Marshbird Response to Invasive Cattail Control Using Grazing, Mowing, and Herbicide Application in the Prairie Pothole Region of Minnesota[1]

Final Report[2]

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Marshbird Response to Invasive Cattail Control Using Grazing, Prescribed Burns, and Herbicide Application in the Prairie Pothole Region of Minnesota

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Abstract: Many secretive marshbirds are difficult to detect, and existing avian survey methods (e.g., Breeding Bird Surveys) do not provide reliable estimates of population size or trends. Recently developed standardized survey protocols for secretive marshbirds provide a framework for evaluating responses of this group of birds to vegetation management and for assessing their distribution and abundance. In 2015 and 2016 we used the Standardized North American Marsh Bird Monitoring Protocol to evaluate differences in marshbird abundance and occurrence associated with different management strategies to control invasive wetland vegetation on public lands in west-central and northwestern Minnesota. At our west-central Minnesota study area, we evaluated management histories from 2000 to 2014 to group wetlands into 4 treatment categories: low frequency fire (n = 48), moderate frequency fire (n = 31), high frequency management with fire and grazing (n = 34), and other high frequency management (i.e., frequent management through grazing, fire, or a combination of grazing and fire; n = 14). At each of these wetlands we conducted 2 marshbird surveys each year and characterized vegetation structure and composition. We detected 596 birds of the 6 species for which we broadcasted vocalizations; sora (*Porzana carolina*) detections comprised 41% of all detections. We observed only weak patterns in marshbird abundance related to treatment category, and are evaluating potential relationships between marshbird abundance and vegetation characteristics and other attributes of individual wetlands. At our northwestern Minnesota study area, we evaluated the effects of herbicide treatment on invasive cattails (*Typha angustifolia* and *Typha x glauca*) by conducting marshbird surveys at treatment locations (n = 9, with 28 survey points) before and after application, and at paired control sites

(*n* = 9 with a total of 28 survey points). We detected 835 individuals of the 6 species for which we broadcasted vocalizations; 41% of detections were of American bitterns (*Botaurus lentiginosus*). Our analyses of marshbird counts related to treatment (spray versus control) suggest no difference in marshbird abundance the spring following herbicide application. However, we caution that a response of marshbirds to herbicide application is likely to take more than a single season. Overall, we conclude that secretive marshbird abundance is likely more strongly related to vegetation and other characteristics of wetlands than to treatment with grazing and fire (Morris study area) and that marshbirds do not immediately respond to herbicide application to control invasive cattails (northwestern Minnesota study area).

Secretive marshbirds, including rails, bitterns, and snipe, are arguably the least monitored group of North American birds due to their cryptic behavior and low detectability in dense wetland vegetation. Existing broad-scale monitoring programs such as the North American Breeding Bird Survey do a poor job monitoring these species (see Ribic et al. 1999). Over the past 15 years, stakeholders have made considerable progress in developing effective monitoring strategies (Seamans et al. 2013). Conway (2011) developed a standardized protocol for conducting marshbird surveys, and Johnson et al. (2009) recommended a sampling framework. The Association of Fish and Wildlife Agencies' Migratory Shore and Upland Game Bird Support Task Force identified developing a national marshbird monitoring program as a high priority (Case and Associates 2009). At the most recent National Marshbird Workshop held in 2011, participants endorsed moving away from a general North American Breeding Bird Survey-type monitoring program, which does not allow for reliable estimates of marshbird population trends, toward an explicit management-based monitoring program that evaluates marshbird response to management actions (Seamans et al. 2013). Since the 2011 workshop, the Midwest Marshbird Monitoring Working Group has begun to identify research questions to guide marshbird monitoring in the Midwest (Midwest Marshbird Monitoring Working Group, unpublished document 2013). One question the working group identified was, "Does control of invasive wetland plants increase marshbird use compared to uncontrolled sites and what techniques or resulting conditions maximize wetland use by marshbirds?" Our research addresses this question by focusing on investigating marshbird response to management of invasive vegetation in the Prairie Pothole Region of Minnesota.

The Prairie Pothole Region, an important breeding area for many marshbird species, is facing serious threats, including wetland loss through drainage and conversion of grassland to agricultural uses and land-management practices that negatively impact wetlands (Dahl and Johnson 1991). Both remnant and restored natural areas are experiencing alteration of habitat quality primarily caused by invasive vegetation (Mulhouse and Galatowitsch 2003). Narrow-leaf (*Typha angustifolia*) and hybrid (*Typha x glauca*) cattail, along with reed canary grass (*Phalaris arundinacea*), have dramatically changed the character of many western Minnesota wetlands. These invasive species form dense monotypic stands that reduce plant diversity and change the vegetative structure in both the emergent and wet meadow zones of prairie wetlands. Invaded wetlands are often characterized by low plant diversity, structural homogeneity, limited interspersion of vegetation and water, and no mudflats (Tuchman et al. 2009, Spyreas et al. 2010). High nutrient and sediment inputs from the surrounding agricultural landscape have likely assisted invasion of wetlands by these species (Svenqsouk and Mitsch 2001, Martina and von Ende 2008). Due to the concern about the effects of invasive wetland vegetation on marshbirds, the Midwest Marshbird Monitoring Working Group has hypothesized that the alteration of wetland vegetation and structure due to invasive species may reduce use of wetlands by breeding marshbirds in the Midwest.

Some information exists regarding habitat preferences of secretive marshbirds, generally indicating that structure, including diversity of vegetation height and density, is related to bird occupancy and reproduction. According to species accounts in Tacha and Braun (1994), rails and snipe typically prefer an interspersion of water and emergent vegetation, open mudflats, a roughly 50:50 emergent-vegetation-to-open-water ratio, and relatively low stem densities. Yellow rails (*Coturnicops novebaracensis*) are known for their preference for sedge wetlands (Goldade et al. 2002); they also nest in grasses, rushes, and bulrushes, and prefer to nest at sites with shallow water depths (0-11 cm, Austin and Buhl 2013). Soras (*Porzana carolina*) prefer to nest in cattails, but near borders with other vegetation types or adjacent to open water (Melvin and Gibbs 1994), and are often documented nesting in relatively short vegetation (Lor and Malecki 2006). Soras and Virginia rails (*Rallus limicola*) both appear to be positively associated with dispersion of vegetation types (Rehm and Baldassarre 2007). Similarly, Virginia rails prefer heterogeneous habitats with high perimeter-to-area ratios (Conway and Eddleman 1994) and are often absent from wetlands without shallow-water pools or mud flats. Virginia rails appear to select wetlands with tall, robust stands of emergent vegetation during the breeding season (Harms and Dinsmore 2013). However, they also avoid sites that are 100% emergent vegetation (Johnson and Dinsmore 1986), and show a strong negative association with percent cover of reed canary grass (Glisson et al. 2015). Pied-billed grebes (*Podilymbus podiceps*), American bitterns (*Botaurus lentiginosus*), and least bitterns (*Ixobrychus exilis*) typically prefer to nest in larger and deeper wetlands, especially sites with low percent cover of woody vegetation (Glisson et al. 2015; Harms and Dinsmore 2013). Currently, many wetlands across western Minnesota are considered to be of poor quality from a wildlife habitat perspective due to lack of diversity and heterogeneity of vegetation types resulting from invasive vegetation. As such, these wetlands may support fewer secretive marshbirds than they might if habitat quality were higher.

Federal and state agencies in Minnesota rely on a variety and combination of tools in ongoing management efforts to control invasive cattails and reed canary grass. Prescribed burns can remove thatch from previous years' growth, thus exposing open water and creating mudflats for species that probe for invertebrates, such as Wilson's snipe (*Gallinago delicata*) and Virginia rail. In addition, cattle watering in wetlands and grazing on early spring growth can affect vegetation in these cover types, largely through hoof action as cattle walk back and forth to the water, mechanically breaking down the vegetation. Such physical disturbance can potentially fragment invasive vegetation, creating a more heterogeneous cover-type composition. Other grazing animals such as goats forage on a diversity of herbaceous and woody vegetation, making them extremely efficient at clearing areas of undesirable vegetation. Management agencies have continued to develop conservation grazing as a management tool for Prairie Pothole wetlands and have found that combining grazing with prescribed burning can be successful in reducing cover of undesirable plant species (Sojda and Solberg 1993). Another long-utilized tool to combat invasive cattail is foliar herbicide application. Chemical control of cattails using glyphosate has proven useful in breaking up large, dense, monotypic stands, allowing a more heterogeneous interspersion of emergent vegetation and open water (Linz and Homan 2011). Widespread herbicide application is typically administered by aircraft, whereas smaller area application is performed using a tank sprayer from airboat or amphibious vehicle in the wetland or using a backpack sprayer.

Our project follows the guidance of the marshbird monitoring community and aims to evaluate the effects of invasive vegetation management on marshbirds in 2 study areas within the Prairie Pothole Region of Minnesota. We addressed a separate question related to marshbird response to control of invasive wetland vegetation in each study area. In west-central Minnesota, our objective was to evaluate whether there is a relationship between marshbird abundance and management history of prescribed burning and grazing, across a range of management intensity. In northwestern Minnesota, our objective was to evaluate whether there was a response of marshbirds to fall herbicide treatment of invasive cattails in wetlands. We focused on marshbird species known to occur in the region, including pied-billed grebe, American bittern, least bittern, yellow rail, Virginia rail, and sora.

Study Areas

One of our study areas was located in west-central Minnesota (hereafter, Morris study area), and the other study area was in northwestern Minnesota (hereafter Northwest MN study area). Both of these study areas included portions of the 36 core areas outlined in the Minnesota Prairie Conservation Plan (Minnesota Prairie Plan Working Group 2011; hereafter, Prairie Plan) as landscapes that have important conservation value because of their relatively high proportion of natural land cover. The Prairie Plan Working Group is a multi-agency/non-governmental organization effort to conserve remaining native prairies across Minnesota, increase prairie-dependent wildlife populations, and integrate working lands (e.g., pastures) into wildlife conservation. Together the 36 core areas currently protect 647,497 ha across the state, which capture 71% of Minnesota's remaining native tallgrass prairie and Prairie Pothole ecosystems. Similarly, our 2 study areas are designated as Minnesota Important Bird Areas (IBAs), which are areas deemed to be significant for the long-term viability of indigenous bird populations across the state (National Audubon Society 2013).

The Morris study area intersects portions of the Big Stone Moraine, Lac Qui Parle Prairie, Residorah, and Glacial Lakes core areas of the Prairie Plan (Fig. 1), and the Lac Qui Parle IBA overlaps much of the western portion of the study area. Survey locations in our Morris study area were on properties and easements managed by the U.S. Fish and Wildlife Service (USFWS), Morris Wetland Management District (Morris WMD) and Big Stone National Wildlife Refuge. Morris WMD oversees an array of 245 waterfowl production areas (WPAs) across an 8-county area as part of the USFWS National Wildlife Refuge System. Together, the WPAs encompass 21,047 ha, and Morris WMD holds permanent easements with partners to protect an additional 13,355 ha, providing blocks of natural cover types for resident and migratory wildlife within an otherwise predominantly agricultural matrix.

Wetlands throughout the Morris study area are typically small, shallow, and seasonally flooded. Many are choked with invasive vegetation, and are heavily influenced by the surrounding land use (Fig. 2). Most of the landscape is annual row crop agriculture, and several of the wetlands on WPAs have been restored from historical ditching and drainage (Fig. 3). The protected wetlands of WPAs are important to watershed hydrology for flood retention, and they provide nesting and foraging habitat to a diversity of bird species. In the 2012 Habitat Management Plan, Morris WMD managers identified the goal of maintaining temporary and semi-permanent marshes with a wetland plant community composed of <50% cover by invasive species (U.S. Fish and Wildlife Service 2012). Prescribed burns and conservation grazing are tools used in tandem to achieve this goal. These management activities are effective in the general maintenance of wetlands (Santisteban 2011), but it is unclear whether they can reduce the impacts of invasive vegetation and affect vegetation composition and interspersion of cover types from an already invaded and choked condition. Our study investigates the effects of invasive vegetation treatments on marshbirds, so that we may inform managers which treatments are most successful in creating and improving vegetation conditions that support marshbirds.

Our Northwest MN study area included portions of the Aspen Parkland, Thief Lake, and Pembina Prairie core areas identified in the Prairie Plan (Fig. 1). Minnesota Audubon recognizes the 4 IBAs of Kittson-Roseau Aspen Parkland, Thief Lake, Agassiz National Wildlife Refuge (NWR), and Goose Lake Swamp that include portions of our study area. Our research focused on large impounded wetlands of wildlife management areas (WMAs) managed by the Minnesota Department of Natural Resources (DNR). The state of Minnesota manages 1,440 properties in public wildlife areas comprising over 526,092 ha. These lands are important for their high value as wildlife habitat, natural landscape, and recreation land for hunting, fishing, and other activities. Our Northwest MN study area included the 8 WMAs of Roseau River, Beaches Lake, Twin Lakes, East Park, Thief Lake, Eckvoll, Elm Lake, and Pembina. Together these WMAs comprise 83,387 ha across 4 counties of northwestern Minnesota.

The landscape of our Northwest MN study area has low relief and wetlands are typically large, shallow, and impounded by levees, where water levels are managed with water control structures. These impounded wetlands are important for migratory waterfowl that use emergent and shrub wetland vegetation. Site managers at WMAs use a variety of tools in managing vegetation at their sites, including water level manipulation, dredging, discing and mowing, and herbicide application. When managing invasive cattails in these wetlands their goal is often to break the dense stands of cattail into a heterogeneous emergent and open water cover type that is attractive to a variety of wildlife. Our study investigates how marshbird abundance is related to herbicide application on impoundments dominated by dense cattails.

Study design

In our Morris study area, we examined how management history (i.e., the frequency of treatment using prescribed burning and grazing) was related to marshbird abundance and occurrence. We surveyed marshbirds at a range of wetlands, from those embedded in landscapes that experienced high frequency management, to wetlands embedded in landscapes that experienced less frequent or no management. We hypothesized that management history influenced composition and structure of wetland vegetation, which in turn influenced marshbird occurrence and abundance. In our Northwest MN study area, we evaluated the relationship between marshbird occurrence and abundance and herbicide application to control invasive cattails. We surveyed marshbirds during the spring breeding season before herbicide application in fall 2015, and surveyed the same sites again during the spring following application. We paired each spray site with a comparison control site. We hypothesized that marshbird occurrence and/or abundance would change in wetlands following herbicide treatment.

Managers at Morris WMD use tools of prescribed burning and grazing to control invasive vegetation. Prescribed burning is conducted as often as every 3-5 years, and grazing is typically implemented on a site for 3-5 consecutive years. Managers have observed the greatest success in controlling invasive vegetation when they apply prescribed burning and grazing combined on the landscape. The effects of both prescribed burning and grazing on invasive emergent vegetation are thought to diminish within 15 years of treatment (Linz and Homan 2011). Therefore, we considered the recent management history from 2000 to 2014 of prescribed burning and grazing to define treatment categories.

Using a GIS and the 15-year management history database from Morris WMD, we defined 4 treatment categories related to management intensity. With the assumption that effects from older treatments were less apparent on the current landscape than those from more recent treatments, we divided records from the 15-year management history into 2 periods: 2000-2010 (period 1) and 2011-2014 (period 2). We defined management histories with a low frequency of actions (≤2 incidents of burning in period 1, ≤1 burn in period 2, and no grazing during either period) as Low treatment intensity. We defined management with a moderate frequency (2 incidents of burning in period 1, 1 burn during period 2, and no grazing during either period) as Moderate treatment intensity. We defined high frequency of management action (≥2 incidents of burning during period 1, ≥1 burn in period 2, and ≥1 incidents of grazing total for periods 1 and 2) as High treatment intensity. An additional category captured management histories with other types of high frequency management actions with varying combinations of burning and grazing (≥1 burn and ≥1 incident of grazing, with total ≥4 actions); we defined this category as Other high treatment intensity. The first 2 categories included only fire as the management tool, the third category included both fire and grazing, and the last category represented areas with the highest intensity of vegetation management activities on Morris WMD.

Using a GIS, we identified areas within the Morris study area WPAs that met the definitions of our 4 treatment categories; within these areas we identified individual wetlands as potential survey locations. Following the classifications of Stewart and Kantrud (1971) used by the National Vegetation Classification Standard (NVCS) GIS dataset, we categorized wetlands by type to account for potential differences in vegetation associated with seasonality of hydroperiod; we considered temporary (type 2), seasonal (type 3), and semi-permanent (type 4) wetland types in our study. We assumed stratification by wetland type also accounted for differences in wetland size, because type and size are correlated, where type 2 and type 3 wetlands tend to be smaller than type 4 wetlands. Typically, there were multiple wetlands within an area included within a single treatment category (Fig. 4). We randomly selected target wetlands to survey within an individual treatment area and across wetland types. We followed the protocol described by Conway (2011) to establish 1 survey point at each target wetland, in the uplands adjacent to each wetland, at a vantage point near the wetland edge. Survey points were >400 m from one another to reduce the possibility of detecting the same birds from different survey points. We grouped 5-9 survey points together that included areas in each of our 4 treatment categories and all 3 wetland types into a route that we could survey in a single evening or morning; we organized 16 routes of 127 survey points throughout the Morris study area. This design allowed us to control for spatial variation in factors that could influence bird abundance (e.g., geophysical characteristics and weather conditions during surveys).

In 2016 we added 16 survey points in our Morris study area, as recent management activities resulted in additional wetlands that met our treatment category criteria (Table 1). Of the survey points added in 2016, we grouped 7 into a new route at Redhead Marsh (1 Low, 0 Moderate, 6 High, and 0 Other high sites), and added 8 points to already established routes of Artichoke Lake, Edwards, Hegland, Hillman, Pedersen, Stenerson Lake, and Twin Lakes (0 Low, 5 Moderate, 4 High, and 0 Other high sites). We replaced 1 Other high treatment point to prioritize survey time for 2 new High points on the Stenerson Lake Route.

At the Northwest MN study area, we investigated the response of marshbirds to 2 large-scale herbicide programs to control dense stands of invasive cattails. One effort was a cooperative Natural Resource Development Project, titled *Northwest MN DNR WMA's Cattail Spraying Project*, which contracted aerial aquatic glyphosate application to 1,215 ha in fall 2015 at Roseau River, Beaches Lake, Twin Lakes, East Park, Elm Lake, Eckvoll, Pembina, Manston, Florian, and Bejou WMAs. We did not include Florian or Bejou in the study because the cattail zones targeted for herbicide application were inaccessible for marshbird surveys. In addition, Manston was later removed from the study by DNR, due to alterations of the spray zone boundaries after we had completed our marshbird surveys. The second control effort was implemented at Thief Lake WMA, where managers completed ground application of imazapyr to 30 ha of invasive cattails in fall 2015.

In the Northwest MN study area, we evaluated 2 categories of treatment, herbicide application (Spray) and no herbicide application (Control). DNR site managers delineated areas of heavy cattail infestation within WMAs to be Spray zones, and we selected analogous wetland areas nearby to serve as comparison Control zones. Where possible, we chose Control zones within the same basin as the Spray zone, or in an adjacent basin as an alternative, and so that they had similar vegetation composition, density, and interspersion to their comparison Spray zones. We followed the protocol of Conway (2011) to establish survey points along the Spray and Control zones, in the uplands adjacent to each wetland at a vantage point near the wetland edge, often along a levee or management access road. Survey points were >400 m apart to minimize the possibility of detecting the same birds from different survey points. We grouped 4-8 survey points together into 9 routes, covering both Spray zones and Control zones for individual WMAs to allow us to control for spatial variation in factors that could influence bird abundance (e.g., geophysical characteristics and weather conditions during surveys).

Methods

Marshbird surveys:--We adapted the Standardized North American Marsh Bird Monitoring Protocol (Conway 2011) to conduct marshbird surveys across both study areas. In our study design we prioritized visiting a greater number of sites, rather than a greater number of visits per site, and made 2 visits, rather than the recommended 3 visits, to each survey point during the survey period each year. At the Morris study area we conducted surveys during 14 – 19 May and 30 May – 17 June in 2015, and again during 5 – 9 May and 20 – 27 May in 2016. At the Northwest MN study area we conducted surveys between 20 – 26 May and 8 – 13 June in 2015, and 15 – 17 May 2016 and 2 – 7 June 2016. We visited each survey point once during each survey period and therefore made 2 visits per year during each of 2 years, for a total of 4 visits per survey point. The standardized protocol (Conway 2011) recommended that a survey point be visited during the same period of the day; however, we adapted the protocol to conduct 2 visits within a year during alternate crepuscular periods to maximize detections of birds that have temporal differences in their calling behavior. Therefore, each year, we conducted 1 survey during the period around sunrise and 1 during the period around sunset.

At our Morris study area, our 2015 surveys consisted of a 10-minute period at each survey point. We used the call sequence provided by the National Marshbird Monitoring Program (Conway 2011, http://ag.arizona.edu/research/azfwru/NationalMarshBird/). The first 5 minutes of the survey were silent, followed by a series of 1-minute periods, consisting of 30 seconds of broadcasted call and 30 seconds of silence, for each of 5 target marshbird species, in the order: least bittern, sora, Virginia rail, American bittern, and pied-billed grebe. When conducting surveys on our Northwest MN study area, our survey protocol was similar to that in our Morris study area, with 5 minutes of passive listening, followed by 6 minutes of broadcasting calls of the same 5 species, with the addition of a yellow rail call (11 minutes total). Observers recorded details of all aural and visual detections of all target species, including bearing and distance estimate to a bird's location, and whether that location was inside or outside the target wetland. We also recorded counts for a number of non-target marshbird species, wind speed, wind direction, and ambient noise level during surveys, noted any disturbances, and listed additional bird species observed at or near the survey points. In 2016 we used the same 11-minute broadcast protocol at both the Morris and Northwestern MN study areas. The protocol for this study was approved by the University of Minnesota Institutional Animal Care and Use Committee (IACUC protocol #1503-32456A).

Vegetation assessments:--To understand the relationship(s) between vegetation management and marshbird abundance, we measured vegetative characteristics of the wetlands we surveyed for marshbirds. We conducted vegetation and cover-type assessments at the Morris study area during 1 July – 2 August 2015 at each of the 112 target wetlands. During 20 June – 28 July 2016 we conducted vegetation measurements at the 16 newly established target wetlands, and randomly selected 10 wetlands of each treatment category to reassess vegetation to evaluate the magnitude of annual variation in vegetation characteristics. At each target wetland we established transects into the wetland to measure vegetation composition and structure. From the marshbird survey point we selected a bearing, using a random number generator, heading into the wetland and estimated the intersection of that line with the edge of the wetland. We identified the edge as approximately halfway through the upland transition zone of vegetation where the predominance of reed canary grass (or plant species associated with uplands) began to transition to cattail (and other hydrophytic species). From this location, we walked a random number between 1 and 10 steps into the wetland and placed a Robel pole (300-cm pole marked in 10-cm increments, Robel 1970), and recorded distance from the pole to the bird survey point. We placed a 1.5-m pole at an observation point 4 m and 90 degrees away, randomly chosen left or right of the transect line, where we measured low and high visual obstruction, water depth or ground saturation, and recorded the number and species of plants touching in each half-meter section of the 1.5-m pole (a variation of the Step-Point Method [Evans 1957] to measure vegetation densities at different horizontal strata). Finally, we recorded all vegetation occurring between the 2 poles, along a path 1-m wide, identifying plants to at least family level, or lower taxonomic level when possible. We repeated these measurements at 10-m intervals along the transect until we had 5 observation points, the transect exited the wetland basin, or the transect entered water deeper than 1.5 m (chest-wader deep). If we measured <5 observation points along the initial transect, we established a second transect, using a different random bearing, to finish the assessment. To assess variation between years in vegetation, we randomly selected 10 survey points in each treatment category (40 survey points) where we measured vegetation in both 2015 and 2016. We used the same protocol as in 2015, and used the transect bearings and distances selected in 2015 to repeat measurements.

The large, deep, densely vegetated wetlands of our Northwest MN study area made vegetation assessments using this method impractical. Instead of measuring wetland vegetation, we delineated distinct cover types on the ground using handheld GPS units and sketched those representative cover types on aerial images. For each cover type we noted the dominant species, visually estimated percent cover, and photographed those locations to aid in subsequent aerial photo interpretation.

Aerial photography interpretation:--Our partners at USFWS obtained high quality aerial photographs for all of our survey wetlands during flights on 5 August 2016 in the Morris study area and 28 June 2016 in the Northwest MN study area. We have not yet analyzed these images, but anticipate using GIS and spatial imagery analysis methods to delineate broad cover-type categories (e.g., open water, cattail-dominated mats, sedge-meadow vegetation, etc.) and derive covariates to assess vegetation and landscape-scale relationships with secretive marshbird abundance.

Data analyses:--We evaluated the potential influence of vegetation management on marshbirds on our Morris study area by relating count data across treatment categories (i.e., Low, Moderate, High, and Other high). We hypothesized that vegetation management has influenced habitat conditions for marshbirds, and that this influence would be evident in the relationship between marshbird abundance and treatment category of management intensity. To account for different amounts of wetland cover (i.e., marshbird habitat) across survey points, and that the probability of an observer detecting a marshbird decreases over distance, we transformed the counts of marshbirds detected during surveys into a measure of bird density as a function of wetland area per point (Fig.8). We adjusted the maximum counts of each species per year by a factor that combined the amount of wetland area at the point and detection probability as a function of distance (Fig. 9). Using ESRI ArcGIS 10.2 (Environmental Systems Research Institute, Redlands, CA) we extracted wetland area estimates from digitized boundaries of palustrine emergent and shrub wetland cover types from the current National Wetland Inventory (NWI) for survey points in Big Stone, Swift, and Lac Qui Parle Counties. Current NWI data were unavailable for Traverse, Stevens, and Pope Counties, so we estimated area of wetland cover types at survey points within these counties using a combination of data from NVCS maps of USFWS properties, and from our manual updates of historical NWI polygons. We estimated the area of wetland cover types classified as type 2, 3, and 4 in NVCS, and added wetland area interpreted from aerial photos taken by USFWS in August 2016, and land cover imagery from U.S. Department of Agriculture National Agricultural Imagery Program imagery from 2013 and 2015, using methods described in the current NWI update. There was considerable rounding in observers' estimates of distance, so we assigned the detections to 23-m intervals to avoid typical rounding distances. We derived detection probability as a function of distance by summing all the detections, including those recorded before or after the official

11-minute survey period, of a species estimated within a distance interval across all survey points, and then dividing by the sum of wetland area within corresponding distance intervals across all survey points (Fig. 8). We applied the adjustment factors of detection probability to the maximum counts within each distance interval at each survey point for both 2015 and 2016. Finally, for each point, we summed the adjusted maximum counts across distances, out to a truncation distance unique to each species (described below), and divided this sum by the area of the target wetland within the truncation distance to derive an estimate of density by species for each point (Fig. 8).

Detection probability as a function of distance was monotonically declining for Virginia rails, soras, and pied-billed grebes, but not for American bitterns; we had too few observations of least bitterns to derive a detection function. We suspect that the presence of the observer influenced vocalization behavior of American bitterns close to the survey point; therefore, we excluded detections close to the observer (0-23 m), and used the remaining detection data to define a half-normal curve weighted by the estimated detection probability (Fig. 9) to estimate detection probability near the survey point.

We estimated the truncation distance for each species by evaluating several proposed approaches to estimate density: distance that contains 90% of detections (Buckland et al. 2001:151), twice the mean detection distance (Buckland et al. 2015:69), and the distance where detection probability = 0.1 (Buckland et al. 2001:151). We calculated adjusted density estimates using all 3 of these approaches (using weighted half-normal detection functions, as described above for American bitterns to estimate detection probability), which resulted in highly correlated density estimates. We therefore chose the simplest of these approaches (90% of detections) to derive a distance at which to truncate our detections and calculate density for each species.

To test the relationship of the bird abundance to management intensity, we created models with the estimated adjusted densities per point for each species as response variables as a function of treatment category. For each year, we used the maximum count of each species at each survey point to estimate density for that survey point for that year, and used the lme4 package in R (Bates et al. 2015, R Core Team 2017) to fit a generalized linear mixedeffects model with year as a random effect and treatment categories of Low, Moderate, and High as fixed effects. We did not include the "Other" treatment category in this model because that category is not additive to any other category, but instead report summary data related to bird abundance for that category (Table 3, Fig. 9).

The next step in our analyses is to assess relationships between marshbird abundance and vegetation and landscape characteristics. We have developed a preliminary list of covariates (Table 5) to consider in generalized linear models of estimated bird density as a function of vegetation and landscape covariates, and these models are currently being developed.

The experimental design at our Northwest MN study area was a before-after design with a control. We compared the difference between the number of marshbirds detected prior to and post fall 2015 herbicide application (i.e., marshbird detections in 2015 versus 2016) at Spray sites and to the difference between the number of marshbirds detected at Control sites in 2015 versus 2016 with a paired *t*-test (Table 7, Fig. 10). Similar to our analyses of data from our Morris study site, we will evaluate marshbird detections as a function of habitat characteristics that we derive from aerial photos and observations at survey points, potentially including proportion of open water to emergent vegetation, proportion of cattail and non-cattail emergent vegetation, amount of residual dead vegetation (following herbicide application), and available wetland cover types in the surrounding landscape.

Results

Marshbird surveys: During the 2015 field season in the Morris study area, 2 observers conducted 215 surveys. Observers recorded 553 bird detections of 8 species, including the 5 species for which we broadcasted calls, American coot (*Fulica americana*), Wilson's snipe, and black tern (*Chlidonias niger*). Observers detected target or non-target marshbird species in 165 (76.7%) of surveys and 266 individuals of species for which we broadcasted calls at target wetlands during surveys, including 111 at 47 Low treatment, 64 at 27 Moderate treatment, 56 at 23 High treatment, and 35 at 15 Other high treatment survey points. In 2016, 2 observers conducted 252 surveys. Observers recorded 1,153 bird detections of 15 species, including the 5 species for which we broadcasted calls, American coot, black tern, Wilson's snipe, red-necked grebe (*Podiceps grisegena*), western grebe (*Aechmophorus occidentalis*), green heron (*Butorides virescens*), black-crowned night heron (*Nycticorax nycticorax*), upland sandpiper (*Bartramia longicuada*), and yellow-headed blackbird (*Xanthocephalus xanthocephalus*). This large increase in the number of species detected in 2016 is not necessarily due to a higher number of species present in the second year, but rather due to observers including a wider range of species in their records. Observers detected target or non-target marshbird species on 227 (90.1%) surveys. We detected 389 individuals of species for which we broadcasted calls at target wetlands during surveys, including 178 at 47 Low, 61 at 33 Moderate, 115 at 33 High, 35 at 13 Other High treatment points.

Trends in abundance of marshbirds as a function of treatment category varied among species and between years (Fig. 9). American bitterns appeared to be more abundant in Medium and High treatment categories in 2015, but in 2016, appeared to be less abundant in Moderate versus Low and High treatment categories. Pied-billed grebes exhibited a decreasing pattern in abundance from Low through Medium and High treatment categories in both 2015 and 2016, with the pattern being much stronger in 2016 than in 2015. Soras appeared to have lower abundance in the Medium versus Low or High categories in both 2015 and 2016, whereas Virginia rails appeared to be most abundant in the Medium treatment category both years. Overall, abundances of all 4 species appeared to be higher in 2016 than in 2015 and there was considerable overlap among treatment categories, suggesting weak association between treatment category and marshbird abundance.

In 2015 at the Northwest MN study area 2 observers conducted 110 surveys at 55 survey points on 9 routes at 8 WMAs scheduled to receive herbicide treatment in fall 2015. Observers recorded 591 bird detections of 12 target or non-target marshbird species. Observers detected target or non-target marshbird species during 103 (93.6%) surveys. We detected 463 birds of species for which we broadcasted calls at target wetlands during surveys, including 220 at 59 Spray points, and 243 at 59 Control points. Herbicide application occurred at Spray sites in August – September 2015 at the Northwest MN study area; thus, surveys at Spray points in spring 2016 occurred post-treatment. Two observers conducted 118 marshbird surveys in 2016 and detected target or non-target marshbird species on 116 (98.3%) surveys. We detected 505 individuals of species for which we broadcasted calls at target wetlands during surveys, including 193 at 56 Spray points, and 312 at 56 Control points. The average number of detections per point for all target species (i.e., those for which we broadcasted calls) was 3.19 at Spray points and 4.17 at Control points (Table 7).

American bitterns and pied-billed grebes had lower counts at Spray sites compared to Control sites during both years, whereas soras showed slightly higher counts at Spray sites (Fig. 10). There were no consistent patterns between years in counts of least bitterns and Virginia rails between treatments. None of the differences in counts between years for any species at Spray and Control sites was statistically significant (Table 7).

Discussion

In our Morris study area, our results and analyses to date suggest only weak patterns between marshbird abundance and treatment category of management intensity. American bitterns exhibited weak within-year patterns in abundance related to treatment category, but these patterns were not consistent between years, suggesting that American bittern abundance is not related to management intensity. Pied-billed grebes exhibited a weak relationship with management intensity, with higher abundance of birds observed at wetlands with lower management intensity. Because pied-billed grebes are associated with wetlands with open water, we suspect that this weak relationship is likely a result of factors other than vegetation management, and may be explained by landscape-scale characteristics (i.e., the abundance of wetlands with open water in the surrounding landscape). Both Virginia rails and soras exhibited similar patterns in abundance between years, with Virginia rails most abundant at Moderate treatment wetlands, and soras most abundant at Low and High treatment wetlands. We suspect that these patterns are related to vegetation characteristics at survey wetlands, which may be related to management intensity. We anticipate furthering evaluating these relationships using models that incorporate vegetation and landscape-scale covariates.

In our Northwestern MN study area we did not see a difference in abundance of marshbirds between Spray and Control treatment categories. Counts of American bitterns and pied-billed grebes for both years were lower at Spray sites, perhaps indicating that they avoid areas dominated by cattails. However, we suspect that any association between secretive marshbird abundance and treatment to control invasive cattails in this system may take more than a single season to be apparent, as both Spray and Control sites are similar the spring following herbicide application (i.e., returning birds are confronted with dead mats of vegetation in both treatment categories the first spring following herbicide application). As the sprayed vegetation continues to decompose, dense mats will break up and sink, opening up patches of water and exposing areas for other plant species to germinate. As these changes progress, it is possible more birds will use these areas. To that end, we conducted additional marshbird surveys in our Northwest MN study area in 2017, and suggest that marshbird monitoring at these sites be continued.

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Tables

Table 1. Number of secretive marshbird surveys conducted, grouped by route and treatment category, in the Morris study area in west-central Minnesota during 2015 and 2016.

	2015					2016					
Route name	**Low[a]**	**Mod[b]**	**High[c]**	**Other[d]**	**Total**	**Low[a]**	**Mod[b]**	**High[c]**	**Other[d]**	**Total**	**Totals**
Artichoke Lake	5	0	0	6	11	6	0	2	6	14	25
Barry Lake	12	4	0	0	16	12	4	0	0	16	32
Benson Lake	6	6	4	0	16	6	6	4	0	16	32
Big Stone NWR	2	6	6	0	14	2	6	6	0	14	28
Edwards	4	10	2	0	16	4	13	1	0	18	34
Hegland	5	1	4	2	12	6	2	4	2	14	26
Hillman	0	0	6	7	13	0	0	8	7	15	28
Johnson	7	0	6	0	13	8	0	6	0	14	27
Kufrin	4	6	4	0	14	4	6	4	0	14	28
Mero	4	2	2	4	12	6	2	2	4	14	26
Pedersen	9	6	0	0	15	9	10	0	0	19	34
Prairie	6	6	0	0	12	6	6	0	0	12	24
RedHead	0	0	0	0	0	2	0	12	0	14	14
Rothi	6	4	4	0	14	6	4	4	0	14	28
Stenerson Lake	5	2	4	2	13	6	2	8	0	16	29
Twin Lakes	4	0	4	4	12	4	2	4	4	14	26
Westport	6	2	0	4	12	8	2	0	4	14	26
Totals	85	55	46	29	215	95	65	65	27	252	467

[a] Low treatment category included parcels that had <3 incidences of fire and no grazing during 2000-2014.

[b] Moderate treatment category included parcels that had ≥3 incidences of fire and no grazing during 2000-2014.

[c] High treatment category included parcels that had ≥3 incidences of burning and some grazing during 2000-2014.

[d] Other high treatment category was different from the other categories in that it included parcels that had ≥3 incidences of fire and grazing, in any combination during 2000-2014.

Table 2. Number of secretive marshbird surveys conducted per route at herbicide application (Spray) and reference (Control) zones in 2015 and 2016 on 8 large wetland complexes in northwestern Minnesota where herbicide was applied in fall 2015 to control cattails.

	2015			2016			Combined
Route name	**Control**	**Spray**	**Total**	**Control**	**Spray**	**Total**	**Total**
Beaches Lake	4	4	8	4	4	8	16
East Park	7	4	11	8	4	12	23
Eckvoll	4	8	12	4	8	12	24
Elm Lake	8	8	16	8	8	16	32
Manston	4	4	8	0	0	0	8
Pembina	8	8	16	8	8	16	32
Roseau River East	8	8	16	8	8	16	32
Roseau River West	4	4	8	4	4	8	16
Thief Lake	6	6	12	6	6	12	24
Twin Lakes	6	5	11	6	6	12	23
Total	59	59	118	56	56	112	230

Table 3. Mean and standard deviation (SD) of adjusted marshbird density per point by treatment category, for American bitterns (AMBI), pied-billed grebes (PBGR), soras (SORA), and Virginia rails (VIRA) for 2015 and 2016 at the Morris study area in west-central Minnesota.

2015

	Low		**Mod**		**High**		**Other**	
Species	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
AMBI	0.07	0.21	0.22	0.67	0.19	0.58	0.23	0.61
PBGR	0.17	0.33	0.16	0.58	0.09	0.49	0.07	0.24
SORA	1.83	3.38	1.04	2.26	2.18	4.81	2.05	2.75
VIRA	0.55	1.51	1.29	3.65	0.27	0.91	2.23	4.00

2016

	Low		**Mod**		**High**		**Other**	
Species	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
AMBI	0.32	0.21	0.16	0.67	0.49	0.58	0.35	0.61
PBGR	0.36	0.33	0.14	0.58	0.05	0.49	0.33	0.24
SORA	4.18	3.38	0.97	2.26	3.76	4.81	1.16	2.75
VIRA	1.27	1.51	1.57	3.65	1.34	0.91	0.89	4.00

Table 4. Parameter estimates, standard deviation (SD), and 95% confidence intervals (CI) for models of secretive marshbird abundance as a function of treatment category (Low, Moderate, and High) for American bitterns (AMBI), pied-billed grebes (PBGR), soras (SORA), and Virginia rails (VIRA) at the Morris study area in west-central Minnesota in 2015 and 2016.

	AMBI			PBGR		
Fixed	**Estimate**	**SD**	**CI**	**Estimate**	**SD**	**CI**
Intercept (Low)	0.19	0.08	0.04 – 0.35	0.26	0.05	0.16 – 0.36
Treatment (Mod)	0.00	0.10	-0.21 – 0.20	-0.11	0.08	-0.27 – 0.05
Treatment (High)	0.15	0.10	-0.05 – 0.35	-0.19	0.08	-0.35 – -0.03
Random						
Year	0.00	0.06		0.00	0.00	
Residual	0.42	0.64		0.26	0.51	

	SORA			VIRA		
Fixed	**Estimate**	**SD**	**CI**	**Estimate**	**SD**	**CI**
Intercept (Low)	3.00	0.72	1.59 – 4.42	0.92	0.30	0.34 – 1.51
Treatment (Mod)	-1.93	0.85	-3.59 – -0.27	0.51	0.37	-0.22 – 1.24
Treatment (High)	0.30	0.82	-1.31 – 1.92	-0.17	0.36	-0.88 – 0.54
Random						
Year	0.48	0.70		0.07	0.26	
Residual	27.00	5.20		5.23	2.29	

Table 5. Covariates (mean and standard deviation [SD]) of site and landscape-scale wetland characteristics used in modeling secretive marshbird abundance at the Morris study area in west-central Minnesota. We measured site-scale characteristics of vegetation structure and hydrology in the field during 2015 and 2016.

	Low		**Mod**		**High**		**Other**	
Characteristic	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Size of target wetland (HA; within 100 m)	1.09	0.55	0.94	0.43	0.76	0.28	0.83	0.48
Amount of wetland area (HA) within 600 m	28.36	14.84	32.68	12.64	29.92	13.25	27.90	9.10
Max height vegetation (cm)	121.81	41.69	112.82	45.15	101.55	39.67	103.85	54.07
Height dead vegetation (cm)	45.20	27.72	37.22	30.93	54.26	34.80	31.77	37.07
Range water depth (cm)	57.05	28.51	55.26	34.42	60.19	25.49	58.50	25.66
Proportion of plots where *Typha* present	0.59	0.32	0.43	0.30	0.55	0.34	0.34	0.33
Number of plant species recorded at wetland	14.70	6.27	18.33	8.38	16.67	8.03	15.93	5.94

Table 6. Sum of maximum number of detections of 5 species of secretive marshbirds at sites in northwestern Minnesota during surveys associated with herbicide application to control invasive cattails during 2015 and 2016. Maximum detections per year are summed for Spray (S) and Control (C) sites along each route for American bitterns (AMBI), least bitterns (LEBI), pied-billed grebes (PBGR), soras (SORA), and Virginia rails (VIRA).

	AMBI				LEBI				PBGR				SORA				VIRA			
	2015		2016		2015		2016		2015		2016		2015		2016		2015		2016	
Route name	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**	**S**	**C**
East Park	0	5	4	9	2	0	1	1	1	5	3	1	2	7	3	8	1	0	1	0
Eckvoll	1	1	15	11	0	0	0	0	1	2	0	0	4	5	12	4	0	1	3	3
Elm Lake	5	7	9	9	1	0	1	0	1	0	5	12	6	4	10	3	5	2	2	0
Pembina	5	12	6	12	7	3	1	1	0	1	2	2	14	11	10	6	3	5	1	3
Roseau River East	14	21	7	16	0	0	0	1	7	1	2	0	5	0	10	4	5	1	0	4
Roseau River West	6	8	8	6	0	0	0	1	2	4	0	3	6	2	4	4	1	1	2	0
Thief Lake	6	6	6	4	2	1	0	0	3	10	3	6	3	3	3	8	0	1	1	2
Twin Lakes	3	6	0	9	0	0	0	0	1	3	0	2	7	1	0	4	0	0	0	0
Total	43	69	57	81	13	6	4	4	16	26	15	28	53	42	58	55	16	12	11	20

Table 7. Paired *t*-test for the difference in means between Spray sites and Control sites of their difference in counts between 2015 and 2016 for 5 species of marshbirds (American bitterns [AMBI], least bitterns [LEBI], pied-billed grebes [PBGR], soras [SORA], and Virginia rails [VIRA]) in northwestern Minnesota.

	Mean count per point							95% Confidence Interval		
	2015		2016							
Species	**Spray**	**Control**	**Spray**	**Control**	**Diff in means**	***t*-stat**	**df**	**Lower**	**Upper**	**P-value**
AMBI	1.59	2.56	3.00	2.11	0.22	0.20	8	-2.35	2.79	0.85
LEBI	0.48	0.22	0.15	0.15	-0.78	-1.42	8	-2.04	0.48	0.19
PBGR	0.59	0.96	1.04	0.56	-0.33	-0.24	8	-3.53	2.86	0.82
SORA	1.96	1.56	2.04	2.15	-0.89	-0.46	8	-5.33	3.55	0.66
VIRA	0.59	0.44	0.74	0.41	-1.44	-1.22	8	-4.17	1.28	0.26

Figures

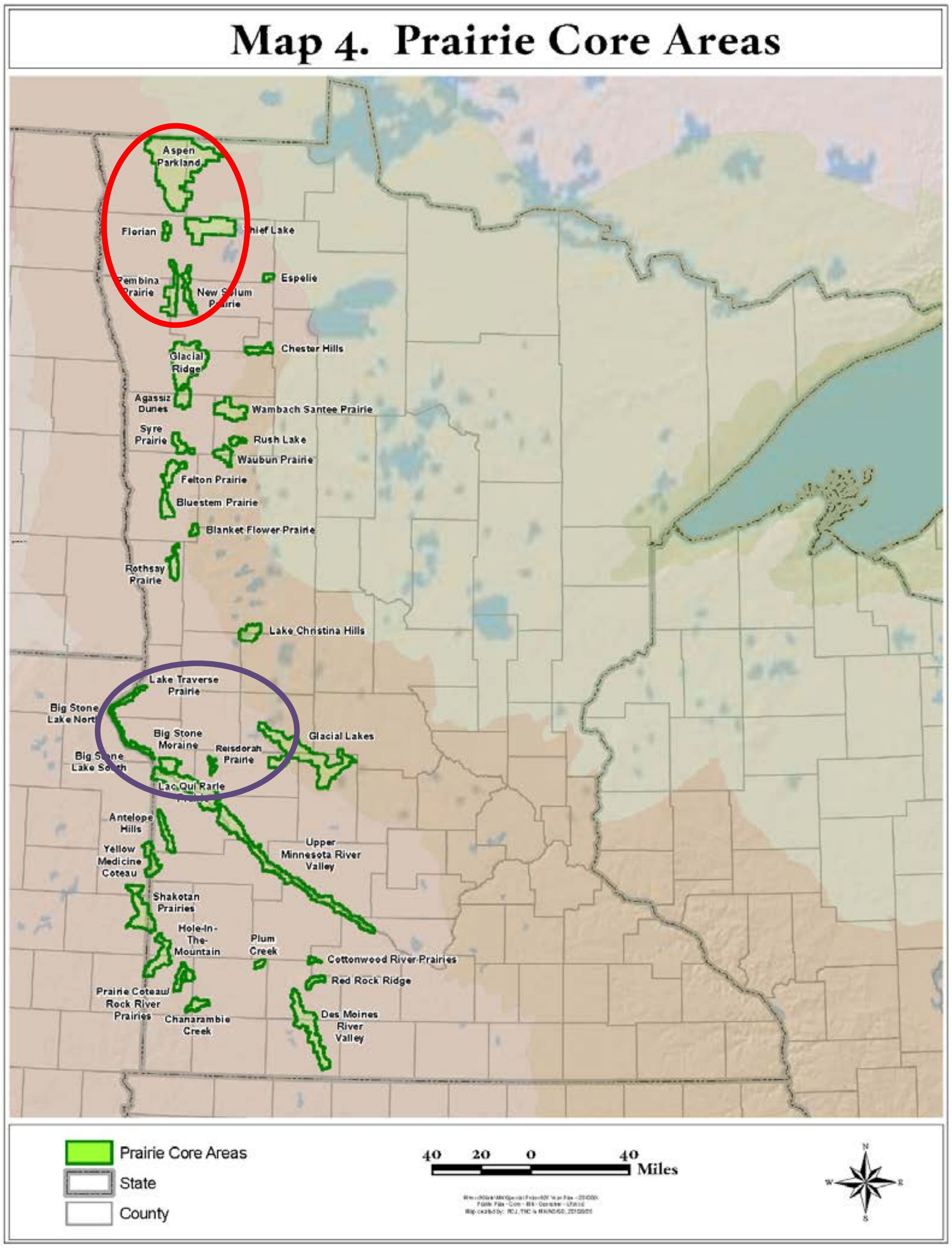

Figure 1. Figure taken from the Minnesota Prairie Conservation Plan highlighting the 36 core conservation areas (Minnesota Prairie Plan Working Group 2011). Our study included sites in the Aspen Parkland, Thief Lake, and Pembina Prairie cores areas as the NW Minnesota study area (circled in red), and Big Stone Moraine, Big Stone Lake South, Lac Qui Parle Prairie, Reisdorah Prairie, and Glacial Lakes core areas in the Morris study area (circled in purple).

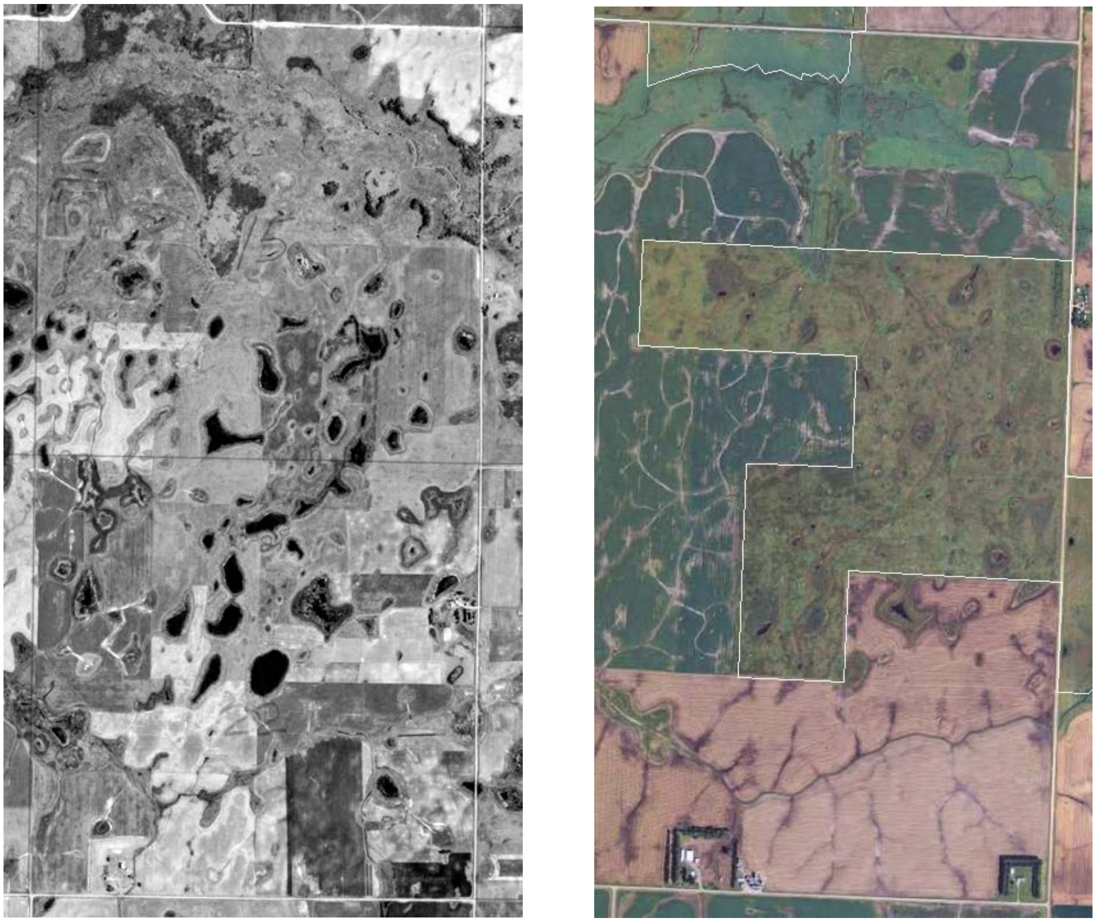

Figure 2. Images from the 1950s and 2010 of a half-section of land in Becker County Minnesota, immediately south of our NW Minnesota study area. In the 1950s most of the wetlands are open with just a fringe of cattail around the perimeter. In the 2010 image, Matter Waterfowl Production Area (WPA) is outlined in white. In this image, the wetlands on the surrounding private lands are almost all drained. The wetlands on the WPA are almost completely overgrown with hybrid cattail.

Figure 3. Syverson Waterfowl Production Area (WPA) in Becker County Minnesota. This 24.3-ha WPA has extensive wetlands but the wetlands are completely overgrown with hybrid cattails. A significant percentage of Minnesota wetlands are in this condition.

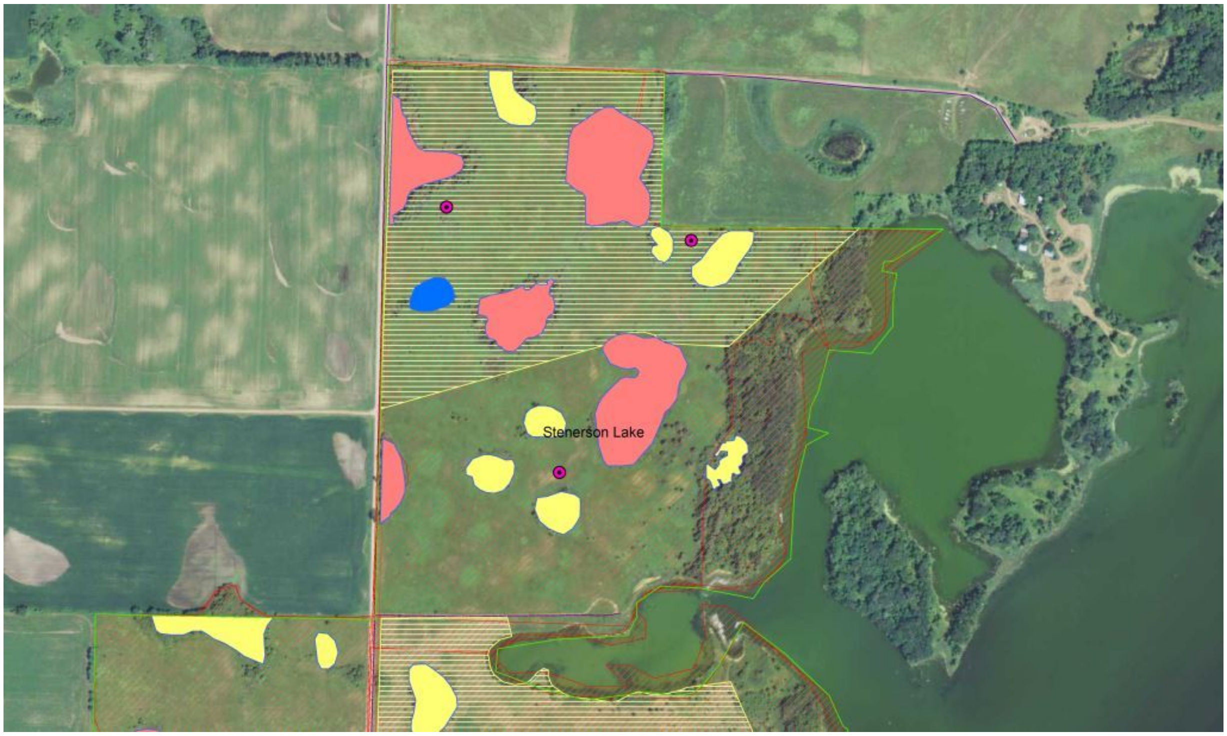

Figure 4. Stenerson Lake Waterfowl Production Area (WPA) in our Morris study area had multiple wetlands (red, blue, and yellow polygons) within multiple treatment units (red and yellow hatched polygons). Pink dots represent bird survey points.

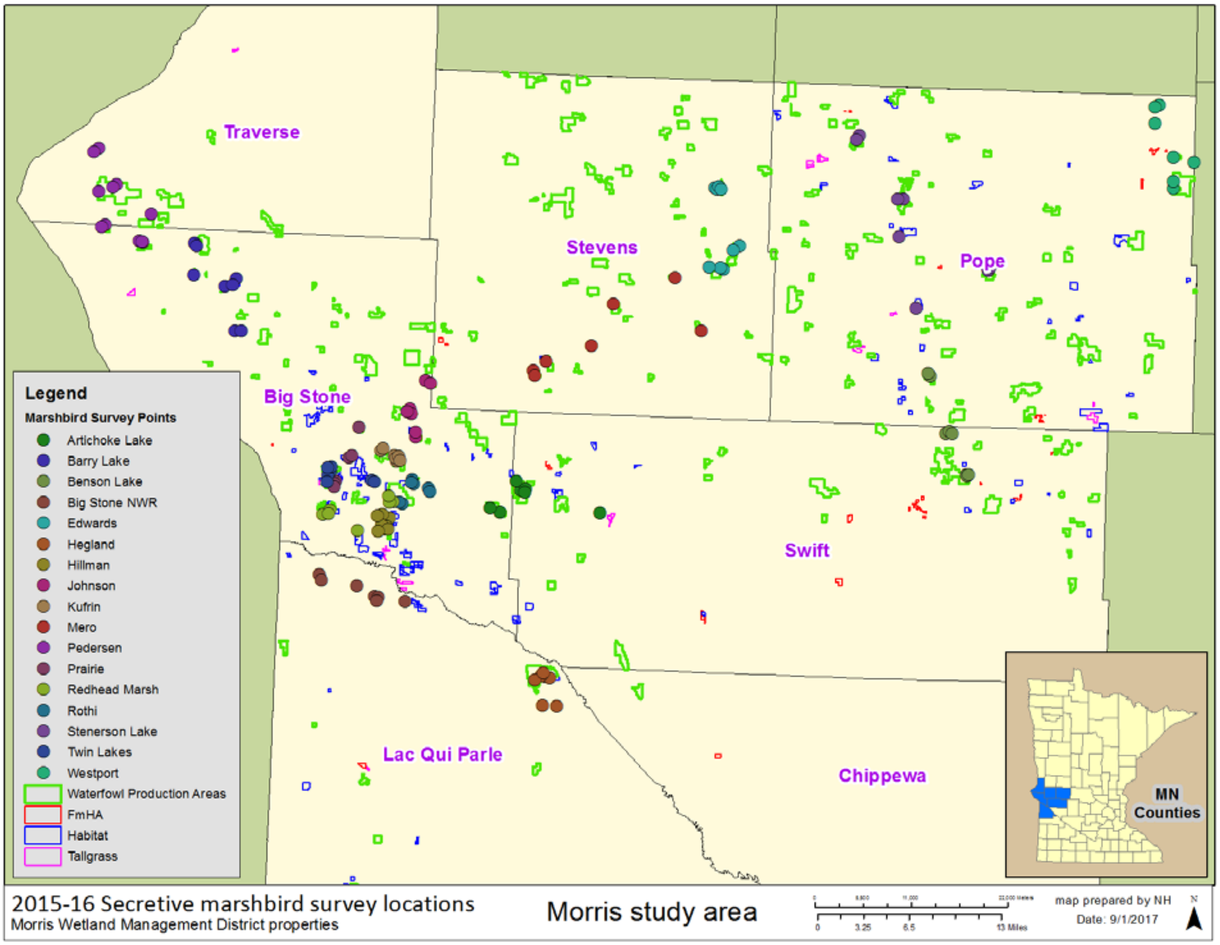

Figure 5. We conducted marshbird surveys at 112 survey points (point colors grouped by route) in 2015, and 127 survey points in 2016, in the Morris study area across west-central Minnesota on properties and easements owned by U.S. Fish and Wildlife Service Morris Wetland Management District.

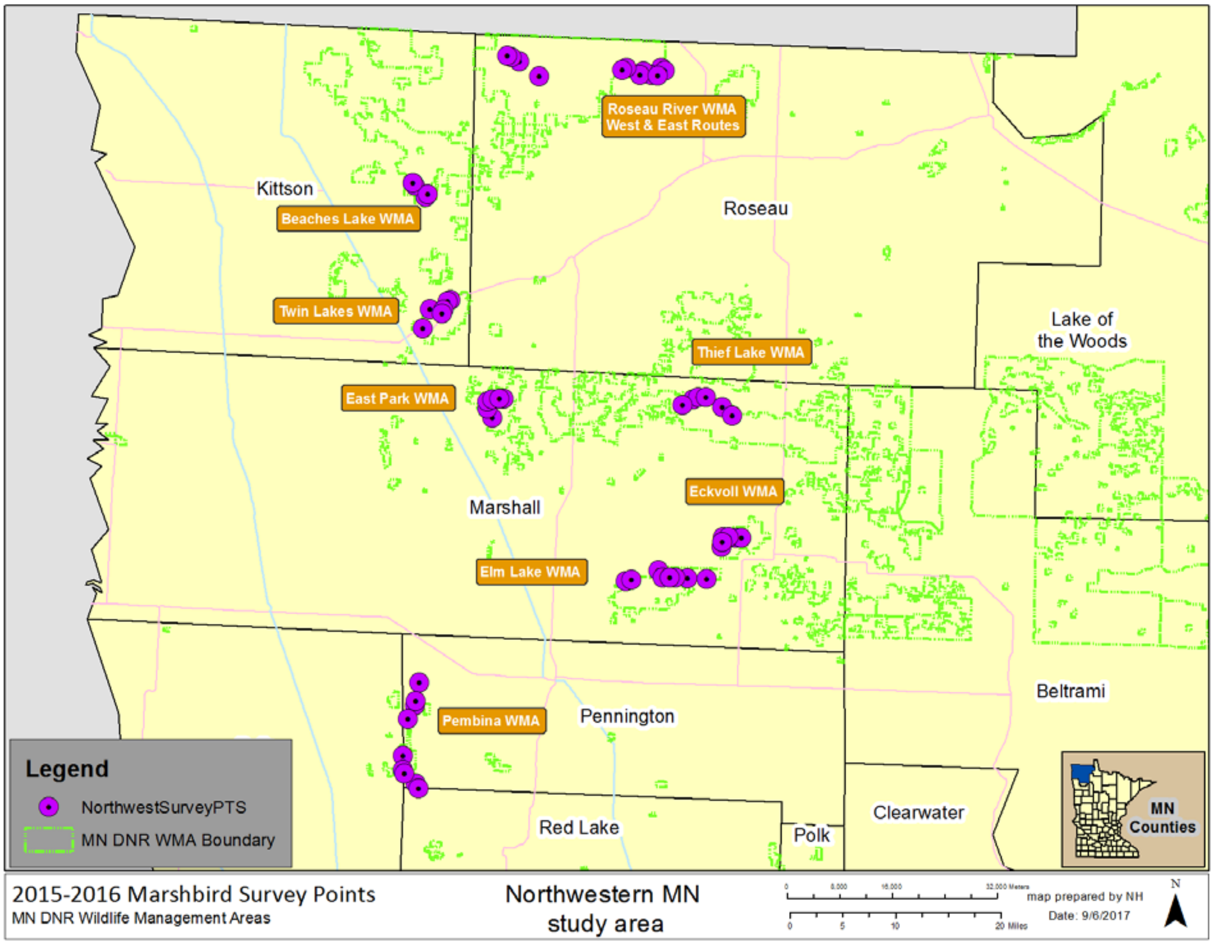

Figure 6. In 2015 and 2016 we surveyed 54 points (in purple) at 8 Minnesota Department of Natural Resources wildlife management areas (WMAs) across our northwestern Minnesota study area.

Figure 7. Route map of Eckvoll Wildlife Management Area (WMA), located in northwestern Minnesota, indicating the spray zones (yellow polygons) and survey points (blue dots). This route has 4 Spray points and 2 Control points.

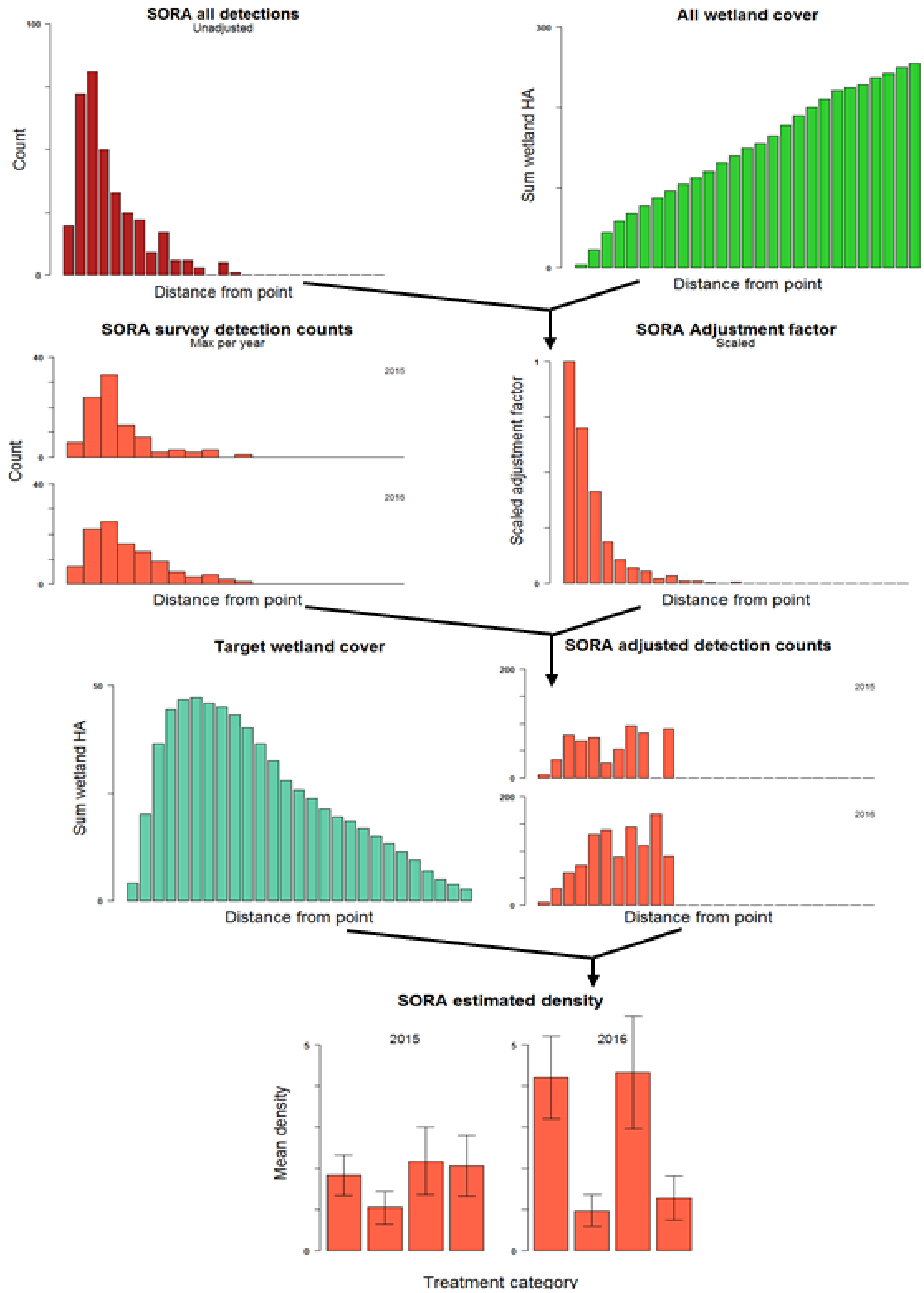

Figure 8: Process for adjusting maximum number of detections at individual survey points and deriving an estimate of mean density as a function of treatment category (Low [L], Medium [M], High [H], and Other [O]) at the Morris study area in west-central Minnesota. The first step was to incorporate frequency of detections and the area of wetland cover types by distance

intervals to derive an adjustment factor to apply to counts of each species at survey points. We then summed adjusted maximum counts at each point and divided by the sum of wetland cover at each survey point to estimate marshbird density per point (bottom panel shows density estimates grouped by treatment category).

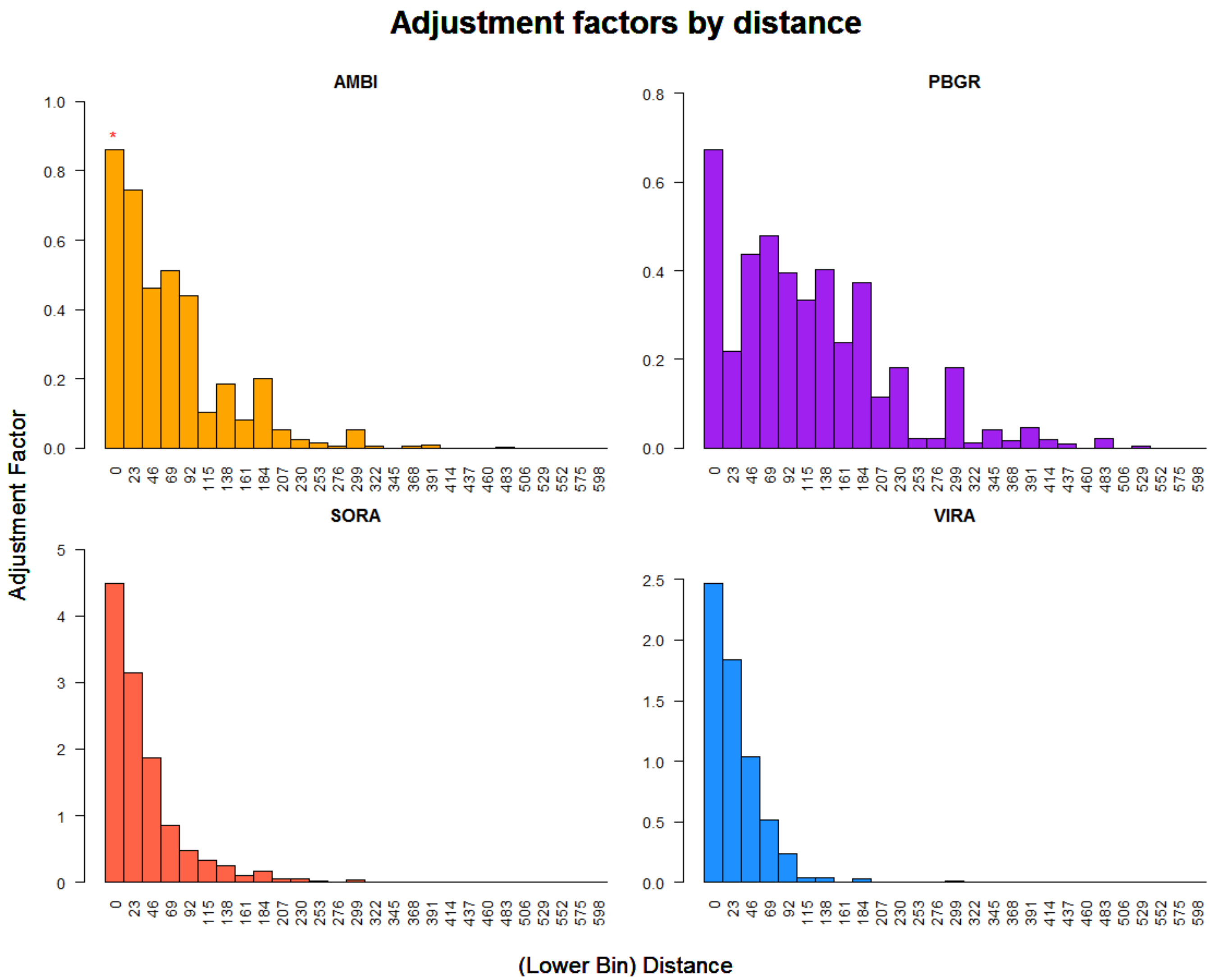

Figure 9. Adjustment factors (number of bird detections divided by wetland area within 23-m distance intervals) for secretive marshbird counts on standardized surveys at the Morris study area in west-central Minnesota during 2015 and 2016. Observers used laser range finders against topographic features (e.g., wetland boundaries), along with aerial photographs and maps, to estimate distances to individual marshbirds detected in association with surveys. We estimated the first distance interval value (red asterisk) for American bitterns (AMBI) from a half-normal model of detections weighted by the detection probabilities. We calculated adjustment factors for pied-billed grebes (PBGR), soras (SORA), and Virginia rails (VIRA) from detections and the area of potential marshbird habitat (i.e., wetland cover types) by distance interval to account for decreasing detection probability as a function of distance.

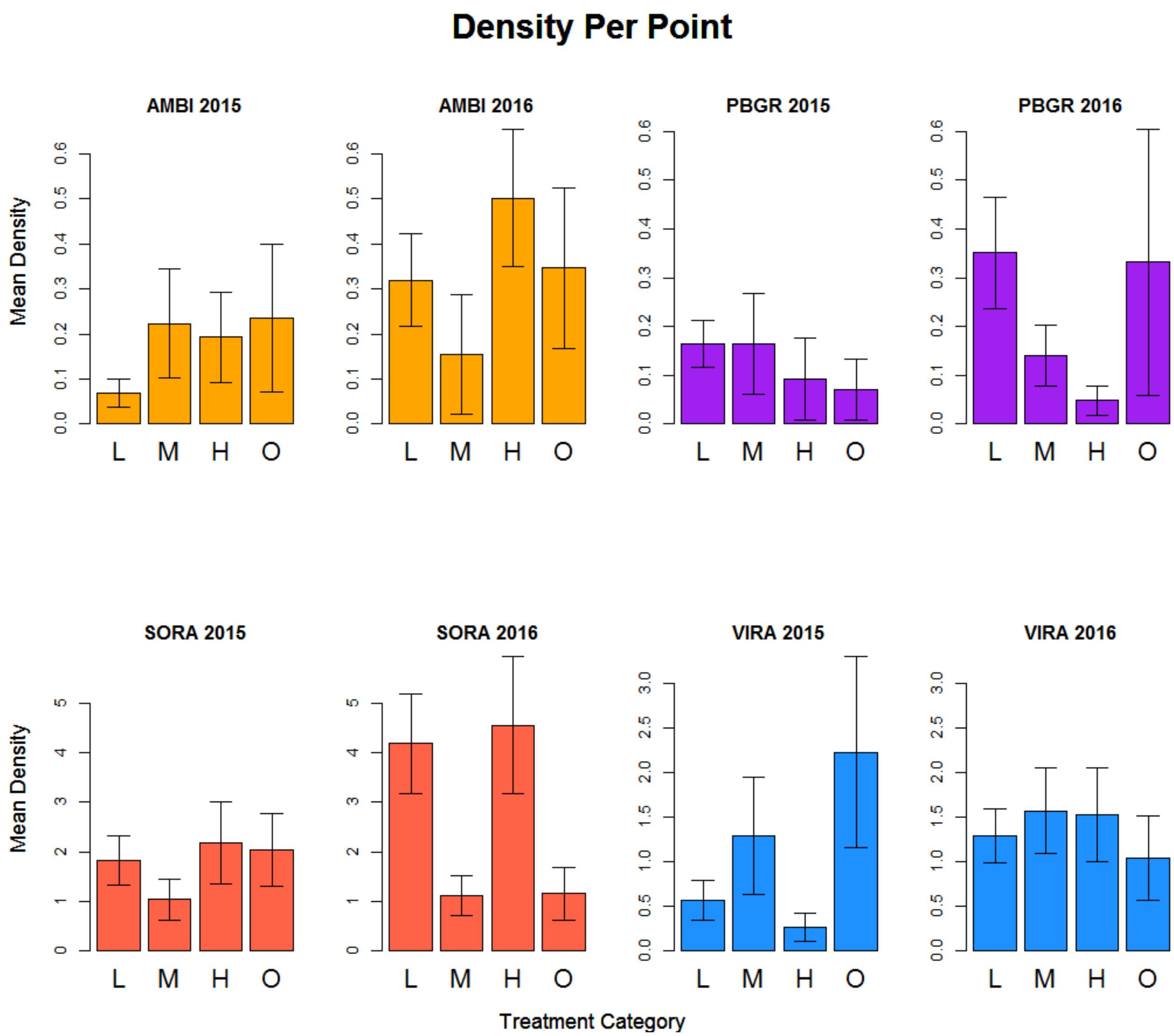

Figure 10. Estimated mean adjusted density (birds/ha of wetland, error bars represent standard error) of the 4 most commonly detected secretive marshbirds (American bitterns [AMBI], pied-billed grebes [PBGR], soras [SORA], and Virginia rails [VIRA]) by treatment category [Low (L), Moderate (M), High (H), Other (O); see text for description of treatments] by year during standardized surveys in the Morris study area in west-central Minnesota during 2015 and 2016.

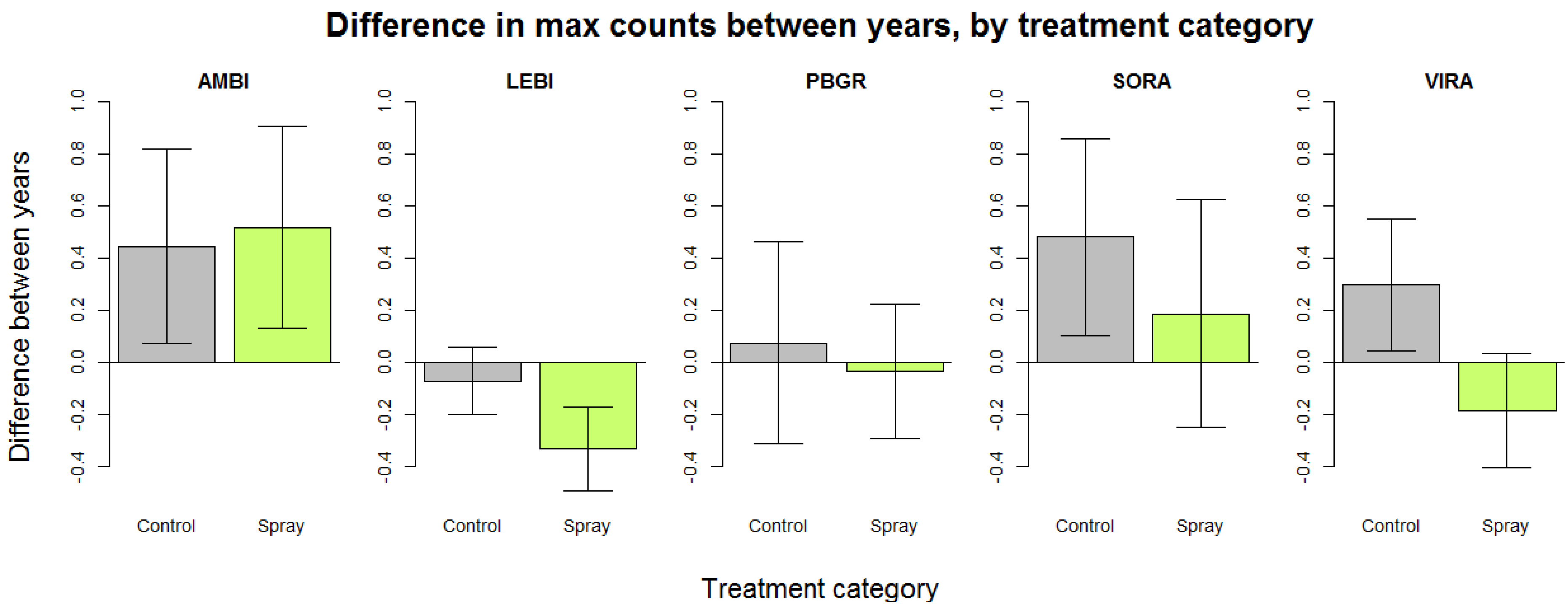

Figure 11. Mean difference in maximum number of detections between 2016 and 2015, grouped by treatment category for each species (American bitterns [AMBI], least bitterns [LEBI], pied-billed grebes [PBGR], soras [SORA], and Virginia rails [VIRA]) at our northwestern Minnesota study area.

Appendix A

Presentations:--

Hill, N., D. E. Andersen, D. H. Johnson, T. Cooper. 2017. Secretive marshbird response to wetland management in western Minnesota. Minnesota Chapter of The Wildlife Society 2017 Annual Meeting, Callaway, Minnesota.

Hill, N., D. E. Andersen, D. H. Johnson, T. Cooper. 2017. Secretive marshbird response to wetland management in western Minnesota. Annual Waterfowl Symposium, Minnesota Waterfowl Association, Bloomington, Minnesota.

Hill, N., D. E. Andersen, D. H. Johnson, T. Cooper. 2017. Secretive marshbird response to wetland management in western Minnesota. Effects of fire symposium, Midwest Fish and Wildlife Conference, Lincoln, Nebraska.

Hill, N., D. E. Andersen, D. H. Johnson, T. Cooper. 2016. Secretive marshbird response to wetland management in western Minnesota. Forest Resources Department Fall 2016 Graduate Seminar Series, University of Minnesota, St. Paul, Minnesota.

Hill, N., D. E. Andersen, D. H. Johnson, T. Cooper. 2016. Secretive marshbird response to management of invasive plants in Prairie Pothole Minnesota. Natural Resources Association of Graduate Students 2016 Annual Symposium, University of Minnesota, St. Paul, Minnesota.

Hill, N., D. E. Andersen, D. H. Johnson, T. Cooper. 2016. Secretive marshbird response to invasive wetland management in western Minnesota. Minnesota Chapter of The Wildlife Society 2016 Annual Meeting, Mankato, Minnesota.

Hill, N., D. E. Andersen, D. H. Johnson, T. Cooper. 2015. (*Invited*). Secretive marshbird response to invasive wetland management in western Minnesota. Minnesota Audubon, St. Paul, Minnesota.