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Strategic Bird Monitoring Guidelines for the Northern Gulf of Mexico

GoMAMN STRATEGIC BIRD MONITORING GUIDELINES: LANDBIRDS

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Wood Thrush (*Hylocichla mustelina*). Photo credit: Steve Maslowski

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GOMAMN STRATEGIC BIRD MONITORING GUIDELINES: LANDBIRDS

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

LANDBIRDS IN THE GULF OF MEXICO REGION include an ecologically diverse group of taxa that depend on a wide range of terrestrial habitats and the airspace above them. For the GoMAMN region of the Gulf of Mexico, the Landbird Working Group identified 19 species from 12 families as priorities for monitoring (Table 3.1). In addition, all species that stopover within the GoMAMN region during migration (i.e., passage migrants) are of concern, as are the habitats they use. The 19 priority species use a wide range of habitat types and include species that spend some (e.g., breeding, wintering, migration seasons) or all (e.g., residents) of their annual cycle in the GoMAMN region. The GoMAMN Landbird Working Group organized the priority landbirds into five groups based on a combination of habitat and season—forest breeding, forest wintering, grassland breeding, grassland wintering, and passage migrants—realizing that there would be overlap of habitats and seasons for some species. For example, Swainson's Warbler (*Limnothlypis swainsonii*) breeds in and migrates through forested habitat in the Gulf of Mexico region and Northern Bobwhite (*Colinus virginianus*) uses both prairie grasslands and evergreen forest (i.e., open pine savannas) (Table 3.1). For some species, such as Painted Bunting (*Passerina ciris*) and Common Ground-Dove (*Columbina passerina*), which often use scrub/shrub vegetation, the habitat-based designations above may be overly simplistic. Although it occurs along higher, drier fringes of palustrine and estuarine emergent marsh habitat, Sedge Wren (*Cistothorus platensis*) is included here as a landbird (rather than a marsh bird) because it is most commonly found during the winter along the Gulf coast in upland evergreen forest (i.e., wet pine savanna) habitat and grassland habitats. Selection of the five groups was predicated on the assumption that management efforts would be similar for species using these habitats in a given season, and that monitoring methods would be habitat and season specific.

For some of the 19 priority landbird species, such as Northern Bobwhite and Red-cockaded Woodpecker (*Dryobates borealis*), there is extensive literature examining life history, ecology, and population status and trends, while others have been studied little. Twelve of the 19 species are currently of moderate to high conservation concern at the continental scale (Rosenberg et al. 2016, U.S. Fish and Wildlife Service 2017). These rankings are from the Avian Conservation Assessment Database, which scores North American landbirds on six criteria with a maximum possible score of 20 (Partners in Flight 2017). The continental concern scores for the 19 species identified by GoMAMN range from 7 for Sedge Wren to 18 for the federally- endangered Red-cockaded Woodpecker (Table 3.1). The 2016 Partners in Flight (PIF) Landbird Conservation Plan (Rosenberg et al. 2016) lists 86 species of continental concern (the PIF Watch List), grouped into three categories:

1. **RECOVER:** Red Watch List – Species with extremely high vulnerability due to small population and range, high threats, and range wide declines. Two of GoMAMN's priority landbird species are in this category: Red-cockaded Woodpecker and Bachman's Sparrow (*Peucaea aestivalis*).

2. **PREVENT DECLINE:** "R" Yellow Watch List – Species not declining but vulnerable due to small range or population and moderate threats. Henslow's Sparrow (*Centronyx henslowii*) falls in this category.

3. **REVERSE DECLINE:** "D" Yellow Watch List – Species with population declines and moderate to high threats. Four of GoMAMN's priority landbird species are in this category: Red-headed Woodpecker (*Melanerpes erythrocephalus*), Wood Thrush (*Hylocichla mustelina*), Prothonotary Warbler (*Protonotaria citrea*), and LeConte's Sparrow (*Ammospiza leconteii*).

Additionally, PIF has identified 24 species as common birds in steep decline. These species are still fairly common and widespread, but have lost from 50–90% of their populations since 1970, and are projected to lose another 50% within the next 20–25 years. GoMAMN landbird species with this designation are Northern Bobwhite, Chuck-will's-widow (*Antrostomus carolinensis*), Loggerhead Shrike (*Lanius*

TABLE 3.1 - *Landbird 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[a]	Latin Name	Breeding	Wintering	Migration	Landcover Association(s)[a]	Continental Trend Score	Continental Concern Score
Northern Bobwhite	*Colinus virginianus*	X	X		Grassland, Evergreen Forest, Mixed Forest, Scrub/Shrub	5	12
Common Ground-Dove	*Columbina passerina*	X	X		Evergreen Forest, Scrub/Shrub	3	9
Chuck-will's-widow	*Antrostomus carolinensis*	X		X	Evergreen Forest, Mixed Forest	5	12
Red-headed Woodpecker	*Melanerpes erythrocephalus*	X	X		Deciduous Forest, Evergreen Forest, Mixed Forest, Palustrine Forested Wetland	5	13
Red-cockaded Woodpecker	*Dryobates borealis*	X	X		Evergreen Forest	5	18
Loggerhead Shrike	*Lanius ludovicianus*	X	X	X	Grassland, Scrub/Shrub	5	12
Brown-headed Nuthatch	*Sitta pusilla*	X	X		Evergreen Forest, Mixed Forest	4	13
Sedge Wren	*Cistothorus platensis*		X		Grassland, Evergreen Forest	1	7
Wood Thrush	*Hylocichla mustelina*	X		X	Deciduous Forest, Mixed Forest	5	14
Louisiana Waterthrush	*Parkesia motacilla*	X		X	Deciduous Forest, Mixed Forest, Palustrine Forested Wetland	2	12
Prothonotary Warbler	*Protonotaria citrea*	X		X	Palustrine Forested Wetland	4	14
Swainson's Warbler	*Limnothlypis swainsonii*	X		X	Deciduous Forest, Evergreen Forest, Mixed Forest, Palustrine Forested Wetland	1	13
Yellow-throated Warbler	*Setophaga dominica*	X	X	X	Deciduous Forest, Evergreen Forest, Mixed Forest, Palustrine Forested Wetland	2	10
Bachman's Sparrow	*Peucaea aestivalis*	X	X		Evergreen Forest	5	16
Grasshopper Sparrow	*Ammodramus savannarum*	X	X	X	Grassland	5	12
Henslow's Sparrow	*Centronyx henslowii*		X		Grassland, Evergreen Forest	3	14
LeConte's Sparrow	*Ammospiza leconteii*		X		Grassland	5	13
Painted Bunting	*Passerina ciris*	X	X	X	Deciduous Forest, Evergreen Forest, Mixed Forest, Scrub/Shrub, Palustrine Forested Wetland	3	11
Rusty Blackbird	*Euphagus carolinus*		X		Palustrine Forested Wetland, Cultivated Crops, Pasture/Hay	5	12

[a] See Chapter 1 and Appendix 2 for full description of landcover associations.

ludovicianus), Grasshopper Sparrow (*Ammodramus savannarum*), and Rusty Blackbird (*Euphagus carolinus*). The remaining six landbird species identified by GoMAMN are birds of regional concern.

Finally, all passage migrants are a GoMAMN priority because it is thought that these species encounter the greatest mortality risk of their annual cycle during migration (e.g., Sillett and Holmes 2002, Newton 2007, Paxton et al. 2017) and stopover habitat may limit some populations within this group (Sherry and Holmes 1995, Newton 2007, 2008). Identifying migrant-habitat relations, including habitat characteristics and quality, threats to populations, and best conservation practices will benefit passage migrants, as well as breeding and wintering species, by establishing unified conservation partnerships (Cohen et al. 2017).

Breeding Season

Fifteen of the 19 selected priority landbird species breed within the GoMAMN boundaries, though some are more common in migration or winter than in the breeding season. Loggerhead Shrike and Northern Bobwhite occur in grassland, scrub/shrub, and savanna habitats throughout the extent of the GoMAMN region (Yosef 1996, eBird 2018, Brennan et al. 2014). Other species occupy only part of the GoMAMN region, or their abundance varies in predictable ways within the region. Common Ground-Dove, while breeding in scrub/shrub and edge habitats throughout the GoMAMN region, shows marked differences in densities during the breeding season, with higher densities in south Texas and Florida, and lower densities in south Louisiana and Mississippi (Bowman 2002, eBird 2018). The breeding ranges of several species are tied to the extent of evergreen forests (i.e., coastal pine flatwoods) within the GoMAMN region, including Chuck-will's-widow, Red-headed Woodpecker, and Brown-headed Nuthatch (*Sitta pusilla*); the woodpecker also uses savanna-like conditions that occur in areas of human habitation (eBird 2018, Straight and Cooper 2012, Slater et al. 2013, Frei et al. 2017). Red-cockaded Woodpecker and Bachman's Sparrow also occur in evergreen forest (i.e., coastal pine flatwoods) but are restricted to specific seral stages and management regimes, resulting in localized distributions (Jackson 1994, eBird 2018, Dunning et al. 2017). For a description of open pine habitats utilized by Red-cockaded Woodpecker, Bachman's Sparrow, and several other GoMAMN priority landbirds, see Appendix 2, GoMAMN Ecological Systems and Nordman et al. (2016).

Within the GoMAMN region, Painted Bunting regularly breeds in scrub/shrub and forest edge-like habitats from the Texas-Mexico border to western Mississippi and becomes much less common in eastern Mississippi, Alabama, and Florida (eBird 2018, Lowther et al. 2015). Prothonotary Warbler is largely absent as a breeder in southern peninsular Florida as well as south of the Texas mid-coast, and is associated with the presence of palustrine forested wetlands in the region in between (Petit 1999, eBird 2018). Yellow-throated Warbler (*Setophaga dominica*) breeds within approximately the same geography as Prothonotary Warbler, but in a greater variety of habitats (eBird 2018, McKay and Hall 2012) (Table 3.1). Wood Thrush, Louisiana Waterthrush (*Parkesia motacilla*), and Swainson's Warbler also breed in forest habitats from the Florida panhandle into Texas, but their distribution in the GoMAMN region is restricted and they are uncommon breeders, being more prevalent during spring and autumn migration than during the breeding season (Mattson et al. 2009, Anich et al. 2010, Evans et al. 2011, eBird 2018). Similarly, although it does breed in the GoMAMN region, Grasshopper Sparrow is more common as a wintering bird than during the breeding season (eBird 2018). Within the GoMAMN region, the species breeds in grassland habitat in coastal Texas (Vickery 1996, Lockwood and Freeman 2004, eBird 2018). Additionally, there is a resident, federally-listed endangered subspecies (*Ammodramus savannarum floridanus*) in southern peninsular Florida (Vickery 1996, U.S. Fish and Wildlife Service 2017); however, GoMAMN's monitoring focus is on the non-listed subspecies (*A. s. pratensis* and *A. s. perpallidus*) which winter throughout the region.

Spring and Autumn Migration Seasons

Habitat within the GoMAMN region may be more important to transient versus breeding landbirds. The majority of Nearctic-Neotropical landbirds breeding in the eastern United States, as well as many western populations of landbirds, move through the region in spring and fall each year (Barrow et al. 2005, Buler et al. 2007a, Buler and Moore 2011, eBird 2018, Lafleur et al. 2016). Given that the habitats used during stopover are generally similar to those used on the breeding grounds (Moore et al. 1995), the majority of passage migrants within the GoMAMN region use forest habitat types (e.g., deciduous, evergreen, and mixed forest types, palustrine forested wetlands; Table 3.1), with grassland and scrub/shrub habitats used to a lesser degree. Additionally, Moore et al. (1995) concluded that during spring migration, forest-dwelling landbirds on the northern Gulf Coast preferentially select structurally-diverse stopover sites consisting of forested areas with mixed shrub layers. This observation is further supported by research, including analysis of weather surveillance radar data to detect reflectivity caused by departing birds, which indicates the importance of the remaining large blocks of riverine hardwood forests along the Gulf of Mexico rim (Able 1972, Barrow et al. 2005, Buler et al. 2007a, 2007b, Buler and

Moore 2011, Lafleur et al. 2016).

Although individuals might prefer specific site characteristics, they tend to show plasticity during migration and may behave differently between migration seasons (Petit 2000). For example, energetic condition and weather can strongly influence habitat selection by forcing migrants to land in areas they might have otherwise overflown (Able 1972, Moore and Aborn 2000, Petit 2000). Moreover, migrant-habitat relations are often scale dependent and are influenced in part by landscape- and habitat-scale factors (e.g., Moore et al. 1995, Buler et al. 2007b, Zenzal et al. 2018). This means an individual's position in space and time may influence where an individual lands and, in turn, the likelihood of encountering different functional habitat types en route that can vary in their size and quality. Toward this end, Mehlman and colleagues (2005) have prioritized functional stopover habitat types for migratory landbirds according to the definitions described below:

- **"FIRE ESCAPE"**: Like fire escapes in human habitations, these stopover sites are infrequently used, but are utterly vital when needed during inclement weather or energy shortfalls. These habitats tend to be small forested or scrub/shrub habitats, such as chenier or coastal/maritime forest, within a typically inhospitable matrix adjacent to an ecological barrier (e.g., ocean or desert). Habitat quality may be too low to allow birds to gain significant mass especially when migrant densities are high, but provides shelter for rest, refueling possibilities (Moore et al. 2017), and freshwater.

- **"CONVENIENCE STORE":** Forested patches, such as small parks or woodlots, in a non-forested matrix and located along migratory routes. These sites offer a place where birds can briefly rest and gain some mass easily, perhaps between short flights to higher quality sites, or when migrants' fuel stores are moderate. A given convenience store may serve the needs of some species better than others.

- **"FULL-SERVICE HOTEL":** Forested sites in a mostly contiguous forested landscape. Full-service hotels are places where all needed resources (food, water, and shelter) are relatively abundant and available. These places serve many individuals of many species. Palustrine forested wetlands (e.g., bottomland hardwood forests) are a good example.

Each functional stopover habitat type plays an important part in the journey of migratory landbirds. For example, although only used sporadically, smaller blocks of forested habitat, especially those adjacent to the Gulf of Mexico shoreline, have been shown to receive heavy use by migrants during inclement weather (Gauthreaux 1971, Barrow et al. 2000, Barrow et al. 2005, Buler et al. 2007b, Buler and Moore 2011, Lafleur et al. 2016). The importance of large blocks of forest (i.e., full-service hotels) is evident based on migrant densities (Barrow et al. 2005, Buler et al. 2007b, Buler and Moore 2011, Lafleur et al. 2016); however, information is lacking on how non-coastal forests (full-service hotels and convenience stores) in the GoMAMN region function for migrants in terms of resource availability and refueling potential. Once we understand how migrants respond to each habitat type as well as the relationships between stopover habitat types across the GoMAMN region (e.g., Cohen et al. 2014), we can begin to estimate the amount of each habitat type needed to sustain or increase migrant populations (reviewed by Cohen et al. 2017).

Red-headed Woodpecker (*Melanerpes erythrocephalus*).
Photo credit: Jessica Bolser

Winter Season

Although numerous GoMAMN priority landbirds overwinter in the region, the presence of only four species is largely limited to the winter season. Rusty Blackbird typically uses palustrine forested wetlands for foraging and roosting, but also forages in agricultural fields adjacent to forested wetlands and pecan groves (Mettke-Hofmann et al. 2015, Avery 2018). Henslow's and LeConte's Sparrows and Sedge Wren are grassland species overwintering in the GoMAMN region (Vickery 1996, Herkert et al. 2002, Lowther 2005). Henslow's Sparrow and Sedge Wren also utilize the grassland-like conditions that exist in evergreen forest (i.e., open pine savanna habitat) (Herkert et al. 2002). Red-headed Woodpecker breeds and winters in the GoMAMN region, but the area is believed to be most important during winter. Various forest types are used by the woodpecker, with a unifying similarity being an open, savanna-like quality (Frei et al. 2017). Other species (besides year-round residents) have breeding and wintering populations in the GoMAMN region. South Florida is an important wintering area for Painted Bunting and Chuck-will's-widow (Straight and Cooper 2012, Lowther et al. 2015). Yellow-throated Warbler overwinters in south Florida, south Texas, and in smaller numbers throughout the rest of the GoMAMN region (McKay and Hall 2012). The Gulf coast is believed to be an important overwintering area for Loggerhead Shrikes breeding in Canada and the northern U.S. (Miller 1931, Burnside 1987, Yosef 1996). Winter habitat used by Painted Bunting, Yellow-throated Warbler, and Loggerhead Shrike is similar to their breeding habitat. Chuck-will's-widow uses a greater variety of GoMAMN region habitats in winter vs. summer, including scrub/shrub in south Texas (Oberholser 1974) and coastal live oak forests (cheniers) in southwestern Louisiana (Lowery 1974).

CONSERVATION CHALLENGES AND INFORMATION NEEDS

Primary Threats and Conservation Challenges

A myriad of threats exist for breeding, migrating (passage migrant), and wintering landbirds in the GoMAMN region (Figure 3.1; Appendix 3). For the current PIF Landbird Conservation Plan, Rosenberg et al. (2016) identified and analyzed continental-scale threats. Their analysis indicated that habitat loss due to urbanization and habitat degradation due to changing forest conditions represented the most critical threats to landbirds in the U.S. and Canada, affecting nearly half of 98 PIF Watch List species and Common Birds in Steep Decline. Habitat loss due to agricultural conversion and tropical deforestation, along with habitat loss and degradation due to climate change, impacted ~30 of these species, and habitat degradation due to rangeland management impacted 20 species (Rosenberg et al. 2016). Other major threats identified in the plan, in order of species impacted, are energy/resource extraction, contaminants, disease, invasive species, and hunting/trapping. Rosenberg et al. (2016) also highlights the direct mortality of North American landbirds from anthropogenic sources including feral cats, collisions with man-made structures such as buildings and power lines, as well as auto strikes (see also Loss et al. 2013, Loss et al. 2014a, 2014b).

The majority of the causes for habitat loss and alteration, and anthropogenic sources of direct mortality described above, are operating in the GoMAMN region (Cohen et al. 2017). Loss or degradation of forests and grasslands due to urbanization and existing management practices is one of the most significant and pervasive threats to landbirds Gulf-wide (Moore et al. 1995, Barrow et al. 2000, Barrow et al. 2005, Buler and Moore 2011, Barnes et al. 2013). The human population along the Gulf Coast continues to grow (Crossett et al. 2004, Partnership for Gulf Coast Land Conservation 2014), and with that growth comes conversion and fragmentation of forested and grassland habitats (e.g., Abdollahi et al. 2005), as well as increased risk of direct mortality from anthropogenic sources.

Invasive plant and animal species have also impacted GoMAMN priority landbird habitat. Chinese tallow (Triadica sebifera) is a medium-sized tree native to China (USDA, NRCS 2017) and is believed to have been introduced into the United States as early as the 1700's as an ornamental and as a source for oil to manufacture soap and candles. Since its introduction, Chinese tallow has spread throughout the southeastern U.S. as well as California. It has significantly altered the composition of Gulf of Mexico coastal prairies and forests due to its ability to rapidly invade prairie soils or forest gaps and out-compete native plant species (Barrilleaux and Grace 2000, Bruce et al. 1995, 1997). Once established, Chinese tallow trees are difficult to remove and control, typically requiring multiple mechanical treatments and herbicide applications. Fire can be effective in controlling Chinese tallow in coastal prairie habitats before it becomes well-established. Chinese tallow has the ability to replace native tree species with monotypic stands that may be ecological traps for insectivorous birds because the foliage contains compounds that render leaves unpalatable to herbivorous arthropods. For example, Barrow and Renne (2001) found that Chinese tallow hosted fewer insects and spiders than native trees in Gulf coastal habitats, and spring migrant landbirds spent significantly less time feeding in Chinese tallow compared to their availability in coastal forests. Similarly, Barrow et al. (2000) noted that Chinese tallow was avoided by spring migrant birds at Smith Point, Texas, an important stopover site for migrant landbirds. Conversely, during autumn migration Conway et al. (2002) recorded 24 species of birds foraging on Chinese tallow fruits during 1995 and 1996, with Yellow-rumped Warbler (*Setophaga coronata*) and Baltimore Oriole (*Icterus galbula*) accounting for 72% of frugivory incidents. Additionally, a study conducted at sites in South

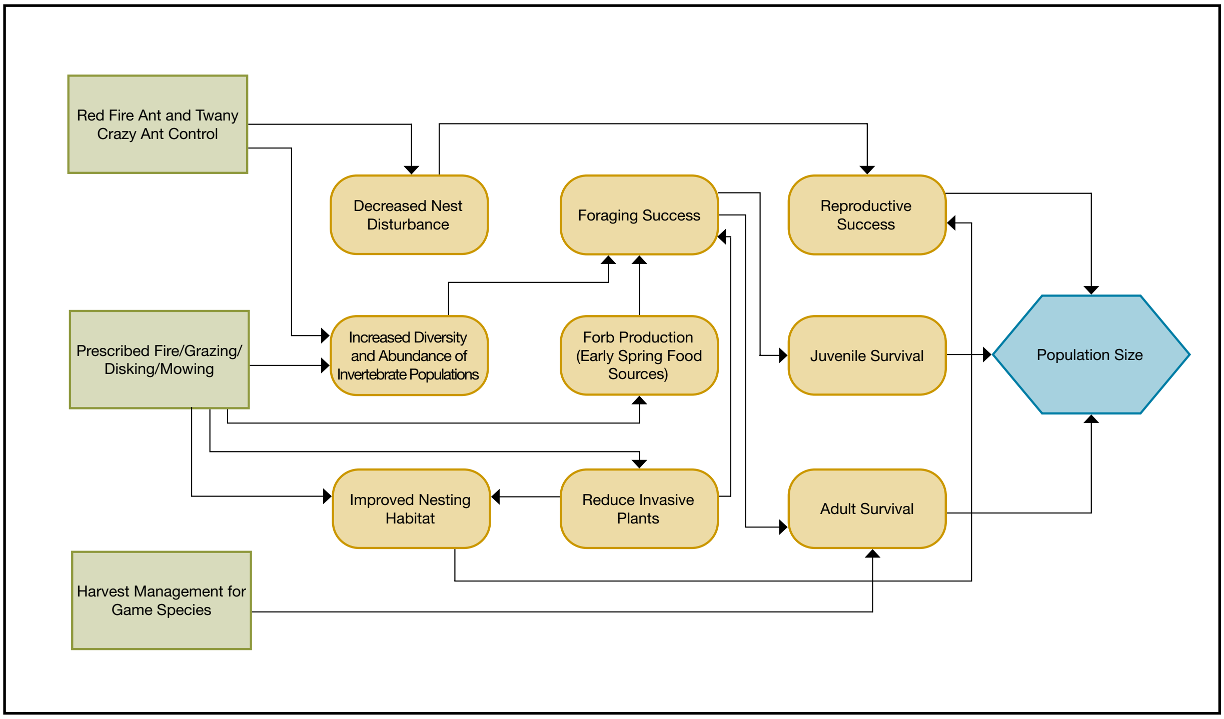

Figure 3.1. *Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the* ***Northern Bobwhite*** *(Colinus virginianus) in grasslands within the Gulf of Mexico region.*

Carolina and Louisiana identified Red-bellied Woodpecker (*Melanerpes carolinus*), Northern Flicker (*Colaptes auratus*), Eastern Bluebird (*Sialia sialis*), American Robin (*Turdus migratorius*), European Starling (*Sturnus vulgaris*), and Northern Cardinal (*Cardinalis cardinalis*) as the most important species to disperse and drop Chinese tallow seeds (Renne et al. 2002). These results suggest that landbirds rely more heavily on the use of Chinese tallow in autumn compared to spring, likely due to availability of tallow fruit in autumn and overall fewer arthropod resources. However, Baldwin et al. (2008) found that Chinese tallow fruits did not constitute a valuable energy source for Northern Cardinals because of their inability to efficiently metabolize the high-melting point fatty acids comprising the fruits. Yet Yellow-rumped Warblers, postulated to be an important dispersal agent (Conway et al. 2002), have a specialized digestive system allowing assimilation of waxy fruits, such as wax myrtle (*Morella cerifera*), and Chinese tallow trees may provide an important winter food source for this species.

In addition to its unsuitability as foraging habitat for insectivorous birds, Chinese tallow has invaded and altered much of the remaining grassland habitat in southeastern Texas and southwestern Louisiana (Bruce et al. 1995, USFWS/USGS 1999), rendering it largely inhospitable for grassland-dependent bird species such as Henslow's, LeConte's and Grasshopper Sparrows. Similarly, various exotic, sod-forming grasses have been introduced along the Gulf Coast, including bermudagrass (*Cynodon dactylon*), tall fescue (*Schedonorus arundinaceus*), and cogongrass (*Imperata cylindrica*), to the detriment of grassland dependent birds (Barnes et al. 2013). These plant species typically provide poor habitat for grassland birds due to their tendency to form thick mats at ground level, making foot travel difficult or impossible for species such as Northern Bobwhite. These exotic grasses form monotypic stands with relatively low insect diversity compared to native grassland-forb habitats (Barnes et al. 2013). An additional problem with cogongrass, a pyrogenic species, is that it has the capacity to disrupt natural fire regimes. Cogongrass fires burn ~15-20% hotter than typical fires occurring in southern pine ecosystems, which reduces competition and increases areal coverage, limiting natural succession from native plants and facilitating development of monotypic cogongrass stands (McDonald 2007). Without fire management or other intervention methods, native woody species such as eastern baccharis (*Baccharis halimifolia*) can also convert grasslands into scrub/shrub habitat that is unsuitable for some priority grassland bird species (USFWS/USGS 1999, Grace et al. 2005).

Invasive animal species, like feral hogs (*Sus scrofa*), also affect landbird habitats along the Gulf coast. In addition to consuming the eggs of ground-nesting bird species (Timmons et al. 2011), feral hogs can significantly alter the structure and plant diversity of forests (Siemann et al. 2009). In Texas, the saplings of large-seeded tree species, such as oaks and hickories, were twice as numerous in forested plots that were inaccessible to hogs. In unprotected plots, hogs created conditions conducive to invasion by Chinese tallow, which as described above is of less value to birds than many native tree species. While efforts are underway in the GoMAMN region as well as other areas of North America to reduce feral hog populations (e.g., hunting, targeted removal, etc.), complete eradication is unlikely.

Climate change is a potentially important ecological process impacting priority landbirds in the GoMAMN region. One concern is that increased temperatures will cause asynchrony between peak resource abundance and peak migrant landbird arrival in the GoMAMN region and the northern hemisphere in general (Both and Visser 2001, Strode 2003, Marra et al. 2005, Visser and Both 2005). While it seems that some North American migrant bird species have adjusted their arrival dates in spring, research indicates that other species have not adjusted their timing to match phenological changes in spring conditions (Paxton et al. 2014, Cohen et al. 2015, Mayor et al. 2017). In addition, climate change may increase the intensity of hurricanes (Scavia et al. 2002; Knutson et al. 2010; Holland and Bruyère 2014), which can alter forest structure and composition and impact migrant landbirds (Lain et al. 2017, Sugi et al. 2017, Dobbs et al. 2009). Barrow et al. (2007) used weather surveillance radar and remotely-sensed vegetation greenness indices (i.e., the normalized difference vegetation index) to document a shift in stopover habitat use from bottomland forests to adjacent pine forests in the Pearl River Basin of Mississippi and Louisiana after the bottomland forests were severely damaged by Hurricane Katrina. However, migrants tend to be less selective during spring migration as found by a lack of response from the majority of species using a hurricane disturbed chenier in southwest Louisiana during the years following hurricanes Rita and Ike (Lain et al. 2017).

Climate change-related sea-level rise has the potential to alter and likely reduce habitats within the GoMAMN region. Reduction in the areal coverage of coastal forests through increased salinities and prolonged flooding, elevated water tables, or through mechanical action from erosion can occur with sea-level rise (Williams et al. 1999). Tree regeneration can be eliminated by increased salinities and/or flooding duration (Conner and Day 1988), though canopy trees may persist for many years. In some areas of the GoMAMN region that experienced sea-level rise, salt tolerant plant species have replaced salt-intolerant plant species (Saha et al. 2011), while in other areas, forests have transitioned into "ghost" forests of dead tree stems underlain with marsh or open water (Penfound and O'Neill 1934, Williams et al. 1999).

Grasshopper Sparrow (*Ammodramus savannarum*).
Photo credit: Aron Flanders

Climate change impacts to existing grasslands in the GoMAMN region are difficult to predict (Bagne et al. 2012). Some experiments have shown that woody plants, legumes, and forbs would be favored over grasses under elevated carbon dioxide levels, whereas others indicate that some grasses would be favored in arid regions due to resistance to desiccation and tolerance of high temperatures and low soil nitrogen levels (Bagne et al. 2012). However, one of the likely changes summarized by Bagne et al. (2012) was that climate suitable for Gulf Coastal grasslands in Texas was expected to contract towards southeastern Texas and have a high proportion of no-analog climates (e.g., projected climates not matching any contemporary biomes). Whether or not GoMAMN priority grassland birds can adapt to novel climate regimes and habitat contraction is unknown. Species with relatively limited dispersal ability, such as Northern Bobwhite, may experience local extirpation.

Direct mortality from anthropogenic sources, such as collisions with towers and other structures, auto strikes, and predation from free-ranging and feral cats, has been identified as a significant source of mortality for North American birds, with losses estimated in the billions per year (Avery 1979, Erickson et al. 2005, Loss et al. 2013). Additionally, due to increasing human population and resultant habitat loss, alteration, and fragmentation, the GoMAMN Landbird Working Group identified the potential for disease to impact populations of migrant birds, as those individuals are constrained to use increasingly smaller areas of stopover habitat, a factor when combined with the stress of migration and resultant high relative bird densities could facilitate disease transmission.

In addition to stopover habitat, there is a growing appreciation of airspace as habitat for passage migrants (Diehl 2013, Cohen et al. 2017). Many questions remain regarding the temporal and spatial bounds of migrant traffic and effects of 1) meteorological, climatic, and geographic features, 2) migrant density and species composition of airspace habitats, and 3) variation at multiple scales in all these features. Nevertheless, threats to airspace habitat are growing along with threats to stopover habitat, as communication towers, wind turbines, and buildings invade the space above traditional, terrestrial habitats.

As with all the bird groups treated under the GoMAMN aegis (Figure 1.2), the threats discussed above relate to how they affect and interact with three overarching science needs:

1. effects of management actions,
2. population status and trends, and
3. effects of ecological processes.

Though the body of scientific literature and other investigation for some landbirds, such as Northern Bobwhite, is comparatively greater than that accumulated for other groups like secretive marsh birds or seabirds, significant data gaps still exist for all three science needs (e.g., Cohen et al. 2017).

IDENTIFICATION OF PRIORITIES

Priority Management Actions

GoMAMN values insights into both the effectiveness of management targeted towards priority avian species, as well as assessment of the impacts of other commonly occurring management actions in the region where avian benefits are not a high priority or even considered. The most important management actions, in terms of the number of priority species affected, include ecosystem restoration, sustainable agriculture and forestry, invasive species removal, and prescribed fire (see Table 3.2). However, because of the diversity of species selected through the GoMAMN process, these actions pertain to a number of habitats in the region—evergreen, deciduous, and mixed forests, grasslands, palustrine forested wetlands, and scrub/shrub (see Appendix 1). Also applicable to all migrant species and to a lesser extent resident birds is anthropogenic collision management—using siting, lighting modifications, or construction techniques to eliminate or minimize bird collisions with man-made structures.

The majority of priority landbirds identified by GoMAMN either occur exclusively in evergreen-dominated systems or utilize these habitats under appropriate management regimes. This includes some species that are normally thought of as grassland dependent (e.g., Northern Bobwhite and Henslow's Sparrow). Sustainable use, restoration, and management of grasslands are high priorities as well, and because grassland and scrub/shrub birds will utilize appropriately managed agricultural habitat, sustainable agriculture is another important technique. One of the most important and widely used management tools in evergreen, mixed forest, and grassland habitat is prescribed fire, albeit use is increasingly constrained by human encroachment on these fire-dependent ecosystems (Haines et al. 2001, Cohen 2008). Management and restoration of mixed and deciduous forests as well as palustrine forested wetlands impact many priority GoMAMN landbirds. A lesser number of species are affected through scrub/shrub management and restoration actions, and three species respond to establishment of artificial nest boxes—Red-cockaded Woodpecker and Brown-headed Nuthatch, in appropriately managed evergreen forest habitat, and Prothonotary Warbler in palustrine forested wetland habitat. Across all habitats, invasive species management can affect numerous GoMAMN priority landbirds. We assume ecosystem restoration actions would include management of invasive plant and animal species.

Geographic ranges differ across the suite of priority landbird species identified by GoMAMN (see Description of Species Groups and Important Habitats in the Gulf of Mexico Region section above and Table 3.1). A few species are found throughout the region in the appropriate season and habitats (e.g., Northern Bobwhite, Loggerhead Shrike, and Sedge Wren), with passage migrants adding a large number of species utilizing habitats across the region in spring and autumn. The other species are mainly restricted to the evergreen forests (i.e., coastal pine flatwoods) from the Florida panhandle to southeast Texas. South Florida is a wintering area for Chuck-will's-widow, Yellow-throated Warbler, and Painted Bunting (McKay and Hall 2012, Straight and Cooper 2012, Lowther et al. 2015). Management actions which are relevant to a high proportion of the GoMAMN region or habitats are highly valued (see Table 3.2, Figure 3.1, Appendix 3). Due to the variety of species selected by GoMAMN as priority

Table 3.2. *Uncertainties underpinning the relationship between management decisions and populations of landbirds 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]
Grassland Landbirds Breeding	Site / Area Management (Land Use)	Does unsustainable agriculture lower grassland bird nesting and reproductive success by degrading soil health, increasing erosion, or altering habitat structure?	Nutrient retention, soil stability, water holding capacity, bulk density, particulate organic matter	Grazing strategies can significantly influence soil function, most research shows rotational versus continuous grazing results in higher organic carbon, C/N ration, and reduced soil compaction. Site-specific conditions, however, may play a role in determining sustainable grazing regimes.	Low	High
Grassland Landbirds Breeding/ Wintering	Invasive / Problematic Species Control (Contaminants)	Does the use of pesticide lead to poor body condition and decline in reproductive success of grassland birds due to decreased invertebrate food sources?	Invertebrate species richness and abundance, avian body condition, fledgling success	Previous research shows invertebrate diversity and abundance decrease in areas where pesticide use is high	Low	High
Grassland Landbirds Breeding/ Wintering	Habitat and Natural Process Restoration (Habitat Management-Agriculture)	Does overgrazing lower reproductive success of grassland birds through the removal of cover and nesting substrate as well as decrease seed and invertebrate food sources?	Invertebrate species richness and abundance, avian body condition, fledgling success	Previous research shows that rotational grazing and light stocking rates increase grassland bird diversity across a landscape	Low	High
Grassland Landbirds Breeding/ Wintering	Invasive / Problematic Species Control (Habitat Management - Invasive Plants)	Does habitat for grassland obligate bird species become unsuitable when invasive species, like woody plants or non-native grasses and forbs, alter the vegetation community and structure?	Amount of woody cover, seed source diversity	Uncertainty regarding season, frequency and intensity of applications to benefit grassland bird survival and successful reproduction.	Low	High
Grassland Landbirds Breeding	Site / Area Management (Land Use)	What constitutes a suitable patch size, shape, and location for grassland birds in the GoMAMN region?	Habitat use, population density	Patch size, shape, and juxtaposition limitations for several species is not well defined. The degree to which patch size influences predation risk is also dependent upon surrounding land use practices. Size limitations for several species is not well defined.	High	High
Grassland Landbirds Breeding	Site / Area Management (Energy Development)	What effects do wind turbines and related activities have on deterring or attracting grassland bird species and nest success along the Gulf Coast?	Habitat use, population density	Which species are most affected? What are the long term effects or cumulative impacts on grassland bird communities? Which species would eventually re-establish or be completely driven out?	High	Unknown
Forest Landbirds Breeding	Habitat and Natural Process Restoration (Habitat Management-Agriculture)	How do agricultural practices associated with cultivated crops affect the quality of adjacent habitat for forest breeding landbirds?	Survival, productivity	Relatively little uncertainty that birds breeding in forest blocks fragemented by agriculture experience decreased productivity.	Low	High
Forest Landbirds Wintering	Habitat and Natural Process Restoration (Habitat Management-Agriculture)	How do agricultural practices associated with cultivated crops affect the quality of adjacent habitat for forest wintering landbirds?	Survival, body condition at spring departure (wintering)	Uncertainty about the long-term effects on populations of landbirds that winter in forest remnants adjacent to row crop agriculture.	High	Unknown

Table 3.2 (continued).

Species Season(s)	Management Category[a]	Question	End-point to measure mgmt. performance	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Forest Landbirds Breeding/ Wintering	Habitat and Natural Process Restoration (Habitat Management-Forestry)	How do silvicultural practices affect habitat quality for forest landbirds?	Survival, population size, productivity (breeding), body condition at spring departure (wintering)	Silvicultural practices can have positive and negative effects on habitat quality of adjacent forest.	High	High
Forest Landbirds Breeding/ Wintering	Site / Area Management (Land Use)	What are the important forest stand characteristics (block size/shape, age, species composition, vertical structure, proximity to other forest blocks, etc.) for maintaining and/ or increasing populations of forest landbirds? What are the appropriate silvicultural techniques for attaining those desired forest characteristics?	Survival, population size, productivity (breeding), body condition at spring departure (wintering)	It is currently unclear how interactions among stand- and site-level vegetation characteristics, forest block size, shape and connectivity, fire history, and arthropod and fruit densities affect avian demography. The degree to which silvicultural practices and other management can replicate natural processes in creating habitat for bird species of concern is not clear, or varies by species.	High	High
Forest Landbirds Breeding	Species Recovery (Habitat Management)	Is deployement of artificial nest boxes an effective and efficient management tool to increase local populations of Prothonotary Warblers or Brown-headed Nuthatches?	Population size, productivity	It is unclear whether investment in nest box deployment programs for Prothonotary Warblers and Brown-headed Nuthatches are an effective management option. It is unknown whether these species' populations are most limited by availability of suitable nest cavities.	Low	Unknown
Forest Landbirds Breeding/ Wintering	Site / Area Management (Land Use)	How does human development affect the quality of remaining habitat for forest breeding landbirds?	Survival, population size, productivity (breeding), body condition at spring departure (wintering)	Some generalist forest breeding species can persist in these altered environments depending on structure and composition of post-development vegetation. Significance of impacts to remnant adjacent forest tracts through increased predation (and/or nest parasitism during the breeding season) will vary depending on the size of the converted area and the size of the remaining adjacent forested tracts.	Low	High
Passage migrant landbirds Migration	Habitat and Natural Process Restoration (Habitat Management-Agriculture)	How do agricultural practices influence likelihood of stopover and stopover success (e.g., food availability, mass gain, stopover duration) in cultivated crop habitats?	Migrant density, refueling rates, stopover duration, survival, population size	Passage migrants such as Dickcissel and Bobolink may use cultivated crop fields during migration, yet little is known about how agricultural practices influence habitat quaility and stopover success.	High	Low
Passage migrant landbirds Migration	Habitat and Natural Process Restoration (Habitat Management-Agriculture)	How do agricultural practices influence likelihood of stopover and stopover success (e.g., food availability, mass gain, stopover duration) in pasture and hay field habitats?	Migrant density, refueling rates, stopover duration, survival, population size	Passage migrants such as Dickcissel and Bobolink may use pasture/hay fields during migration, yet little is known about how agricultural practices influence habitat quaility and stopover success.	High	Low

Table 3.2 (continued).

Species Season(s)	Management Category[a]	Question	End-point to measure mgmt. performance	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Passage migrant landbirds Migration	Habitat and Natural Process Restoration (Habitat Management)	How do changes in vegetation composition affect stopover habitat quality, passage migrant habitat usage, condition, and survival?	Migrant density, refueling rates, stopover duration, survival, population size	Studies have shown that migrants exhibit differential selection related to vegetation composition and habitat structure, but more study is needed to determine how habitat use during migration is related to survival or carryover effects.	High	High
Passage migrant landbirds Migration	Site/Area Management (Land Use)	How do land use-related changes in vegetation composition and structure affect the quality of stopover habitat?	Migrant density, refueling rates, stopover duration, survival, population size	There is uncertainty about how land use changes in vegetation composition and structure affect quality and carrying capacity of stopover habitat.	High	High
Passage migrant landbirds Migration	Site/Area Management (Land Use)	How does the number and size of habitat patches in the landscape influence survival of passage migrants?	Migrant density, refueling rates, stopover duration, survival, population size	There is uncertainty about the number and size of habitat patches needed to support passage migrants given that extrinsic factors can influence where migrants stopover.	High	High
Passage migrant landbirds Migration	Site/Area Management (Land Use)	How does anthropogenic development affect stopover habitat selection, stopover success, and survival of passage migrants?	Migrant density, refueling rates, stopover duration, survival, population size	Uncertainty about how the distribution of anthropogenic development and its associated threats affects survival of passage migrants	High	High
Passage migrant landbirds Migration	Site/Area Management (Species Stewardship)	Does artificial lighting affect migrant distribution patterns at stopover?	Migrant density, refueling rates, stopover duration, survival, population size	Artificial lights are known to attract migrants and there is uncertainty about how lights influence stopover habitat selection.	High	High

[a]Categories follow the classification scheme and nomenclature presented by Salafsky et al. (2008) and Conservation Measures Partnership (2016). GoMAMN derived level three actions are noted in parentheses.
[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.

landbirds, the body of management-related research is large for certain species, such as Northern Bobwhite and Red-cockaded Woodpecker, and sparse for others.

In particular, little management-related research has been directed towards effects on wintering or migrant species; most management that does occur is directed at breeding landbirds. And, even where breeding-season focused management is taking place, the long-term effectiveness is not clear. A review of literature including the Birds of North America accounts pertinent to the GoMAMN's priority landbirds identifies some management-related research needs to reduce uncertainty and better manage landbird populations (see literature cited). For example, despite the large volume of management-related research previously directed at Northern Bobwhite, Brennan et al. (2014) note the need for studies relating to seven different factors, including restoration techniques and various habitat management applications. For most other GoMAMN priority landbirds the list of identified management-related research needs is brief or non-existent. For species with identified needs, questions exist regarding prescribed fire intervals and season for Red-headed Woodpecker, Brown-headed Nuthatch, and Grasshopper Sparrow (Vickery 1996, Slater et al. 2013, Frei et al. 2017), the effects of various silvicultural harvest methods, entry interval, and snag creation for Red-headed Woodpecker, Brown-headed Nuthatch, Wood Thrush, and Swainson's Warbler (Anich et al. 2010, Evans et al. 2011, Slater et al. 2013, Frei et al. 2017), and the effects of timing and types of disturbance regimes for grasslands and scrub/shrub habitat for Common Ground-Dove, Grasshopper Sparrow, Henslow's Sparrow, and LeConte's Sparrow (Vickery 1996, Bowman 2002, Lowther 2005, Baldwin et al. 2007, Johnson et al. 2011).

The management practices commonly used as part of restoration activities in the Gulf of Mexico region are 1) prescribed fire, 2) ecosystem restoration, 3) invasive species removal, and 4) establishment of artificial nest boxes. Other common management actions unrelated to restoration can have significant effects on landbirds in the GoMAMN region. These include conversion of forest to agriculture and subsequent agricultural practices, and silvicultural practices to produce forest products (e.g., pulp and lumber). Landbird priorities for management actions, management related questions, and suggested avian response variables and non-avian covariates to monitor can be found in Table 3.2 and in the Influence Diagrams (Figure 3.1 and Appendix 3). Priorities ranked as high, impact a larger number of priority species as well as passage migrants.

For all monitoring projects that address management actions and their impacts on landbirds, the timing of those actions in different seasons and habitats must also be considered. The same management action, for example, may have a different impact on a species or community depending on when and where it is performed (e.g., burning during the breeding vs the winter season; burning grassland vs evergreen habitat). Additionally, it is essential to understand the full annual cycle (Marra et al. 2015, Cohen et al. 2017) as the conditions experienced one season can carry over to influence subsequent seasons (e.g., Smith and Moore 2003, Paxton and Moore 2015, Paxton and Moore 2017).

Priority Status and Trend Assessments

Species status and trend information is a common currency of wildlife management and strongly influences conservation funding as well as research and management priorities. Therefore, this information is valued by the GoMAMN community of practice, at the full range of spatial scales (global to local), as a measure of response to priority management actions and ecological drivers. The continental concern score for each of our priority species is included in Table3.1. For some priority species, population level status and trend assessments are likely accurate and appropriate (e.g., Northern Bobwhite, Red-cockaded Woodpecker), whereas these metrics may not be appropriate for other, less well-studied species. Additionally, given the large suite of species that make up passage migrants, we are unable to provide metrics for each species, but long-term datasets reveal that some passage migrant species have declined over the past quarter century (see Terborgh 1989, Askins et al. 1990, Both et al. 2006, Wilcove and Wikelski 2008).

Priorities follow the metrics found in the status and trends section of the objective hierarchy, in which we value collecting information on species with declining trends and/or great uncertainty about their trend (Figure 2.2). Ideal monitoring and research efforts will collect data over large spatiotemporal scales, which can greatly reduce uncertainty as well as provide meaningful conservation and management implications (e.g., Buler et al. 2007b, Buler and Moore 2011, Cohen et al. 2015, Lain et al. 2017, Moore et al. 2017, Sands et al. 2017). In conjunction with bird monitoring data, we value the committed collection of habitat quantity and quality data over long time scales for species of interest. For the collection of these data over broad geographic scales, we rely on data collected by the Gulf States via the Gulf of Mexico Alliance Master Mapping Program, the Multi-Resolution Land Characteristics Consortium, a Federal agency partnership responsible for production of the National Landcover Database (NLCD), NOAA Coastal Change Analysis Program (C-CAP), and the Council Monitoring and Assessment Program, a RESTORE Council led effort. In addition, we will collaborate with habitat data collection and evaluation with the Migratory Bird Joint Venture programs (Migratory Bird Joint Ventures 2018) in the GoMAMN region: Gulf Coast, Atlantic Coast, East Gulf Coastal Plain, Lower Mississippi Valley, Rio Grande, and Oaks and Prairies.

Given that information on status and trends as well as monitoring programs should be more similar for species that share the same habitat during various seasons, below we provide information specific to: forest breeding, forest wintering, grassland breeding, grassland wintering, and passage migrant landbirds.

FOREST BREEDING. Some status and trend information for GoMAMN forest breeding birds is available through analysis of Breeding Bird Survey (BBS) data, a road-based point count program. For detailed information on the BBS see Sauer et al. (1997). The BBS currently provides trend information from 1966–2015. Trend information is available by state and physiographic region, but unfortunately there is no direct correspondence with the GoMAMN boundary, thus no trend information is available for that specific area. For each region in which a species' trend is reported, the BBS provides a species and region-specific Regional Credibility Measure, indicated by one of three colors: red, yellow, or blue (Sauer et al. 2017). The lowest confidence category (red) includes data with important deficiencies related to very low abundance, small sample size (less than five routes in the region) or imprecision such that a 5% change per year would not be detected over the long term. The second highest level of confidence (yellow) reflects data with deficiencies related to low abundance, small sample size (less than 14 routes in the region), or imprecisions such that a 3% change per year would not be detected over the long term. Estimates with the highest confidence, denoted by blue, include data with moderate abundance, at least 14 samples in the long term, and are of moderate precision. For example, the trend for Northern Bobwhite in Florida is given a blue regional credibility measure, because the species is detected on 90 routes, while the trend for Northern Bobwhite in New Hampshire is given a red credibility measure, due to the species being detected on only four routes and in low numbers. Given sufficient detections, species trends are also available for individual BBS routes in the GoMAMN region. There are ~200 current or historic BBS routes in the GoMAMN region. Sands et al. (2017) used BBS data to analyze trends for 27 bird species in the Gulf Coast Joint Venture (GCJV) geography, and conducted a power analysis to estimate 80% power to detect trends at 3, 5, 10, and 20-year intervals based on ±1%, ±3%, ±5%, and ±10% rates of annual population changes. Several of the 27 species treated in Sands et al. (2017) are also GoMAMN priority landbirds: Bachman's Sparrow, Brown-headed Nuthatch, Loggerhead Shrike, Northern Bobwhite, Painted Bunting, Prothonotary Warbler, Red-cockaded and Red-headed Woodpeckers, Swainson's Warbler, and Wood Thrush. Of these, Red-cockaded Woodpecker had insufficient detections prohibiting reliable trend estimates for the GCJV region. The power analysis indicated that BBS data could reliably estimate trends for 4 of the 27 species: Brown-headed Nuthatch [-0.50%, 95% Confidence Interval (CI) (-1.88%, 1.01%)], Northern Bobwhite [-4.50%, 95% CI (-5.16%, -3.92%)], Swainson's Warbler [-3.44%, 95% CI (-5.73%, -1.09%)], and Wood Thrush [-1.78%, 95% CI (-3.05%, -0.58%)].

Hamel et al. (1996) recommended the use of 5–10 minute point counts as a means for land managers in the southeast U.S. to obtain information on numbers of birds and population trends on their properties. Hamel et al.'s (1996) methodology entails the use of discrete distance and temporal categories, where the bird's distance from the observer and the interval of detection (first three minutes, the next two minutes, or final five minutes of the count) are recorded. Subsequent to publication of Hamel et al. (1996), other researchers expressed doubt regarding the utility of unadjusted point counts in determining bird species abundance or density because of issues related to incomplete detection. Recommendations to address these detection issues include changes in sampling techniques (Nichols et al. 2000, Bart and Earnst 2002) or estimating detection probabilities through data analysis, provided the data are grouped by distance and time observed (Farnsworth et al. 2002, Rosenstock et al. 2002). Similarly, Somershoe et al. (2006) recommended incorporation of distance sampling and quantitative habitat characterization into BBS monitoring, and Twedt (2015) recommended distance sampling and using three 1-minute time intervals on BBS points to improve detection probabilities. If additional information on vital rates is desired, the approach utilized by Saracco et al. (2008) should be considered.

FOREST WINTERING. The Audubon Christmas Bird Count (CBC) is the only long-term dataset available for the GoMAMN region with potential for tracking wintering forest landbird status and trends. However, the CBC was not designed for population monitoring and has numerous problems restricting its use for that purpose, including variability in count effort within and across individual CBC areas (circles), and nonrandom count circle distribution (Dunn et al. 2005). Notwithstanding its flaws, Dunn et al. (2005) cited the potential application of CBC data to large-scale studies because of its broad temporal and spatial coverage, and offered suggestions for improving the utility of existing data, and for collecting future data. Sauer and Link (2002) and Niven et al. (2004) describe modeling approaches they used to account for CBC data shortcomings to develop population trends for selected bird species in specific regions of North America.

Similar to their analysis of BBS data, Sands et al. (2017) used CBC data to analyze population trends of 37 bird species in the GCJV region. Sands et al. (2017) also conducted a power analysis on the CBC data, using the parameters described above for their BBS analysis. GoMAMN priority landbirds included in the analysis were LeConte's Sparrow, Loggerhead Shrike, and Northern Bobwhite. The authors found that the CBC reliably estimated trends for two of the 37 species in the GCJV region: Ring-necked Duck (*Aythya collaris*) and Loggerhead Shrike.

Point count methodology (Hamel et al. 1996) that has been modified to improve detection probabilities (Nichols et al. 2000, Bart and Earnst 2002, Farnsworth et al. 2002, Rosenstock et al. 2002) may be appropriate to determine the status and trends of priority forest landbirds wintering in the GoMAMN region. If additional information on vital rates is desired, the approach utilized by Saracco et al. (2008) should be considered.

GRASSLAND BREEDING. Status and trend information from 1966–2015 and 2005–2015 are available through the aforementioned BBS analysis (Sauer et al. 1997) for Northern Bobwhite in several survey regions that overlap with the GoMAMN boundary; all indicate an overall decline in bobwhite abundance for these regions. Credibility measurement indicators for all survey regions within the GoMAMN boundary are in the blue category, meaning sample size, precision, and abundances are adequate for reliable trend estimates. Similarly, Loggerhead Shrike shows declines across the GoMAMN region according to the BBS, with reliable trend estimates according to BBS credibility measurement indicators. Grasshopper Sparrow breeding is much more localized in the GoMAMN region vs Northern Bobwhite and Loggerhead Shrike. The BBS indicates a non-significant increasing trend for the Gulf Coastal Prairie and Tamaulipan Brushland physiographic regions, but assigns a red credibility measurement indicator for the data, reflecting some combination of very low abundance, very small sample size, and/or imprecision. Besides BBS trend data, comprehensive population trend data are scarce for grassland species breeding in the U.S. Gulf Coastal Plain.

Buckland (2006) provides information comparing five common methods of estimating bird densities: five-minute point counts where the observer remained stationary and recorded distances to birds detected, three-minute snapshot surveys where the observer was allowed to move around after the snapshot period, five-minute cue-count surveys where the observer recorded songbursts only, line transects where the observer traveled along a line and recorded distances to all bird detections, and territory mapping where an observer recorded locations of birds detected during nine visits. Of these sampling techniques, the line transect method proved to be the most efficient sampling method and overall provided the most precise estimates when comparing reported coefficient of variations (CV). Because grasslands have less visual obstruction from an observer point of view and maneuverability tends to be more flexible than in forested habitat, walking line transects may be best suited for monitoring breeding grassland bird densities and abundances. Ideal number of detections for reliable estimates is >60 (Buckland et al. 2001). To maximize number of detections, number and length of transects on the landscape will vary depending on habitat availability and size. The use of multiple covariates may also increase the precision of density estimates (Marques et al. 2007); common covariates used in analyses include observer, julian date, and time of day or hours after sunrise.

GRASSLAND WINTERING. Very limited information is available on population trends of wintering grassland birds in the GoMAMN region. General trends for wintering priority species primarily rely on the Audubon CBC. Number of count circles recording Henslow's Sparrow from 1970–2005 has generally increased, with the lowest number of recordings in 1985 and peak number of recordings in 2001 (Cooper 2012). An analysis of CBC data for the Le Conte's Sparrow from 1965–2002 showed a slight negative population trend; however, populations have generally remained stable (Niven et al. 2004).

Loggerhead Shrike (*Lanius ludovicianus*).
Photo credit: Tom Koerner

Because of the non-parameterized nature of the CBCs, populations trends may be unreliable. Twedt et al. (2008) compared two methods of winter grassland bird surveys: Winter Bird Population Studies, an area-search method by a single observer over multiple visits, and Project Prairie Birds survey where an observer walks a line transect recording birds that are flushed by two "non-observing flushers." The authors found that while the Winter Bird Population Studies method produced higher estimates of species richness, Project Prairie Bird survey methods tended to provide higher abundances, especially of secretive species, and recommended the use of the latter method for species specific surveys. Further, by incorporating distance sampling to the Project Prairie Bird method, researchers can obtain detection probabilities, yielding more precise and comparable estimates of densities and abundances across grassland types throughout the region.

PASSAGE MIGRANTS. There is limited information on the status and trends of the specific populations using stopover habitat within the GoMAMN region, although many migrant populations are in decline (reviewed by Cohen et al. 2017; see also Sauer et al. 2013, Rosenberg et al. 2016). Thus, we would be most interested in broad-scale, population-level trends over time that inform migrant-habitat relations within the Gulf of Mexico region as well as between different functional

Table 3.3. *Uncertainties related to how ecological processes impact populations of landbirds in the northern Gulf of Mexico*

Species Seasons	Ecological Process Category[a]	Question	Endpoint to Measure	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Grassland Landbirds Breeding/ Wintering	Climatic Processes	How are grassland obligate bird populations, nesting productivity, and food sources affected by variation in annual precipitation?	Population size, productivity, invertebrate and seed species richness and abundance	Difficult to predict impacts. Some insect population are cyclic in nature and independent of weather condtions.	High	Unknown
Grassland Landbirds Breeding/ Wintering	Natural Disturbance Regime	How do periods of extreme drought affect population dynamics of grassland obligate birds?	Population size, survival	How long does it take for populations significantly affected by drought to recover? What is the definition of recovery (what is the timeline when determining stable or recovered population: 1, 5, 10 years)?	High	Unknown
Grassland Landbirds Breeding	Interactions Between Organisms	How is nestling success of grassland birds impacted by fire ant predation?	Productivity, nestling and fledgling success, fire ant abundance, habitat use	How are populations of different species affected? Does nesting ecology of species significantly influence vulnerability to predation (i.e. ground nesting birds versus slightly elevated nests)?	Low	High
Grassland Landbirds Breeding/ Wintering	Interactions Between Organisms	How are invertebrate food sources for grassland birds affected by the establishment of red imported fire ant colonies?	Invertebrate species richness and abundance, fire ant abundance, habitat use	What is the overlap between grassland bird and fire ant food sources? Many studies are related to economic rather than ecological impact.	High	Unknown
Forest Landbirds Breeding/ Wintering	Climatic Processes	How do changes in annual precipitation and temperature affect food availability for forest landbirds during breeding and wintering seasons?	Invertebrate species richness and abundance, fruiting plant species richness and abundance, habitat use	Difficult to predict impacts. Some insect population are cyclic in nature and independent of weather condtions.	High	Unknown
Forest Landbirds Breeding	Natural Disturbance Regimes	How do extreme weather events affect the nest success and survival of forest landbirds?	Productivity, fledgling success, survival	Difficult to predict the impacts of extreme weather events and likely impossible to influence.	High	Unknown
Forest Landbirds Wintering	Climatic Processes	How do extreme cold events affect the overwinter survival of forest landbirds?	Invertebrate species richness and abundance, fruiting plant species richness and abundance, survival, body condition	Difficult to predict the impacts of extreme cold events and likely impossible to influence.	High	Unknown
Forest Landbirds Breeding/ Wintering	Natural Disturbance Regimes	How do storm-induced changes in vegetation structure and composition affect habitat quality for forest lanbirds during breeding and wintering seasons?	Invertebrate species richness and abundance, fruiting plant species richness and abundance, survival, body condition at spring/autumn departure, productivity (breeding), habitat use	Depending on the bird species, storm-created forest gaps may have positive or negative effects on forest breeding landbirds.	High	Unknown

Table 3.3 (continued).

Species Seasons	Ecological Process Category[a]	Question	Endpoint to Measure	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Forest Landbirds Breeding	Climatic Processes	Will climate induced changes in vegetation structure and composition affect resources available to forest breeding landbirds?	Invertebrate species richness and abundance, fruiting plant species richness and abundance, body condition at autumn departure, productivity, habitat use	There is uncertainty about how climate induced changes in the vegetation composition and structure of habitats influence food availability and nesting substrates for forest breeding landbirds.	High	High
Forest Landbirds Wintering	Climatic Processes	Will climate induced changes in vegetation structure and composition affect resources available to forest wintering landbirds?	Invertebrate species richness and abundance, fruiting plant species richness and abundance, body condition at spring departure, survival, habitat use	There is uncertainty about how climate induced changes in the vegetation composition and structure of habitats influence food availability for forest wintering landbirds.	High	High
Forest Landbirds Breeding	Interactions Between Organisms	How does forest patch size and landscape context influence predation on forest breeding landbirds?	Habitat use, population density, survival, productivity	There is uncertainty about the minimum forest patch size needed to reduce predation of forest breeding landbirds and about how this relationship is influenced by landscape context.	High	Unknown
Forest Landbirds Wintering	Interactions Between Organisms	How does forest patch size and landscape context influence predation on forest wintering landbirds?	Habitat use, population density, survival	There is uncertainty about the minimum forest patch size needed to reduce predation of forest wintering landbirds and about how this relationship is influenced by landscape context.	High	Unknown
Forest Landbirds Breeding	Interactions Between Organisms	How does deer browsing affect the nesting and foraging habitat of forest breeding landbirds?	Habitat use, population density, productivity, invertebrate species richness and abundance, fruiting plant species richness and abundance, body condition at autumn departure	There is uncertainty regarding what level of deer herbivory results in forest block-level changes in survival and productivity of priority forest breeding landbirds, and which GoMAMN priority breeding landbirds are impacted.	High	Unknown
Forest Landbirds Wintering	Interactions Between Organisms	How does deer browsing affect the foraging habitat of forest wintering landbirds?	Habitat use, population density, survival, invertebrate species richness and abundance, fruiting plant species richness and abundance, body condition at spring departure	There is uncertainty regarding what level of deer herbivory results in forest block-level changes in survival of priority forest wintering landbirds, and which GoMAMN priority wintering landbirds are impacted.	High	Unknown
Forest Landbirds Breeding	Hydrological Processes	How does a change in hydrology affect nest sites and food availability for forest breeding landbirds?	Habitat use, population density, productivity, invertebrate species richness and abundance, fruiting plant species richness and abundance, body condition at autumn departure	Hydrologic changes that alter plant species composition may have positive and negative affects on nesting substrates and food availability for forest breeding landbirds.	High	Unknown

Table 3.3 (continued).

Species Seasons	Ecological Process Category[a]	Question	Endpoint to Measure	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Forest Landbirds Wintering	Hydrological Processes	How does a change in hydrology affect roost sites and food availability for forest wintering landbirds?	Habitat use, population density, survival, invertebrate species richness and abundance, fruiting plant species richness and abundance, body condition at spring departure	Hydrologic changes that alter plant species composition may have positive and negative affects on roosting substrates and food availability for forest wintering landbirds.	High	Unknown
Forest Landbirds Breeding	Interactions Between Organisms	How do invasive plant species affect food availability for forest breeding landbirds?	Habitat use, population density, productivity, invertebrate species richness and abundance, fruiting plant species richness and abundance, body condition at autumn departure	Some invasive plant species produce fruits that can be used by forest breeding landbirds while other plant species decrease food availability by hosting fewer insects than native plants.	High	Unknown
Forest Landbirds Wintering	Interactions Between Organisms	How do invasive plant species affect food availability for forest wintering landbirds?	Habitat use, population density, survival, invertebrate species richness and abundance, fruiting plant species richness and abundance, body condition at spring departure	Some invasive plant species produce fruits that can be used by forest wintering landbirds while other plant species decrease food availability by hosting fewer insects than native plants.	High	Unknown
Passage migrant landbirds Migration	Climatic Processes	Will climate induced changes in precipitation and temperature patterns reduce food availability for passage migrants?	Migrant density, refueling rates, stopover duration, survival, population size, invertebrate species richness and abundance, fruiting plant species richness and abundance	Climate change may result in asynchrony between peak food availability and peak migration traffic. Uncertainty remains about how climate change will affect the food resources migrants currently depend on.	High	High
Passage migrant landbirds Migration	Natural Disturbance Regime	Will increases in severe storm frequency significantly alter the vegetation structure and composition of stopover habitat and affect resources available to migrants?	Migrant density, refueling rates, stopover duration, survival, population size, invertebrate species richness and abundance, fruiting plant species richness and abundance, habitat use	There is uncertainty about how an increase in severe storm frequency will influence the availability of food and shelter for passage migrants.	High	High
Passage migrant landbirds Migration	Natural Disturbance Regime	Do hurricane induced changes in vegetative composition and structure have a negative effect on landbird use of stopover sites?	Migrant density, refueling rates, stopover duration, survival, population size, invertebrate species richness and abundance, fruiting plant species richness and abundance, habitat use	There is uncertainty about how hurricane-induced changes in the vegetation composition and structure of habitats influences stopover success of passage migrants.	High	High

Table 3.3 (continued).

Species Seasons	Ecological Process Category[a]	Question	Endpoint to Measure	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Passage migrant landbirds Migration	Interactions Between Organisms	Do invasive species negatively affect passage migrants by altering the quality of stopover habitat?	Migrant density, refueling rates, stopover duration, survival, population size, invertebrate species richness and abundance, fruiting plant species richness and abundance, habitat use	Although many passage migrants exhibit dietary plasticity, there is uncertainty that invasive species provide quality food resources for passage migrants.	High	High

[a]Categories follow the classification scheme and nomenclature presented by Bennet 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.

types of stopover habitats. There are essentially no long-term monitoring programs, and no projects which collect data across multiple states, which limits our ability to understand how en route events in the GoMAMN region impact passage migrant populations. Such monitoring programs are needed to address key research needs, including distribution, timing and habitat associations, habitat characteristics and quality, migratory connectivity, as well as threats to and current conservation status of airspace and stopover habitat (Cohen et al. 2017). However, there have been a few long-term (20+ years) migration banding stations that may provide a starting point for population metrics. Current landbird projects are collecting important data in key stopover areas and we hope many of these projects will continue long term, but data collected at larger continuous spatial scales are needed to truly understand the status and trend of passage migrants (see Cohen et al. 2017 for additional needs). The integration of weather surveillance radar and banding data, along with new technologies, provide powerful tools to better monitor and understand migrants across the region.

Priority Ecological Processes

Identifying important ecological processes and reducing uncertainty associated with their effects on populations of GoMAMN priority landbirds is highly valued by the GoMAMN community of practice. We ranked questions about how ecological processes impact landbirds with a combination of our estimated effect size (Unknown > High > Low) and uncertainty (High > Low). Questions with the same combination of effect size and uncertainty have the same rank and were not placed in a particular order within their group (Table 3.3). The landbird working group developed the elements found in the ecological processes table through several conference calls drawing on expert knowledge from scientists, researchers, and managers across the Gulf of Mexico who study landbirds and/or manage their appropriate habitats. To prioritize these processes, we used the ecological process objective hierarchy values, which emphasize our collective interest in questions relevant to our priority species and reduce uncertainty in how ecological processes influence population dynamics and improve our ability to predict those dynamics (Figure 2.2). We used the landbird influence diagrams (Figure 3.1 and Appendix 3) to connect our ecological processes with population dynamics. The Influence Diagrams and Table 3.3 identify questions associated with priority ecological processes and suggest avian response variables and non-avian covariates that should be considered in developing monitoring programs. Ecological processes for each habitat/season group are described below:

FOREST BREEDING. The GoMAMN Landbird Working Group identified a number of ecological processes influencing populations of forest breeding landbirds. Anthropogenic habitat changes have resulted in conversion of forested habitat to agriculture and residential or commercial development. Loss and fragmentation of forested habitat have negatively impacted many species of North American birds through reduction in available nesting and foraging habitat and increased predation and nest parasitism rates (Freemark and Collins 1989, Robinson 1989, Harris and Gosselink 1990, Smith et al. 1993). Depending on the practices and

Painted bunting (*Passerina ciris*). Photo credit: Robert Pos

bird species of interest, alteration of forest structure and plant species composition through silvicultural practices can have positive or negative impacts (Harris and Gosselink 1990, Drapeau et al. 2000, Bassett-Touchell and Stouffer 2006, Heltzel and Leberg 2006, Brockerhoff et al. 2008, Twedt and Somershoe 2009). Techniques and scale of timber harvest, or conversion of natural forests to monotypic forest product plantations can have significant impacts to forest breeding birds by altering forest structure and plant species composition (Harris and Gosselink 1990, Drapeau et al. 2000, Bassett-Touchell and Stouffer 2006, Heltzel and Leberg 2006, Brockerhoff et al. 2008, Twedt and Somershoe 2009, Yahner et al. 2012). Even-aged timber harvest (e.g. clear-cutting) typically produces habitat dominated by shrubs and saplings and is used by bird species dependent on that vegetative structure, such as Yellow-breasted Chat (*Icteria virens*) and Common Yellowthroat (*Geothlypis trichas*), while bird species which utilize mature forests, such as woodpeckers, are typically absent (Yahner et al. 2012). Even-aged timber harvest may subject nesting birds in adjacent mature forest blocks to increased predation and nest parasitism (Yahner et al. 2012). Conversely, habitat for early successional habitat birds may be lacking in mature forest stands, and managers may utilize selective timber harvest to mimic natural disturbance and create small inclusions of early successional habitat (Twedt and Someshoe 2009). The impacts of weather on food supplies, survival, and forest structure to forest breeding landbirds is believed to be significant (Blake et al. 1989, Sherry and Holmes 1989, Wiley and Wunderle 1993, Torres and Leberg 1996); with the added impacts of altered weather patterns due to changing climatic conditions (Butler 2003, Crick 2004, Hitch and Leberg 2007). Other ecological processes identified by the GoMAMN Landbird Working Group include predation (possibly influenced by anthropogenic habitat changes described above), altered hydrology due to water withdrawals or flood control measures, and invasive plant and animal species.

FOREST WINTERING. The same ecological processes identified for forest breeding landbirds are expected to be important for forest wintering landbirds in the GoMAMN region. Overwinter survival and body condition may be impacted by conversion of forests to other habitat types (Greenberg and Droege 1999, Greenberg and Matsuoka 2010), forest fragmentation (Doherty and Grubb 2000, Doherty and Grubb 2002), alterations to forest structure and species composition through timber management (White et al. 1996), changes in hydrology, weather extremes (Rice 1924, Petit 1989, Avery 2018) and shifts from normal patterns due to climate change, predation, and invasive species. Greenberg and Droege (1999) and Greenberg and Matsuoka (2010) postulated that loss and degradation of woody wetlands on the winter range of Rusty Blackbird was a major factor in that species' population decline. Dougherty and Grubb (2000) studied winter bird distribution in small (0.54–6.01 hectares) forest fragments in Ohio and found strong positive relationships between species presence, density and diversity and forest fragment size. Dougherty and Grubb (2000) also found that isolation, as measured by distance to adjacent forest fragments and patch connection through fencerows, negatively influenced the presence of many bird species. However, Hamel et al. (1993) did not detect any effects of forest fragmentation (smallest patch = 17 hectares) on wintering avian species richness and evenness in Tennessee. White et al. (1996) examined distribution and abundance of wintering birds in Georgia in fragmented mature pine, fragmented mature upland hardwood, and pine plantation habitats. Overall, they found that only about 25% of bird species detected showed significant habitat preferences, but species richness, diversity, and evenness was higher in the mature forest types versus pine plantations.

GRASSLAND BREEDING. Like forest breeding birds, many of the ecological processes affecting grassland breeding birds derive from anthropogenic changes on the landscape. These include invasion of woody species as a result of fire suppression, habitat loss or fragmentation from agriculture, and incompatible land management practices (i.e., inappropriately timed mowing/haying, overstocked livestock) (Potter et al. 2007, Jaster et al. 2012, Kreitinger et al. 2013). The introduction of non-native grasses for livestock forage is a major threat to many grassland birds. Establishment of exotic grasses leads to decreased diversity in plant and invertebrate communities and structural changes to potential nesting habitat (Fleischner 1994, Flanders et al. 2009, Flory and Clay 2010). Many commonly introduced species include cool-season grasses, or grasses that grow during spring or fall when temperatures are cooler (i.e. Tall Fescue [*Schedonorus arundinaceus*], Bromegrasses [*Bromus* spp.], Ryegrasses [*Lolium* spp.]). Native prairies within the GoMAMN region, however, are historically dominated by warm-season grasses that provide appropriate nesting and foraging habitat for grassland birds. Additionally, increased levels of atmospheric CO_2 combined with predictions of hotter, dryer summers are projected to create conditions that favor non-native cool-season grasses (Collatz et al. 1998, Wand et al. 1999).

The use of pesticides in agricultural areas may also pose a significant threat to grassland birds; reduced insect availability to insectivores can affect all life stages of birds and may have an even greater impact on populations than agriculture (Mineau and Whiteside 2013). The introduction of non-native red imported fire ants (*Solenopsis invicta*) and tawny crazy ants (*Nylanderia fulva*) can decrease insect food sources and prey upon ground nesting birds as well (Allen et al. 2004, LeBrun et al. 2013). Little research, however, has been focused on tawny crazy ant effects on wildlife. Other non-anthropogenic related threats include nest predation by Brown-headed Cowbirds (*Molothrus ater*). Songbird reproductive success rates have been shown to be negatively affected by cowbird nest predation, and effects may be further exacerbated with the encroachment of woody vegetation (Shaffer et al. 2003, Patten et al. 2006).

GRASSLAND WINTERING. Most ecological processes that affect wintering grassland birds are the same as those listed under the breeding grassland birds section above. These include invasion of woody species as a result of fire suppression, habitat loss or fragmentation from agriculture, and incompatible land management practices (i.e., inappropriately timed mowing/haying, overstocked livestock) (Potter et al. 2007, Jaster et al. 2012, Kreitinger et al. 2013). Wintering populations may also be affected by climate change. As atmospheric CO_2 increases and climatic conditions begin to favor cool-season non-native grasses, prairies may no longer be able to support populations of wintering grassland birds. Seeds make up the majority diet of overwintering birds. However, as non-native grasses become established and prairie species richness declines, food availability for wintering birds may be significantly limited. Additionally, frequent extreme weather events, such as freezes and floods, can impact foraging success by lowering the abundance of insect food sources (Serie and Jones 1976, Graber and Graber 1979). There is high uncertainty, however, as climate models are variable.

PASSAGE MIGRANTS. Interactions among ecological processes influencing passage migrants are complex and operate at multiple scales, both temporally and spatially, with effects experienced at one place in time (e.g., stopover) carrying over to influence an individual's success in the subsequent stage of the annual cycle (e.g., breeding) (Cohen et al. 2017). During migration, individuals must stop in order to rest and refuel and decisions about when and where to stop typically occur with incomplete information, in unfamiliar places, and within landscapes that have heterogeneous configurations of habitat quality and quantity (reviewed by Moore 2018). At stopover sites, migrants then must attain a positive energy balance in the face of variable food availability, competition with other migrants as well as resident birds, and predation, all the while needing to resume migration in a timely fashion (Moore 2018). The four major categories of ecological processes identified to influence passage migrants include climate change, vegetative composition of stopover sites, anthropogenic development, and habitat availability. Increasing our understanding of these underlying processes will increase understanding of population changes, including the effects of direct management actions versus ecological processes that affect the populations of migratory species.

The effects of climate change on migrant populations is uncertain and has the potential to impact a significant proportion of the population. Climate change can affect passage migrants through a mismatch in peak migration traffic and peak food availability—arguably the most important factor influencing migrant distributions (e.g., Buler et al. 2007b, Zenzal et al. 2018). Additionally, climate change can influence the composition and structure of vegetation, through changes in temperature and precipitation as well as increased frequency of severe storms like hurricanes (Scavia et al. 2002; Knutson et al. 2010; Holland and Bruyère 2014), which may influence the availability and quality of food resources (Dobbs et al. 2009, Lain et al. 2017). In addition to hurricanes, vegetative composition at a stopover site can also be influenced by the invasion of exotic species (e.g., Chinese tallow), which can occur in conjunction with hurricanes. As discussed in the Primary Threats and Conservation Challenges section above, invasive species such as Chinese tallow may provide fewer resources, both direct (fruit) and indirect (arthropods), for migrants (Barrow et al. 2000, Barrow and Renne 2001; but see Conway et al. 2002). Land use changes also influence vegetative composition; for example, the conversion of forested habitat to cattle grazing or agricultural lands may still provide habitat but likely at a lower quality to the detriment of migrants (Barrow et al. 2000, Barrow et al. 2005). Urbanization also decreases available habitat and can introduce factors, such as invasive species, tall structures, pollution, pesticides, and free ranging/feral cats that may degrade existing habitats (Barrow et al. 2005). Additionally, urban areas create artificial light pollution that has been shown to attract migrants, possibly increasing the risk of collision or influencing migrants to select lower quality habitats (Gauthreaux and Belser 2006 and references therein; Van Doren et al. 2017, McLaren et al. 2018). None of these factors act alone, rather they interact in complex ways to influence migrant decisions.

SUMMARY AND MONITORING RECOMMENDATIONS

Forest breeding and wintering birds

★ Forest management practices have profound positive and negative, species-dependent impacts on GoMAMN priority forest breeding and wintering landbirds. Some forestry practices occurring in the region are targeted at production of fiber, with wildlife benefits typically less of a priority. In other instances, forestry practices are intended to produce habitat for game species, and in others, management is executed with the intent of improving habitat for one or more GoMAMN priority bird species. Thus, a range of management-related monitoring is required. In the case of commercial timber and pulp production, monitoring the response of priority birds to normal and experimental forestry practices is needed. In the case of wildlife and bird-specific forestry practices, monitoring the species' response to various treatments to improve future management methodology is critical. For many GoMAMN forest breeding and wintering birds, optimal forest stand conditions are poorly understood, and research needs have not been identified. For species with identified needs, questions exist regarding prescribed fire intervals and season for Red-headed Woodpecker, Brown-headed Nuthatch, and Grasshopper Sparrow (Vickery 1996, Slater et al. 2013, Frei et al. 2017), and the effects of various silvicultural harvest methods, entry interval, and snag creation for Red-headed Woodpecker, Brown-headed Nuthatch, Wood Thrush, and Swainson's Warbler (Anich et al. 2010, Evans et al. 2011, Slater et al. 2013, Frei et al. 2017). These needs can serve as initial foci for experimental forest treatments and monitoring species response.

★ The effects of climate change on forest structure and species composition may have significant effects on priority forest bird species distribution and population trajectory. Monitoring the changes in forest composition and structure and avian species response is a high priority.

★ While existing status and trend monitoring and information is likely better for landbirds than some of the other GoMAMN avian guilds, it is important to maintain (and fully implement) existing protocols, such as the BBS. However, it may be necessary to develop specific status and trend monitoring protocols that are better suited to detect population changes in priority forest bird species.

Grassland breeding and wintering birds

★ Grasslands are one of the most threatened and under-protected habitat types of North America. Conversion of native prairie for livestock and crop production has led to the decline of many bird species populations, including GoMAMN priority grassland breeding and wintering landbirds. However, several conservation programs are available to landowners that aid in protecting land productivity and improvement of habitat for wildlife (e.g., Conservation Reserve Program, Environmental Quality Incentives Program, Conservation Stewardship Program). Although these programs provide assistance to land managers, benefits to wildlife, particularly GoMAMN priority bird species, are not consistently measured or monitored. Additionally, species may respond differently to various management tools and application regimes. For example, Henslow's Sparrow populations have benefited since the establishment of the Natural Resources Conservation Service Conservation Reserve Program while Grasshopper Sparrow population trends continue to decline (Herkert 1997, Sauer et. al. 1999). Because most research on declining species tend to be focused on their breeding range, little is known about response to habitat management within their wintering range. As a result, conservation of wintering habitat may be limited by this lack of information. All GoMAMN priority grassland birds depend on the GoMAMN region during wintering months with two species (Grasshopper Sparrow and Northern Bobwhite) breeding in this region. Research should include influence of management and connectivity of grasslands on species during both wintering and breeding seasons.

★ Climate change may impact prairie quality. Predictions of increased temperatures and reduced rainfall may encourage the spread of non-native grasses and decrease insect availability as well as diversity (Peterson 2003, Thuiller et al. 2007). These changes may also cause phenological shifts that impact grassland bird reproduction, however there is little information or long-term datasets documenting changes in synchrony of food sources or predator/prey interactions (Parmesan 2006, Visser and Both 2005). Encouraging research projects to include collecting data on grassland invertebrate communities may provide better insight to population dynamics of grassland birds..

★ Existing status and trend monitoring protocols, such as the BBS and CBC, provide valuable information about species on a large scale. However, these types of surveys do not lend themselves to understanding how specific habitat management or other changes on the landscape can impact populations of grassland birds. It may be necessary to develop specific status and trend monitoring protocols that are better suited to detect population changes in priority grassland bird species.

Passage migrants

★ Arguably, stopover habitat for migratory landbirds is the most important habitat found within the GoMAMN region. These stopover habitats constitute various forested, grassland, and scrub/shrub habitats, function in different ways (see Mehlman et al. 2005), and are used by a wide variety of species as areas to rest and refuel during both spring and autumn (Barrow et al. 2005, Buler et al. 2007a, Buler and Moore 2011, eBird 2018, Lafleur et al. 2016). The conservation and preservation of these stopover habitats is especially critical given that the migratory period is thought to account for the greatest risk of mortality during the annual cycle (e.g., Sillett and Holmes 2002, Newton 2007, Paxton et al. 2017). Moreover, stopover habitat is thought to limit the population size of some migratory species (see Sherry and Holmes 1995, Newton 2007, 2008).

★ Climate change and anthropogenic activities (e.g., land use change, urbanization) are the two major factors that can impact passage migrants as they can decrease available stopover habitat, alter the vegetative composition and structure of habitats, as well as influence food resources. Climate change, for example, can instigate a mismatch between the arrival of migrants and food availability as well as alter the structure and composition of habitats due to changes in temperature and precipitation. Urbanization can have similar negative impacts, the most obvious decreasing available stopover habitat but also include the introduction of invasive species, tall structures, pollution (e.g., chemicals, light, etc), pesticides, and free ranging/feral cats. While there is some information on how passage migrants cope with these challenges, the impacts of climate change, anthropogenic development, habitat availability, and vegetative composition on population size and other metrics (e.g., refueling rates, stopover duration) are still highly uncertain for the GoMAMN region and should be the focus of monitoring efforts in the near future (Cohen et al. 2017).

★ Due to their ephemeral nature, passage migrants are likely the hardest group for which to monitor status and trends. Unlike breeding and wintering species, which use BBS and CBC protocols, no such widespread monitoring protocol exists for en route migrants. In the absence of well-established protocols, passage migrant populations should be monitored using a multi-scale approach, which can focus on fine scale habitat factors through regional patterns found across the GoMAMN region. At the largest scale, weather surveillance radar can address uncertainties associated with status and trends as well as ecological processes, such as atmospheric conditions across the entire Gulf of Mexico region. Banding stations and surveys can address local and, potentially, landscape scale management actions and ecological processes for the migrant community depending on the sampling design. Finally, automated telemetry can provide information on how individuals respond to management actions and ecological processes locally as well as at larger scales if an appropriate network of automated receiving units exist (e.g., MOTUS). Additionally, integrating these monitoring tools can provide resource managers and conservation planners a holistic framework for which to establish appropriate and meaningful conservation practices for passage migrants as well as reduce uncertainty at multiple scales.

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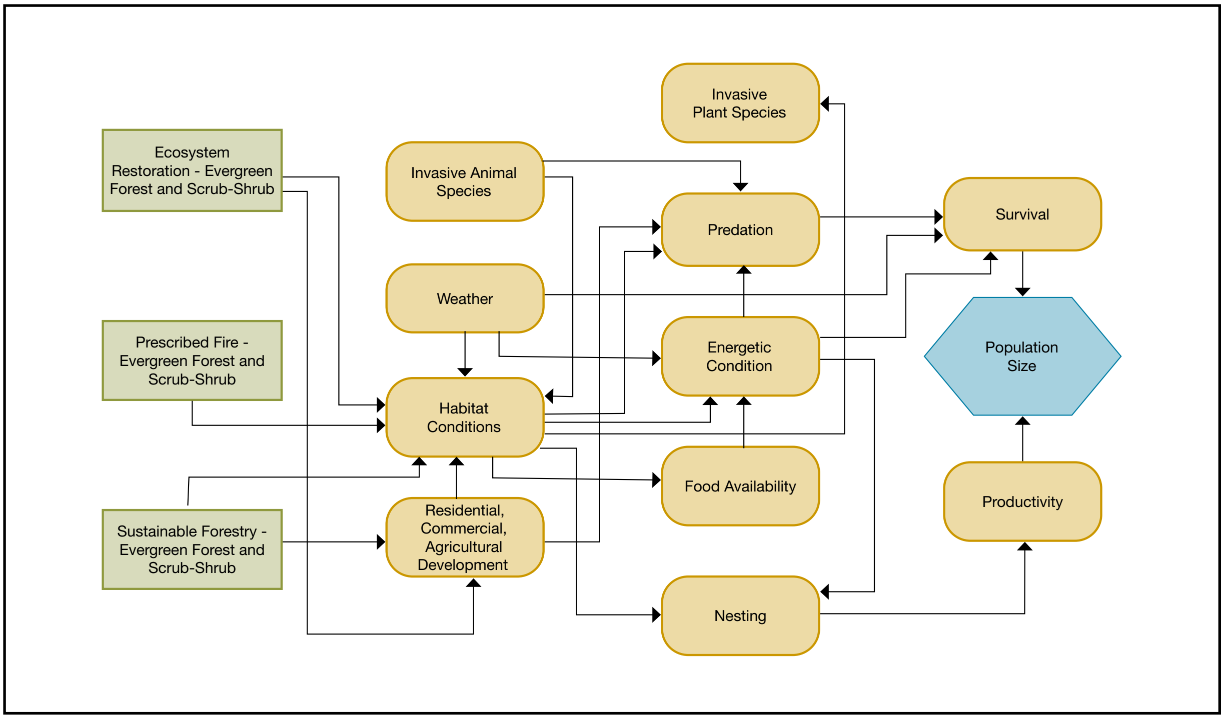
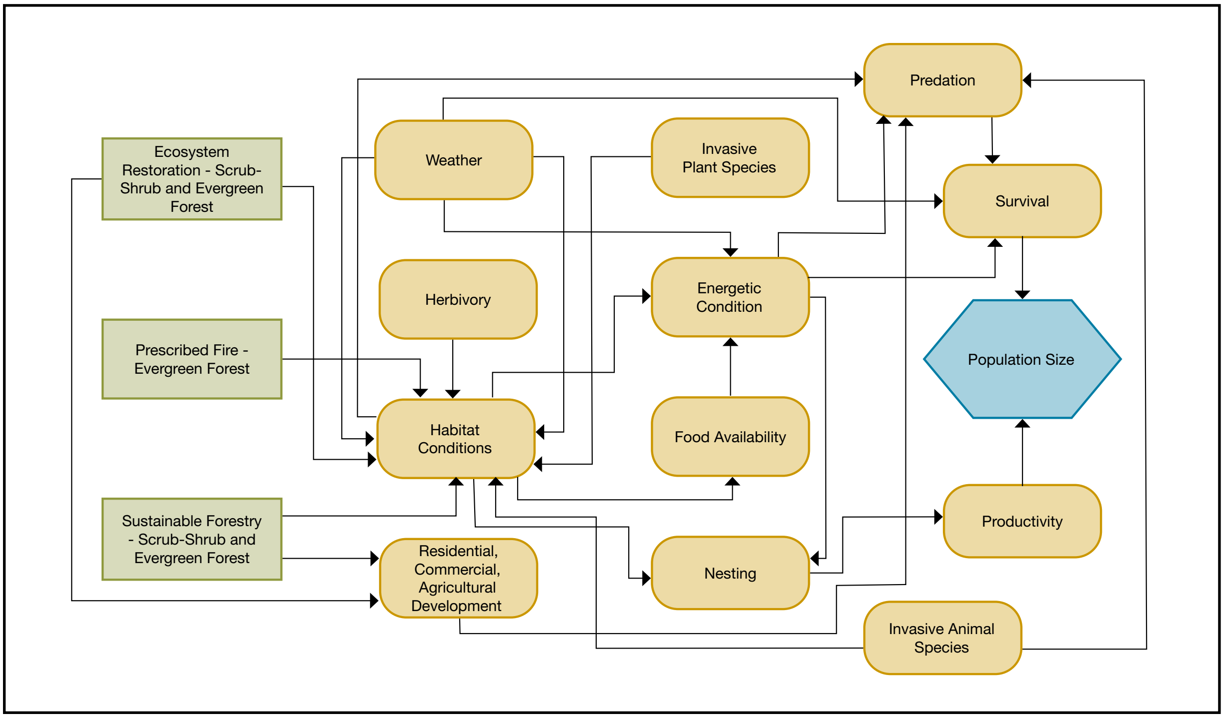
APPENDIX 3

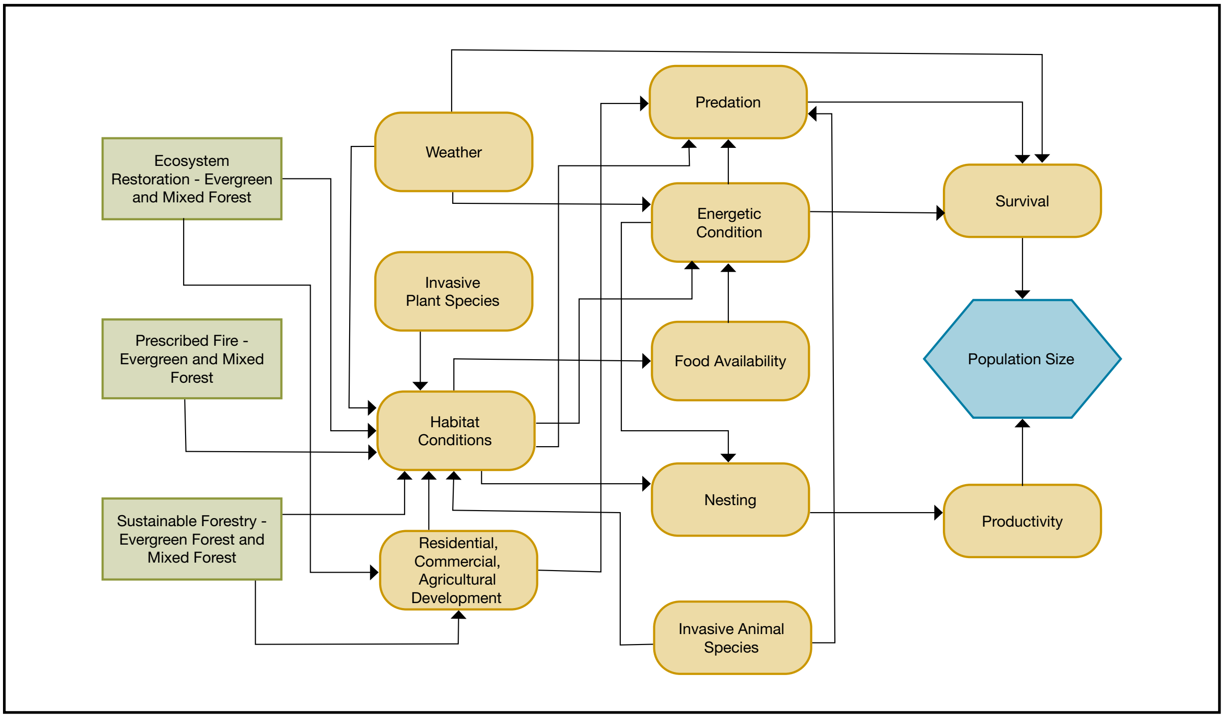
Supplementary influence diagrams depicting mechanistic relationships between management actions and population response of landbirds.



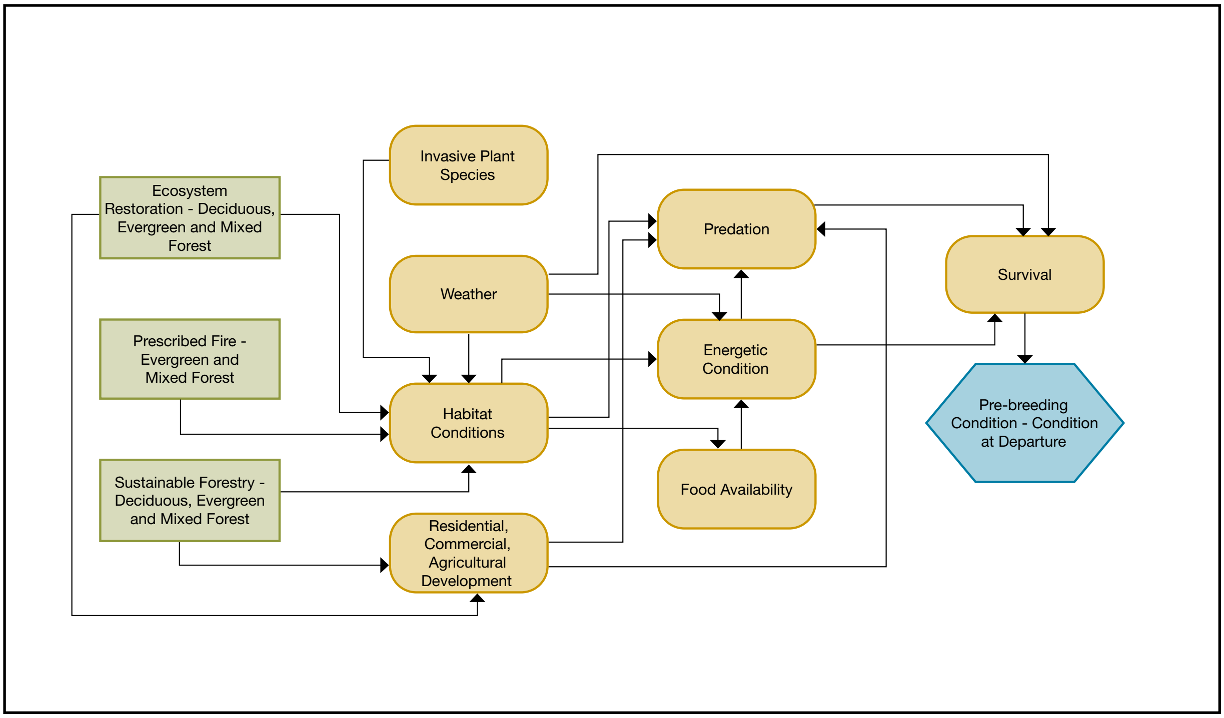
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Northern Bobwhite*** *(Colinus virginianus) forest breeding within the Gulf of Mexico region.*



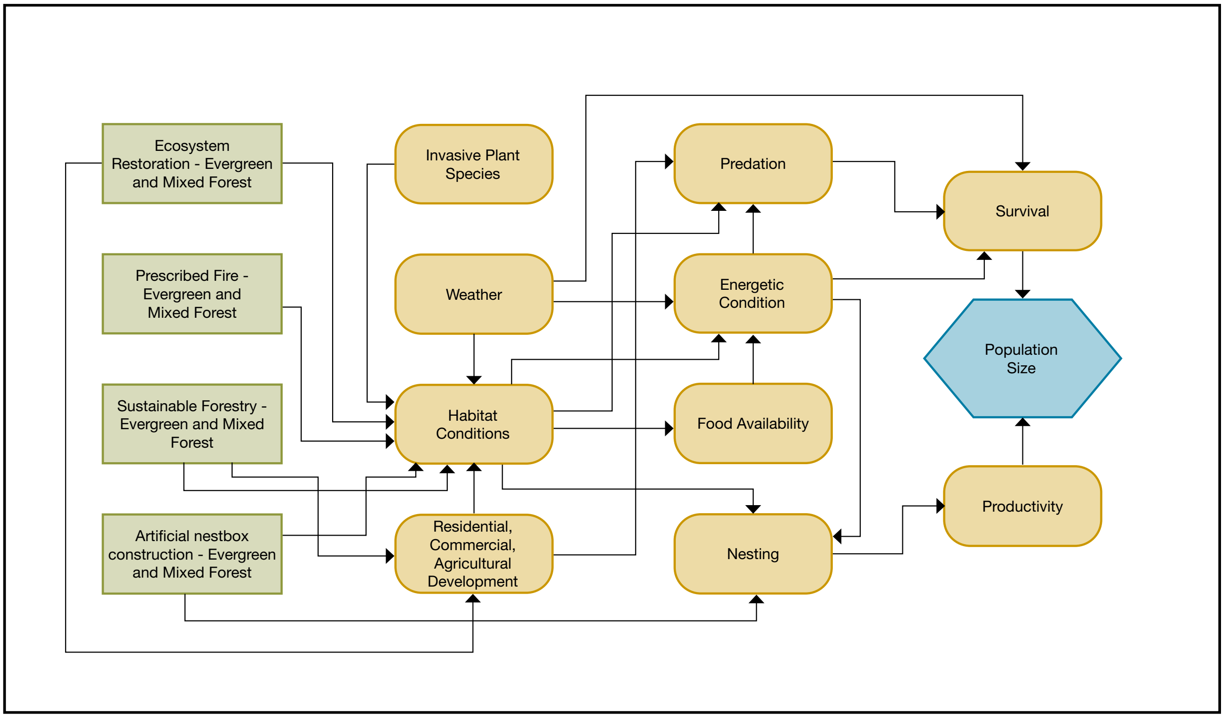
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Common Ground Dove*** *(Columbina passerina) breeding within the Gulf of Mexico region.*



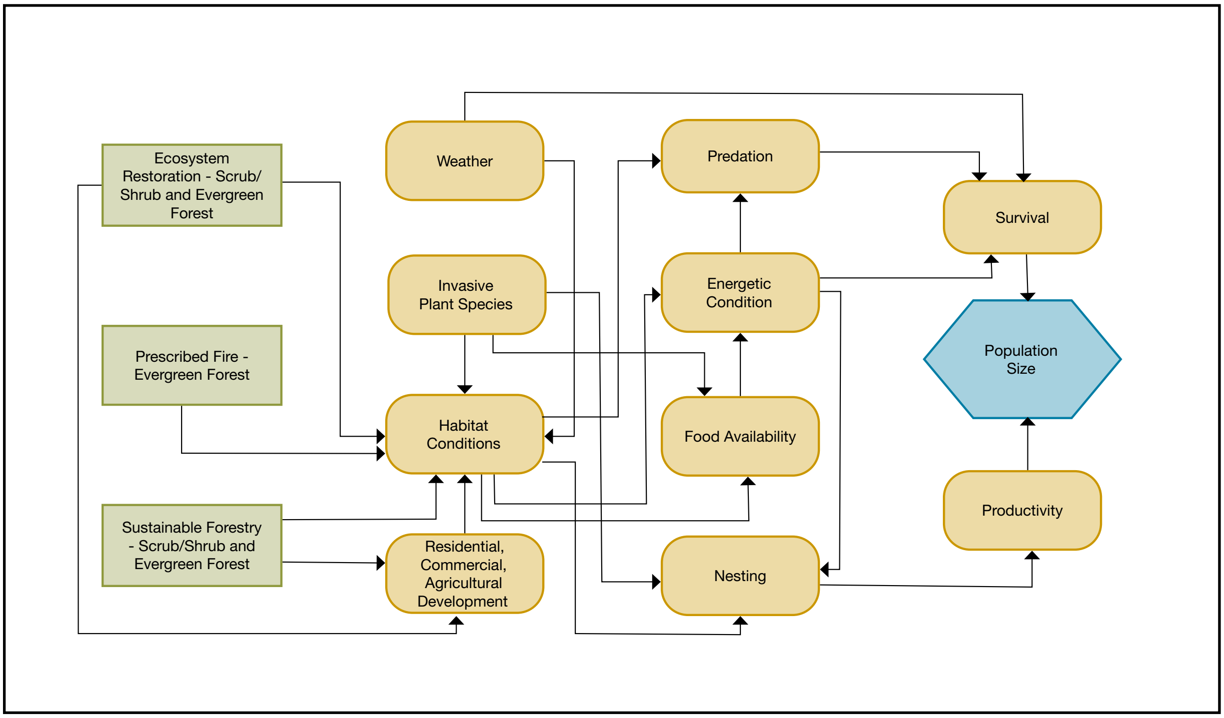
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Chuck-will's-widow*** *(Antrostomus carolinensis) breeding within the Gulf of Mexico region.*



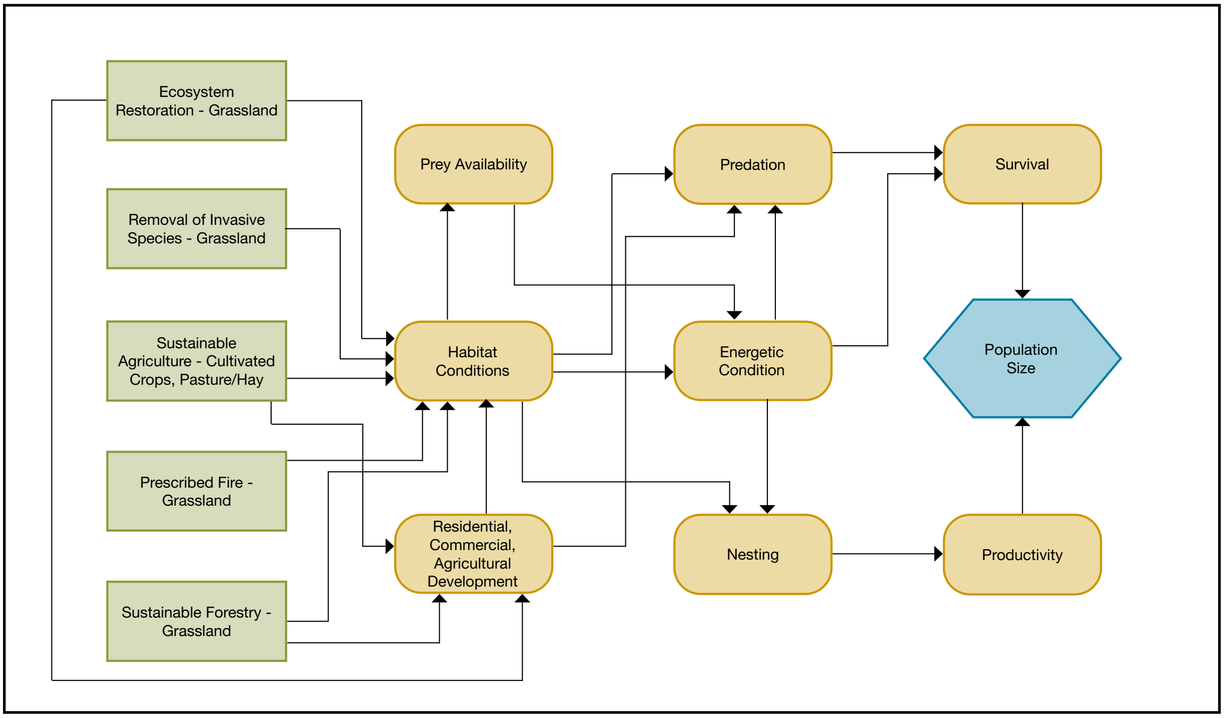
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and pre-breeding condition-condition at departure (blue hexagon) for the ***Red-headed Woodpecker*** *(Melanerpes erythrocephalus) wintering within the Gulf of Mexico region.*



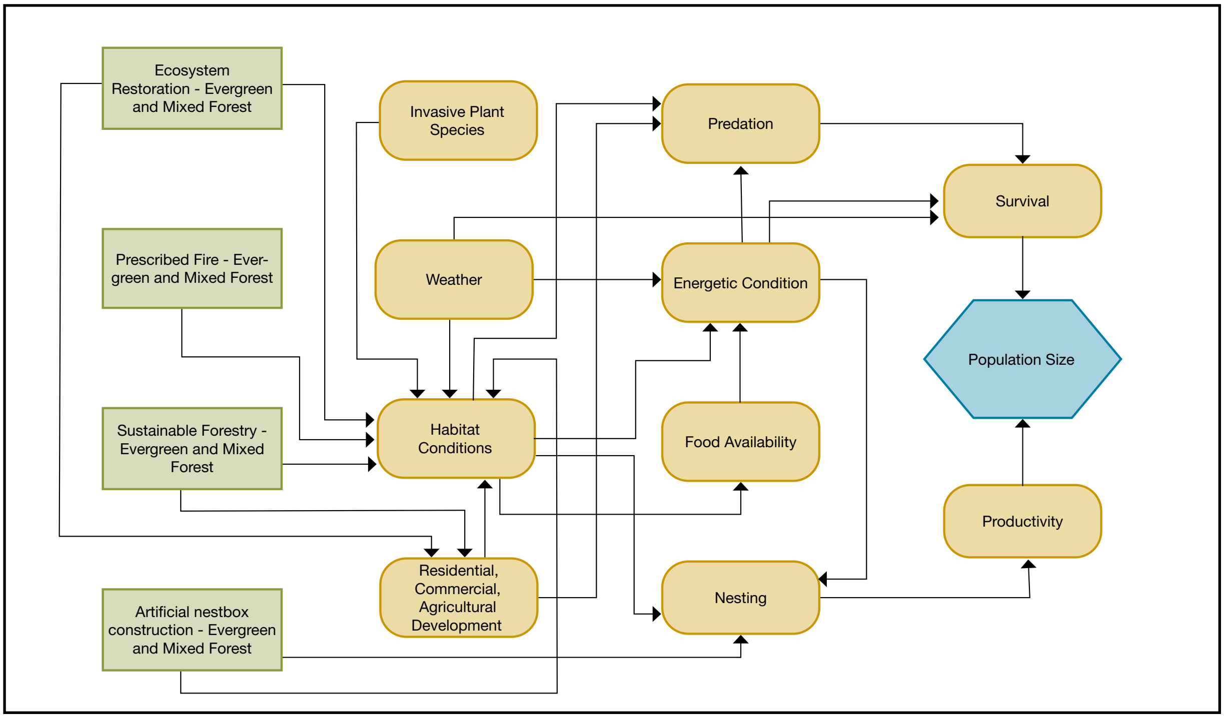
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Red-cockaded Woodpecker*** *(Dryobates borealis) breeding within the Gulf of Mexico region.*



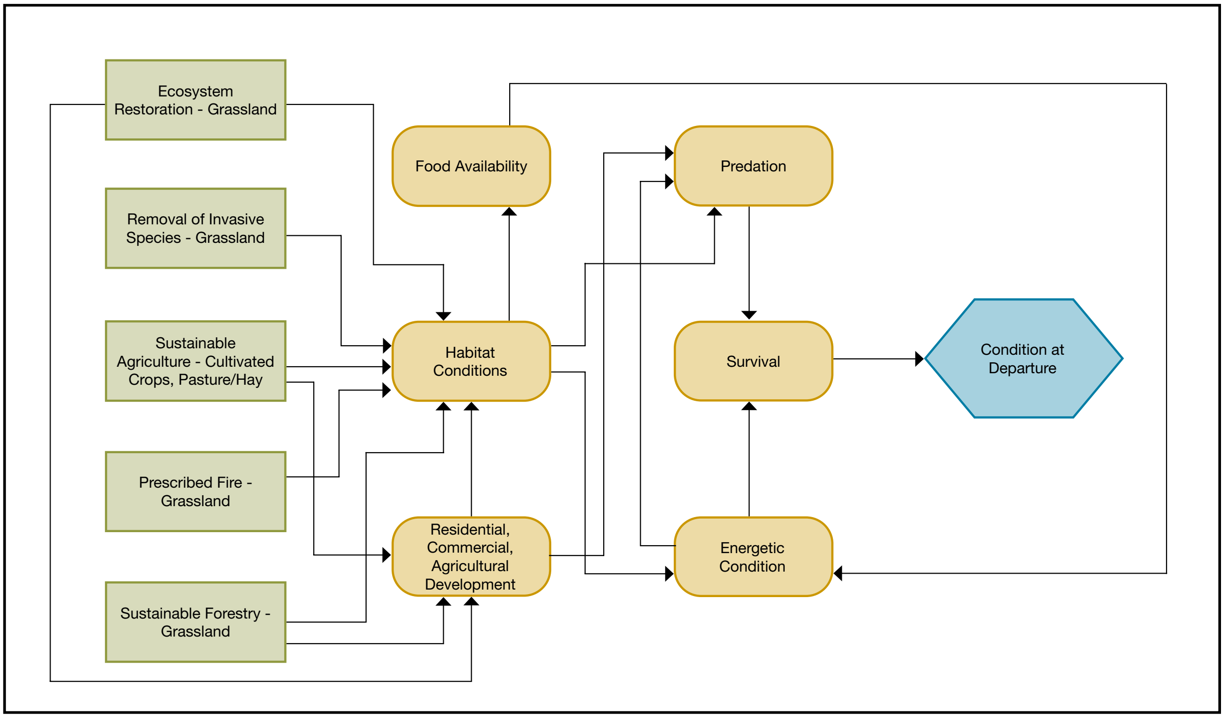
*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the forest breeding **Loggerhead Shrike** (Lanius ludovicianus) within the Gulf of Mexico region.*



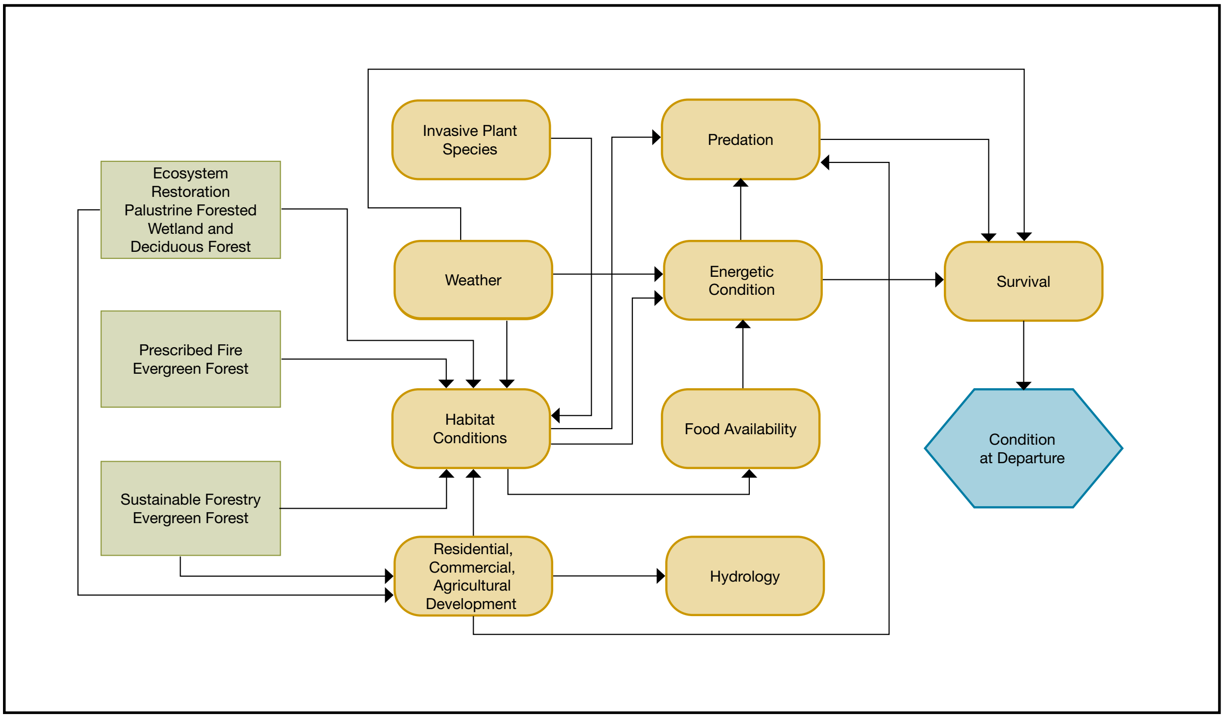
*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the grassland breeding **Loggerhead Shrike** (Lanius ludovicianus) within the Gulf of Mexico region.*



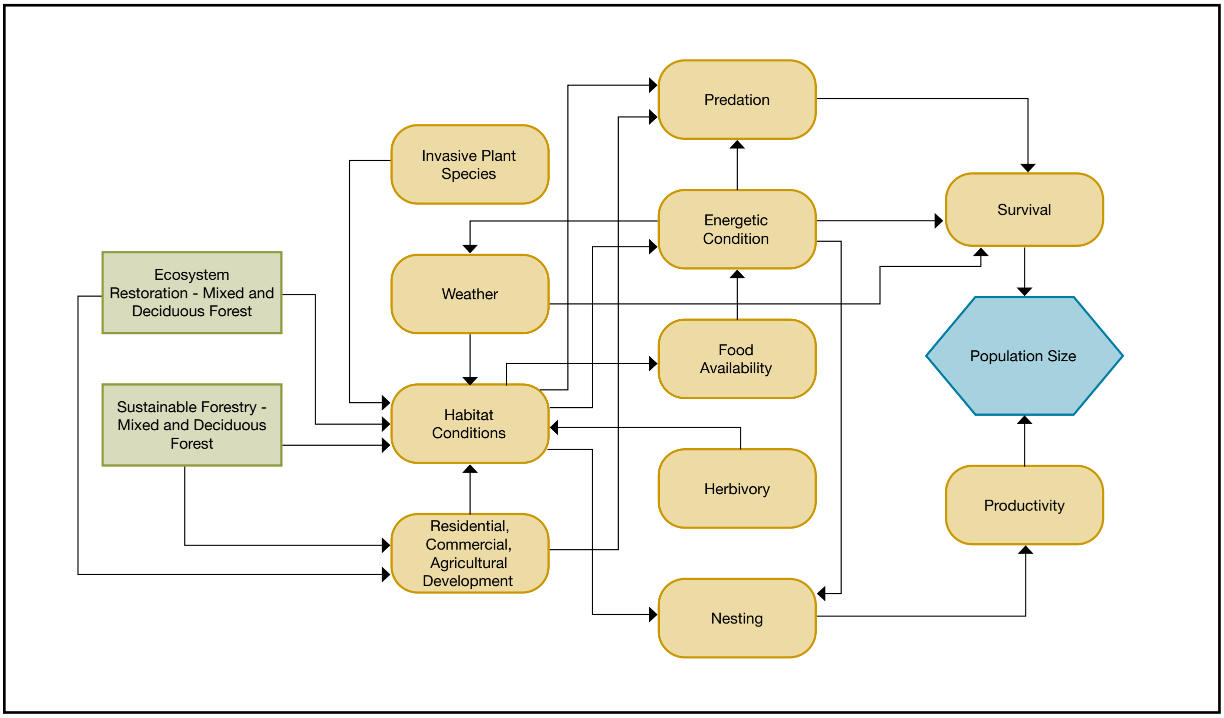
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Brown-headed Nuthatch*** *(Sitta pusilla) breeding within the Gulf of Mexico region.*



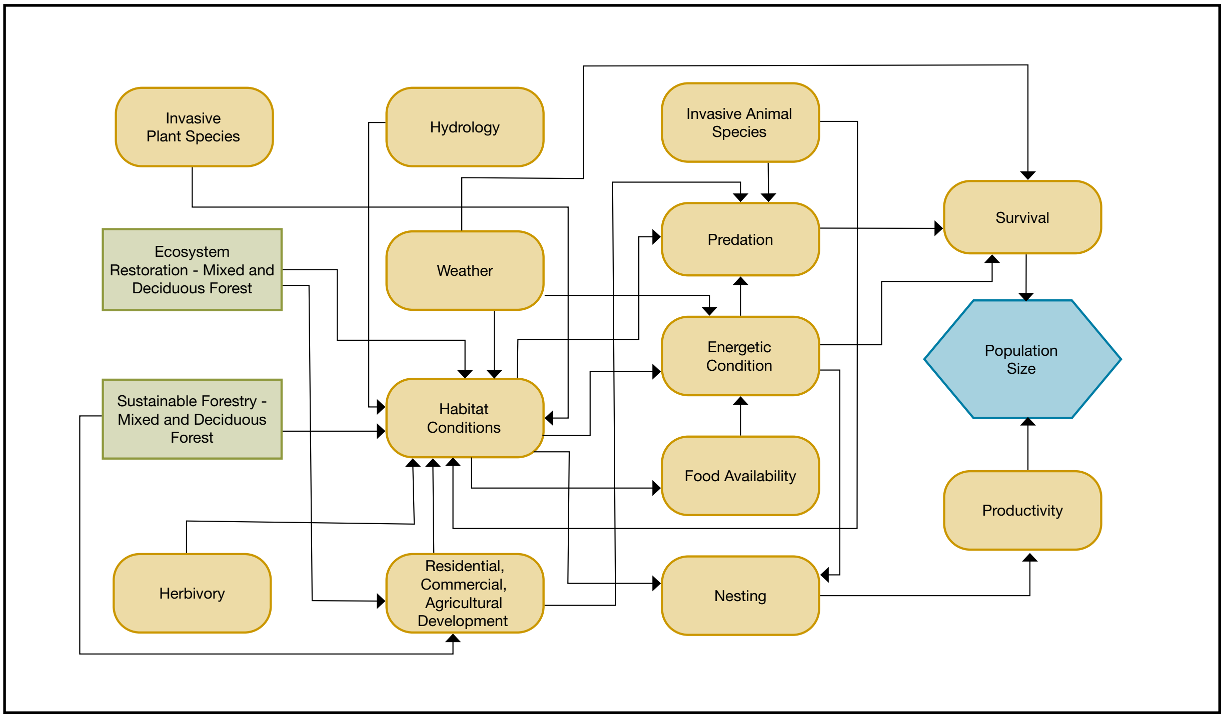
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Sedge Wren*** *(Cistothorus platensis) grassland wintering within the Gulf of Mexico region.*



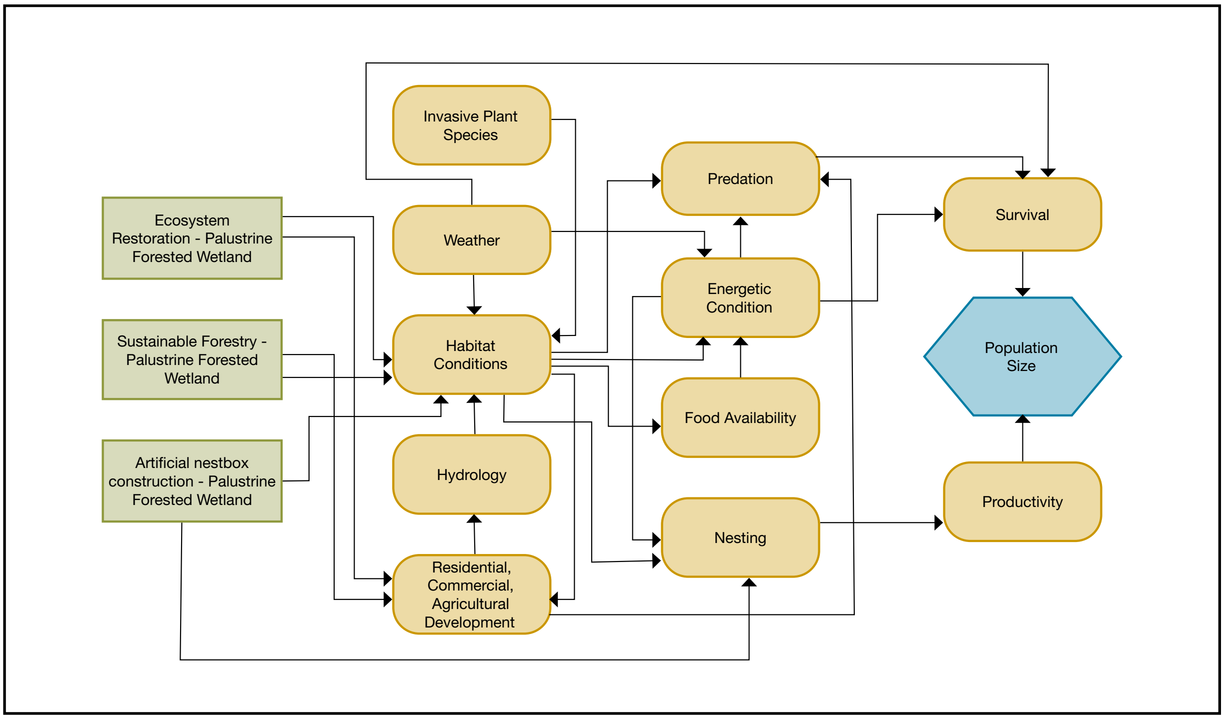
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and condition at departure (blue hexagon) for the ***Sedge Wren*** *(Cistothorus platensis) forest wintering within the Gulf of Mexico region.*



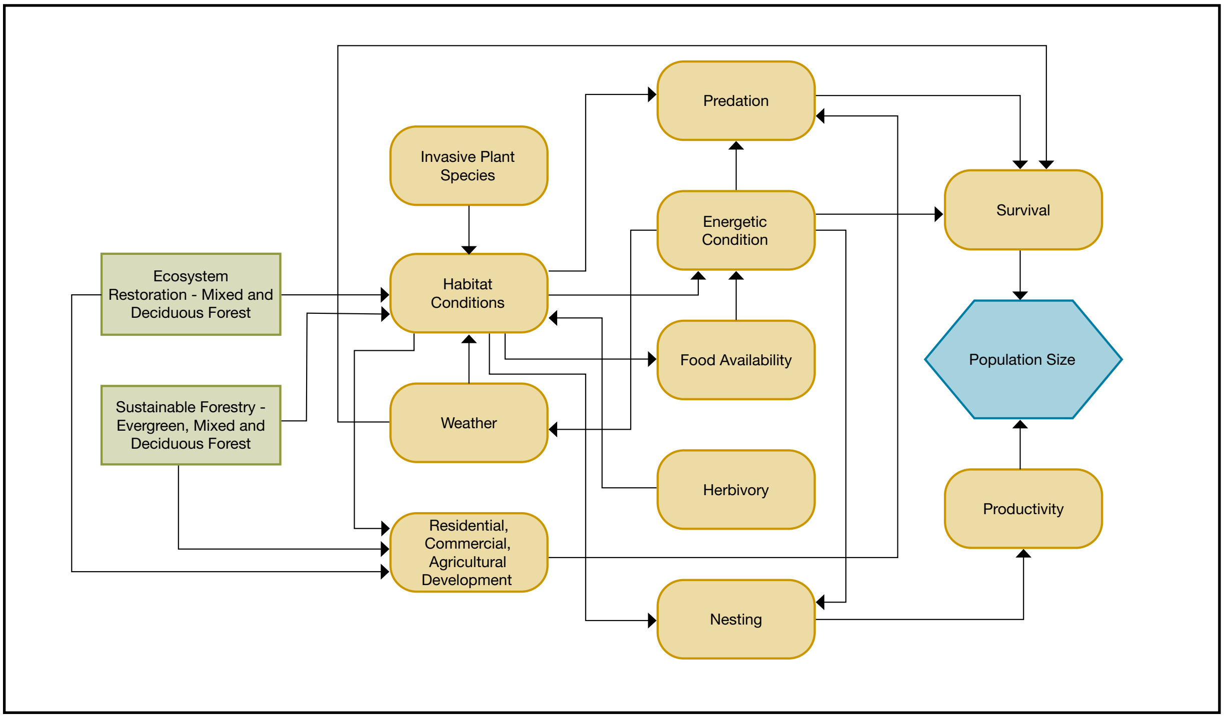
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Wood Thrush*** *(Hylocichla mustelina) breeding within the Gulf of Mexico region.*



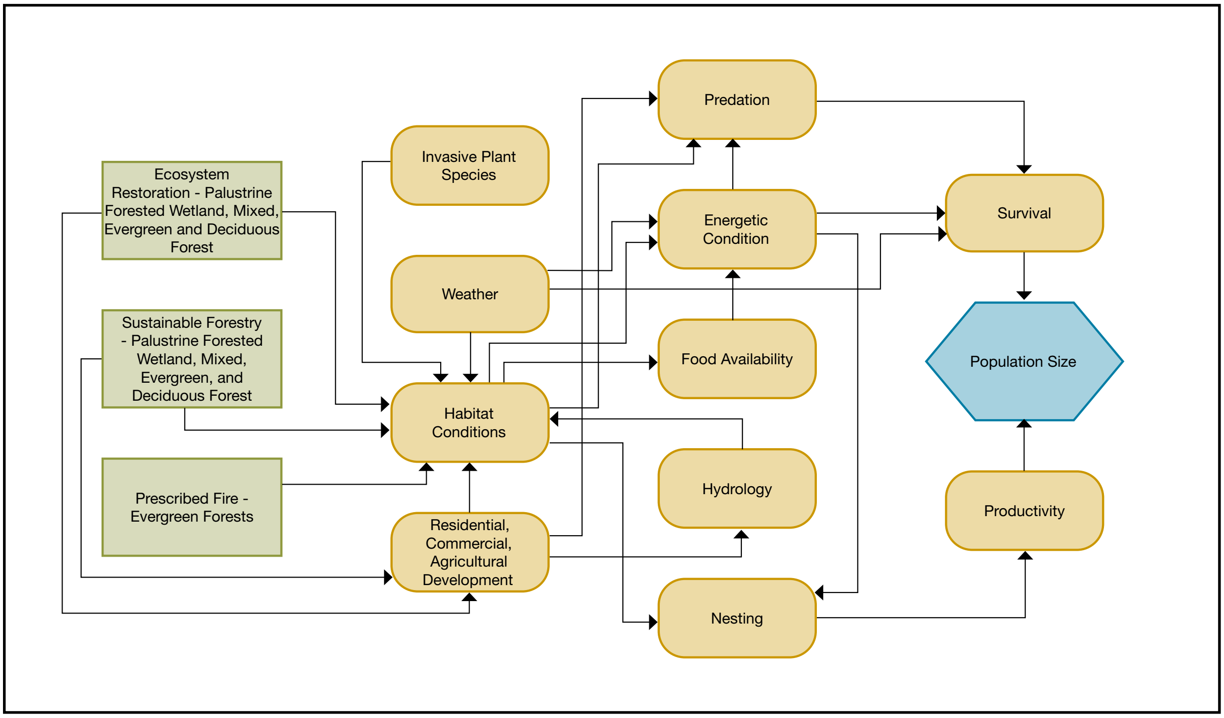
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Louisiana Waterthrush*** *(Parkesia motacilla) breeding within the Gulf of Mexico region.*



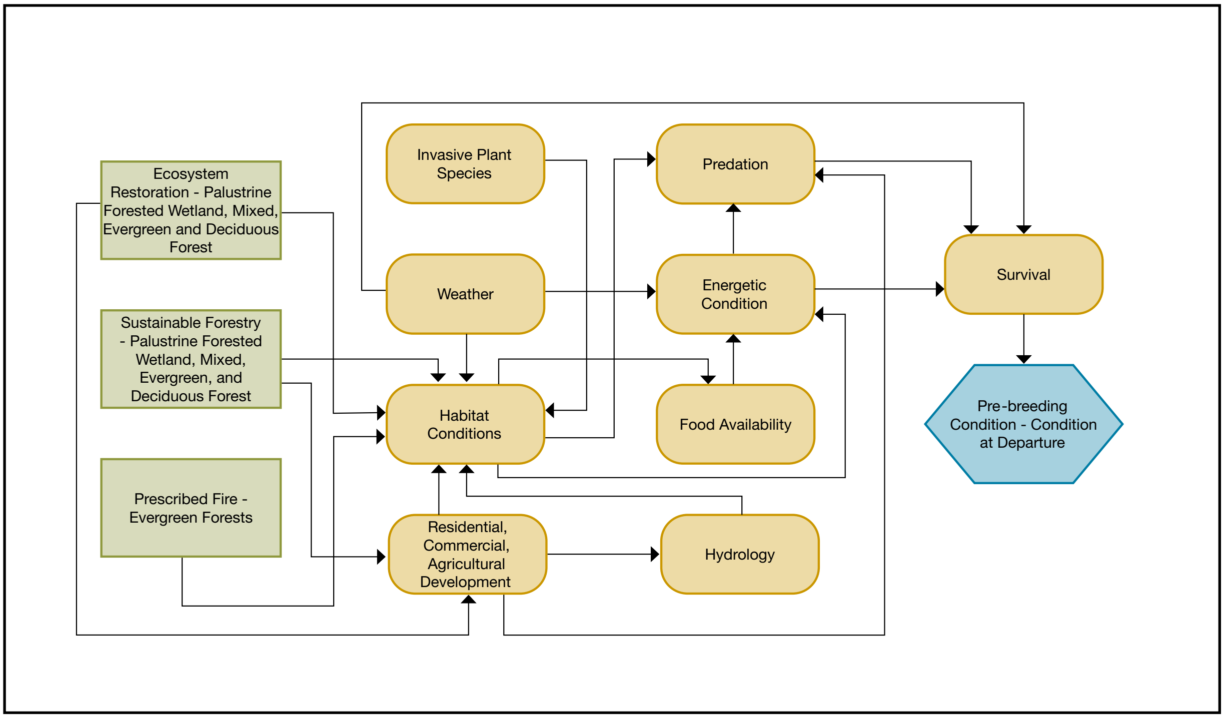
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Prothonotary Warbler*** *(Protonotaria citrea) breeding within the Gulf of Mexico region.*



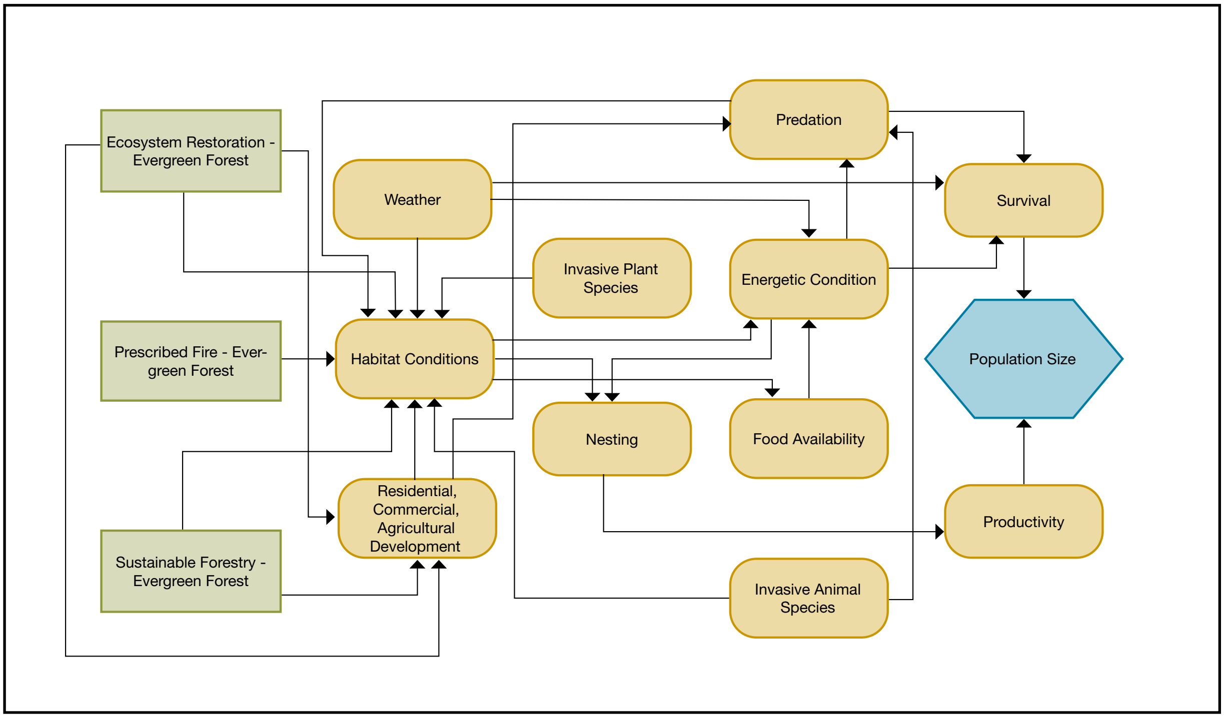
*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the **Swainson's Warbler** (Limnothlypis swainsonii) breeding within the Gulf of Mexico region.*



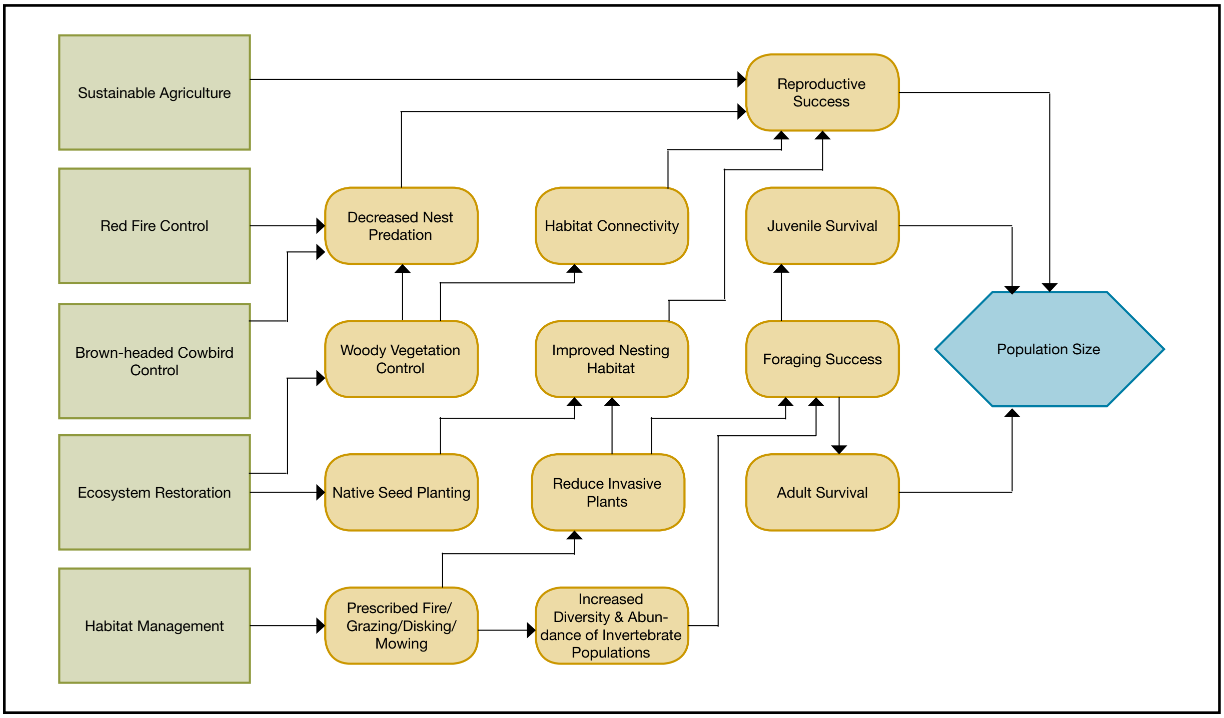
*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the **Yellow-throated Warbler** (Setophaga dominica) breeding within the Gulf of Mexico region.*



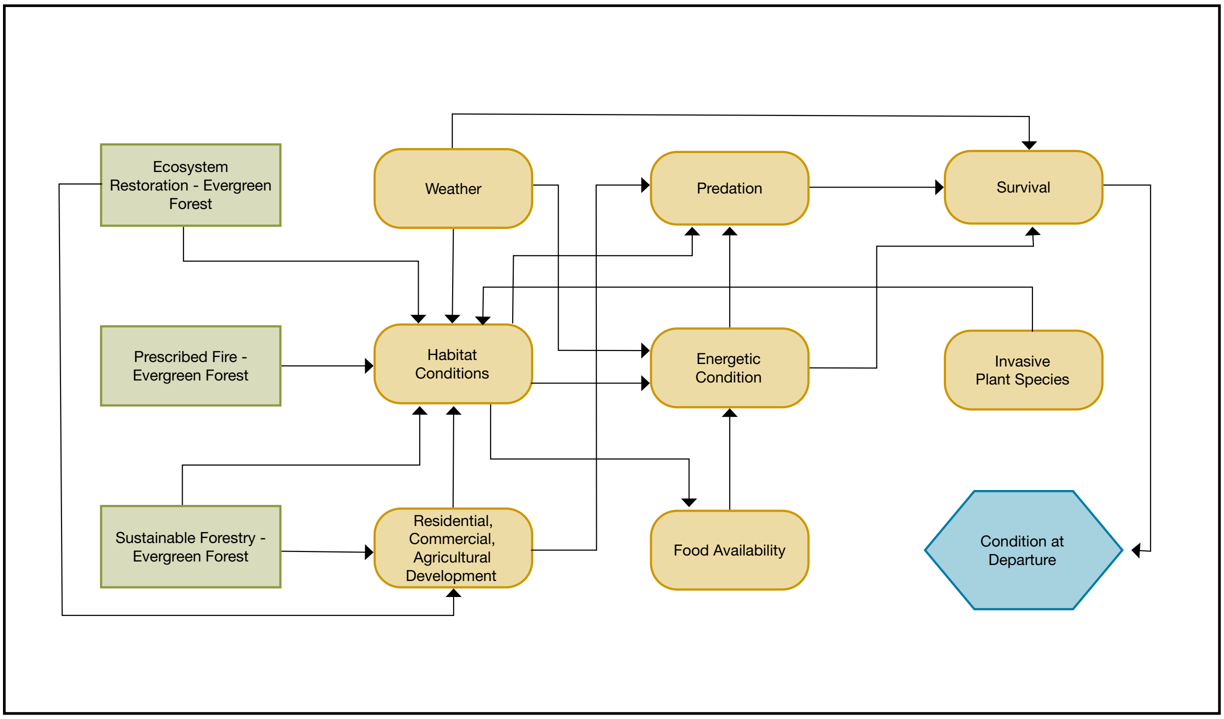
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and pre-breeding condition - condition at departure (blue hexagon) for the ***Yellow-throated Warbler*** *(Setophaga dominica) wintering within the Gulf of Mexico region.*



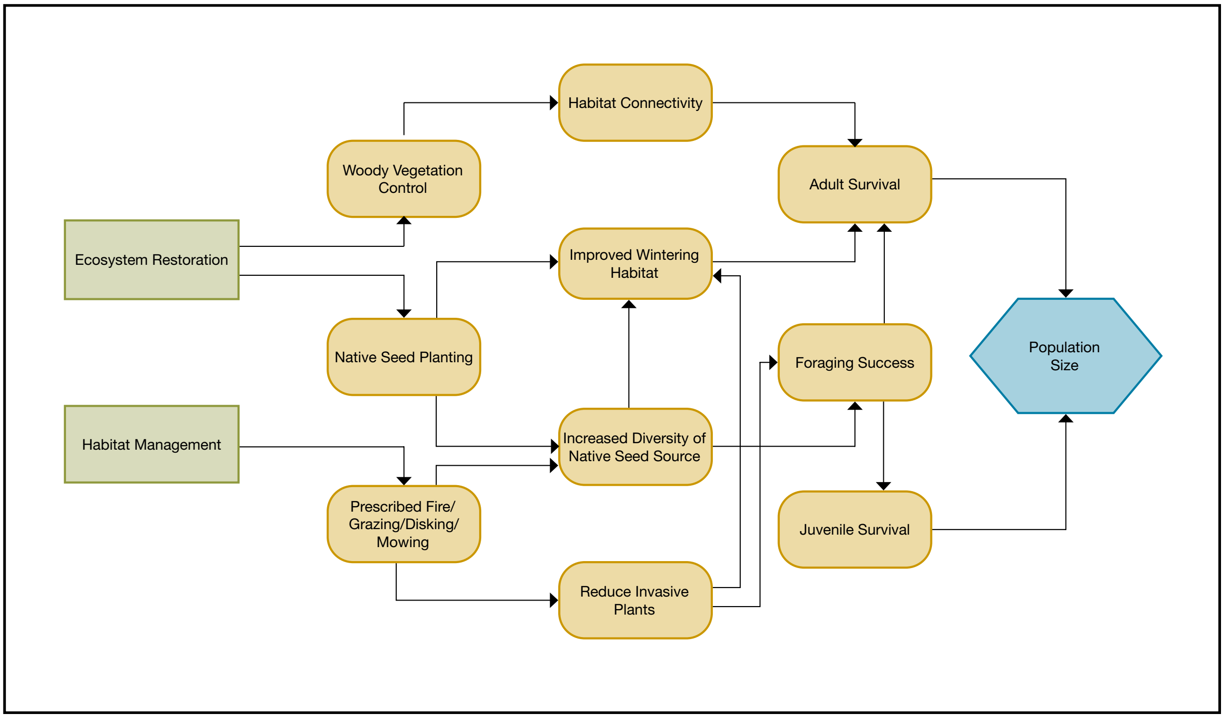
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and pre-breeding condition - condition at departure (blue hexagon) for the ***Bachman's Sparrow*** *(Peucaea aestivalis) breeding within the Gulf of Mexico region.*



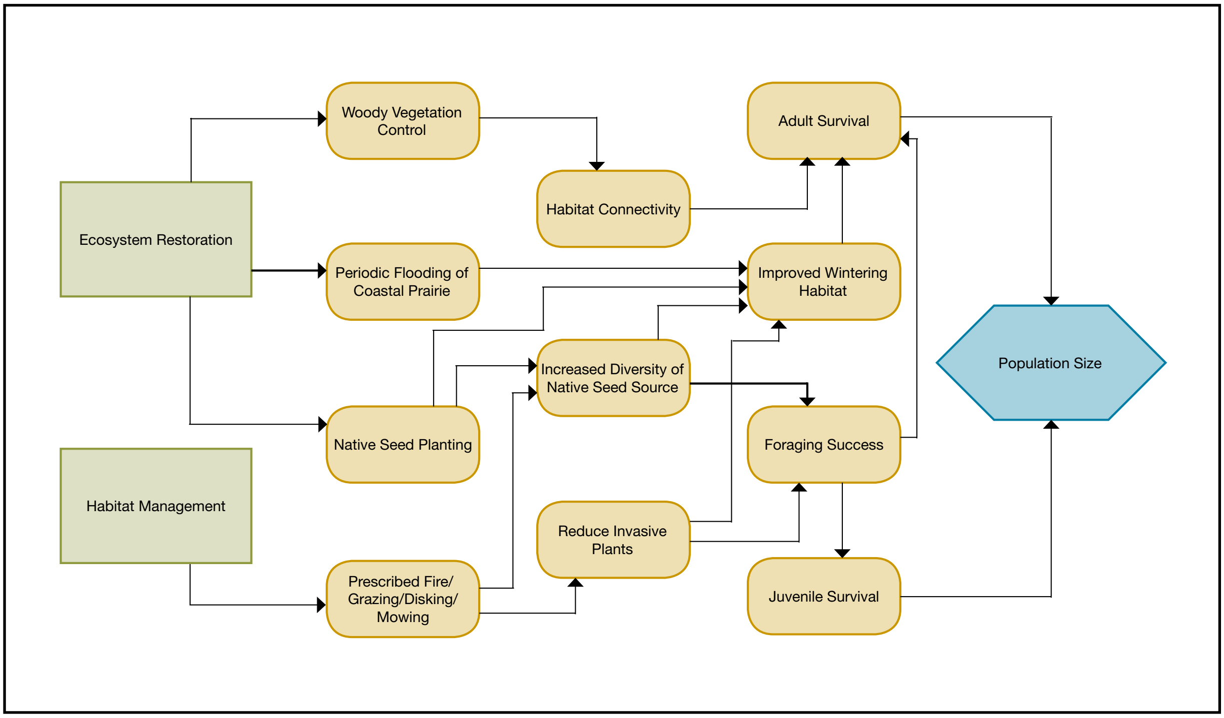
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Grasshopper Sparrow*** *(Ammodramus savannarum) in wintering grasslands within the Gulf of Mexico region.*



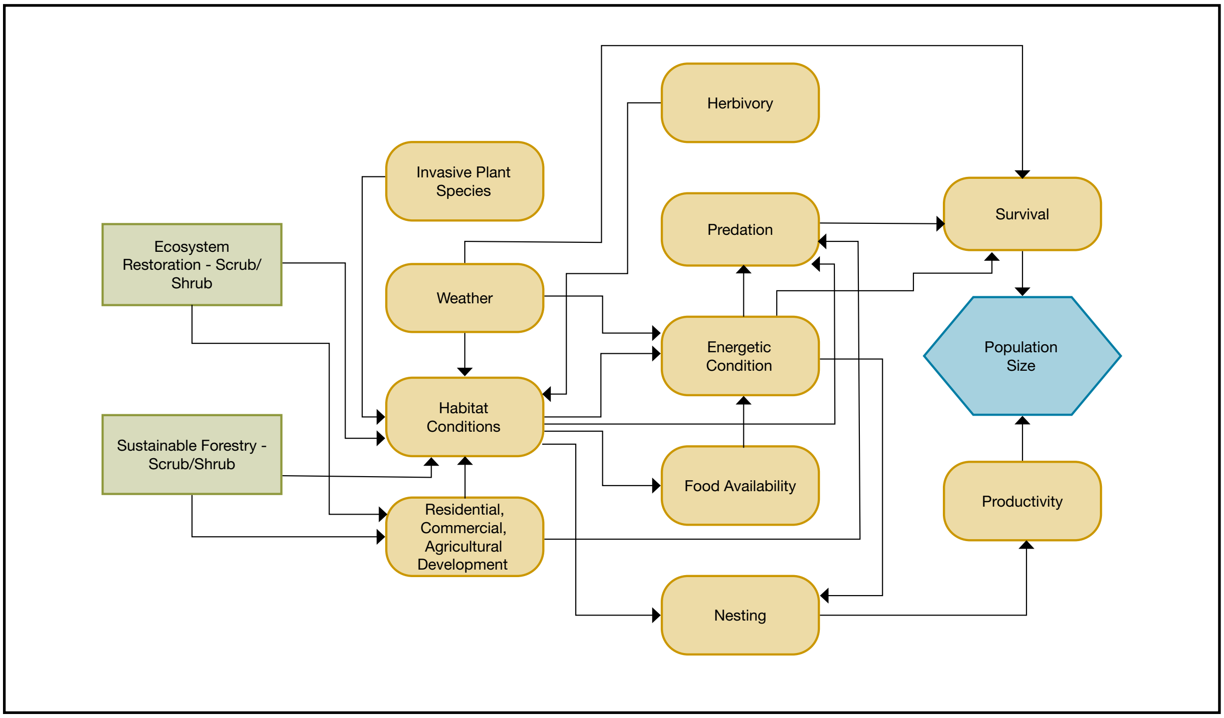
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and condition at departure (blue hexagon) for the ***Henslow's Sparrow*** *(Centronyz henslowii) forest wintering within the Gulf of Mexico region.*



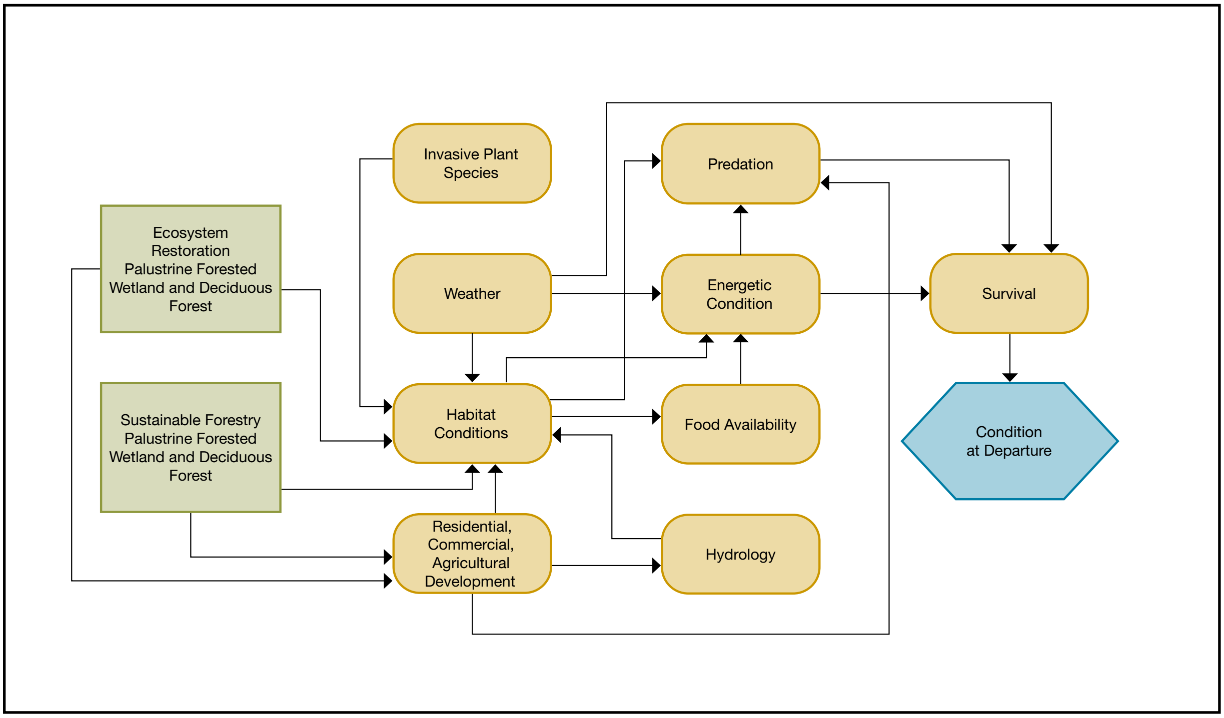
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Henslow's Sparrow*** *(Centronyz henslowii) in wintering grasslands within the Gulf of Mexico region.*



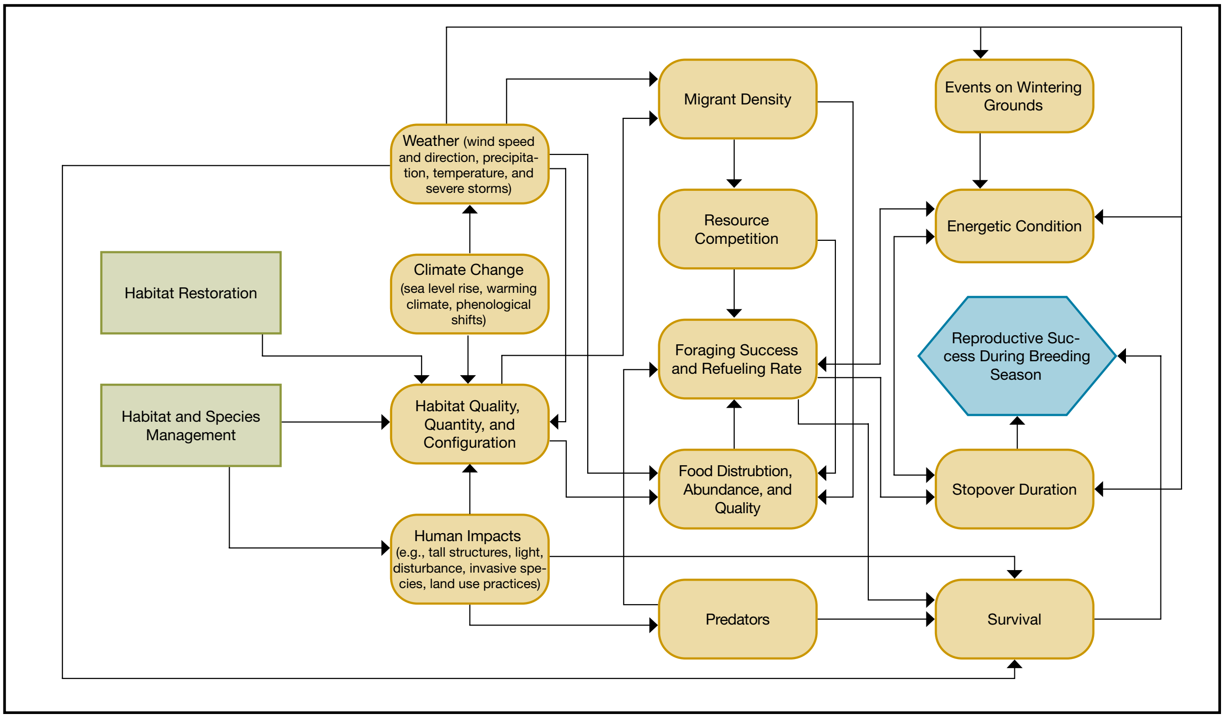
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***LeConte's Sparrow*** *(Ammospiza leconteii) wintering within the Gulf of Mexico region.*



Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population size (blue hexagon) for the ***Painted Bunting*** *(Passerina ciris) breeding within the Gulf of Mexico region.*



Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and condition at departure (blue hexagon) for the ***Rusty Blackbird*** *(Euphagus carolinus) wintering within the Gulf of Mexico region.*



*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population (metric) size (blue hexagon) for **passage migrant landbirds** within the Gulf of Mexico region.*

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