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Strategic Bird Monitoring Guidelines for the Northern Gulf of Mexico

GoMAMN STRATEGIC BIRD MONITORING GUIDELINES: MARSH BIRDS

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Clapper Rail (*Rallus crepitans*). Photo credit: Michael Gray.

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Chapter 4

GOMAMN STRATEGIC BIRD MONITORING GUIDELINES: MARSH BIRDS

DESCRIPTION OF SPECIES GROUPS AND IMPORTANT HABITATS IN THE GULF OF MEXICO REGION

MARSH BIRDS ARE A GROUP OF BIRDS LIVING AT THE interface of aquatic and the terrestrial ecosystems. Living along this edge exposes them to myriad threats and stressors; thus, understanding threats and ecological relationships in both upland and wetland ecosystems is critical to effective conservation of these species. Marsh birds are a poorly understood group, in general, due to their cryptic coloration and generally elusive nature (Ribic et al. 1999, Woodrey et al. 2012). We know relatively little about marsh bird ecology and biology, including their population status and trends (Johnson et al. 2009, Conway 2011). Nearly 50% of marsh bird species in the Gulf region are of conservation concern (Table 4.1), mostly due to the loss of wetland habitats: American (*Botaurus lentiginosus*) and Least Bittern (*Ixobrychus exilis*), Yellow (*Coturnicops noveboracensis*), Black (*Laterallus jamaicensis*), and King Rail (*Rallus elegans*), Marsh (*Cistothorus palustris*) and Sedge Wren (*Cistothorus platensis*), and Nelson's (*Ammospiza nelsoni*) and Seaside Sparrow (*Ammospiza maritimus*) (Table 4.1; Eddleman et al. 1994, Herkert et al. 2001, Post and Greenlaw 2009, Poole et al. 2009, Lowther et al. 2009, Shriver et al. 2011, Kroodsma and Verner 2013, Leston and Bookhout 2015, Pickens and Meanley 2015). Several other marsh bird species are hunted on the Gulf Coast and elsewhere during their annual cycle (Case and McCool 2009). As a group marsh birds display a high degree of endemism—like many other terrestrial vertebrate species found in tidal marshes (Greenberg 2006, Greenberg and Maldonado 2006, Greenberg et al. 2006). In addition, marsh birds have been shown to be bio-indicators of emergent marsh ecosystem health (Novak et al. 2006). Addressing our current uncertainties—a lack of understanding of the status, ecology, and management of this group—is critical to marsh bird conservation.

The Gulf of Mexico (GoM) is home to 20 species of marsh birds, (Woodrey et al. 2012, Table 4.1), from the most common and abundant marsh bird of the Gulf region, the Clapper Rail (*Rallus crepitans*), to the widespread, but locally common Seaside Sparrow, to the Limpkin (*Aramus guarauna*) which is for the most part restricted to freshwater marshes in Florida (Post and Greenlaw 2009, Rush et al. 2012).

Breeding Season

Fourteen marsh bird species breed within the boundaries of the GoM Avian Monitoring Network (GoMAMN) (Figure 1.2, Table 4.1). Clapper Rail is the most abundant species and has a nearly continuous distribution in salt marshes across the region, whereas its congener, the King Rail is less abundant and has a more sporadic distribution concentrated in the coastal marshes of Louisiana and Texas (Rush et al. 2012, Pickens and Meanley 2015). Although a widespread breeder along the Gulf Coast, Common Gallinule (*Gallinula chloropus*) abundance is localized (Bannor and Kiviat 2002). Marsh Wrens are known to breed across much of the GoMAMN region, but in Florida they are not known to breed south of the Big Bend Region (Kroodsma and Verner 2013).

Other breeding marsh bird species have more restricted breeding ranges throughout the Gulf Coast. Black Rails breed from south Florida north through Alabama, with the highest abundance found in south-central Florida and declining towards the northern GoM; coastal Texas appears to be a stronghold for breeding and wintering Black Rails across the eastern United States (Tolliver et al. 2018, Haverland 2019) and they have recently been regularly found in coastal southwest Louisiana throughout the year (Johnson and Lehman 2019). American Coots (*Fulica americana*) breed in peninsular Florida and coastal Texas with isolated populations along the Gulf Coast to west Louisiana (Brisbin and Mowbray 2002). Limpkins are a sporadically distributed, permanent resident of freshwater marshes, found most commonly throughout peninsular Florida (Bryan 2002). Gulf Coast populations of the Seaside Sparrow are irregularly distributed from the Everglades through south Texas (Post and Greenlaw 2009). The Boat-tailed Grackle (*Quiscalus major*) is irregularly distributed along the Gulf Coast from southwest Florida to southeast Texas (Post et al. 2014), breeding throughout most of peninsular Florida, whereas the Great-tailed Grackle (*Quiscalus mexicanus*) has a more western gulf breeding distribution, nesting from southwest Louisiana south through Mexico (Johnson and Peer 2001).

Table 4.1. *Marsh bird species to be considered for monitoring programs at multiple geographic scales across the northern Gulf of Mexico. Table includes species residency status, landcover association, and the North American continental trend and conservation concern scores (Partners in Flight 2017).*

Common Name	Latin Name	Breeding	Winter	Migration	Landcover Association(s)[a]	Trend Score	Continental Concern Score
Pied-billed Grebe[b]	*Podilymbus podiceps*	X	X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	2	8
Yellow Rail	*Coturnicops noveboracensis*		X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland, Evergreen Forest	3	15
Black Rail	*Laterallus jamaicensis*	X	X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	5	17
Clapper Rail[b]	*Rallus crepitans*	X	X	X	Estuarine Emergent Wetland	3	13
King Rail	*Rallus elegans*	X	X	X	Palustrine Emergent Wetland	5	15
Virginia Rail[b]	*Rallus limicola*		X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	1	9
Sora[a]	*Porzana carolina*		X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	2	9
Purple Gallinule[b]	*Porphyrio martinicus*	X	X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	4	11
Common Gallinule[a]	*Gallinula galeata*	X	X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	3	10
American Coot[b]	*Fulica americana*	X	X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	2	8
Limpkin[b]	*Aramus guarauna*	X	X	X	Palustrine Emergent Wetland	3	10
American Bittern	*Botaurus lentiginosus*		X	X	Palustrine Emergent Wetland	4	12
Least Bittern	*Ixobrychus exilis*	X	X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	3	10
Sedge Wren	*Cistothorus platensis*		X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland, Evergreen Forest	1	7
Marsh Wren	*Cistothorus palustris*	X	X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	1	7
Seaside Sparrow	*Ammospiza maritima*	X	X	X	Estuarine Emergent Wetland	2	14
Nelson's Sparrow	*Ammospiza nelsoni*		X	X	Estuarine Emergent Wetland	1	12
Red-winged Blackbird[b]	*Agelaius phoeniceus*	X	X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	4	8
Boat-tailed Grackle[b]	*Quiscalus major*	X	X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	4	12
Great-tailed Grackle[b]	*Quiscalus mexicanus*	X	X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	1	4

[a]See Chapter 1 and Appendix 2 for full description of landcover associations.
[b]Species not included on the GoMAMN Birds of Conservation Concern list (see Appendix 1) but included here due to their ecological importance and/or ability to serve as an ecosystem indicator.

Marsh birds use a variety of mostly tidal wetland types across the Gulf Coast, including salt, brackish, intermediate, and fresh marsh (Table 4.1). Salt and brackish marsh (C-CAP Estuarine Emergent Wetland), typically dominated by *Spartina alterniflora* and *Juncus roemerianus* along the Gulf Coast, provide critical habitat for breeding Least Bitterns, Clapper Rails, Marsh Wrens, and Seaside Sparrows (Gabrey and Afton 2004, Rush et al 2009, Stouffer et al. 2013). The importance of salt and brackish marsh (C-CAP Estuarine Emergent Wetland) to Clapper Rails appears to be directly related with the distribution and abundance of fiddler crabs (*Uca* spp.), a critical food resource during the breeding season (Rush et al 2010a, 2010b). Black Rail along the Gulf Coast appear to have very specific habitat preferences; they are typically found along the interface between emergent marsh and upland habitats (C-CAP Estuarine Emergent Wetland and Grassland) in areas that experience infrequent inundation and are dominated by fine-stemmed vegetation such as *Spartina patens* and *S. spartinae* (Haverland 2019).

Some breeding marsh bird species, such as King Rail, Marsh Wren, and Boat-tailed Grackle occur in low numbers in salt marsh habitats (C-CAP Estuarine Emergent Wetlands), but are more common in lower salinity habitats including brackish and intermediate marsh (C-CAP Estuarine Emergent Wetlands and Palustrine Emergent Wetlands). In the case of King Rail, they use cultivated rice fields (C-CAP Cultivated Crops - Rice), with seasonal shifts from more intermediate areas to brackish marsh habitats (C-CAP Palustrine Emergent Wetland and Estuarine Emergent Wetland) during the nonbreeding season (Pickens and Meanley 2015). Other species depend almost exclusively on intermediate and freshwater marsh, including tidal freshwater habitats (C-CAP Palustrine Emergent Wetlands), for nesting (Table 4.1).

Spring and Autumn Migration Seasons

Migratory marsh birds are largely short- to mid-distance migrants that use fresh and salt marshes (C-CAP Palustrine Emergent Wetlands and Estuarine Emergent Wetlands) for stopover habitat during migration (Bent 1926). The GoM provides habitat for migratory marsh birds twice each year (roughly February-May and August-November).

There are seven migratory marsh birds of conservation concern: Least Bittern, American Bittern, King Rail, Yellow Rail, Black Rail, Marsh Wren, and Nelson's Sparrow. For each of these species, part of the population spends the winter along the Gulf Coast and the rest continue migrating and spend the winter farther south. Some Black and King Rails are year-round residents of the Gulf Coast (Butler et al. 2015), while others of both species cover a wide geographic area among their breeding ranges, from the Pacific to Atlantic coasts, and northward to the United States and Canada border (Kroodsma and Verner 2013, Lowther et al. 2009, Pickens and Meanley 2015, Poole et al. 2009, Shriver et al. 2011, Butler et al. 2016, Fournier et al. 2017a,d).

All migratory marsh bird species of conservation concern breed in freshwater or brackish wetlands, and use fresh and saltwater marshes for stopover during migration. Wetlands across the GoM region are diverse and encompass salt marsh to emergent estuarine fresh and brackish systems (C-CAP Estuarine Emergent Wetlands to Palustrine Emergent Wetlands) to heavily forested freshwater swamps (C-CAP Palustrine Forested Wetlands). Each wetland type serves a unique avian community while also serving many other important ecological purposes. These purposes include flood water control, cleaning water, protection from storm surge, as well as supporting the majority of commercially and recreationally important fisheries (Costanza et al. 2008, Engle 2011). For migratory species, the timing of available habitat is crucial, since habitat available at the wrong time of year is of limited benefit to a migratory species (Fournier et al. 2015, 2017b, 2017c, 2018).

How migratory marsh bird species move within and across the GoM is not well understood. Little is known about species-specific timing of their migrations, what populations migrate through the region versus stay along the coast in winter, the spatial extent and seasonality of their movements along the coast, and what proportion cross versus take an overland route around the GoM. Answers to these and other questions relating to marsh bird migration are critical for the development of a strategic comprehensive conservation plan.

Winter Season

In general, little attention has been focused on winter marsh birds in ongoing bird conservation efforts, including in the GoM Region. Yet of the 20 marsh bird species found using Gulf Coast habitats, 18 spend the winter in coastal wetland habitats across the region (Table 4.1). In a recent effort to promote effective monitoring of bird restoration activities, Woodrey (2017) recommended including monitoring focused on non-breeding marsh birds, since non-breeding marsh birds include some species not present in the breeding season and that may have habitat needs that are different from those of breeding birds. Some species, such as Pied-billed Grebe (*Podilymbus podiceps*), Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), and American Coot winter across a broad suite of habitat types across a broad geographic area (Muller and Storer 1999, Conway 1995, Melvin and Gibbs 2012, Brisbin and Mowbray 2002). Others, such as Least Bittern, Purple Gallinule (*Porphyrio martinicus*), Limpkin, and Nelson's Sparrow are more restricted in their habitat use and/or their distribution during the winter (Bryan 2002, Poole et al. 2009, West and Hess 2002, Shriver et al. 2011).

Found in the GoM region during winter, American Bitterns are typically associated with freshwater marshes (C-CAP Palustrine Emergent Wetlands) with their highest concentrations in the Everglades and along the Louisiana coast (Lowther et al. 2009). Yellow and Black Rails are also widespread during winter along the Gulf Coast (Eddleman et al. 1994) although Yellow Rails are not found in south Texas (Leston and Bookhout 2015). Recent work on winter Yellow Rails has shown selection for wet pine savanna habitats (C-CAP Evergreen Forest) and high marsh (C-CAP Estuarine Emergent Wetlands; Morris et al. 2017). However, GoM-wide, systematic searches for Yellow Rails are necessary to better understand their regional winter habitat selection. Habitat selection of Black Rails remains unknown although a growing interest in their status and conservation will likely reduce the uncertainty around suitable winter habitat (Watts 2016).

Marsh bird habitat use along the northern Gulf Coast is less varied during the winter season than the breeding season. Nearly all 18 marsh bird species found in the region during the winter can be observed across the salinity gradient of a typical estuary, from high salinity (30–35 ppt) or polyhaline areas to low salinity or oligohaline (0–5 ppt) areas. However, the abundance of a given species varies greatly across these marsh zones in winter. Clapper and King Rail, Marsh Wren, and Nelson's and Seaside Sparrow are most abundant in salt and brackish marsh habitats while many other species, including Pied-billed Grebe, American Bittern, Virginia Rail, Sora, Purple and Common Gallinule, American Coot and Limpkin, are most abundant in freshwater marshes (C-CAP Palustrine Emergent Wetlands, Gabrey et al. 1999, Gabrey and Afton 2000, Greenlaw and Wolfenden 2007). Other species, including Yellow and Black Rail and Sedge Wren, are not typically associated with emergent marsh habitats, instead they are most often observed in adjacent upland habitats (C-CAP Grasslands), including wet pine savanna (C-CAP Evergreen Forest).

CONSERVATION CHALLENGES AND INFORMATION NEEDS

Primary Threats and Conservation Challenges

Threats to coastal marshes and marsh birds are widespread and varied across the northern GoM region. Four of the five Gulf Coast states have experienced significant wetland loss over the last several decades (Table 4.2).

Marsh loss in the GoM Region is due to both anthropogenic and natural threats and stressors. Anthropogenic threats (Eddleman et al. 1988, Greenberg 2006, Greenberg et al 2006, Greenberg et al. 2014) include development, hydrologic modifications, grazing and agriculture, marsh burning, invasive species, contaminants, and sea-level rise.

Of these, coastal development is the primary concern, threatening the integrity of coastal marshes in the GoM and globally (Greenberg 2006, Greenberg et al. 2006, Battaglia et al. 2012, Greenberg et al 2014). Development of coastal areas continues to be driven by the influx of humans to coastal zones; in the GoM region the human population continues to grow at a rate more than double the national average, and wetlands are disappearing faster than anywhere else in the continental United States (Partnership for Gulf Coast Land Conservation 2014).

Hydrologic modifications such as ditching, channel dredging, tidal flow restriction, and water-level manipulations for waterfowl have been and continue to be a major factor influencing marsh systems, resulting in major changes in plant community associations, which in turn affect marsh bird communities (Eddleman et al. 1988, Greenberg 2006, Shriver and Greenberg 2012). Grazing and agriculture alter plant communities in some areas, such as Louisiana and Texas where row crop agriculture, rice, and grazing

Table 4.2. *Percent change of emergent wetland by state for the Gulf of Mexico region.*

State	Percent Change	Years	Citation
Florida	-45[a]	1956-1996	Handley, L., K. A. Spear, C. Thatcher, and S. Wilson. 2015a
Alabama	-54	1955-2002	Handley, L., K. A. Spear, C. Thatcher, and S. Wilson. 2015b
Mississippi	-55	1979-2007	Handley, L., K. A. Spear, C. Thatcher, and S. Wilson. 2015c
Louisiana	-33	1955-2007	Handley, L., K. A. Spear, C. Thatcher, and S. Wilson. 2015d
Texas	+11[b]	1956-2006	Handley, L., K. A. Spear, C. Thatcher, and S. Wilson. 2015e

[a]The percent change for Florida is the mean percent change of two coastal regions of the state.
[b]The percent change for Texas is the mean percent change of two coastal regions of the state.

Seaside Sparrow (*Ammospiza maritima*).
Photo credit: Michael Gray.

are common practices in coastal areas (Stutzenbaker and Weller 1989, Hobaugh et al. 1989). Likewise, marsh burning for waterfowl and furbearers, a relatively frequent practice across portions of the south Atlantic and Gulf Coast Regions and particularly common in coastal Louisiana and Texas, may alter the suitability of these habitats for marsh birds (Stutzenbaker and Weller 1989, Hobaugh et al. 1989, Nyman and Chabreck 1995, Mitchell et al. 2006). However, the broader impacts of more frequent marsh burning than would occur under a natural fire regime are only now being investigated in a rigorous manner (Mitchell et al 2006).

The high frequency of natural disturbance (e.g. tropical storms and hurricanes) make Gulf Coast landscapes highly susceptible to the effects of invasive plant species (Battaglia et al. 2012). Although not specifically evaluated in the GoM Region, negative impacts of invasive plant species on marsh bird communities and other estuarine vertebrates have been demonstrated in other regions of the U.S. (Benoit and Askins 1999, Guntenspergen and Nordby 2006). Direct impacts, including storm-related mortality, are poorly known for marsh birds although short-term population impacts have been documented in a few cases (Holliman 1981, Marsh and Wilkinson 1991). However, broad-scale, process-level studies are lacking but must be implemented to understand the regional variation of impacts to coastal marsh birds.

Sources of contamination in coastal marsh ecosystems include agricultural and urban runoff, application of pesticides, and oil and chemical spills. Polychlorinated biphenyls (PCBs) and metals appear to be most problematic contaminants for marsh birds due to chronic, long-term input, and exposure (Greenberg 2006, Novak et al. 2006). For example, Novak et al (2006) demonstrated that Clapper Rails serve as excellent indicators of PCB contamination in estuarine-marsh ecosystems. In addition to PCBs, mercury contamination may also be a threat in the region. Several areas around the GoM, including the Everglades, Tampa Bay, and Escambia Bay in Florida, Mobile Bay in Alabama, and Vermilion Bay in Louisiana, have been noted as mercury hotspots or suggested as areas to serve as long-term mercury monitoring and research sites (Schmeltz et al. 2011, Commission for Environmental Cooperation 2017). Shriver et al. (2006) and Winder and Emslie (2011) used Sharp-tailed and Nelson's Sparrows, respectively, and Fournier et al. (2016) used Clapper Rails to determine mercury levels in breeding and wintering individual's habitats. Oil spills, while episodic, can have detrimental effects on a variety of coastal wildlife, including marsh birds (Bergeon-Burns et al. 2014). Direct contact with polycyclic aromatic hydrocarbons occur during the initial phase following a spill produces often lethal effects on vertebrate organisms. Nonlethal oil effects typically accumulate over long periods of time given the persistence of many oil-based products. These long-term effects manifest themselves through physiological response and altered coastal food webs, resulting in significant fitness impacts on vertebrate species.

Sea-level rise is expected to have a significant impact on coastal ecosystems and species that occupy coastal emergent wetlands. A recent vulnerability assessment for the GoM region indicated that both natural communities and species are vulnerable to future threats from sea-level rise (Reece et al. 2018). Emergent marsh communities and avian species that depend on these habitats, such as Mottled Duck (*Anas fulvigula*) and Clapper Rail, have a compromised adaptive capacity due to habitat loss and degradation. Modeling studies, focused on marsh bird response to sea-level rise, do provide insight into potential species-level impacts. Rush et al. (2009) predicted species-specific response to sea-level rise: Clapper Rails and Seaside Sparrows, both salt marsh specialists, had a predicted positive response to future increases in sea level while freshwater specialists such as Least Bittern and Marsh Wren showed decreased occupancy rates. In the San Francisco Bay Area, Veloz et al. (2013) also found species-specific variation in response to various sea level rise scenarios. These studies, while informative, are limited in geographic scope but strongly suggest the need for more broad-scale studies to fully understand the implications of future sea-level rise. Conroy et al. (2010) provide an explicit framework for conservation decision-making, using the effects of climate change on coastal marsh birds to illustrate their framework. They provide a series of explicit climate-related hypotheses, predictions, and tests, which can be evaluated using local efforts/studies nested within a regional context to explore population-level impacts on marsh birds.

Outside of the threats noted above, one of the largest conservation issues facing marsh birds is a lack of understanding of their migratory ecology. Understanding migratory connectivity for marsh bird species, like other migratory organisms, is critical because of the consequences to the ecology, evolution, and conservation of their populations (Webster et al. 2002). Given the various migratory life history strategies demonstrated across GoM marsh bird species (Table 4.1), it is imperative that efforts be undertaken to reduce uncertainty around this critical period. We know little about the timing of arrival and departure of different species, the proportion of many of the migratory populations that simply stopover on the Gulf Coast versus those who spend the winter on the coast, and the geographic origins of populations migrating through or to the GoM region. In addition, for most species of marsh birds, migratory routes in the region are unknown, though some have been documented from oil platforms, suggesting at least some individuals cross, rather than circumnavigate, the open waters of the GoM (Russell 2005). Thus, studies that address any of these data gaps should be strongly considered in the near future.

IDENTIFICATION OF PRIORITIES

The conservation community seeks to use the best available information to manage and conserve bird populations and habitats in the face of uncertainty (Mace et al. 2000, Margules and Pressey 2000). To effectively understand the impacts of natural and anthropogenic disasters, such as hurricanes or the Deepwater Horizon Oil Spill, critical data gaps must be addressed (NASEM 2017). Based on experience with the Deepwater Horizon Natural Resources Damage Assessment, long-recognized gaps in avian monitoring data, and evaluation of population and habitat objectives in existing bird conservation plans, GoMAMN identified three broad monitoring priorities across the GoM region (Figure 2.2):

- Evaluating Management Actions (How are things we are doing impacting bird populations?)
- Determining Status and Trends (How are populations and habitats doing?)
- Understanding Ecological Processes (How are the larger ecosystem processes impacting birds?)

Using these priorities, the GoMAMN Marsh Bird Working Group identified specific subsets of priority monitoring activities, discussed below, to be addressed to reduce uncertainty associated with bird populations across the northern GoM region.

Priority Management Actions

Monitoring that answers questions about management and restoration actions is valued by GoMAMN because monitoring these actions will provide improved understanding of marsh bird response to a given management action, evaluate management and restoration success, and better inform future management and restoration decisions relative to marsh bird conservation. We prioritized monitoring management actions that have the highest impact (i.e., reduce uncertainty associated with specific action) on marsh bird populations. For example, we know little about the population level effects of emergent marsh restoration on breeding marsh birds. Specifically, how do marsh bird populations respond to the creation of emergent marsh islands versus marsh restoration adjacent to an existing emergent marsh complex? We are also interested in monitoring management actions which are currently practiced in the Gulf, because monitoring these actions will help inform current management practices.

We developed species-specific influence diagrams, which provide simple graphical representations of the ecological linkages between management actions and our response metric, population size, that potentially impact marsh birds (Conroy and Peterson 2013). There are several management actions including ecosystem restoration, freshwater management, integrated predator control, prescribed fire, stormwater management, sustainable agriculture, and disturbance reduction that are commmon across all species of marsh birds of conservation concern (Figure 4.1 and Appendix 4). We prioritized our management actions based on their uncertainty and effect size because improving our understanding (i.e., reducing uncertainty) is a core value of GoMAMN.

Wetland loss along the northern GoM has been well documented (Handley et al. 2015a, b, c, d, e). In addition, the restoration of emergent marsh habitats have been identified as a focus area in many post-Deepwater Horizon recovery documents (e.g., DWH Trustees 2016). However, marsh bird response to emergent marsh restoration efforts at the project scale or how populations respond at a regional scale is essentially unknown, particularly in the GoM (Woodrey 2017). Given the unprecedented scale at which marsh restoration will take place across the GoM in response to the Deepwater Horizon Oil Spill, the marsh bird working group identified the monitoring of marsh bird response to emergent marsh restoration as one of its highest priority management actions (Table 4.3). Response metrics associated with marsh restoration would be primarily aerial extent of marsh creat-

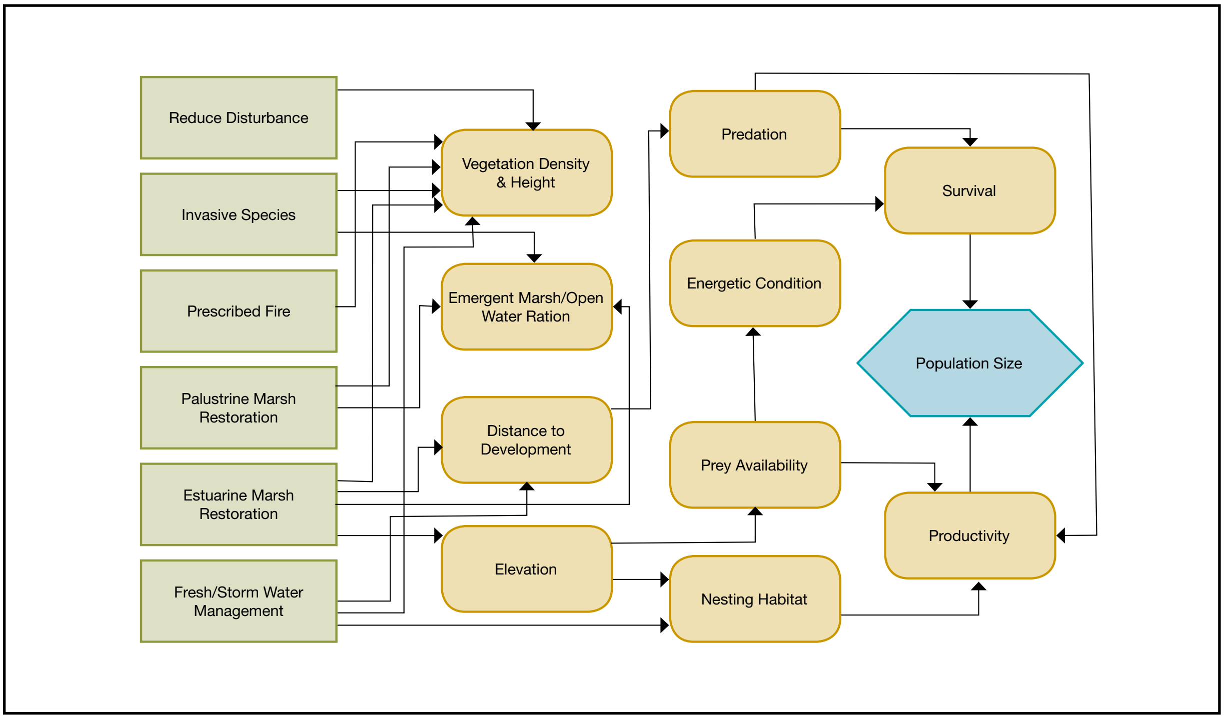

Figure 4.1. *Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the* ***Black Rail*** *(Laterallus jamaicensis) within the Gulf of Mexico Region.*

ed but should include marsh bird community assemblage and/or species-specific marsh bird abundance, depending on the project objective(s). Marsh restoration projects are typically of a smaller scale, limiting the opportunity for generating robust species abundance estimates. However, the use of community assemblages can allow for a robust evaluation of marsh creation projects. At the broader regional scale encompassing a collection of projects, species-specific abundance data can be used effectively to evaluate the cumulative effects of multiple restoration efforts across the region.

Freshwater management, defined as any management action that influences the amount of fresh water flowing into a system, including storm water, impacts marsh birds in several key ways. First, changing of salinity levels, via altered freshwater inflows, in a wetland system affects the plant communities and invertebrate prey available in that wetland. It can also change the sediment deposition rates in a wetland system, change the ratio of open to emergent marsh, and influence vegetation density and height. The major factors influencing marsh zonation patterns we see along the northern GoM, namely salinity and tidal regime, are well understood from a mechanistic perspective, yet little is known about how changes in salinity indirectly affect marsh bird populations via changes in plant community assemblages in coastal marshes. Given this relationship, priority should be given to reducing the uncertainty associated with vegetation assemblages and marsh bird populations where both plant assemblage and marsh bird abundance are monitored.

A more substantial uncertainty exists concerning the process of how salinity changes prey species abundance and diversity of marsh bird foods such as fiddler crabs (*Uca*. spp.), insects, benthic invertebrates, and plant seeds. Further, there is also uncertainty around the dietary plasticity of marsh birds as freshwater inputs influence salinity changes which in turn impact prey. Diet studies, such as those for Clapper Rail (Rush et al. 2010a), as well as ecological studies relating prey abundance and distribution to rail movements and nesting habits (Rush et al 2010b, c), are critical to reducing uncertainty. To better understand this relationship, studies should be rigorously designed to determine crab abundance across existing salinity gradients. In addition to fiddler crabs, the same approach and metrics would apply to reducing uncertainty surrounding the impacts of salinity for tidal marsh insects, benthic invertebrates, and seed abundances.

Table 4.3. *Uncertainties underpinning the relationship between management decisions and populations of marsh birds in the northern Gulf of Mexico.*

Species Season(s)	Management Category[a]	Question	End-point to measure mgmt. performance	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Marsh Birds All	Habitat and Natural Process Restoration (Habitat Restoration)	How does emergent marsh restoration influence marsh bird community assemblages and species-specific abundances?	aerial extent of emergent marsh created; marsh bird community assemblage; marsh bird abundance	marsh bird community assemblage and species-specfic abundance response to emergent marsh restoration	High	High
Marsh Birds All	Habitat and Natural Process Restoration (Freshwater Management)	How do changes in salinity influence prey communities (e.g.,fiddler crabs, insects)?	fiddler crab, insect abundance	relationship between salinity and prey abundance (e.g., fiddler crabs, insect abundance)	High	High
Marsh Birds All	Invasive/ Problematic Species Control (Predator Management)	Is nest predation a significant source of low productivity?	nest predation rates	geographic variability highly uncertain; predator identity uncertain	High	Unknown
Yellow Rail Winter	Habitat and Natural Process Restoration (Freshwater Management)	How do hydrological changes to pine savanna change habitat suitability for wintering Yellow Rails?	soil moisture, surface water depth	uncertainty around seasonal/ annual changes in wet pine savanna hydrology in relation to Yellow Rail utilization	High	Unknown
Black and Yellow Rail All	Habitat and Natural Process Restoration (Freshwater Management)	How do changes in the timing and extent of freshwater inputs change the plant community/structure?	plant community assemblage	extent of plant community assemblage change based on altered freshwater inflow and resulting changes in Black and Yellow Rail populations	High	Unknown
Marsh Birds All	Habitat and Natural Process Restoration (Habitat Management-Prescribed Fire)	What are the long-term benefits of maintaining a marsh plant community assemblage with prescribed fire?	plant commuity assemblage response; plant species-specific stem densities; percent dead herbaceous material	whether changes in a marsh plant community due to prescribed fire will benefit marsh birds	High	Unknown
Marsh Birds All	Site/Area Management (Freshwater Management)	Does storm water runoff negatively impact survivorship and productivity of marsh birds?	percent impervious surface; percent human development at landscape scale	relationship between stormwater runoff and marsh birds	Low	Unknown
Yellow Rail Winter	Habitat and Natural Process Restoration (Habitat Management-Agriculture)	Does cultivated rice agriculture provide suitable stopover and possibly wintering habitat for Yellow Rails?	aerial extent of second crop (i.e., ratoon crop) of cultivated rice; Yellow Rail abundance	very high uncertainity associated with Yellow Rail abundance estimates and patterns of use in cultivated rice impoundments	High	Unknown
Yellow Rail Winter	Habitat and Natural Process Restoration (Habitat Management-Prescribed Fire)	What is the relationship between prescribed fire (for management/restoration of wet pine savanna habitat) and Yellow Rail abundance?	plant community assemblage, including structure; Yellow Rail abundance	uncertainity exists regarding the population repsonse of Yellow Rails to prescribed fire across the Gulf of Mexico region.	High	Unknown

Table 4.3 (continued).

Species Season(s)	Management Category[a]	Question	End-point to measure mgmt. performance	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Black Rail All	Habitat and Natural Process Restoration (Habitat Management-Prescribed Fire)	What is the relationship between high marsh management management (i.e., prescribed fire) and Black Rail abundance	plant community assemblage, including structure; Black Rail abundance	whether changes in high marsh plant community (i.e., species composition and structure) due to prescribed fire will affect Black Rail abundance	High	Unknown
King Rail All	Habitat and Natural Process Restoration (Habitat Management-Agriculture)	Does cultivated rice agriculture provide suitable habitat for breeding, migrating, and wintering habitat for King Rails?	aerial extent of cultivated rice agriculture; King Rail abundance	high level of uncertainity surrounding King Rail abundance estimates and patterns of use in cultivated rice impoundment lanscapes.	High	Unknown
Marsh Birds All	Site/Area Management (Freshwater Management)	How do changes in salinity influence plant communities?	salinity regime, plant community assemblage	relationship betweeen salinity and marsh plant species	Low	High
Marsh Birds All	Invasive/ Problematic Species Control (Predator Management)	Is direct predation (raccoons, harriers, etc.) a significant source of mortality for adults and subadults?	abundance of marsh bird predators (e.g., racoons, Northern Harriers)	sources of mortality are unknown; precise estimates of mortality are unknown	High	Low
Marsh Birds All	Invasive/ Problematic Species Control (Habitat Management-Invasive Plants)	What is the impact of invasive plant species on marsh bird comuunity assemblages, species-specific abundance, and demography?	aerial extent of invasive plant species (e.g., Phragmites spp., Cogon grass, etc.); marsh bird community assemblage; marsh bird deomography	marsh bird community assemblages and species-specific abundance and demography responses to various levels of invasive plant species	High	Low

[a]Categories follow the classification scheme and nomenclature presented by Salafsky et al. (2008) and Conservation Measures Partnership (2016).
[b]Based on expert opinion using two levels of classification (high level of uncertainty or low level of uncertainty) based on anecdotal observations and published literature.
[c]Based on expert opinion using three levels of classification (high, low, and unknown) per the potential positive or negative impact on a population. Where high represents the likelihood of a major impact; low represents a minor impact; and unknown represents unknown consequences.
[d]To facilitate decision making, we utilized a scoring rubric that contrasted the degree of uncertainty against the presumed population effect size, where High-High=1 (highest priority); High-Unknown=2; Low-Unknown=2; Low-High=3; High-Low=4; and Low-Low=5 (lowest priority). Here, we only present questions that scored a 1, 2, or 3.

The effective management of wet pine savanna and high marsh habitats (defined as *Spartina patens* and *S. spartinae*-dominated transition zones at the ecotone of tidal marsh and pine forests) where Yellow and Black Rails have recently been found is virtually unknown, although the use of prescribed fire is beginning to be understood for the north-central regions of the Gulf (Morris et al. 2017, Soehren et al. 2018). Given the restricted geographic limits of these studies, a critical need for wintering marsh birds are survey and monitoring efforts focused on Yellow and Black Rails across the Gulf region. In addition to prescribed fire, freshwater inflows and hydrologic regime are two factors also thought to influence plant communities for these high marsh and pine savanna habitats, but these relationships are, for the most part, undescribed and understudied Thus, the GoMAMN marsh bird working group has prioritized monitoring efforts focused on tracking plant community assemblage and species-specific stem density in responses in these critical habitats to changes in freshwater hydrology for these two high priority species (Figure 4.1 and Appendix 4).

In the GoM region, nest predation appears to be the significant source of nest loss and resulting reduced productivity (Rush et al. 2010c; Lehmicke 2014). Although the specific species of predators are not known, it is hypothesized that mammalian predators are primarily responsible for the majority of nest loss in GoM tidal marsh systems. However, our certainty associated with this hypothesis is limited, due to the lack of nest monitoring data for breeding marsh birds. Thus, the marsh bird working group prioritized collecting nest predation rates across the Gulf region as part of local and regional projects. Further, monitoring marsh bird nest predation rates in areas where an integrated predator program is used for beach nesting birds would provide information regarding potential indirect benefits to birds nesting in the marsh near these beach habitats, an additional unknown which should be addressed across the Gulf region.

While the effects of prescribed fire are well studied in many upland systems, uncertainty remains around prescribed fire impacts on tidal marsh vegetation diversity and structure, wetland invertebrates, and the birds which depend on them, particularly in the unimpounded, natural marshes found along the Gulf coast. The most common questions members of the marsh bird working group hear from land managers revolve around the fire return interval for tidal marsh management. Unfortunately, there are little empirical data or published studies to provide guidance for the management community. Further, little is known regarding how changes in climate might impact land managers' ability to burn in the future. A focus on quantifying plant community response, including plant species assemblage, species composition, and species-specific stem densities, to prescribed fire is a significant priority for marsh bird monitoring. A focused evaluation of the long-term benefits of maintaining marsh plant communities via fire are critical to reducing uncertainty around marsh bird response to marsh management, and monitoring efforts should be undertaken to better understand regional differences in fire effects across the GoM region.

Many coastal wetlands, especially in Texas and Louisiana, have been converted into impounded wetland agricultural fields, often growing crops such as rice. Many rail species in North America are known to use these rice fields, along with several other species of marsh birds, though what kinds of rice agriculture are best for providing food, shelter, and wintering and/or breeding habitat is not well known (Eadie et al. 2008, Acosta et al. 2010).

For some species of birds, disturbance, especially during the breeding season, can have a large impact on the ability of birds to successfully fledge offspring. Disturbance during migration/winter can also cause birds to expend their limited energy reserves, as has been studied in several waterfowl species. Whether disturbance by humans impact the ability of marsh birds to successfully nest, or puts extra stress on their ability to survive during migration is unknown. Given winter ecology of marsh birds is not well known, little is known about the relative impacts that different types of disturbance might have. For example, what is the relative impact of a human near a nest, impacts of boat wake, or a person fishing several meters away in a boat?

Priority Status and Trends Assessments

Our highest priority is given to species with declining population trends and/or great uncertainty about their trend over long time spans and a broad geography (Figure 2.2, Table 4.1). We have included the population status of each of our marsh birds of conservation concern, as well as other marsh bird species considered potential monitoring targets (Table 4.1). These trends are from the Partners in Flight (2017) Species Assessment. For species which do not breed in the GoM and for which we do not know the relative proportion of the population wintering in the GoM (e.g., Yellow Rail), population level status and trends assessment in the GoM may not be appropriate. In those cases, trends of just the GoM wintering population may be useful. Population level status and trends assessment for a resident species such as Seaside Sparrow, are appropriate and should be given serious consideration.

Due to the lack of region-wide population estimatees and trend data for marsh birds, we value information related to the status and trends of our bird species of conservation concern that address both population-level and habitat (quantity and quality) over long time periods that span the entirety of the northern GoM. Because of their secretive nature, inaccessibility of their habitats, and relative paucity of information about them, we know very little about the status and trends of any of these marsh bird species of conservation concern. This information is vital for assessing/documenting changes in populations and their habitats, as well as to provide data to facilitate understanding of large-scale ecological processes such as sea-level rise and their impacts to birds and their habitats.

The highest monitoring priority is population-level trends over time, at a region-wide scale for breeding marsh bird species, collected in such a way as to inform the wider population trends for species that migrate to and through the GoM. Presently, there are no long-term avian monitoring programs in place and no restoration projects that collect marsh bird data across multiple states or over meaningful time scales. However, a robust marsh bird sampling framework is available (Johnson et al. 2009) and this sampling frame allows for the incorporation of historic data, thus taking advantage of the limited monitoring efforts to date.

Table 4.1 provides habitat associations for marsh bird species considered in this monitoring plan. Habitats are prioritized in the same order as the priority species, because status

Black Rail (*Laterallus jamaicensis*). Photo credit: Michael Gray.

and trends assessment is a two-pronged approach whereby we evaluated the status and trends of marsh birds of conservation concern and the habitats they use along the GoM. The long-term trends of marsh birds are best assessed by implementing a Gulf-wide monitoring program designed to estimate abundance using established point count monitoring protocol (Conway 2011) and sampling design (Johnson et al. 2009).

Priority Ecological Processes

Marshes and marsh birds are subject to a variety of ecological processes including, but not limited to hurricanes and other extreme weather events, changes in salinity, and predation (Day et al. 2013). By understanding these underlying processes, the bird conservation community of practice will be better prepared to understand marsh bird population changes, including the impacts of forces that can and cannot be managed. While there are many uncertainties about how marsh birds will be impacted by restoration techniques in wetland ecosystems, there are additional key uncertainties about related ecological processes (NASEM 2017).

The impacts on marsh birds of changing precipitation patterns, hydrological and fire regimes due to climate change and hurricane intensity and frequency are uncertain (Woodrey et al. 2012). Given these and other uncertainties identified by the GoMAMN Marsh Bird Working Group, the ecological process questions detailed in Table 4.4 were determined to be of the highest priority for better understanding marsh bird populations in the GoM.

The fragmentation of wetlands by human development has likely had impacts on the movement of organisms across the landscape, and even in some cases possibly at a local level. How this development impacts movement and other aspects of individual survival is not well known, and uncertainty about effects of different types of development on marsh bird ecology still exists.

There are several key areas of uncertainty around how hurricanes (and other named tropical storms) impact marsh birds (Table 4.4). First is the uncertainty around the short- and long-term effects on marsh bird communities, as well as the timing of the storms in relation to the breeding season. Storm surge, extensive rainfall and wind could all have detrimental impacts on individual marsh birds, their nests, and young, though how well individuals or their young are able to anticipate and respond to these impacts is not known. Long-term impacts of hurricanes could affect marsh birds through changes in the vegetation community from storm surge or other landform changes. This uncertainty is whether those changes to habitat impact marsh birds, and if they do, for how long a time period.

Marsh restoration is assumed to provide habitat for marsh birds, yet, we have little data to support this supposition (NASEM 2017). While there are many uncertainties about how marsh birds will be impacted by restoration techniques in wetland ecosystems there are additional key uncertainties about related ecological processes (NASEM 2017). For example, how do birds colonize these areas, and how is colonization affected by succession? Understanding individual bird movements would also allow us to assess the effects of human development and how it influences occupancy, as well as assessing the effects of fire on occupancy. In addition to assessing occupancy, telemetry data would be important because it allows for the study of movement and home range.

SUMMARY & MONITORING RECOMMENDATIONS

We see three main priorities for monitoring of marsh birds in the GoM:

★ Coordinated GoM-wide marsh bird monitoring is sorely needed. A robust framework exists for collecting data that can answer local and region wide questions and is already being successfully implemented in the north eastern US through the SHARP (Saltmarsh Habitat and Avian Research Program, tidalmarshbirds.org). The same sampling framework, and similar monitoring protocols should be implemented across all five northern GoM

Table 4.4. *Uncertainties related to how ecological processes impact populations of marsh birds in the northern Gulf of Mexico.*

Species Season(s)	Ecological Process Category[a]	Question	End point to measure	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Marsh birds All	Movement of Organisms	Does human development adjacent to wetlands influence the occupancy of marsh birds?	occupancy; species-specfic marsh bird abundance	whether human development of any kind has an impact; do certain kinds of development have more impact than others	High	High
Marsh birds All	Natural Disturbance Regimes	Do hurricanes impact marsh bird abundance in the short- or long-term?	species-specfic marsh bird abundance	uncertainty about birds ability to move and avoid negative impacts; how hurricanes impact habitat quality and marsh bird survival	High	Unknown
Marsh birds All	Natural Disturbance Regimes	Are there differential impacts of hurricanes on adult versus juvenile annual survivorship?	adult and juvenile annual survivorship estimates	uncertainty about adult vs juvenile ability to avoid natural disturbances	High	Unknown

[a]Categories follow the classification scheme and nomenclature presented by Bennett et al. (2009).
[b]Based on expert opinion using two levels of classification (high level of uncertainty or low level of uncertainty) based on anecdotal observations and published literature.
[c]Based on expert opinion using three levels of classification (high, low, and unknown) per the potential positive or negative impact on a population. Where high represents the likelihood of a major impact; low represents a minor impact; and unknown represents unknown consequences.
[d]To facilitate decision making, we utilized a scoring rubric that contrasted the degree of uncertainty against the presumed population effect size, where High-High=1 (highest priority); High-Unknown=2; Low-Unknown=2; Low-High=3; High-Low=4; and Low-Low=5 (lowest priority). Here, we only present questions that scored a 1, 2, or 3.

states, to allow us to estimate population size and trend, as well as address uncertainties associated with management actions and the impacts of ecological processes.

★ Monitoring of marsh bird response to various estuarine wetland restoration techniques is greatly needed, both to evaluate ongoing restoration work, and to inform future restoration efforts. Monitoring should seek to understand the impact of different restoration techniques, as well as the amount of time it takes marsh birds, and the vegetation/food resources they rely on, to respond to different techniques. In addition, the monitoring of the effects of prescribed fire in estuarine wetlands could have wide ranging implications for marsh birds, especially black rail, as well as other birds which use coastal wetlands such as waterfowl. Monitoring should seek to understand the effects of prescribed fire in different seasons, and with different intensities on the marsh bird community and the vegetation/food it relies on.

★ Sea-level rise is the ecological process we are most certain will influence marsh bird populations in the coming decades, though how it will impact all species is not well known. Additional work is needed to better predict how marshes will respond and/or move as sea levels rise, and what role extreme weather events such as hurricanes play in the short- and long-term survival of marsh bird species, especially earlier season tropical storms which could affect breeding birds.

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LITERATURE CITED

Acosta, M., L. Mugica, D. Blanco, B. López-Lanús, R. A. Dias, L. W. Doodnath, J. Hurtado. 2010. Birds of rice fields in the Americas. Waterbird 33 (Special Publication 1):105-122.

Bannor, B. K., E. Kiviat. 2002. Common Gallinule (*Gallinula galeata*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology. Retrieved from https://birdsna.org/Species-Account/bna/species/comgal1/

Battaglia, L. L., M. S. Woodrey. M. S. Peterson, K. S. Dillon, J. M. Visser. 2012. Wetlands of the Northern Gulf Coast. Pages 75-88 in D. Batzer and A. Baldwin (Eds.), Wetland Habitats of North America: Ecology and Conservation Concerns. University of California Press, Berkeley, CA, USA.

Bennett, A. F., A. Haslem, D. C. Cheal, M. F. Clarke, R. N. Jones, J. D. Koehn, P. S. Lake, L. F. Lumsden, I. D. Lunt, B. G. Mackey, R. M. Nally, P. W. Menkhorst, T. R. New, G. R. Newell, T. O'Hara, G. P. Quinn, J. Q. Radford, D. Robinson, J. E. M. Watson, A. L. Yen. 2009. Ecological processes: A key element in strategies for nature conservation.Ecological Management & Restoration 10(3):192-199.

Benoit, K.L., R.A. Askins. 1999. Impact of the spread of *Phragmites* on the distribution of birds in Connecticut tidal marshes. Wetlands 19:194-208.

Bent, A.C. 1926. Life histories of North American marsh birds. Smithsonian Institution United States National Museum Bulletin 135. United States Government Printing Office, Washington, D.C., USA.

Bergeon-Burns, C. M., J. A. Olin, S. Woltmann, P. C. Stouffer, S. S. Taylor. 2014 . Effects of oil on terrestrial vertebrates: Predicting impacts of the Macondo blowout. Bioscience 64:820-828.

Brisbin Jr., I. L., T. B. Mowbray. 2002. American Coot (*Fulica americana*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology. Retrieved from https://birdsna.org/Species-Account/bna/species/y00475/

Bryan, D. C. 2002. Limpkin (*Aramus guarauna*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology. Retrieved from https://birdsna.org/Species-Account/bna/species/limpki/

Butler, C. J., J. B. Tibbits, J. K. Wilson. 2015. Assessing Black Rail occupancy and vocalizations along the Texas Gulf Coast. Unpublished report to Texas Parks and Wildlife Department, Austin, TX, USA. Retrieved from https://tpwd.texas.gov/huntwild/wild/wildlife_diversit/nongame/grants-research/media/2015-black-raid.pdf

Butler, C. J., J. K. Wilson, S. R. Frazee, J. F. Kelly. 2016. A comparison of the origins of Yellow Rails (*Coturnicops noveboracensis*) wintering in Oklahoma and Texas, USA. Waterbirds. 39:156-164.

Case, D. J., D. D. McCool (Compilers/Eds.). 2009. Priority information needs for rails and snipe: A funding strategy. Report developed by the Association of Fish and Wildlife Agencies' Migratory Shore and Upland Game Bird Task Force. Retrieved from https://www.fws.gov/migratorybirds/pdf/surveys-and-data/Info-Needs-Rails-Snipe.pdf

Commission for Environmental Cooperation (for North America). 2017. Mercury hot spots of North America (Map). Retrieved from http://www3.cec.org/islandora/en/item/1935-mercury-hot-spots-north-america-en.pdf.

Conroy, M. J., R. J. Cooper, S. A. Rush, K. W. Stodola, B. L. Nuse, M. S. Woodrey. 2010. Effective use of data from marshbird monitoring programs for conservation decision-making. Waterbirds. 33:397-404.

Conroy, M. J., J. T. Peterson. 2013. Decision Making in Natural Resource Management: A Structured, Adaptive Approach. John Wiley & Sons Ltd., Hoboken, NJ, USA.

Conservation Measures Partnership. 2016. Classification of Conservation Actions and Threats, Version 2.0. Retrieved from http://cmp-openstandards.org/tools/threats-and-actions-taxonomies/.

Conway, C. J. 1995. Virginia Rail (*Rallus limicola*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology. Retrieved from https://birdsna.org/Species-Account/bna/species/virrai/

Conway, C. J. 2011. Standardized North American marsh bird monitoring protocol. Waterbirds. 34:319-346.

Costanza R., O. Pérez-Maqueo, M. L. Martinez. 2008. The value of coastal wetlands for hurricane protection. AMBIO: A Journal of the Human Environment 37:241-248.

Day Jr., J. W., B. C. Crump, W. M. Kemp, A. Yáñez-Arancibia. 2013. Estuarine Ecology. John Wiley & Sons Ltd., Hoboken, NJ, USA.

Deepwater Horizon Natural Resource Damage Assessment Trustees (DHNRDAT). 2016. Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement. Retrieved from http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan.

Eadie, J. M., C. S. Elphick, K. J. Reinecke, M. R. Miller. 2008. Wildlife values of North American ricefields. In S. W. Manley (Ed.), Conservation of Ricelands in North America. The Rice Foundation, Stuttgart, AR, USA.

Eddleman, W. R., F. L. Knopf, B. Meanley, F. A. Reid, R. Zembal. 1988. Conservation of North American rallids. Wilson Bulletin 100:458-475.

Eddleman, W. R., R. E. Flores, M. Legare. 1994. Black Rail (*Laterallus jamaicensis*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology. Retrieved from https://birdsna.org/Species-Account/bna/species/blkrai/

Engle, V. D. 2011. Estimating the provision of ecosystem services by Gulf of Mexico coastal wetlands. Wetlands 31:179-193.

Fournier A. M. V., D. C. Mengel, D. G. Krementz. 2018 Sora (*Porzana carolina*) autumn migration habitat use. Royal Society Open Science 5:171664.

Fournier, A. M. V., K. L. Drake, D. C. Tozer. 2017a. Using citizen science monitoring data in species distribution models to inform isotopic assignment of migratory connectivity in wetland birds. Journal of Avian Biology 48:1556-1562.

Fournier, A. M. V., D. C. Mengel, D. G. Krementz. 2017b. Virginia and Yellow Rail autumn migration ecology: Synthesis using multiple data sets. Animal Migration 4:15-22.

Fournier, A. M. V., D. C. Mengel, E. E. Gbur, D. G. Krementz. 2017c. The timing of Autumn Sora (*Porzana carolina*) migration in Missouri. Wilson Journal of Ornithology 129:675-770.

Fournier, A. M. V., A. R. Sullivan, J. K. Bump, M. Perkins, M. C. Shieldcastle, S. L. King. 2017d. Combining citizen science species distribution models and stable isotopes reveals migratory connectivity in the secretive Virginia rail. Journal of Applied Ecology 54:618-627.

Fournier, A. M. V., K. J. Welsh, M. Polito, S. D. Emslie, R. Brasso. 2016. Levels of mercury in feathers of Clapper Rails (*Rallus crepitans*) over 45 Years in coastal salt marshes of New Hanover County, North Carolina. Bulletin of Environmental Contamination and Toxicology 97:469-473.

Fournier, A. M. V., M. C. Shieldcastle, T. Kashmer, K. A. Mylecraine. 2015. Comparison of arrival dates of rail migration in the Southwest Lake Erie Marshes, Ohio, USA. Waterbirds 38:312-314.

Gabrey, S. W., A. D. Afton, B. C. Wilson. 1999. Effects of winter burning and structural marsh management on vegetation and winter bird abundance in the Gulf Coast Chenier Plain, USA. Wetlands 19:594-606.

Gabrey, S. W., A. D. Afton. 2000. Effects of winter marsh burning on abundance and nesting activity of Louisiana Seaside Sparrows in the Gulf Coast Chenier Plain. Wilson Bulletin 112:365-372.

Gabrey, S. W., A. D. Afton. 2004. Composition of breeding bird communities in Gulf Coast Chenier Plain marshes: Effects of winter burning. Southeastern Naturalist 3:173-185.

Greenberg, R. 2006. Tidal marshes: Home for the few and the highly selected. In R. Greenberg, J. E. Maldonado, S. Droege, and M. V. MacDonald (Eds.), Terrestrial Vertebrates of Tidal Marshes: Evolution, Ecology, and Conservation. Studies in Avian Biology 32:2-9.

Greenberg, R., A. Cardoni, B. J. Ens, X. Gan, J. P. Isacch, K. Koffijberg, R. Loyn. 2014. The distribution and conservation of birds of coastal salt marshes. Pages 180-242 in B. Maslo, J. L. Lockwood (Eds.), Coastal Conservation. Cambridge University Press, New York, NY, USA.

Greenberg, R., J. Maldonado. 2006. Diversity and endemism in tidal-marsh vertebrates. In R. Greenberg, J. E. Maldonado, S. Droege, and M. V. McDonald (Eds.), Terrestrial Vertebrates of Tidal Marshes: Evolution, Ecology, and Conservation. Studies in Avian Biology 32:32-53.

Greenberg, R., J. E. Maldonado, S. Droege, M. V. McDonald. 2006. Tidal marshes: A global perspective on the evolution and conservation of their terrestrial vertebrates. Bioscience 58:675-685.

Greenlaw, J. S., G. E. Woolfenden. 2007. Wintering distributions and migration of Saltmarsh and Nelson's sharp-tailed sparrows. Wilson Journal of Ornithology 119:361-377.

Guntenspergen, G. R., J. C. Nordby. 2006. The impact of invasive plants on tidal-marsh vertebrate species: Common Reed (*Phragmites australis*) and smooth cordgrass (*Spartina alterniflora*) as case studies. In R. Greenberg, J. E. Maldonado, S. Droege, and M. V. McDonald (Eds.), Terrestrial Vertebrates of Tidal Marshes: Evolution, Ecology, and Conservation. Studies in Avian Biology 32:229-237.

Handley, L., K. A. Spear, C. Thatcher, S. Wilson. 2015a. Statewide summary for Florida (Chapter L). In Emergent Wetlands Status and Trends in the Northern Gulf of Mexico, 1950-2010: USGS Scientific Investigations Report. Wetland and Aquatic Research Center, Lafayette, LA, USA. Retrieved from https://www.usgs.gov/atom/86027.

Handley, L., K. A. Spear, C. Thatcher, S. Wilson. 2015b. Statewide summary for Alabama (Chapter J). In Emergent Wetlands Status and Trends in the Northern Gulf of Mexico, 1950-2010: USGS Scientific Investigations Report. Wetland and Aquatic Research Center, Lafayette, LA, USA. Retrieved from https://www.usgs.gov/atom/86026.

Handley, L., K. A. Spear, C. Thatcher, S. Wilson. 2015c. Statewide summary for Mississippi (Chapter H). In Emergent Wetlands Status and Trends in the Northern Gulf of Mexico, 1950-2010: USGS Scientific Investigations Report. Wetland and Aquatic Research Center, Lafayette, LA, USA. Retrieved from https://www.usgs.gov/atom/86025.

Handley, L., K. A. Spear, C. Thatcher, S. Wilson. 2015d. Statewide summary for Louisiana (Chapter E). In Emergent Wetlands Status and Trends in the Northern Gulf of Mexico, 1950-2010: USGS Scientific Investigations Report. Wetland and Aquatic Research Center, Lafayette, LA, USA. Retrieved from https://www.usgs.gov/atom/86024.

Handley, L., K. A. Spear, C. Thatcher, S. Wilson. 2015e. Statewide summary for Texas (Chapter B). In Emergent Wetlands Status and Trends in the Northern Gulf of Mexico, 1950-2010: USGS Scientific Investigations Report. Wetland and Aquatic Research Center, Lafayette, LA, USA. Retrieved from https://www.usgs.gov/atom/86023.

Haverland, A. A. 2019. Determining the status ad distribution of the eastern Black Rail (*Laterallus jamaicensis*) in coastal Texas. Ph.D. dissertation. Texas State University, San Marcos, TX, USA.

Herkert, J. R., D. E. Kroodsma, J. P. Gibbs. 2001. Sedge Wren (*Cistothorus platensis*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology. Retrieved from https://birdsna.org/Species-Account/bna/species/sedwre/

Hobaugh, W. C., C. D. Stutzenbaker, E. L. Flickinger. 1989. The rice prairies. Pages 367-383 in L. M. Smith, R. L. Pederson and R. M. Kaminski (Eds.), Habitat Management for Migrating and Wintering Waterfowl in North America. Texas Tech University Press, Lubbock, TX, USA.

Holliman, D. C. 1981. A survey of the September 1979 hurricane damage to Alabama Clapper Rail habitat. Northeast Gulf Science 5:95-98.

Johnson, K. , B. D. Peer. 2001. Great-tailed Grackle (*Quiscalus mexicanus*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology. Retrieved from https://birdsna.org/Species-Account/bna/species/grtgra/.

Johnson, D. H., J. P. Gibbs, M. Herzog, S. Lor, N. D. Niemuth, C. A. Ribic, M. Seamans, T. L. Shaffer, W. G. Shriver, S. V. Stehman, W. L. Thompson. 2009. A sampling design framework for monitoring secretive marshbirds. Waterbirds 32:203-215.

Johnson, E. I., J. Lehman. 2019 Spatial and temporal distribution of Black Rail (*Laterallus jamaicensis*) in coastal Louisiana. Unpublished Report to U. S. Fish and Wildlife Service Region 4, Migratory Bird Program, Atlanta, GA, USA.

Kroodsma, D. E., J. Verner. 2013. Marsh Wren (*Cistothorus palustris*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology. Retrieved from https://birdsna.org/Species-Account/bna/species/marwre/.

Lehmicke, A. A. J. 2014. Breeding ecology of the Seaside Sparrow (*Ammodramus maritimus*) in northern Gulf of Mexico tidal salt marshes. Ph.D. dissertation, University of Georgia, Athens, GA, USA.

Leston, L. and T. A. Bookhout. 2015. Yellow Rail (*Coturnicops noveboracensis*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/yelrai/.

Lowther, P. E., A.F . Poole, J. P. Gibbs, S. M. Melvin, F. A. Reid. 2009. American Bittern (*Botaurus lentiginosus*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/amebit/.

Mace, G. M., A. Balmford, L. Boitani, G. Cowlishaw, A. P. Dobson, D. P. Faith, K. J. Gaston, C. J. Humphries, R. I. Vane-Wright, P. H. Williams, J. H. Lawton, C. R. Margules, R. M. May, A. O. Nicholls, H. P. Possingham, C. Rahbek, A. S. van Jaarsveld. 2000. It's time to work together and stop duplicating conservation efforts. Nature 405:393.

Marsh, C. P., P. M. Wilkinson. 1991. The impact of hurricane Hugo on coastal bird populations. Journal of Coastal Research Special issue 8:327-334.

Margules, C. R., R. L. Pressey. 2000. Systematic conservation planning. Nature 405:243-253.

Melvin, S. M., J.P . Gibbs. 2012. Sora (*Porzana carolina*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/sora/

Mitchell, L. R., S. Gabrey, P. P. Marra, R. M. Erwin. 2006. Impacts of marsh management on coastal-marsh bird habitats. Pages 155-175 in R. Greenberg, J. E. Maldonado, S. Droege, and M. V. McDonald (Eds.), Terrestrial Vertebrates of Tidal Marshes: Evolution, Ecology, and Conservation. Studies in Avian Biology 32:155-175.

Morris, K. M., M. S. Woodrey, S. G. Hereford, E. C. Soehren, T. J. Conkling, S. A. Rush. 2017. Yellow Rail (*Coturnicops noveboracensis*) occupancy in the context of fire in Mississippi and Alabama, USA. Waterbirds 40:95-104.

Muller, M. J., R. W. Storer. 1999. Pied-billed Grebe (*Podilymbus podiceps*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/pibgre/.

(The) National Academies of Sciences, Engineering, and Medicine (NASEM). 2017. Effective monitoring to evaluate ecological restoration in the Gulf of Mexico. The National Academies Press, Washington, DC, USA.

Novak, J. M., K. F. Gaines, J. C. Cumbee Jr, G. L. Mills, A. Rodriguez-Navarro, C. S. Romanek. 2006. Clapper rails as indicator species of estuarine marsh health. In R. Greenberg, J. E. Maldonado, S. Droege, and M. V. McDonald (Eds.), Terrestrial Vertebrates of Tidal Marshes: Ecology, Evolution, and Conservation. Studies in Avian Biology 32:320-281.

Nyman, J. A., R. H. Chabreck. 1995. Fire in coastal marshes: History and recent concerns. Proceedings of the Annual Tall Timbers Fire Ecology Conference 19:134-141.

Partners in Flight. 2017. Avian Conservation Assessment Database, version 2017. Retrieved from http://pif.birdconservancy.org/ACAD.

Partnership for Gulf Coast Land Conservation. 2014. A land conservation vision for the Gulf of Mexico Region: An overview. Partnership for Gulf Coast Land Conservation, Biloxi, MS, USA. Retrieved from https://gulfpartnership.org/a-land-conservation-vision-for-the-gulf-of-mexico-region/

Pickens, B. A., B. Meanley. 2015. King Rail (*Rallus elegans*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/kinrai4/.

Poole, A. F., P. E. Lowther, J. P. Gibbs, F. A. Reid, S. M. Melvin. 2009. Least Bittern (*Ixobrychus exilis*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/leabit/.

Post, W., J. S. Greenlaw. 2009. Seaside Sparrow (*Ammodramus maritimus*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/seaspa/.

Post, W., J. P. Poston, G. T. Bancroft. 2014. Boat-tailed Grackle (*Quiscalus major*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/botgra/.

Reece, J. S., A. Watson, P. S. Dalyander, C. K. Edwards. L. Geselbracht, M. K. LePeyre, B. E. Tirpak, J. M. Tirpak, M. Woodrey. 2018. A multiscale natural community and species-level vulnerability assessment of the Gulf Coast, USA. PLoS ONE 13(6): e0199844.

Ribic, C., S. J. Lewis, S. Melvin, J. Bart, B. Peterjohn. 1999. Proceedings of the marsh bird monitoring workshop. U.S. Fish and Wildlife Service, Laurel, MD, USA.

Rush, S. A., E. C. Soehren, M. S. Woodrey, C. L. Graydon, R. J. Cooper. 2009. Occupancy of select marsh birds within Northern Gulf of Mexico tidal marsh: Current estimates and projected change. Wetlands 29:798-808.

Rush, S. A., J. A., Olin, A. T. Fisk, M. S. Woodrey, R. J. Cooper. 2010a. Trophic relationships of a marsh bird differ between Gulf Coast estuaries. Estuaries and Coasts 33:963-970.

Rush, S. A., R. Mordecai, M. S. Woodrey, R. J. Cooper. 2010b. Prey and habitat influences the movement of Clapper Rails in northern Gulf Coast estuaries. Waterbirds 33:389-396.

Rush, S. A., M. S. Woodrey, R. J. Cooper. 2010c. Variation in the nesting habits of Clapper Rails in tidal marshes of the northern Gulf of Mexico. Condor 112:356-362.

Rush, S. A., K. F. Gaines, W. R. Eddleman, C. J. Conway. 2012. Clapper Rail (*Rallus crepitans*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/clarai11/.

Russell, R. W. 2005. Interactions between migrating birds and offshore oil and gas platforms in the northern Gulf of Mexico: Final Report. OCS Study MMS 2005-009. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA, USA.

Salafsky, N., D. Salzer, A. J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S. H. M. Butchart, B. Collen, N. Cox, L. L. Master, S. O'Connor, D. Wilkie. 2008. A standard lexicon for biodiversity conservation: Unified classifications of threats and actions: Conservation Biology 22(4):897-911.

Schmeltz, D., D. C. Evers, C. T. Driscoll, R. Artz, M. Cohen, D. Gay, R. Haeuber, D. P. Krabbenhoft, R. Mason, K. Morris, J. G. Weiner. 2011. MercNet: A national monitoring network to assess responses to changing mercury emissions in the United States. Ecotoxicology 20:1713-1725.

Shriver, W. G., R. Greenberg. 2012. Avian community responses to tidal restoration along the North Atlantic coast of North America. Pages 119-143 in C.T. Roman, and D.M. Burdick (Eds.), Tidal Marsh Restoration: A Synthesis of Science and Practice, Island Press, Washington, DC, USA.

Shriver, W. G., D. C. Evers, T. P. Hodgman, B. J. MacCulloch, R. J. Taylor. 2006. Mercury in Sharp-Tailed Sparrows breeding in coastal wetlands. Environmental Bioindicators 1:129-235.

Shriver, W. G., T. P. Hodgman, A. R. Hanson. 2011. Nelson's Sparrow (*Ammodramus nelsoni*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/nstspa/

Soehren, E. C., S. G. Hereford, K. M. Morris, J. A. Trent, J. N. Walker, M. S. Woodrey, S. A. Rush. 2018. Winter use of wet pine savannas by Yellow Rail (*Coturnicops noveboracensis*) along coastal Alabama and Mississippi. Wilson Journal of Ornithology 130:615-625.

Stouffer, P. C., S. Taylor, S. Woltmann, C. M. Bergeon Burns. 2013. Staying alive on the edge of the earth: Response of Seaside Sparrows (*Ammodramus maritumus*) to salt marsh inundation, with implications for storms, spills, and climate change. Pages 82-93 in T.F. Shupe and M.S. Bowen (Eds.), Proceedings of the 4th Louisiana Natural Resources Symposium, Louisiana State Universtiy AgCenter, Baton Rouge, LA, USA.

Stutzenbaker, C. D., M. W. Weller. 1989. The Texas Coast. Pages 385-405 in L. M. Smith, R. L. Pederson, and R. M. Kaminski (Eds.), Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, TX, USA.

Tolliver, J. D. M., A. A. Moore, M. C. Green, F. W. Weckerly. 2018. Coastal Texas Black Rail population states and survey effort. Journal of Wildlife Management 83:312-324.

Veloz, S. D., N. Nur, L. Salas, D. Jongsomjit, J. Wood, D. Stralberg, G. Bullard. 2013. Modeling climate change impacts on tidal marsh birds: Restoration and conservation planning in the face of uncertainty. Ecosphere 4:1-25.

Watts, B. D. 2016. Status and distribution of the eastern black rail along the Atlantic and Gulf Coasts of North America. The Center for Conservation Biology Technical Report Series, CCBTR-16-09. College of William and Mary/ Virginia Commonwealth University, Williamsburg, VA, USA. 148 pp.

Webster, M. S., P. P. Marra, S. M. Haig, S. Bensch, R. T. Holmes. 2002. Links between worlds: Unraveling migratory connectivity. Trends in Ecology & Evolution 17:76-83.

West, R. L., G. K. Hess. 2002. Purple Gallinule (*Porphyrio martinica*). In P. G. Rodewald (Ed.), The Birds of North America. Cornell Lab of Ornithology, Ithaca, NY, USA. Retrieved from https://birdsna.org/Species-Account/bna/species/purgal2/.

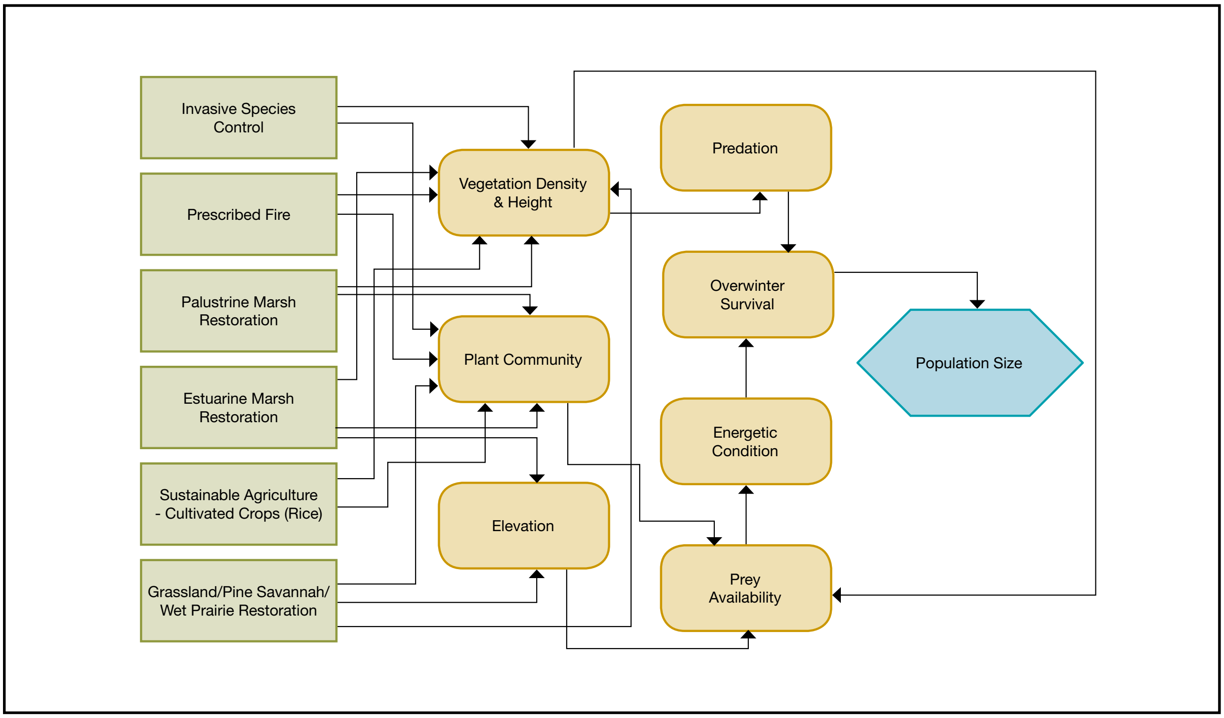
Winder, V. L., S. D. Emslie. 2011. Mercury in breeding and wintering Nelson's Sparrows (*Ammodramus nelsoni*). Ecotoxicology 20:218-225.

Woodrey, M. S. 2017. Bird Restoration Monitoring. In Effective Monitoring to Evaluate Ecological Restoration in the Gulf of Mexico. The National Academies Press 159-179.

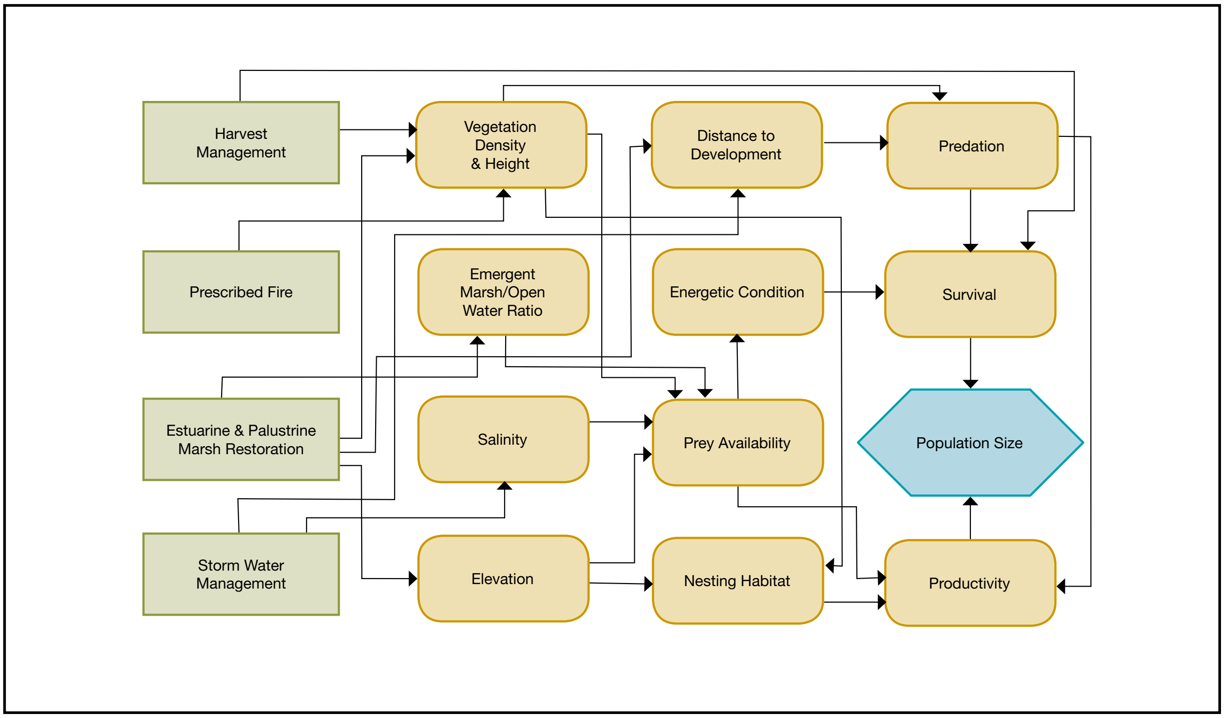
Woodrey, M. S., S. A. Rush, J. A. Cherry, B. L. Nuse, R. J. Cooper, A. J. J. Lehmicke. 2012. Understanding the potential impacts of global climate change on marsh birds in the Gulf of Mexico region. Wetlands 32:35-49.

APPENDIX 4

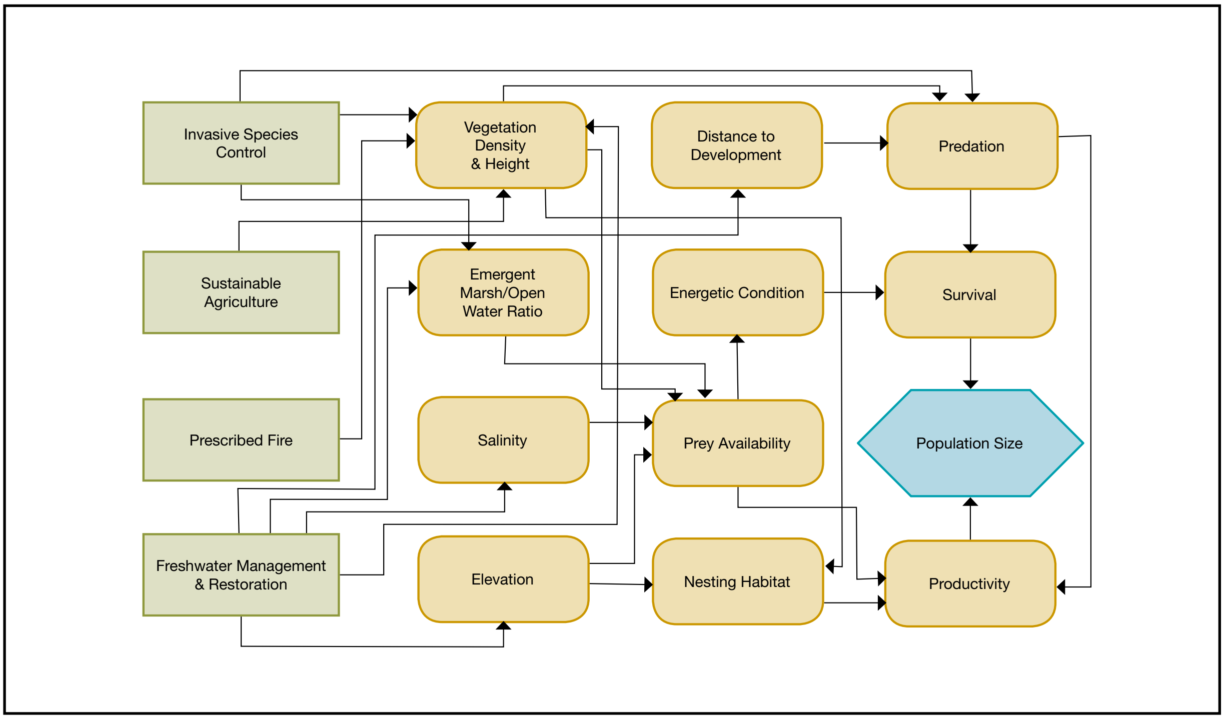
Supplementary influence diagrams depicting mechanistic relationships between management actions and population response of marsh birds.



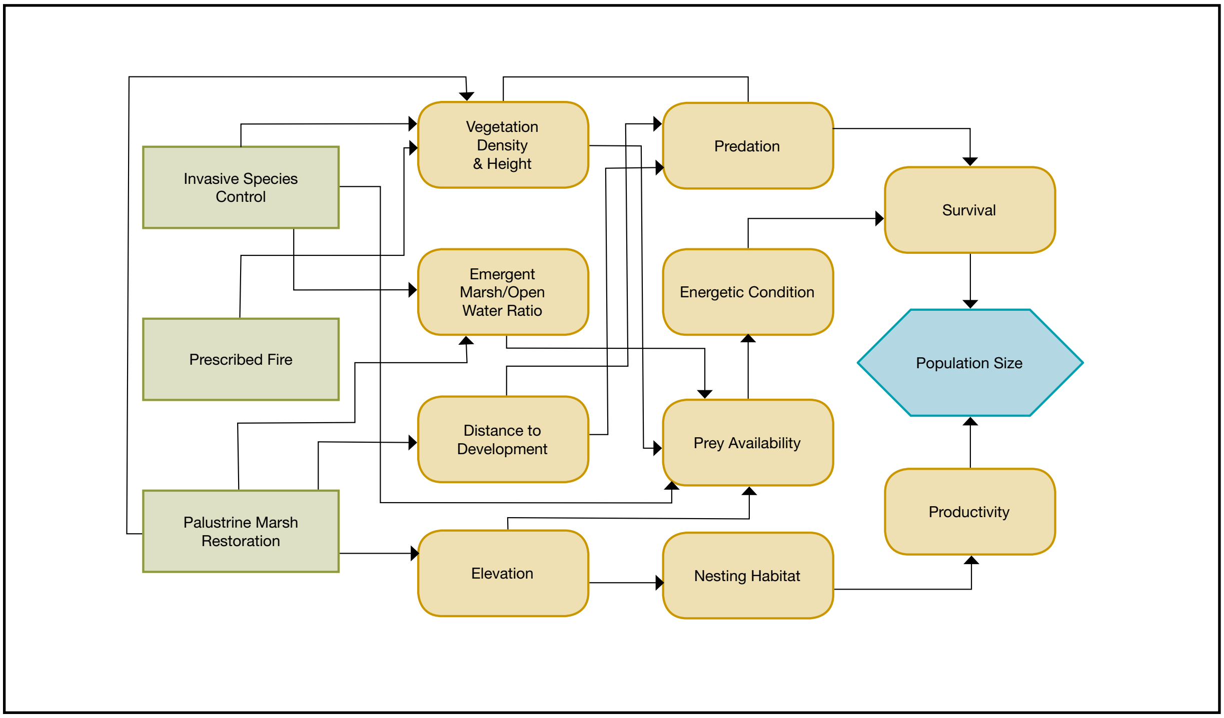
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Yellow Rail*** *(Colurnicops noveboracensis) within the Gulf of Mexico region.*



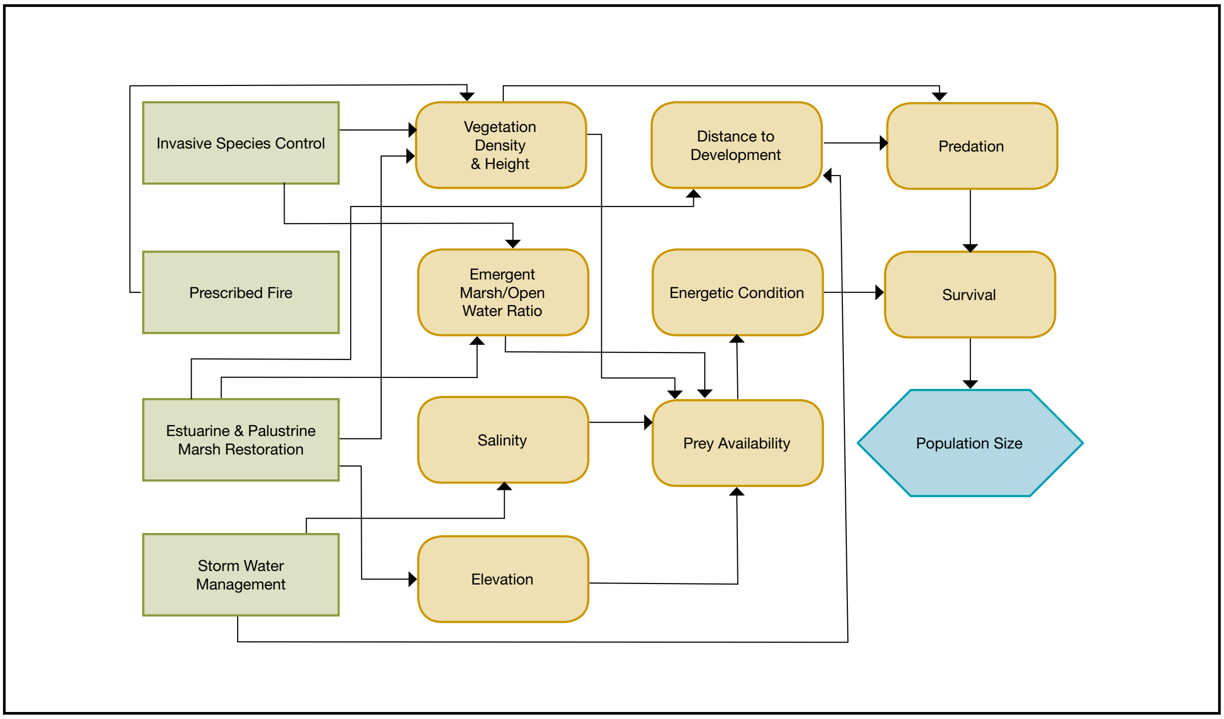
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Clapper Rail*** *(Rallus crepitans) within the Gulf of Mexico region.*



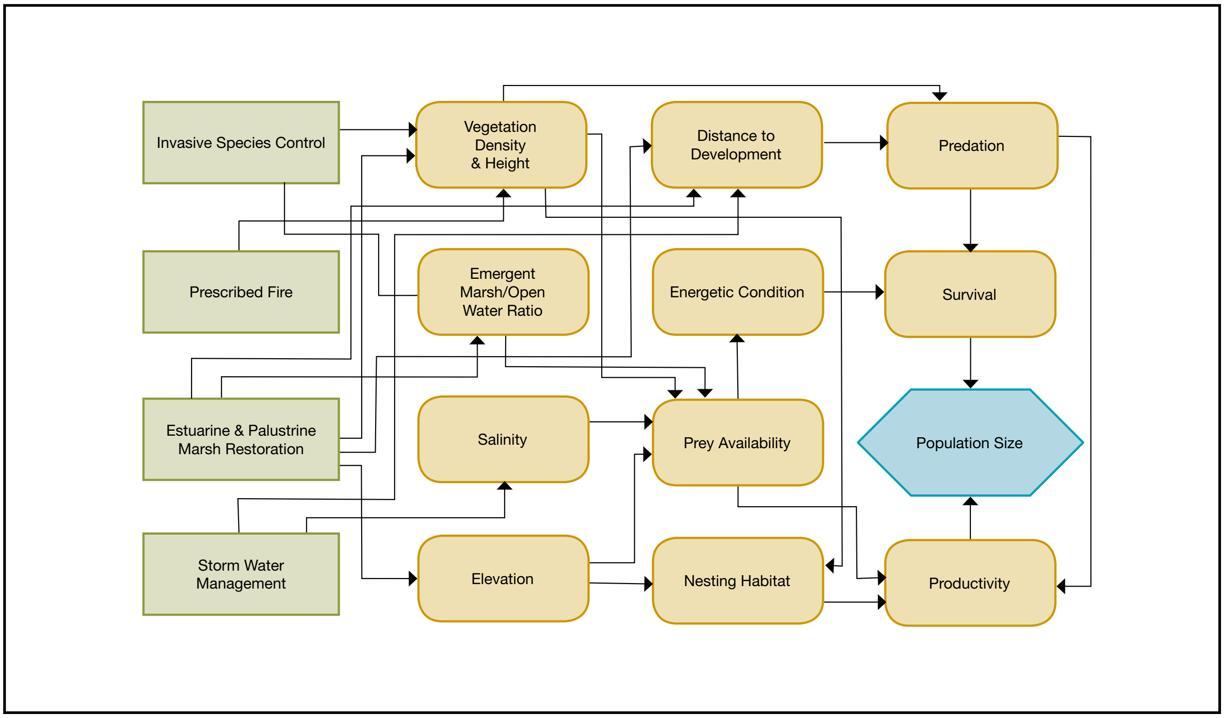
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***King Rail*** *(Rallus elegans) within the Gulf of Mexico Region.*



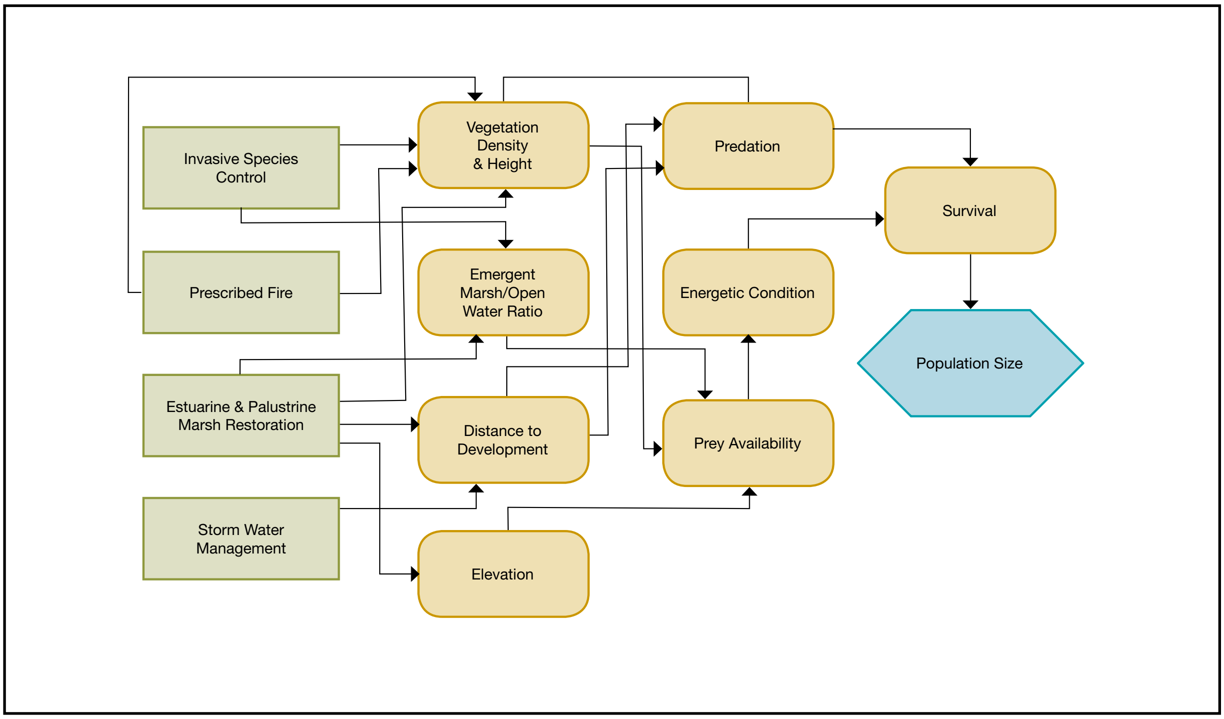
*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the **Limpkin** (Aramus guarauna) within the Gulf of Mexico Region.*



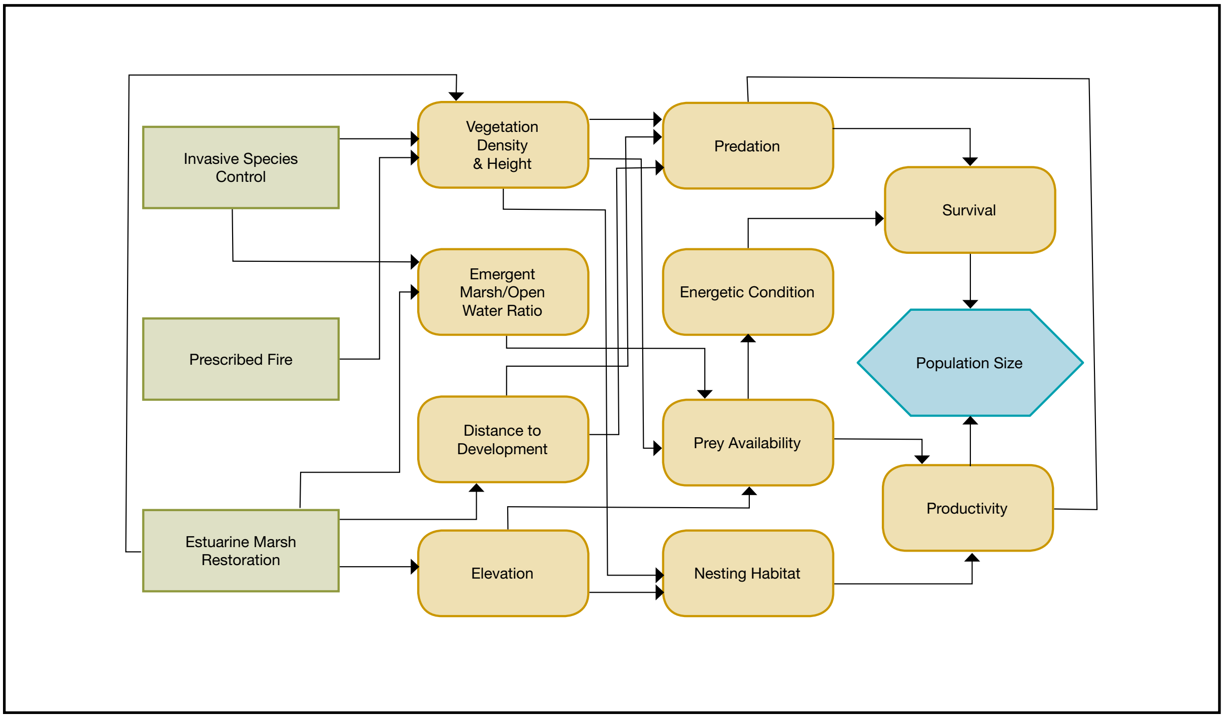
*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the **American Bittern** (Botaurus lentiginosus) within the Gulf of Mexico Region.*



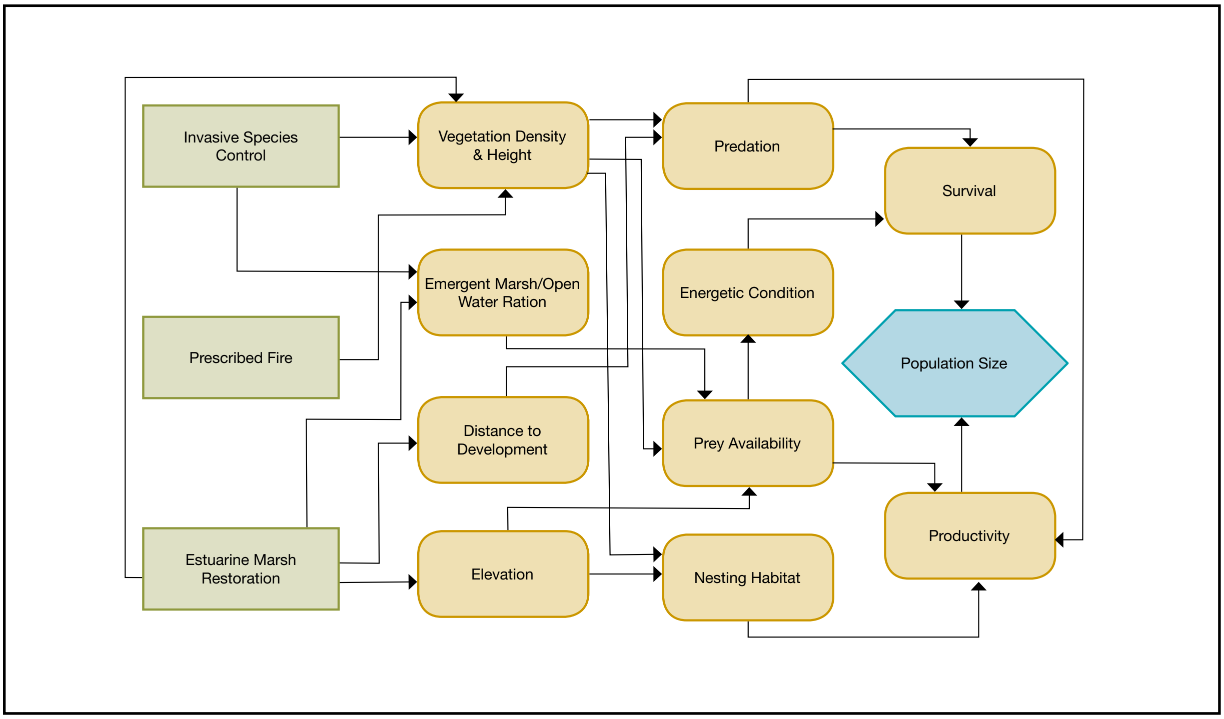
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Least Bittern*** *(Ixobrychus exillis) within the Gulf of Mexico Region.*



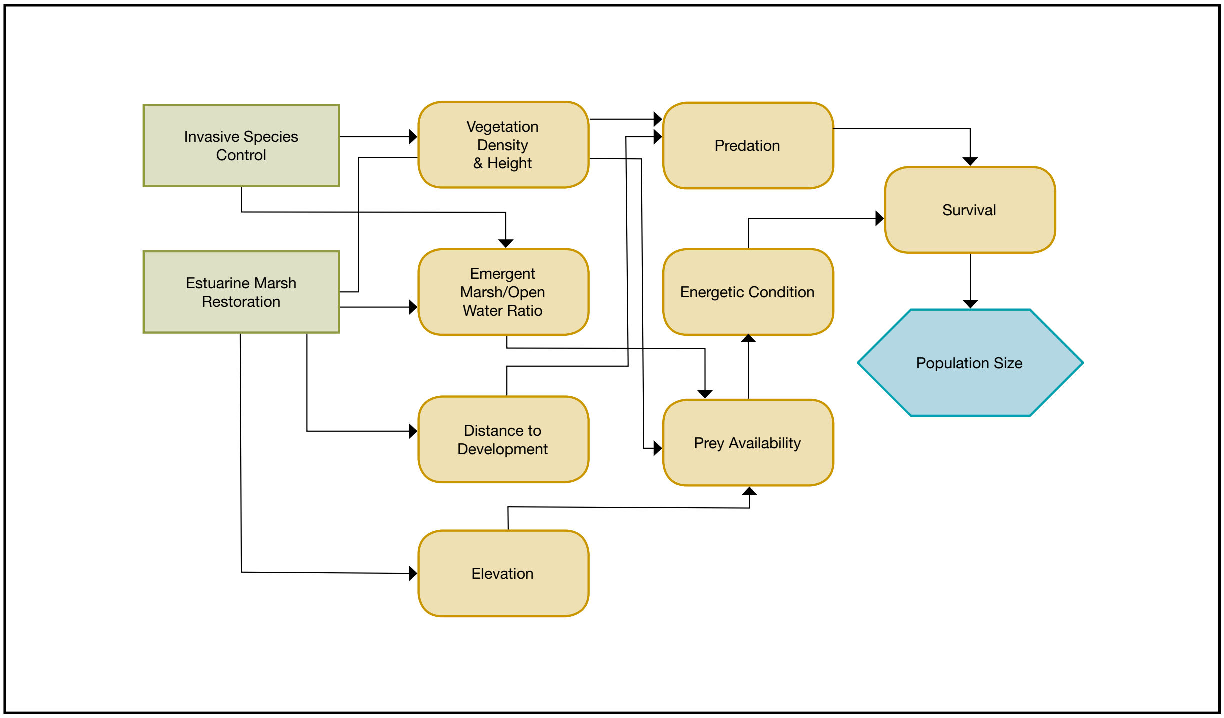
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Marsh Wren*** *(Cistothorus palustris) within the Gulf of Mexico region.*



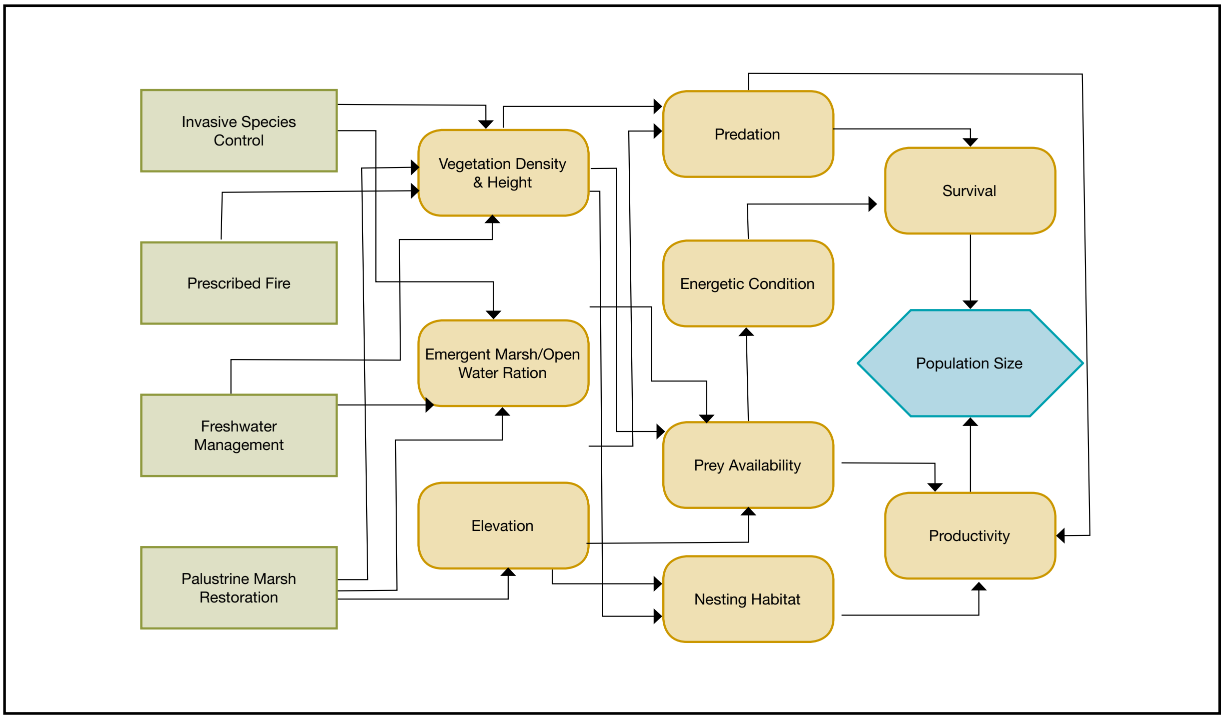
*Influence Diagram of the relationship between Management Actions (Green Boxes), Intermediate Processes (gold boxes) and Population Size (Blue Hexagon) for the **Mariah's Marsh Wren** (Cistothorus palustris marianae) within the Gulf of Mexico Region.*



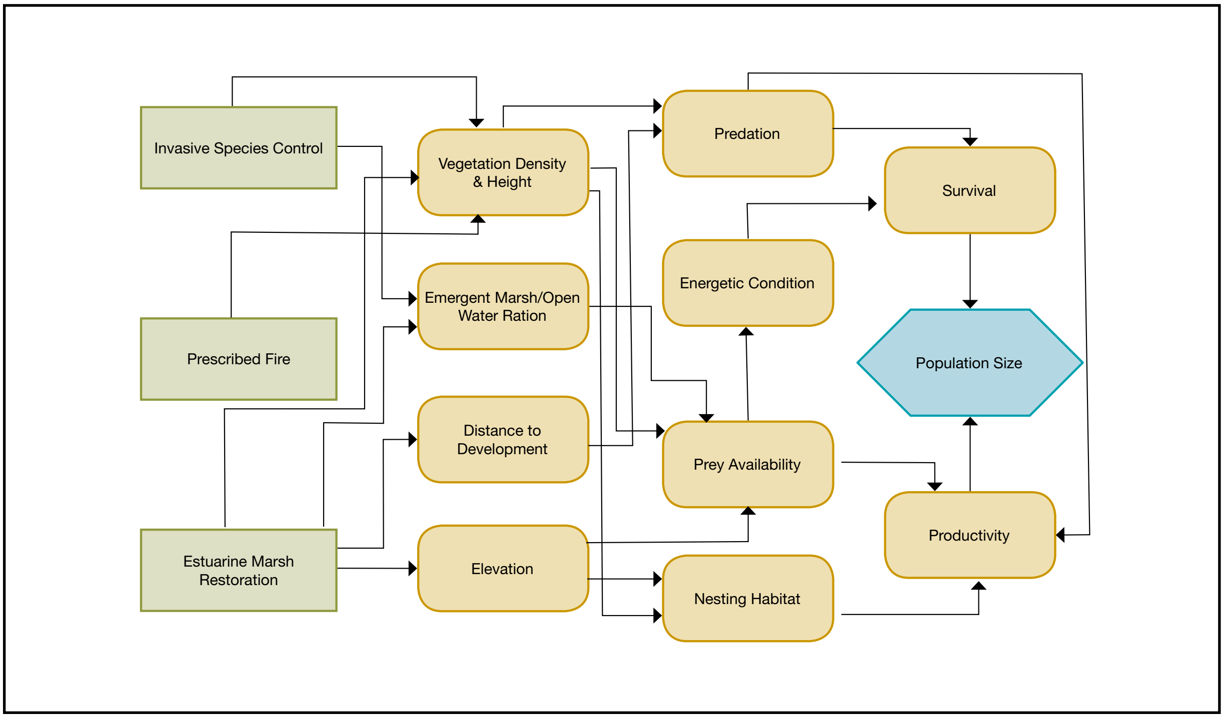
*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the **Seaside Sparrow** (Ammospiza maritima) within the Gulf of Mexico region.*



*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the **Nelson's Sparrow** (Ammospiza nelsoni) within the Gulf of Mexico Region.*



*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the **Cape Sable Seaside Sparrow** (Ammospiza maritima mirabilis) within the Gulf of Mexico Region.*



Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Texas Seaside Sparrow*** *(Ammospiza maritima sennetti) within the Gulf of Mexico region.*