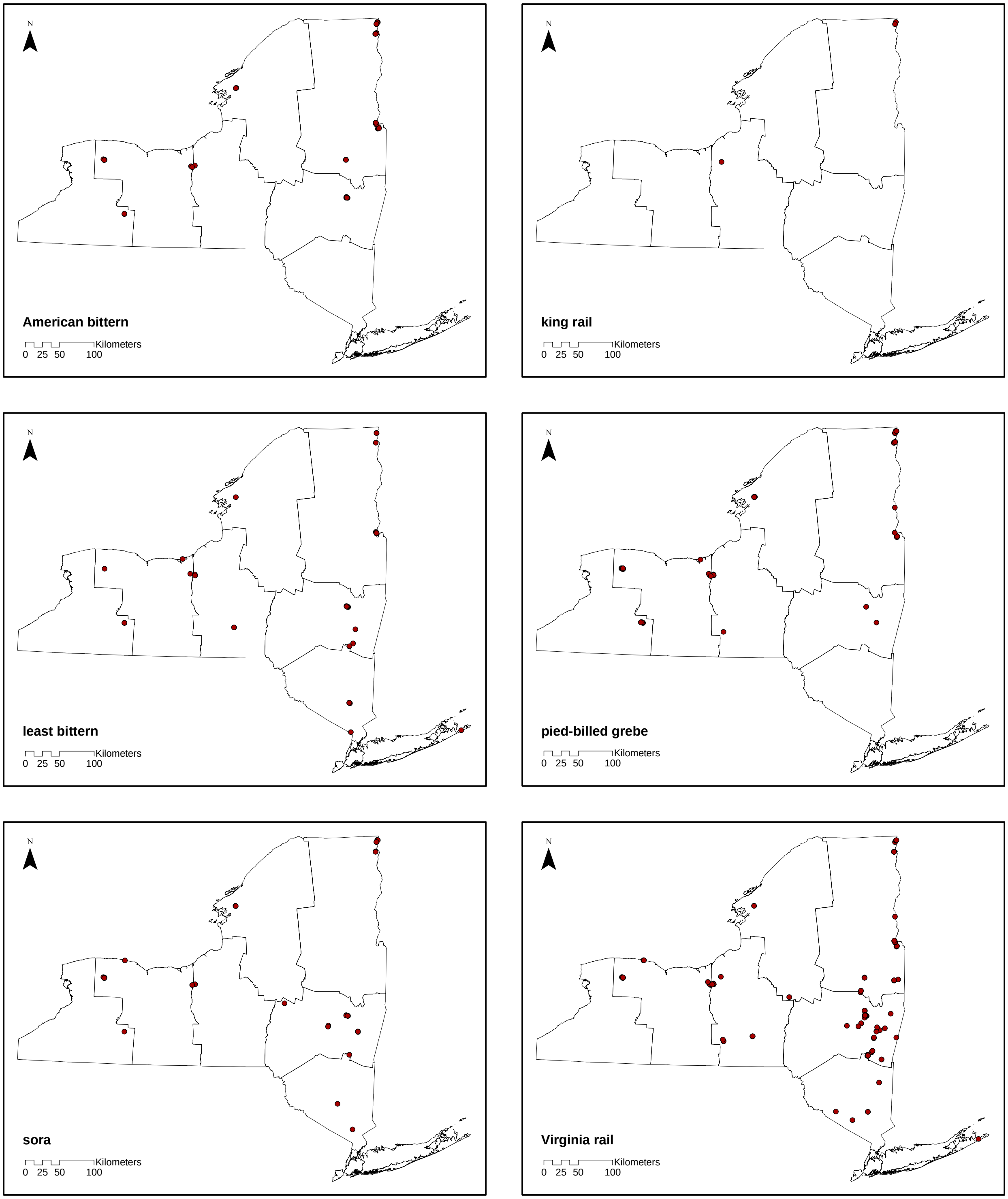

Figure 2. Primary focal species detections during the New York State Marsh Bird Monitoring Program, 2009-2011.

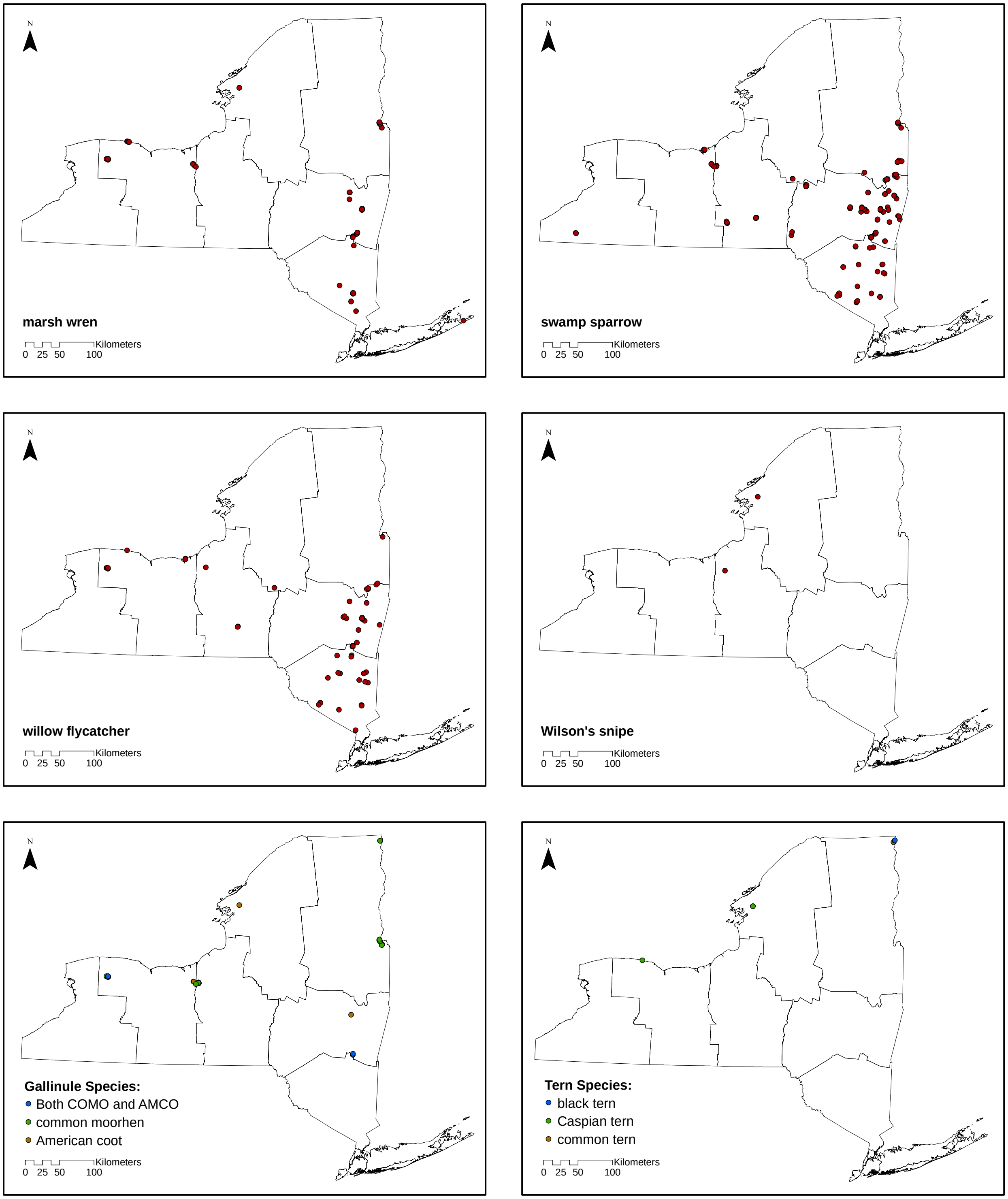

Figure 3. Secondary focal species detections during the New York State Marsh Bird Monitoring Program, 2009-2011.

Occupancy (ψ) and detection (*p*) maximum likelihood estimates

Focal species detection histories from the repeated surveys provided the opportunity to explore probability of occupancy and detection as an index of population status. However, results should be interpreted with caution because of low abundance in the case of some species (i.e., least bittern, sora) (Conway et al. 2008) especially for 2009 results, and issues with multiple observer bias (MacKenzie et al. 2003). An extremely low detection rate precluded modeling for king rail. The multi-season occupancy and detection estimates could be refined by modeling parameters as a function of habitat covariates. Thus, although they provide an index of abundance, the following MLEs should be viewed as the *estimates* that they are. (See Appendix B).

Virginia rail.—Weighted model-averaged MLEs of ψ were 13.3% in 2009, 30.5% in 2010, and 31.7% in 2011. Naïve estimates (actual proportion of sites where VIRAs were detected) were 11.2%, 27.0%, and 24.7%, respectively. Model averaged MLEs of *p* were similar across years at 56.1% in 2009, 54.9% in 2010, and 46.3% in 2011. The top-supported model [ψ(2009)γ(yr)ε(.)*p*(.)] indicated that colonization should be modeled as year-dependent while persistence and *p* should most likely be held constant. There was also strong support for model [ψ(2009)γ(yr)ε(.)*p*(yr)] with year-dependent colonization and detection (Table B1).

Pied-billed grebe.—Weighted model-averaged MLEs of ψ were 0.6% in 2009, 17.0% in 2010, and 15.9% in 2011. MLEs slightly exceed the naïve estimates of 0.5% in 2009, 15.5% in 2010 and 14.2% in 2011. Model averaged *p* was 75.2% in 2009, 58.6% in 2010, and 58.4% in 2011. The top-supported model [ψ(2009)γ(yr)ε(.)*p*(.)] included year-dependent colonization and constant persistence and detection. There was also strong support for the model [ψ(2009)γ(yr)ε(yr)*p*(.)] indicating that ε could also be modeled as year-dependent (Table B2)

American bittern.—Weighted model-averaged ψ MLEs were 4.2% in 2009, 19.8% in 2010, and 29.3% in 2011, exceeding naïve estimates of 0.5%, 13.2%, and 15.3%, respectively. Model-averaged MLEs of *p* were 20.7% in 2009, 33.7% in 2010, and 23.7% in 2011. The top model [ψ(2009)γ(.)ε(.)*p*(survey)] included survey-dependent *p*, reflecting the fact the peak AMBI calling typically occurs earlier in the breeding season (first survey replicate) and declines thereafter (Rehm & Baldassarre 2007). The models [ψ(2009)γ(.)ε(.)*p*(yr)] and [ψ(2009)γ(yr)ε(.)*p*(.)] also had good support (Table B3).

Least bittern.—Weighted model-averaged ψ MLEs were 7.8% in 2009, 14.9% in 2010, and 17.5% in 2011. The naïve estimates were 1.1% in 2009, 9.8% in 2010, and 11.6% in 2011. Model averaged MLEs of *p* were 21.3% in 2009, 34.5% in 2010, and 33.6% in 2011. Least bittern's top supported model [ψ(2009)γ(yr)ε(.)*p*(.)] included year-dependent γ and constant ε and *p*. The model with the second greatest AIC weight [ψ(2009)γ(.)ε(.)*p*(survey)] showed that γ could be held constant and *p* could be modeled as survey-dependent (Table B4).

Sora.—Weighted model-averaged estimates of ψ were 13.6% in 2009, 26.8% in 2010, and 21.5% in 2011. Sora observations were sparse in all years, with naïve estimates of only 1.1% in 2009, 10.9% in 2010, and 5.8% in 2011. Model averaged *p* were 6.3% in 2009, 20.1% in 2010, and 11.1% in 2011. The top-supported model [ψ(2009)γ(yr)ε(.)*p*(.)] indicated year-dependent γ and constant ε and *p*. Model [ψ(2009)γ(.)ε(.)*p*(yr)] also had good support, indicating that *p* could also be modeled as year-dependent (Table B5).

Habitat covariates at detection vs. non-detection points

Habitat surveys were completed at 145 of 174 points in 2010 and 179 of 190 points in 2011. Six of eight habitat covariates (trees and snags were combined) in 2010 and five of eight covariates in 2011 differed significantly between survey points where focal species were detected vs. not detected (Table 3). In 2010, water depth was greater at points where both least and American bittern were detected than at points where these species were not detected (P = 0.037 and P = 0.035, respectively) (Figure 4A). Percent cover of emergent vegetation was greater at sites where Virginia rail were detected (P = 0.034) and marginally greater (P = 0.053) at sites with American bittern detections (Figure 4B). There was a greater percentage of open water at sites where least bittern (P = 0.033), Virginia rail (P = 0.046), and American bittern (P = 0.023) were detected (Figure 4C). Scrub-shrub cover was lower at sites where Virginia rail (P = 0.033) and American bittern (P = 0.003) were detected (Figure 4D), as was the percentage of upland habitat (P = 0.002 and P = 0.018, respectively) (Figure 4E). Floating vegetation was greater at sites where Virginia rail (P <0.001) and sora (P = 0.045) were detected (Figure 4F). Percent cover of trees/snags and mudflats did not differ for any species.

In 2011, water depth was also greater at points where American bittern were detected than at nondetection points (P = 0.005) and marginally (non-significant) greater at points where least bittern were detected (P = 0.058) (Figure 5A). Percent cover of emergent vegetation was lower where pied-billed grebe were detected (P = 0.005) (Figure 5B). Percent of open water was greater at sites where least bittern, Virginia rail, American bittern, and pied-billed grebe were detected (P = 0.005, 0.024, <0.001, and 0.013, respectively) (Figure 5C). Virginia rail were also detected more often at sites with less upland habitat (P = 0.016) (Figure 5D). There was more floating vegetation at American bittern detection sites (P = 0.043) (Figure 5E). Percent cover of shrubs, trees/snags, and mudflats did not differ between detection and nondetection points.

Additionally, there were significant differences in the frequency of a species' detection/nondetection among different vegetation height classes (0-1m, 1-3m, 3-6m, >6m) for four focal species. Most Virginia rail detections were at points with vegetation height of 1-3m in both 2010 (χ^2 = 7.811, P = 0.050) and 2011 (χ^2 = 14.21, P = 0.003) (Figures C1 and C2). For American bittern, there was a difference in 2011 (χ^2 = 9.261, P = 0.026) and a marginal but non-significant difference in 2010 (χ^2 = 7.365, P = 0.061); most detections in 2010 were at sites with vegetation height of 1-3m (Figure C3). For sora, there was a significant difference in 2010 (χ^2 = 7.820, P = 0.050) but not in 2011 (χ^2 = 1.872, P = 0.599); all sora detections in 2010 were at sites where vegetation height was less than 3m (Figure C4). Least bittern differed significantly in 2011 (χ^2 = 10.644, P = 0.014) but not in 2010 (χ^2 = 5.746, P = 0.125); most 2011 detections were at sites with vegetation height of 1-3m (Figure C5). There was no difference for pied-billed grebe in either 2010 (χ^2 = 1.074, P = 0.783) or 2011 (χ^2 = 0.539, P = 0.910). (See Appendix C).

There was also a significant difference in the frequency of occurrence among vegetation density classes (none, sparse, moderate, rank) for Virginia rail in both 2010 (χ^2 = 7.811, P = 0.050) and 2011 (χ^2 = 8.107, P = 0.044). In both years, sites where Virginia rail were detected had greater vegetation density (moderate or rank) than nondetection sites (Figure C6 and C7). Pied-billed grebe differed significantly in 2011 (χ^2 = 18.048, P < 0.001) but not in 2010 (χ^2 = 1.807, P = 0.613); in 2011 most detection sites had either sparse or moderate vegetation (Figure C8). There were no differences among vegetation height classes for least bittern (2010: χ^2 = 2.896, P = 0.408; 2011: χ^2 = 2.563, P = 0.464), sora (2010: χ^2 = 5.718, P = 0.126; 2011: χ^2 = 2.346, P = 0.504), or American bittern (2010: χ^2 = 3.019, P = 0.389; 2011: χ^2 = 2.973, P = 0.396). (See Appendix C).

Table 3. Comparison of habitat covariate means ($\bar{x}$) ± standard errors at survey points where focal species were detected (1) or not detected (0) during the New York State Marsh Bird Monitoring Program, 2010-2011. *P* values <0.05 (bold) are significantly different.

	Water depth (cm)			**Emergent (%)**			**Open water (%)**			**Shrub (%)**		
	$\bar{x}$		*P*	$\bar{x}$		*P*	$\bar{x}$		*P*	$\bar{x}$		*P*
Species	0	1		0	1		0	1		0	1	
2010[a]												
LEBI	30.5 ± 2.7	43.9 ± 5.5	**0.037**	44.7 ± 2.3	51.7 ± 4.2	0.222	22.4 ± 1.8	31.7 ± 4.2	**0.033**	11.9 ± 1.4	7.1 ± 3.2	0.090
VIRA	31.1 ± 3.1	34.2 ± 4.0	0.263	42.7 ± 2.6	52.6 ± 3.1	**0.034**	21.8 ± 2.1	27.5 ± 2.9	**0.046**	12.8 ± 1.7	7.6 ± 1.9	**0.033**
SORA	32.8 ± 2.7	24.3 ± 6.5	0.308	44.8 ± 2.2	51.0 ± 6.4	0.441	23.3 ± 1.8	24.0 ± 6.2	0.961	11.8 ± 1.4	7.9 ± 2.9	0.687
AMBI	30.6 ± 2.7	44.2 ± 4.7	**0.035**	44.2 ± 2.2	56.8 ± 4.5	0.053	22.3 ± 1.8	33.6 ± 4.7	**0.023**	12.4 ± 1.4	2.1 ± 1.1	**0.003**
PBGR	31.9 ± 2.8	32.6 ± 4.4	0.466	44.5 ± 2.2	52.5 ± 6.1	0.292	22.9 ± 1.8	26.6 ± 5.1	0.413	12.2 ± 1.5	4.9 ± 1.5	0.126
2011[b]												
LEBI	51.8 ± 5.5	81.9 ± 16.5	0.058	44.9 ± 2.3	41.2 ± 5.6	0.602	22.9 ± 1.9	37.1 ± 5.6	**0.005**	12.5 ± 1.3	12.7 ± 4.3	0.689
VIRA	48.8 ± 5.8	72.9 ± 11.3	0.075	43.2 ± 2.6	47.9 ± 4.0	0.298	22.7 ± 2.1	30.1 ± 3.7	**0.024**	13.6 ± 1.5	9.5 ± 2.0	0.546
SORA	55.7 ± 5.6	61.9 ± 12.9	0.167	44.0 ± 2.2	50.9 ± 7.8	0.381	24.1 ± 1.9	33.4 ± 6.5	0.113	12.7 ± 1.3	9.8 ± 3.6	0.866
AMBI	48.6 ± 5.6	86.9 ± 13.8	**0.005**	46.1 ± 2.4	35.6 ± 4.1	0.116	21.8 ± 1.9	39.6 ± 5.1	**<0.001**	13.2 ± 1.4	8.8 ± 2.0	0.723
PBGR	54.4 ± 6.0	64.1 ± 11.4	0.118	47.0 ± 2.4	29.8 ± 4.1	**0.005**	22.8 ± 2.0	35.3 ± 5.3	**0.013**	12.2 ± 1.4	14.0 ± 2.8	0.243

	Upland (%)			**Trees and snags (%)**			**Floating veg (%)**			**Mudflat (%)**		
	$\bar{x}$		*P*	$\bar{x}$		*P*	$\bar{x}$		*P*	$\bar{x}$		*P*
Species	0	1		0	1		0	1		0	1	
2010												
LEBI	12.0 ± 1.8	2.0 ± 1.1	0.127	4.8 ± 1.0	5.0 ± 1.9	0.661	3.4 ± 0.8	4.0 ± 1.4	0.168	1.6 ± 0.7	0.0 ± 0.0	0.246
VIRA	14.4 ± 2.2	2.0 ± 0.8	**0.002**	5.5 ± 1.1	3.0 ± 1.1	0.104	2.2 ± 0.7	6.9 ± 1.6	**<0.001**	1.3 ± 0.8	1.8 ± 1.3	0.509
SORA	11.1 ± 1.8	10.0 ± 3.9	0.315	5.0 ± 1.0	3.5 ± 2.0	0.994	3.4 ± 0.7	4.0 ± 1.5	**0.045**	1.6 ± 0.7	0.1 ± 0.1	0.843
AMBI	12.1 ± 1.8	0.4 ± 0.4	**0.018**	4.8 ± 1.0	4.8 ± 1.9	0.337	3.5 ± 0.7	3.3 ± 1.5	0.689	1.6 ± 0.7	0.1 ± 0.1	0.901
PBGR	11.5 ± 1.8	7.1 ± 3.3	0.800	4.8 ± 1.0	4.4 ± 2.1	0.596	3.3 ± 0.8	4.5 ± 1.4	0.100	1.6 ± 0.8	0.1 ± 0.1	0.738
2011												
LEBI	11.4 ± 1.5	2.8 ± 1.3	0.198	6.6 ± 1.0	5.5 ± 3.0	0.166	1.5 ± 0.3	1.5 ± 0.5	0.246	0.4 ± 0.1	0.0 ± 0.0	0.227
VIRA	12.5 ± 1.8	4.3 ± 1.5	**0.016**	6.3 ± 1.0	7.0 ± 2.3	0.665	1.4 ± 0.3	1.7 ± 0.6	0.370	0.3 ± 0.1	0.6 ± 0.4	0.309
SORA	10.7 ± 1.4	5.9 ± 4.6	0.291	6.8 ± 1.0	1.8 ± 1.0	0.351	1.6 ± 0.3	0.5 ± 0.5	0.235	0.4 ± 0.1	0.0 ± 0.0	0.411
AMBI	11.5 ± 1.6	4.5 ± 1.7	0.214	6.1 ± 1.0	8.6 ± 3.2	0.635	1.2 ± 0.2	3.0 ± 1.0	**0.043**	0.4 ± 0.1	0.1 ± 0.1	0.575
PBGR	11.2 ± 1.6	5.9 ± 2.4	0.387	5.5 ± 0.9	12.1 ± 3.7	0.119	1.3 ± 0.3	2.7 ± 0.8	0.056	0.4 ± 0.1	0.1 ± 0.1	0.634

[a] 2010 H_2O depth: LEBI (n=15), VIRA (n=39), SORA (n=15), AMBI (n=14), PBGR (n=17); % cover: LEBI (n=15), VIRA (n=40), SORA (n=15), AMBI (n=14), PBGR (n=17).

[b] 2011 H_2O depth: LEBI (n=21), VIRA (n=45), SORA (n=9), AMBI (n=29), PBGR (n=26); % cover: LEBI (n=22), VIRA (n=47), SORA (n=11), AMBI (n=29), PBGR (n=27).

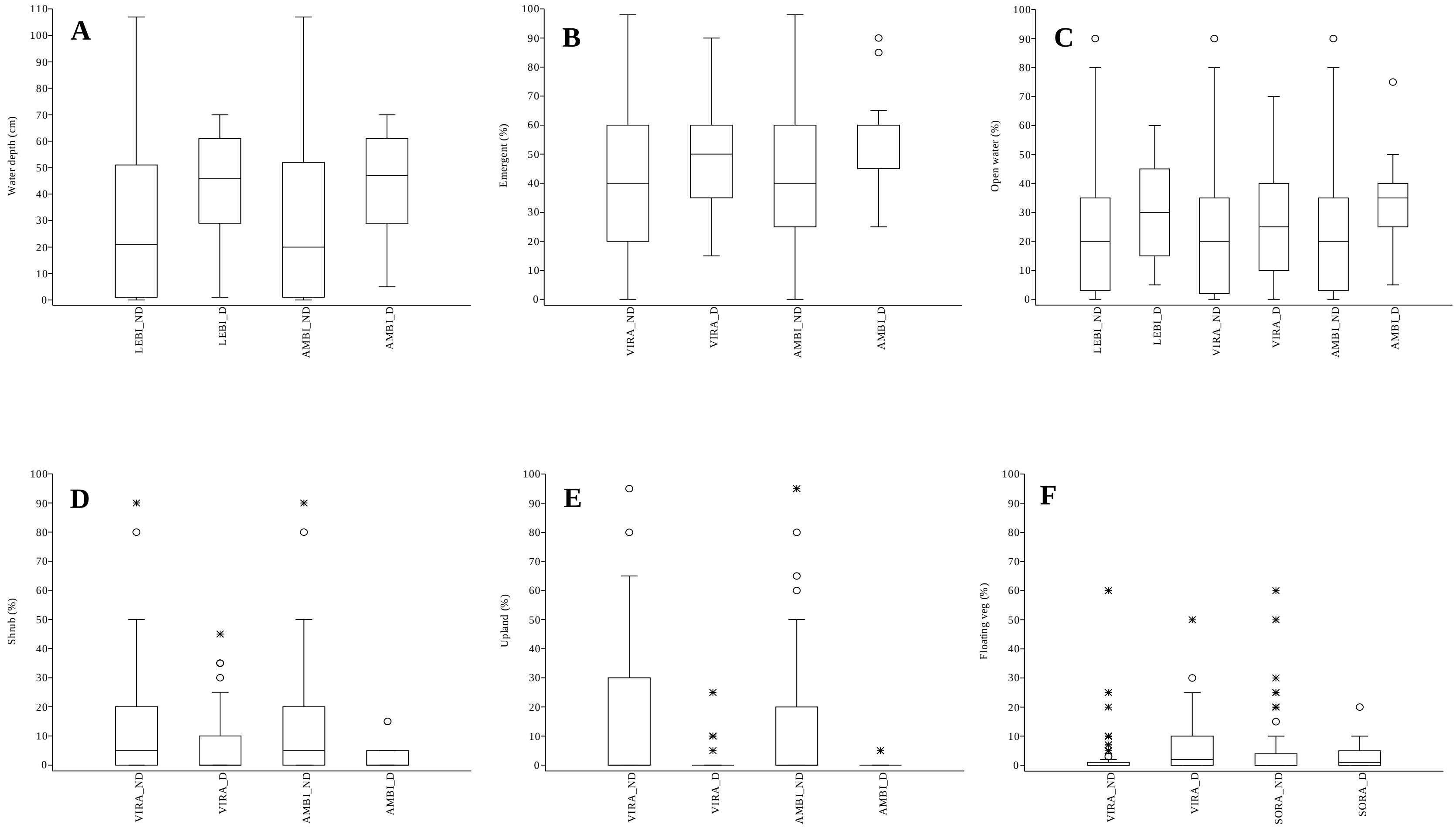

Figure 4. Boxplot comparisons of minimum and maximum values, interquartile range (25-75 percentiles), and median values for habitat covariates (A: water depth; B: % emergent vegetation; C: % open water; D: % shrub; E: % upland; F: % floating vegetation) at survey points where focal species were not detected (ND) or were detected (D) during the NYS Marsh Bird Monitoring Program, 2010. Whiskers indicate the range of values that fall within 1.5 times the height of the interquartile range (box height). Two strata of outliers are indicated: (1) circles (o) represent values that are greater than 1.5 times the box height, and (2) stars (*) represent values that exceed three times the box height.

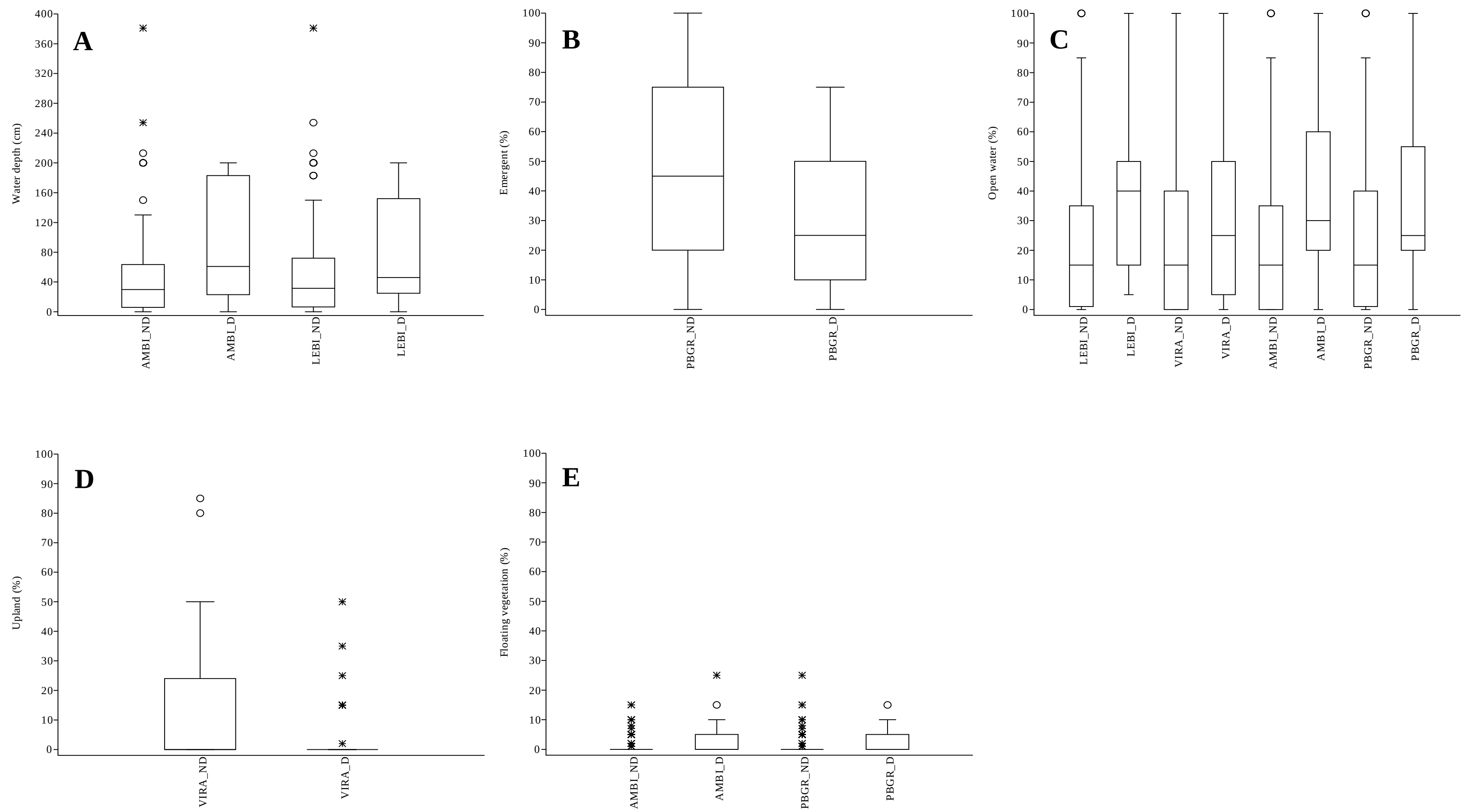

Figure 5. Boxplot comparisons of minimum and maximum values, interquartile range (25-75 percentiles), and median values for habitat covariates (A: water depth; B: % emergent vegetation; C: % open water; D: % upland; E: % floating vegetation) at survey points where focal species were not detected (ND) or were detected (D) during the NYS Marsh Bird Monitoring Program, 2011. Whiskers indicate the range of values that fall within 1.5 times the height of the interquartile range (box height). Two strata of outliers are indicated: (1) circles (o) represent values that are greater than 1.5 times the box height, and (2) stars (*) represent values that exceed three times the box height.

Pilot study considerations

Deviations from sampling design.—In general, surveyors followed the Johnson et al. (2009) sampling design; however, in several circumstances it was logistically unreasonable to proceed with the sampling design. First, the random selection of both PSUs and SSUs was occasionally compromised due to logistics, i.e., a PSU with suitable habitat could have been omitted for logistical/access reasons. Second, within a PSU it was often difficult to find the minimum of four accessible SSUs in "suitable" habitat and the inclusion or elimination of a SSU was left at the discretion of the surveyor. Third, the sampling design required SSUs to be selected in a manner that differentiated between small (≤ 3 ha) and large (> 3 ha) wetlands. Due to the difficulty of establishing a minimum of four survey points per hexagon, we largely abandoned the wetland size component of the sampling design. Finally, focal species were not detected in the majority of PSUs. Although one strength of the sampling design is its intention of understanding where marsh birds do and *do not* occur for a given year or habitat type, it could be difficult to recruit and retain surveyors for a group of birds that often are not observed.

Monitoring private land.—The transition in 2010 to a new stratification of SSUs by land ownership appeared to work well. With fairly little effort, we were able to meet the target 75:25 public to private land ratio of SSUs in both 2010 and 2011. In part, NYSDEC staff achieved this by accessing SSUs located on private land by adjacent public areas (i.e., roadsides, open waterways). Without this "work around" approach, extra effort was required to conduct surveys on private land, including: (1) mailings/phone calls/house visits requesting land-access targeting landowners with a priority SSU on their property, (2) after obtaining permission, multiple phone calls to inform landowner of intent to survey for each survey replicate, and (3) a thank you letter containing a mini-report of birds observed on their property at end of season. Maintaining or expanding monitoring efforts on privately owned wetlands requires these additional pre- and post-season efforts in order to avoid straying from the random sampling scheme.

Transitioning to long-term monitoring program

Much progress has been made towards full implementation of a long-term Marsh Bird Monitoring Program throughout New York State. The 2009-2011 pilot study provided the foundation for such an undertaking by: (1) troubleshooting a statistically rigorous sampling design, (2) ground-truthing and selecting survey routes, (3) familiarizing NYSDEC staff with the standardized Conway (2009, 2011) survey protocols, (4) revising habitat survey protocols, and (5) beginning to build relationships with other agencies and organizations to increase the capacity of the program. The ability to understand population status and trends of marsh bird species improves with increased monitoring intensity and duration, particularly for difficult-to-detect species with low abundances (Bart 2006; Conway et al. 2008). Osborne et al. (2011) recommended annual or biennial surveys, because the secretive nature of the focal species makes it difficult to determine changes in site occupancy and therefore difficult to detect population declines. This observation is especially applicable to species with lower detection rates, like least bittern and king rail; it may be necessary to consider additional efforts for these species. Moreover, most states involved with current marsh bird monitoring efforts agree that annual surveys are preferable to intermittent surveys because of existing data for focal species shows a great amount of variability (Atlantic Flyway Technical Section, pers. comm.). With this in mind, we recommend that the current level of monitoring continue, with addition of survey routes if we are able. Maintaining or increasing monitoring efforts may necessitate recruiting and training of volunteer surveyors, although this scenario raises several concerns, including: (1) extensive training for such a detailed survey protocol and difficult-to-detect species would be required, (2) negative effects of multiple observer bias issues in the data analysis could increase, and (3) it may be difficult to recruit and retain volunteers when the focal species are rarely seen and seldom heard. Full implementation will also require more even coverage throughout the state, especially areas where few survey routes currently exist compared to other NYSDEC Regions. Surveys in freshwater wetlands in Regions 1 and 2 may also be considered, although efforts of the SHARP program (saltmarsh habitat) and a proposed salt marsh breeding bird study through the State University of New York – College of Forestry and Environmental Sciences (SUNY-CESF) somewhat alleviates the need for NYSDEC staff to establish survey routes in these Regions. Ultimately, determining both the timeframe (annual, long-term) and scale (state, regional, flyway) at which we want to be able to detect changes in marsh bird population trends will drive the duration and intensity of the statewide marsh bird monitoring program.

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Appendix A

NYS Marsh Bird Monitoring Program survey routes, 2009-2011

Table A1. New York State Marsh Bird Monitoring Program freshwater wetland routes surveyed and ground-truthed, 2009 - 2011.

Routes surveyed	# Points	Sampling design[a]	Year established	Year surveyed	DEC Region	Property ownership
Hexagon 9	5	1	2009	09	5	-
Hexagon 19	5	1	2009	09	3	-
Hexagon 25	7	1	2009	09	5	-
Hexagon 30	6	1	2009	09	6	-
Hexagon 37	7	1	2009	09	3	-
Hexagon 43	5	1	2009	09	5	-
Hexagon 67	5	1	2009	09	5	-
Hexagon 69	10	1	2009	09	3	-
Hexagon 73	7	1	2009	09	5	-
Hexagon 83	5	1	2009	09	3	-
Hexagon 89	6	1	2009	09	5	-
Hexagon 90	6	1	2009	09	5	-
Hexagon 101	6	1	2009	09	3	-
Hexagon 113	6	1	2009	09	3	-
Hexagon 117	6	1	2009	09	5	-
Hexagon 118	5	1	2009	09	5	-
Hexagon 133	4	1	2009	09	3	-
Hexagon 134	4	1	2009	09	3	-
Hexagon 150	9	1	2009	09	3	-
Hexagon 177	6	1	2009	09	3	-
Hexagon 181	7	1	2009	09	5	-
Hexagon 201	6	1	2009	09	5	-
Hexagon 229	5	1	2009	09	5	-
Hexagon 245	8	1	2009	09	5	-
Hexagon 309	5	1	2009	09	5	-
Hexagon 341	8	1	2009	09	5	-
Hexagon 371	8	1	2009	09	5	-
Hexagon 377	7	1	2009	09	5	-
Hexagon 389	6	1	2009	09	5	-
Hexagon 057/Perch River WMA	3	1	2010	10	6	PU
199994/King's Bay	5	1	2010	10, 11	5	PR
200780/Monty's Bay	5	1	2010	10, 11	5	PU

Routes surveyed	# Points	Sampling design[a]	Year established	Year surveyed	DEC Region	Property ownership[b]
206284/Putt's Creek WMA	2	1	2010	10	5	PR
208250/Chubb's Dock Lk Champlain	6	1	2010	10, 11	5	PR
208643/East Bay WMA	5	1	2010	10, 11	5	PU
211784/Lake Desolation SF	4	1	2010	10, 11	5	PU
214122/Lake Shore Marshes	6	1	2010	10, 11	8	PU
214508/Hamlin Beach	7	1	2011	11	8	PU
214518/Cato	7	1	2010	11	7	PR
214540/Capital District WMA	5	1	2010	10, 11	4	PU
215715/Westerlo	6	1	2010	10, 11	4	PR
215717/Schodack Island SP North	6	1	2010	10, 11	4	PR
216110/Schodack Island SP South	5	1	2010	10, 11	4	PU
216471/Oak Orchard WMA	10	1	2010	10, 11	8	PU
217682/Hudson River Catskill	5	1	2010	10, 11	4	PR
218075/Great Vly WMA	3	1	2010	10, 11	4	PU
219252/Wilson Park	4	1	2010	10, 11	3	PU
219629/Danby State Forest	6	1	2010	10, 11	7	PU
220405/Keeney Swamp	5	1	2011	11	9	PU
223972/Croton Point	4	1	2011	11	3	E
45930/Woodford State Forest	4	1	2011	11	6	PU
46325/Exeter SF	6	1	2010	10, 11	4	PU
47516/Beebe Hill	3	1	2010	10, 11	4	PU
49070/Region 7 Virgil	6	1	2010	10, 11	7	PR
49857/Upper Lisle	4	1	2010	10, 11	7	PU
51838/Region 3 LaGrange	6	1	2010	10, 11	3	PU
52225/Region 3 Fallsburg	5	1	2010	10	3	PR
53408/Stewart State Forest	10	1	2010	10, 11	3	PU
53803/Constitution Marsh	6	1	2010	10, 11	3	E
53817/Hither Hills	4	1	2011	11	1	PU
54552/Hartson Swamp WMA	4	1	2010	10, 11	9	PR
54589/Iona Marsh	7	1	2010	10	3	E
Black Creek Marsh WMA	8	2	2004	10, 11	4	PU
Canoga N Private Land	1	2	2008	10	8	PR
Coxsackie	8	2	2011	11	4	PU
Crusoe Lake	2	2	2011	11	8	PU
Franklinton Vlaie WMA	6	2	2004	10, 11	4	PU
Galen WMA	1	2	2008	09	8	PU
Great Vly WMA	5	2	2004	10, 11	4	PU
Northern Montezuma WMA	9	2	2008	09, 10, 11	7, 8	PU
Vailis	1	2	2006	10	8	PR

Routes surveyed	# Points	Sampling design[a]	Year established	Year surveyed	DEC Region	Property ownership[b]
Watervliet Reservoir	5	2	2010	10	4	PU
Routes ground-truthed						
45133/private land	n/a	1	2011	-	8	PR
46721/Bear Swamp WMA	n/a	1	2011	-	4	PU
46728/South Schodack	n/a	1	2011	-	4	PR
51042/Delaware River West Branch	n/a	1	2011	-	4	PU
53410/Clarence Fahnestock SP	n/a	1	2011	-	3	PU
54198/Lewisboro	n/a	1	2011	-	3	PR

[a] Survey points selected by either (1) USFWS pilot study random sampling design, or (2) NYSDEC long-term monitoring points at wetlands of interest.

[b] Property ownership included three strata: (PU) Freshwater Public, (PR) Freshwater Private, and (E) Estuarine. Survey routes were not stratified by property ownership in 2009.

APPENDIX B

Model averaged maximum likelihood estimates of occupancy and detection probabilities

Table B1. Model selection and maximum likelihood estimates of occupancy (ψ) ±1 SE for Virginia rails detected in New York 2009-2011. Model-averaged estimates of detection probability were 0.561 in 2009 0.549 in 2010 and 0.463 in 2011.

Model	AICc	ΔAICc	AIC wgt	Model Likelihood	K	2*Log Like	ψ_{2009}	ψ_{2010}	ψ_{2011}
ψ(2009)γ(yr)ε(.)p(.)	911.57	0.00	0.245	1.000	5	901.42	0.133 ± 0.028	0.327 ± 0.041	0.298 ± 0.038
ψ(2009)γ(yr)ε(.)p(yr)	912.61	1.04	0.146	0.595	7	898.34	0.125 ± 0.027	0.316 ± 0.041	0.322 ± 0.046
ψ(2009)γ(.)ε(.)p(yr)	912.96	1.39	0.122	0.499	6	900.76	0.134 ± 0.028	0.275 ± 0.028	0.354 ± 0.046
ψ(2009)γ(yr)ε(yr)p(.)	913.32	1.75	0.102	0.417	6	901.12	0.132 ± 0.027	0.329 ± 0.041	0.296 ± 0.038
ψ(2009)γ(.)ε(yr)p(.)	913.34	1.77	0.101	0.413	5	903.19	0.145 ± 0.028	0.289 ± 0.028	0.304 ± 0.038
ψ(2009)γ(.)ε(yr)p(yr)	913.66	2.09	0.086	0.352	7	899.39	0.133 ± 0.027	0.289 ± 0.028	0.332 ± 0.047
ψ(2009)γ(.)ε(.)p(.)	914.39	2.82	0.060	0.244	4	906.29	0.146 ± 0.030	0.265 ± 0.026	0.324 ± 0.037
ψ(2009)γ(yr)ε(yr)p(yr)	914.55	2.98	0.055	0.225	8	898.20	0.125 ± 0.027	0.317 ± 0.041	0.319 ± 0.046
ψ(2009)γ(yr)ε(.)p(survey)	915.85	4.28	0.029	0.118	13	888.95	0.123 ± 0.026	0.314 ± 0.040	0.324 ± 0.046
ψ(2009)γ(.)ε(.)p(survey)	916.04	4.47	0.026	0.107	12	891.27	0.132 ± 0.027	0.274 ± 0.028	0.355 ± 0.046
ψ(2009)γ(.)ε(yr)p(survey)	916.79	5.22	0.018	0.074	13	889.89	0.131 ± 0.026	0.287 ± 0.028	0.333 ± 0.047
ψ(2009)γ(yr)ε(yr)p(survey)	917.81	6.24	0.011	0.044	14	888.77	0.123 ± 0.026	0.315 ± 0.041	0.321 ± 0.046
Model averaged estimates							0.132 ± 0.002	0.300 ± 0.006	0.323 ± 0.005
Weighted model averaged estimates							**0.133**	**0.305**	**0.317**
Naïve estimate							0.112	0.270	0.247

K = number of parameters

Table B2. Model selection and maximum likelihood estimates of occupancy (ψ) ±1 SE for pied-billed grebes detected in New York 2009-2011. Model-averaged estimates of detection probability were 0.752 in 2009 0.586 in 2010 and 0.584 in 2011.

Model	AICc	ΔAICc	AIC wgt	Model Likelihood	K	2*Log Like	ψ_{2009}	ψ_{2010}	ψ_{2011}
ψ(2009)γ(yr)ε(.)p(.)	459.11	0.00	0.504	1.000	5	448.96	0.006 ± 0.006	0.170 ± 0.029	0.159 ± 0.028
ψ(2009)γ(yr)ε(yr)p(.)	460.75	1.64	0.222	0.440	6	448.55	0.006 ± 0.006	0.170 ± 0.029	0.158 ± 0.028
ψ(2009)γ(yr)ε(.)p(yr)	461.21	2.10	0.177	0.350	7	446.94	0.005 ± 0.005	0.172 ± 0.031	0.159 ± 0.028
ψ(2009)γ(yr)ε(yr)p(yr)	462.88	3.77	0.077	0.152	8	446.53	0.005 ± 0.005	0.173 ± 0.031	0.157 ± 0.028
ψ(2009)γ(yr)ε(.)p(survey)	467.34	8.23	0.008	0.016	13	440.44	0.005 ± 0.005	0.169 ± 0.030	0.153 ± 0.027
ψ(2009)γ(.)ε(.)p(.)	468.65	9.54	0.004	0.009	4	460.55	0.008 ± 0.008	0.111 ± 0.017	0.183 ± 0.029
ψ(2009)γ(yr)ε(yr)p(survey)	469.01	9.90	0.004	0.007	14	439.97	0.005 ± 0.005	0.170 ± 0.030	0.151 ± 0.027
ψ(2009)γ(.)ε(yr)p(.)	470.00	10.89	0.002	0.004	5	459.85	0.009 ± 0.009	0.112 ± 0.018	0.180 ± 0.029
ψ(2009)γ(.)ε(.)p(yr)	470.80	11.69	0.002	0.003	6	458.60	0.007 ± 0.007	0.112 ± 0.018	0.186 ± 0.030
ψ(2009)γ(.)ε(yr)p(yr)	472.29	13.18	0.001	0.001	7	458.02	0.007 ± 0.007	0.113 ± 0.018	0.184 ± 0.030
ψ(2009)γ(.)ε(.)p(survey)	476.97	17.86	0.000	0.000	12	452.20	0.007 ± 0.007	0.109 ± 0.017	0.180 ± 0.029
ψ(2009)γ(.)ε(yr)p(survey)	478.42	19.31	0.000	0.000	13	451.52	0.007 ± 0.007	0.110 ± 0.017	0.177 ± 0.029
Model averaged estimates							0.006 ± 0.000	0.141 ± 0.009	0.169 ± 0.004
Weighted model averaged estimates							**0.006**	**0.170**	**0.159**
Naïve estimate							0.005	0.155	0.142

K = number of parameters

Table B3. Model selection and maximum likelihood estimates of occupancy (ψ) ±1 SE for American bitterns detected in New York 2009-2011. Model-averaged estimates of detection probability were 0.207 in 2009 0.337 in 2010 and 0.237 in 2011.

Model	AICc	ΔAICc	AIC wgt	Model Likelihood	K	2*Log Like	ψ_{2009}	ψ_{2010}	ψ_{2011}
ψ(2009)γ(.)ε(.)p(survey)	467.86	0.00	0.209	1.000	12	443.09	0.006 ± 0.006	0.169 ± 0.030	0.305 ± 0.050
ψ(2009)γ(.)ε(.)p(yr)	468.23	0.37	0.174	0.831	6	456.03	0.085 ± 0.112	0.199 ± 0.048	0.298 ± 0.056
ψ(2009)γ(yr)ε(.)p(.)	468.57	0.71	0.146	0.701	5	458.42	0.010 ± 0.010	0.247 ± 0.056	0.277 ± 0.047
ψ(2009)γ(yr)ε(.)p(survey)	469.19	1.33	0.107	0.514	13	442.29	0.006 ± 0.006	0.194 ± 0.047	0.279 ± 0.051
ψ(2009)γ(.)ε(yr)p(survey)	469.99	2.13	0.072	0.345	13	443.09	0.006 ± 0.006	0.169 ± 0.030	0.305 ± 0.050
ψ(2009)γ(yr)ε(.)p(yr)	470.30	2.44	0.062	0.295	7	456.03	0.199 ± 0.050	0.199 ± 0.318	0.298 ± 0.057
ψ(2009)γ(.)ε(yr)p(yr)	470.30	2.44	0.062	0.295	7	456.03	0.085 ± 0.112	0.199 ± 0.048	0.298 ± 0.056
ψ(2009)γ(yr)ε(yr)p(.)	470.62	2.76	0.053	0.252	6	458.42	0.010 ± 0.010	0.247 ± 0.056	0.277 ± 0.047
ψ(2009)γ(.)ε(.)p(.)	471.12	3.26	0.041	0.196	4	463.02	0.011 ± 0.011	0.174 ± 0.032	0.293 ± 0.059
ψ(2009)γ(yr)ε(yr)p(survey)	471.33	3.47	0.037	0.176	14	442.29	0.006 ± 0.006	0.194 ± 0.047	0.279 ± 0.051
ψ(2009)γ(yr)ε(yr)p(yr)	472.38	4.52	0.022	0.104	8	456.03	0.199 ± 0.048	0.199 ± 0.048	0.298 ± 0.057
ψ(2009)γ(.)ε(yr)p(.)	472.88	5.02	0.017	0.081	5	462.73	0.011 ± 0.011	0.174 ± 0.032	0.285 ± 0.057
Model averaged estimates							0.053 ± 0.021	0.197 ± 0.008	0.291 ± 0.003
Weighted model averaged estimates							**0.042**	**0.198**	**0.293**
Naïve estimate							0.005	0.132	0.153

K = number of parameters

Table B4. Model selection and maximum likelihood estimates of occupancy (ψ) ±1 SE for least bitterns detected in New York 2009-2011. Model-averaged estimates of detection probability were 0.213 in 2009 0.345 in 2010 and 0.336 in 2011.

Model	AICc	ΔAICc	AIC wgt	Model Likelihood	K	2*Log Like	ψ_{2009}	ψ_{2010}	ψ_{2011}
ψ(2009)γ(yr)ε(.)p(.)	391.93	0.00	0.199	1.000	5	381.78	0.016 ± 0.012	0.160 ± 0.041	0.175 ± 0.042
ψ(2009)γ(.)ε(.)p(survey)	392.14	0.21	0.179	0.900	12	367.37	0.166 ± 0.109	0.161 ± 0.047	0.157 ± 0.038
ψ(2009)γ(.)ε(.)p(.)	392.62	0.69	0.141	0.708	4	384.52	0.019 ± 0.013	0.117 ± 0.023	0.186 ± 0.040
ψ(2009)γ(yr)ε(yr)p(.)	392.78	0.85	0.130	0.654	6	380.58	0.017 ± 0.012	0.163 ± 0.041	0.189 ± 0.036
ψ(2009)γ(.)ε(.)p(yr)	393.61	1.68	0.086	0.432	6	381.41	0.149 ± 0.105	0.162 ± 0.048	0.172 ± 0.043
ψ(2009)γ(.)ε(yr)p(.)	394.18	2.25	0.065	0.325	5	384.03	0.016 ± 0.011	0.111 ± 0.022	0.189 ± 0.040
ψ(2009)γ(yr)ε(.)p(survey)	394.27	2.34	0.062	0.310	13	367.37	0.012 ± 0.008	0.161 ± 0.047	0.157 ± 0.038
ψ(2009)γ(yr)ε(yr)p(survey)	395.12	3.19	0.040	0.203	14	366.08	0.012 ± 0.008	0.154 ± 0.044	0.161 ± 0.040
ψ(2009)γ(yr)ε(.)p(yr)	395.68	3.75	0.031	0.153	7	381.41	0.191 ± 0.075	0.162 ± 0.048	0.172 ± 0.044
ψ(2009)γ(.)ε(yr)p(survey)	395.84	3.91	0.028	0.142	13	368.94	0.012 ± 0.008	0.109 ± 0.022	0.192 ± 0.048
ψ(2009)γ(yr)ε(yr)p(yr)	396.36	4.43	0.022	0.109	8	380.01	0.846 ± 0.048	0.155 ± 0.048	0.179 ± 0.050
ψ(2009)γ(.)ε(yr)p(yr)	396.71	4.78	0.018	0.092	7	382.44	0.030 ± 0.062	0.114 ± 0.023	0.213 ± 0.056
Model averaged estimates							0.124 ± 0.069	0.144 ± 0.007	0.178 ± 0.005
Weighted model averaged estimates							**0.078**	**0.149**	**0.175**
Naïve estimate							0.011	0.098	0.116

K = number of parameters

Table B5. Model selection and maximum likelihood estimates of occupancy (ψ) ±1 SE for soras detected in New York 2009-2011. Model-averaged estimates of detection probability were 0.063 in 2009 0.201 in 2010 and 0.111 in 2011.

Model	AICc	ΔAICc	AIC wgt	Model Likelihood	K	2*Log Like	ψ_{2009}	ψ_{2010}	ψ_{2011}
ψ(2009)γ(yr)ε(.)p(.)	323.51	0.00	0.309	1.000	5	313.36	0.029 ± 0.022	0.305 ± 0.120	0.156 ± 0.069
ψ(2009)γ(.)ε(.)p(yr)	324.38	0.87	0.200	0.647	6	312.18	0.202 ± 0.859	0.241 ± 0.094	0.250 ± 0.181
ψ(2009)γ(yr)ε(yr)p(.)	325.34	1.83	0.124	0.401	6	313.14	0.029 ± 0.023	0.305 ± 0.121	0.158 ± 0.070
ψ(2009)γ(.)ε(.)p(.)	325.58	2.07	0.110	0.355	4	317.48	0.029 ± 0.023	0.244 ± 0.117	0.233 ± 0.092
ψ(2009)γ(.)ε(yr)p(yr)	326.01	2.50	0.089	0.287	7	311.74	0.093 ± 0.481	0.229 ± 0.081	0.335 ± 0.222
ψ(2009)γ(yr)ε(.)p(yr)	326.44	2.93	0.071	0.231	7	312.17	0.559 ± 0.541	0.240 ± 0.095	0.253 ± 0.196
ψ(2009)γ(.)ε(yr)p(.)	327.11	3.60	0.051	0.165	5	316.96	0.038 ± 0.029	0.259 ± 0.117	0.220 ± 0.089
ψ(2009)γ(yr)ε(yr)p(yr)	328.05	4.54	0.032	0.103	8	311.70	0.766 ± 0.097	0.235 ± 0.097	0.299 ± 0.276
ψ(2009)γ(.)ε(.)p(survey)	330.90	7.39	0.008	0.025	12	306.13	0.322 ± 0.842	0.229 ± 0.087	0.211 ± 0.142
ψ(2009)γ(.)ε(yr)p(survey)	332.66	9.15	0.003	0.010	13	305.76	0.160 ± 0.454	0.212 ± 0.074	0.325 ± 0.216
ψ(2009)γ(yr)ε(.)p(survey)	333.00	9.49	0.003	0.009	13	306.10	0.602 ± 0.574	0.227 ± 0.089	0.218 ± 0.166
ψ(2009)γ(yr)ε(yr)p(survey)	334.65	11.14	0.001	0.004	14	305.61	0.779 ± 0.085	0.221 ± 0.085	0.259 ± 0.236
Model averaged estimates							0.301 ± 0.086	0.246 ± 0.009	0.243 ± 0.016
Weighted model averaged estimates							**0.136**	**0.268**	**0.215**
Naïve estimate							0.011	0.109	0.058

K = number of parameters

APPENDIX C

Frequency of focal species detection/nondetection among vegetation height and density classes

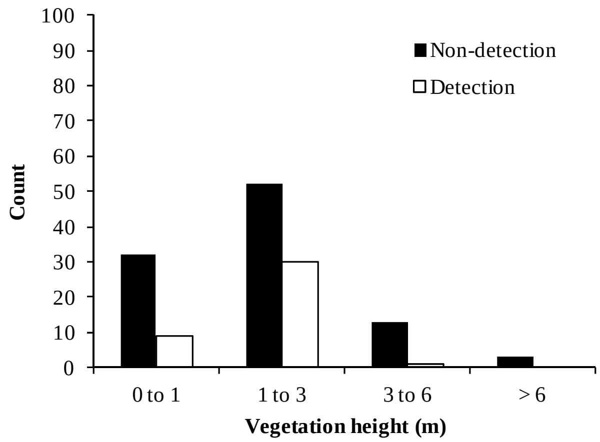

Figure C1. Vegetation height at Virginia rail detection nondetection sites, 2010.

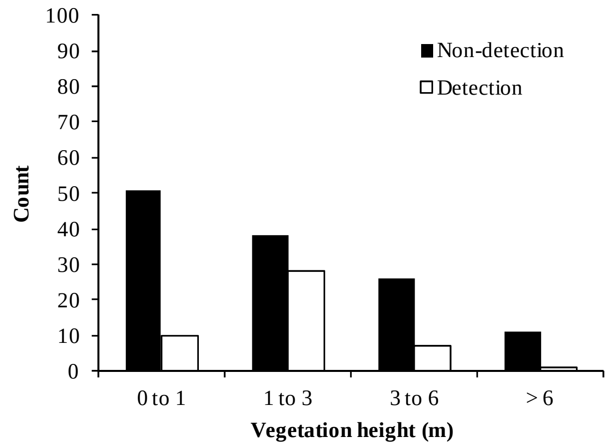

Figure C2. Vegetation height at Virginia rail detection/nondetection sites, 2011.

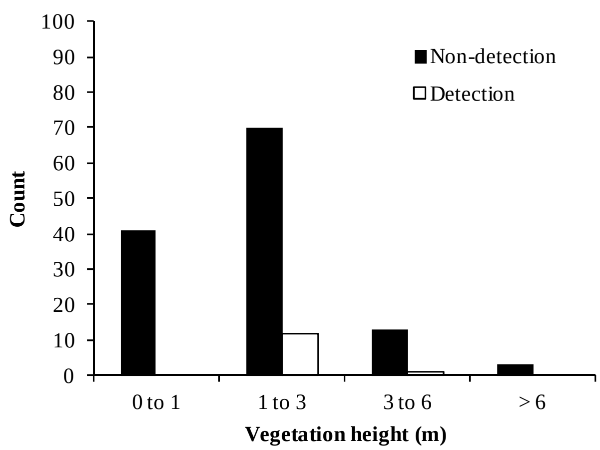

Figure C3. Vegetation height at American bittern detection/nondetection sites, 2010.

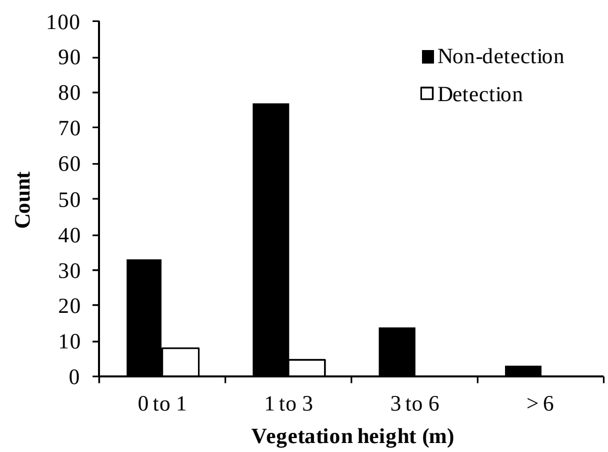

Figure C4. Vegetation height at sora detection/nondetection sites, 2010.

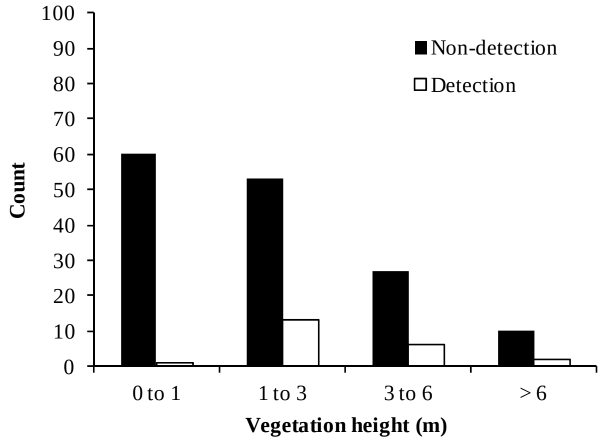

Figure C5. Vegetation height at least bittern detection/nondetection sites, 2011.

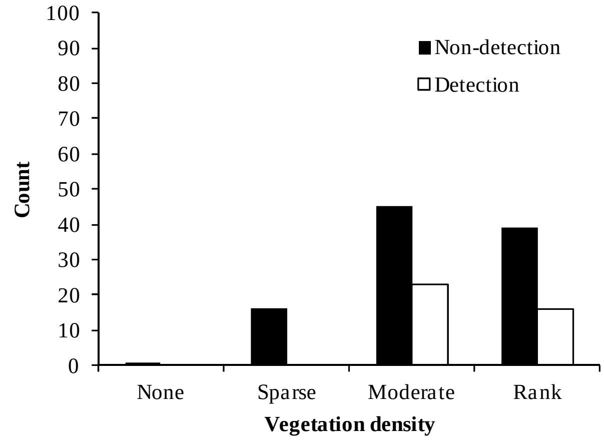

Figure C6. Vegetation density at Virginia rail detection/nondetection sites, 2010.

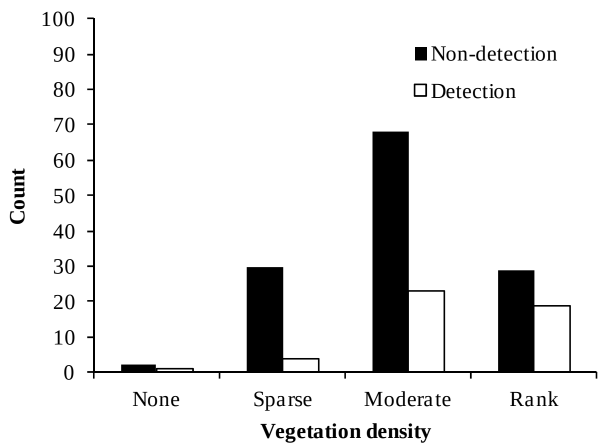

Figure C7. Vegetation density at Virginia rail detection/nondetection sites, 2011.

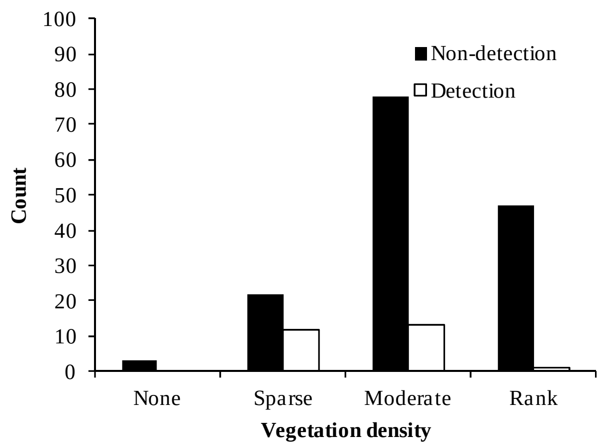

Figure C8. Vegetation density at pied-billed grebe detection/nondetection sites, 2011.