Marsh Bird Use of Impounded and Unimpounded Wetlands of the Great Lakes Region: An Assessment to Inform Future Management and Monitoring

Final Report

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ABSTRACT

Declines in wetland bird populations have increased interest implementing conservation actions to reverse these trends, yet much remains unknown as to how marsh birds respond to management actions. Our goal was to compare marsh bird use of impounded and unimpounded wetlands using data from Michigan, Ohio, and Wisconsin, and use those results to develop recommendations for future management and monitoring. Marsh bird surveys in the three states were conducted using the Standardized North American Marsh Bird Monitoring Protocols. We used aerial imagery to categorize the impoundment status of 726 survey points from the three states and compared bird use at 553 points classified as impounded (243 points) or unimpounded (310 points), at which 5,059 point counts were conducted during 2008-2015. We found a pattern of greater abundance, naïve occupancy, and model-estimated occupancy in impounded compared to unimpounded wetlands for most of the 12 species surveyed in all three states. Abundance (detections/point) was significantly greater in impounded compared to unimpounded wetlands for eight of 12 species (Pied-billed Grebe [*Podilymbus Podiceps*], American Bittern [*Botaurus lentiginosus*], Least Bittern [*Ixobrychus exilis*], Virginia Rail [*Rallus limicola*], American Coot [*Fulica americana*], Sandhill Crane [*Grus canadensis*], Marsh Wren [*Cistothorus palustris*], and Swamp Sparrow [*Melospiza georgiana*]), but no species had greater abundance in unimpounded wetlands. Logistic regression models indicated six species (Pied-billed Grebe, American and Least Bittern, Virginia Rail, Common Gallinule [*Gallinula galeata*], and American Coot) had greater probability of occurrence in impounded wetlands. Four surrounding land cover variables, emergent wetland, developed open space, open water, and upland forest, were included in logistic regression models of at least half of the species, with most species showing positive associations with emergent wetland and open water, and negative relationships with upland forest. We found greater occupancy estimates in impounded compared to unimpounded wetlands for all species except Swamp Sparrow. Eight of the nine species analyzed via occupancy modeling showed a relationship between detection probability and impoundment status, with seven species being more likely to be detected in impounded wetlands. The most common occupancy covariates included in best-approximating models were emergent wetland, upland forest, and woody wetland; except for Swamp Sparrow, occupancy was positively related to emergent wetland and negatively associated with upland forest and woody wetlands. Our study indicates impounded wetlands may benefit several bird species, but more study is needed to determine the factors driving occurrence patterns, optimal management strategies, and effects to population status. The baseline data collected by these states presents opportunities for future monitoring to help address remaining knowledge gaps. To further regional wetland bird management and monitoring, we recommend 1) taking a long-term, experimental approach to management and monitoring to evaluate how birds and their habitats respond to conservation actions; 2) begin collecting information on recent management actions influencing conditions at survey points; and 3) increasing volunteer participation in the collection of environmental and habitat information for use in future analyses. We present several elements to be considered in the development of a regional experimental management and monitoring program and provide a conceptual design for a program within Bird Conservation Region 23 as an example.

INTRODUCTION

Concern about declining marsh bird populations has grown in recent years and there is substantial interest in reversing these population trends (Kushlan et al. 2002, Soulliere et al. 2007a, Wires et al. 2010). Unfortunately, conservation efforts are often hindered by the lack of biological and ecological data needed to support planning and management (Soulliere et al. 2007a, 2018). Water levels have long been manipulated in wetlands to enhance conditions for wetland wildlife, primarily waterfowl species (Kadlec 1962, Harris and Marshall 1963, Whitman 1976). However, few studies have investigated the effects of water level management on marsh bird use of wetlands in the Midwest (Larkin et al. 2013). The Midwest Marsh Bird Working Group (MMBWG) and Upper Mississippi River and Great Lakes Region Joint Venture (hereafter Joint Venture) identified research and monitoring priorities to address this knowledge gap (Soulliere et al. 2007a, Larkin et al. 2013).

Several states in the U.S. have implemented volunteer-based secretive marsh bird surveys using a consistent survey protocol (Conway 2011) and sample design (Johnson et al. 2009). In the Great Lakes region, annual surveys have been conducted in Wisconsin since 2008, in Michigan since 2010, and in Ohio since 2011. Recently, more focus has been paid to designing monitoring efforts to address high priority information needs, including investigating questions regarding habitat management for marsh birds in the Midwest (Seamans et al. 2013). Larkin et al. (2013) identified the following question as a priority for research: does management of impoundments for waterfowl influence marsh bird use relative to unimpounded wetlands, and what conditions maximize use by both bird groups? Although marsh bird conservation planning and monitoring typically occur at large spatial scales, implementation and assessment of management actions usually happen at the site level. Large-scale assessments of management actions are needed to determine if assumptions made during conservation planning are correct. For example, conservation planners generally assume that management conducted for waterfowl will benefit other species, such as secretive marsh birds, yet little research has tested this assumption. A study by Tozer et al. (2018) in southern Ontario is the only research we found to evaluate this assumption in the Great Lakes region and the authors observed greater occupancy rates within conservation projects compared to unmanaged wetlands for several marsh bird species.

Our goal was to examine marsh bird use of impounded and unimpounded wetlands using data from the Michigan, Ohio, and Wisconsin marsh bird surveys. We set out to compare the abundance and probability of occupancy of several marsh bird species between impounded and unimpounded wetlands, as well as exploring potential differences in marsh bird assemblages between the two wetland types using multivariate techniques. We also aimed to develop a framework for gathering information on management actions (e.g., drawdowns, prescribed fire, etc.) occurring at the study sites, which would facilitate future investigations into the effects of management on marsh birds beyond the impounded-unimpounded wetland comparison. Based on the results of our analyses, we developed a conceptual plan to conduct regional-scale, experimental management and monitoring to specifically address the uncertainty associated with bird responses to management actions.

METHODS

Study Area

We examined marsh bird use of impounded and unimpounded wetlands within Michigan, Ohio, and Wisconsin (Figure 1), where volunteer-based surveys have been conducted using the same sample design (Johnson et al. 2009) and survey protocol (Conway 2011). Sampling conducted within the three states falls largely within two bird conservation regions (BCRs), the boreal hardwood transition (BCR 12) and prairie hardwood transition (BCR 23). About 20% of Ohio's survey points occur within the eastern tallgrass prairie region (BCR 22).

The sample design for each state was developed within wetlands classified as palustrine emergent or split-classed as palustrine emergent-scrub-shrub by the National Wetlands Inventory using a two-stage process. Primary sample units (PSUs) were randomly selected from a sample frame of 40-km^2 hexagons overlaying the three states. Secondary sample units, or survey points, were created within the selected PSUs in a spatially balanced manner using a generalized random tesselation procedure (Johnson et al. 2009), with points were separated by $\geq$ 400 m (Conway 2011). The two-stage process was used to create clusters (i.e., survey routes) of randomly selected points, resulting in an efficient sample design. Survey developers ground-truthed the potential points in the field to verify that they indeed occurred within wetlands dominated by emergent vegetation and to ensure the points could be reasonably accessed by volunteers. Points occurring within wetlands dominated by woody vegetation (>50% cover within 100 m) or deemed inaccessible (e.g., > 400 m from nearest road/trail or requiring >20 min to reach) were discarded. Personnel conducting ground truthing sometimes moved survey points up to 150 m to improve accessibility and/or avoid inappropriate wetland types (e.g., forested wetland), but the minimum separation distance of 400 m was maintained.

Bird Surveys

Standardized North American Marsh Bird Monitoring Protocols (Conway 2011) were used for all three state surveys. This methodology provides flexibility in the selection of target species and the species for which broadcasts are played during surveys; however, there was substantial coordination among the three states to match target species as much as possible. Of the 21 species surveyed by at least one state, 12 species were surveyed by all three (Table 1). These 12 species were the focus of analyses conducted for this study.

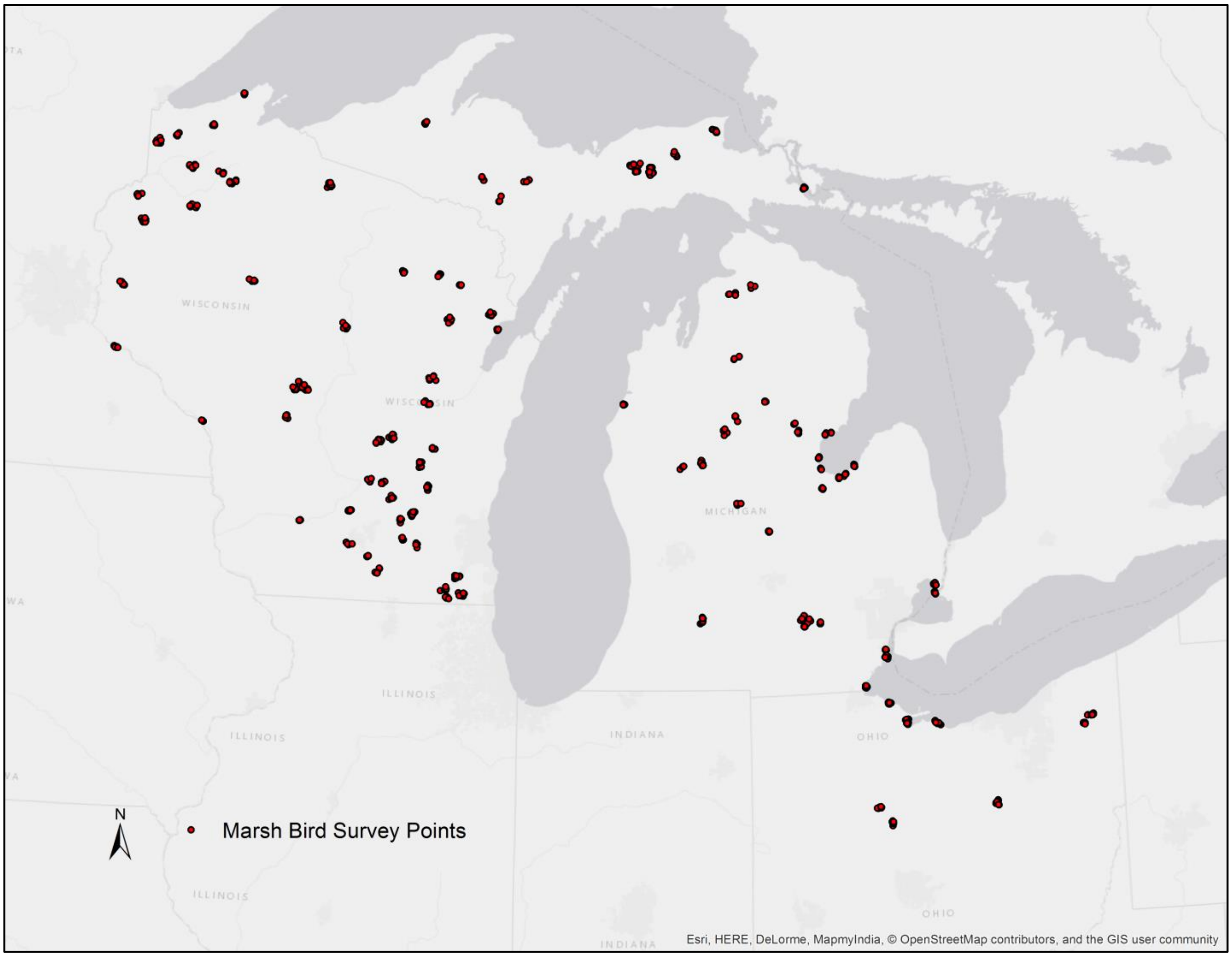

Figure 1. Locations of marsh bird survey stations in Wisconsin, Michigan, and Ohio during 2008-2015.

Table 1. Primary and secondary target species of the Michigan, Ohio, and Wisconsin marsh bird surveys. An “x” indicates a target species for the state and a capital “X” is listed if broadcasts for the species are included as part of the state’s survey protocol.

	Michigan	Ohio	Wisconsin
Primary Species			
Pied-billed Grebe (*Podilymbus podiceps*)	x	x	x
American Bittern (*Botaurus lentiginosus*)	X	X	X
Least Bittern (*Ixobrychus exilis*)	X	X	X
Yellow Rail (*Coturnicops noveboracensis*)	X		X
King Rail (*Rallus elegans*)	X	X	X
Virginia Rail (*Rallus limicola*)	X	X	X
Sora (*Porzana carolina*)	X	X	X
Common Gallinule (*Gallinula galeata*)	x	x	x
American Coot (*Fulica americana*)	x	x	x
Wilson’s Snipe (*Gallinago delicata*)	x		x
Secondary Species			
Wood Duck (*Aix sponsa*)		x	
Sandhill Crane (*Grus canadensis*)	x	x	x
Black Tern (*Chlidonias niger*)	x	x	x
Forster’s Tern (*Sterna forsteri*)	x		x
Willow Flycatcher (*Empidonax traillii*)		x	
Sedge Wren (*Cistothorus platensis*)	x		x
Marsh Wren (*Cistothorus palustris*)	x	x	x
Swamp Sparrow (*Melospiza georgiana*)	x	x	x
Le Conte’s Sparrow (*Ammodramus leconteii*)	x		x
Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)	x		x
Red-necked Grebe (*Podiceps grisegena*)			x

Analysis

We examined 726 points surveyed within the three states and classified their impoundment status as one of eight categories: intentionally impounded, unintentionally impounded, intentionally lowered, unintentionally lowered, beaver impounded, beaver lowered, not impounded, and uncertain (see Appendix A for definitions). Points were classified based on aerial photo interpretation using imagery from multiple sources (ESRI, Google Earth, Bing Maps, and State of Michigan) and time periods (mid-1990s to 2015). If the impoundment status of a point was unclear, it was classified as uncertain. Most of the points were classified as not impounded (43%) or intentionally impounded (33%; Table 2). Because our intent was to compare marsh bird use between impounded and unimpounded wetlands and the other categories occurred in small numbers and often were not represented in all three states, we only used the 553 points classified as impounded (243 points) or unimpounded (310 points) in our analyses.

Table 2. Number of marsh bird survey points falling within the eight impoundment status categories within the three states examined. Proportions of the total by state and combined are provided in ().

	Michigan		Ohio		Wisconsin		Total	
Impounded								
Intentionally	94	(0.37)	70	(0.76)	79	(0.21)	243	(0.33)
Unintentionally	3	(0.01)	7	(0.08)	8	(0.02)	18	(0.02)
Beaver	8	(0.03)	---	---	21	(0.05)	29	(0.04)
Lowered								
Intentionally	1	(<0.01)	---	---	73	(0.19)	74	(0.10)
Unintentionally	9	(0.04)	---	---	1	(<0.01)	10	(0.01)
Beaver	2	(0.01)	---	---	1	(<0.01)	3	(<0.01)
Unimpounded	134	(0.53)	14	(0.15)	162	(0.42)	310	(0.43)
Uncertain	1	(<0.01)	1	(0.01)	37	(0.10)	39	(0.05)
Total	252		92		382		726	

To evaluate marsh bird use of impounded and unimpounded wetlands, we compared bird assemblages, abundance of individual species, and probability of occupancy by individual species using multiple analytical approaches. Bird assemblages were examined using two multivariate analyses, non-metric multidimensional scaling and multi-response permutation procedures, whereas bird species abundance was compared using mixed model analyses. We assessed the influence of wetland type (i.e., impounded or unimpounded) and land cover variables on probability of occupancy by implementing two modeling techniques, logistical regression and occupancy modeling. The use of two techniques allowed us to determine if similar patterns of variable selection emerged under different modeling approaches. Occupancy modeling also explicitly addresses the problem of species being imperfectly detected even when present. By comparing different indices of marsh bird use (abundance, assemblages, and occupancy), we were able to provide a more complete understanding of the influence of impoundment management on marsh birds.

Bird Assemblage Patterns: We used nonmetric multidimensional scaling (NMS) to explore possible patterns in relative abundance of marsh bird species between impounded and unimpounded wetlands. To minimize the influence of rare or nonbreeding transient species, we only included bird species detected at > 5% of the points, which resulted in nine species (Pied-billed Grebe, American Bittern, American Coot, Least Bittern, Sandhill Crane, Sora, Virginia Rail, Marsh Wren, and Swamp Sparrow) being included. Analysis was attempted on the data in two ways: 1) with bird abundance (detections within 100 m) averaged by year and point; and 2) with bird abundance averaged by year, survey route, and hydrologic type. We performed NMS using the Bray-Curtis distance measure, 250 runs on the original data matrix, and a maximum of 500 iterations. A final solution was achieved when an instability value of 0. 0000001 was obtained or after 500 iterations. A Monte-Carlo permutation procedure (McCune and Grace 2002) was conducted with 250 randomized runs to evaluate if axes produced by NMS explained more variation than by chance alone. We used multi-response permutation procedures (MRPP) to test for differences in the marsh bird assemblages between impounded and unimpounded points. Bray-Curtis distance measures and natural weighting ($n_i/\Sigma n_i$; Mielke 1984) were used in the MRPP analysis. We conducted NMS and MRPP analyses using PC-ORD v.6.08 (McCune and Mefford 2011).

Bird Abundance Comparisons: We used a mixed model (PROC MIXED, SAS Institute, Cary, NC) to compare mean abundance per point between impounded and unimpounded wetlands. Because of decreasing detectability of marsh birds with increasing distance and to ensure independence of the sample points, we only included birds detected ≤ 100 m in our analysis. This boundary also provided consistency with similar surveys and studies (e.g., Great Lakes Marsh Monitoring Program, Tozer et al. 2018). The mixed model consisted of wetland type (impounded or not impounded) and survey period (early, mid, and late season) as fixed effects, and year, state, site, and point count station as random effects. We used a repeated measures component to account for multiple surveys at the same point. Four commonly used covariance structures were evaluated for each species: variance components, autoregressive order 1, compound symmetric, and unstructured (Littell et al. 1996, Kincaid 2005). We compared models and selected the best-approximating model using Akaike's Information Criterion (AIC). If residuals from initial models using untransformed data were not normally distributed, we log transformed ($\log_e[x + 1]$ abundance in the final analysis.

Probability of Occupancy: To assess the potential influence of impoundment status and surrounding land cover on species' occurrence, we conducted logistic regression analysis for the 12 species surveyed in all three states. Wetland type (impounded or not impounded) was included in the analysis as a categorical variable, with models evaluating the influence of points occurring within impounded wetlands on probability of occurrence as compared to unimpounded points. We used land cover data from the 2011 National Land Cover Database (NLCD; Homer et al. 2015) to characterize the proportion of the area within 200 m falling within each NLCD class. A buffer distance of 200 m was selected to avoid overlap with nearby survey points. The following land cover categories occurred near the survey points: open water, developed open space, developed light intensity, developed medium intensity, developed high intensity, bare land, upland forest (deciduous, coniferous, and mixed forest combined), upland scrub-shrub, grassland/herbaceous (hereafter herbaceous), pasture/hay, cultivated crops, woody wetland, and emergent wetland. We only used a land cover variable if it occurred in at least 10% of all point buffers and we removed variables correlated ($r \geq 0.50$) with other cover classes, resulting in 10 variables being used in analyses (developed open space, developed low-intensity, cultivated crops, herbaceous, pasture/hay, upland scrub-shrub, upland forest, woody wetland, emergent wetland, and open water). Bird detections were summarized by point and year; points having a species detected during at least one visit within 100 m were assigned a "1", whereas points lacking detections were given a "0". Variables were selected using a forward stepwise procedure, with the maximum *P*-value for model entry being 0.20. Regression analyses were conducted using SAS (PROC LOGISTIC, SAS Institute, Cary, NC).

In addition to logistic regression, we conducted single-season occupancy analyses according to MacKenzie et al. (2002), who presented a model to estimate occupancy (probability a species is present at a site, or estimated proportion of sites occupied) when detectability (probability of detecting a species at a site when present) is < 1. The observed proportion of sample units at which a species is detected is termed "naïve" occupancy. Because species commonly go undetected even when present at a site, naïve occupancy typically does not represent the true proportion of sites occupied. Thus, this modeling approach allowed us to produce marsh bird occupancy estimates for impounded and unimpounded wetlands that incorporated imperfect and potentially differing detection rates. We did not attempt analyses using a multi-season occupancy model (MacKenzie et al. 2003), because only a small number of sites had consistent survey coverage across years. Only 4% of survey points were visited in all eight years during 2008-2015 and only 52% were visited in four or more of the eight years examined. Although sample size varied among years, year did not appear to be an important variable ($P > 0.05$) in mixed models used to compare abundances of most species. Only models for Sandhill Crane, Marsh Wren, and Swamp Sparrow indicated year as a significant ($P < 0.05$) variable. Furthermore, our interest was in understanding the influence of impoundment status on marsh bird occupancy, rather than estimating extinction and colonization probabilities. Thus, we treated each year at a given point as an independent observation and combined observations from all years in the same analysis, but then included year of survey as a categorical occupancy covariate.

Occupancy modeling was conducted for nine of the 12 species, with naïve occupancy levels for King Rail, Common Gallinule, and Black Tern (0.01, 0.02, and 0.03, respectively) being too low for analysis. We used a tiered approach to developing candidate models. We examined models with detection covariates first and then incorporated the best-supported detection configuration into all subsequent models (Olson et al. 2005, Kroll et al. 2006, Yates and Muzika 2006, Darrah and Krementz 2009). We began by comparing two detection models, one assuming constant probability of detection across survey periods and the second incorporating variable detection probabilities by survey period. The best-supported configuration of the two models, as indicated by AIC, was used in subsequent models. We then compared models containing all possible combinations of three covariates that could influence marsh bird detection: time of day (categorical variable of morning [0] or evening [1]), noise level (ranked from 0 [no noise] to 4 [intense noise]), and wetland type (not impounded [0] or impounded [1]). The best-approximating detection model was included in all subsequent occupancy models. Next, we compared a model with no occupancy covariates with a model containing year of survey as a covariate. If year of survey appeared important as compared to the null model, it was included in all subsequent models. We then compared 11 models, each of which contained one occupancy covariate (wetland type and the same 10 land cover variables used in logistic regressions). We then produced four two- and three-variable models using combinations of occupancy covariates from the top three models from our set of 11 one-variable models. A goodness-of-fit test with 1,000 bootstraps was run for each species using the most parameterized model as the global model. If overdispersion appeared likely (i.e., $\hat{c} > 1.0$), we used quasi-AIC values to rank our candidate models (Burnham and Anderson 2002). Occupancy models were produced using Presence 2.12.17 (Hines 2006).

RESULTS

We compared marsh bird use between 243 impounded and 310 unimpounded survey points in Wisconsin, Michigan, and Ohio, at which at total of 5,059 point counts were conducted during 2008-2015. All 12 species surveyed in the three states were detected during the survey period in both wetland types (i.e., impounded and not impounded). In Michigan and Wisconsin, all 12 species were detected in both wetland types, whereas in Ohio, all 12 species were observed at impounded points but only eight species were detected at unimpounded points (Table 3). Combining all states and both wetland types, naïve occupancy (observed proportion of points having detections within 100 m) was greatest for Swamp Sparrow (0.46), followed by Marsh Wren (0.18), Sora (0.17), Virginia Rail (0.14), Sandhill Crane (0.12), and American Bittern (0.10). Pied-billed Grebe, Least Bittern, King Rail, Common Gallinule, American Coot, and Black Tern were recorded at less than 10% of the points. For most species, naïve occupancy was similar among the three states, except for Pied-billed Grebe, American Bittern, Sandhill Crane, and Swamp Sparrow (Table 3). Pied-billed Grebe was observed more often at points in Ohio compared to the other states, whereas American Bittern was detected more often in Michigan and Wisconsin. Sandhill Crane was detected more often at Wisconsin points compared to the other states. Swamp Sparrow was recorded at much greater rates in Michigan and Wisconsin compared to points in Ohio. There was a consistent pattern of greater naïve occupancy of marsh bird species at impounded compared to unimpounded points, both overall and within a given state (Table 3).

Table 3. Proportion of points where specific marsh bird species were detected within the Great Lakes region during 2008-2015 by wetland type and state (*n* indicates the number of point counts conducted).

	Impounded (n = 2,218)				Not Impounded (n = 2,841)			
Species	MI	OH	WI	Total	MI	OH	WI	Total
Pied-billed Grebe	0.14	0.27	0.07	0.15	0.02	0.06	0.05	0.04
American Bittern	0.22	<0.01	0.23	0.16	0.08	---	0.06	0.07
Least Bittern	0.10	0.06	0.05	0.06	0.02	0.06	0.02	0.02
King Rail	0.02	0.03	0.01	0.02	0.01	0.06	<0.01	0.01
Virginia Rail	0.18	0.15	0.23	0.19	0.07	0.04	0.12	0.10
Sora	0.17	0.20	0.27	0.22	0.06	0.15	0.19	0.14
Common Gallinule	0.06	0.07	0.01	0.04	0.01	---	0.01	0.01
American Coot	0.11	0.11	0.02	0.07	0.01	0.06	0.03	0.02
Sandhill Crane	0.10	0.07	0.24	0.14	0.08	---	0.11	0.10
Black Tern	0.04	<0.01	0.06	0.04	0.01	---	0.02	0.02
Marsh Wren	0.28	0.25	0.22	0.24	0.09	0.15	0.16	0.13
Swamp Sparrow	0.60	0.13	0.64	0.47	0.48	0.06	0.48	0.46

We investigated possible patterns in marsh bird assemblages at impounded and unimpounded wetlands using NMS analyses of data summarized by both point and survey route, but a useful ordination of marsh bird data was not obtained from either analysis. This result was likely due to the data set having a large proportion of zeroes. However, bird assemblages of impounded and unimpounded points appeared to differ according to multi-response permutation procedures analysis (T = -16.11, A = 0.01, P < 0.0001).

Estimates of marsh bird abundance were consistent with the greater naïve occupancy rates that we observed at impounded points, with eight of 12 species having significantly greater abundance at impounded compared to unimpounded points (Table 4). Abundance of four species was similar between wetland types but none had greater abundance at unimpounded points. For those species that differed between wetland types, abundance was about 2-3 times greater at impounded points; however, mean abundance (detections per point) was < 0.10 for all species except Swamp Sparrow and Marsh Wren (Table 4).

Table 4. Comparison of marsh bird mean abundance (detections within 100 m) between impounded and unimpounded points within the Great Lakes region during 2008-2015 (n indicates the number of point counts conducted). Significant P-values (P < 0.05) are bolded.

	Impounded (n = 2,218)			Not Impounded (n = 2,841)			
Species	Mean	LCL	UCL	Mean	LCL	UCL	P-value
Pied-billed Grebe	0.05	0.03	0.08	0.03	0.01	0.04	**0.0068**
American Bittern	0.06	0.02	0.10	0.02	-0.01	0.06	**0.0013**
Least Bittern	0.02	0.02	0.03	0.01	0.00	0.01	**0.0016**
King Rail	<0.01	0.00	0.01	<0.01	0.00	0.01	0.5300
Virginia Rail	0.09	0.05	0.13	0.04	0.00	0.08	**0.0003**
Sora	0.09	0.06	0.13	0.08	0.04	0.12	0.3105
Common Gallinule	0.02	0.01	0.02	0.01	0.00	0.02	0.1062
American Coot	0.03	0.02	0.05	0.01	0.00	0.03	**0.0156**
Sandhill Crane	0.07	0.01	0.14	0.05	-0.01	0.11	**0.0441**
Black Tern	0.01	0.00	0.02	0.01	0.00	0.02	0.4836
Marsh Wren	0.21	0.13	0.29	0.11	0.04	0.18	**0.0029**
Swamp Sparrow	0.54	0.11	1.15	0.31	-0.06	0.83	**<0.0001**

Ten land cover class variables were used as potential covariates in logistic regression and occupancy models. The most common cover classes in the 200-m buffers surrounding survey points were emergent wetland, woody wetland, upland forest, and open water (Table 5). Impounded wetlands tended to have greater proportions of emergent wetland compared to unimpounded sites, whereas unimpounded points tended to have greater proportions of woody wetland and upland forest. Average proportion of row crops was about 0.08 for both wetland types. Half of the variables represented small proportions of the buffers on average, regardless of wetland type. Developed open space, developed low intensity, herbaceous, pasture/hay, and upland scrub-shrub had average proportions of < 0.05 (Table 5).

Table 5. Mean proportions of 10 land cover classes by wetland type within 200-m buffers surrounding marsh bird survey points within the Great Lakes region according to the 2011 National Land Cover Database.

	Impounded (n = 243)		Not Impounded (n = 310)	
Land cover class	Mean	SE	Mean	SE
Developed, open space	0.039	0.004	0.048	0.004
Developed, low-intensity	0.011	0.002	0.013	0.002
Cultivated crops	0.075	0.011	0.081	0.011
Herbaceous	0.014	0.003	0.018	0.003
Pasture/hay	0.013	0.004	0.021	0.005
Upland scrub-shrub	0.012	0.003	0.013	0.002
Upland forest	0.106	0.011	0.200	0.014
Woody wetland	0.182	0.014	0.229	0.013
Emergent wetland	0.411	0.021	0.252	0.016
Open water	0.128	0.011	0.118	0.012

Pied-billed Grebe, American Bittern, Least Bittern, Virginia Rail, Common Gallinule, and American Coot had greater probability of occurrence in impounded wetlands in final logistic regression models. Except for Common Gallinule, these species also had significantly greater abundance in impounded compared to unimpounded sites. All 10 of the land cover variables used in regression analyses were included in the model for at least one species (Table 6). Four of the variables, emergent wetland, developed open space, open water, and upland forest, were included in the models of at least half of the species. Emergent wetland was selected in the models of 10 species, with probability of occurrence for all species except Swamp Sparrow being positively associated with the variable. Six of the seven species models that included open water indicated a positive association with probability of occurrence. Associations between probability of occurrence and proportion of developed open space were inconsistent, with four species exhibiting a positive and three species a negative relationship. All six of the models containing upland forest as a variable indicated a negative association between probability of occurrence and the variable.

Table 6. Variables included in stepwise logistic regression analyses conducted using land cover information for 12 marsh bird species detected during surveys in the Great Lakes region, 2008-2015. Positive and negative signs indicate direction of association between probability of occurrence and variable.

Variable	Pied-billed Grebe	American Bittern	Least Bittern	King Rail	Virginia Rail	Sora	Common Gallinule	American Coot	Sandhill Crane	Black Tern	Marsh Wren	Swamp Sparrow	No. Species
Impoundment status													
Impounded vs. not impounded	+	+	+		+		+	+					6
Land cover class (proportions)													
Developed, open space	-	+		-		+	-			+		+	7
Developed, low-intensity		-		+	-				-			-	5
Cultivated crops		+				+		+			+	-	5
Herbaceous		+						+				-	3
Pasture/hay				+								-	2
Upland scrub-shrub		+											1
Upland forest	-			-		-				-	-	-	6
Woody wetland	-	+								+			3
Emergent wetland		+	+		+	+	+	+	+	+	+	-	10
Open water	+		+				+	+		+	+	-	7

We calculated detection and occupancy probability estimates by wetland type (i.e., impounded, not impounded) using point estimates from our best-approximating models for each species. Table 7 provides the greatest average detection probability among the three survey periods for each species. Swamp Sparrow had the greatest detectability (0.782), followed by Marsh Wren (0.632) and Sora (0.629). Lowest overall detection probabilities were estimated for Least Bittern (0.137), Pied-billed Grebe (0.218), and American Coot (0.220). Detection probabilities for the remaining three species, Sandhill Crane, Virginia Rail, and American Bittern, were intermediate at 0.302, 0.342, and 0.432, respectively. Detectability differed by wetland type for most species, with six species having greater probability of detection in impounded wetlands and only one species, Virginia Rail, being more likely to be detected at unimpounded sites (Table 7). Overall estimates of occupancy probability were low (0.114 – 0.259) for all species except Swamp Sparrow (0.497). We found greater occupancy estimates in impounded compared to unimpounded wetlands for all species except Swamp Sparrow, which had similar estimates between wetland types (Table 7). Differences in occupancy probabilities between the wetland types were generally small (≤ 0.10), except for Virginia Rail (0.413 compared to 0.157).

Table 7. Model-estimated detection probability (p), naïve occupancy, and model-estimated occupancy (ψ) by wetland type (impounded [IM] and not impounded [NI]) for nine bird species detected during marsh bird surveys in the Great Lakes region, 2008-2015. Estimates of ψ and p were obtained using the best-approximating model for each species.

	Estimated Detectability[1]				Naïve Occupancy		Estimated Occupancy			
	IM		NI				IM		NI	
Species	p	SE	p	SE	IM	NI	ψ	SE	ψ	SE
Pied-billed Grebe	0.336	0.044	0.127	0.027	0.154	0.042	0.255	0.057	0.198	0.052
American Bittern	0.493	0.049	0.392	0.058	0.156	0.065	0.191	0.038	0.134	0.030
Least Bittern	0.202	0.049	0.089	0.027	0.065	0.023	0.151	0.042	0.111	0.034
Virginia Rail	0.262	0.041	0.403	0.051	0.191	0.095	0.413	0.073	0.147	0.032
Sora	0.634	0.043	0.626	0.052	0.221	0.138	0.295	0.027	0.221	0.024
American Coot	0.316	0.066	0.145	0.045	0.073	0.024	0.129	0.043	0.103	0.037
Sandhill Crane	0.342	0.041	0.273	0.037	0.143	0.096	0.250	0.030	0.203	0.025
Marsh Wren	0.660	0.035	0.609	0.043	0.245	0.133	0.255	0.057	0.198	0.052
Swamp Sparrow	0.785	0.017	0.781	0.018	0.470	0.460	0.490	0.034	0.502	0.034

[1]For species with detectability that varied by survey period, we report the maximum detection probability observed from the three survey periods.

Several variables were associated with probabilities of detection and occupancy (Table 8). Eight of nine species exhibited differing detection probabilities among the three survey periods. Pied-billed Grebe, American Bittern, Virginia Rail, Sora, American Coot, and Sandhill Crane had greatest detectability during the first survey period, with detection probability declining with each subsequent visit. Conversely, Marsh Wren and Swamp Sparrow showed increasing detection probabilities across the three visits, with greatest detectability during the third survey. Impoundment status was included in the best-approximating models for eight of nine species, and seven of these species were more likely to be detected in impounded wetlands (Table 8). Virginia Rail was the only species with lower detectability estimates in impounded sites. Time of day and noise level were included as detection covariates in some of the models, but the associations with detection probability were not consistent across species. Probability of occupancy appeared to vary by year of survey for six of the nine species analyzed. The most common occupancy covariates included in the best-approximating models were emergent wetland, upland forest, woody wetland, and open water (Table 8). Occupancy of six species was positively associated with proportion of emergent wetland within 200 m, whereas six species were negatively related to proportion of upland forest. Three species were negatively associated with woody wetland; Swamp Sparrow was the only species positively associated with the variable. Occupancy of four species was related to proportion of open water, with Pied-billed Grebe and American Coot being positively associated and American Bittern and Swamp Sparrow having a negative relationship. The Virginia Rail model was the only one to include the impoundment status variable, with occupancy probability being greater in impounded wetlands.

Table 8. Variables included in occupancy models developed for nine bird species detected during marsh bird surveys in the Great Lakes region, 2008-2015. Variables included in best-approximating models are indicated by an "x" or where appropriate by a positive or negative sign to indicate direction of association with probability of detection or occupancy.

Variable	Pied-billed Grebe	American Bittern	Least Bittern	Virginia Rail	Sora	American Coot	Sandhill Crane	Marsh Wren	Swamp Sparrow	No. Species
Detection covariates										
Survey period	x	x		x	x	x	x	x	x	8
Time of day	-			+	+				-	4
Noise level		-		+		+		+		4
Impoundment status	+	+	+	-	+	+	+	+		8
Occupancy covariates										
Impoundment status				+						1
Year of survey	x	x		x		x		x	x	6
Land cover class (proportions)										
Developed, open space			-							1
Developed, low-intensity							-			1
Cultivated crops										0
Herbaceous										0
Pasture/hay									-	1
Upland scrub-shrub										0
Upland forest	-	-	-		-	-		-		6
Woody wetlands	-				-			-	+	4
Emergent wetlands		+	+	+	+		+	+		6
Open water	+	-				+			-	4

DISCUSSION

For the bird species examined in this study, we found a consistent pattern of greater abundance, naïve occupancy, and model-estimated occupancy in impounded compared to unimpounded wetlands. Estimates of abundance and occupancy for secretive marsh birds were generally low, so the biological significance of the greater estimates in impounded wetlands to regional populations is unknown. However, our results support an overall pattern of greater marsh bird use at impounded compared to unimpounded points. All eight species showing a significant difference in abundance between wetland types were more abundant at impounded sites. Of the four species with similar abundance between wetland types, three species (King Rail, Common Gallinule, and Black Tern) were the least common of the 12 species surveyed. Sora was the only relatively common secretive marsh bird species with similar abundance between wetland types.

Eight of the 12 species analyzed in our study had greater abundance in impounded compared to unimpounded wetlands. Galloway et al. (2006) observed greater indices of abundance for marsh-nesting obligate birds, marsh-nesting generalists, and area-sensitive marsh-nesting obligates in impounded compared to unimpounded coastal wetlands in southern Ontario. Results of a study in Michigan coastal wetlands were mixed, with densities of American Bittern, Least Bittern, and Common Gallinule being greater in impounded wetlands, American Coot and Forster's Tern being more abundant in unimpounded marshes, and most species showing no significant difference (Monfils et al. 2014). In a study of managed and unmanaged Wetlands Reserve Program sites in New York, Kaminski et al. (2006) found greater abundance of waterbirds at managed compared to unmanaged restored wetlands during breeding and migration periods. Greater waterbird use-days were associated with actively managed restored wetlands within the Illinois River watershed (O'Neal et al. 2008).

We found eight of the nine species analyzed had greater average occupancy probabilities on impounded compared to unimpounded points using single-season occupancy models. Tozer et al. (2018) similarly found probability of occupancy for several marsh bird species was greater within conservation projects (i.e., wetlands with managed water levels) compared to unmanaged wetlands in the southeastern Great Lakes. Monfils et al. (2014) found probability of occupancy for several species was similar between impounded and unimpounded Michigan coastal wetlands; however, estimates for a few wetland-dependent species appeared to differ between the wetland types. Pied-billed Grebe and American Bittern had greater average occupancy at impounded points, whereas Mallard (*Anas platyrhynchos*) and Forster's Tern had greater occupancy probabilities at unimpounded sites (Monfils et al. 2014). American Bittern, Virginia Rail, and Sora occupancy was greater in natural compared to restored sites in Wisconsin, with the restored wetlands being characterized by greater abundance of reed canarygrass (*Phalaris arundinacea*) and lower coefficients of conservatism (Glisson et al. 2015).

Some past studies have indicated greater bird species/taxa richness in managed wetlands (Galloway et al. 2006, Connor and Gabor 2006, Kaminski et al. 2006, O'Neal et al. 2008). Our multivariate MRPP analysis indicated assemblages of the 12 species surveyed differed between impounded and unimpounded wetlands, but NMS analyses did not provide useful ordinations. McCune and Grace (2002) cautioned that significant differences can result from MRPP analyses even when the effect size (*A*) is small in cases of large sample size (e.g., >200). Galloway et al.

(2006) found greater cumulative species richness in impounded compared to unimpounded sites for several marsh bird groups, with only aerial forager species richness being greater in unimpounded coastal wetlands. Connor and Gabor (2006) found greater wetland obligate bird species richness in impounded compared to seasonally flooded wetlands in New Brunswick. Greater taxa richness was observed in managed compared to unmanaged restored wetlands in New York (Kaminski et al. 2006). O'Neal et al. (2008) noted that waterbird species richness was greater at actively managed restored wetlands in the Illinois River watershed. Conversely, species richness estimates and similarity indices indicated comparable breeding bird communities between impounded and unimpounded Michigan coastal wetlands (Monfils et al. 2014). Additional surveys are needed beyond the limited set of target species used in the region for marsh bird surveys to facilitate further investigation of the influence of management on wetland bird communities.

We used logistic regression and occupancy modeling to understand the potential influence of impoundment status and land cover variables on the occurrence of marsh birds. Six secretive marsh bird species had greater probability of occurring at impounded points in our regression models. Although the probability of detecting several species was greater at impounded points, Virginia rail was the only species with occupancy positively associated with impounded wetlands in our best models. Proportion of emergent wetland, developed open space, open water, and upland forest were the variables most often included in regression models, and emergent wetland, upland forest, open water, and woody wetland were the variables most often included in the top occupancy models. Impounded points tended to have greater amounts of surrounding emergent wetland, whereas unimpounded points had greater amounts of woody wetland and upland forest. Several researchers noted associations between marsh bird metrics and the amount of emergent wetland in the surrounding landscape (Craig and Beal 1992, Naugle et al. 1999, Fairbairn and Dinsmore 2001, Rehm and Baldassarre 2007, Smith and Chow-Fraser 2010, Panci et al. 2017). Some studies found relationships between marsh bird use and percentage of open water within the wetlands being surveyed (Craig and Beal 1992, Murkin et al. 1997, Moore et al. 2009). Our results were also consistent with several studies indicating negative associations between marsh bird occupancy and surrounding cover of woody vegetation (Bolenbaugh et al. 2011, Valente et al. 2011, Harms and Dinsmore 2013). We found occurrence of seven species was associated (four positively, three negatively) with the developed open space variable in logistic regression models. The NLCD 'developed open space' category is defined as areas having a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses, such as large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes (Homer et al. 2015). We did not see similar variables cited in past research as being associated with marsh bird indices. Marsh bird occupancy and abundance are also influenced by fine-scale habitat variables, but adequate information was not available for our analyses. More work is needed to sample the wetland characteristics of impounded and unimpounded wetlands to better understand the habitat factors that may be driving observed differences in marsh bird use.

Our results were consistent with other studies that found greater use of managed wetlands by some waterbird species (Connor and Gabor 2006, Galloway et al. 2006, Kaminski et al. 2006, O'Neal et al. 2008, Monfils et al. 2014, Tozer et al. 2018), but several knowledge gaps remain, including the factors driving differences in abundance and occupancy (e.g., habitat variables), management strategies that maximize use by marsh birds and other bird groups, and the implications of management to population sustainability. Tozer et al. (2018) suggested differences in occupancy may have been due to conservation projects having deeper and more permanent water and greater interspersion of emergents and open water. We similarly hypothesize that greater marsh bird abundance and occupancy was related to habitat components making the managed wetlands more attractive compared to unimpounded sites, such as deeper water depths, more stable hydroperiods, increased interspersion of emergent vegetation and open water, and/or greater productivity and food resources resulting from trapped nutrients and stabilized water levels. Additional study is needed to understand the relationships between bird use and fine- and large-scale habitat factors, food resources, and management actions. Tozer et al. (2018) noted that drawdowns only occurred infrequently at less than half of their conservation project study sites and questioned if occupancy estimates would have been even greater had drawdowns been conducted more often. Kaminski et al. (2006) and O'Neal et al. (2008) noted greater waterbird use of restored wetlands undergoing active management, but these studies did not include natural wetlands as a reference. Monfils et al. (2014, 2015) suggested breeding and migrant bird use of impounded coastal wetlands in Michigan could be increased through more regular drawdowns and shallower water levels. More study is needed to understand how birds respond to wetland management and identify the practices (e.g., water depths, frequency of drawdowns) that maximize use by the overall wetland bird community (Larkin et al. 2013). Research is also needed to sample indicators of population status, such as nest success and survival rates, to determine if greater abundance/occupancy in impounded wetlands is indicative of sustainable populations.

A coordinated regional approach to wetland management and monitoring could help address many of the information needs noted above. We recommend taking a long-term, experimental approach to management and monitoring directed at the knowledge gaps limiting all-bird conservation efforts. A critical first step toward that goal would be recording and tracking the management history at wetlands, especially those undergoing research and monitoring activities. Tozer et al. (2018) suggested research to assess the effectiveness of wetland management could be facilitated by organizations maintaining and making available information on the conservation actions that have occurred. We recommend management information be gathered and coordinated at the regional level in tandem with ongoing research and monitoring activities and we provide a draft framework for consideration in Appendix B.

RECOMMENDATIONS FOR MANAGEMENT AND MONITORING

This study increased our understanding of marsh bird response to wetland management, highlighted remaining knowledge gaps, and elucidated additional needs for regional coordination in data gathering and monitoring. Several marsh bird species appear to be benefitting from impoundment management, but the habitat factors associated with greater use, as well as the "best" management actions to maximize use, remain unclear. Marsh birds may be attracted to deeper and/or more stable hydroperiods of impounded wetlands, but changes to water depths (greater or lower) and/or drawdown frequency could further enhance use by these species. In addition, we do not have adequate information on the use of impounded and unimpounded wetlands by other bird groups. Greater use of impounded wetlands by marsh birds does not necessarily equate to greater use by other bird groups, such as waterfowl and shorebirds.

Management strategies that maximize use by all birds and promote sustainable populations are needed to achieve regional population goals. We used the results of this study, past research, and critical information gaps, to frame a potential approach to regional management and monitoring that addresses these uncertainties. We offer several recommendations to move regional wetland bird management and monitoring forward: 1) take a long-term, experimental approach to management and monitoring to address knowledge gaps regarding how birds and their habitats respond to conservation actions; 2) begin collecting information on management influencing conditions at survey sites; and 3) increase volunteer participation in the collection of environmental and habitat information for use in future analyses.

1) Potential Elements of an Experimental Approach to Management and Monitoring

We suggest using an experimental approach to management and associated monitoring that builds upon the base of information already collected. This approach could reduce the uncertainty associated with bird response to water level management that is typically conducted for waterfowl and assumed to benefit other birds. Substantial marsh bird data have already been collected at both impounded and unimpounded wetlands in the Great Lakes region (Figure 2), which provides an opportunity to develop a robust sample design that maximizes learning by examining experimentally managed wetlands over time and in comparison with reference sites. This approach could be spatially replicated in ecologically meaningful geographic zones (e.g., BCRs, northern vs. southern Great Lakes). Ongoing marsh bird surveys in Michigan, Minnesota, Ohio, and Wisconsin have closely aligned survey methodologies and target species, so there is good potential to implement a coordinated experimental plan in both BCRs 12 and 23 (Figure 2). The management and monitoring plan proposed in this report could serve as pilot effort to better coordinate management among Joint Venture partners, directly link management actions with assessment, and implement integrated bird management in alignment with regional goals.

Below we suggest several elements to be considered in developing a regional management and monitoring plan. In Figure 3, we present a conceptual design to assess the effects of management on birds and their habitats within BCR 23. This framework could be expanded to other geographies (e.g., BCR 12, entirety of the four states) or focused on smaller areas to address high priority regional needs. The proposed design incorporates multiple management strategies and variable frequencies of complete drawdowns that fit within the typical recommendations for managed freshwater marshes (Harris and Marshall 1963, Knighton 1985).

a) *Implement a large-scale, experimental approach*: Although some past studies have assessed bird response to management and habitat factors, few studies have been conducted in the Great Lakes or Midwest regions, the research has been limited in spatial and taxonomic scope, and experimental management is rarely attempted at a large scale. Given that most bird conservation planning has been done at the regional level (e.g., Soulliere et al. 2018), implementing a management and monitoring plan at a large, regional scale would provide valuable information to assist strategic habitat conservation.

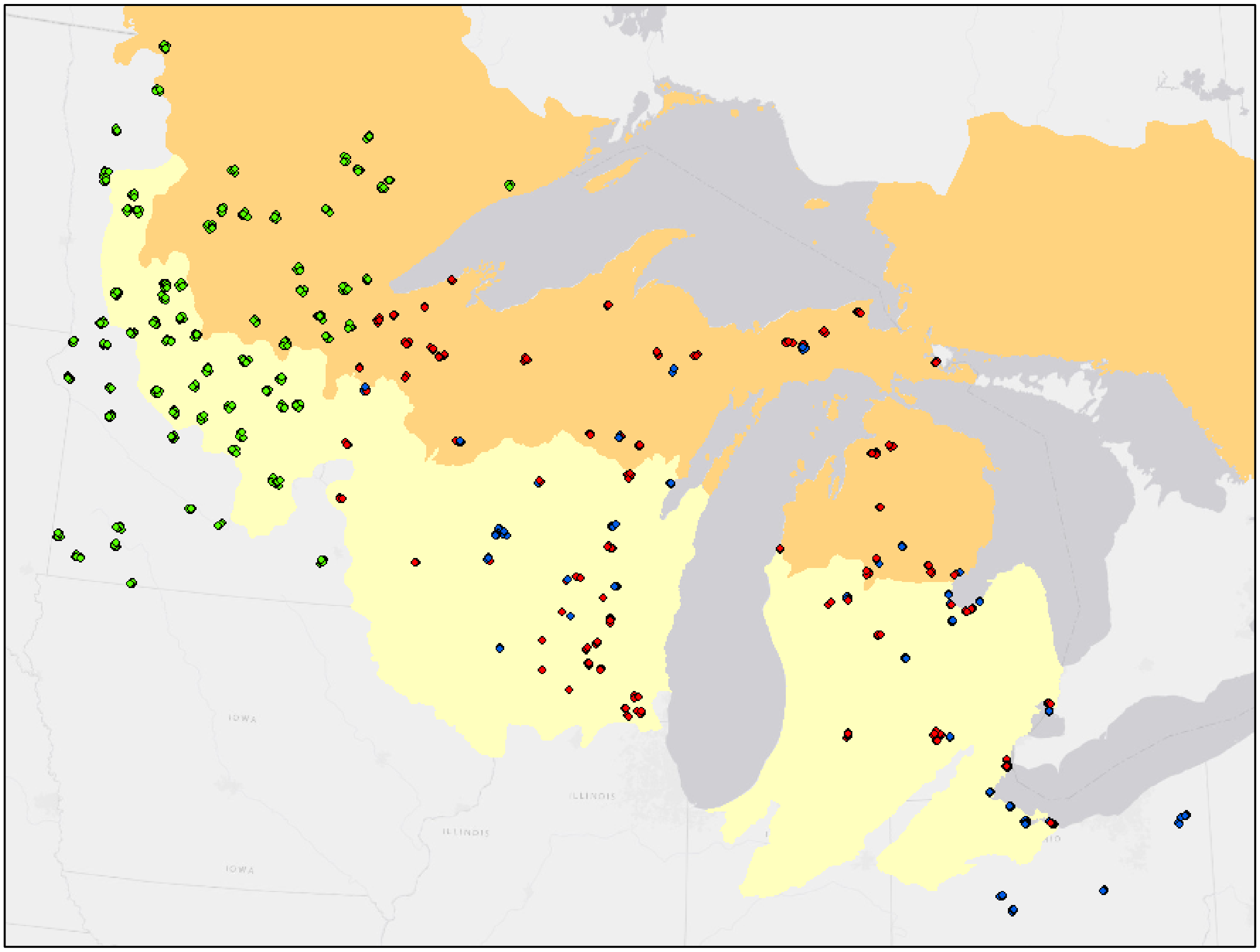

Figure 2. Marsh bird survey points within Bird Conservation Regions 12 (orange shading) and 23 (yellow shading). Points are color coded according to impoundment status (red = not impounded, blue = impounded, and green = undetermined).

State	Type	Freq	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
MI	DM	Short		0	1	2	0	1	2	0	1	2	0	1	2	0	1
MI	DM	Medium		0	1	2	3	4	5	0	1	2	3	4	5	0	1
MI	DM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
MI	MM	Short			0	1	2	0	1	2	0	1	2	0	1	2	0
MI	MM	Medium		0	1	2	3	4	5	0	1	2	3	4	5	0	1
MI	MM	Long			0	1	2	3	4	5	6	7	8	0	1	2	3
MI	SM	Short			0	1	2	0	1	2	0	1	2	0	1	2	0
MI	SM	Medium			0	1	2	3	4	5	0	1	2	3	4	5	0
MI	SM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
MI	SQ	NA															
MI	RE	NA															
MN	DM	Short	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2
MN	DM	Medium		0	1	2	3	4	5	0	1	2	3	4	5	0	1
MN	DM	Long			0	1	2	3	4	5	6	7	8	0	1	2	3
MN	MM	Short	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2
MN	MM	Medium		0	1	2	3	4	5	0	1	2	3	4	5	0	1
MN	MM	Long	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5
MN	SM	Short		0	1	2	0	1	2	0	1	2	0	1	2	0	1
MN	SM	Medium	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2
MN	SM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
MN	SQ	NA															
MN	RE	NA															
OH	DM	Short	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2
OH	DM	Medium	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2
OH	DM	Long	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5
OH	MM	Short		0	1	2	0	1	2	0	1	2	0	1	2	0	1
OH	MM	Medium			0	1	2	3	4	5	0	1	2	3	4	5	0
OH	MM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
OH	SM	Short		0	1	2	0	1	2	0	1	2	0	1	2	0	1
OH	SM	Medium			0	1	2	3	4	5	0	1	2	3	4	5	0
OH	SM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
OH	SQ	NA															
OH	RE	NA															
WI	DM	Short			0	1	2	0	1	2	0	1	2	0	1	2	0
WI	DM	Medium	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2
WI	DM	Long	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5
WI	MM	Short			0	1	2	0	1	2	0	1	2	0	1	2	0
WI	MM	Medium			0	1	2	3	4	5	0	1	2	3	4	5	0
WI	MM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
WI	SM	Short		0	1	2	0	1	2	0	1	2	0	1	2	0	1
WI	SM	Medium		0	1	2	3	4	5	0	1	2	3	4	5	0	1
WI	SM	Long			0	1	2	3	4	5	6	7	8	0	1	2	3
WI	SQ	NA															
WI	RE	NA															

Water Levels

- Drawdown
- Shallow pool
- Normal pool
- Full pool
- Unmanaged

Management Types

Shallow Marsh (SM)	Drawdown followed by shallow pool water levels
Medium Marsh (MM)	Drawdown followed by normal pool water levels
Deep Marsh (DM)	Drawdown followed by full pool water levels
Status Quo (SQ)	No drawdown with normal pool water levels and natural fluctuations
Reference (RE)	No water level or other management implemented

Management Frequency

Short	Drawdown every 3 years
Medium	Drawdown every 6 years
Long	Drawdown every 9 years

Figure 3. Conceptual design for a 15-year experimental monitoring plan within BCR 23 to assess the effects of wetland management on bird use and habitat characteristics. Numbers within cells indicate the number of years since last drawdown.

b) *Evaluate multiple management strategies*: We suggest multiple strategies be assessed to address key knowledge gaps. Although more is known about waterfowl, optimal management strategies for marsh birds are less understood and the management actions that provide for the greatest overall use of multiple bird groups (e.g., waterfowl, marsh birds, and shorebirds) remain unknown (Larkin et al. 2013). Our proposed design incorporates three management strategies and varies the frequencies at which drawdowns occur (Figure 3). We defined three potential management strategies: 1) shallow marsh (drawdown followed by shallow reflooding, e.g., 15-30 cm), 2) medium marsh (drawdown followed by moderate flooding, e.g., 30-45 cm), and 3) deep marsh (drawdown followed by deep flooding, e.g., 45-60 cm). Additional factors, such as timing of drawdowns (e.g., early, mid, and late season), could be explored. However, invasive plant species, such as narrowleaf/hybrid cattail (*Typha angustifolia*, *T*. x *glauca*), purple loosestrife (*Lythrum salicaria*), and common reed (*Phragmites australis*), are likely to respond to early and mid-season drawdowns (Fredrickson 1991, Sojda and Solberg 1993, Michigan Department of Environmental Quality 2014), so we suggest consistently applying late-season drawdowns across all management strategies.

c) *Examine legacy effects*: Early studies evaluating the use of drawdowns as a wetland management technique provide information on the response of waterfowl, vegetation, and invertebrates during multiple seasons after drawdowns occurred (e.g., Kadlec 1962, Harris and Marshall 1963, Whitman 1976), yet follow-up surveys usually lasted a few seasons at most and were focused on a small number of impoundments. We are not aware of any large-scale studies examining the how the frequency of drawdowns influences bird use and habitat characteristics. Our design provides for short (3 years), medium (6 years), and long (9 years) drawdown intervals, allowing us to compare bird and habitat metrics based on years since disturbance (e.g., drawdown +1 year, +2 years, etc.). The design would also allow us to assess differences in variables (bird or habitat) based on whether a drawdown was followed by shallow, moderate, or deep flooding.

d) *Compare managed units to reference sites*: Sampling reference sites is vital to evaluating the response of birds and their habitats to management. We suggest conducting the same monitoring of birds and habitat at a set of unimpounded, unmanaged reference sites. In addition, we recommend a set of "status quo" impounded wetlands also be incorporated into the design (Figure 3). These units would be held at average pool levels with no drawdowns beyond the normal lowering of water levels that often occurs in late summer. Status quo wetlands would provide an example of the passive management that often occurs in impounded wetlands as a comparison to the more active experimental management we propose.

e) *Stagger when management starts at the sites*: When implementing experimental management, we recommend staggering drawdowns across the sites over multiple years. Drawing down all or most of the sites in a given year could confound management actions with weather conditions. In our example design, we randomly selected whether management in an impoundment would start in year one, two, or three of the program (Figure 3).

f) *Use existing data*: As much as possible, the monitoring program should build upon sites with existing marsh bird data, some of which have survey information dating back to 2008. In addition to providing before-after management comparisons, effort could be made to determine the management history at impounded sites and fit them within the experimental monitoring framework moving forward.

g) *Provide spatial replication*: Given funding and logistical constraints, spatial replication of sites within management categories should be maximized across the region(s) of interest (e.g., states, BCRs) to better capture the range of variation within each management category.

h) *Expand monitoring beyond marsh birds*: To help facilitate holistic bird management, the response of other bird groups (e.g., waterfowl, shorebirds) should be monitored in addition to continuing marsh bird surveys. Monitoring of multiple bird groups is essential to determining management strategies that benefit the greatest number of species and to meeting the goals of Joint Venture plans. Although point counts for marsh birds should continue, alternative survey methods would be needed to assess the response of other waterbirds, waterfowl, and shorebirds to management. The Joint Venture uses both breeding and non-breeding population targets to set waterfowl habitat objectives (Soulliere et al. 2007b, Soulliere et al. 2017), so partners would need to determine the target species (e.g., focal species vs. all species) and priorities for monitoring waterfowl response to management (e.g., breeding, migration [spring and/or fall], or both). Assessing breeding waterfowl use would require breeding pair, nest, and/or brood surveys, whereas other techniques would be necessary to evaluate migrant use, such as stationary ground surveys, flush counts, and/or aerial surveys. Similar decisions would be necessary to identify priorities for shorebird monitoring, such as target species, methodology, and survey timing (i.e., spring, fall, or both migration periods). The Integrated Waterbird Management and Monitoring (IWMM) Program has standardized protocols that could be used to survey non-breeding waterfowl, waterbirds, and shorebirds and to characterize wetland unit conditions (Loges et al. 2017).

i) *Collect information on vegetation response*: The vegetation response to management should be monitored concurrent with bird surveys. Although the wetland characteristics gathered by marsh bird survey volunteers could be used if collected consistently, additional sampling would be required to assess management actions. Two scales of characterization would be useful in comparing management categories: 1) wetland-scale digitization of emergent vegetation and open water encompassing all survey areas using aerial photography interpretation; and 2) fine-scale sampling of wetland variables using quadrats or other methods at bird survey sites (e.g., points, areas). Fine-scale sampling should focus on variables most likely to influence bird use, such as water depth, interspersion, vegetation structure, and dominant taxa. If bird surveys were conducted using the IWMM protocol, then survey units should be characterized according to the methods described by Loges et al. (2017).

j) *Commit to long-term (≥10 years) management and monitoring*: Given the inherent variability and complexity of wetland ecosystems, a long-term approach will likely be needed to discern relationships among management, birds, and their habitats. In Figure 3, we show how an experimental management and monitoring plan could be implemented over a 15-year period.

k) *Consider efficient sample designs*: A monitoring program at the scale proposed here could be facilitated using a panel design, which can be implemented in many ways. Using the example provided in Figure 3, we would need a minimum of 44 sites (11 management categories x 4 states). As an example, a panel design could consist of surveying a subset of 11 sites, one randomly selected for each management category, in a given season. A new set of 11 wetlands would be sampled in the following year, such that all 44 sites are surveyed by the end of four years. An alternative approach could be to conduct specific surveys at a subsample of sites representing all management categories on a rotating basis. For example, in year one, a third of the sites are surveyed for waterfowl, a third for shorebirds, and a third for marsh birds, with the bird groups being surveyed at each subset of sites being rotated in years two and three so that all sites would be surveyed for all three bird groups by the end of the three years. A panel design could be an efficient means to implement the monitoring, especially if it is designed as a long-term program. Figures C1 and C2 (Appendix C) provide visual representations of these example panel designs.

l) *Characterize the land cover surrounding study sites*: In addition to management, factors at landscape, wetland, and smaller scales can influence where birds occur during both breeding and non-breeding periods. As part of a long-term management and monitoring program, the land cover surrounding study sites should be quantified periodically using existing data sources, such as the NLCD (Homer et al. 2015). The information could be used in analyses to examine how landscape context influences bird response to management.

m) *Consider associated research projects*: Where feasible, research could be coordinated within the long-term monitoring and management program to address other information needs. Because population indices, such as abundance and occupancy, are not necessarily indicative of population status, additional research will ultimately be needed to assess the status of priority species. Studies that produce estimates of population metrics (e.g., nest density and success, adult and juvenile survival) for focal and/or indicator species would be valuable. Investigations of food resource availability as related to management practices are also needed.

2) Collection of Management Information

If gaining a better understanding of how wetland birds respond to management continues to be a goal for regional partners, then effort should be directed toward recording the management history (i.e., techniques, dates, duration, etc.) at sites where bird surveys are conducted. Management actions should be described for all survey points, not just those actively managed using water level manipulations. We developed a potential framework (Appendix B) for gathering this information at marsh bird survey points at the regional scale (e.g., Great Lakes, Midwest). A spreadsheet tool for collecting this information was developed as a potential mechanism for collecting information from managers. However, a variety of tools could be used to gather these data, such as online survey platforms (e.g., Qualtrics, SurveyMonkey), document sharing services (e.g., Google Drive, Microsoft OneDrive), web-based GIS systems (e.g., ArcGIS Online, Data Basin), and the Midwest Avian Data Center (e.g., user interface for data entry). We suggest the framework developed under this project be presented to the Midwest Marsh Bird Working Group and potentially the Joint Venture Waterbird and Waterfowl Committees. The partners should first discuss the potential uses and value of the management information and decide if collecting this information is a priority. By identifying the expected uses of the data, the scale at which the information should be solicited will become clear. For example, if the intent is to use the information as covariates in future marsh bird monitoring and analyses, then the focus might be collecting data at surveyed points in the Great Lakes states having consistent survey protocols. Additional uses of management data may be identified, such as assessing the status of wetland management in the Midwest (e.g., typical strategies, opportunities for coordination), which would likely require different spatial scales and perhaps methods of data collection (e.g., delineation of polygons indicating specific management actions).

3) Collection of Environmental and Habitat Information

Communication among the coordinators of the Michigan, Ohio, and Wisconsin marsh bird surveys resulted in consistent sampling methodologies, including the variables collected to characterize environmental and habitat conditions during surveys. If gathered consistently across sites and visits, these data could be used as covariates in data analyses (e.g., occupancy models). However, inconsistent data collection was common in the datasets examined for this study, making the use of many variables in data analyses problematic or impossible. For example, weather and noise data were commonly missing and the collection of habitat information is considered optional by Wisconsin and Michigan did not make the collection of these data mandatory until 2015, resulting in many observations having no information on wetland characteristics. We suggest members of the Midwest Marsh Bird Working Group identify a small set of priority environmental and habitat covariates that could be valuable in future analyses and require them to be collected by volunteers. The overall amount of information to be collected could be reduced to make it easier for surveyors to gather the data. Some volunteers are intimidated by habitat sampling due to limited abilities in plant identification. Additional training materials and/or workshops in plant identification may reduce this concern and increase the likelihood of participation. Regular communication with volunteers before, during, and after surveys about the importance of these data might increase participation rates. Providing volunteers brief annual reports summarizing the bird and habitat observations could also highlight the value and potential uses of the data. Given the good alignment of sampling methods among state partners, efforts to increase data collection could be coordinated at the regional level to increase efficiency.

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APPENDIX A

Definitions and Process for Classifying Impoundment Status of Survey Points

Impoundment Status Category Definitions

Intentionally impounded	Water level at point is intentionally raised by man-made water-control structures; site may not be flooded in all years (e.g., drawdown period) and could be periodically flooded above intended depth (e.g., after major precipitation event).
Unintentionally impounded	Water level at point is unintentionally raised by man-made structures (e.g., road bed); site may not be flooded in all years (e.g., during drought).
Intentionally lowered	Water level at point is intentionally lowered by nearby drainage ditches/tiles (i.e., partially drained); site may still be seasonally or periodically flooded.
Unintentionally lowered	Water level at point is unintentionally lowered by man-made structures above the point (e.g., located immediately below a dike or road bed that is impounding water); site may still be seasonally or periodically flooded.
Beaver impounded	Water level at point is raised by beaver activity (e.g., dam, plugged culvert); site may only be seasonally flooded and could dry periodically (e.g., during drought).
Beaver lowered	Water level at point is lowered by beaver activity above the point (e.g., located immediately below beaver dam); site may still be seasonally or periodically flooded.
Not impounded	Water level at point is not raised or lowered by man-made structures or beaver activity.
Uncertain	Point is near a man-made structure (e.g., dike, road) or beaver dam, but it is not clear if the water level is being raised or lowered.

Survey Points Data Layer

- This is a point data layer representing survey stations for the Wisconsin, Michigan, and Ohio marsh bird surveys. This is the data layer in which the impoundment status categories will be entered.

Aerial Imagery

- Several map and aerial imagery data layers are available through ESRI and have been incorporated into the ArcGIS Online project. Additional Michigan-specific imagery layers are listed below.
- MIS Public Imagery – Best Available Mosaic: The best available image service is a mosaic composed of the latest aerial photography existing in the state of Michigan. As new county

image sets are made available they are added to the mosaic. If a county has not partnered with the State than the region is back filled with the natural color NAIP 2010 imagery.

- MIS Public Imagery – NAIP 2012 Color Infrared: This data set contains color infrared (infrared, red, green) imagery derived from aerial photography acquired for the National Agriculture Imagery Program (NAIP).
- MIS Public Imagery – USGS Topographic DRG: This is a statewide mosaic of all TOPO quads in the state of Michigan. Digital Raster Graphics (DRGs) are scanned US Geological Survey (USGS) topographic maps. These maps show political boundaries, surface features, hydrographic features, survey boundaries, buildings, roads, contour lines, and other features.
- NAIP\Michigan_2014_1m: This is a statewide mosaic of the most recent (2014) aerial imagery available from National Agriculture Imagery Program (NAIP) at 1 m resolution.

<u>Other Information</u>

- MI_Wetlands: This is a polygon data layer indicating wetlands identified in Michigan by the National Wetlands Inventory. Each polygon is labeled by its map code.
- NWI_map_code_diagram: This is a PDF detailing the meaning of the codes used to describe wetlands identified by the National Wetlands Inventory. There is also an online wetland code interpreter located at http://107.20.228.18/decoders/wetlands.aspx.
- MI_Dams: Locations of dams in Michigan as compiled by the Michigan Department of Environmental Quality.

<u>Evaluation Process</u>

- Navigate to the point you are evaluating and examine aerial photos at the wetland scale to determine if the water level appears to have been impounded, lowered, or altered by beaver activity.
- Turn on the NWI wetlands layer to determine if the wetland has been identified as having been diked or excavated.
- Examine USGS topographic maps to evaluate if any human alteration of the wetland may have occurred in the past (e.g., roads, ditches, dikes, etc.).
- Once you have determined the impoundment status category that best describes the point, enter it in the “IMP_STATUS” field of the “all_point_combined” shapefile attribute table. If you are uncertain about the impoundment status of the point, enter “Uncertain” in the attribute table and provide a brief description of the situation in the “Comments” field.
- If you believe the water level has been altered at the point, measure the distance to the nearest hydrologic alteration that you feel is affecting water levels at the point (i.e., nearest distance to the dike, road, beaver dam, etc., that is altering water levels).
- Enter the distance in the “DIST_HYRO” field of the shapefile attribute table. If there is no alteration of the hydrology, make sure the default entry for the field remains at “0”.
- Briefly describe your justification for selecting the impoundment status category that you used in the “Comments” field of the attribute table.

APPENDIX B

Draft Framework for Gathering Management Information at Marsh Bird Survey Points

HABITAT MANAGEMENT/DISTURBANCE AT MARSH BIRD SURVEY POINTS IN THE GREAT LAKES REGION

Goal:

- Describe management activities and other disturbances near survey points to facilitate future analyses that improve our understanding of the influence of habitat changes on marsh bird use over time. I suggest we use the area within 100 m of each survey point as the area of reference. This area is consistent with the wetland characteristics already described annually by marsh bird survey volunteers, encompasses most marsh bird detections, and avoids us having to ask managers to delineate areas on maps where particular activities occurred.

Information to be collected at each survey point:

- Action/disturbance

    - *Drawdown*
        - Type
            - Partial
            - Complete
        - Cause
            - Structure manipulation (e.g., control structure, pump)
            - Natural event
            - Infrastructure failure (e.g., dike wash-out)
            - Beaver management (e.g., dam removed, structure unplugged)
        - Season
            - Spring
            - Summer
            - Fall
            - Winter
        - Duration
            - ≤ 1 month
            - > 1 month – 1 growing season
            - > 1 – 2 growing seasons
            - > 2 growing seasons

    - *Flooding*
        - Type
            - Partial
            - Complete
        - Cause
            - Structure manipulation (e.g., control structure, pump)
            - Natural event
            - Infrastructure failure (e.g., pump breakdown)
            - Beaver activity (e.g., dam construction, structure plugged)
        - Season
            - Spring
            - Summer

    - Fall
    - Winter
  - Duration
    - ≤ 1 month
    - > 1 month – 1 growing season
    - > 1 – 2 growing seasons
    - > 2 growing seasons

- *Mowing*
  - Type
    - Large equipment (e.g., tractor/other vehicle with mowing deck)
    - Hand-held equipment (e.g., weed trimmer)
  - Season
    - Spring
    - Summer
    - Fall
    - Winter

- *Fire*
  - Type
    - Prescribed
    - Other man-made (e.g., unintentional, arson)
    - Natural
  - Season
    - Spring
    - Summer
    - Fall
    - Winter

- *Disking*
  - Season
    - Spring
    - Summer
    - Fall
    - Winter

- *Herbicide application*
  - Type
    - Broad-scale (e.g., aerial or boom application)
    - Spot treatment (e.g., backpack sprayer, hand treatment)
  - Season
    - Spring
    - Summer
    - Fall
    - Winter

- *Micro-topography manipulation*
  - Type
    - Opening (created opening through removal of soil/vegetation mats)
    - Island (created island of upland/emergent vegetation through addition of soil/organic matter)
  - Season
    - Spring
    - Summer
    - Fall
    - Winter

- *Uncertain* (management actions may have occurred but no documentation or current knowledge).

- *None* (no known or visible management or disturbance)

- <u>Other information</u> (for each management action, we would request the information below)

  - *Year of implementation*
    - Enter year of action
    - If year unknown, use the following time framework:
      - ≤ 2 years before present
      - > 2 – 5 years before present
      - > 5 – 10 years before present

  - *Scale of management/disturbance* (i.e., overall area or footprint of the management/disturbance; numbers below are based on circular areas with radiuses of 100, 250, 500, and 1000 m)
    - ≤ 3 ha (≤ 8 ac)
    - > 3 – 20 ha (> 8 – 49 ac)
    - > 20 -79 ha (> 49 – 194 ac)
    - > 79 – 314 ha (> 194 – 776 ac)
    - > 314 ha (> 776 ac)

  - *Accuracy of information* (need to ask managers about their level of confidence in data collection)
    - Are you confident all management occurring at this point in the last 10 years has been described?
      - Yes
      - No
      - Uncertain

APPENDIX C

Conceptual Examples of Long-term Monitoring Programs Using Panel Designs

State	Type	Freq	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
MI	DM	Short		0	1	2	0	1	2	0	1	2	0	1	2	0	1
MI	DM	Medium		0	1	2	3	4	5	0	1	2	3	4	5	0	1
MI	DM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
MI	MM	Short			0	1	2	0	1	2	0	1	2	0	1	2	0
MI	MM	Medium		0	1	2	3	4	5	0	1	2	3	4	5	0	1
MI	MM	Long			0	1	2	3	4	5	6	7	8	0	1	2	3
MI	SM	Short			0	1	2	0	1	2	0	1	2	0	1	2	0
MI	SM	Medium			0	1	2	3	4	5	0	1	2	3	4	5	0
MI	SM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
MI	SQ	NA															
MI	RE	NA															
MN	DM	Short	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2
MN	DM	Medium		0	1	2	3	4	5	0	1	2	3	4	5	0	1
MN	DM	Long			0	1	2	3	4	5	6	7	8	0	1	2	3
MN	MM	Short	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2
MN	MM	Medium		0	1	2	3	4	5	0	1	2	3	4	5	0	1
MN	MM	Long	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5
MN	SM	Short		0	1	2	0	1	2	0	1	2	0	1	2	0	1
MN	SM	Medium	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2
MN	SM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
MN	SQ	NA															
MN	RE	NA															
OH	DM	Short	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2
OH	DM	Medium	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2
OH	DM	Long	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5
OH	MM	Short		0	1	2	0	1	2	0	1	2	0	1	2	0	1
OH	MM	Medium			0	1	2	3	4	5	0	1	2	3	4	5	0
OH	MM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
OH	SM	Short		0	1	2	0	1	2	0	1	2	0	1	2	0	1
OH	SM	Medium			0	1	2	3	4	5	0	1	2	3	4	5	0
OH	SM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
OH	SQ	NA															
OH	RE	NA															
WI	DM	Short			0	1	2	0	1	2	0	1	2	0	1	2	0
WI	DM	Medium	0	1	2	3	4	5	0	1	2	3	4	5	0	1	2
WI	DM	Long	0	1	2	3	4	5	6	7	8	0	1	2	3	4	5
WI	MM	Short			0	1	2	0	1	2	0	1	2	0	1	2	0
WI	MM	Medium			0	1	2	3	4	5	0	1	2	3	4	5	0
WI	MM	Long		0	1	2	3	4	5	6	7	8	0	1	2	3	4
WI	SM	Short		0	1	2	0	1	2	0	1	2	0	1	2	0	1
WI	SM	Medium		0	1	2	3	4	5	0	1	2	3	4	5	0	1
WI	SM	Long			0	1	2	3	4	5	6	7	8	0	1	2	3
WI	SQ	NA															
WI	RE	NA															

Water Levels
- Drawdown
- Shallow pool
- Normal pool
- Full pool
- Unmanaged

Management Types
- Shallow Marsh (SM) Drawdown followed by shallow pool water levels
- Medium Marsh (MM Drawdown followed by normal pool water levels
- Deep Marsh (DM) Drawdown followed by full pool water levels
- Status Quo (SQ) No drawdown, normal pool water levels, and natural fluctuations
- Reference (RE) No water level or other management implemented

Management Frequency
- Short Drawdown every 3 years
- Medium Drawdown every 6 years
- Long Drawdown every 9 years

Panel Sampling
- Sampled wetland

Figure C2. Conceptual design for a 15-year experimental monitoring plan within BCR 23 to assess the effects of wetland management on bird use and habitat characteristics using a panel design in which one of four subsets of wetlands is sampled annually on a rotating basis. The wetlands sampled in a given year are indicated by red outline. Numbers within cells indicate the number of years since last drawdown.

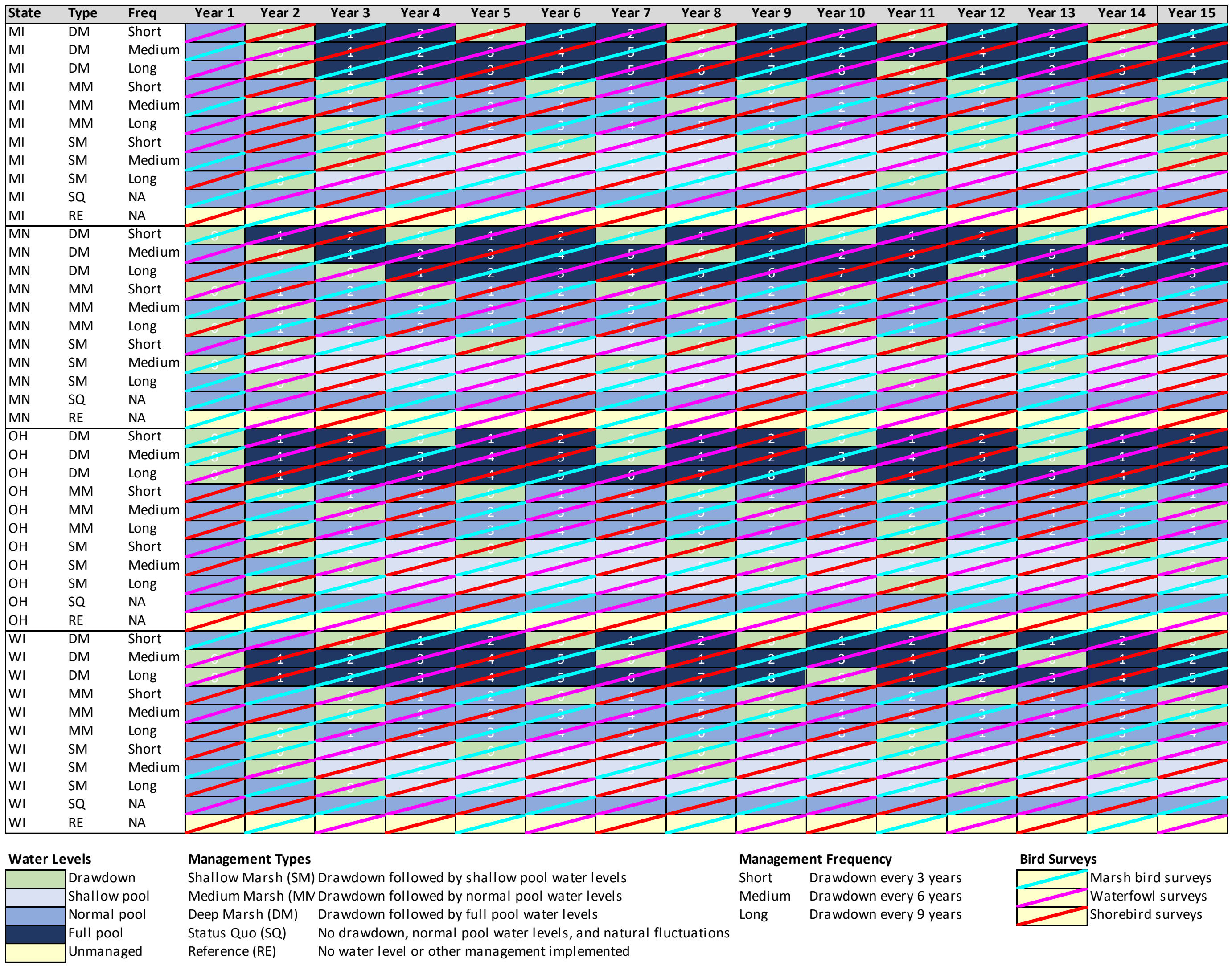

Figure C2. Conceptual design for a 15-year experimental monitoring plan within BCR 23 to assess the effects of wetland management on bird use and habitat characteristics using a panel design in which the type of bird surveys conducted at a site is rotated annually. Colored slashes indicated the bird surveys conducted in a given year (light blue = marsh bird, magenta = waterfowl, and red = shorebird). Numbers within cells indicate the number of years since last drawdown.