Wetland management practices and secretive marsh bird habitat in the Mississippi Flyway: a review

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ABSTRACT Management regimes on publicly owned freshwater wetlands in the Mississippi Flyway of North America (i.e., Flyway) have historically emphasized waterfowl, but there is limited information on how waterfowl-focused wetland management affects other wetland-dependent wildlife. Secretive marsh birds (SMBs) depend on wetlands with emergent vegetation throughout their migratory life cycle and often encounter vegetation and water conditions resulting from waterfowl-focused management regimes. Thus, there is a need for better understanding of how SMBs are affected by wetland management and the extent to which waterfowl-focused management regimes provide habitat for SMBs. In this review, we identify the vegetation and water conditions resulting from typical management objectives on freshwater emergent wetlands in the Flyway, review and qualitatively synthesize results from studies that directly evaluate how wetland management practices affect SMBs or their habitat, and assess how the vegetation and water conditions being produced for target species (mainly waterfowl) align with SMB habitat requirements. We searched online databases and used Google Scholar to locate peer-reviewed literature, technical reports, and graduate theses that pertained to responses of SMBs or their habitat to water-level manipulation, herbicide application, prescribed fire, disking, mowing, and planting crops. There are several management strategies that complement SMBs and waterfowl, such as reducing cover of woody species and providing flooded emergent vegetation. We also highlight management strategies that may not currently align with SMB life-cycle needs and suggest adjustments that might promote habitat for SMBs while still achieving

waterfowl population objectives. For example, adjusting the dates and duration of spring water-level drawdowns on a portion of wetlands within a larger complex can provide for spring migrating waterfowl and ensure habitat for migrating and nesting SMBs. Ideally, future studies would address how modifications to management practices affect SMBs and monitor potential effects on waterfowl, resulting in a more holistic approach to wetland management.

KEYWORDS bittern, cattail, emergent vegetation, full annual life cycle, moist soil, rail, sora, waterfowl, water-level manipulation

Management actions to improve habitat are often targeted at 1 species or group of species, yet the consequences can resonate for non-target species within the community (Leopold 1933, Gallo and Pejchar 2016, Carlisle et al. 2018, Mustin et al. 2018). Game species have been a primary focus of land management, and, in many cases, successful recovery of game populations has been the result of widespread, game-focused management (Stoddard 1931, Leopold 1933, Nichols et al. 1995). Game-focused management has been instrumental in advancing the fields of ecology and conservation biology with our understanding of game species ecology and responses to management often more extensive and nuanced than for non-game species. But contemporary conservation targets are expanding beyond game species; biodiversity conservation depends on management plans addressing a broad suite of species' annual life-cycle needs (Simberloff 1988, Haig et al. 2008). Game species management can serve as an umbrella to create and maintain habitat for other species (Suter et al. 2002, Hanser and Knick 2011), although negative and neutral responses of non-target species to game species management have also been observed (Laubhan and Fredrickson 1993, Gallo and Pejchar 2016, Mustin et al. 2018, Kramer et al. 2019).

Management practices on publicly owned freshwater wetlands in the Mississippi Flyway of North America (Figure 1) have historically focused on habitat for waterfowl (*Anatidae*) game species (North American Waterfowl Management Plan 2012, Gray et al. 2013). The Mississippi Flyway (i.e., Flyway) is 1 of 4 flyways for migrating birds in North America and is the most heavily used flyway by waterfowl (Bellrose 1980, Raftovich et al. 2022). After a marked decline of waterfowl numbers in the early twentieth century resulting primarily from wetland loss, the introduction of flyway-scale harvest regulations and habitat restoration through wetland conservation and habitat management resulted in waterfowl population recovery, demonstrated by population increases for most waterfowl species since 1970 (North American Waterfowl Management Plan 2012, U.S. Fish and Wildlife Service [USFWS] 2018, Rosenburg et al. 2019). Successful recovery of waterfowl populations was ultimately due in large part to coordination at a continental scale and a vested interest from hunters (with the notable exception of the trumpeter swan [*Cygnus buccinator*], which attracted a wide array of conservation partners), which is not typically demonstrated for other non-harvested wetland bird species. Wetland management practices in the Flyway and elsewhere have been developed to produce vegetation and water conditions that benefit waterfowl throughout their full annual cycle (Nelms 2007).

Other wetland-dependent species can benefit from current management practices (Bradshaw et al. 2020), but studies are limited on how waterfowl-focused wetland management affects non-target wildlife species (Gallo and Pejchar 2016). Despite the extensive wetland restoration that has occurred since the 1990s, wetlands are still substantially less abundant than they were historically (Dahl 1990, Dahl 2011). If the expanding scope of biodiversity conservation goals are to be met, remaining wetlands must provide habitat for all wetland-dependent species (Rands et al. 2010).

Secretive marsh birds (SMBs) are a guild that relies on wetlands in the Flyway throughout their annual life cycle. Secretive marsh birds, including rails (*Rallidae*) and bitterns (*Ardeidae*), are migratory, understudied, and designated species of conservation concern by many state, provincial, and federal natural resource agencies (Environmental Canada 2013, U.S. Geological Survey [USGS] 2021) owing to population declines (Tozer 2016, Sauer et al. 2020). The development of a standardized monitoring protocol for SMBs (Conway 2011) prompted an influx of studies evaluating SMB habitat associations since approximately 2011 (Malone et al. 2021). Presence of SMBs is positively associated with robust, perennial vegetation, including cattail (*Typha* spp.), during the breeding season and spring migration. During autumn migration, SMBs may also positively associate with non-robust, annual wetland vegetation, although evidence supporting this pattern is limited. While there is strong evidence that SMBs avoid woody wetland vegetation during the breeding season, evidence during other life stages is limited. Secretive marsh birds require inundation at shallow depths during migration and breeding (Malone et al. 2021).

Because of their dependence on wetlands with emergent herbaceous plant communities and the limited number of wetlands remaining in the Flyway, SMBs often encounter vegetation and water conditions resulting from waterfowl management regimes (Cowardin et al. 1979, Eddelman et al. 1988). But data are scarce on how wetland management practices affect SMBs and their habitat. These effects may be regionally or locally specific, as wetland plant communities and hydrologic regimes vary throughout the Flyway. There is some evidence that waterfowl act as umbrella species for SMBs; Bradshaw et al. (2020) reported that on public wetlands in Illinois, USA, SMB occupancy peaked at wetlands with intermediate levels of waterfowl management intensity. Yet other researchers reported waterfowl and SMBs have significantly different habitat associations (Valente et al. 2011, Studholme et al. 2022). Despite the dearth of information and contradictory outcomes from past researchers, concerns over SMB declines have prompted interest in SMB-focused management at some public wetlands. Still, there is a need for better understanding of how SMBs are affected by wetland management practices and the extent to which waterfowl-focused management regimes provide for SMB habitat requirements. Synthesis of this information will contribute to more comprehensive understanding of the effects of wetland management on multi-species habitat and provide a basis for designing management regimes that are more inclusive of a broader suite of wetland-dependent species.

In this review, we address how conditions produced by current wetland management practices in the Flyway provide for SMB habitat needs throughout their annual cycle. Our objectives were to identify the vegetation and water conditions that are typical objectives of management on freshwater emergent wetlands in the Flyway; review and qualitatively synthesize results from studies that directly evaluate how wetland management practices affect SMBs or their habitat; assess how the vegetation and water conditions being produced for target species (mainly waterfowl) align with SMB habitat requirements; and discuss opportunities, limitations, and considerations for future management and research.

STUDY AREA

The Flyway is used by several species of SMB throughout their annual cycle (Fink et al. 2021). Breeding grounds for most SMB species within the Flyway are located in the upper Midwest and Prairie Pothole regions, with the remainder of the Flyway providing migration and wintering habitat (Figure 1; Huschle et al. 2013, Fournier et al. 2017, Leston and Bookhout 2020, Webb et al. 2022). The Flyway spans from the Gulf of Mexico in the southeastern United States and generally follows the Mississippi River north to Ontario, Canada, and expands west to Saskatchewan, Canada (Figure 1). The Flyway contains Eastern Temperate Forest, Great Plains, and Northern Forest ecoregions, and the Great Lakes (U.S. Environmental Protection Agency 2022). The area of the Flyway is approximately 4.3 million km^2 and includes 15 Bird Conservation Regions (BCRs). Detailed descriptions of major plant communities, common wildlife, topography, and land use for each of the BCRs is available at the North American Bird Conservation Initiative website (http://nabci-us.org/resources/bird-conservation-regions-map/, accessed 8 May 2023). Elevation in the Flyway ranges from 3 m above sea level to 2,024 m in the mountains of eastern Tennessee, USA. In winter (Dec–Feb), SMBs use the southern portion of the Flyway, where winter precipitation averages 13 cm and winter average high and low temperatures vary from 11–18°C and 1–9°C, respectively. In spring (Mar–May) and autumn (Sep–Nov), SMBs are common at middle latitudes of the Flyway, where spring precipitation averages 10 cm; spring average high and low temperatures are 15–18°C and 4–7°C, respectively; autumn precipitation averages 7.5 cm; autumn average high and low temperatures are 15–18°C and 3–5°C, respectively. In summer (Jun–Aug), SMBs use middle and northern latitudes of the Flyway. At northern latitudes, summer precipitation ranges from 8–11 cm and average high and low temperatures range from 23–26°C and 10–12°C, respectively. The flyway spatial scope not only captures full life-cycle habitat needs of SMBs but is practical from a conservation standpoint because the administrative flyway councils facilitate coordination of management and conservation actions among states and provinces within a flyway. A recent meta-analysis (Malone et al. 2021) identified multi-scale habitat associations of SMBs within inland wetland ecosystems of the Flyway, making a parallel spatial scope for this review pragmatic. Likewise, we aligned our taxonomic scope for this review with Malone et al. (2021): least bittern

(*Ixobrychus exilis*), American bittern (*Botaurus lentiginosus*), sora (*Porzana carolina*), Virginia rail (*Rallus limicola*), king rail (*Rallus elegans*), yellow rail (*Coturnicops noveboracensis*), and black rail (*Laterallus jamaicensis*). Although the focal species' overwintering ranges include coastal wetlands of the Gulf of Mexico, this review focuses on inland wetland systems because of the lack of information on winter habitat requirements for SMBs (Malone et al. 2021).

METHODS

Because the literature on how SMBs are affected by wetland management practices is too limited for a quantitative meta-analysis, we used a qualitative, multifaceted approach to address our objectives. We combined an informal survey of state, provincial, and federal wetland managers throughout the Flyway (based on discussions with representatives of the Game Bird and Non-game Bird Technical Sections of the Mississippi Flyway Council) with a systematic literature review.

We surveyed managers of herbaceous emergent wetlands throughout the Flyway about their management objectives, the management practices they use to achieve their objectives, and when (in terms of season or month) they implement those management practices (Supporting Information 1). Thirty representatives from the Game and Nongame Bird Technical Sections of the Mississippi Flyway Council identified the relevant federal, state, and provincial wetland managers within their state or province and distributed the survey via email. We summarized the survey responses to determine which management practices were most common within the Flyway, when they were used, and the intentions of the management practice in terms of vegetation and water conditions (Supporting Information 2).

We searched online databases (Web of Science, ProQuest) and used the internet search engine Google Scholar to locate peer-reviewed literature, technical reports, and graduate theses that pertained to responses of SMBs to the management practices identified by managers, which included water-level manipulation, herbicide application, prescribed fire, disking, mowing, and planting crops; and responses of robust emergent vegetation, woody vegetation, water level, or wetland invertebrates to water-level manipulation, herbicide application, prescribed fire, disking, mowing, and planted crops. We included studies within the taxonomic and spatial scope defined above. We also included additional literature in reference citations from our systematic literature search when relevant.

RESULTS

We received 201 survey responses from wetland managers in 16 of 17 states or provinces within the Flyway (Figure S3). We determined response rates to the wetland management survey for 9 states in the Flyway for which we knew with certainty how many managers were emailed the survey. The median response rate among those states was 87%. Surveys were anonymous, which precluded follow up surveys of non-respondents to assess non-response bias associated with managers. Survey responses were biased geographically, with more responses from the United States than Canada and considerable variation among states in the number of responses (Figure S3). For the literature review, 10 studies directly examined how ≥1 wetland management practice influenced SMBs in the Mississippi Flyway (Table 1). Fourteen studies examined how ≥1 wetland management practice influenced robust emergent vegetation, woody vegetation, water level, or wetland invertebrates and had study sites in or near the Mississippi Flyway.

What vegetation and water conditions are typical objectives of management on herbaceous emergent wetlands in the Mississippi Flyway?

A common goal of wetland management on public lands in the Flyway is to provide habitat to sustain waterfowl populations at desired levels (North American Waterfowl Management Plan

2012, Gray et al. 2013, Williams et al. 2014). Waterfowl were reported most frequently as the target taxon for management by survey respondents in all but 1 state or province, more so than SMBs, shorebirds, cranes, waterbirds as a whole, or herpetofauna (Figure S5). In North America, waterfowl habitat requirements have been studied extensively (North American Waterfowl Management Plan 2012). Specific waterfowl habitat management goals for herbaceous, emergent wetlands vary throughout the Flyway in terms of vegetation amount, structure, and species composition, water depth, and extent. The variation in desired conditions depends largely on the specific life history and phenological events (i.e., molt, wintering, migration, nesting) waterfowl complete in different geographic regions, although there are common goals throughout the Flyway and across life stages. Wetland managers throughout the Flyway generally promote early-successional herbaceous plant communities, discourage woody shrubs, provide flooded areas at appropriate depths when waterfowl are present, and control invasive or overabundant plant species (Fredrickson and Taylor 1982, Merendino et al. 1990, Fleming 2010, Gray et al. 2013).

Like SMBs, many waterfowl species that use the Flyway nest and rear broods in the prairie regions of the upper Midwest and Canada, migrate through the upper and mid-latitude Midwest, and spend the winter in the Lower Mississippi Alluvial Valley, Mexico, or the Caribbean (Fink et al. 2021). For migration and winter waterfowl habitat, managers in every state within the Flyway often use mechanical water control structures to de-water a wetland in spring (Figure S7), followed by some form of soil or vegetation disturbance, such as disking or prescribed fire, to reset vegetation succession and encourage germination and maximum seed production of annual plants during summer (Strader and Stinson 2005, Nelms 2007). Plant species encouraged in some regions include annual smartweeds (*Persicaria* spp.), panic grasses

(*Panicum* spp.), barnyard grasses (*Echinochloa* spp.), beggarticks (*Bidens* spp.), spikerushes (*Eleocharis* spp.), or rice cutgrass (*Leersia oryzoides*; Fredrickson and Taylor 1982, Nelms 2007). The resulting annual plant community is then flooded again in autumn to provide waterfowl foraging opportunities during autumn migration and winter (Strader and Stinson 2005, Nelms 2007). Wetlands remain inundated throughout winter and contain seeds from annual plants grown the previous summer (Herbert et al. 2021). This management regime, involving seasonal drawdown and flooding combined with soil disturbance, is often carried out on human-made impoundments and is broadly referred to as moist-soil management (Fredrickson and Taylor 1982, Strader and Stinson 2005).

For breeding waterfowl, managers often reduce or prevent monocultures of cattail and common reed (*Phragmites* spp.), while maximizing coverage of perennial sedges such as alkali bulrush (*Schoenoplectus maritimus*) and hardstem bulrush (*S. acutus*) and seed production of all herbaceous emergent plants (Merendino et al. 1990). Hemi-marsh conditions of emergent vegetation and open water, or a relatively even ratio of open water and emergent vegetation coverage, are often desired in wetlands where waterfowl nest and rear broods (and have also been positively linked to waterfowl abundance during spring migration; Kaminski and Prince 1981, Webb et al. 2010, Gray et al. 2013). Plant and water conditions that support diverse and abundant protein-rich macroinvertebrate communities, such as plentiful emergent vegetation and hemi-marsh conditions (Voigts 1973, Reinecke 1977), are important habitat components for ducklings and post-breeding females (Sedinger 1992).

How do common management practices used on wetlands in the Mississippi Flyway affect SMBs and their habitat?

Herbicide

Wetland managers throughout the Flyway use herbicide to reduce non-native or invasive plant species, decrease woody species, prevent monocultures, and consequently, promote a target plant community. Herbicide application was the most commonly reported wetland management practice among survey respondents, and it was reported by managers of every state within the Flyway (Figure S8). Non-native or invasive plant species can substantially alter wetland ecosystems by displacing native vegetation, changing vegetation structure, and altering hydrology (Galatowitsch et al. 1999). Even some native plant species are prone to monoculture formation when natural ecosystem processes are disrupted (Apfelbaum 1985). Throughout the Flyway, managers use herbicide to control cattail, common reed, perennial smartweeds, river bulrush (*Bolboshoenus fluviatilis*), and woody vegetation (e.g., willow [*Salix* spp.], poplar [*Populus* spp.], buttonbush [*Cephalanthus occidentalis*]; Figure S10). At middle and southern latitudes of the Flyway, wetland managers often use herbicide to control cocklebur (*Xanthium strumarium*) and in northern and middle latitudes, managers commonly use herbicide to control reed canary grass (*Phalaris arundinacea*) and purple loosestrife (*Lythrum salicaria*; Figure S10). The goal of herbicide application is often restoration of the native plant community and associated wildlife. The wildlife response to herbicide application and the resulting plant community, however, are not well studied.

Many of the typical herbicide targets are robust, perennial species (cattail, common reed, river bulrush), some of which provide the habitat structure that SMBs need for protection from predators, building nesting platforms (Lor and Malecki 2006), and foraging, at least during the breeding season (Valente et al. 2011, Fournier et al. 2021, Malone et al. 2021). Cattail, in particular, is often controlled through herbicides, yet across studies of SMB breeding season habitat associations, cattail is positively associated with SMBs (Malone et al. 2021). Data are lacking regarding the percent cattail coverage at which managers will apply herbicide to control it, and if there is a threshold of cattail coverage at which SMBs disassociate with the wetland. Research on how SMBs are affected by herbicide use to manage wetlands has focused on non-native cattail at northern latitudes of the Flyway, yet results of these studies are equivocal. For example, Anderson et al. (2019) applied herbicide experimentally to hybrid cattail (*Typha* x *glauca*) and examined the response of sora and Virginia rail density to the herbicide treatment and to variation in cattail biomass across study sites in central Minnesota, USA. Relative to control sites, there was no significant change in abundance for either SMB species in the first or second year following herbicide treatment, although both species were less abundant at sites with lower cattail biomass (0 birds at biomass <1,400 kg/ha, 1–5 birds at biomass >1,400 kg/ha; Anderson et al. 2019). In northwestern Minnesota, using a before-after-control-impact study design, Hill (2021) assessed how SMB relative abundance changed in relation to autumn herbicide treatment of hybrid cattail. They reported American bittern, sora, and Virginia rail relative abundance increased within 3 years, although there was a 1–2-year lag in the response, and that least bittern abundance did not respond to the treatment (Hill 2021). Conversely, Linz et al. (1990) treated dense stands of cattail with herbicide in prairie pothole wetlands of North Dakota, USA, and reported significant declines (from 4 birds to 0 birds) of sora and Virginia rail in 1–2 years following treatment. Thus, even within a relatively limited region, on just a single herbicide target, results from 3 studies evaluating how herbicide treatments affect SMBs provide disparate findings. These disparities may be due to herbicide applications at varying intensities or comparing effects among wetlands that differ in physical characteristics, including soils or hydrology.

Other researchers evaluated how herbicide affects the robust, perennial wetland vegetation that SMBs are often positively associated with, namely cattail. From the northern region of the Flyway, 2 studies provide evidence that when cattail is treated with herbicide alone, plants die but dead biomass remains standing (Bruggman 2017, Anderson et al. 2019). Bruggman (2017) used a before-after-control-impact experiment to measure changes in wetland vegetation following herbicide application to cattail-choked wetlands in North Dakota. They reported herbicide application reduced the percent cover of live cattail, although dead cattail remained and amount of open water increased minimally in the 2 years following treatments. Similarly, Anderson et al. (2019) reported that herbicide application alone did not significantly reduce cattail biomass in Minnesota wetlands because the dead cattail stalks remained standing. Standing, dead, robust non-woody emergent vegetation, including cattail and invasive reed species, provides structure that SMBs need; thus, if robust non-woody emergents are left standing after herbicide application, an important structural component of SMB habitat remains (Arnold 2005, Lor 2007, Poole et al. 2020). Herbicide, however, is often coupled with other management techniques to remove the dead vegetation and create areas of open water (Hill 2021). If dead biomass is not removed by other management techniques, it will eventually collapse and degrade (Mason and Bryant 1975) but could provide habitat for SMBs until then (Martin 2012, Poole et al. 2020).

We are not aware of any studies that evaluated SMB diet or body condition relative to herbicide application to wetland vegetation, but herbicides can be toxic to non-target organisms, including wetland invertebrates (Pérez et al. 2013) that SMBs rely on as a food source (Pickens and Meanley 2020, Poole et al. 2020). Herbicides commonly used for controlling robust emergent vegetation, including glyphosate and imazapyr, have been examined for non-target effects in field and laboratory settings and those studies were reviewed by Breckels and Kilgour (2018). Across studies, effects of glyphosate and imazapyr on fish and aquatic invertebrates were generally negligible or short-term. Certain surfactants used to increase the efficacy of the herbicide could be more toxic than the herbicide itself, but more studies are needed to determine the toxicity of surfactants to wetland wildlife (Breckels and Kilgour 2018).

Water-level manipulation

Inundation timing and water depth in many wetlands today are asynchronous with their historical hydrology and inundation patterns because of anthropogenic changes to the landscape (Naiman and Turner 2000, Pringle 2000). Managers frequently manipulate water levels to emulate historical flooding regimes and produce vegetation communities and water conditions that provide habitat for target wildlife species, particularly waterfowl (Fredrickson and Taylor 1982). A majority of survey respondents in each state within the Flyway reported manipulating water levels through active management (Figure S7). Water depth and the timing and rate of disturbance from flooding influences the species composition of emergent and submergent wetland vegetation, which in turn affects essential SMB resources such as invertebrate prey, nesting sites, and cover from predators (Robel 1961, Lowther 1977, Baschuk et al. 2012).

Drawdown

Water-level drawdown is the intentional draining of water from a wetland through use of water control structures and typically is conducted during or after spring waterfowl migration. The duration, timing, and frequency of drawdown can vary based on latitude, environmental conditions such as soil type, and management objectives, resulting in different habitat outcomes for SMBs and waterfowl (Meeks 1969, Scott 2010). A slow drawdown generally takes place over ≥2 weeks, whereas a fast drawdown is generally completed within a few days (Nelms 2007). The proximate purpose of a drawdown is typically to establish or re-establish a target community of emergent vegetation while concurrently concentrating food resources for spring migrating waterfowl and shorebirds (Fredrickson and Taylor 1982). In the Flyway, drawdowns in March–June are common (Figure S11).

During spring migration, water availability and emergent vegetation are important characteristics of stopover habitat for SMBs (Blake-Bradshaw 2018, Webb et al. 2022). Thus, if water is drawn down prior to SMBs migrating through an area, SMB stopover may be detrimentally affected by lack of surface water (Scott 2010). In Arkansas, Scott (2010) reported wetland use by SMBs was significantly associated with spring drawdown date, with substantially fewer SMB detections in wetlands with earlier drawdowns. Among their study wetlands, many were drawn down prior to peak SMB presence during spring migration and SMBs were detected most frequently at sites where drawdowns were not completed (i.e., water remained) until after 15 May (Scott 2010). Similarly, researchers of managed wetlands in Missouri, USA, reported the number of use days by sora and Virginia rail was greater when wetlands were not drawn down until mid- or late-May relative to complete drawdowns in April (Rundle and Fredrickson 1981). On moist-soil units, however, early-successional grasses, sedges, and other herbaceous plants that are beneficial to waterfowl can be enhanced (e.g., species diversity, seed production) by earlier spring drawdowns (mid-Mar to May in Mississippi, USA; Fleming 2010). In Missouri wetlands, Webb et al. (2022) estimated spring migrant SMB site colonization probabilities at wetlands throughout the state that were managed with spring drawdowns. Although there was no direct relationship between drawdown start date or drawdown duration and SMB site colonization, colonization rates of least bitterns showed a significant positive relationship with water depth (100 cm max.), and all species showed positive relationships with the percent cover of emergent vegetation (Webb et al. 2022).

During the breeding season, surface water maintenance is important to SMBs (Lowther 1977, Bradshaw et al. 2020). In Missouri wetlands, water depth was the most important predictor of nest site selection and survival rate of least bittern nests; nest survival rate peaked to 1.0 at water depths of 50–80 cm (Hill 2015). In wetlands in which SMBs nest, drawdowns completed prior to incubation completion are likely to impede SMB productivity (Lowther 1977). Wetlands that initially contained water depths attractive to SMBs selecting nest locations in the spring may have much shallower or no water by the time the incubation period ends if an early drawdown has occurred, potentially creating an ecological trap. In Manitoba, Canada, however, where SMBs nest and rear young, late water-level drawdowns (after 15 Jul) meant that moist-soil vegetation was established too late in the growing season to produce much seed, resulting in less food available for fall migrating and wintering waterfowl (Merendino et al. 1990). There is also evidence from Manitoba that June (mid-season) drawdowns can maximize the establishment of cattail and purple loosestrife (Merendino et al. 1990), species that are typically discouraged for waterfowl (Nelms 2007), but cattails can be beneficial for SMBs (Malone et al. 2021).

Flooding

Following spring water-level drawdowns or water evaporation over summer, re-watering a wetland (i.e., flooding, inundation) often occurs to ensure available habitat for fall migrating waterbirds. Similar to drawdowns, flood timing has important implications for waterbirds and the timing of deliberate wetland inundation can vary with overall management objectives and latitude throughout the Flyway. Waterfowl (other than blue-winged teal [*Spatula discors*] and green-winged teal [*Anas crecca*]) migrate later in autumn than SMBs (Bellrose 1980, Fournier et al. 2017, Fink et al. 2021), and it is typical for managers to inundate wetlands just prior to migrant waterfowl arrival (Strader and Stinson 2005). While research on SMB habitat requirements during autumn migration in the Mississippi Flyway is particularly limited, if autumn flooding is delayed too late, SMB autumn stopover habitat may not be available in time for them to use it (Fournier et al. 2019).

There is evidence that the timing of autumn inundation and the presence of annual emergent vegetation are important environmental characteristics for autumn migrating SMBs in Missouri (Fournier et al. 2018, 2019). Fournier et al. (2019) evaluated if flooding wetlands earlier in autumn to provide habitat for migrating sora would still provide habitat for migrating waterfowl. Among early- and late-flooded impoundments in Missouri, they reported no difference in waterfowl abundance; however, they reported a positive effect of early-flooding on sora density (increase of approximately 3 birds/ha; Fournier et al. 2019). The effect of early flooding on sora was not surprising given it provided more habitat during the peak of the species' migration through the region (Fournier et al. 2017). The more noteworthy conclusion was that waterfowl abundance need not be sacrificed to provide for sora and that water can likely be managed to provide wetland habitat for both taxonomic groups during autumn migration. Another Missouri study compared rail use days among multiple wetland units flooded in late autumn (Nov) in 1 year, then flooded in late summer (early Sep) the following year (Rundle and Fredrickson 1981). The number of use days by sora and Virginia rail was significantly greater (2.6–35.2 times greater) when wetlands were flooded in late summer compared to late autumn (Rundle and Fredrickson 1981). When wetlands are inundated throughout the winter, ice and wave action can destroy emergent vegetation, leaving little or none available the following spring (Rundle and Fredrickson 1981). Leaving portions of wetlands with substantial emergent vegetation unflooded during the winter, and then flooding before the following spring migration could preserve emergent vegetation and provide stopover habitat for SMBs and other waterbirds during spring migration (Greer et al. 2010).

Prescribed fire

Fire is often used by land managers to control woody vegetation and promote herbaceous vegetation (Stoddard 1931, Auclair et al. 1973, Kirby et al. 1988). When emergent wetlands dry out, prescribed fire can be applied to suppress shrub encroachment and remove litter and dead standing vegetation, allowing light and soil conditions to promote new growth of herbaceous species (Nyman and Chabreck 1995, Lugo 1995). Prescribed fire was reported as a management tool by survey respondents from 13 of 14 states in the Flyway (Figure S8) and is commonly used to reset ecological succession; control woody species, invasive species, or dense perennials; and promote herbaceous annuals that produce food for waterfowl (Lynch 1941). While prescribed fire in other ecosystems has been extensively studied, the science of prescribed fire in freshwater emergent wetlands is relatively limited, including within the Flyway (Kirby et al. 1988, Brennan et al. 2005, Mitchell 2006, Williams-Jara et al. 2022). Accordingly, empirical information on how prescribed fire may alter habitat conditions for SMBs in the Flyway is correspondingly rare.

Using prescribed fire to reduce presence of woody species in wetlands is likely beneficial to SMBs throughout the Flyway because SMBs often avoid wetlands with woody vegetation during migration stopover and nesting (Darrah and Krementz 2010, Tozer 2016, Hansen 2019). At least one species of SMB (yellow rail) may also avoid woody vegetation during winter

(Morris et al. 2017). In the southernmost part of the Flyway, where many SMBs overwinter, Morris et al. (2017) studied the effect of prescribed fire on yellow rail occupancy in longleaf pine (*Pinus palustris*) ecosystems and found yellow rails were most likely to occupy sites that had recently (<2 yr) been managed with prescribed fire. The authors postulated that the observed effect of time since fire was due to fire's suppression of woody species and promotion of herbaceous species (Morris et al. 2017). Additional evidence that the frequent application of prescribed fire provides habitat for yellow rails comes from studies on their breeding range; in the upper peninsula of Michigan, USA, Austin and Buhl (2013) reported yellow rail occupancy probability was significantly greater in areas that had been burned within the past 2–5 years (0.285 ± 0.132) relative to sites that burned >10 years ago (0.028 ± 0.019). Conversely, in Minnesota wetlands with varying histories of fire frequency, abundances of sora, Virginia rail, American bittern, and least bittern showed no pattern relative to fire history (Hill 2021). Yellow rails were not detected in that study (Hill 2021). Thus, fire is evidently beneficial for yellow rail; however, we know little else about yellow rail habitat requirements throughout the Flyway (Malone et al. 2021) or how other SMB species directly respond to fire as a management tool.

Prescribed fire is used for management purposes beyond reduction of woody vegetation, such as control of robust perennial vegetation, especially invasives, or to create interspersion of vegetation and water. Interspersion of water with emergent vegetation is important for SMBs in at least some parts of the Flyway, particularly for least bittern (Darrah and Krementz 2010, Bolenbaugh et al. 2011, Webb et al. 2022). Thus, prescribed fire that maintains some openings within robust emergent vegetation may be beneficial for SMBs. Fire is also used to control cattail, which, as discussed above, is often beneficial for SMBs. In cattail-dominated wetlands in Wisconsin, Minnesota, and New York, USA, Gleason et al. (2012) studied how fire seasonality affects cattail and vegetative cover. They reported overall vegetative cover was similar in quantity 1 year after the burn relative to before the burn regardless of when the burn was conducted, although before the burn, much of the vegetation was dead, while after the burn, vegetative cover was primarily alive (Gleason et al. 2012). If prescribed fire to control cattail is implemented during autumn or winter, then the quick return of cattail may mean the robustly structured vegetation that SMBs prefer for nesting is still available. Spring or growing season fire within the breeding range of SMBs could have negative short-term effects by destroying nesting structure and materials or directly destroying SMB nests (Bray 1984, Fournier et al. 2021).

Disking

Disking is a soil disturbance technique that is often used to set back vegetation community succession in wetlands, including control of perennial emergent and woody species (Fredrickson and Taylor 1982, Reid et al. 1989, Gray et al. 1999). Survey respondents from all latitudes of the Flyway reported using disking as a wetland management tool (Figure S8). Disking typically occurs after water has been drawn down from a wetland, when the soil is dry enough to use a tractor and disk implement (Kelley 1990). If many woody plants are already present, mowing or herbicide may be implemented before disking, to ensure disking effectively scarifies the soil (Gray et al. 1999). Disking is often used to promote annual plant communities that provide food for waterfowl and is typically carried out in late spring or summer to stimulate plant growth before flooding a wetland for fall migrants or wintering birds.

No studies were available on the direct effects of disking on SMBs. Because a wetland must dry out before disking can occur, direct mortality of SMB nests from disking is unlikely because active nests are typically only found over water (Lowther 1977, Fournier et al. 2021). The longer-term effects of disking could be beneficial to SMBs if disking reduces the presence and cover of woody species, given studies throughout the Flyway suggest SMBs are negatively associated with woody wetland vegetation (Bolenbaugh et al. 2011, Valente et al. 2011, Tozer 2016, Malone et al. 2021). The frequency of disking is also likely important; if the between-disking interval is too long, woody species may take over, whereas if the interval is too short, robust perennials may be too scarce for SMBs (Gray et al. 1999). Besides reducing woody species, disking could also benefit SMBs by increasing their invertebrate food resources (Benson et al. 2007). In river floodplain wetlands in Iowa, USA, that were restored from agricultural production, summer disking ultimately led to reduced woody species, fewer monotypic stands of reed canary grass, and increased abundance and biomass of arthropods, likely from increased plant diversity (Benson et al. 2007, Haddad et al. 2001).

Mowing

Mowing wetland vegetation is a management practice used throughout the Flyway (Figure S8), often in conjunction with another management tool, such as disking or herbicide application. Mowing can be used to control cattail (Ball 1990), invasive species, and woody species, or to set back vegetation succession or create interspersion of water and vegetation. Mowing is typically implemented following drawdown and drying of the soil, although it can be conducted in winter when water is frozen (Ball 1990).

None of the studies we examined directly examined how SMBs were affected by mowing in emergent herbaceous wetlands. Like other forms of disturbance, if mowing effectively controls woody wetland vegetation, it likely benefits SMBs (Bolenbaugh et al. 2011, Valente et al. 2011, Tozer 2016), although mowing may not always effectively control woody wetland species (Clark and Wilson 2001). Researchers have examined how mowing wetlands can influence abundance of macroinvertebrates, which are important food resources for SMBs (Pickens and Meanly 2020, Pool et al. 2020). In Mississippi wetlands, Gray et al. (1999) reported autumn mowing resulted in greater macroinvertebrate mass compared to disking in autumn. Batzer (2013) reviewed many studies and reported the effects of mowing emergent vegetation on wetland invertebrates varied, even within a wetland complex. Thus, the relationship between mowing wetland vegetation and SMB food resources may be specific to site characteristics and subject to temporal variation. Secretive marsh birds will also consume vertebrate prey (Poole et al. 2020), but the focus of research regarding management has been on invertebrates. Another component of SMB habitat that we have previously discussed, cattail, has been experimentally controlled with mowing (Ball 1990). In Ontario, Ball (1990) mowed cattail over ice in shallow water wetlands and reported cattail regrowth was suppressed in the following growing season. Partial mowing of cattail may simulate the cutting of cattail by muskrats (*Ondatra zibethicus*; Proulx and Gilbert 1983), which could benefit SMBs by creating interspersion in otherwise uniformly dense cattail stands (Darrah and Krementz 2009, Bolenbaugh et al. 2011).

Planting crops

The planting of agricultural crops within shallower portions of wetlands is often used as a management tool at middle and southern latitudes of the Flyway (Figure S8) to provide autumn and winter forage for waterfowl migrants and overwintering populations, and provide soil disturbance that can promote early-successional plant communities (Gray et al 2013). Water is drawn down in the spring so that soil can dry out sufficiently to disk, plant, and grow seedproducing crops, such as corn, millet, or sorghum, within wetlands. Crops are then flooded in autumn, providing carbohydrate-rich food resources and foraging opportunities for large numbers of waterfowl (Gray et al. 2013). Because some crop seeds decompose quickly when inundated (Nelms and Twedt 1996), crops are typically flooded immediately prior to waterfowl migration into the region. Crops can provide high-energy food for large concentrations of waterfowl (Fredrickson and Taylor 1982). For the purpose of this review, we distinguish planting crops by public wetland managers from crops that are planted for human food but are used by waterfowl.

We did not examine any studies that examined how SMBs were affected by planting crops within wetlands as a management tool for waterfowl. Planting crops may have little benefit to SMBs during the breeding season. In addition to not being flooded, crops may not provide the robust vegetation structure that SMBs need, although research on this topic is limited. Sora could be an exception; sora have a positive affiliation with agriculture at the landscape scale during the breeding season (Malone et al. 2021), but the type of crop and other specifics of how sora are associated with agriculture are unknown. Planting crops within wetlands generally requires water to be completely drawn down during spring or early summer; water may be drawn down in April–May (or after waterfowl migrants pass through) so that areas are dry enough to plant by summer. The timing of water-level drawdowns to allow for planting crops (early spring) likely makes many of these wetlands functionally unavailable to spring migrating or nesting SMBs. Similarly, autumn flooding of plantings may occur too late to benefit autumn migrating SMBs (Fournier et al. 2019), and wetland crops do not contain the abundance of invertebrates that native wetland vegetation does (Fredrickson and Taylor 1982), which are important food sources for SMBs.

How does waterfowl habitat management align with SMB habitat requirements?

There are similarities in the habitat requirements of waterfowl and SMBs and therefore overlap in management actions that could be used to benefit both groups. Although SMBs require robust perennial vegetation during the breeding season, there is evidence that annual non-robust vegetation is also important to SMBs during autumn migration (Fournier et al. 2017), which is often favored to provide autumn waterfowl habitat. The control of woody vegetation in wetlands is also important to both waterfowl and SMBs, and many commonly used management practices, such as herbicide, fire, disking, and drawdowns, can help control woody species (Fredrickson and Taylor 1982, Lugo 1995). Additionally, the frequency and timing of water-level management activities, including drawdown and flooding, is key in fulfilling habitat requirements for waterfowl and SMBs. In mid-latitude states of the Flyway, if spring drawdowns are delayed until late spring, wetlands can provide waterfowl and SMB spring stopover habitat (Scott 2010). Shallow flooding of emergent vegetation that commences in late summer would provide autumn migration stopover habitat for SMBs and waterfowl (Fournier et al. 2019). Indeed, modifications to the timing of drawdown and inundation is a multi-species management opportunity that is supported by research, at least in the mid-latitude region of the Flyway (Scott 2010, Fournier et al. 2019). Lastly, herbicide application to control invasive plant species likely has ecosystem-wide benefits that extend to waterfowl and SMBs.

In contrast, there are also several non-overlapping habitat requirements between waterfowl and SMBs and some management practices implemented to meet waterfowl habitat requirements that misalign with SMB life-history needs. Management for migration and winter waterfowl habitat often focuses on maximizing moist-soil seed production, which means annual plants with their high seed yields are favored over perennials. For SMBs, vegetation that has the necessary structural components (i.e. tall, robust, dense) flooded with shallow water is likely more important than any particular plant species composition or seed production (Rundle and Fredrickson 1981, Bradshaw et al. 2020, Fournier et al. 2021). The frequent drawing down of water in spring to promote annual over perennial vegetation benefits waterfowl but likely does not benefit SMBs because it precludes 2 important SMB habitat characteristics: presence of water during migration and nesting and robust emergent vegetation during nesting. The management actions needed to produce native annual wetland plants or a viable crop from planting domestic grains is likely disconnected from the life-history needs of SMBs. While the control of woody wetland vegetation is beneficial to waterfowl and SMBs, the vegetative community needed by SMBs is different than what is often produced for migrating and wintering waterfowl. The frequency of management techniques intended to simulate disturbance and set back ecological succession of vegetative communities, such as burning and disking, could potentially be adjusted to strike a balance in vegetative communities that would create more SMB habitat while still providing waterfowl habitat.

Cattail is a robust, perennial emergent plant that is often deterred in waterfowl-focused management throughout the Flyway because it does not provide waterfowl forage and is prone to quickly filling in areas of open water (Bansal et al. 2019). The invasive cattail species (*Typha angustifolia*) is common in the Flyway and will hybridize with a native species (*T. latifolia*). Although there is strong evidence that SMBs positively associate with cattail throughout the Flyway, results from the few studies that assessed how SMBs were affected by cattail control, mainly through herbicide application, were variable (Linz et al. 1990, Anderson et al. 2019, Hill 2021). Leaving some dense stands of cattail (native, invasive, hybrid species) and keeping them flooded throughout the breeding season is likely beneficial to SMBs.

Finally, some of the other conditions produced by waterfowl habitat management in the Flyway have potential to benefit SMBs, but research is either lacking or inconclusive. For example, interspersion of vegetation and water is an important habitat characteristic for breeding and non-breeding waterfowl within the Mississippi Flyway (Kaminski and Prince 1981, Webb et al. 2010, Hagy and Kaminski 2012, Ballard et al. 2021) and is often created or maintained in managed wetlands by partial mowing or disking of emergent vegetation just before wetlands are flooded. Research on how interspersion affects SMBs is less conclusive across species and latitudes within the Flyway (Bolenbaugh et al. 2011, Baschuk et al 2012, Malone et al. 2021). Multiple studies at middle latitudes of the Flyway indicate least bitterns are positively associated with vegetative interspersion, but most studies on SMB habitat associations in other parts of the Flyway and on other SMB species have not examined the relationship between interspersion and SMBs (Malone et al. 2021). There is evidence that some SMB species may prefer little or no interspersion. For example, as cattail coverage of wetlands in Iowa increased up to 90%, wetland occupancy by Virginia rails also increased (Harms and Dinsmore 2013). In western New York, although not in the Mississippi Flyway, only least bittern nests were found in hemi-marsh conditions (50:50 water to vegetation ratio), whereas sora, Virginia rail, and American bittern nests were at sites with high percentages (>70%) of dense emergent vegetation cover (Lor and Malecki 2006).

Achieving wetland management objectives is most likely if the management regime and target plant community for a wetland align with the hydrogeomorphic features of a wetland, in particular the site hydrology and geomorphic setting (Smith et al. 1995). Based on their hydrogeomorphic characteristics, some sites are less likely to support robust perennial emergent vegetation and more likely to support non-robust annuals, and vice versa. Perhaps at a local scale (i.e., within a conservation area or wetland complex), few sites have suitable environmental characteristics to support emergent marsh vegetative communities, but at a broader, regional scale, some sites may have the appropriate features (longer hydroperiod, deeper water depth) that facilitate management of emergent marsh. Thus, realizing multi-species objectives on the limited remaining wetlands may require deliberate and thoughtful planning at multiple spatial scales. Increased efforts in freshwater wetland restoration since the 1990s (Dahl 2011) could create more opportunities for targeted diverse management.

RESEARCH IMPLICATIONS

Managing for diverse wetland communities undoubtedly involves tradeoffs, but tradeoffs are difficult to assess without sufficient data. Three decades ago, Eddelman et al. (1988) summarized the research needs of North American rallids and called for experimental studies on SMB relationships to waterfowl management (Eddelman et al. 1988). Despite this, the majority of the studies we review here occurred within the past 10 years, possibly reflecting a response to the establishment of a standardized monitoring protocol for SMBs (Conway et al. 2011) and growing concerns over the continued declines of some SMB species. Most studies included in our review evaluated the effects of a management action on abundance or occupancy measures, which do not necessarily reflect habitat quality (Van Horne 1983). Improved understanding of how wetland management actions affect SMB populations will require studies that monitor survival, nesting success, and physiological conditions or behaviors of individuals. Ideally, future studies would address not just how adjustments to management affect SMBs across the annual life cycle, but also monitor potential effects on waterfowl and other wetland-dependent taxa (Fournier et al. 2019).

Despite numerous reports of a positive association between cattail and SMB site occupancy or detection during the breeding season, opportunities abound for this relationship to be further explored given that cattail is prone to aggressive spreading and subsequent management actions (Bansal et al. 2019). Absent from the literature are studies documenting SMB population or behavioral responses after a wetland becomes choked with cattail or as open water patches are closed in by cattail. What is the range of cattail coverage that SMBs will use? It is also unclear if SMBs associate with cattail during the non-breeding season, as they do during the breeding season, or if their associations differ between native, invasive, and hybrid cattail species (Malone et al. 2021).

Experimental manipulations of environmental conditions and concurrent monitoring of wildlife populations are important to assess the efficacy and efficiency of management actions (Gallo and Pejchar 2016, Malone et al. 2022). To advance our understanding of how to optimize and coordinate wetland management in the Flyway for multi-species objectives that include SMBs, manipulative studies that empirically evaluate management practices would also be beneficial. Much of the research thus far has tested SMB habitat relationships for only conditions that currently exist, often as a result of prevailing waterfowl management regimes, yet manipulative studies could deliver key insights on how SMBs (and other waterbirds) relate to a broader set of vegetation and water conditions and expand the potential for successful multi-species wetland management.

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ETHICS STATEMENT

Our survey of wetland managers was in accordance with University of Missouri human subject research policies (Institutional Review Board 00000731, 00009014).

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Table 1. Wetland management practices studied for their effect on secretive marsh birds (SMB) in the Mississippi Flyway, United States and Canada, based on a 2022 literature review.

Management practice studied	Location	SMB species studied	Main findings	Reference
Herbicide to control cattails	North Dakota[a]	sora, Virginia rail	Cattails were nearly eradicated and SMBs numbers declined significantly.	Linz et al. (1990)
Autumn herbicide to control cattails	Minnesota	sora, Virginia rail, American bittern	Initial decline (year 1) followed by increase (years 2–3) in SMB density.	Hill (2021)
Spring drawdown	Missouri	sora, Virginia rail, American bittern, least bittern	Spring drawdown did not directly influence SMB use of spring stopover sites.	Webb et al. (2022)
Spring drawdown	Missouri	least bittern	Drawdown initiation date and duration were not directly important to least bittern nest site selection or nest success.	Hill (2015)
Spring drawdown	Arkansas	sora, king rail, American bittern, least bittern	SMBs detected less often when drawdowns were completed before 15 May.	Scott (2010)

Early autumn flooding	Missouri	sora	Sora abundance increased with early fall flooding; waterfowl abundance was unchanged.	Fournier et al. (2019)
Early autumn flooding	Missouri	sora, Virginia rail	Number of use days by rails increased with early fall flooding.	Rundle and Fredrickson (1981)
Prescribed fire	Michigan	yellow rail	Yellow rails were most likely to use sites with a fire return interval of 2–5 years.	Austin and Buhl (2013)
Winter prescribed fire	Mississippi, Alabama	yellow rail	Yellow rail winter occupancy related negatively to time since fire.	Morris et al. (2017)
Prescribed fire	Minnesota	sora, Virginia rail, American bittern	SMB abundance showed no pattern relative to fire history.	Hill (2021)
Prescribed fire and grazing	Minnesota	sora, Virginia rail, American bittern	SMB density was not greater in wetlands managed with prescribed fire and grazing.	Hill (2021)
Autumn wild rice harvest	Minnesota	sora	Wild rice harvest had a short-term negative impact on soras.	Fannucchi (1983)

[a] Not within the administrative boundaries of the Mississippi Flyway.

Figure 1. Generalization of the annual life-cycle pattern of secretive marsh birds in the Mississippi Flyway of the United States and Canada and their seasonal habitat needs on managed freshwater herbaceous wetlands based on a 2022 review. Photographs are by the Missouri Department of Conservation.