A synthesis of bird biodiversity studies in geographically isolated wetlands reveals research synergies and opportunities

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Abstract

Geographically isolated wetlands represent integral foraging and breeding habitat for many bird species across the United States, yet few studies have attempted to synthesize existing research to quantify generalizable relationships between bird biodiversity and geographically isolated wetlands. We conduct a systematic review of bird biodiversity in geographically isolated wetlands of the continental United States to explore the taxonomic and geographic areas of research and quantify the overarching themes in the literature. Most studies on bird biodiversity in GIWs come from the Midwestern United States, and only a third of all studies measured species richness and/or abundance for the entire avian community, with two thirds considering only a single taxonomic group (e.g., waterbirds) or a few key species (e.g., Black Tern, Northern Harrier, etc.). We find support from 15 US states for the species-area relationship for birds in geographically isolated wetlands. Semi-permanent wetlands (hydroperiod >9 months) support higher species richness of birds compared to seasonal or permanent wetlands, albeit most studies came from the Midwestern United States. Future research of bird biodiversity in geographically isolated wetlands is needed outside of the Midwestern United States, especially in high wetland cover areas like Florida or countries like Brazil and Botswana. Studies should also examine biodiversity metrics (e.g., phylogenetic or functional diversity) beyond abundance and species richness which do not capture the multifaceted nature of biodiversity. Long-term temporal and spatial analyses of community composition and organization are also needed to determine if bird communities are homogenizing through time or supporting especially unique communities across space.

Keywords: synthesis, review, birds, biodiversity, wetlands, geographically isolated wetlands

Introduction

Wetlands are vital habitats for wildlife that occur at the interface between terrestrial and aquatic systems, accounting for over a third of rare and endangered species in the United States alone (US EPA 2015). Yet, wetlands have undergone considerable losses estimated between 20-35% in the last 300 years (Dixon et al. 2016; Fluet-Chouinard et al. 2023). Many of these lost wetlands come in the form of isolated or geographically isolated wetlands (hereafter referred to as GIWs), due to land conversion for housing and agriculture across the world (McCauley, Jenkins, and Quintana-Ascencio 2013; Leibowitz and Nadeau 2003). GIWs are wetlands that are completely surrounded by upland habitat that lack a direct surface water connection for all, or some portion, of the year (adapted from Tiner 2003). GIWs have recently been revoked of federal protections under the Clean Water Act due to their lack of surface water connection, highlighting an urgent need for greater biodiversity and conservation attention as they continue to be lost or destroyed ("Revised Definition of 'Waters of the United States'; Conforming" 2023). Documenting biodiversity and biodiversity loss in wetland ecosystems, tends to be concentrated in large biodiversity hotspots or coastal wetlands like the Everglades in Florida, the Okavango Delta in Botswana, or the Pantanal in Brazil, that contain high rates of endemism and species diversity (Junk et al. 2006; Ma et al. 2010). But, GIWs are also especially important for wetland biodiversity (Comer et al. 2005) and they are widely distributed, representing an estimated 16% of total wetland area in the United States alone (Lane and D'Amico 2016; Lane et al. 2023). Given their large spatial distribution in the United States, their removal of legal protections, and their continued loss, synthesizing the existing biodiversity patterns in these systems is imperative.

GIWs have unique hydrologic conditions because they lack surface water connection to other wetlands, creating ideal conditions for herpetological species, herbaceous plants, and higher dispersal organisms like birds. Birds are important biodiversity indicators (Oertli and Parris 2019), are well-documented taxonomically, and their use of and reliance on many wetland habitats makes them an excellent taxonomic group to understand biodiversity patterns in GIWs. Waterbirds rely on these ecosystems for various stages of their annual biology and survival (e.g., breeding, migration) (Forcey et al. 2011; Paracuellos 2006). Their importance to waterbird biodiversity has been studied most intensely in the Prairie Pothole Region of the midwestern United States, where many waterbird species use them as migratory staging and breeding habitat (Elliott, Igl, and Johnson 2020; Fairbairn and Dinsmore 2001; Kantrud and Stewart 1977). GIWs may also act as satellite habitats for a variety of species to meet their life-history, especially for foraging as water levels fluctuate to match various prey and niche widths of a wide array of species (McKinney and Paton 2009). Although additional research on birds in GIWs has been conducted outside of this region (Barratt Heitmann et al. 2025; Czapka and Kilgo 2011; McKinney et al. 2011), it is unclear if similar biodiversity questions have been investigated in different parts of the United States. For example, determining support for the species-area relationship in different ecosystems, impacts of anthropogenic land cover at different spatial grains and extents, and the impacts of environmental filtering due to variable wetland hydrology. Furthermore, existing studies in GIWs have received considerable attention for wading birds and waterfowl, but it is unclear how, and to what extent, these patterns hold for other taxonomic groups (e.g., passerines) that are equally, if not more important for maintaining biodiversity.

Systematic reviews and syntheses can offer more generalizable conclusions through research weaving and collation of multiple, heterogeneous studies that have focused on different spatial and temporal units of analysis and geographic locations (Lortie 2014; Nakagawa et al. 2019; Spake et al. 2022). Systematic reviews for GIW biodiversity have focused extensively on certain anuran and herpetological species (Burrow and Lance 2022; Hamer and McDonnell 2008), but these systems are also heavily utilized by various avifauna across the continental United States. Another challenge in the review of GIWs studies is that current definitions and typologies associated with GIWs are primarily North America-centric. Nevertheless, the variety of terminologies that could characterize GIWs is numerous – e.g., over 35 different names as shown in Tiner (2003) alone. Such inconsistency and lack of clarity in GIW terminology can create research silos that overlook relevant research and lead to inaccurate or even misinterpretations of biodiversity patterns across the plethora of isolated wetlands in the United States and potentially the globe (Junk et al. 2006). Although global in distribution, nomenclature and wetland typology descriptions are only available for the United States. In order to review these systems globally, additional research is needed to identify the various names and wetland descriptions for these systems outside of North America—an objective outside the scope of this review. This nomenclature can silo different bird biodiversity studies in GIWs, highlighting the need for a more inclusive investigation of bird biodiversity studies in these systems more broadly.

Here in this study, we present a synthesis and systematic review of bird biodiversity studies conducted in GIW habitats from the continental United States. Our overall goal was to synthesize the bird biodiversity-GIW literature to date and provide an overview of gaps in this literature. To achieve this, we address three key objectives. Our first objective was to assess what bird species or groups of birds have been studied and where these studies have been conducted in the continental United States. Our second objective was to investigate which metrics of bird biodiversity have been measured (e.g., abundance, species richness, diversity, evenness) and determine whether these biodiversity measurements are consistent among species or taxonomic groups of birds and across the continental United States. Lastly, our third objective was to identify the emerging main thematic questions researchers have asked in this bird biodiversity-GIW literature.

Methods

We conducted our literature search and screening following the PRISMA protocol (Page et al. 2021). Specifically, we used 2 sets of keyword strings for literature searches on Web of Science and Scopus, on June 10, 2024 (Fig 1). The first topic search conducted on each of the aforementioned databases, screened articles by keywords, article titles, and abstracts. Our first search had to include 1 word from each of 3 sets of nested terms: ("isolated" OR "ephemeral" OR "geographically isolated" OR "temporary"), ("pond" OR "wetland" OR "marsh" OR "depression"), and ("bird" OR "avifauna" OR "waterfowl" OR "passerine"). We also conducted a secondary topic search on both databases, that targeted explicit types of GIWs from Tiner 2003, and had to contain 1 word from each of 2 sets of nested terms: ("pothole" OR "rainwater basin" OR "sandhill" OR "salt flat" OR "salt lake" OR "desert spring" OR "kettle-hole" OR "Carolina Bay" OR "Cypress dome" OR "sinkhole" OR "vernal pool" OR "interdunal" OR "intradunal" OR "bog" OR "geysers" OR "rock pool" OR "seepage slope" OR "fen" OR "depression" OR "excavated pond" OR "tarn" OR "excavated" OR "inactive floodplain" OR "Alvar"), and ("bird" OR "avifauna" OR "waterfowl" OR "passerine"). We performed multiple keyword searches to generate the greatest number of publication search results. Instead of restricting search terms to only GIW-specific wetland types found in Tiner (2003) (our second search), we included more general GIW related search terms to remove temporal bias for publications published after Tiner (2003) and Leibowitz and Nadeau (2003) using the aforementioned terminology (our first search).

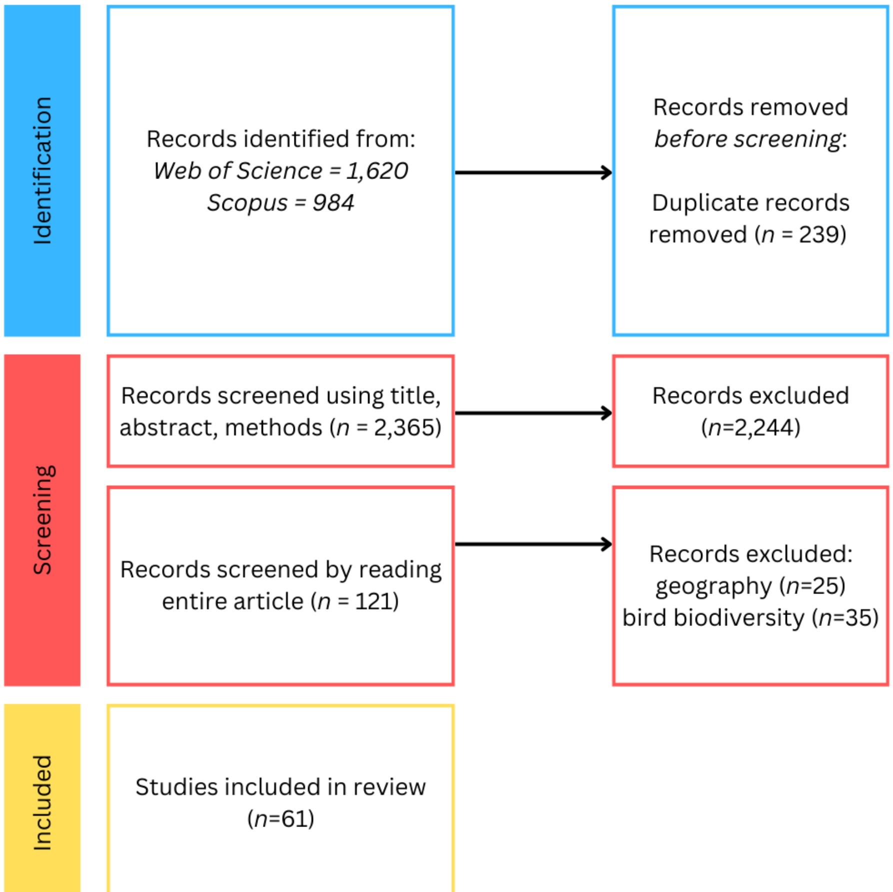

Figure 1. Path diagram using PRISMA standards for publication screening and inclusion.

We downloaded a total of *n*=1,620 articles from Web of Science and *n*=984 from Scopus, totaling *n*=2,604. After merging these datasets and removing duplicates, we obtained a total of *n*=2,365. We then began our screening process, where we removed all publications that did not include an explicit measurement of bird biodiversity (i.e., abundance, density, species richness, diversity) and/or was not conducted in at least one GIW by reading the title, abstract, and methods. This reduced the number of articles to *n*=121. We then performed a second screening of these articles, where we read the entirety of the publication to ensure the aforementioned requirements were met, and also removed publications that conducted research outside of the continental United States, since our definition of geographically isolated wetland by Tiner (2003) could not be easily applied to wetlands internationally or those in Alaska and Hawaii. GIWs represent a suite of different types of wetlands that may have different hydrologic, vegetative, and human-manufactured characteristics. In an attempt to be as inclusive as possible of all these different wetland types, we adapted our definition directly from Tiner (2003), where the wetland needed to be surrounded by upland habitat and lack direct surface water connection for all, or part, of the year. This includes seasonally pulsed wetlands adjacent to permanent water bodies like lakes and streams, man-made stormwater wetlands, or catchment wetlands that only have below-ground water transportation systems. These different wetlands are included because our birds are not able to travel via underground engineered hydrologic components, and so these still meet our definition of being surrounded by upland and lacking direct *surface* water connection. We applied this definition to descriptions and/or images by the authors in the methods sections used to describe their study sites.

Of the n=121 articles, in our first screening, we removed *n*=25 for their presence outside the continental United States. We removed these because we did not feel confident that we had adequately sampled for the many types of GIWs globally with our list of United States-centric wetland search terms. We also removed an additional *n*=35 publications that failed to either address bird biodiversity as a response variable, or the study was not explicitly conducted in at least one type of GIW. After this second screening, our database resulted in total of *n*=61 studies of bird biodiversity in GIWs which were considered for our synthesis (Table S1). Hereafter we will refer to this as the *bird biodiversity-GIW literature*.

We then subsequently extracted data from each individual article. This included the study location (state), biodiversity measures collected/calculated, GIW type (if referenced by author), taxonomic unit of interest (waterbirds, passerines, etc.), and any themes in the analysis. Themes were developed during the review of each article after reading the methods and results, and were not compiled *a priori*. Themes were assigned based on the research objectives and questions from the authors in the study. These themes therefore were not mutually exclusive and were determined by screening the authors defined research questions in the introduction and subsequent results. Following the review of all articles, we grouped publications into general thematic categories based on the questions addressed by authors (Fig S1). After reviewing all publications, we had *n*=27 identified themes, but in our results and discussion we only report on themes that had at least *n*=5 articles (Table 1). Articles could fall into more than 1 theme, if for example the authors measured differences in bird species richness between wetlands and surrounding uplands, as well as those along a rural-urban gradient (e.g., McKinney and Paton 2009). Therefore, the total number of publications per thematic category are not mutually exclusive and do not add up to *n*=61 in the results section.

Counting methodology

Given the sample size and heterogeneity in the datasets, we used a counting methodology (instead of calculating effect sizes using response ratios) to count occurrences for our 3 research objectives. For our first two objectives we simply tallied the number of times a biodiversity metric was collected and/or calculated and in which US state(s) the study was conducted in. For our final objective we counted the number of times an identified theme was addressed by the authors in each study. Using the counting methodology allowed us to easily quantify the total number of occurrences of each theme and then discuss the overarching findings. This approach allowed us to gauge overall results and research implications more broadly, rather than using a topical modelling approach to extract certain words or phrases from manuscripts—which can narrow the interpretations of results or make publications difficult to compare more qualitatively. We therefore do not make any quantitative suggestions of significance, only suggest what signals have generally been found and emerged in the context of each theme. Compared to formal meta-analyses, one possible caveat for this method is that we do not extract effect sizes and the strength of each analytic technique is weighted equally regardless of the statistical modelling technique employed by the authors (Allen 2017). Within each theme, we counted how the bird biodiversity metric was affected by the associated theme. For example, if a publication found that agricultural cover was negatively associated with species richness at the landscape scale, that publication received a count of *n*=1 for “agriculture landscape negative”. This made comparisons between publications within the same theme simpler qualitatively albeit less stringent quantitatively, to better assess overall findings in the literature (see Fig S2-S9).

Table 1. Themes with more than 5 publications in the bird biodiversity-GIW literature and their respective descriptions. A full list of all publications in our final dataset (*n*=61) and their associated themes are provided in Table S1.

Themes	Description	Example publication
Wetland Area	Bird counts and/or analyses were compared between GIWs with varying areas	*Mamo and Bolen 1999*
Hydrology	Bird counts and/or analyses were compared in GIWs with varying hydrology, in either naturally occurring or experimentally manipulated systems	*Kantrud and Stewart 1977*
Wetland Type	Bird counts and/or analyses were compared between different types of GIWs or GIWs were compared to other types of wetlands more broadly	*Herteux et al. 2020*
Vegetation	Bird counts and/or analyses were compared between predominant forms of vegetation in GIWs or surrounding GIWs including tree species identities and dominant vegetation types	*Keppeler et al. 2016*
Local and Landscape Land Cover	Bird counts and/or analyses were compared between local conditions surrounding and/or within GIWs and their landscape land cover context (continuous)	*Anderson and Rooney 2019*
Restoration	Bird counts and/or analyses were compared between GIWs in natural (degraded) and restored states, or across some restoration gradient	*Vanausdall and Dinsmore 2020*
Temporal	Bird counts and/or analyses were compared between seasons or across years (temporal) in GIWs	*Tsai et al. 2012*
Climate	Bird counts and/or analyses were compared or modelled by abiotic climactic conditions, or projected climate change scenarios in GIWs	*Steen and Powell 2012*

Results

Bibliometric summaries

After screening *n*=2,604 articles, we had *n*=61 (2%) that met our review criteria for being about bird biodiversity in isolated wetland(s) in the continental United States. These articles came from *n*=27 different journals, *Wetlands* had the greatest number of articles with *n*=12, followed by *Journal of Wildlife Management* with *n*=10, but the median number of articles per journal was *n*=1 (Fig. 2). Publications ranged in publication date from 1953-2023, with a 10-fold increase in number of publications since 1970 (Fig. 2).

Studies came predominantly from the Prairie Pothole Region (*n*=37) located in the Great Plains which includes Iowa (*n*=15), Montana (*n*=8), Nebraska (*n*=8), North Dakota (*n*=20), South Dakota (*n*=18), and Minnesota (*n*=12) in the United States (Fig. 3). All of the lower 48 states had at least 1 publication, however, *n*=13 of these came from a single study (Dertien et al. 2014).

The most common reported measurements and metrics by authors across all studies was abundance (*n*=61), followed by species richness (*n*=41), density (*n*=22), some measurement of diversity (Shannon-Wiener Index, Jaccard's Index, Sorensen Index) (*n*=7), and presence/absence (*n*=6) (Fig. 2).

About half of studies counted all species within the community (*n*=27), while others were more taxonomically focused/restricted (Fig. 2). Of the more taxonomically constrained studies, most were interested primarily in waterbirds (*n*=22), although some studies focused even more specifically on this group and restricted their analyses to only waterfowl (*n*=4), shorebirds (*n*=4), or marsh birds (*n*=4) (Fig. 2). The remaining studies had two or more specific focal species specifically, including Black Tern (*n*=1), Marsh Wren (*n*=1), Northern Harrier (*n*=1), Red-winged blackbird (*n*=2), and Yellow-headed blackbird (*n*=2).

Thematic representation

We identified a total of *n*=26 themes in the bird biodiversity-GIW literature (Fig S1). Of these, *n*=8 themes had more than five articles (Fig 4). Of the *n*=8 themes that met our criteria of having more than 5 papers, the most common theme was local and landscape land cover (*n*=23), followed by wetland area (n=12), hydrology (*n*=11), climate (*n*=7), temporal (*n*=6), vegetation (*n*=6), wetland type (*n*=6), and restoration (*n*=6) (Fig 4).

With the caveat that authors defined spatial scales quite variably, species richness and/or abundance were positively associated with higher wetland cover at the landscape scale in *n*=9 (*9/23, 39%*) of these studies. An additional *n*=4 (*4/23*, 17%) publications however found that increased wetland cover at the landscape scale was associated with lower species richness or density of at least 1 species in the study. Surprisingly, *n=4* (*4/23, 17%*) publications found a positive relationship between urbanization cover at the landscape scale and species richness (Eakin, Hunter, and Calhoun 2018; McKinney and Paton 2009) or abundance of a single species (Ballard, Jones, and Janke 2021; Saunders et al. 2019). Only a single study (*1/23, 4%*) found a negative relationship between urbanization cover at the landscape scale and abundance of half the study species (Saunders et al. 2019).

A majority of studies (*16/19, 84%*) found that increasing wetland area was associated with increased abundance (*n*=9), density (*n*=1), species richness (*n*=10), occupancy (*n*=1), and/or diversity (*n*=1). *N*=7 publications quantified impacts of climate in the bird biodiversity-GIW literature, including projected changes due to climate change and annual effects of precipitation on abundance and species richness. Three publications (*3/7, 43%*) found significant species range contractions due to climate change projections including highly variable annual precipitation and drought severity (Sorenson et al. 1998; Steen and Powell 2012; Steen et al. 2014). The other four publications (*4/7, 57%*) in the climate theme modelled abundance and species richness changes due to abiotic climatic conditions, including precipitation (Forcey et al. 2007; Forcey et al. 2011; Niemuth and Solberg 2003) and temperature (Dertien et al. 2014).

Of the *n*=11 papers in the hydrology theme, most (*8/11, 72%*) investigated different defined hydrology in the PPR region of the United States, where semi-permanent wetlands often had the highest species richness, compared to seasonal and permanent wetland classes. In the temporal theme, all of the studies looked at seasonal changes in bird species richness and abundance, with half (*3/6, 50%*) considering the changes across the full annual cycle, and the other half only considering the Spring, Summer, and small portions of the Fall. In the wetland type theme, three of the publications (*3/6, 50%)* compared bird biodiversity estimates between agricultural (man-made) wetlands to natural wetlands, and another three compared bird biodiversity between GIWs and other wetland types.

In the vegetation theme, half of the papers (*2/6, 33%)* found that emergent vegetation increased abundance for waterbirds, and half (*3/6, 50%)* found that trees, or specieific tree species, increased species richness. Of the four publications in the restoration theme analyzing differences in richness, abundance, and density of birds in natural compared to restored wetlands, (*2/4, 50%*) found that restored wetlands had higher estimates (Creighton et al. 1997; Elliott, Igl, and Johnson 2020), (*1/4, 25%*) found that natural wetlands were higher (Delphey and Dinsmore 1993), and (1/4, 25%) found no difference (Ratti et al. 2001).

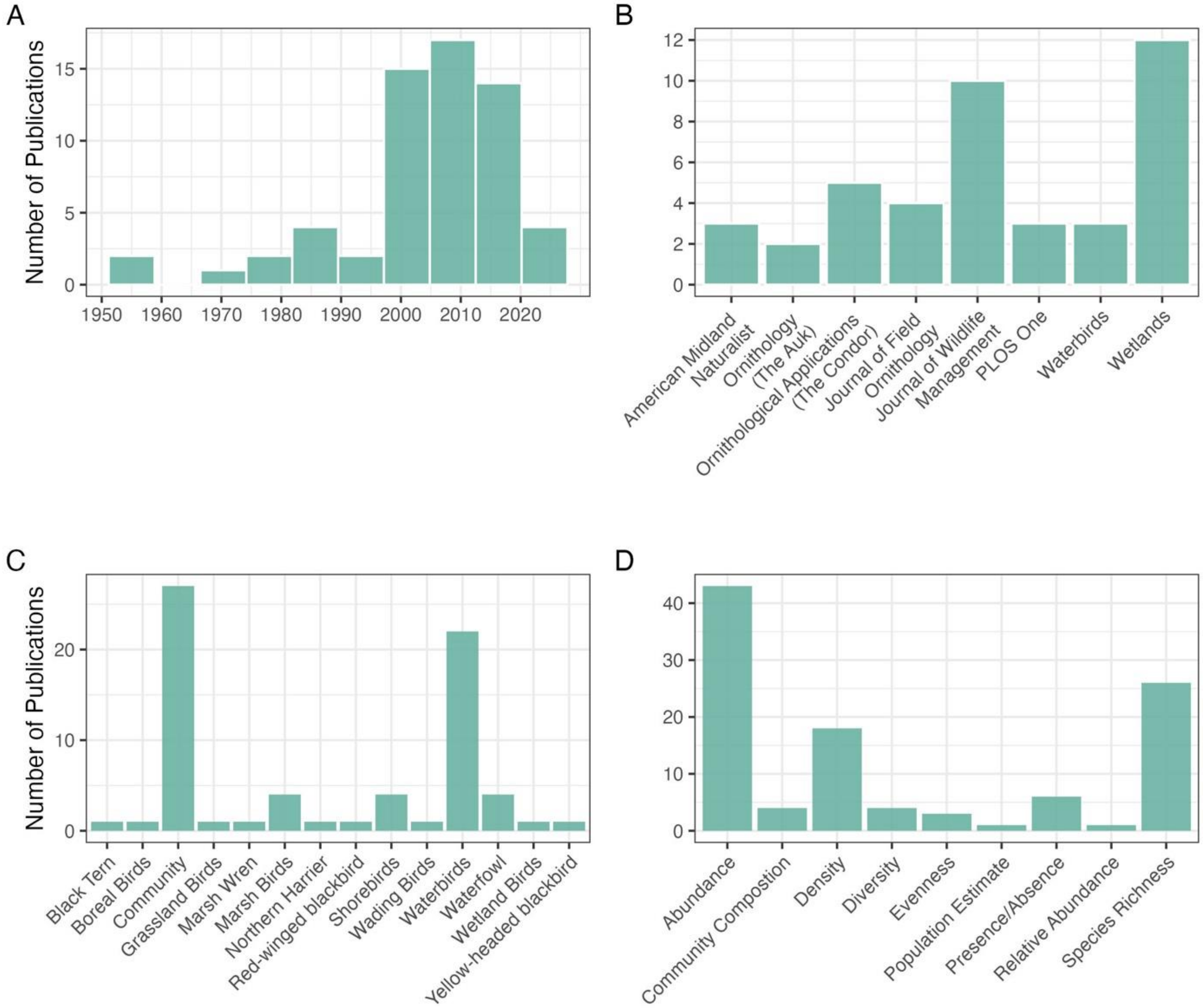

Figure 2. Summary information for number of publications by **A**) year, **B**) journal, **C**) taxonomic unit of interest, and **D**) biodiversity metric collected.

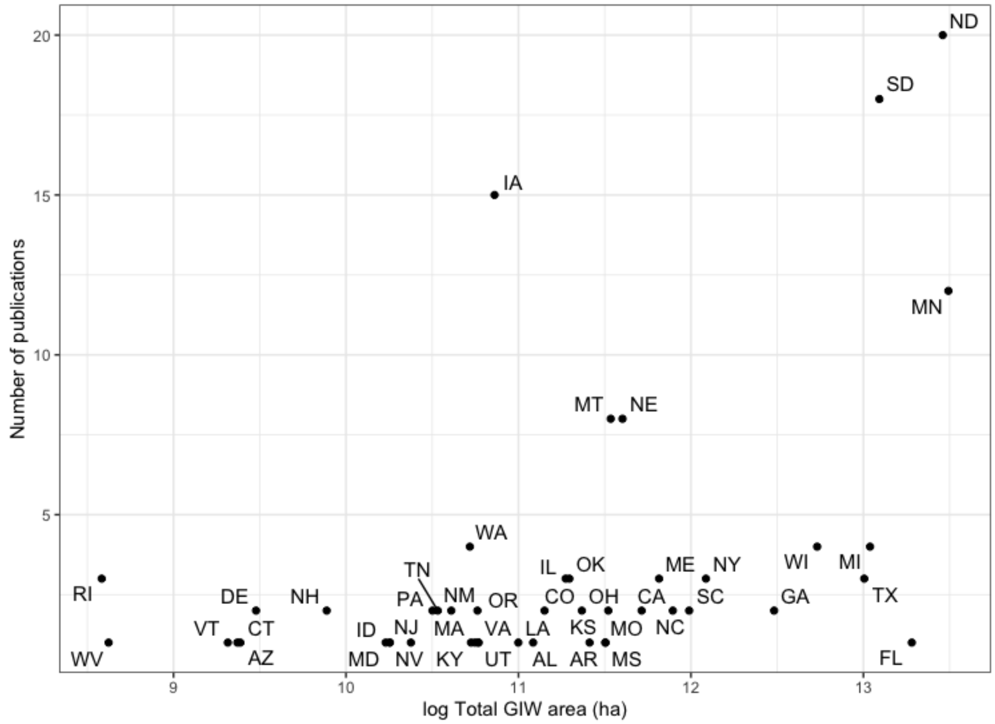

Figure 3. Number of publications by US state and their respective GIW areas (Lane and D'Amico 2016). If studies were conducted across multiple states, each state was counted and weighted equally. States with 1 publication all come from a single study at the continental scale (Dertien et al. 2020).

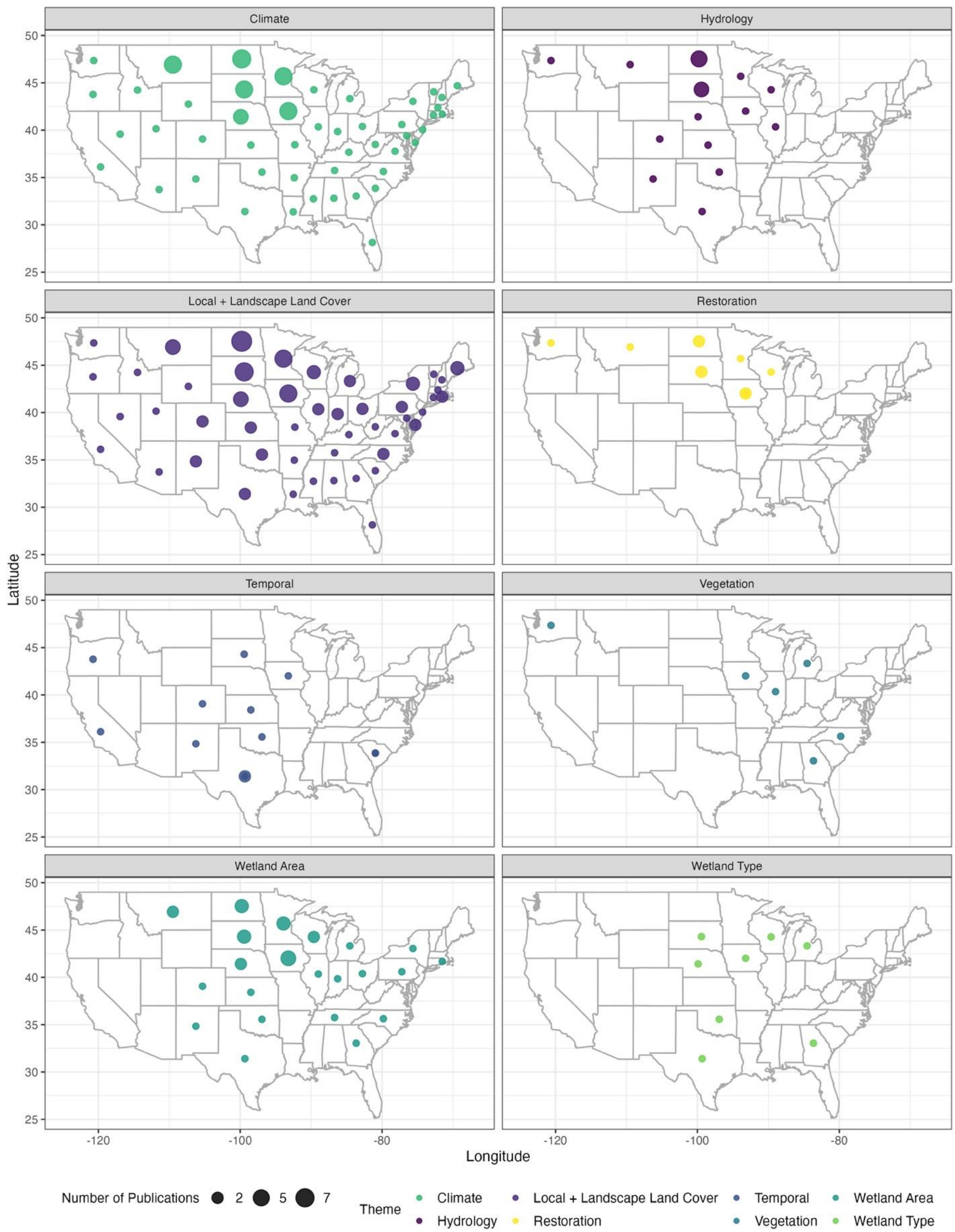

Figure 4. Number of publications per theme from each state in the continental United States. Only publications containing themes that had >5 publications are displayed (*n*=8).

Discussion of top identified themes

The themes and aims of the publications we identified in this review are not mutually exclusive, as vegetation can also be a component of local and landscape land cover comparisons, as is hydrology and wetland type. Therefore, although we break these different themes up into separate sub-categories, we do recognize that there are cross-cutting themes in some of the results. Due to our counting method, we recognize that equal weight is being attributed to each publication regardless of how strong the evidence was in the results of the publication (Game et al. 2018). However, we only count a themes' reported pattern if the test was deemed statistically significant by the author. Themes and the number of publications that were included in that theme are reviewed in turn below.

(1) Local and landscape land cover (N=23)

The scale and buffers at which authors defined local and landscape land cover varied across publications; local land cover scale varied from the attributes of a single wetland to 1 km radius around wetlands (Eakin, Hunter, and Calhoun 2018; McKinney and Paton 2009) and landscape land cover scale varied from 3 km to EPA Level II ecoregion (e.g., Mojave and Sonoran Desert Plains) (Dertien et al. 2020; Fairbairn and Dinsmore 2001; Forcey et al. 2011; Forcey et al. 2007). For example, Webb et al. (2010) used a 25km buffer to infer an overall negative species richness relationship to landscape-scale wetland cover in Nebraska, while Fairbairn and Dinsmore (2001) used a 3km buffer and found a strong positive relationship between total species richness and wetland landscape land cover in Iowa. Both of these studies examined wetland-dependent waterbird and shorebird species, which may indicate that foraging distance and/or dispersal range is impacting habitat use variably between the scales of 3km to 25km. However, it is important to note that buffer distance choices are not consistent amongst studies, likely reflecting arbitrary choices by the authors, rather than reflecting a true ecological mechanism. Future studies need to test multiple buffers to ensure they can find the true scale of effect (Barratt Heitmann et al. 2025).

Of the four studies that quantified the impacts of urbanization cover most found a positive relationship between urbanization and abundance or species richness. Three found a positive relationship with at least 1 species, while only 1 study found a negative relationship. This points to the value of wetland habitats in urbanized landscapes which can provide important biodiversity value, and potentially higher value than in rural settings due to increased urban tolerance in select bird species and/or reduced wetland cover creating fewer habitats throughout the landscape (Callaghan et al. 2021). However, of the three publications which found this positive association, 2 were only documented in 1 species' abundance (American Coot and Marsh Wren) in Minnesota and North Dakota with low urbanization footprints, and a third only found this positive relationship in Maine in urban-tolerant species richness. These important caveats mean that urbanized land cover may not act uniformly across all landscapes and ecotones, and that environmental filtering of the communities utilizing wetlands are not one-size-fits-all.

Lastly, total species richness was positively associated with increased local vegetation cover within GIWs in Webb et al. (2010) and Fairbarin and Dinsmore (2001), while Naugle et al. (2001) found a significantly positive relationship for only some species of waterfowl. Ballard et al. (2021) found that dabbling duck abundance was positively associated with emergent vegetation cover and diving duck abundance with submerged vegetation. All four studies that found a significant positive relationship were from the PPR region, and ¾ only considered waterbirds/waterfowl–not the entire community. Nonetheless, it appears that emergent vegetation at the local scale can play an important positive role in increasing both abundance and richness in GIW habitats for birds. This likely indicates that restored and created wetlands should leverage both flooded vegetation or submerged aquatic vegetation to promote bird habitat use, especially in manicured and mowed urban stormwater ponds that lack suitable vegetation characteristics to support biodiverse bird communities.

(2) Wetland area (N=19)

This indicates that these habitats are increasingly more valuable the larger they are, contrary to other wetland habitats like lakes which don't always show similar patterns of increased abundance or density with area (Ballard, Jones, and Janke 2021; Ruwaldt, Flake, and Gates 1979). Isolated wetlands therefore conform generally to the species-area relationship indicating that larger wetlands tend to support more individuals and species than smaller ones, possibly due to increased wetland edge for foraging, a greater variety of niches, or generally greater prey availability (Barratt Heitmann, Mason, et al. 2025; Cerda-Peña and Rau 2023). Only two found no relationship, and only a single study found that wading bird density was negatively associated with increased wetland surface area. These studies may have not found a positive relationship due to isolated wetlands being too similar in size, such that the gradient was not large enough to detect a significant difference (e.g., McKinney and Paton 2009; Scheffers, Harris, and Haskell 2006). The only publication to find a negative result was attributed to lower water depths in smaller wetlands that made foraging much easier for wading birds compared to larger excavated wetlands with large water depths and therefore inadequate foraging habitat (Herteux, Gawlik, and Smith 2020). The majority of papers suggest that wetland area plays a key role in increasing both abundance and species richness in birds, and when choosing to conserve or preserve wetlands, larger GIWs will typically have higher biodiversity value to birds.

(3) Hydrology (N=11)

The hydrologic regimes in wetlands, including wetland depth and hydroperiod, have long been studied for their impacts to biodiversity and birds are sensitive to changes in hydrologic condition of wetlands for foraging, nesting, and evasion of predators. Many of the papers that compared the impacts of different wetland hydroperiod (water permanence) occurred in the Prairie Pothole Region, where a robust system of wetland ranking based on hydrology exists from ephemeral (IV) to permanent (I). These publications consistently found that semi-permanent wetlands (II) had the highest estimates of species richness and abundance compared to all other wetland hydrologies (Austin 2002; Kantrud and Stewart 1984; 1977; Ruwaldt, Flake, and Gates 1979; O'Neal, Heske, and Stafford 2008). Semi-permanent wetlands often do not dry up every year, meaning that they seem to retain ideal hydrologic conditions for a large variety of avifauna to forage, promoting sustained emergent and aquatic plant growth due to lower hydrologic stress from annual drying. Additionally, these semi-permanent wetlands may offer more spatial and temporal heterogeneity of water permanence and vegetation, that meet expands the niche space for a greater number of species. have higher Seasonal (III) and ephemeral (IV) wetlands however also showed proportionally high species richness and abundance even with relatively less wetland area, but were subject to more year-to-year variation due to being shallow, precipitation-fed wetlands (Kantrud and Stewart 1984; Ruwaldt, Flake, and Gates 1979). Many of the aforementioned publications were primarily concerned with waterbird species use of these wetlands, other studies from outside the PPR region found that marsh birds had varying response to water levels in GIWs; e.g., American Bitterns responded positively to increased water depth, and marsh birds in the Great Lakes coastal wetlands responded positively to higher water permanence (Gnass Giese et al. 2018; Jorgensen, Brenner, and Greenwalt 2022). Furthermore, wetland hydroperiod manipulation in Illinois had a positive effect on abundance and richness for shorebirds and waterbirds compared to wetlands with little or no water management (O'Neal, Heske, and Stafford 2008). More permanent wetland hydrology in permanent and semi-permanent wetlands is generally associated with higher species richness and abundance of most bird species in GIWs, but those wetlands with more ephemeral hydrology can still contribute greatly to species richness in high precipitation years, often having higher species turnover than their more permanent counterparts (Daniel et al. 2019). Land managers looking to increase species richness and abundance should consider managing GIWs for increasing water permanence, especially in drought years when wetland availability on the landscape can be quite low. Another potential implication to consider from this review, is that the wetland hydrologic regimes are well-documented in the PPR region, but hydrologic regimes in other parts of the United States may vary considerably. For example, vernal pools (a type of GIW) in the Northeastern United States tend to be very ephemeral with no semi-permanent hydrolgies (Tiner 2003). Therefore, the spatial configuration and arrangement of these hydrologies spatially may not mimic that of the PPR region, where they occur in high densities, and close spatial proximity for birds to exploit.

(4) Climate (*N*=7)

Climatic conditions and abiotic variables influence GIWs specifically, due to being primarily precipitation fed across much of their continental distribution (Tiner 2003). In some cases, modelled species ranges and abundances were eliminated entirely in increased atmospheric CO_2 climate conditions (100%: Black Tern) while others experienced only moderate range reductions (29%: American Bittern) (Steen, Skagen, and Noon 2014). Higher soil moisture, previous year precipitation, and same year precipitation were all positively associated with higher duck abundance in the Prairie Pothole Region and the Northern Great Plains (Forcey et al. 2007; Forcey et al. 2011; Niemuth and Solberg 2003) and at the continental scale higher temperature (i.e., lower latitudes) were associated with higher species richness (Dertien et al. 2014). Importantly, Dertien et al. (2014) did not simulate potential temperature changes due to climate change within respective latitudes, suggesting rather, that this is more likely a product of higher biodiversity closer to the equator (Brown 2014). Publications which investigated the impacts of precipitation found higher abundance associated with higher same year and previous year precipitation. This means that the bird biodiversity in GIW systems are highly correlated with increased rainfall, that likely lead to higher reproductive success due to higher food availability and more suitable nesting areas, especially in the Prairie Pothole Region. However, higher rates of endemism and richness in southern regions of the United States (Dertien et al. 2014) may indicate that greater attention is needed to understand the implications of climate on birds in GIWs, including temperature fluctuations at a single site, especially because waterbirds and waterfowl were the taxonomic units considered by all but one publication in this theme.

(5) Temporal (N=6)

Changes in community composition or biodiversity seasonally, or across years has become a central tenet of many biodiversity studies aiming to document population declines or variation in species occupancy through the year. However, in our review only six publications investigated this theme, with most considering only seasonal changes and only a single study comparing long-term changes over multiple years. California vernal pools had the highest abundance of waterbirds present in early spring prior to migration northward, similar to Carolina Bays in South Carolina that had higher species richness and abundance in the winter months prior to migration (Bogiatto and Karnegis 2006; Czapka and Kilgo 2011). Long-term historical studies of bird habitat use in Oregon from the 1800s to present suggests there has been a decrease in 4 particular species of waterbirds (Taft and Haig 2003). The number of breeding duck pairs was higher in playa lakes in Texas in May compared to June, highlighting their importance early in the breeding season (Ray, Sullivan, and Miller 2003). Hartzell et. al (2007) found that the proportion of wetland-dependent species was highest in the spring compared to all other seasons but the proportion of waterfowl species was similar in both spring and fall (Hartzell, Bidwell, and Davis 2007). A final study comparing ground count and aerial survey methods found that May aerial surveys in South Dakota occurred too early and overestimated the breeding duck population, and subsequently underestimated brood success in most species due to late nesting attempts in late July and August (Naugle et al. 2000). In total, all studies found that GIWs had the highest abundance or richness of avifauna in the spring or winter. This suggests that although much attention has been paid to these systems as breeding habitat in summer months (Naugle et al. 2000), they may be of equal or greater importance as winter or spring migration staging habitat for waterbirds. Furthermore, this is evidence that wetland habitats with mild winter climates (South Carolina, California, and Texas) require attention outside of the breeding season, when they support the most species and highest abundance of migrating waterbirds. Lastly, although seasonal changes have received attention in this literature, only one single study documenting long-term temporal changes in biodiversity was identified in our review that wasn't directly measuring the impacts of restoration (see *Restoration* below). Future work on long-term temporal changes in these communities is warranted especially in the context of huge avifauna declines in North America (Rosenberg et al. 2019). One important consideration not directly addressed in these papers is also that precipitation that fills GIWs may be timed different latitudinally, and may also be shifting as climate change alters precipitation patterns seasonally, potentially changing when birds can utilize these wetlands. The implications of seasonal changes on birds in GIWs also appears to be highly context dependent, but current studies often lack true annual survey methodologies leaving gaps in the biodiversity utility of these systems outside of the typical breeding and migratory seasons.

(6) Vegetation (N = 6)

GIWs are unique in that their vegetation and vegetative structural components beyond broad land cover categories (trees, shrubs, emergent vegetation), can vary widely depending on the type of wetland, land management, and hydrology (Tiner 2003; Herteux, Gawlik, and Smith 2020). Herteux et al. (2020) found that open agricultural ponds with little vegetation were used primarily during the early spring by wading birds, before shifting to Cypress-Gum ponds dominated by Bald Cypress and Black Gum in late spring and early summer. Similarly, Mamo and Bolen (1999) found that Carolina Bays embedded in forests with higher canopy cover had higher abundance and species richness of songbirds than those embedded in clear-cut pine plantations. In Michigan, Black Spruce Tamarack bogs harbored the highest abundance of songbirds compared to their open canopy counterparts (Ewert 1984). Two studies from the PPR region found that emergent vegetation in wetlands increased abundance of dabbling ducks and submerged aquatic vegetation increased abundance of diving ducks (Ballard, Jones, and Janke 2021; O'Neal, Heske, and Stafford 2008). Studies investigating this theme came from 6 different states across the US, and all identified that wetland vegetation in the form of submerged vegetation, emergent vegetation, and shrubs or trees (at some spatial scale) increase abundance and richness of avifauna. We should note however, that we did not directly test how these vegetation attributes differed across geographies, so we can only comment on the general signal we found, not the relative importance of each within their given geographic contexts. This does suggest that open water may not be optimal for high biodiversity value, but rather that plant and tree species indicative of their respective geographies help promote biodiversity in GIWs. This is consistent with findings from the land cover section above, which indicates that environmental filtering of the bird community that use GIWs is not constrained at the landscape scale, but rather by the local vegetation attributes present at wetland sites. Critically, it means that vegetation characteristics at the wetland scale can be harmonized to meet the foraging requirements of the greatest number of species, i.e., aquatic vegetation for diving ducks, emergent vegetation for dabbling ducks, and wetland dependent tree species for songbirds.

(7) Wetland type (N=6)

Of the publications in this review six compared bird biodiversity metrics at one or more types of wetlands, including among different types of GIWs and between GIWs and other wetland types (e.g., lakes or rivers). Playa wetlands, circular shallow depressional wetlands in deserts and prairie habitats, had higher density of duck pairs in Texas than their created counterparts (Ray, Sullivan, and Miller 2003), but agricultural wetlands had higher densities of wading birds than natural ones for half the year, and less than natural Cypress-Gum ponds in the other half (Herteux, Gawlik, and Smith 2020). In Oklahoma, depression wetlands and man-made wetlands did not differ significantly in species richness, but natural wetlands had higher evenness than created wetlands which showed high dominance by a single species (Hartzell, Bidwell, and Davis 2007). However, community composition was quite similar (*Jaccard's Similarity Index = 67%*) between natural and man-made wetlands (Hartzell, Bidwell, and Davis 2007). Of the remaining publications looking at wetland type differences, Ewert (1982) focused on bog type in Michigan, where open bogs had the lowest estimates of abundance and only contained relatively common species compared to White-Cedar and Black Spruce-Tamarack bogs (Ewert 1982). Gnass Giese et al. (2018) documented that inland GIW wetland types in Wisconsin acted as refugia for bird species in dry years, but that coastal wetlands around the Great Lakes had higher species richness in years with high precipitation. Finally, amongst all wetland types in Iowa, semi-permanent GIWs had the highest abundance (corrected for wetland area) compared to lakes, man-made wetlands, and seasonal GIWs (Ballard, Jones, and Janke 2021). Overall studies on wetland types yielded inconsistent results. Species richness and abundance don't seem to respond uniformly to created agricultural wetlands versus natural wetlands a variety of environmental contexts. This may indicate that there is either a temporal component driving habitat-use of man-made wetlands following vegetation succession, or the management regimes in created wetlands significantly impact the observed biodiversity compared to their natural counterparts.

(8) Restoration (N=6)

The impacts of wetland restoration on biodiversity compared to their natural counterparts has been of critical interest to restoration ecologists. In two studies that examined how restoration impacted the bird community over time, one study found that wetland-dependent bird density did not increase through time (Fletcher and Koford 2003). The other study found that over 10 years, abundance, richness, and density of birds in the entire community increased, likely due to vegetation succession, and high vegetation heterogeneity within individual restored wetlands (Hapner et al. 2011). However, Hapner et al. (2011) did find that wetland-dependent species richness decreased over the restoration period. Fletcher and Koford (2003) argued that restoration was not effective at increasing density, abundance, or species richness because of low precipitation in restored wetland habitats on former agricultural fields. Conflicting evidence for increased species richness and abundance of birds in restored wetlands and in time since restoration, indicates that management throughout restoration including through plant installation and hydrologic control likely influences biodiversity responses to restoration. Studies that found either no response or a negative response in restored sites over time or compared to natural wetlands, had less stable hydrology compared to the studies which found a positive response to restoration. Of the studies in this theme, a few compared GIWs to their baseline year (*2/6, 33%*), while others compared restored wetlands to natural counterparts that were similar in size and vegetation (*4/6, 66%*). Importantly, the conflicting results of restoration on biodiversity from the studies may be due in part to these contrasting study designs and references, and the fact that restorations ranged in age from 1-16 years, but there was not an even number of age classes in all of these studies, since many of the restorations were carried out by Ducks Unlimited, and were outside the purview of the researchers. This suggests that restoration studies need to consider how the temporal scope of their study design impacts the species richness and abundance accumulation curves in both linear and non-linear ways.

Limitations of current review

An important limitation of this synthesis is that apparent differences among studies should not be interpreted as evidence of regional effects. Most studies differed simultaneously in wetland type, hydrologic regime, surrounding landscape, focal taxa, sampling methodology, and geographic location. Consequently, our synthesis identifies recurring ecological patterns across studies but cannot attribute contrasting results to geography itself. Future quantitative meta-analyses with sufficient replication across wetland types and regions will be needed to separate geographic effects from other sources of ecological variation. Similarly, extracting data from these papers to analyze the quantitative variation in biodiversity indices can shed light on which factors (land cover, hydrology, wetland vegetation, etc.) are most important, and what their quantitative relationship is to biodiversity (e.g., linear v non-linear). Lastly, our review here is quite restrictive in terms of terminology that needed to be present, and restrictive geographically due to our search terminology. GIWs are present globally and future work needs to consider how to incorporate the most inclusive set of search terms, especially in different languages, across the globe.

Synthesis and Conclusion

Our review of the bird biodiversity-GIW literature has elicited a few key significant findings on the taxonomic units of study, the geographic scope of research, and overarching themes and biodiversity metrics that would inform future research avenues in this field. First, taxonomic representation is quite varied in the bird biodiversity-GIW literature. Only one third of the reviewed publications measured biodiversity for the entire bird community, while the remaining two thirds were more taxonomically restricted considering only a single taxonomic group of birds like waterbirds and waterfowl. Unsurprisingly, the geographic scope is also skewed to the Prairie Pothole region of the United States where ~2/3 of all studies were conducted because of their dense waterfowl breeding bird populations. Although not a central objective of this review, the term GIW in our searching has largely failed to coalesce the GIW literature more generally. This is evidenced by only a single publication (Hertuex et al. 2020) using the term GIW to describe these wetlands even though considerable attention has been paid to uniform naming conventions of these wetlands (Mushet et al. 2015; Leibowitz 2015). Lastly, we found that close to 2/3 of all the publications in this review measured only abundance and/or density, with the other 1/3 collecting species richness metrics. Fewer than 10% of all the studies in this review measured diversity as a metric in their studies, even though biodiversity is inherently multifaceted including functional and phylogenetic components not captured in any of the publications in this review and not captured holistically by abundance or species richness alone (Hillebrand et al. 2018; Htay et al. 2023).

We also identified some key takeaways from our thematic analysis of the bird biodiversity-GIW literature. We found strong support for the species-area relationship in GIWs, indicating that larger wetlands support a greater number of species. However, we should not discount the importance of smaller wetlands that play an outsized role in high precipitation years when seasonal wetlands show considerable increases in abundance and species richness of birds wetlands (Kantrud and Stewart 1984; Ruwaldt, Flake, and Gates 1979). Semi-permanent hydrologic conditions are the most biodiverse GIWs and support the greatest number of individuals (Austin 2002; Kantrud and Stewart 1984; 1977; Ruwaldt, Flake, and Gates 1979; O'Neal, Heske, and Stafford 2008). Importantly, this means that vegetative restoration in restored or created wetlands is not enough to increase abundance and species richness of birds, but instead requires a combination of hydrologic and vegetative restoration in concert (Hapner et al. 2011; Fletcher and Koford 2003). Temporal studies in this review showed that the non-breeding season may support the highest abundance and richness of species in GIWs, especially in ecoregions outside of the Prairie Pothole Region (Bogiatto and Karnegis 2006; Czapka and Kilgo 2011). Collectively, these studies suggest that bird biodiversity in GIWs is governed by a relatively small number of interacting ecological processes (e.g., hydrology, wetland size, vegetation, and landscape context) despite the wide diversity of wetland types and bird taxa studied.

In addition to our main identified themes, we also found a considerable number of additional themes that contained only a few publications (Fig S1). Of these, the chief themes with more than a single publication included those interested in documenting differences particularly in species richness of GIWs and their surrounding upland habitats. Of which, many documented higher richness in wetlands compared to their surrounding uplands (McKinney and Paton 2009; Scheffers et al. 2006; Czapka and Kilgo 2011). Additionally, authors were also concerned with changes between rural and urban GIWs (McKinney and Paton 2009), measurements of waterbird populations and their breeding success (Skagen et al. 2008; Sorenson et al. 1998), and older papers containing general natural history descriptions of bird and their abundances (Harris 1954; McKown et al. 2021).

The future of bird biodiversity-GIW research could be organized towards three main axes of knowledge gaps identified in this review: space, time, and taxa. None of the studies we identified in this review, to date, have considered the biodiversity value of GIWs continentally, or more importantly, at the global scale, where they may be more important at lower latitudes with higher precipitation. In light of our current biodiversity crisis and substantial ongoing wetland loss (Dixon et al. 2016; Fluet-Chouinard et al. 2023), it is critical to know if these wetlands are extraordinarily important for birds outside of the United States or if they're more or less valuable to non-waterbird taxonomic groups, which reflect only a fraction of all species with different functional and phylogenetic biodiversity values. Finally, none of the studies in this review have investigated temporal biodiversity trends in depth, which can be challenging due to data constraints. As local, national, and international policies continue to change, it is important that future research works to identify long-term trends in richness, species turnover, or abundance that may indicate particular vulnerability to climate change and urbanization, ultimately highlighting the continued importance of GIWs for bird biodiversity.

Statements & Declarations

Competing Interests

The authors declare no relevant financial or non-financial interests to disclose.

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Author Contributions

Jackson Barratt Heitmann, Jiangxiao Qiu, and Corey T. Callaghan conceived and designed the study. Jackson Barratt Heitmann collected and analyzed the data. Jackson Barratt Heitmann wrote the first draft of the manuscript, and all authors commented, revised, and approved the final manuscript.

Data Availability

The datasets generated and analyzed in this study are available on Zenodo: https://doi.org/10.5281/zenodo.22836565.

References

Allen, Mike. 2017. “Vote Counting Literature Review Methods.” In *The SAGE Encyclopedia of Communication Research Methods*, 1868–70. SAGE Publications, Inc. https://doi.org/10.4135/9781483381411.

Anderson, Marti J., Thomas O. Crist, Jonathan M. Chase, Mark Vellend, Brian D. Inouye, Amy L. Freestone, Nathan J. Sanders, et al. 2011. “Navigating the Multiple Meanings of β Diversity: A Roadmap for the Practicing Ecologist.” *Ecology Letters* 14 (1): 19–28. https://doi.org/10.1111/j.1461-0248.2010.01552.x.

Austin, Jane E. 2002. “Responses of Dabbling Ducks to Wetland Conditions in the Prairie Pothole Region.” *Waterbirds: The International Journal of Waterbird Biology* 25 (4): 465–73.

Ballard, Derek C., Orrin E. Jones, and Adam K. Janke. 2021. “Factors Affecting Wetland Use by Spring Migrating Ducks in the Southern Prairie Pothole Region.” *The Journal of Wildlife Management* 85 (7): 1490–1506.

Barratt Heitmann, Jackson, Travis H. Folk, Lisa J. Lord, and Daniel J. McGlinn. 2025. “Geographically Isolated Wetlands Have Higher Alpha Diversity than Surrounding Uplands in Pine Savanna Ecosystems.” *Wetlands Ecology and Management* 33 (1): 18. https://doi.org/10.1007/s11273-025-10035-6.

Barratt Heitmann, Jackson, Brittany M. Mason, and Corey T. Callaghan. 2025. “Land Cover and Area Influence Bird Biodiversity in Geographically Isolated Wetlands.” *Diversity and Distributions* 31 (3): e70012. https://doi.org/10.1111/ddi.70012.

Bogiatto, Raymond J, and John D Karnegis. 2006. “The Use of Eastern Sacramento Valley Vernal Pools by Ducks.” *California Fish & Game*.

Brown, James H. 2014. “Why Are There so Many Species in the Tropics?” *Journal of Biogeography* 41 (1): 8–22. https://doi.org/10.1111/jbi.12228.

Burrow, Angela K., and Stacey Lance. 2022. “Restoration of Geographically Isolated Wetlands: An Amphibian-Centric Review of Methods and Effectiveness.” *Diversity* 14 (10): 879. https://doi.org/10.3390/d14100879.

Callaghan, Corey T., Jonathan M. Chase, and Daniel J. McGlinn. 2024. “Anthropogenic Habitat Modification Causes Nonlinear Multiscale Bird Diversity Declines.” *Ecography* 2024 (1): e06759. https://doi.org/10.1111/ecog.06759.

Callaghan, Corey T., Alistair G. B. Poore, Richard E. Major, William K. Cornwell, John H. Wilshire, and Mitchell B. Lyons. 2021. “How to Build a Biodiverse City: Environmental Determinants of Bird Diversity within and among 1581 Cities.” *Biodiversity and Conservation* 30 (1): 217–34. https://doi.org/10.1007/s10531-020-02088-1.

Cerda-Peña, Carol, and Jaime R. Rau. 2023. “The Importance of Wetland Habitat Area for Waterbird Species-Richness.” *Ibis* 165 (3): 739–52. https://doi.org/10.1111/ibi.13205.

Cohen, Matthew J., Irena F. Creed, Laurie Alexander, Nandita B. Basu, Aram J. K. Calhoun, Christopher Craft, Ellen D’Amico, et al. 2016. “Do Geographically Isolated Wetlands Influence Landscape Functions?” *Proceedings of the National Academy of Sciences* 113 (8): 1978–86. https://doi.org/10.1073/pnas.1512650113.

Comer, P, K Goodin, A Tomaino, G Hammerson, G Kittel, S Menard, C Nordman, et al. 2005. “Biodiversity Values of Geographically Isolated Wetlands in the United States.” NatureServe.

Creighton, Janean H., Rodney D. Sayler, James E. Tabor, and Matthew J. Monda. 1997. “Effects of Wetland Excavation on Avian Communities in Eastern Washington.” *Wetlands* 17 (2):

216–27. https://doi.org/10.1007/BF03161410.
Czapka, Stephen J., and John C. Kilgo. 2011. "Importance of Carolina Bays to the Avifauna of Pinelands in the Southeastern United States." *Southeastern Naturalist* 10 (2): 321–32.
Daniel, Jody, Jennifer Erin Gleason, Karl Cottenie, and Rebecca C. Rooney. 2019. "Stochastic and Deterministic Processes Drive Wetland Community Assembly across a Gradient of Environmental Filtering." *Oikos* 128 (8): 1158–69. https://doi.org/10.1111/oik.05987.
Delphey, Philip J., and James J. Dinsmore. 1993. "Breeding Bird Communities of Recently Restored and Natural Prairie Potholes." *Wetlands* 13 (3): 200–206. https://doi.org/10.1007/BF03160881.
Dertien, Jeremy S., Stella Self, Beth E. Ross, Kyle Barrett, and Robert F. Baldwin. 2020. "The Relationship between Biodiversity and Wetland Cover Varies across Regions of the Conterminous United States." Edited by Daehyun Kim. *PLOS ONE* 15 (5): e0232052. https://doi.org/10.1371/journal.pone.0232052.
Dirzo, Rodolfo, Hillary S. Young, Mauro Galetti, Gerardo Ceballos, Nick J. B. Isaac, and Ben Collen. 2014. "Defaunation in the Anthropocene." *Science* 345 (6195): 401–6.
Dixneuf, Charly, Parami Peiris, Petri Nummi, and Janne Sundell. 2021. "Vernal Pools Enhance Local Vertebrate Activity and Diversity in a Boreal Landscape." *Global Ecology and Conservation* 31 (November):e01858. https://doi.org/10.1016/j.gecco.2021.e01858.
Dixon, M. J. R., J. Loh, N. C. Davidson, C. Beltrame, R. Freeman, and M. Walpole. 2016. "Tracking Global Change in Ecosystem Area: The Wetland Extent Trends Index." *Biological Conservation* 193 (January):27–35. https://doi.org/10.1016/j.biocon.2015.10.023.
Eakin, Carly J., Malcolm L. Hunter, and Aram J. K. Calhoun. 2018. "Bird and Mammal Use of Vernal Pools along an Urban Development Gradient." *Urban Ecosystems* 21 (6): 1029–41. https://doi.org/10.1007/s11252-018-0782-6.
Elliott, Lisa H, Lawrence D Igl, and Douglas H Johnson. 2020. "The Relative Importance of Wetland Area versus Habitat Heterogeneity for Promoting Species Richness and Abundance of Wetland Birds in the Prairie Pothole Region, USA." *The Condor* 122 (1): duz060. https://doi.org/10.1093/condor/duz060.
Ewert, David. 1982. "Birds in Isolated Bogs in Central Michigan." *The American Midland Naturalist* 108 (1): 41–50. https://doi.org/10.2307/2425290.
Fairbairn, Steve E., and James J. Dinsmore. 2001. "Local and Landscape-Level Influences on Wetland Bird Communities of the Prairie Pothole Region of Iowa, USA." *Wetlands* 21 (1): 41–47. https://doi.org/10.1672/0277-5212(2001)021[0041:LALLIO]2.0.CO;2.
Fletcher, Robert J., and Rolf R. Koford. 2003. "Changes in Breeding Bird Populations with Habitat Restoration in Northern Iowa." *The American Midland Naturalist* 150 (1): 83–94.
Fluet-Chouinard, Etienne, Benjamin D. Stocker, Zhen Zhang, Avni Malhotra, Joe R. Melton, Benjamin Poulter, Jed O. Kaplan, et al. 2023. "Extensive Global Wetland Loss over the Past Three Centuries." *Nature* 614 (7947): 281–86. https://doi.org/10.1038/s41586-022-05572-6.
Forcey, G.M., G.M. Linz, W.E. Thogmartin, and W.J. Bleier. 2007. "Influence of Land Use and Climate on Wetland Breeding Birds in the Prairie Pothole Region of Canada." *Canadian Journal of Zoology* 85 (3): 421–36. https://doi.org/10.1139/Z07-005.
Forcey, Greg M., Wayne E. Thogmartin, George M. Linz, William J. Bleier, and Patrick C. McKann. 2011. "Land Use and Climate Influences on Waterbirds in the Prairie Potholes." *Journal of Biogeography* 38 (9): 1694–1707. https://doi.org/10.1111/j.1365-

2699.2011.02510.x.

Game, Edward T., Heather Tallis, Lydia Olander, Steven M. Alexander, Jonah Busch, Nancy Cartwright, Elizabeth L. Kalies, et al. 2018. “Cross-Discipline Evidence Principles for Sustainability Policy.” *Nature Sustainability* 1 (9): 452–54. https://doi.org/10.1038/s41893-018-0141-x.

Gaston, K. J., T. M. Blackburn, and K. K. Goldewijk. 2003. “Habitat Conversion and Global Avian Biodiversity Loss.” *Proceedings of the Royal Society of London. Series B: Biological Sciences* 270 (1521): 1293–1300. https://doi.org/10.1098/rspb.2002.2303.

Gnass Giese, Erin E., Robert W. Howe, Amy T. Wolf, and Gerald J. Niemi. 2018. “Breeding Birds and Anurans of Dynamic Coastal Wetlands in Green Bay, Lake Michigan.” *Journal of Great Lakes Research* 44 (5): 950–59. https://doi.org/10.1016/j.jglr.2018.06.003.

Hamer, Andrew J., and Mark J. McDonnell. 2008. “Amphibian Ecology and Conservation in the Urbanising World: A Review.” *Biological Conservation* 141 (10): 2432–49. https://doi.org/10.1016/j.biocon.2008.07.020.

Hapner, Jill A., James A. Reinartz, Glen G. Fredlund, Karla G. Leithoff, Noel J. Cutright, and William P. Mueller. 2011. “Avian Succession in Small Created and Restored Wetlands.” *Wetlands* 31 (6): 1089–1102. https://doi.org/10.1007/s13157-011-0220-5.

Harris, Stanley W. 1954. “An Ecological Study of the Waterfowl of the Potholes Area, Grant County, Washington.” *The American Midland Naturalist* 52 (2): 403–32. https://doi.org/10.2307/2422243.

Hartzell, Dena, Joseph R. Bidwell, and Craig A. Davis. 2007. “A Comparison of Natural and Created Depressional Wetlands in Central Oklahoma Using Metrics from Indices of Biological Integrity.” *Wetlands* 27 (4): 794–805. https://doi.org/10.1672/0277-5212(2007)27[794:ACONAC]2.0.CO;2.

Herteux, Camille E., Dale E. Gawlik, and Lora L. Smith. 2020. “Habitat Characteristics Affecting Wading Bird Use of Geographically Isolated Wetlands in the U.S. Southeastern Coastal Plain.” *Wetlands* 40 (5): 1149–59. https://doi.org/10.1007/s13157-019-01250-y.

Hillebrand, Helmut, Bernd Blasius, Elizabeth T. Borer, Jonathan M. Chase, John A. Downing, Britas Klemens Eriksson, Christopher T. Filstrup, et al. 2018. “Biodiversity Change Is Uncoupled from Species Richness Trends: Consequences for Conservation and Monitoring.” *Journal of Applied Ecology* 55 (1): 169–84. https://doi.org/10.1111/1365-2664.12959.

Htay, Thazin, Eivin Røskaft, Thor Harald Ringsby, and Peter Sjolte Ranke. 2023. “Spatio-Temporal Variation in Avian Taxonomic, Functional, and Phylogenetic Diversity and Its Relevance for Conservation in a Wetland Ecosystem in Myanmar.” *Biodiversity and Conservation* 32 (8): 2841–67. https://doi.org/10.1007/s10531-023-02632-9.

Jorgensen, Joel G., Stephen J. Brenner, and Lauren R. Greenwalt. 2022. “A Tale of Two Complexes: Secretive Marsh Bird Abundance Differs in the Sandhills and Rainwater Basin, Nebraska.” *Wetlands* 42 (5): 41. https://doi.org/10.1007/s13157-022-01551-9.

Junk, Wolfgang J., Mark Brown, Ian C. Campbell, Max Finlayson, Brij Gopal, Lars Ramberg, and Barry G. Warner. 2006. “The Comparative Biodiversity of Seven Globally Important Wetlands: A Synthesis.” *Aquatic Sciences* 68 (3): 400–414. https://doi.org/10.1007/s00027-006-0856-z.

Kantrud, Harold A., and Robert E. Stewart. 1977. “Use of Natural Basin Wetlands by Breeding Waterfowl in North Dakota.” *The Journal of Wildlife Management* 41 (2): 243–53. https://doi.org/10.2307/3800601.

———. 1984. “Ecological Distribution and Crude Density of Breeding Birds on Prairie Wetlands.” *The Journal of Wildlife Management* 48 (2): 426–37. https://doi.org/10.2307/3801174.

Leibowitz, Scott G. 2003. “Isolated Wetlands and Their Functions: An Ecological Perspective.” *Wetlands* 23 (3): 517–31. https://doi.org/10.1672/0277-5212(2003)023[0517:IWATFA]2.0.CO;2.

Leibowitz, Scott G., and Tracie -Lynn Nadeau. 2003. “Isolated Wetlands: State-of-the-Science and Future Directions.” *Wetlands* 23 (3): 663–84. https://doi.org/10.1672/0277-5212(2003)023[0663:IWSAFD]2.0.CO;2.

Lortie, Christopher J. 2014. “Formalized Synthesis Opportunities for Ecology: Systematic Reviews and Meta-Analyses.” *Oikos* 123 (8): 897–902. https://doi.org/10.1111/j.1600-0706.2013.00970.x.

Ma, Zhijun, Yinting Cai, Bo Li, and Jiakuan Chen. 2010. “Managing Wetland Habitats for Waterbirds: An International Perspective.” *Wetlands* 30 (1): 15–27. https://doi.org/10.1007/s13157-009-0001-6.

Mamo, Lisa B., and Eric G. Bolen. 1999. “Effects of Area, Isolation, and Landscape on the Avifauna of Carolina Bays (Efectos Del Área, Aislamiento, y Del Paisaje En La Avifauna de Las Bahías de Carolina).” *Journal of Field Ornithology* 70 (3): 310–20.

McCauley, Lisa A., David G. Jenkins, and Pedro F. Quintana-Ascencio. 2013. “Isolated Wetland Loss and Degradation Over Two Decades in an Increasingly Urbanized Landscape.” *Wetlands* 33 (1): 117–27. https://doi.org/10.1007/s13157-012-0357-x.

McGlinn, Daniel J., Xiao Xiao, Felix May, Nicholas J. Gotelli, Thore Engel, Shane A. Blowes, Tiffany M. Knight, Oliver Purschke, Jonathan M. Chase, and Brian J. McGill. 2019. “Measurement of Biodiversity (MoB): A Method to Separate the Scale-Dependent Effects of Species Abundance Distribution, Density, and Aggregation on Diversity Change.” *Methods in Ecology and Evolution* 10 (2): 258–69. https://doi.org/10.1111/2041-210X.13102.

McKinney, Richard A., and Peter W. C. Paton. 2009. “Breeding Birds Associated with Seasonal Pools in the Northeastern United States.” *Journal of Field Ornithology* 80 (4): 380–86. https://doi.org/10.1111/j.1557-9263.2009.00244.x.

McKinney, Richard A., Kenneth B. Raposa, and Rose M. Cournoyer. 2011. “Wetlands as Habitat in Urbanizing Landscapes: Patterns of Bird Abundance and Occupancy.” *Landscape and Urban Planning* 100 (1): 144–52. https://doi.org/10.1016/j.landurbplan.2010.11.015.

McKown, J. Grant, Gregg E. Moore, Andrew R. Payne, Natalie A. White, and Jennifer L. Gibson. 2021. “Successional Dynamics of a 35 Year Old Freshwater Mitigation Wetland in Southeastern New Hampshire.” *PLOS ONE* 16 (5): e0251748. https://doi.org/10.1371/journal.pone.0251748.

Nakagawa, Shinichi, Gihan Samarasinghe, Neal R. Haddaway, Martin J. Westgate, Rose E. O’Dea, Daniel W. A. Noble, and Malgorzata Lagisz. 2019. “Research Weaving: Visualizing the Future of Research Synthesis.” *Trends in Ecology & Evolution* 34 (3): 224–38. https://doi.org/10.1016/j.tree.2018.11.007.

Naugle, David E., Rex R. Johnson, Thomas R. Cooper, Matthew M. Holland, and Kenneth F. Higgins. 2000. “Temporal Distribution of Waterfowl in Eastern South Dakota: Implications for Aerial Surveys.” *Wetlands* 20 (1): 177–83. https://doi.org/10.1672/0277-5212(2000)020[0177:TDOWIE]2.0.CO;2.

Oertli, Beat, and Kirsten M. Parris. 2019. “Review: Toward Management of Urban Ponds for Freshwater Biodiversity.” *Ecosphere* 10 (7): e02810. https://doi.org/10.1002/ecs2.2810.

O’Neal, Benjamin J., Edward J. Heske, and Joshua D. Stafford. 2008. “Waterbird Response to Wetlands Restored Through the Conservation Reserve Enhancement Program.” *The Journal of Wildlife Management* 72 (3): 654–64. https://doi.org/10.2193/2007-165.

Page, Matthew J., Joanne E. McKenzie, Patrick M. Bossuyt, Isabelle Boutron, Tammy C. Hoffmann, Cynthia D. Mulrow, Larissa Shamseer, et al. 2021. “The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews.” *BMJ* 372 (March):n71. https://doi.org/10.1136/bmj.n71.

Paracuellos, Mariano. 2006. “How Can Habitat Selection Affect the Use of a Wetland Complex by Waterbirds?” *Biodiversity & Conservation* 15 (14): 4569–82. https://doi.org/10.1007/s10531-005-5820-z.

Ramsar Convention on Wetlands. 2021. “Global Wetland Outlook.” 2021. https://www.ramsar.org/sites/default/files/documents/library/gwo_2021_e.pdf.

Ratti, John T., Ann M. Rocklage, John H. Giudice, Edward O. Garton, and Daniel P. Golner. 2001. “Comparison of Avian Communities on Restored and Natural Wetlands in North and South Dakota.” *The Journal of Wildlife Management* 65 (4): 676–84. https://doi.org/10.2307/3803019.

Ray, James D., Brian D. Sullivan, and Harvey W. Miller. 2003. “Breeding Ducks and Their Habitats in the High Plains of Texas.” *The Southwestern Naturalist* 48 (2): 241–48.

“Revised Definition of ‘Waters of the United States’; Conforming.” 2023. Federal Register. September 8, 2023. https://www.federalregister.gov/documents/2023/09/08/2023-18929/revised-definition-of-waters-of-the-united-states-conforming.

Rosenberg, Kenneth V., Adriaan M. Dokter, Peter J. Blancher, et al. 2019. “Decline of the North American Avifauna.” *Science (New York, N.Y.)* 366 (6461): 120–24. https://doi.org/10.1126/science.aaw1313.

Ruwaldt, James J., Lester D. Flake, and John M. Gates. 1979. “Waterfowl Pair Use of Natural and Man-Made Wetlands in South Dakota.” *The Journal of Wildlife Management* 43 (2): 375–83. https://doi.org/10.2307/3800346.

Saunders, Sarah P, Kristin A L Hall, Nina Hill, and Nicole L Michel. 2019. “Multiscale Effects of Wetland Availability and Matrix Composition on Wetland Breeding Birds in Minnesota, USA.” *The Condor* 121 (3): duz024. https://doi.org/10.1093/condor/duz024.

Scheffers, Brett R., J. Berton C. Harris, and David G. Haskell. 2006. “Avifauna Associated with Ephemeral Ponds on the Cumberland Plateau, Tennessee.” *Journal of Field Ornithology* 77 (2): 178–83. https://doi.org/10.1111/j.1557-9263.2006.00039.x.

Skagen, Susan K., Diane A. Granfors, and Cynthia P. Melcher. 2008. “On Determining the Significance of Ephemeral Continental Wetlands to North American Migratory Shorebirds.” *The Auk* 125 (1): 20–29. https://doi.org/10.1525/auk.2008.125.1.20.

Sorenson, Lisa G., Richard Goldberg, Terry L. Root, and Michael G. Anderson. 1998. “Potential Effects of Global Warming on Waterfowl Populations Breeding in the Northern Great Plains.” *Climatic Change* 40 (2): 343–69. https://doi.org/10.1023/A:1005441608819.

Spake, Rebecca, Rose E. O’Dea, Shinichi Nakagawa, C. Patrick Doncaster, Masahiro Ryo, Corey T. Callaghan, and James M. Bullock. 2022. “Improving Quantitative Synthesis to Achieve Generality in Ecology.” *Nature Ecology & Evolution* 6 (12): 1818–28. https://doi.org/10.1038/s41559-022-01891-z.

Steen, Valerie, and Abby N. Powell. 2012. "Potential Effects of Climate Change on the Distribution of Waterbirds in the Prairie Pothole Region, U.S.A." *Waterbirds* 35 (2): 217–29. https://doi.org/10.1675/063.035.0204.

Steen, Valerie, Susan K. Skagen, and Barry R. Noon. 2014. "Vulnerability of Breeding Waterbirds to Climate Change in the Prairie Pothole Region, U.S.A." *PLOS ONE* 9 (6): e96747. https://doi.org/10.1371/journal.pone.0096747.

Taft, Oriane W., and Susan M. Haig. 2003. "Historical Wetlands in Oregon's Willamette Valley: Implications for Restoration of Winter Waterbird Habitat." *Wetlands* 23 (1): 51–64. https://doi.org/10.1672/0277-5212(2003)023[0051:HWIOWV]2.0.CO;2.

Tiner, Ralph W. 2003. "Geographically Isolated Wetlands of the United States." *Wetlands* 23 (3): 494–516. https://doi.org/10.1672/0277-5212(2003)023[0494:GIWOTU]2.0.CO;2.

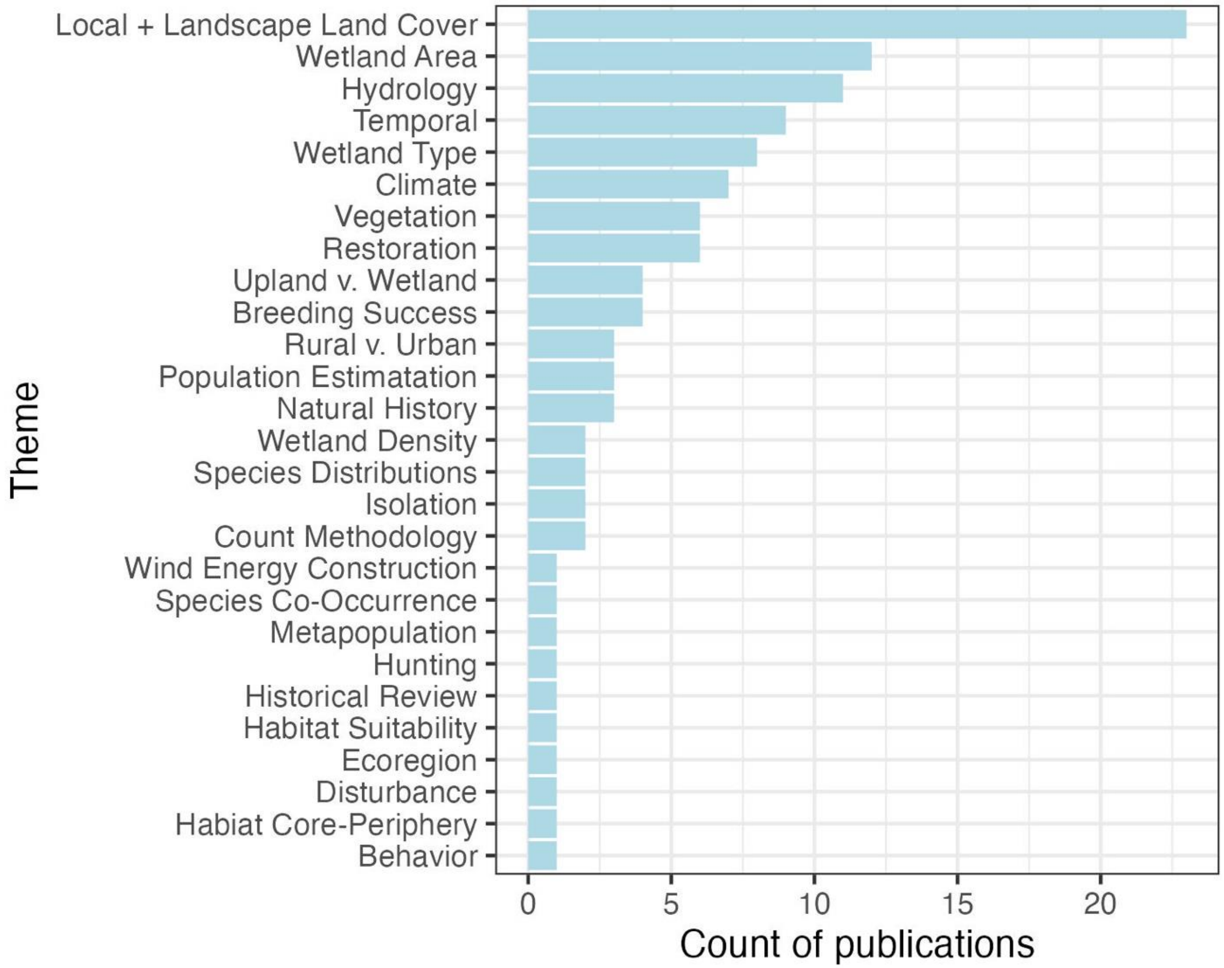
US EPA, OW. 2015. "Why Are Wetlands Important?" Overviews and Factsheets. April 9, 2015. https://www.epa.gov/wetlands/why-are-wetlands-important.

Webb, Elisabeth B., Loren M. Smith, Mark P. Vrtiska, and Theodore G. Lagrange. 2010. "Effects of Local and Landscape Variables on Wetland Bird Habitat Use During Migration Through the Rainwater Basin." *The Journal of Wildlife Management* 74 (1): 109–19. https://doi.org/10.2193/2008-577.

Xu, Donghui, Gautam Bisht, Zeli Tan, Eva Sinha, Alan V. Di Vittorio, Tian Zhou, Valeriy Y. Ivanov, and L. Ruby Leung. 2024. "Climate Change Will Reduce North American Inland Wetland Areas and Disrupt Their Seasonal Regimes." *Nature Communications* 15 (1): 2438. https://doi.org/10.1038/s41467-024-45286-z.

Xu, Xibao, Minkun Chen, Guishan Yang, Bo Jiang, and Ji Zhang. 2020. "Wetland Ecosystem Services Research: A Critical Review." *Global Ecology and Conservation* 22 (June):e01027. https://doi.org/10.1016/j.gecco.2020.e01027.

Supplementary Information



Supplementary Figure 1. Number of publications from all identified themes *(n*=26)*,* including comparisons with less than *n*=5 publications

Supplementary Table 1. List of articles included in this review with diversity metrics, taxonomic unit(s) of interest, and identified theme(s).

Authors	**Title**	**Journal**	**Year**	**Diversity Metrics**	**Taxa measured**	**State(s)**	**Theme(s)**
Scheffers, BR; Harris, JBC; Haskell, DG	Avifauna associated with ephemeral ponds on the Cumberland Plateau, Tennessee	JOURNAL OF FIELD ORNITHOLOGY	2006	species_richness, diversity, evenness, community_composition, abundance	community	**Tennessee**	**Upland-Wetland, Wetland Area**
McKinney, RA; Paton, PWC	Breeding birds associated with seasonal pools in the northeastern United States	JOURNAL OF FIELD ORNITHOLOGY	2009	species_richness, evenness, abundance, diversity	community	**Rhode Island**	**Upland-Wetland, Rural-Urban, Wetland Area**
Herteux, CE; Gawlik, DE; Smith, LL	Habitat Characteristics Affecting Wading Bird Use of Geographically Isolated Wetlands in the US Southeastern Coastal Plain	WETLANDS	2020	density	wading_birds	**Georgia**	**Wetland Type, Vegetation, Wetland Area**
KANTRUD, HA; STEWART, RE	USE OF NATURAL BASIN WETLANDS BY BREEDING WATERFOWL IN NORTH-DAKOTA	JOURNAL OF WILDLIFE MANAGEMENT	1977	density	waterfowl	**North Dakota**	**Hydrology**
BROWN, M; DINSMORE, JJ	IMPLICATIONS OF MARSH SIZE AND ISOLATION FOR MARSH BIRD MANAGEMENT	JOURNAL OF WILDLIFE MANAGEMENT	1986	species_richness	community, marsh_birds	**Iowa**	**Wetland Area, Wetland Isolation**
RUWALDT, JJ; FLAKE, LD; GATES, JM	WATERFOWL PAIR USE OF NATURAL AND MAN-MADE WETLANDS IN SOUTH-DAKOTA	JOURNAL OF WILDLIFE MANAGEMENT	1979	abundance, density, relative_abundance	waterfowl	**South Dakota**	**Hydrology**
Naugle, DE; Johnson, RR; Estey, ME; Higgins, KF	A landscape approach to conserving wetland bird habitat in the prairie pothole region of eastern South Dakota	WETLANDS	2001	presence	waterfowl	**South Dakota**	**Habitat Suitability, Local and Landscape Land Cover**
Austin, JE	Responses of dabbling ducks to wetland conditions in the Prairie Pothole region	WATERBIRDS	2002	abundance, density	waterfowl	**South Dakota, North Dakota, Canada**	**Hydrology, Wetland Density**
McKinney, RA; Raposa, KB; Cournoyer, RM	Wetlands as habitat in urbanizing landscapes: Patterns of bird abundance and occupancy	LANDSCAPE AND URBAN PLANNING	2011	species_richness, abundance	community	**Rhode Island**	**Upland-Wetland, Rural-Urban, Local**

							and Landscape Land Cover
KANTRUD, HA; STEWART, RE	ECOLOGICAL DISTRIBUTION AND CRUDE DENSITY OF BREEDING BIRDS ON PRAIRIE WETLANDS	JOURNAL OF WILDLIFE MANAGEMENT	1984	species_richness, abundance, density	community	**South Dakota, North Dakota**	**Hydrology**
Czapka, SJ; Kilgo, JC	Importance of Carolina Bays to the Avifauna of Pinelands in the Southeastern United States	SOUTHEASTERN NATURALIST	2011	species_richness, abundance	community	**South Carolina**	**Upland-Wetland, Temporal**
Jorgensen, JG; Brenner, SJ; Greenwalt, LR	A Tale of Two Complexes: Secretive Marsh Bird Abundance Differs in the Sandhills and Rainwater Basin, Nebraska	WETLANDS	2022	abundance, density	marsh_birds	**Nebraska**	**Hydrology**
Mamo, LB; Bolen, EG	Effects of area, isolation, and landscape on the avifauna of Carolina bays	JOURNAL OF FIELD ORNITHOLOGY	1999	species_richness	community	**North Carolina**	**Wetland Area, Vegetation, Wetland Isolation, Local and Landscape Land Cover**
Skagen, SK; Granfors, DA; Melcher, CP	On determining the significance of ephemeral continental wetlands to north American migratory shorebirds	AUK	2008	abundance	shorebirds	**North Dakota, South Dakota, Minnesota**	**Population Estimation**
Glennon, MJ	Dynamics of Boreal Birds at the Edge of Their Range in the Adirondack Park, NY	NORTHEASTERN NATURALIST	2014	presence	boreal_birds	**New York**	**Local and Landscape Land Cover, Metapopulation**
Niemuth, ND; Solberg, JW; Shaffer, TL	Influence of moisture on density and distribution of grassland birds in North Dakota	CONDOR	2008	abundance	grassland_birds	**North Dakota**	**Local and Landscape Land Cover, Climate**
Niemuth, ND; Solberg, JW	Response of waterbirds to number of wetlands in the Prairie Pothole Region of North Dakota, USA	WATERBIRDS	2003	abundance	waterbirds, shorebirds, marsh_birds	**North Dakota**	**Local and Landscape Land Cover**
JOHNSGARD, PA	EFFECTS OF WATER FLUCTUATION AND VEGETATION CHANGE ON BIRD POPULATIONS, PARTICULARLY WATERFOWL	ECOLOGY	1956	abundance, species_richness	community	**Washington**	**Vegetation, Hydrology**

Webb, EB; Smith, LM; Vrtiska, MP; Lagrange, TG	Effects of Local and Landscape Variables on Wetland Bird Habitat Use During Migration Through the Rainwater Basin	JOURNAL OF WILDLIFE MANAGEMENT	2010	abundance, species_richness	waterbirds, shorebirds	**Nebraska**	**Wetland Area, Local and Landscape Land Cover, Wetland Density**
STEWART, RE; KANTRUD, HA	BREEDING WATERFOWL POPULATIONS IN PRAIRIE POTHOLE REGION OF NORTH-DAKOTA	CONDOR	1974	species_richness, abundance	waterbirds	**North Dakota**	**Hydrology**
Ratti, JT; Rocklage, AM; Giudice, JH; Garton, EO; Golner, DP	Comparison of avian communities on restored and natural wetlands in North and South Dakota	JOURNAL OF WILDLIFE MANAGEMENT	2001	abundance, species_richness, density	waterbirds, community	**North Dakota, South Dakota**	**Restoration**
Austin, JE; Buhl, TK; Guntenspergen, GR; Norling, W; Sklebar, HT	Duck populations as indicators of landscape condition in the Prairie Pothole Region	ENVIRONMENTAL MONITORING AND ASSESSMENT	2001	abundance	waterbirds	**North Dakota**	**Local and Landscape Land Cover**
Orr, JT; Duquette, CA; Hovick, TJ; Geaumont, BA; Harms, TM	Secretive Marsh Bird Densities and Habitat Associations in the Prairie Pothole Region	WETLANDS	2020	abundance, density	marshbirds	**North Dakota**	**Local and Landscape Land Cover**
Cordts, SD; Zenner, GG; Koford, RR	Comparison of helicopter and ground counts for waterfowl in Iowa	WILDLIFE SOCIETY BULLETIN	2002	abundance	waterbirds	**Iowa**	**Count Methodology**
Saunders, SP; Hall, KAL; Hill, N; Michel, NL	Multiscale effects of wetland availability and matrix composition on wetland breeding birds in Minnesota, USA	CONDOR	2019	abundance	wetland_birds	**Minnesota**	**Local and Landscape Land Cover**
Webb, EB; Smith, LM; Vrtiska, MP; Lagrange, TG	Community Structure of Wetland Birds During Spring Migration Through the Rainwater Basin	JOURNAL OF WILDLIFE MANAGEMENT	2010	abundance, species_richness, community_composition	community	**Nebraska**	**Species Co-Occurence**
Dinges, AJ; Webb, EB; Vrtiska, MP	Effects of the Light Goose Conservation Order on non-target waterfowl distribution during spring migration	WILDLIFE BIOLOGY	2015	abundance	waterbirds	**Nebraska**	**Hunting**
Loesch, CR; Walker, JA; Reynolds, RE; Gleason, JS; Niemuth, ND;	Effect of wind energy development on breeding duck densities in the Prairie Pothole Region	JOURNAL OF WILDLIFE MANAGEMENT	2013	density	waterbirds	**North Dakota, South Dakota**	**Wind Energy Construction**

Stephens, SE; Erickson, MA							
Feldman, RE; Anderson, MG; Howerter, D; Murray, DL	Where does environmental stochasticity most influence population dynamics? An assessment along a regional core-periphery gradient for prairie breeding ducks	GLOBAL ECOLOGY AND BIOGEOGRAPHY	2015	population, abundance, species_richness	waterbirds	**Alberta, Manitoba, Saskatchewan, Iowa, Montana, South Dakota, North Dakota, Minnesota**	**Habitat Core-Periphery**
Bogiatto, RJ; Karnegis, JD	The use of eastern Sacramento Valley vernal pools by ducks	CALIFORNIA FISH AND GAME	2006	abundance	waterbirds	**California**	**Behavior, Temporal**
Steen, V; Skagen, SK; Noon, BR	Vulnerability of Breeding Waterbirds to Climate Change in the Prairie Pothole Region, USA	PLOS ONE	2014	presence	waterbirds	**Iowa, Montana, South Dakota, North Dakota, Minnesota**	**Climate, Species Distributions**
EWERT, D	BIRDS IN ISOLATED BOGS IN CENTRAL MICHIGAN	AMERICAN MIDLAND NATURALIST	1982	abundance	community	**Michigan**	**Wetland Type, Vegetation**
Oneal, BJ; Heske, EJ; Stafford, JD	Waterbird response to wetlands restored through the conservation reserve enhancement program	JOURNAL OF WILDLIFE MANAGEMENT	2008	abundance, species_richness, density	waterbirds, shorebirds	**Illinois**	**Hydrology, Vegetation, Breeding Success**
Hapner, JA; Reinartz, JA; Fredlund, GG; Leithoff, KG; Cutright, NJ; Mueller, WP	Avian Succession in Small Created and Restored Wetlands	WETLANDS	2011	species_richness, abundance, density	community	**Wisconsin**	**Restoration, Wetland Area, Local and Landscape Land Cover**
HARRIS, SW	AN ECOLOGICAL STUDY OF THE WATERFOWL OF THE POT-HOLES AREA, GRANT COUNTY, WASHINGTON	AMERICAN MIDLAND NATURALIST	1954	species_richness, abundance	waterbirds	**Washington**	**Population Estimation, Natural History, Breeding Success**
DELPHEY, PJ; DINSMORE, JJ	BREEDING BIRD COMMUNITIES OF RECENTLY RESTORED AND	WETLANDS	1993	species_richness, abundance	community	**Iowa**	**Restoration**

	NATURAL PRAIRIE POTHOLES						
Sorenson, LG; Goldberg, R; Root, TL; Anderson, MG	Potential effects of global warming on waterfowl populations breeding in the Northern Great Plains	CLIMATIC CHANGE	1998	abundance	waterbirds	**Alberta, Manitoba, Saskatchewan, Iowa, Montana, South Dakota, North Dakota, Minnesota**	**Climate, Population Estimation**
Wilson, WH; Zierzow, RE; Savage, AR	Habitat selection by peatland birds in a central Maine bog: The effects of scale and year	JOURNAL OF FIELD ORNITHOLOGY	1998	abundance	community	**Maine**	**Local and Landscape Land Cover**
Fletcher, RJ; Koford, RR	Changes in breeding bird populations with habitat restoration in northern Iowa	AMERICAN MIDLAND NATURALIST	2003	density	community	**Iowa**	**Restoration**
Eakin, CJ; Hunter, ML; Calhoun, AJK	Bird and mammal use of vernal pools along an urban development gradient	URBAN ECOSYSTEMS	2018	community_composition	community	**Maine**	**Rural-Urban, Local and Landscape Land Cover**
Alsfeld, AJ; Bowman, JL; Deller-Jacobs, A	The Influence of Landscape Composition on the Biotic Community of Constructed Depressional Wetlands	RESTORATION ECOLOGY	2010	species_richness, diversity, abundance	community	**Delaware**	**Local and Landscape Land Cover**
Taft, OW; Haig, SM	Historical wetlands in Oregon's Willamette Valley: Implications for restoration of winter waterbird habitat	WETLANDS	2003		waterbirds	**Oregon**	**Historical Review, Temporal**
Fairbairn, SE; Dinsmore, JJ	Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA	WETLANDS	2001	species_richness, density	community	**Iowa**	**Local and Landscape Land Cover, Wetland Area**
Elliott, LH; Igl, LD; Johnson, DH	The relative importance of wetland area versus habitat heterogeneity for promoting species richness and abundance of wetland birds in the Prairie Pothole Region, USA	CONDOR	2020	species_richness, abundance	community	**Iowa, Montana, South Dakota, North Dakota, Minnesota**	**Local and Landscape Land Cover, Hydrology, Wetland Area, Restoration**

Forcey, GM; Thogmartin, WE; Linz, GM; Bleier, WJ; McKann, PC	Land use and Climate influences on waterbirds in the Prairie Potholes	JOURNAL OF BIOGEOGRAPHY	2011	abundance	waterbirds	**Iowa, Montana, South Dakota, North Dakota, Minnesota, Nebraska**	**Local and Landscape Land Cover, Wetland Area, Climate**
Forcey, GM; Thogmartin, WE; Linz, GM; McKann, PC	Land use and Climate affect Black Tern, Northern Harrier, and Marsh Wren abundance in the Prairie Pothole Region of the United States	CONDOR	2014	abundance	Northern Harrier, Black Tern, Marsh Wren	**Iowa, Montana, South Dakota, North Dakota, Minnesota, Nebraska**	**Local and Landscape Land Cover, Climate**
Ballard, DC; Jones, OE; Janke, AK	Factors Affecting Wetland Use by Spring Migrating Ducks in the Southern Prairie Pothole Region	JOURNAL OF WILDLIFE MANAGEMENT	2021	abundance	waterbirds	**Iowa**	**Local and Landscape Land Cover, Vegetation, Wetland Type**
Janke, AK; Anteau, MJ; Stafford, JD	Prairie wetlands confer consistent migrant refueling conditions across a gradient of agricultural land use intensities	BIOLOGICAL CONSERVATION	2019	abundance	waterbirds	**South Dakota**	**Local and Landscape Land Cover**
Giese, EEG; Howe, RW; Wolf, AT; Niemi, GJ	Breeding birds and anurans of dynamic coastal wetlands in Green Bay, Lake Michigan	JOURNAL OF GREAT LAKES RESEARCH	2018	community_composition, abundance	community	**Wisconsin**	**Hydrology, Wetland Type**
Creighton, JH; Sayler, RD; Tabor, JE; Monda, MJ	Effects of wetland excavation on avian communities in eastern Washington	WETLANDS	1997	density, abundance	community	**Washington**	**Restoration**
Steen, V; Powell, AN	Potential Effects of Climate Change on the Distribution of Waterbirds in the Prairie Pothole Region, USA	WATERBIRDS	2012	presence	waterbirds	**Iowa, Montana, South Dakota, North Dakota, Minnesota, Nebraska**	**Climate, Species Distributions**
Tsai, JS; Venne, LS; Smith, LM; McMurry, ST; Haukos, DA	Influence of Local and Landscape Characteristics on Avian Richness and Density in Wet	WETLANDS	2012	species_richness, density	community	**Colorado, Kansas, New Mexico,**	**Hydrology, Local and Landscape Land Cover, Wetland Area**

	Playas of the Southern Great Plains, USA					**Oklahoma, Texas**	
Elliott, LH; Bracey, AM; Niemi, GJ; Johnson, DH; Gehring, TM; Giese, EEG; Fiorino, GE; Howe, RW; Lawrence, GJ; Norment, CJ; Tozer, DC; Igl, LD	Application of habitat association models across regions: Useful explanatory power retained in wetland bird case study	ECOSPHERE	2023	presence	waterbirds	**North Dakota, South Dakota, Minnesota, Michigan, Illinois, Ohio, Pennsylvania, New York, Wisconsin, Indiana, Ontario, Quebec**	**Local and Landscape Land Cover, Ecoregion, Wetland Area**
Hartzell, D; Bidwell, JR; Davis, CA	A comparison of natural and created depressional wetlands in central Oklahoma using metrics from indices of biological integrity	WETLANDS	2007	species_richness, abundance, diversity	community	**Oklahoma**	**Wetland Type, Temporal**
Ray, JD; Sullivan, BD; Miller, HW	Breeding ducks and their habitats in the high plains of Texas	SOUTHWESTERN NATURALIST	2003	abundance, density, presence	waterbirds	**Texas**	**Wetland Type, Temporal**
Naugle, DE; Johnson, RR; Cooper, TR; Holland, MM; Higgins, KE	Temporal distribution of waterfowl in eastern South Dakota: Implications for aerial surveys	WETLANDS	2000	abundance	waterbirds	**South Dakota**	**Temporal, Count Methodology, Breeding Success**
NIEMI, GJ; HANOWSKI, JM	EFFECTS OF A TRANSMISSION-LINE ON BIRD POPULATIONS IN THE RED LAKE PEATLAND, NORTHERN MINNESOTA	AUK	1984	abundance, density, species_richness	community	**Minnesota**	**Disturbance**
Fletcher, RJ; Koford, RR	Consequences of rainfall variation for breeding wetland blackbirds	CANADIAN JOURNAL OF ZOOLOGY	2004	density	Red-winged blackbird, Yellow-headed blackbird	**Iowa**	**Breeding Success**
Burton, TM; Uzarski, DG	Biodiversity in protected coastal wetlands along the west coast of Lake Huron	AQUATIC ECOSYSTEM HEALTH & MANAGEMENT	2009	species_richness	community	**Michigan**	**Natural History**
Dertien, JS; Self, S; Ross, BE; Barrett, K; Baldwin, RF	The relationship between biodiversity and wetland cover	PLOS ONE	2020	species_richness	community	**Alabama, Arizona, Arkansas,**	**Local and Landscape Land Cover, Climate**

	varies across regions of the conterminous United States					**California, Colorado, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusett s, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West**	

						Virginia, Wisconsin, Wyoming	
McKown, JG; Moore, GE; Payne, AR; White, NA; Gibson, JL	Successional dynamics of a 35 year old freshwater mitigation wetland in southeastern New Hampshire	PLOS ONE	2021	evenness, species_richness, abundance	community	**New Hampshire**	**Natural History**

Supplementary Table 2. Articles in the *Local and Landscape Land Cover* theme.

Authors	Metric(s)	Title	Wetland Cover Positive	Wetland Cover Negative	Grassland Cover Positive	Veg Cover Positive	Veg Cover Negative	Forest Cover Positive	Forest Cover Negative	Urban Positive
Naugle, DE; Johnson, RR; Estey, ME; Higgins, KF	presence	A landscape approach to conserving wetland bird habitat in the prairie pothole region of eastern South Dakota	landscape		landscape	local				
McKinney, RA; Raposa, KB; Cournoyer, RM	species_richness, abundance	Wetlands as habitat in urbanizing landscapes: Patterns of bird abundance and occupancy								landscape
Mamo, LB; Bolen, EG	species_richness	Effects of area, isolation, and landscape on the avifauna of Carolina bays	landscape							
Glennon, MJ	presence	Dynamics of Boreal Birds at the Edge of Their Range in the Adirondack Park, NY								
Niemuth, ND; Solberg, JW; Shaffer, TL	abundance	Influence of moisture on density and distribution of grassland birds in North Dakota	landscape							
Niemuth, ND; Solberg, JW	abundance	Response of waterbirds to number of wetlands in the Prairie Pothole Region of North Dakota, USA	landscape (abundance)							

Webb, EB; Smith, LM; Vrtiska, MP; Lagrange, TG	abundance, species_richness	Effects of Local and Landscape Variables on Wetland Bird Habitat Use During Migration Through the Rainwater Basin	landscape (dabbling duck abundance, shorebird abundance)	landscape (overall richness)		local (intermediate veg, less than 50%)				
Austin, JE; Buhl, TK; Guntenspergen, GR; Norling, W; Sklebar, HT	abundance	Duck populations as indicators of landscape condition in the Prairie Pothole Region								
Orr, JT; Duquette, CA; Hovick, TJ; Geaumont, BA; Harms, TM	abundance, density	Secretive Marsh Bird Densities and Habitat Associations in the Prairie Pothole Region		landscape (Sora density)						landscape (Coots density only)
Saunders, SP; Hall, KAL; Hill, N; Michel, NL	abundance	Multiscale effects of wetland availability and matrix composition on wetland breeding birds in Minnesota, USA								landscape (Marsh Wren)

Hapner, JA; Reinartz, JA; Fredlund, GG; Leithoff, KG; Cutright, NJ; Mueller, WP	species_richness, abundance, density	Avian Succession in Small Created and Restored Wetlands							landscape	
Wilson, WH; Zierzow, RE; Savage, AR	abundance	Habitat selection by peatland birds in a central Maine bog: The effects of scale and year								
Eakin, CJ; Hunter, ML; Calhoun, AJK	community_composition	Bird and mammal use of vernal pools along an urban development gradient								landscape (urban-affiliated birds only)
Alsfeld, AJ; Bowman, JL; Deller-Jacobs, A	species_richness, diversity, abundance	The Influence of Landscape Composition on the Biotic Community of Constructed Depressional Wetlands		landscape (abundance and richness wetland birds only)				local (species richness and diversity)		
Fairbairn, SE; Dinsmore, JJ	species_richness, density	Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA	landscape (species richness)			local (species_richness)				

Elliott, LH; Igl, LD; Johnson, DH	species_richness, abundance	The relative importance of wetland area versus habitat heterogeneity for promoting species richness and abundance of wetland birds in the Prairie Pothole Region, USA								
Forcey, GM; Thogmartin, WE; Linz, GM; Bleier, WJ; McKann, PC	abundance	Land use and climate influences on waterbirds in the Prairie Potholes	landscape (waterbird abundance)							
Forcey, GM; Thogmartin, WE; Linz, GM; McKann, PC	abundance	Land use and climate affect Black Tern, Northern Harrier, and Marsh Wren abundance in the Prairie Pothole Region of the United States	landscape (abundance)							
Ballard, DC; Jones, OE; Janke, AK	abundance	Factors Affecting Wetland Use by Spring Migrating Ducks in the Southern Prairie Pothole Region			,	local (emergent for dabbling duck abundance, submerged veg for diving ducks)				

Janke, AK; Anteau, MJ; Stafford, JD	abundance	Prairie wetlands confer consistent migrant refueling conditions across a gradient of agricultural land use intensities								
Tsai, JS; Venne, LS; Smith, LM; McMurry, ST; Haukos, DA	species_richness, density	Influence of Local and Landscape Characteristics on Avian Richness and Density in Wet Playas of the Southern Great Plains, USA		local and landscape (density)						
Elliott, LH; Bracey, AM; Niemi, GJ; Johnson, DH; Gehring, TM; Giese, EEG; Fiorino, GE; Howe, RW; Lawrence, GJ; Norment, CJ; Tozer, DC; Igl, LD	presence	Application of habitat association models across regions: Useful explanatory power retained in wetland bird case study								

Dertien, JS; Self, S; Ross, BE; Barrett, K; Baldwin, RF	species_richness	The relationship between biodiversity and wetland cover varies across regions of the conterminous United States	landscape (species richness)							

Supplementary Table 2. Continued.

Authors	Metric(s)	Title	Urbanization Negative	Wetland Connectivity	Agriculture Cover Positive	Agriculture Cover Negative	Heterogeneity Positive	Heterogeneity Negative
Naugle, DE; Johnson, RR; Estey, ME; Higgins, KF	presence	A landscape approach to conserving wetland bird habitat in the prairie pothole region of eastern South Dakota						
McKinney, RA; Raposa, KB; Cournoyer, RM	species_richness, abundance	Wetlands as habitat in urbanizing landscapes: Patterns of bird abundance and occupancy						
Mamo, LB; Bolen, EG	species_richness	Effects of area, isolation, and landscape on the avifauna of Carolina bays						

Glennon, MJ	presence	Dynamics of Boreal Birds at the Edge of Their Range in the Adirondack Park, NY		positive				
Niemuth, ND; Solberg, JW; Shaffer, TL	abundance	Influence of moisture on density and distribution of grassland birds in North Dakota						
Niemuth, ND; Solberg, JW	abundance	Response of waterbirds to number of wetlands in the Prairie Pothole Region of North Dakota, USA						
Webb, EB; Smith, LM; Vrtiska, MP; Lagrange, TG	abundance, species_richness	Effects of Local and Landscape Variables on Wetland Bird Habitat Use During Migration Through the Rainwater Basin						

Austin, JE; Buhl, TK; Guntenspergen, GR; Norling, W; Sklebar, HT	abundance	Duck populations as indicators of landscape condition in the Prairie Pothole Region				landscape		
Orr, JT; Duquette, CA; Hovick, TJ; Geaumont, BA; Harms, TM	abundance, density	Secretive Marsh Bird Densities and Habitat Associations in the Prairie Pothole Region						
Saunders, SP; Hall, KAL; Hill, N; Michel, NL	abundance	Multiscale effects of wetland availability and matrix composition on wetland breeding birds in Minnesota, USA	landscape, local (half of species)					
Hapner, JA; Reinartz, JA; Fredlund, GG; Leithoff, KG; Cutright, NJ; Mueller, WP	species_richness, abundance, density	Avian Succession in Small Created and Restored Wetlands						
Wilson, WH; Zierzow, RE; Savage, AR	abundance	Habitat selection by peatland birds in a central Maine bog: The effects of scale and year						

Eakin, CJ; Hunter, ML; Calhoun, AJK	community_composition	Bird and mammal use of vernal pools along an urban development gradient						
Alsfeld, AJ; Bowman, JL; Deller-Jacobs, A	species_richness, diversity, abundance	The Influence of Landscape Composition on the Biotic Community of Constructed Depressional Wetlands						
Fairbairn, SE; Dinsmore, JJ	species_richness, density	Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA						
Elliott, LH; Igl, LD; Johnson, DH	species_richness, abundance	The relative importance of wetland area versus habitat heterogeneity for promoting species richness and abundance of wetland birds in the Prairie Pothole Region, USA					landscape	

Forcey, GM; Thogmartin, WE; Linz, GM; Bleier, WJ; McKann, PC	abundance	Land use and climate influences on waterbirds in the Prairie Potholes						
Forcey, GM; Thogmartin, WE; Linz, GM; McKann, PC	abundance	Land use and climate affect Black Tern, Northern Harrier, and Marsh Wren abundance in the Prairie Pothole Region of the United States						
Ballard, DC; Jones, OE; Janke, AK	abundance	Factors Affecting Wetland Use by Spring Migrating Ducks in the Southern Prairie Pothole Region						
Janke, AK; Anteau, MJ; Stafford, JD	abundance	Prairie wetlands confer consistent migrant refueling conditions across a gradient of agricultural land use intensities			landscape (only one species)			

Tsai, JS; Venne, LS; Smith, LM; McMurry, ST; Haukos, DA	species_richness, density	Influence of Local and Landscape Characteristics on Avian Richness and Density in Wet Playas of the Southern Great Plains, USA						
Elliott, LH; Bracey, AM; Niemi, GJ; Johnson, DH; Gehring, TM; Giese, EEG; Fiorino, GE; Howe, RW; Lawrence, GJ; Norment, CJ; Tozer, DC; Igl, LD	presence	Application of habitat association models across regions: Useful explanatory power retained in wetland bird case study						
Dertien, JS; Self, S; Ross, BE; Barrett, K; Baldwin, RF	species_richness	The relationship between biodiversity and wetland cover varies across regions of the conterminous United States						

Supplementary Table 3. Articles in the *Wetland Area* theme.

Authors	Metric(s)	Title	Area Positive	Area Negative	Area Neutral
Scheffers, BR; Harris, JBC; Haskell, DG	species_richness, diversity, evenness, community_composition, abundance	Avifauna associated with ephemeral ponds on the Cumberland Plateau, Tennessee			X - abundance, richness, diversity
McKinney, RA; Paton, PWC	species_richness, evenness, abundance, diversity	Breeding birds associated with seasonal pools in the northeastern United States			X - abundance, richness, diversity
Herteux, CE; Gawlik, DE; Smith, LL	density	Habitat Characteristics Affecting Wading Bird Use of Geographically Isolated Wetlands in the US Southeastern Coastal Plain		X - density	
Sebastián-González, E; Green, AJ	species_richness, density, abundance	Habitat Use by Waterbirds in Relation to Pond Size, Water Depth, and Isolation: Lessons from a Restoration in Southern Spain	X - abundance, richness, density		
BROWN, M; DINSMORE, JJ	species_richness	IMPLICATIONS OF MARSH SIZE AND ISOLATION FOR MARSH BIRD MANAGEMENT	X - species richness		
Keppeler, FW; Cruz, DA; Dalponti, G; Mormul, RP	abundance	The role of deterministic factors and stochasticity on the trophic interactions between birds and fish in temporary floodplain ponds	X - abundance		
Messmer, DJ; Petrie, SA; Badzinski, SS; Gloutney, ML; Schummer, ML	abundance	Habitat Associations of Breeding Mallards and Canada Geese in Southern Ontario, Canada	X - abundance		

CELADA, C; BOGLIANI, G	species_richness	BREEDING BIRD COMMUNITIES IN FRAGMENTED WETLANDS	X - species richness, diversity		
Mamo, LB; Bolen, EG	species_richness	Effects of area, isolation, and landscape on the avifauna of Carolina bays	X - species richness		
Webb, EB; Smith, LM; Vrtiska, MP; Lagrange, TG	abundance, species_richness	Effects of Local and Landscape Variables on Wetland Bird Habitat Use During Migration Through the Rainwater Basin	X - species richness		
Tellería, JL; Venero, JL; Santos, T	abundance, species_richness	Conserving birdlife of peruvian highland bogs:: Effects of patch-size and habitat quality on species richness and bird numbers	X - species richness, abundance		
Rosselli, L; Stiles, FG	abundance, density	Local and Landscape Environmental Factors are Important for the Conservation of Endangered Wetland Birds in a High Andean Plateau	X - abundance		
Hapner, JA; Reinartz, JA; Fredlund, GG; Leithoff, KG; Cutright, NJ; Mueller, WP	species_richness, abundance, density	Avian Succession in Small Created and Restored Wetlands	X - species richness, abundance		
Fairbairn, SE; Dinsmore, JJ	species_richness, density	Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA	X - species richness		
Elliott, LH; Igl, LD; Johnson, DH	species_richness, abundance	The relative importance of wetland area versus habitat heterogeneity for promoting species richness and abundance of wetland birds in the Prairie Pothole Region, USA	X - species richness, abundance		

Forcey, GM; Thogmartin, WE; Linz, GM; Bleier, WJ; McKann, PC	abundance	Land use and climate influences on waterbirds in the Prairie Potholes	X - abundance		
Tsai, JS; Venne, LS; Smith, LM; McMurry, ST; Haukos, DA	species_richness, density	Influence of Local and Landscape Characteristics on Avian Richness and Density in Wet Playas of the Southern Great Plains, USA	X - species richness		
Elliott, LH; Bracey, AM; Niemi, GJ; Johnson, DH; Gehring, TM; Giese, EEG; Fiorino, GE; Howe, RW; Lawrence, GJ; Norment, CJ; Tozer, DC; Igl, LD	presence	Application of habitat association models across regions: Useful explanatory power retained in wetland bird case study	X - occupancy		
Bartzen, B; Dufour, KW; Bidwell, MT; Watmough, MD; Clark, RG	abundance, density	Relationships Between Abundances of Breeding Ducks and Attributes of Canadian Prairie Wetlands	X - abundance		

Supplementary Table 4. Articles in the *Hydrology* theme.

Authors	Metric(s)	Title	Hydroperiod	Water Depth	Hydroperiod Management
KANTRUD, HA; STEWART, RE	density	USE OF NATURAL BASIN WETLANDS BY BREEDING WATERFOWL IN NORTH-DAKOTA	seasonal		
RUWALDT, JJ; FLAKE, LD; GATES, JM	abundance, density, relative_abundance	WATERFOWL PAIR USE OF NATURAL AND MAN-MADE WETLANDS IN SOUTH-DAKOTA	semi-permanent		
Austin, JE	abundance, density	Responses of dabbling ducks to wetland conditions in the Prairie Pothole region	semi-permanent		
KANTRUD, HA; STEWART, RE	species_richness, abundance, density	ECOLOGICAL DISTRIBUTION AND CRUDE DENSITY OF BREEDING BIRDS ON PRAIRIE WETLANDS	semi-permanent		
Jorgensen, JG; Brenner, SJ; Greenwalt, LR	abundance, density	A Tale of Two Complexes: Secretive Marsh Bird Abundance Differs in the Sandhills and Rainwater Basin, Nebraska		higher	
JOHNSGARD, PA	abundance, species_richness	EFFECTS OF WATER FLUCTUATION AND VEGETATION CHANGE ON BIRD POPULATIONS, PARTICULARLY WATERFOWL	descriptive		
STEWART, RE; KANTRUD, HA	species_richness, abundance	BREEDING WATERFOWL POPULATIONS IN PRAIRIE POTHOLE REGION OF NORTH-DAKOTA	seasonal / semi-permanent		
Oneal, BJ; Heske, EJ; Stafford, JD	abundance, species_richness, density	Waterbird response to wetlands restored through the conservation reserve enhancement program	semi-permanent		positive

Elliott, LH; Igl, LD; Johnson, DH	species_richness, abundance	The relative importance of wetland area versus habitat heterogeneity for promoting species richness and abundance of wetland birds in the Prairie Pothole Region, USA	permanent		
Giese, EEG; Howe, RW; Wolf, AT; Niemi, GJ	community_composition, abundance	Breeding birds and anurans of dynamic coastal wetlands in Green Bay, Lake Michigan	permanent		
Tsai, JS; Venne, LS; Smith, LM; McMurry, ST; Haukos, DA	species_richness, density	Influence of Local and Landscape Characteristics on Avian Richness and Density in Wet Playas of the Southern Great Plains, USA	permanent	intermediate (30-80cm)	

Supplementary Table 5. Articles in the *Climate* theme.

Authors	Metric(s)	Title	Climate Negative	Climate Positive	No Response	Precipitation Positive	Temperature Positive
Niemuth, ND; Solberg, JW; Shaffer, TL	abundance	Influence of moisture on density and distribution of grassland birds in North Dakota				Yes	
Steen, V; Skagen, SK; Noon, BR	presence	Vulnerability of Breeding Waterbirds to Climate Change in the Prairie Pothole Region, USA	Yes				
Sorenson, LG; Goldberg, R; Root, TL; Anderson, MG	abundance	Potential effects of global warming on waterfowl populations breeding in the	Yes				

		Northern Great Plains					
Forcey, GM; Thogmartin, WE; Linz, GM; Bleier, WJ; McKann, PC	abundance	Land use and climate influences on waterbirds in the Prairie Potholes				Yes	
Forcey, GM; Thogmartin, WE; Linz, GM; McKann, PC	abundance	Land use and climate affect Black Tern, Northern Harrier, and Marsh Wren abundance in the Prairie Pothole Region of the United States				Yes	
Steen, V; Powell, AN	presence	Potential Effects of Climate Change on the Distribution of Waterbirds in the Prairie Pothole Region, USA	Yes				
Dertien, JS; Self, S; Ross, BE; Barrett, K; Baldwin, RF	species_richness	The relationship between biodiversity and wetland cover varies across regions of the conterminous United States					Yes

Supplementary Table 6. Articles in the *Vegetation* theme.

Authors	Metric(s)	Title	Vegetation Positive

Herteux, CE; Gawlik, DE; Smith, LL	density	Habitat Characteristics Affecting Wading Bird Use of Geographically Isolated Wetlands in the US Southeastern Coastal Plain	none / trees (cypress-gum)
Mamo, LB; Bolen, EG	species_richness	Effects of area, isolation, and landscape on the avifauna of Carolina bays	trees
JOHNSGARD, PA	abundance, species_richness	EFFECTS OF WATER FLUCTUATION AND VEGETATION CHANGE ON BIRD POPULATIONS, PARTICULARLY WATERFOWL	descriptive
EWERT, D	abundance	BIRDS IN ISOLATED BOGS IN CENTRAL MICHIGAN	trees (black spruce tamarack)
Oneal, BJ; Heske, EJ; Stafford, JD	abundance, species_richness, density	Waterbird response to wetlands restored through the conservation reserve enhancement program	emergent
Ballard, DC; Jones, OE; Janke, AK	abundance	Factors Affecting Wetland Use by Spring Migrating Ducks in the Southern Prairie Pothole Region	emergent

Supplementary Table 7. Articles in the *Wetland Type* theme.

Authors	Metric(s)	Title	Agricultural v. Natural Comparison	Wetland Type
Herteux, CE; Gawlik, DE; Smith, LL	density	Habitat Characteristics Affecting Wading Bird Use of Geographically Isolated Wetlands in the US Southeastern Coastal Plain	yes	Agricultural Forested
EWERT, D	abundance	BIRDS IN ISOLATED BOGS IN CENTRAL MICHIGAN		Forested

Ballard, DC; Jones, OE; Janke, AK	abundance	Factors Affecting Wetland Use by Spring Migrating Ducks in the Southern Prairie Pothole Region		Emergent Open
Giese, EEG; Howe, RW; Wolf, AT; Niemi, GJ	community_composition, abundance	Breeding birds and anurans of dynamic coastal wetlands in Green Bay, Lake Michigan		Inland Coastal
Hartzell, D; Bidwell, JR; Davis, CA	species_richness, abundance, diversity	A comparison of natural and created depressional wetlands in central Oklahoma using metrics from indices of biological integrity	yes	Man-made Depression
Ray, JD; Sullivan, BD; Miller, HW	abundance, density, presence	Breeding ducks and their habitats in the high plains of Texas	yes	Emergent Man-made

Supplementary Table 8. Articles in the *Temporal* theme.

Authors	Metric(s)	Title	Season Highest
Czapka, SJ; Kilgo, JC	species_richness, abundance	Importance of Carolina Bays to the Avifauna of Pinelands in the Southeastern United States	Winter (full year collected)
Bogiatto, RJ; Karnegis, JD	abundance	The use of eastern Sacramento Valley vernal pools by ducks	Spring Winter (full year collected)
Taft, OW; Haig, SM		Historical wetlands in Oregon's Willamette Valley: Implications for restoration of winter waterbird habitat	Winter Fall (full year collected)
Ray, JD; Sullivan, BD; Miller, HW	abundance, density, presence	Breeding ducks and their habitats in the high plains of Texas	Summer (May and June only, highest in May)
Naugle, DE; Johnson, RR; Cooper, TR; Holland, MM; Higgins, KE	abundance	Temporal distribution of waterfowl in eastern South Dakota: Implications for aerial surveys	Summer (May-August only, highest in May)

Hartzell, D; Bidwell, JR; Davis, CA	species_richness, abundance, diversity	A comparison of natural and created depressional wetlands in central Oklahoma using metrics from indices of biological integrity	Spring (Spring, Summer, Fall seasons collected)

Supplementary Table 9. Articles in the *Restoration* theme.

Authors	Metric(s)	Title	Restored Higher	Natural Higher	No Difference
Ratti, JT; Rocklage, AM; Giudice, JH; Garton, EO; Golner, DP	abundance, species_richness, density	Comparison of avian communities on restored and natural wetlands in North and South Dakota			x
Hapner, JA; Reinartz, JA; Fredlund, GG; Leithoff, KG; Cutright, NJ; Mueller, WP	species_richness, abundance, density	Avian Succession in Small Created and Restored Wetlands			
DELPHEY, PJ; DINSMORE, JJ	species_richness, abundance	BREEDING BIRD COMMUNITIES OF RECENTLY RESTORED AND NATURAL PRAIRIE POTHOLES		x	
Elliott, LH; Igl, LD; Johnson, DH	species_richness, abundance	The relative importance of wetland area versus habitat heterogeneity for promoting species richness and abundance of wetland birds in the Prairie Pothole Region, USA	x		
Creighton, JH; Sayler, RD; Tabor, JE; Monda, MJ	density, abundance	Effects of wetland excavation on avian communities in eastern Washington	x		
Fletcher, RJ; Koford, RR	density	Changes in breeding bird populations with habitat restoration in northern Iowa	x (only for 2 species)		