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Strategic Bird Monitoring Guidelines for the Northern Gulf of Mexico

GoMAMN STRATEGIC BIRD MONITORING GUIDELINES: WATERFOWL

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Pair of Mottled Ducks (*Anas fulvigula*). Photo credit: Ron Bielefeld

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Chapter 9

GOMAMN STRATEGIC BIRD MONITORING GUIDELINES: WATERFOWL

Conditions on the breeding grounds and the demographic parameters associated with the breeding season tend to influence waterfowl populations more significantly than any other part of their lifecycle (Koons et al. 2014). However, without adequate migration and winter habitat, waterfowl may experience lower seasonal survival and return to the breeding grounds in poorer body condition (Ankney and Macinnes 1978, Krapu 1981, Kaminski and Gluesing 1987, Johnson et al. 1992, Dubovsky and Kaminski 1994, Heitmeyer 1995, Newton 2006, Moon et al. 2007, DeVries et al. 2008, Guillemain et al. 2008, Anteau and Afton 2009, Sedinger and Alisauskas 2014). Poor body condition can result in reduced reproductive success, thus, lowering recruitment into the following year's breeding population. Therefore, wintering habitat quantity and quality along the Gulf Coast is critical to many waterfowl species (NAWMP 1986, DU 1997). For example, Blue-winged Teal (*Spatula discors*)spend ≤5 months on the breeding grounds, spending the remainder of the year in migration and on the wintering grounds (Rohwer et al. 2002). Given the downward trajectory of quantity and quality of most migration and wintering habitats for waterfowl, it is also important to ensure that additional significant population bottlenecks do not occur within the northern Gulf of Mexico geography (Figure 1.2).

Waterfowl hunters have an important economic impact on local, state, and national economies (USFWS 2015). Waterfowl hunters spend money on a variety of goods and services for trip-related and equipment-related purchases. Trip-related expenditures include food, lodging, transportation, and other incidentals. Equipment expenditures consist of guns, decoys, calls, hunting dogs and food, camping equipment, specialized hunting clothing (e.g., camouflage chest waders), boat-motor-trailer, and other input costs. These impacts send ripple effects throughout the economy with these direct expenditures only part of the economic impact of waterfowl hunting. Trip-related and equipment-related expenditures associated with waterfowl hunting generated over $3.0 billion in total economic output in 2011. This impact was dispersed across local, state, and national economies (USFWS 2015). Waterfowl hunters also directly pay for conservation efforts at the national and state levels through the Pittman-Robertson Act, and through the purchase of both federal and state duck stamps.

The Gulf of Mexico coastal region is an important area for many wintering waterfowl species (NAWMP 1986, DU 1997, Bellrose 1980, Baldassarre 2014). Three species of waterfowl [Mottled Duck (*Anas fulvigula*), Northern Pintail (*Anas acuta*), and Lesser Scaup (*Aythya affinis*)] met the criteria to be considered species of conservation concern by GoMAMN (Appendix 1). Moreover, the GoMAMN Waterfowl Working Group strongly believes that Redhead (*Aythya americana*), Blue-winged Teal, and Gadwall (*Mareca strepera*) also warranted inclusion herein as additional targets for monitoring (Table 9.1).

Mottled Ducks spend their entire life cycle in coastal marshes and inland landscapes along the Gulf of Mexico (Stutzenbaker 1988). The remaining waterfowl species migrate through and/or overwinter in coastal habitats of the Gulf of Mexico in continentally-significant numbers (Bellrose 1980, NAWMP 1986, Baldassarre 2014).

DESCRIPTION OF WATERFOWL SPECIES AND THEIR HABITATS IN THE GULF OF MEXICO REGION

MOTTLED DUCK (*Anas fulvigula*). Mottled Ducks are nonmigratory, and must satisfy all of their annual resource needs from habitats existing within a relatively small geographic area (Stutzenbaker 1988, Wilson 2007, Bielefeld et al. 2010, Haukos 2012). There are two distinct populations of Mottled Ducks—a Florida population and a Western Gulf Coast population, which are separated both genetically and geographically (McCracken et al. 2001, Bielefeld et al. 2010). The native Mottled Duck range includes peninsular Florida and coastal marshes along the Gulf of Mexico from Alabama west and south to Tampico, Mexico. This is a dabbling duck species that prefers fresh to brackish wetlands including marshes, natural and human-made ponds, ditches, and impoundments in both rural and suburban areas in Florida, and coastal marshes and inland freshwater wetlands along the western Gulf Coast. Although often the least gregarious of North American dabbling ducks, large concentrations may be found in fallow-flooded agricultural

Table 9.1. *Waterfowl species to be considered for monitoring programs at multiple geographic scales across the northern Gulf of Mexico. Table includes residency status, landcover association, and the North American continental trend and conservation concern scores (Partners in Flight 2017).*

Common Name	Latin Name	Breeding	Wintering	Migratory	Landcover Association(s)[a]	Trend Score	Continental Concern Score
Blue-winged Teal[b]	*Spatula discors*		X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	1	7
Gadwall[b]	*Mareca strepera*		X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland	1	8
Mottled Duck	*Anas fulvigula*	X	X		Palustrine Emergent Wetland, Estuarine Emergent Wetland (brackish to saltwater marshes), Cultivated Crops, Grassland	5	17
Northern Pintail	*Anas acuta*		X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland, Estuarine-Coastal, Cultivated Crops	4	12
Redhead[b]	*Aythya americana*		X	X	Estuarine Emergent Wetland, Estuarine-Coastal, Estuarine-Open Water, Marine-Nearshore	1	8
Lesser Scaup	*Aythya affinis*		X	X	Palustrine Emergent Wetland, Estuarine Emergent Wetland, Estuarine-Coastal, Estuarine-Tidal Riverine Open Water, Estuarine-Open Water, Marine-Nearshore	4	11

[a]See Chapter 1 and Appendix 2 for full description of landcover associations.
[b]This species is not included in the GoMAMN Birds of Conservation Concern list (Appendix 1), but is considered an important monitoring target by the Waterfowl Working Group, as well as its socio-political importance (hunted species) and its ecological importance and/or potential for use as an indicator species (Caro 2010).

fields and storm- and wastewater treatment impoundments during the wing molt in Florida and in harvested rice (*Oryza sativa*) fields after breeding along the western Gulf Coast (Bielefeld et al. 2010).

Mottled Ducks are seasonally monogamous. Compared to other species of ducks, pair formation occurs early, with nearly 80% of all individuals paired by November. Breeding starts in January, continuing into July and usually peaking in March–May. Females build nests on the ground or suspended immediately above it in dense stands of grass or other vegetation. Most pair bonds probably terminate during incubation, but some may persist through brood-rearing; only females incubate eggs (Bielefeld et al. 2010).

Wetland drainage in Florida, degradation of coastal marshes by saltwater intrusion and erosion in Louisiana and Texas, and urban development throughout the range pose serious conservation challenges for managers of this species (Figure 9.1). It should be made clear here, that though there are range-wide conservation issues for this species like habitat loss, the primary threats and thus, management actions in response to those threats for the Florida and Western Gulf Coast populations may be vastly different. For example, in Florida, introgressive hybridization with feral Mallards (*Anas platyrhynchos*; domesticated strains released into the wild) is possibly the single greatest threat to the future of the Mottled Duck as a unique species (Williams et al. 2005, Bielefeld et al. 2010). Certainly, hybridization with Mallards is a concern for the Western Gulf Coast population, but probably lesser so than for the Florida population (Ford et al. 2017). For the Western Gulf Coast population, the highest priority conservation actions revolve around increasing both nest success and brood survival (Wilson 2007, see also Rigby and Haukos 2014), and better targeting limited conservation dollars on the landscape to the highest priority habitats (Krainyk and Ballard 2014).

Though we consider both populations in this document, much of the information specific to Mottled Ducks is based largely, but not solely on the Western Gulf Coast population. Partly this is a function of the relatively larger portion of the GoMAMN geography (Figure 1.2) covered by this population. Additionally, it is related to the composition of the GoMAMN Community of Practice (CoP) and the Waterfowl Working Group, as well as the conservation impetus for this population in the Gulf Coast Joint Venture. Finally, it is a simple function of the large volume of scientific literature for this particular population of Mottled Duck.

LESSER SCAUP (*Aythya affinis*). This medium-sized black and white diving duck is one of the most abundant and widespread of North American diving ducks. This late fall migrant is one of the last waterfowl to leave an area at freeze-up. Throughout fall and winter, Lesser Scaup form large flocks on rivers, lakes, and large wetlands. Individuals also winter in estuaries and marine habitats of the Gulf of Mexico with areas like Lakes Borgne, Maurepas, and Ponchartrain in Louisiana holding fairly large numbers of scaup in some years (Kinney 2004, Louisiana Department of Wildlife and Fisheries unpublished data). Large rafts of this species have been observed wintering offshore in the Gulf of Mexico during some winters (Anteau et al. 2014, GoMMAPPS unpublished data).

Lesser Scaup are among the latest of migrant waterfowl to move north in spring; small migrant flocks often are still moving through southern portions of the Prairie Pothole Region in mid-May (Naugle et al. 2000). Ducklings hatch synchronously, spending less than one day in the nest before they follow the female to water, and they fledge by late August or September. Adults and ducklings are mainly carnivorous, consuming aquatic invertebrates (mainly crustaceans, insects, and mollusks) during the breeding season and throughout the annual cycle (Anteau et al. 2014).

Our knowledge of population size and trends is confounded by 1) unknown biases in the waterfowl breeding population survey because timing of the survey does not always match that of Lesser Scaup migration and breeding (Naugle et al. 2000, Schummer et al. 2018), and 2) the inability to separate Greater (*Aythya marila*) and Lesser Scaup in survey data (Afton and Anderson 2001), although Lesser Scaup are estimated to make up 80% of the "scaup" counted during the May waterfowl breeding population surveys (USFWS 2017). Though the potential reasons for long-term population

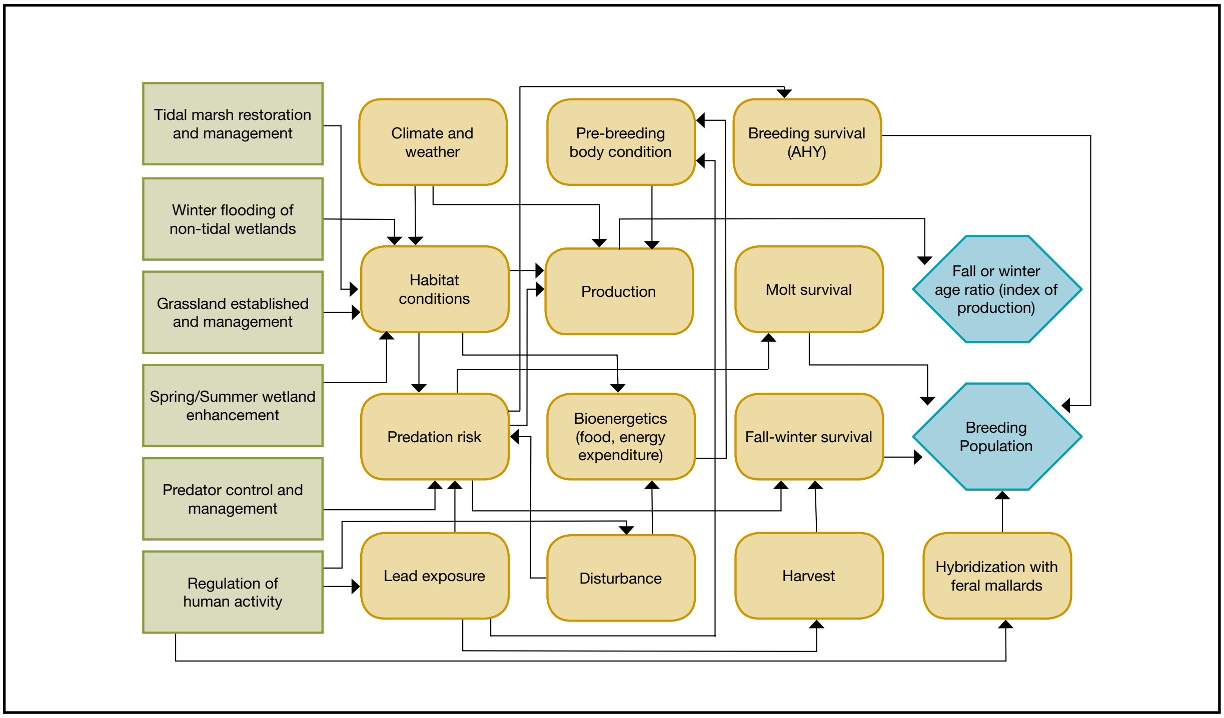

Figure 9.1. *Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population (metrics) size (blue hexagons) for the* ***Mottled Duck*** *(Anas fulvigula) within the Gulf of Mexico Region.*

Lesser Scaup (*Aythya affinis*). Photo credit: Ron Bielefeld

declines of Lesser Scaup are varied and uncertain (Austin et al. 2000), scaup numbers have declined significantly (but see Afton and Anderson 2001, Schummer et al. 2018) from 6–8 million in the early 1970s and has been around 3–5 million beginning in the mid-1980s and continuing today (USFWS 2017). It appears the scaup population has stabilized, but remains below the long-term average of 5 million in most years. Like for the Northern Pintail, the USFWS implemented an Adaptive Harvest Management (AHM) framework to inform scaup harvest regulations (Boomer and Johnson 2007, USFWS 2018). Ongoing conservation measures coupled with prudent harvest management (USFWS 2018, see also Koons et al. 2006), suggest that Lesser Scaup and scaup, in general, should have a secure future in North America (Anteau et al. 2014).

NORTHERN PINTAIL (*Anas acuta*). This medium-sized dabbling duck is circumpolar in distribution and abundant in North America, with core nesting habitat in Alaska and the Prairie Pothole Region of southern Canada and the northern Great Plains. An early fall migrant, the species arrives on Gulf Coast wintering areas beginning in October, after wing molt, often forming large roosting and feeding flocks on open, shallow wetlands and flooded agricultural fields (Clark et al. 2014).

Northern Pintails are among the earliest nesting ducks in North America, beginning shortly after ice-out in many northern areas. Annual nest success and productivity vary with water conditions, predation, weather, and geography. Ducklings hatch together in one day, follow the female to water after a day in the nest, and fledge by July or August (Clark et al. 2014).

On both breeding and non-breeding portions of its range, Northern Pintails typically select habitats with large expanses of low emergent cover. Winter habitats are threatened by hydrologic and water quality changes impacting seagrasses, water scarcity (directly impacting rice culture and the ability to flood fields post-harvest), and loss of habitat quantity and quality (through increased salinization) of coastal marsh. Other threats include: water shortages, conversion of rice into other agricultural commodities, drainage of wetlands and grassland for agriculture, commercial and residential development, and urbanization. Periods of extended drought in prairie nesting regions have caused dramatic population declines, usually followed by periods of recovery. Over the long term, however, the continental population of Northern Pintails has declined significantly from 6 million in the early 1970s to less than 3 million in the late 1980s and early 1990s (USFWS 2017). Since then, the population appears to have stabilized. Ongoing conservation measures, such as habitat restoration and enhancement of agricultural lands, as well as prudent harvest management (USFWS 2010), suggest that Northern Pintails should have a secure future in North America (Clark et al. 2014).

REDHEAD (*Aythya americana*). This diving duck, restricted to North America, breeds widely throughout the Prairie Pothole Region of the United States and Canada. This wide-ranging species exhibits a high degree of flexibility in habitat and food use and reproductive behavior. In contrast to its extensive breeding distribution, the Redhead in winter is concentrated mostly in coastal areas along the Gulf of Mexico, with hundreds of thousands of birds (about 80% of the continental population) traditionally found in the hypersaline lagoons of the Laguna Madre of Texas and the Laguna Madre of Tamaulipas, Mexico (Bellrose 1980, Woodin and Michot 2002, Baldassarre 2014).

The Redhead begins arriving from its northern breeding grounds to its winter range in October. The species depends heavily on rhizomes of shoal grass (*Halodule wrightii*), a seagrass species, for winter nutrition (Cornelius 1977, Michot and Nault 1993, Mitchell et al. 1994, Adair et al. 1996, Michot et al. 2008). Pairs begin to form on the winter range, and by the time the last birds have left on their northward migration in March, pair formation is well underway (Woodin and Michot 2002).

The Redhead demonstrates facultative brood parasitism to a greater extent than any other North American duck. Inter- and intraspecific egg parasitism is very common with

Flock of Redhead (*Aythya americana*) ducks.
Photo credit: Ron Bielefeld

this species; parasitic egg-laying has been known to increase nest abandonment and depress clutch size, nest success, and egg success for some host species (Sayler 1992, Woodin and Michot 2002). This species is considered primarily an over-water nester (though some upland nesting does occur) with nests commonly comprised of dominant emergent vegetation (e.g., *Typha* spp., *Scirpus* spp.) within semi-permanent and seasonal wetlands (Woodin and Michot 2002).

This species breeds primarily in the Prairie Pothole Region of the northern Great Plains and Canada, across the Intermountain West into northern California, with scattered smaller numbers breeding into Alaska (Woodin and Michot 2002, Baldassarre 2014). Like other northern breeding species of ducks herein, Redhead populations are influenced by wet-dry cycles in their northern breeding range, as well as conversion of both wetland and grassland habitats to rowcrop agriculture (Drever et al. 2007, Doherty et al. 2013, Wright and Wimberly 2013). Threats on the wintering grounds are varied and include natural and anthropogenic changes to their habitats and the seagrass beds in and around Laguna Madre and into Mexico. Wind energy development in coastal Texas is a relatively recent potential population impacting factor that is poorly understood (but see Lange 2014, Lange et al. 2018). The continental Redhead population hovered around an estimated half-million birds from 1955–early 1990s and has since increased fairly dramatically, likely partially owing to a 10-year wet-cycle on the prairies. The population has been at or exceeding the long-term average (700,000) since about 2005 (USFWS 2017). Unlike Northern Pintails and Scaup, there is no AHM harvest management process designed specifically for this species (USFWS 2018). Redhead populations appear generally resilient to past and current harvest pressures (Péron et al. 2012) and as such, this species should be secure across North America well into the future.

GADWALL (*Mareca strepera*). A medium-sized dabbling duck that breeds throughout the north-central United States and Prairie Provinces of Canada, the Gadwall winters in the southern United States and coastal Mexico, the largest concentrations occurring along the Gulf Coasts of Louisiana and Texas. During winter, individuals spend most of the day feeding on leaves and stems of aquatic vegetation in mixed flocks with other waterfowl (Paulus 1982). Gadwall will extensively use brackish marsh, where submerged aquatic vegetation is available (LeSchack et al. 1997). Gray (2010) found that female Gadwall in Southwestern Louisiana used freshwater and intermediate marsh types substantially more so than other marsh types found within the coastal marsh zone. Also, Gadwall use of freshwater marsh increased after Hurricane Ike altered the natural salinity gradient within most of the coastal marsh zone. This characteristic is rather unique among the species selected by the waterfowl working group.

Habitat degradation and drought conditions on breeding areas during the 1960s, 1970s, and early 1980s led to declines in many populations of waterfowl in the United States (Reynolds et al. 2007, Doherty et al. 2013, 2015). More recently, commodity prices and changing technology has allowed for the spread of corn (*Zea mays*) and soybeans (*Glycine max*) much further north and west, into what was considered to be traditionally wheat-country (Higgins et al. 2002). As a result, both wetland drainage and grassland conversion dramatically increased across the Prairie Pothole Region (Rashford et al. 2011, Doherty et al. 2013, Walker et al. 2013, Wright and Wimberly 2013, Johnston 2014). Gadwall population response to wet-dry cycles on the prairies was much like that of the Blue-winged Teal, in that the population began a strong increase in the early- to mid-1990s as a function of a lengthy wet-cycle. The population estimate has been well above the long-term average (2.0 million birds) since 1995 (USFWS 2017) owing to improved wetland conditions (LeSchack et al. 1997).

BLUE-WINGED TEAL (*Spatula discors*). One of the most common breeding ducks in the north-central United States and prairie Canada, Blue-winged Teal are early migrants for wintering habitats largely south of the United States. Adult males begin southern migration well in advance of migrating females and juveniles, and are often abundant in Gulf Coast marshes by mid-August (Bellrose 1980, Rohwer et al. 2002, Baldassarre 2014).

Blue-winged Teal limit foraging to aquatic areas where the majority of their diet is plant matter, particularly seeds. On migration and wintering areas, they use a variety of shallow open water wetland habitats, such as flooded agricultural lands, palustrine wetlands, and fresh to intermediate coastal marsh. During the period just before and during egg-laying, adult females consume large amounts of aquatic invertebrates, mainly insect larva and snails, to meet the heightened protein requirements for egg production (Alisauskas and Ankney 1992). Like many other waterfowl, females store fat prior to nesting and then use this energy to form eggs and help meet the demands of incubation (Alisauskas and Ankney 1992, Rohwer et al. 2002).

The population status of the Blue-winged Teal mirrors wetland conditions on the prairie breeding grounds. Populations dropped to a 40-year low in 1990 after several dry years, but in the decade following numbers more than doubled (USFWS 2017). Blue-winged Teal population estimates was at or below the long-term average of 5.1 million birds from 1955–mid-1990s, and since then, the populations has responded to a lengthy wet period on the prairies with recent population estimates of 6.4–6.7 million birds (USFWS 2017). This positive response suggests that long-term wetland degradation on the prairies had not irreversibly damaged teal breeding habitat. However, the combination of wetland drainage and conversion of grasslands for row crop agriculture remain the biggest threat to waterfowl breeding habitat (Reynolds et al. 2007, Stephens et al. 2008, Wright and Wimberly 2013, Johnston 2017). Like other prairie-nesting ducks, the local productivity of a population is strongly influenced by nest success and brood survival (Rohwer et al. 2002).

Breeding Season

Mottled Ducks are the only dabbling duck to breed in significant numbers across the Gulf of Mexico (Baker 1983, Stutzenbaker 1988). Breeding and nesting season begins in January and generally peaks in March and April, when females are typically well into incubation (Rigby 2008, Bielefeld et al. 2010). Mottled ducks typically nest in coastal marsh and adjacent grasslands (Grand 1988, Stutzenbaker 1988, Rigby 2008, Haukos et al. 2010), where nests are built in large grass expanses that are adjacent to permanently flooded marsh, impoundments, or other areas with wetland habitat is available during spring/summer (Stutzenbaker 1988). Nests are built on the ground within mixture(s) of live and dehiscent portions of species such as marsh-hay cordgrass (*Spartina patens*), Gulf cordgrass (*S. spartinae*), and saltgrass (*Distichlis spicata*) (Baker 1983, Rorabaugh and Zwank 1983, Grand 1988, Stutzenbaker 1988, Rigby 2008). Nest success of dabbling ducks is usually higher (i.e., lower predator efficiency) in large, unfragmented blocks of grassland habitat (e.g., Stephens et al. 2004, 2005). Moorman et al. (1991) found that Mottled Duck ducklings had higher survival and growth rates when salinity levels were <9 parts per thousand (ppt).

Spring and Autumn Migration Seasons

Among the waterfowl that utilize habitats along the Gulf Coast during the non-breeding period, Blue-winged Teal are among the most transient, as they mostly winter south of this region in Mexico, Central and South America, and the Caribbean islands. For the rest of the non-breeding waterfowl species of conservation concern (Table 9.1) the Gulf of Mexico region is generally viewed as a winter terminus (Bellrose 1980, Baldassarre 2014). The primary habitats for Blue-winged Teal during the migratory seasons are marsh (Palustrine and Estuarine Emergent Wetlands) and agricultural lands, i.e., flooded rice. Some segment of the Blue-winged Teal population embarks on a Trans-Gulf migratory route (Russell 2005, GoMMAPPS unpublished data) from staging areas along the northern Gulf Coast to their wintering destinations further south (Bellrose 1980, Baldassarre 2014); also cross the Gulf on their way back north in the spring.

Winter Season

Coastal marshes, ricelands, seagrass meadows, and non-tidal palustrine wetlands provide the most important habitat for waterfowl in the Gulf Coast region during the non-breeding period (Chabreck et al. 1989, Hobaugh et al. 1989, Stutzenbaker and Weller 1989). Other habitat types used by waterfowl in lesser numbers within this region include nearshore marine waters and coastal embayments, some of which support large concentrations of wintering scaup and smaller numbers of other diving ducks (Kinney 2004).

Among these habitat types, coastal marshes are the most expansive, totaling over 1,324,700 ha throughout the region (Enwright et al. 2015). The vast majority (82%) of coastal marsh within this region occurs in Louisiana and southeastern Texas (Enwright et al. 2015). Management of coastal marshes for wintering waterfowl revolves around hydrologic restoration and management to encourage growth of vegetation communities that provide abundant foraging resources, which typically includes actions to produce low salinity, low turbidity waters at appropriate foraging depths (Chabreck et al. 1989, Nyman and Chabreck 2012).

Ricelands are the dominant and most important waterfowl habitat type within inland regions of the western Gulf Coast (i.e., Louisiana and Texas). While essentially all waterfowl within this region exploit food resources within ricelands, this habitat type is particularly valuable for Northern Pintails and Arctic-breeding geese. Several characteristics of ricelands within the Gulf Coast region make these habitats uniquely valuable to waterfowl, most notably the frequent practice of producing two rice crops annually. The first crop is typically harvested during July–August, and harvest of a ratoon crop often follows in October–November (Hobaugh et al. 1989, Petrie et al. 2014). This results in two pulses of waste rice and natural seeds whose timing generally coincides with the arrival of early and late migrating waterfowl (Wilson and Esslinger 2002). Additionally, when not in active production, ricelands in this region may be left idle during which time they will support communities of annual grasses and sedges (Hobaugh et al. 1989). When flooded during winter, idled ricelands provide abundant seed resources that are readily used by waterfowl (Marty 2013).

Seagrass meadows occur in saline and hypersaline shallow waters along the Gulf Coast, being most prevalent in the Big Bend area of Florida, Mobile Bay in Alabama, Mississippi Sound in Alabama and Mississippi, Chandeleur Islands in Louisiana, Texas Coastal Bend and the Laguna Madre in Texas (Handley et al. 2007). Shoal grass and wigeon grass (*Ruppia maritima*) are among the most valuable seagrasses in the Gulf Coast region, being an especially important component of the diet of Redhead, Northern Pintail, and American Wigeon (*Mareca americana*) (Ballard et al. 2004, Michot et al. 2008). Lesser and Greater Scaup are also common within the Laguna Madre, although their diet in coastal waters is dominated by Atlantic surf clams (*Spisula solidissima*) (Harmon 1962). Weller (1964) recognized the importance of the Laguna Madre area for wintering Redheads, likely due primarily to the abundant shoal grass meadows and availability of other essential habitat resources.

Non-tidal, non-agricultural palustrine wetlands provide additional foraging habitat for waterfowl in this region, although their importance varies geographically. Across most of this region, these wetlands are valued for their food resources (Anderson 2008); yet in south Texas, they provide both food resources (Mitchell et al. 2014) and dietary fresh water for waterfowl that have been foraging in hypersaline waters of the Laguna Madre (Adair et al. 1996, Ballard et al. 2010). Landscape positioning of palustrine wetlands in south Texas is an important determinant of waterfowl use for dietary fresh water, as waterfowl use is higher on wetlands closer to seagrass bed foraging sites in the Laguna Madre (Adair et al. 1996).

CONSERVATION CHALLENGES AND INFORMATION NEEDS

Primary Threats and Conservation Challenges

The widespread, persistent loss of Gulf Coast wetlands is the most significant threat to priority waterfowl habitats in this region. Since 1932, more than 487,650 hectares of coastal marshes and forested wetlands have been converted to open water in Louisiana alone (Couvillion et al. 2011). Additionally, from 2004–2009, intertidal wetlands along the entire U.S. Gulf of Mexico decreased by 38,445 hectares (Dahl and Stedman 2013). The primary causes of coastal wetland loss are numerous and include relative sea-level rise, reduced riverine sediment loads, leveeing of major rivers, excavation of canals and waterways for oil and gas extraction and navigation, saltwater intrusion caused by hydrologic alteration, industrial and residential development, and increased frequency and/or intensity of hurricanes and tropical storms (Craig et al. 1979, Moulton et al. 1997, Gosselink et al. 1998, Glick et al. 2013, Handley et al. 2015). While projections of future marsh loss are not available for the entire Gulf Coast region, another 453,250 hectares of vegetated marsh in Louisiana is expected to be converted to open water by 2060 (CPRA 2012).

Rice has existed as a dominant agricultural crop in coastal Louisiana and Texas since the late 1800s (Phillips 1951, Craigmiles 1975). In the early 1980s, Gulf Coast rice production began a significant long-term decline as a result of various programmatic and economic factors. Some of the more important drivers of declines in rice acreage include the Federal Acreage Reduction Programs (Brewer 1984), rising land prices, higher land opportunity costs, and increased competition for limited water (Alston et al. 2000). Moving forward, the factor likely to have the greatest impact on future rice trends is the availability and affordability of reliable water supplies (Alston et al. 2000, Baldwin et al. 2011). Flooded rice fields (i.e., ricelands or rice prairies) are a critically important habitat type, as well as an important food resource for waterfowl wintering within the GoMAMN geography (Hobaugh et al. 1989, Krapu and Reinecke 1992, Baldassarre and Bolen 1994).

Seagrass coverage and distribution have varied across the region since the mid-20th century with most sites experiencing declines (Handley et al. 2007). Natural processes along with human activities have contributed to these changes through impacts on water clarity, salinity, sediment deposition, and physical disturbance (Onuf 1996, Handley et al. 2007). Primary causes of seagrass change are maintenance dredging, which buries seagrasses and elevates turbidity, nutrient and contaminant burdens from agricultural and industrial land uses, stormwater run-off, altered hydrology, as well as physical damage from propeller scarring (Handley et al. 2007, Martin et al. 2008).

Shifts in seagrass species composition in the northern Gulf of Mexico are also a concern, chiefly because of their implications to these plants as important waterfowl food resources. Notable shifts [i.e., replacement of shoal grass by manatee grass (*Syringodium filiforme*) and turtle grass (*Thalassia testudinum*)] have been documented in the Laguna Madre of Texas, caused primarily by salinity moderation following construction of the Gulf Intracoastal Waterway and ship passes through Padre Island (Quammen and Onuf 1993). Because shoal grass is the dominant food source for wintering

Redheads and Northern Pintails in south Texas (Ballard et al. 2004), continued declines in shoal grass availability are likely to reduce the capacity of the region to support wintering waterfowl populations.

Wind energy development is another emerging concern for wintering waterfowl populations and their habitats in south Texas (Kuvlesky et al. 2007). Beginning in 2008, several large wind farms were constructed adjacent to the Laguna Madre, encompassing lands that contain >10% of the non-tidal freshwater ponds upon which Redheads depend for dietary fresh water (Lange 2014). A recent study revealed evidence for strong negative impacts of these developments on Redhead behaviors and habitat use (Lange et al. 2018). Redhead use of freshwater ponds within the wind farms decreased 78% between pre- and post-construction periods, despite the total number of wintering Redheads in the region increasing by 228% between these same time periods (Lange et al. 2018). Effects of wind energy development apparently extended to Redhead habitats as well, as fewer wetlands contained water during the post-construction period, after correcting for differences in environmental conditions (Lange et al. 2018). Due to the potential for expansion of wind energy development proximal to critical Redhead habitats in south Texas, wind energy development is expected to grow in south Texas, which may intensify threats to wintering Redhead populations (Lange et al. 2018). Wind energy development is not constrained to just land-based siting, as there is interest (Bureau of Ocean Energy Management and National Renewable Energy Laboratory) in developing offshore windfarms as well. The combination of both land-based and offshore windfarms in key waterfowl wintering areas of the northern Gulf of Mexico has the potential to make key foraging, roosting, loafing, and freshwater habitats functionally unavailable (e.g., Larsen and Guillemette 2007, Loesch et al. 2013).

In general, all the waterfowl species considered herein (Table 9.1) tend to occupy specific habitat types (Block and Brennan 1993) within their geographic range, principally palustrine and estuarine emergent wetlands for Lesser Scaup, Mottled Duck, Northern Pintail, Blue-winged Teal, and Gadwall, or estuarine-coastal for Lesser Scaup, Northern Pintail, and Redhead. In addition, Mottled Duck and Northern Pintail are found in shallow-flooded cultivated croplands and Lesser Scaup can be found in deep-flooded agricultural fields (i.e., crawfish ponds). Management actions which impact more habitats or a greater proportion of the Gulf of Mexico Region (Figure 1.2) and a greater number of the GoMAMN Birds of Conservation Concern (Appendix 1) are a higher priority (refer to Priority Management Actions below).

Influence diagrams represent an hypothesized cause-effect web of key factors affecting species or ecological (or management) outcomes (Marcot et al. 2006), or more simply, how we think the system behaves. Here, the Waterfowl Working Group used a series of WebEx's, Conference Calls, and emails to create draft versions of species-specific influence diagrams, and through an iterative process and series of reviews arrived at final versions of the influence diagrams (Figure 9.1, Appendix 9). The influence diagrams should be read from left to right with management activities and/or restoration projects on the left, ecological processes and/or potential population impacting factors in the center, and avian response parameters of interest on the right. Each of the waterfowl species' influence diagrams (Figure 9.1, Appendix 9) should be considered unique given species differences in migration chronology, habitat use and preferences (Kaminski et al. 1988, Baldassarre and Bolen 1994), foraging behavior and diets, morphology, etc. (Nudds 1992). However, when comparing all of the influence diagrams, that of the Mottled Duck (Figure 9.1) and Blue-winged Teal (Appendix 9) are probably the most distinctive, but for vastly different reasons. In the case of the Mottled Duck, it is the only species that carries-out its entire annual life-cycle within the GoMAMN geography (Bielefeld et al. 2010). In contrast, the Blue-winged Teal which breeds in the Prairie Pothole Region is the earliest arriving migrant in the fall (July–Sept), overwinters in areas to the south across the Gulf of Mexico, and is one of the latest waterfowl species to move through the geography during the spring migration back north to the breeding grounds (Rohwer et al. 2002). Given inherent differences across these influence diagrams, there are also clear similarities especially with regards to management actions and/or restoration projects and the avian response parameters of interest (Table 9.2). This is particularly true for the traditional migrant waterfowl species; Lesser Scaup, Northern Pintail, Redhead, and Gadwall (see Appendix 9).

Here forward within the context of priorities, we are limiting discussions to only those three waterfowl species identified as GoMAMN Birds of Conservation Concern (see Appendix 1): Mottled Duck, Lesser Scaup, and Northern Pintail. However, the other three waterfowl species (Redhead, Gadwall, and Blue-winged Teal) remain relevant to the broader discussions of monitoring and avian response metrics or parameters of interest, particularly given that status and trends (abundance or population estimates) type monitoring often includes all waterfowl species, e.g., Mid-winter Waterfowl Surveys (Dubovsky 2017, Fronczak 2017).

Additional threats and conservation challenges to birds of the Gulf of Mexico can be found in Burger (2017, 2018). Though not strictly limited to just breeding and wintering waterfowl in the Gulf of Mexico, Burger (2017, 2018) does a good job of describing the importance of this

Northern Pintail (*Anas acuta*). Photo credit: Donna Dewhurst

area to Gulf of Mexico breeding birds and North American migrant birds, discussing potential population impacting factors, providing monitoring and research needs, and describing the respective habitats in both the northern (i.e., GoMAMN geography Figure 1.2) and southern Gulf of Mexico.

IDENTIFICATION OF PRIORITIES

Monitoring

Here we briefly describe the Waterfowl Working Group's perspectives related to monitoring. Additional, more specific information will be provided later as it relates to priority management actions, status and trends assessments, and ecological processes (Tables 9.2-9.3). We recommend the reader review and consider the three roles of monitoring related to a given management action(s) within an adaptive management framework as described by Lyons et al. (2008); see also Hutto and Belote (2013) and Reynolds et al. (2016).

Generally speaking, the most rigorous and expansive waterfowl monitoring and population estimation efforts traditionally and currently occur on the breeding grounds (Cowardin and Blohm 1992, Smith 1995). Nonetheless, numerous surveys are conducted by both state (e.g., Mississippi and Louisiana; e.g., Pearse et al. 2008a) and federal agencies during the non-breeding period to index regional distribution and abundance of waterfowl (Sharp et al. 2002, Soulliere et al. 2013, Andersson et al. 2015). Despite the availability of data from these surveys, in some cases, we still lack basic information regarding the potential impacts of landscape change and habitat conditions on migrating and wintering waterfowl demography. We similarly lack a thorough understanding of how environmental and habitat conditions influence Mottled Duck vital rates throughout their annual cycle.

These data deficits directly relate to our three sub-objectives:

1. A need for status and trends data for both waterfowl populations and their habitats within the GoMAMN boundary (Figure 1.2),
2. An improved understanding of the areas required by waterfowl and specific actions to better and/or more efficiently manage those areas, and
3. A better understanding of the ecological processes affecting waterfowl within the GoMAMN boundary (Figure 1.2) and beyond (e.g., cross-seasonal effects; Sedinger and Alisauskas 2014).

The GoMAMN Waterfowl Working Group values monitoring that 1) have explicit objectives that are clearly linked to management objectives/decisions and conservation actions, 2) estimate metrics (Sauer and Knutson 2008) with a sampling design and methodology that permits unbiased and statistically rigorous results while minimizing costs (Field et al. 2005, MacKenzie and Royle 2005) and logistical issues, 3) ensures continuity despite changes in objectives, personnel, and technologies, and 4) makes monitoring results readily available and easily interpretable (and implementable) for a variety of partners and stakeholders, including decision- and policy-makers (Figure 2.2).

For example, the development and implementation of a Gulf of Mexico-wide waterfowl monitoring "program" would generate species-specific baseline population abundance estimates, which will allow for the effective evaluation of future anthropogenic (e.g., oil spills) and natural events (e.g., hurricanes). Also, understanding changes in daily lipid-reserves in migrating wild birds can be used as an indicator when evaluating habitats and species management and conservation (Anteau and Afton 2008, Anteau and Afton 2009, Anteau and Afton 2011). As such, we consider that some index [BCI = body mass (g)/wing chord (mm); Dzubin and Cooch 1992] of body condition (Ringelman and Szymczak 1985, Dooley et al. 2010; but see also Schamber et al. 2009) for wintering waterfowl may be just as or more important than estimating abundance for the target species (Table 9.1). In addition, we believe a better understanding of both seasonal (Moon and Haukos 2006, Moon et al. 2017) and/or annual (Haukos 2015) survival (apparent) estimates for all relevant sex-age classes is a particularly salient avian response metric (Lebreton et al. 1992, Sæther and Bakke 2000, Koons et al. 2014) for evaluating both management actions and ecological processes. Furthermore, we believe if these waterfowl data streams were collected repeatedly over a long period of time across multiple sites (i.e., Gulf-wide) it would allow us to not only evaluate population (and habitat) trends, but also to evaluate species-level responses to management actions and/or restoration efforts, i.e., monitoring roles 2 and 3 in Lyons et al. (2008). That is to say, we will have collected data on important individual-level demographic parameters at a temporal and spatial scale that matters (Robinson et al. 2014), thus, increasing our strength of interference. Together, these data would allow us to develop and further refine diurnal and nocturnal waterfowl-habitat associations for species across the region, which should result in greater management efficacy at specific areas (and specific times) (Davis et al. 2018). As an example, it has been well documented that Northern Pintails have different diurnal and nocturnal habitat associations in southwestern Louisiana (Cox 1996, Cox and Afton 1997, Link et al. 2011), but such information is generally lacking for the other GoMAMN waterfowl species targets (Table 9.1). Estimating population size/abundance and associated trends, collecting body condition data, in particular, pre-departure body condition, spring departure dates by species, and deriving seasonal and/or annual survival estimates for adult females are all high priority avian metrics across species and sub-objectives (Figure 9.1, Appendix 9). Additionally for Mottled Ducks, data on the breeding population size (USFWS 2016) and fall/winter age ratios from birds harvested by waterfowl hunters (Dubovsky 2017, Fronczak 2017), as an index to annual productivity (Nichols 1991), is also relevant.

Priority Management Actions

In general, the Waterfowl Working Group has traditionally relied upon national (NAWMP 1986 and revisions), regional (Wilson 2007), and state-level (TPWD 2011) waterfowl planning efforts to inform waterfowl habitat management and conservation decisions, as well as to prioritize research and monitoring efforts (Brasher et al. 2012). In addition, here we also utilized and applied the standard lexicon of conservation actions classification developed by Salafsky et al. (2008:Table 2) to define and inform priority management actions. More broadly, the bird conservation community (i.e., GoMAMN) has outlined its values through the objectives hierarchy (Figure 2.2). Part of the objectives hierarchy refers specifically to management actions, which indicates that the broader GoMAMN Community of Practice values monitoring efforts that: 1) affect multiple GoMAMN Birds of Conservation Concern, in this case, several waterfowl species (Appendix 1), has a large footprint or large spatial scope, 2) identify the various types of uncertainty while simultaneously reducing uncertainty associated with given management action(s) (Williams 2011), 3) address management actions which are commonly/frequently used as part of Gulf of Mexico restoration activities, and 4) address explicit objectives and/or questions about management action(s) all within an adaptive management framework (Williams et al. 2009).

The Waterfowl Working Group, used Lyons et al. (2008), Salafsky et al. (2008), and Williams (2011) as anchoring points for prioritizing management actions. We evaluated and selected from a suite of potential management actions that were believed to have the highest probability of affecting a large number of priority waterfowl species. The management actions that were selected included: habitat and natural process restoration (e.g., Deepwater Horizon Project Tracker, http://dwhprojecttracker.org), and site/area management efforts to reduce and/or mitigate disturbance to waterfowl (maximizing energy intake while minimizing energy expenditure) (Table 9.2). Of these, the most consistent and potentially influential management action appeared to be habitat and natural process restoration in estuarine and palustrine emergent wetland systems, aquatic bed, grasslands, and open water (Appendix 9). Habitat and natural process restoration appears in all influence diagrams and is related to the greatest number of ecosystem processes in those diagrams of any management activity. Some management actions are not likely to have a major influence on waterfowl. For example, though harvest management is broadly applied across a variety of habitats and has potential to influence myriad waterfowl species across North America, harvest-related effects are generally thought to be relatively minor at the population-level, at least for most duck species (Sedinger and Herzog 2012, Cooch et al. 2014). Alternatively, wastewater management is not practiced widely across the GoMAMN geography, i.e., relatively small spatial scale, but could potentially affect (positively or negatively) wintering waterfowl if the management action happened to overlap spatially and temporally with a high concentration of wintering waterfowl area. Both the frequency of management actions and the amount of habitat affected by these individual categories of management actions vary widely across the Gulf of Mexico (see Deepwater Horizon Project Tracker). When we further evaluated the various management actions using a matrix of the Effect Size (ES) x Uncertainty Score (US) whereby only species and management actions that had values <3 were considered important, only management actions associated with the Mottled Duck are considered high priority. Sustainable energy development for wintering Redheads had an ES x US = 2, due to the potential for direct (i.e., reduced overwinter survival) and indirect effects (i.e., reduced body condition) of wind energy development, primarily in the Laguna Madre area of Texas. However, the Redhead is not identified on the GoMAMN Birds of Conservation Concern (Appendix 1) and is therefore, not discussed further. The Mottled Duck is discussed further here, because as previously indicated, it is unique in that its full-annual-cycle occurs in the GoMAMN geography (Figure 1.2). Interestingly, none of the ES x US values were <3 during the winter period, whereas all but one of the ES x US values were <3 during the breeding period (Table 9.2). The Waterfowl Working Group clearly believed that potential population bottlenecks for this species were limited to the breeding season (Figure 9.1). As such, both wetland and grassland habitat needs for this species require on-the-ground management actions within the GoMAMN geography (e.g., Wilson 2007). Mottled ducks typically nest in coastal marsh and adjacent prairie habitats (Grand 1988, Stutzenbaker 1988, Rigby 2008, Haukos et al. 2010), where nests are built in large grass expanses that are adjacent to permanently flooded marsh or impoundments (Stutzenbaker 1988). Therefore, management of grass for nesting habitat and palustrine emergent marsh and sustainable agriculture (i.e., rice) provide brood-rearing habitat and foraging areas throughout the year (Krainyk and Ballard 2015). This requires a diversity of management actions depending on the habitat and other limiting factors related to the management action like cost constraints and/or funding availability, timing, and ability to actually implement a given management action. Freshwater emergent wetland systems that include rice fields and wetlands devoted to crawfish aquaculture and activities related to sustainable agriculture are also important for this species.

Because little research has been conducted to directly evaluate efficacy of management actions for waterfowl in the Gulf of Mexico Region, significant reduction in uncertainty of the effects of management on priority species would likely occur for any management action(s) if properly monitored. Further, these activities could be assessed in an adaptive management framework (Williams et al. 2009), although for many actions the recurring decision would be made at different locations (e.g., marsh restoration sites), rather than in the same location at different times (e.g., flooding of agricultural fields). All waterfowl monitoring projects addressing management actions and their effects on waterfowl also need to consider the timing of those actions (Table 9.2), since region-specific timing of migration for most waterfowl species is pretty poorly documented, and migration chronology is changing rapidly (Notaro et al. 2016). Management actions may have differential effects on target waterfowl species and their respective populations within and across seasons (Sedinger and Alisauskas 2014). Also, the same management action may also have different effects on a target waterfowl species or waterfowl community depending on what season the specific management action(s) is performed (e.g., burning grasslands for Mottled Duck nesting). Finally, we should expect or anticipate potential for delayed response in a given waterfowl species to a given management action, but the response will likely depend on a myriad of factors including, but not limited to the type of management action, and the scope and scale of the action (NASEM 2017).

Although, some waterfowl data needs and specific avian metrics were mentioned previously, here we provide several specific examples for Mottled Ducks during the breeding season related to a given management action, all of which had ES x US values <3 (Table 9.2). For brevity, not all Mottled Duck management action examples with values <3 are included here.

The first management action example relates to the loss of grassland nesting habitat (through various causes) which reduces the availability (i.e., quantity) of suitable nest sites in proximity to low salinity wetlands leading to poor productivity via both reduced breeding propensity and lower nest success (Table 9.2, Figure 9.1). Per Salafsky et al. (2008:Table 2) the two management actions that most directly relate to this: land/water protection and land/water management. This management priority could potentially be addressed through policy changes and/or additional targeted funding for conservation programs like wetland and grassland easements (i.e., perpetual or term-limited; protect remaining grassland parcels) and wetland and grassland restorations, as well as conservation delivery via working with private landowners to provide technical assistance (i.e., to better manage existing lands). One could use the Mottled Duck Decision Support Tool (DST) to target specific management actions to specific tracts of land identified as "highest priority" (Krainyk and Ballard 2015). Avian metrics of interest related to this priority management action would be estimating breeding propensity, deriving daily survival rates of marked nests, and estimating hen breeding season survival (Table 9.2). Initially, these data would most likely address monitoring role number 1, as identified by Lyons et al. (2008). However, if this were done within a broader experimental design at a relatively large spatial scale (at a minimum with multiple experimental and control sites across Louisiana and Texas) with recurring decision-points, it could potentially address all three roles of monitoring.

The second management action example is only slightly different from the first (Table 9.2). It relates to the fragmentation of nesting habitat (through various causes) which enables greater search efficiency by predators thereby reducing nest success and breeding season survival of hens, not only leading to lower productivity in year t, but also lost reproductive potential in years $t + 1$, $t + 2$, etc., due to the mortality of some proportion of breeding-age hens (see Sargeant and Raveling 1992). The management action(s) most directly related to this is: species management and land/water management. Building off the first example, one could potentially use the

Mottled Duck DST (Krainyk and Ballard 2015) to identify the "highest priority" grassland tracts and conduct mammalian predator removal at some sites (i.e., experimental) in combination with non-removal sites (i.e., controls) with predator surveys at all sites (see Sargeant et al. 1993); within a well thought-out experimental design at a relatively large spatial scale; sites across the Mottled Duck breeding range from Alabama to Texas. Avian metrics that would be priorities are estimating daily survival rates of marked nests, estimating duckling and/or brood survival, and estimating hen breeding season survival. At the patch-scale, important parameters to describe sites would determine the quantity and configuration (e.g., patch size, perimeter:area ratio, distance to brood wetland) of grassland tracts. At the nest-scale, measurements like visual obstruction readings (Robel et al. 1970), i.e., height/density of vegetation, would be collected at all marked nests (see Durham and Afton 2003). These data would most likely address monitoring role number 1 as identified by Lyons et al. (2008). Ultimately, the data collected would address monitoring role number 2 (Lyons et al. 2008) with the appropriate design, scale, and replication (Eberhardt and Thomas 1991, Johnson 2002a, 2002b).

The third management action example for the Mottled Duck during the breeding season is much different than the previous two (Table 9.2). Low water availability for wetland management reduces the availability of preferred low salinity wetlands at various times during the annual lifecycle of the Mottled Duck which may negatively affect: 1) breeding propensity, re-nesting effort, and brood survival, 2) breeding season hen survival, and 3) survival of flightless adults and immatures during the molt period (e.g., Moon et al. 2017); through reduced food availability and/or food quality, increased physiological stress due to higher salinities (Moorman et al. 1991), and potentially increased predation risk. The two management actions that most directly relate to this: land/water protection and land/water management. This management priority could potentially be addressed through policy changes and/or additional targeted funding for conservation programs like wetland easements (i.e., perpetual or term-limited; protect remaining land parcels that are known brood and molting marshes) along with wetland restorations (and associated habitat management), as well as partnering with Ducks Unlimited to deliver beneficial conservation outcomes on private lands (i.e., technical assistance with water management and manipulation). Much like the previous examples, the where on the landscape question could be informed using the Mottled Duck DST (Krainyk and Ballard 2015). Clearly, it is not only about getting the where on the landscape right, but also about putting water on the landscape at the right time and in the right volume/amount. Priority avian metrics to evaluate management effectiveness for this example have been identified above. Monitoring roles number one and two (Lyons et al. 2008) would be addressed given the appropriate study design (experimental and reference sites), spatial and temporal resolution, and replication (Anderson 2001).

Though hybridization with Mallards is a concern for the Western Gulf Coast population of Mottled Ducks (Figure 9.1) and it received an ES x US score of 3 (Table 9.2) and is not considered further here. Hybridization is almost certainly a serious threat for the Florida population of Mottled Ducks (Bielefeld et al. 2010), but does not appear to require management intervention, at least not at this time, for the Western Gulf Coast population (see Ford et al. 2017).

Priority Status and Trends Assessments

GoMAMN and the Waterfowl Working Group both value monitoring efforts that address the question of how are avian populations and their respective habitats faring given current (and future) conditions within the GoMAMN geography (Figure 2.1). To better understand future, desired conditions and response to either or both management actions and restoration activities within the geography, we must first establish current population (i.e., how many of a given species within a defined time and space) and habitat (i.e., how many acres of a given habitat class/type within a defined time and space) baselines (NASEM 2017, Brasher et al. 2018). Point estimates for both population(s) and habitat(s) should provide a reasonable measure of their respective status or condition (e.g., May Waterfowl Breeding Population and Habitat Survey, also referred to as Waterfowl Population Status Report; USFWS 2017). Given a sufficient period of time over which the estimates are collected and assuming a given level of precision or confidence in the point estimates, one can then start to evaluate species (and habitat) trends through time (e.g., Breeding Bird Survey; Sauer et al. 2013).

The bird conservation community (i.e., GoMAMN) has outlined its values through the objectives hierarchy (Figure 2.2) and part of the objectives hierarchy refers specifically to status and trends assessment (Lindenmayer and Likens 2010a, 2010b; but see Nichols and Williams 2006) for both populations (Sauer and Droege 1990) and habitats. Not unlike monitoring associated with evaluating efficacy of management actions, the GoMAMN CoP values monitoring that: 1) include multiple GoMAMN Birds of Conservation Concern, in this case, several waterfowl species (Appendix 1), 2) has a large footprint or large spatial scope, 3) identify the various types of uncertainty while simultaneously reducing uncertainty associated with a given management action(s) (Williams 2011), 4) address management actions which are commonly/frequently used as part of Gulf of Mexico

Table 9.2. *Uncertainties underpinning the relationship between management decisions and waterfowl populations in the northern Gulf of Mexico.*

Species Season(s)	Management Category[a]	Question(s)	End-point to measure mgmt. performance	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Mottled Duck, Lesser Scaup, Northern Pintail, Gadwall, Blue-winged Teal Winter, Migration, Breeding (MODU only)	Habitat and Natural Process Restoration (Freshwater Management)	What are the consequences of low water conditions, limited wetland availability, & drought-like conditions on breeding Mottled Ducks? Cross-seasonal effects? Annual variation?	Pre-departure body condition, peak departure date(s), overwinter survival, and food resource availability (covariate)- e.g., obtain survival estimates for sample of marked birds across the geography from birds in DRY v WET years	Research shows a link between indices of food abundance & body condition & cross-seasonal reproductive success at large spatial scales, but strength & consistency of the relationship is uncertain.	High	Low
Mottled Duck, Lesser Scaup, Northern Pintail, Gadwall, Blue-winged Teal Winter, Migration, Breeding (MODU only)	Habitat and Natural Process Restoration (Freshwater Management)	What are the consequences of low water conditions, limited wetland availability, & drought-like conditions on wintering waterfowl? Cross-seasonal effects? Species-specific variation?	Pre-departure body condition, peak departure date(s), overwinter survival and food resource availability (covariate)- e.g., obtain survival estimates for sample of marked birds (LESC, NOPI, GADW, BWTE) across the geography in DRY v WET years	Research shows a link between indices of food abundance & body condition & cross-seasonal reproductive success at large spatial scales, but strength & consistency of the relationship is uncertain particularly for these spp. wintering in this geography.	High	Low
Mottled Duck, Northern Pintail, Blue-winged Teal Winter, Migration, Breeding (MODU only)	Habitat and Natural Process Restoration (Habitat Management - Agriculture)	What are the effects of declines in rice acres & production on breeding Mottled Ducks & wintering waterfowl? Do reductions in availability of this habitat result in subsequent declines in pre-departure body condition (e.g., fat reserves)?	Pre-departure body condition & peak departure date(s)- e.g., obtain body condition measurements (+ food habits/diets) for a sample of birds (MODU, NOPI, BWTE) in areas of primarily rice agr & more coastal ref sites	Reductions in acres of high energy food resources (e.g., rice) on the wintering grounds may lead to decreased body condition & later departure dates resulting in cross-seasonal effects to reproductive effort & output.	Low	High
Mottled Duck, Lesser Scaup, Northern Pintail, Gadwall, Blue-winged Teal Winter, Migration, Breeding (MODU only)	Site/Area Management (Disturbance)	Does human disturbance (hunting, ag operations, etc.) negatively affect wintering waterfowl body condition & delay spring departure date(s) due to increased movements (freq, duration, & total distance) & greater cumulative energy expenditure? Cross-seasonal effects?	Pre-departure body condition & departure dates- e.g., obtain body condition measurements throughout the Fall-Winter period (+ food habits/diet from sample collected by hunters) for sample of birds primarily using coastal estuarine habitats	Fairly certain that disturbance negatively affects energy expenditure, but uncertain about relationship between energy expenditure & body condition (i.e., how easily birds can compensate for greater energy expenditure).	High	Low

Table 9.2 (continued).

Species Season(s)	Management Category[a]	Question(s)	End-point to measure mgmt. performance	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Mottled Duck, Lesser Scaup, Northern Pintail, Gadwall, Blue-winged Teal Winter, Migration, Breeding (MODU only)	Site/Area Management (Disturbance)	Does human disturbance (hunting, ag operations, etc.) negatively affect wintering waterfowl body condition & delay spring departure date(s) due to increased movements (freq, duration, & total distance) & greater cumulative energy expenditure? Cross-seasonal effects?	Pre-departure body condition & departure dates- e.g., obtain body condition measurements throughout the Fall-Winter period (+ food habits/diets from sample collected by hunters) for sample of birds using primarily inland palustrine habitats	Fairly certain that disturbance negatively affects energy expenditure, but uncertain about relationship between energy expenditure & body condition (i.e., how easily birds can compensate for greater energy expenditure).	High	Low
Lesser Scaup, Redhead Winter, Migration	Site/Area Management (Contaminants)	Does high anthropogenic nutrient inputs negatively affect wintering waterfowl food resources, i.e., seagrasses and mollusks? Are there then impacts to waterfowl via constraints on Fall-Winter energetics, pre-departure body condition, & delays in spring departure date(s)? Cross-seasonal effects?	Pre-departure body condition, departure date(s), overwinter survival & food resource availability (covariate)- e.g., obtain survival estimates from sample of marked birds (LESC, REDH) at known affluent sites & nearby ref sites. Also, tox. 'panel' of potential contaminants (e.g., Mg, Pb, Se, PCB, HCB, PAHs, etc.) from sample of collected birds	Research shows a link between indices of food abundance & body condition & cross-seasonal reproductive success at large spatial scales, but strength & consistency of the relationship is uncertain; particularly for these spp. wintering in this geography.	High	Low
Lesser Scaup, Redhead Winter, Migration	Site/Area Management (Disturbance)	Does human disturbance (hunting, comm & rec fishing, O&G operations, etc.) in marine environment negatively affect wintering waterfowl body condition & delay spring departure date(s) due to increased movements (freq, duration, & total distance) & greater cumulative energy expenditure? Cross-seasonal effects?	Pre-departure body condition, departure date(s), overwinter survival & food resource availability (covariate)- e.g., obtain overwinter survival estimates & body condition throughout the Fall-Winter period (+ food habits/diets for sample collected by hunters); primarily marine/estuarine habitats in "high" v. "low" disturbance sites	Fairly certain that disturbance negatively affects energy expenditure, but uncertain about relationship between energy expenditure & body condition (i.e., how easily can birds compensate for greater energy expenditure).	High	Low
Lesser Scaup Winter, Migration	Habitat and Natural Process Restoration (Freshwater Management)	Does altered hydrology increasing salinity thus, negatively affecting wintering waterfowl food availability & distribution, in particular bivalve/ mollusks? Do these changes influence pre-departure body condition & delayed spring departure date(s)? Cross-seasonal effects?	Pre-departure body condition, departure date(s), overwinter survival & food resource availability (covariate)- e.g., obtain overwinter survival estimates & body condition throughout the Fall-Winter period (+ food habits/diets for sample collected by hunters); primarily marine/estuarine habitat in "high" v "low" altered sites	Research shows a link between indices of food abundance & body condition & cross-seasonal reproductive success at large spatial scales, but strength and consistency of the relationship is uncertain; particularly for this species wintering in this geography.	High	Low

Table 9.2 (continued).

Species Season(s)	Management Category[a]	Question(s)	End-point to measure mgmt. performance	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Lesser Scaup, Northern Pintail, Redhead Winter, Migration	Habitat and Natural Process Restoration (Freshwater Management)	Does altered hydrology result in increasing salinity thus, negatively affecting waterfowl food availability and/or quality, in particular bivalve/mollusk (LESC), SAV (NOPI), & seagrass (REDH)? Do these changes influence pre-departure body condition & delay spring departure date(s)? Cross-seasonal effects?	Pre-departure body condition, departure date(s), overwinter survival & food resource availability (covariate)- e.g., obtain overwinter survival estimates and body condition throughout the Fall-Winter period (+ food habits/diets for sample collected by hunters); primarily estuarine habitat in "high" v "low" altered sites	Research shows a link between indices of food abundance & body condition & cross-seasonal reproductive success at large spatial scales, but strength and consistency of the relationship is uncertain; particularly for these spp. wintering in this geography.	High	Low
Redhead Winter, Migration	Habitat and Natural Process Restoration (Freshwater Management)	Does altered hydrology result in increasing salinity thus, negatively affecting preferred seagrass species distribution & abundance? Do these changes influence pre-departure body condition & delay spring departure date(s)? Cross-seasonal effects?	Pre-departure body condition, departure date(s), overwinter survival & food resource availability (covariate)- e.g., obtain overwinter survival estimates & body condition throughout the Fall-Winter period (+ food habits/diets for sample collected by hunters); primarily marine habitat in "high" v "low" altered sites	Research shows a link between indices of food abundance & body condition & cross-seasonal reproductive success at large spatial scales, but strength & consistency of the relationship is uncertain; particularly for this species wintering in this geography.	High	Low
Redhead Winter, Migration	Site/Area Management (Energy Development)	Does the presence of wind energy development in proximity to freshwater wetlands negatively affect overwinter survival of wintering REDH? Direct mortality or indirect effects related to the presence of wind energy development?	Over-winter survival- e.g., obtain survival estimates on sample of marked birds using sites w/ wind energy development & nearby reference sites w/out wind energy development	Though recent research (Lange et al. 2018) has identified reduced use (based on counts) of wetlands in an area of wind energy development, overwinter survival in relation to the presence of wind towers is poorly understood in this geography.	High	Unknown
Redhead Winter, Migration	Site/Area Management (Energy Development)	Is body condition of wintering REDH negatively affected by wind energy development through reduced access to inshore freshwater wetlands? What is/are the mechanisms that influence body condition of REDH in the presence of wind energy development?	Pre-migration body condition- e.g., obtain body condition measurements on sample of birds using sites w/ wind energy development & nearby reference sites w/out wind energy development	Though recent research (Lange et al. 2018) has identified reduced use (based on counts) of wetlands in an area of wind energy development, overwinter & pre-migration body condition related to wind energy development is poorly understood.	High	Unknown
Mottled Duck Breeding only	Habitat and Natural Process Restoration (Freshwater Management)	Does altered hydrology result in increasing salinity thus, negatively affecting preferred food production, distribution, & availability? Do these changes negatively affect body condition & ultimately, breeding propensity, re-nesting effort, nest success, & brood survival?	Breeding propensity, re-nesting effort, estimating nest success & brood survival- 3 of the 4 require marked adult females (and ducklings); estimating nest success would also benefit from a marked sample, but is not a requirement per se	Several previous studies suggested link between habitat conditions (precip) & breeding propensity, but data are generally sparse, & no data linking weather/ habitat condition impacts on re-nesting or brood survival.	High	High

Table 9.2 (continued).

Species Season(s)	Management Category[a]	Question(s)	End-point to measure mgmt. performance	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Mottled Duck Breeding only	Habitat and Natural Process Restoration (Freshwater Management)	Does coastal marsh loss reduce wetland availability thus, increasing salinity levels in remaining wetlands? Does this negatively affect breeding propensity, re-nesting effort, nest success, & brood survival?	Breeding propensity, re-nesting effort, estimating nest success & brood survival- 3 of the 4 require marked adult females (and ducklings); estimating nest success would also benefit from a marked sample, but is not a requirement per se	Uncertain about effects of marsh loss & increasing salinity levels (marsh migration) on availability of nest sites, breeding propensity, nest success, & brood survival.	High	High
Mottled Duck Breeding only	Habitat and Natural Process Restoration (Freshwater Management)	Does reduced water availability constrain or limit wetland management capabilities to produce low salinity wetlands during breeding/nesting period & into brood-rearing? Does this ultimately affect breeding propensity, re-nesting effort, nest success, & brood survival?	Breeding propensity, re-nesting effort, estimating nest success & brood survival- 3 of the 4 require marked adult females (and ducklings); estimating nest success would also benefit from a marked sample, but is not a requirement per se	Several previous studies suggested link between habitat conditions (precip) & breeding propensity, but data are generally sparse, & no data linking weather/ habitat condition impacts on re-nesting or brood survival.	High	High
Mottled Duck Breeding only	Habitat and Natural Process Restoration (Freshwater Management)	Does altered hydrology result in increasing salinity thus, negatively affecting waterfowl food availability and/or quality (SAVs) for pre-breeding, breeding, brood-rearing, & molting MODU? Do these changes negatively affect breeding season survival of adult female MODU?	Survival estimation of adult female MODU during the various annual life-history periods, including molt	At least 1 study suggests breeding season survival decreases during "drought", but this contrasts with what we know about MALL in which dry or drought conditions results in reduced nesting propensity & thus, higher adult female survival.	High	Unknown
Mottled Duck Breeding ONLY	Habitat and Natural Process Restoration (Freshwater Management)	Does coastal marsh loss reduce wetland availability thus, increasing salinity levels in remaining wetlands? Does this negatively affect breeding season survival (MODU) of adult females (& their broods)?	Survival estimation for adult females during the breeding season- evaluate across the breeding range & compare period-specific survival estimates among years considered as WET v DRY w/ varying salinity levels of individual wetlands used by marked MODU	At least 1 study suggests breeding season survival decreases during "drought", but this contrasts with what we know about MALL in which dry or drought conditions results in reduced nesting propensity & thus, higher adult female survival.	High	Unknown
Mottled Duck Breeding ONLY	Habitat and Natural Process Restoration (Freshwater Management)	Does reduced water availability constrain or limit wetland management capabilities to produce low salinity wetlands during breeding/nesting period & into brood-rearing? Does this ultimately affect breeding season survival of adult females (MODU)?	Survival estimation for adult females during the breeding season- evaluate across the breeding range & compare period-specific survival estimates among years considered as WET v DRY w/ varying salinity levels of individual wetlands used by marked MODU	At least 1 study suggests breeding season survival decreases during "drought", but this contrasts with what we know about MALL in which dry or drought conditions results in reduced nesting propensity & thus, higher adult female survival.	High	Unknown

Table 9.2 (continued).

Species Season(s)	Management Category[a]	Question(s)	End-point to measure mgmt. performance	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Mottled Duck Breeding ONLY	Habitat and Natural Process Restoration (Habitat Management)	Does the loss of nesting habitat (via various causes) affect the availability of suitable nest sites in proximity to low salinity wetlands? Does this situation result in lower productivity due to reduced breeding propensity, lower re-nesting probability, & lower nest success?	Breeding propensity, re-nesting effort, & nest success- e.g., study design should account for spatial configuration at the landscape scale & site-scale variables; compare "high" quality wetland density (Experimental) & "low" quality wetland density (Control) sites (Krainyk and Ballard 2015)	Loss of nesting habitat is believed to have significant negative impact on productivity, but aspects of nesting habitat & particular effect sizes on productivity parameters is highly uncertain.	Low/High	High
Mottled Duck Breeding ONLY	Habitat and Natural Process Restoration (Habitat Management)	Does loss & fragmentation of grassland nesting habitat quality (e.g., overgrazing, encroachment of woody vegetation) negatively affect breeding propensity, re-nesting effort, & nest success (MODU)?	Estimate nest success in conjunction w/ breeding season survival of adult females & brood survival from marked sample- e.g., study design should account for spatial configuration at the landscape scale & site-scale variables; compare "high" v "low" quality sites (Krainyk and Ballard 2015)	Fragmentation of nesting habitat is believed to have significant impact on productivity, but aspects of nesting habitat & particular effect sizes on productivity parameters is highly uncertain.	High	Low/High
Mottled Duck Breeding ONLY	Habitat and Natural Process Restoration (Habitat Management)	Does loss & fragmentation of grassland nesting habitat quality (e.g., overgrazing, encroachment of woody vegetation) negatively affect breeding propensity, re-nesting effort, & nest success (MODU)?	Breeding propensity, re-nesting effort, & estimating nest success; consider breeding season survival of adult females & brood survival from a marked sample- e.g., study design should account for spatial configuration at the landscape & site-scale; predator v no predator removal sites	Degradation of nesting habitat believed to impact productivity through response by predators, but how particular aspects of fragmentation affect predator species composition & abundance not clear, & effect sizes are poorly understood for this species in this landscape.	High	Unknown

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

Abbreviations Used: MODU (Mottled Duck), LESC (Lesser Scaup), NOPI (Northern Pintail), REDH (Redhead), GADW (Gadwall), BWTE (Blue-winged Teal), MALL (Mallard) restoration activities, and 5) address explicit objectives and/or questions about management action(s) all within an adaptive management framework (Williams et al. 2009).

GoMAMN has established the following status and trends priorities for waterfowl in the Gulf of Mexico. Here, are included three waterfowl species considered as GoMAMN Birds of Conservation Concern (Appendix 1) as the highest priority, as well as three other waterfowl species considered as monitoring targets by the Waterfowl Working Group (Table 9.1). The details associated with this process are described previously in Chapter 1. We further used population trend data from the Partners in Flight (2017) Species Assessment. Waterfowl species for which the population trend is highly uncertain or highly variable received a score of 3, whereas species with a trend score <3 are of less concern, and those species with a score >3 are of higher concern (Table 9.1).

- **Priority 1** - Mottled Duck
- **Priority 2** - Lesser Scaup and Northern Pintail
- **Priority 3** - Redhead
- **Priority 4** - Gadwall and Blue-winged Teal

GoMAMN prioritized the species-habitats in the same relative "ranks" as the priority species. We believe any status and trends assessment represents a two-pronged approach where both the status and trends of priority species are monitored in conjunction with their associated habitats (see Osnas et al. 2014, Sedinger and Alisauskas 2014). Broadly speaking, when GoMAMN and the Waterfowl Working Group considered appropriate avian metrics for status and trends assessment, the typical avian parameters revolve around addressing monitoring role number one as identified by Lyons et al. (2008); system-state variables. In the case of priority waterfowl species this would include some estimate of abundance, population size, or density within a specified time and space, given some set of methodological and statistical assumptions associated with a given sampling frame. Concurrent, to the above waterfowl population estimates, ideally one would also collect habitat-related data (Osnas et al. 2014, Williams et al. 2014).

There are a number of existing avian (e.g., eBird-Walker and Taylor 2017; CBC-Dunn et al. 2005, Niven and Butcher 2011; BBS-Sauer et al. 2003, Sauer and Link 2011) and waterfowl (e.g., Midwinter Waterfowl Survey-Soulliere et al. 2013, Andersson et al. 2018; state-based winter waterfowl surveys-Pearse et al. 2008a, 2008b; IWMM-Loges et al. 2014; Mottled Duck Breeding Survey-USFWS 2016) monitoring programs that may (or may not) be appropriate within the broader GoMAMN monitoring framework to provide data on status and trends assessment for waterfowl. Each of the existing monitoring efforts has its own set of fundamental and means objectives (Lyons et al. 2008), as well as a respective set of assumptions, data limitations, biases, and caveats (e.g., Midwinter Waterfowl Survey; Andersson et al. 2015). Of the existing monitoring efforts identified above, those most likely to be of value include some version of a wintering waterfowl survey and the Mottled Duck breeding population survey. As has been documented by previous research (Eggeman and Johnson 1989, Heusmann 1999), we are not advocating here for the use of the Midwinter Waterfowl Survey per se, as the "best" existing survey platform given its obvious short-comings (Soulliere et al. 2013; but see also Johnson 2008). Though the Midwinter Waterfowl Survey is still conducted in at least some of the southern wintering waterfowl states in the GoMAMN geography (e.g., Texas), a number of states have either dropped this survey entirely (e.g., Florida), no longer conduct coastal waterfowl survey transects/segments (e.g., Alabama, Mississippi), or have created a state-based winter waterfowl survey sampling design (Pearse et al. 2008a, 2008b; e.g., Louisiana and Mississippi). Clearly there is a need for a survey platform and sampling design that provide statistically rigorous point estimates of abundance with some level of precision, a means of dealing with visibility (Pollock and Kendall 1987), observer, and detection bias while accounting for variation in effort (Pollock et al. 2002, 2006; Pearse et al. 2008b, Soulliere et al. 2013, Andersson et al. 2015, 2018), at a spatial and temporal resolution that provides data that simultaneously address GoMAMN objectives and allow assessment of waterfowl status and trends. What is less certain is that in the absence of an existing winter waterfowl survey that addresses GoMAMN objectives (Figure 2.2), is there funding available and the geo-political will to create and implement a "new" winter waterfowl survey? Any such waterfowl survey would require collaboration, cooperation, funding, and buy-in from diverse stakeholders; federal and state agencies, as well as the Flyways and Joint Ventures.

For waterfowl species that do not breed in the Gulf of Mexico and for which the proportion of the population wintering in the Gulf of Mexico is variable and unknown (e.g., Lesser Scaup, Northern Pintail, Blue-winged Teal, Gadwall, and Redhead), population-level status and trends assessment of ducks wintering in the Gulf of Mexico are simply not appropriate. However, the status and trends of just the Gulf of Mexico "wintering populations" of priority waterfowl species within the GoMAMN geography (Figure 1.2) may be appropriate and is a clear data need. Alternatively, population-level status and trends assessment for a species that carries-out its entire annual life-cycle in the Gulf of Mexico, like the Mottled Duck, seems appropriate (USFWS 2016, see also Ballard et al. 2001). The Mottled Duck Breeding Population Survey was initiated in 2010, in partnership with the Gulf Coast Joint

Venture, Louisiana Department of Wildlife and Fisheries, and the Texas Parks and Wildlife Department, appears to be a viable survey for estimating breeding population for the Western Gulf Coast population of Mottled Ducks. Currently, there are two breeding population surveys for Mottled Ducks, one for the Florida population (Bielefeld 2006) and one for the Western Gulf Coast population.

In addition to population and habitat surveys described above, the Waterfowl Working Group believes that evaluating body condition and/or lipid-reserve dynamics over the wintering period (Reinecke et al. 1988, Krapu and Reinecke 1992, Anteau and Afton 2008, Anteau and Afton 2009, Anteau and Afton 2011) for priority wintering waterfowl species is also a means of evaluating status and trends; as or more important than abundance status and trend assessments. In particular, the Waterfowl Working Group believes that data related to pre-departure body condition would be most relevant, if there were constraints on when data could be collected. This would be particularly so, if an appropriate sampling design is in place through a coordinated, integrated monitoring effort such that implementation was relatively simple, data were collected over an appropriate temporal and spatial scale, and a database provided readily available information for end-users. Body condition index data could be collected using existing waterfowl hunter check stations on National Wildlife Refuges and state Wildlife Management Areas in conjunction with site-scale research projects (e.g., Moon et al. 2007, Moon and Haukos 2009). In addition, these data could be used to evaluate a number of potential competing hypotheses, including the influence of climate-related variability on body mass, lipid reserves, and body condition (e.g., Guillemain et al. 2010).

Current waterfowl projects are collecting important data in important places and the Waterfowl Working Group recommends such site-scale, short-term research projects continue into the future. Nevertheless, GoMAMN values (Chapters 1 and 2) and desires waterfowl data collected at a larger contiguous spatial scale and a longer temporal scale to truly understand the status and trends of our priority waterfowl species (Table 9.2). In addition to limitations previously identified regarding population abundance data, additional constraints include the confounding effects of the continental population size, weather-induced migration intensity (Schummer et al. 2010, Notaro et al. 2016), and variability and changing habitat conditions (Davis et al. 2014) elsewhere within and across the relevant Flyways. New and existing monitoring efforts should also include consideration of major marsh types (Appendix 2), which in many cases may best be accomplished with stratification, e.g., for marsh birds (Johnson et al. 2009).

Priority Ecological Processes

GoMAMN and the Waterfowl Working Group both value monitoring efforts that address the question of how are the broader ecological processes affecting avian populations and their respective habitats within the GoMAMN geography (Figure 1.2)? The seasonality of ecological processes should also be considered, since a process impacting a system or species during the breeding season versus wintering season (e.g., an early vs late season hurricane) could have dramatically different effects on the system or species of interest. Uncertainty about how a process impacts a species or the waterfowl guild may also vary by season, e.g., we may have a good understanding of the impacts of sea-level rise on nesting waterfowl, but at the same time, a very poor understanding of how it might affect wintering waterfowl. To address these questions, GoMAMN and the Ecological Process Working Group therein initially utilized and applied the standard lexicon of threats classification developed by Salafsky et al. (2008:Table 1) to define and inform priority ecological processes (EPA 1999). Clearly, this was a fairly biased perspective of the realities and complexities of the Gulf of Mexico ecosystem (Chapters 1 and 2; see also Burger 2017, 2018); this approach really only considers anthropogenic impacting factors (see Johnson and St.-Laurent 2011). In addition, such an approach would have further underestimated the ecological relationships and myriad of complex interactions between management actions and/or restoration projects within the context of broader environmental variability (Benedetti-Cecchi 2003, NASEM 2017). Finally, such an explicit focus on anthropogenic threats would not allow us to learn (i.e., monitoring role 3 in Lyons et al. 2008), given uncertainty from unanticipated results (Wintle et al. 2010) that could lead us to additional testable hypotheses, provide context to avian response(s) to a given management action, or further clarify avian response(s) within the Gulf of Mexico ecosystem (Bjorndal et al. 2011). The Ecological Process Working Group used a series of WebEx's, Conference Calls, and emails through an iterative process to create draft version(s) of species-specific Taxa-based Working Groups ecological process spreadsheets. Additional details from Bennett et al. (2009:Table 1) were later incorporated into the process and final versions of spreadsheets were created by each of the seven Taxa-based Working Groups. In this case, the Waterfowl Working Group then populated columns and rows within the ecological process spreadsheet (Table 9.3), which was then used to inform final versions of the influence diagrams (Figure 9.1, Appendix 9).

More broadly, the bird conservation community (i.e., GoMAMN) has outlined its values through the objectives hierarchy (Figure 2.2). Part of the objectives hierarchy refers specifically to ecological processes and the GoMAMN CoP values monitoring that have a number of previously defined characteristics (Wilson et al. 2019). The Waterfowl Working Group, used Bennett et al. (2008), Lyons et al. (2008), and Williams (2011) as anchoring points for prioritizing relevant ecological processes. We evaluated and selected from a suite of potential processes that were believed to have the highest probability of affecting a large number of priority waterfowl species (Table 9.3). Finally, we further evaluated the various management actions using a matrix of the Effect Size (ES) x Uncertainty Score (US) whereby only species and ecological processes that had values <3 were considered important (Table 9.3). From Bennett et al. (2009), there were two ecological processes that were most relevant and broadly applicable: hydrological processes and climatic processes, but also interactions between organisms (i.e., predation) were important (Figures 9.1, Appendix 9). Similar to the Effect Size (ES) x Uncertainty Score (US) for management actions, none of the scores for species other than Mottled Ducks had values <3. Also similar to the ES x US values for management actions (Table 9.2), all high priority ecological processes (Table 9.3) for Mottled Ducks in which values <3 were almost exclusively during the breeding season.

Although, some waterfowl data needs and specific avian metrics were mentioned previously, here we provide several examples specific to Mottled Ducks during the breeding season related to a given ecological process, all of which had ES x US values <3 (Table 9.3). For a given ecological process, there may be multiple, potentially competing hypotheses (Lebreton et al. 1992), as well as different avian response metrics or parameters associated with each individual hypothesis. Therefore, for brevity, we did not include all Mottled Duck ecological processes examples with values <3 here.

The first ecological process example relates to hydrological processes and how altered hydrology may reduce wetland availability and abundance on the landscape (Table 9.3), which in turn, can lead to elevated salinity levels in remaining wetlands (Sklar and Browder 1998). This is particularly the case following tropical storms or hurricanes, whereby higher salinity offshore waters are pushed further inland from the associated winds and storm surge. Such an event could result in both direct (e.g., mortality of nesting hens, abandonment of nests due to flooding) and indirect (e.g., negative effects to food quantity or quality thereby increasing physiological stresses associated with molt) effects to breeding Mottled Ducks (see Ross et al. 2018). Moon et al. (2017) documented salinity ranges at some sites of 36ppt to >50ppt during their study of adult female survival of Mottled Ducks in Texas, partly owing to drought, as well as Hurricane Ike. In addition, sea-level rise may lead to movement of higher salinity waters further inland (Glick et al. 2013, Watson et al. 2015). For breeding Mottled Ducks elevated wetland (marsh) salinity may lead to reduced breeding season survival of adult females (Moon et al. 2017) and lower duckling and/or brood survival (Moorman et al. 1991). In addition, there may be sub-lethal effects (i.e., increased physiological stresses, reduced body condition) for both breeding females and ducklings using wetlands above what is thought to be the salinity threshold value of 9ppt (Moorman et al. 1991, see also Leberg 2017); compromised physiological condition could also result in increased vulnerability to predation. The issues associated with hydrological processes in the Gulf of Mexico are myriad and complex (Sklar and Browder 1998) as are potential solutions. In Louisiana at least, policy-makers and decision-makers have come together to attempt to address some of these very issues via the Louisiana Coastal Master Plan; some of the proposed projects are revolutionary with respect to design, scope, and scale (CPRA 2017). At a finer-spatial scale, some of the hydrological processes impacts could be addressed through policy changes in conjunction with targeted funding for on-the-ground conservation delivery via wetland easements (i.e., perpetual or term-limited), wetland restorations, and working with conservation partners and private landowners to provide resources such as funding, technical assistance, and equipment (e.g., water control structures, pumps, etc.) necessary to ameliorate high (>9ppt; Moorman et al. 1991) salinity levels (at critical times of the years) on priority wetlands on the landscape.

There are a multiple competing hypotheses nested within this single ecological process (Table 9.3, Figure 9.1). Hydrological processes are complicated even further in the face of climate change (Conroy et al. 2011) and related effects like sea-level rise (Watson et al. 2015). Avian metrics of interest related to this priority ecological process (Table 9.3) would be estimating breeding season survival of adult females and estimating duckling and/or brood survival (Figure 9.1) over a range of salinities in coastal marshes across the GoMAMN geography (Figure 1.2). In addition, data from marked females would provide information on potential habitat switching, whereby, brood-rearing and molting areas were selected primarily as function of salinity levels. Ultimately, we are interested in reducing the uncertainty associated with this ecological process and associated hypotheses (Williams 2011). The over-arching source of uncertainty, at least initially, would be environmental variation, but with an appropriate experimental design at a relatively large spatial and temporal scale with recurring decision-points, such an effort could potentially lead to reductions in structural or process uncertainty and partial controllability as well (Williams 2011). Such a monitoring effort here would really be focused on monitoring role number three, as identified by Lyons et al. (2008).

The second ecological process example relates to climatic processes (i.e., precipitation), though droughts are defined as natural disturbance regime. Here, we are considering precipitation and natural variability in wet-dry cycles. Generally speaking, Mottled Duck productivity appears to be negatively affected during dry periods, within or among years (Bielefeld et al. 2010). Under such a dry period, we might expect decreases in overall wetland availability, reduced size of wetlands, and overall reduction of wet area of wetlands; resulting in elevated salinity levels in remaining wetlands (Sklar and Browder 1998). This has the very real potential to result in reduced productivity through lower breeding propensity (Rigby and Haukos 2012), reduced re-nesting effort (Finger et al. 2003), and possibly lower brood survival (Rigby and Haukos 2014, but see Rigby and Haukos 2015). Ross et al. (2018) documented population responses (abundance declined) during years with an increase in days with extreme 1-day precipitation from June to November (hurricane season) and an increase in drought severity. Wetlands that have salinities in the range of >9–12ppt may result in slower growth and reduced duckling survival (Moorman et al. 1991, Bielefeld et al. 2010) which tend to be exacerbated during dry years or under drought conditions. An alternative to the above under climate change scenarios for the southeastern U.S. (Kunkel et al. 2013) indicated warmer ambient temperatures and more extreme precipitation events. This could potentially have the opposite effects from the dry-to-drought scenario previously described. In any case, higher salinity levels would almost certainly negatively affect some important Mottled Duck demographic parameters. Those tasked with reviewing the Mottled Duck for the Gulf Coast Vulnerability Assessment (Watson et al. 2015) indicated that although there was uncertainty regarding synergistic effects of sea-level rise, climate change, and land use, there was agreement that this species will likely experience negative impacts due to potential interactions of these three key drivers.

Similar to the first example, the decisions and processes required to address this ecological process is socio-politically challenging and will require decisions and actions at multiple spatial scales. At a finer-spatial scale, conservation decisions seem more tenable and conservation delivery on the ground would likely be fairly similar to the previous example. Though the hypotheses are different for this example, they remain multiple and competing for this single ecological process (Figure 9.1). However, with the appropriate study design (Johnson 2002a, 2002b) accounting for landscape-scale (e.g., wetland density, total wetland area, juxtaposition, etc.) and site-scale environmental factors and wetland conditions (e.g., wetland size, perimeter : area ratio, depth, salinity, etc.) with data collected at appropriate temporal and spatial scales, we should be able to tease-out the dominant factors driving the system. Avian metrics of interest related to this priority ecological process (Table 9.3) would be estimating breeding propensity, re-nesting effort, daily survival rates of marked nests, and duckling survival and/or brood survival over a range of salinities and wetland sizes across the GoMAMN geography (Figure 1.2). Ultimately, we are interested in reducing the uncertainty (Williams 2011) associated with this ecological process and potentially competing hypotheses (Lebreton et al. 1992, Williams et al. 2002).

The third ecological process example relates to interactions between organisms. Within this ecological process, such interactions may take several forms from predation, to intra- and interspecific competition (Nudds 1983, 1992). In this case, we will be limiting the discussion to the role of predation on breeding Mottled Ducks, and how weather, altered hydrology, and coastal marsh loss may functionally reduce wetland availability and abundance on the landscape (Table 9.3). This, in turn, can lead to elevated salinity levels in remaining wetlands thereby inducing physiological stresses on adult female Mottled Ducks and their ducklings leading to sub-lethal effects that increase susceptibility to predation. Similar to the previous examples, there are a multiple competing hypotheses and multiple mechanisms operating simultaneously nested within this single ecological process (Figure 9.1).

Addressing this issue from a management actions and/restoration project is relatively straightforward and would follow previous examples above in this section and the last example in the management actions section. Avian response metrics or parameters of interest to evaluate this ecological process and competing hypotheses would include: estimating daily survival rates of marked nests, estimating breeding season survival rates of marked adult females, and estimating duckling and/or brood survival (Figure 9.1). With the appropriate study design (Block et al. 2001, Morrison et al. 2010, Sanderlin et al. 2014) accounting for landscape-scale and site-scale environmental factors and wetland conditions, with data collected at appropriate temporal and spatial scales, we should be able to determine the dominant drivers in the system. One may consider implementation of a predator-removal program, as part of the study design framework as a means of evaluating the importance of mammalian predators on Mottled Duck parameters of interest within the broader context of the entire system (Sargeant and Raveling 1992, Sovada et al. 2001). In the absence of predator-removal program or other management action, monitoring associated with this effort would be clearly linked to monitoring role number three identified by Lyons et al. (2008). If, however, a predator-removal program and/or other management actions

Blue-winged Teal (*Spatula discors*). Photo credit: Tom Koerner

were initiated on the front-end of a larger project to try and increase any of the Mottled Duck demographic parameters, then monitoring role number two would be invoked (Lyons et al. 2008). Ultimately, we are interested in reducing the uncertainty (Williams 2011) associated with this ecological process and learning along the way (Shaffer and Johnson 2008). Irrespective of the types of uncertainty, we would certainly like to control for, account for, or otherwise recognize their influence within the context of evaluating this ecological process and the associated challenges of teasing-out a single hypothesis to explain our results (Williams 2001, 2003).

The waterfowl habitats within the Gulf of Mexico Region and the associated bird species are subject to many ecological processes; e.g., hurricanes, floods, and other extreme weather events, changes in salinity in wetland habitats, and predation (Day et al. 2013). By better understanding these underlying ecological processes, it will allow us to better understand population-level variation (Eberhardt 1978, 1988) and variation in waterfowl responses for cases in which there is some form of management control, as well as factors beyond management control (e.g., confounding effects of the continental population size, weather-induced migration intensity, and habitat conditions elsewhere within the relevant flyways). These issues revolve around environmental variation and partial controllability (Williams 2011). While there are many uncertainties around how waterfowl will be affected by specific restoration projects within the northern Gulf of Mexico wetland ecosystem, there are some additional uncertainties which have been identified elsewhere (NASEM 2017). For example, in the face of human population growth, continued human development, and land-use change in the region (Martinuzzi et al. 2013, 2015; Hamilton et al. 2016) along with sea-level rise (Enwright et al. 2016, Osland et al. 2016, Borchert et al. 2018), how will freshwater flows be maintained? How might emergent marsh habitat distribution and availability change in the face of hydrologic regime shift? Sea-level rise is predicted to shift wetlands landward, through a combination of ecology, geomorphology, and sediment deposition (Kirwan and Megonigal 2013, Raabe and Stumpf 2015), though whether this will ultimately result in a net loss of wintering waterfowl habitat is still unclear (Kirwan et al. 2016). The impacts of changing precipitation patterns, hydrological and fire regime shifts due to climate change, as well as predicted increases in hurricane frequency and intensity may all impact waterfowl (in different ways), but the magnitude of those effects (Johnson and St.-Laurent 2011) is highly uncertain.

Table 9.3. *Uncertainties related to how ecological processes impact waterfowl populations in the northern Gulf of Mexico.*

Species Season(s)	Ecological Process Category[a]	Question	End point to measure	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Mottled Duck Breeding/ Wintering	Hydrological Processes (Altered Hydrology)	Are MODU populations influenced by wetland abundance, salinity, and inundation frequency?	Breeding propensity, re-nesting effort, estimating nest success, & brood survival estimates	Several previous studies suggested link between habitat conditions (precipitation) & breeding propensity, but data are generally sparse, & no data linking weather/habitat condition impacts on re-nesting or brood survival.	High	High
Mottled Duck Breeding	Hydrological Processes (Coastal Marsh Loss)	Does coastal marsh loss reduce wetland density (availability) thus, elevating salinity levels in remaining marsh/wetlands? Does coastal marsh loss negatively affect MODU productivity? If it does, what parameters are affected & what are the mechanisms?	Breeding propensity, re-nesting effort, estimating nest success, & brood survival estimates	Uncertain about effects of marsh loss, & sea-level rise more directly, on availability of nest sites, breeding propensity, probability of nest flooding (nest success), & brood survival.	High	High
Mottled Duck Breeding	Hydrological Processes (Coastal Marsh Loss)	Does coastal marsh loss reduce wetland density (availability) thus, elevating salinity levels in remaining marsh/wetlands? Does coastal marsh loss negatively affect MODU breeding season survival? If so, what are the mechanisms?	Adult female survival estimates during the breeding season	At least 1 study suggests breeding season survival decreases during drought, but this contrasts with what we know about MALL, for which drought reduces nesting propensity & thus, leads to reduced mortality.	High	High
Mottled Duck Breeding	Hydrological Processes (Altered Hydrology)	Does altered hydrology reduce wetland density (availability) thus, elevating salinity levels in remaining marsh/ wetlands? Does altered hydrology negatively affect MODU breeding season survival? If so, what are the mechanisms?	Adult female survival estimates during the breeding season & during the molt	At least 1 study suggests breeding season survival decreases during drought, but this contrasts with what we know about MALL, for which drought reduces nesting propensity & thus, leads to reduced mortality.	High	Unknown
Mottled Duck Breeding	Climatic Processes (Limited water available for wetland management)	Does low/limited water availability for wetland management negatively affect availability of low salinity marsh/wetlands during the spring & summer? Does low/limited water availability negatively affect MODU breeding propensity, re-nesting effort, nest success, & brood survival?	Breeding propensity, re-nesting effort, estimating nest success, & brood survival estimates	Several previous studies suggested link between habitat conditions (precipitation) & breeding propensity, but data are generally sparse, & no data linking weather/habitat condition impacts on re-nesting or brood survival.	High	High
Mottled Duck Breeding	Climatic Processes (Limited water available for wetland management)	Does low/limited water availability for wetland management negatively affect availability of low salinity marsh/wetlands during the spring & summer? Does low/limited water availability negatively affect MODU breeding season survival? If so, what are the mechanisms?	Adult female survival estimates during the breeding season	At least 1 study suggests breeding season survival decreases during drought, but this contrasts with what we know about MALL, for which drought reduces nesting propensity & thus, leads to reduced mortality.	High	High

Table 9.3 (continued).

Species Season(s)	Ecological Process Category[a]	Question	End point to measure	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Mottled Duck Breeding	Climatic Processes (Weather, i.e., precipitation)	Do dry/drought conditions reduce wetland availability & increase salinity levels in remaining marsh/ wetlands? Do dry/drought conditions negatively affect MODU breeding propensity, re-nesting, nest success, & brood survival? If so, what are the mechanisms?	Breeding propensity, re-nesting effort, estimating nest success & brood survival estimates + adult female survival estimation during breeding season & the molt	Several previous studies suggested link between habitat conditions (precip) & breeding propensity, but data are generally sparse, & no data linking weather/habitat condition impacts on re-nesting or brood survival.	High	High
Mottled Duck Breeding/ Wintering	Climatic Processes (Weather, i.e., precipitation)	Do dry/drought conditions reduce wetland availability & increase salinity levels in remaining marsh/ wetlands? Do dry/drought conditions negatively affect MODU breeding season survival? If so, what are the mechanisms?	Breeding propensity, re-nesting effort, estimating nest success & brood survival + adult female survival estimation during breeding season & molt; female body condition as a covariate for all parameters	At least 1 study suggests breeding season survival decreases during drought, but this contrasts with what we know about MALL, for which drought reduces nesting propensity & thus, leads to reduced mortality.	High	Unknown
Mottled Duck Breeding	Interactions Between Organisms	Do dry/drought conditions, altered hydrology, & coastal marsh loss increase salinity levels in remaining marsh/ wetlands? Does predation have a greater negative affect on MODU population dynamics in dry v wet years, in low v high altered hydrology sites, or in areas with low v high wetland availability (low salinity)?	Adult female survival estimates during the breeding season, estimating nest success & brood survival	At least 1 study suggests breeding season survival decreases during drought, but this contrasts with what we know about MALL, for which drought reduces nesting propensity & thus, leads to reduced mortality.	High	Unknown
Mottled Duck Breeding	Natural Disturbance Regimes	Does coastal marsh loss reduce wetland density (availability) thus, elevating salinity levels in remaining marsh/wetlands? Does coastal marsh loss negatively affect MODU productivity? If it does, what parameters are affected & what are the mechanisms?	Breeding propensity, re-nesting effort, estimating nest success & brood survival + adult female survival estimation during breeding season & molt; female body condition as a covariate for all parameters	Uncertain about effects of marsh loss, & sea-level rise more directly, on availability of nest sites, breeding propensity, probability of nest flooding (nest success), & brood survival.	High	High

Waterfowl

Table 9.3 (continued).

Species Season(s)	Ecological Process Category[a]	Question	End point to measure	Uncertainty Description	Uncertainty Category[b, d]	Effect Size[c, d]
Mottled Duck Breeding	Natural Disturbance Regimes	Does coastal marsh loss reduce wetland density (availability) thus, elevating salinity levels in remaining marsh/wetlands? Does coastal marsh loss negatively affect MODU breeding season survival? If so, what are the mechanisms?	Breeding propensity, re-nesting effort, estimating nest success & brood survival + adult female survival estimation during breeding season & molt; female body condition as a covariate for all parameters	At least 1 study suggests breeding season survival decreases during drought, but this contrasts with what we know about MALL, for which drought reduces nesting propensity & thus, leads to reduced mortality.	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.

Abbreviations Used: MODU (Mottled Duck), MALL (Mallard)

SUMMARY & MONITORING RECOMMENDATIONS

Herein, we have identified a number of monitoring priorities related to management actions (Table 9.2), status and trends assessment (see section above), and ecological processes (Table 9.3). We have used a combination of management actions and ecological processes spreadsheets, as well as species-specific influence diagrams (Figure 9.1, Appendix 9) to inform the monitoring priorities for waterfowl species of conservation concerns, and other monitoring targets identified by the GoMAMN Waterfowl Working Group (Table 9.1) within the GoMAMN geography (Figure 1.2).

When attempting to study questions and hypotheses regarding waterfowl, we recommend to the extent practicable, sampling encompass all sex-age classes for a given species and that all experiments have controls, are randomized, and replicated (Hurlbert 1984, Eberhardt and Thomas 1991, Anderson 2001, Block et al. 2001, Johnson 2002a, 2002b). However, when sampling of all sex-age classes is simply not feasible or appropriate per study design, it is a common practice to focus solely on monitoring females, because this sex-class tends to be the cohort that drives population viability and sustainability (see Cooke et al. 1995, Newton 1998). Because females in most waterfowl species exhibit lower breeding season survival, sex ratios of adults in the population tend to be substantially sex-biased toward males, suggesting that this cohort is more expendable (Bellrose 1980, Baldassarre 2014, Koons et al. 2014).

The GoMAMN Waterfowl Working Group has identified some 'measure' of population abundance or density, a high priority avian metric for monitoring wintering waterfowl. However, there are some real concerns about the value of the data generated from the existing Midwinter Waterfowl Survey. The limitations of the Midwinter Waterfowl Survey have been clearly articulated elsewhere (Eggeman and Johnson 1989, Heusmann 1999, Andersson et al. 2015) so are not elaborated here. That said, an over-arching criticism of the Midwinter Waterfowl Survey is that there is no explicit survey design (Reinecke et al. 1992, Pearse et al. 2008a). We believe that to be of value for addressing GoMAMN objectives (Figure 2.2) per status and trends assessment, Midwinter Waterfowl Survey proponents and implementers would need to address the seven recommendations described in Andersson et al. (2015) in conjunction with an effort to account for visibility bias, observer bias, and other detection-related issues (Koneff et al. 2008, Pearse et al. 2008a, 2008b). Additionally, we would have to achieve consensus on a clear definition of what this survey actually is: are we determining absolute population size or is this an index to population size (Gregory et al. 2004)? In the latter case, there would have to be some effort to 'measure' the relationship (i.e., correlation) between the index and the true, but unknown population size. An index may very well be appropriate (see Johnson 2008) if we are not interested in population size per se, but rather we are interested in determining if the population is increasing, decreasing, or stable (Gregory et al. 2004). Finally, an agreed-upon survey design (e.g., stratified random sampling; Gregory et al. 2004, Pearse 2007, Pearse et al. 2008a) with sample units and an *a priori* defined level of precision (Coefficient of Variation) would need to be developed and agreed upon, along with additional transect segments (or survey plots) across the GoMAMN geography (Figure 1.2) in coastal areas of the five Gulf states to address any existing spatial coverage gaps. Specifically for breeding Mottled Ducks, the Waterfowl Working Group believes that the current Western Gulf Coast Mottled Duck population survey (USFWS 2016) provides valuable data. However, there remains concern over spatial variability in associated Visibility Correction Factors and Coefficients of Variation. The group further suggests these concerns warrant further study.

There may be cases when estimates of abundance or density simply cannot be obtained, in which case, occupancy (i.e., presence/absence; MacKenzie et al. 2006) is often the next logical avian response parameter to estimate. An example where this may be appropriate for waterfowl, would be where there was interest in determining if birds (all species) responded positively to a given coastal marsh restoration project and there was interest in relatively efficiently (at relatively low cost) determining 'bird use' associated with the project. In this case, there was a clear recognition that presence-only data (Pearce and Boyce 2006) may not be sufficient to address the objectives, so a decision was made to conduct weekly, bi-weekly, or monthly 'counts' of birds across multiple sites (experimental and control) where both presence/absence data are collected before and after the restoration project was completed. In the process of estimating species-specific occupancies, one also addresses issues associated with the detection process and detection probability (Royle and Nichols 2003, MacKenzie et al. 2006). For waterfowl specifically, occupancy estimation can be problematic in that in many cases, managers and decision-makers desire population estimates (or indices), and occupancy estimation can actually mask large changes in abundance. Occupancy only requires a single individual to be present (i.e., present =1, absent = 0) and, therefore, does not directly provide population or abundance estimates per se (but see MacKenzie and Nichols 2004). Even occupancy estimation can be difficult to assess outside of the breeding season for many waterfowl species, partly owing to the mixed-species assemblages, generally larger numbers of birds, diurnal and nocturnal fluctuations in distribution and abundance, and highly variable environmental and anthropogenic factors (e.g., hunting pressure) that can affect waterfowl abundance and use of habitats in the winter. Though occupancy estimation is not explicitly identified within management actions, status and trends assessments, or ecological processes above; we consider it a potentially valuable avian monitoring tool/technique (NASEM 2017).

Another monitoring priority identified by the GoMAMN Waterfowl Working Group is that for body condition of wintering waterfowl, in particular, pre-departure body condition. The group strongly believes in the value of these data, so much so, that we considered these data equally valuable or even more valuable than abundance surveys of wintering waterfowl. One advantage of these data is that once standardized protocols were in place, data could be relatively easily collected from waterfowl hunters at check stations on state Wildlife Management Areas and federal National Wildlife Refuges. In addition, there would be the potential to collect fairly large sample sizes through time and space, depending on the species. Additional research projects could be conducted to evaluate not only body condition, but also lipid-reserve dynamics, overall carcass composition, and diets of wintering waterfowl. If scaled appropriately, we could learn a lot about how these avian response variables change over time and space.

Frequently, waterfowl managers and researchers are interested in how management actions or ecological processes impact survival or other relevant demographic parameters either within or across seasons, within or across years, or for a specific cohort of the population (e.g., adult females; Cooke et al. 1995:Figure 4.1). Survival can be estimated using a variety of marking techniques (Hestbeck et al. 1990) and a variety of analytical approaches, depending on the study design, objectives, and hypotheses (Lebreton et al. 1992). For the most part herein, when we refer to the term survival, we are limiting the discussion to either individuals marked with standard metal (e.g., aluminum) leg-bands or those fitted with either a VHF transmitter or satellite transmitter. In addition, the term survival is typically a reference to apparent survival and not true survival (see Gilroy et al. 2012), but the definition is often study-specific. There are advantages and disadvantages of each approach, though in general; the key underlying assumptions with each of the marking techniques are similar (Brownie et al. 1985:6). An important difference, however, is that in the case of both VHF and satellite transmitters, one should be cognizant of potential transmitter-related effects on marked individuals (Barron et al. 2010, Bodey et al. 2018), and whether or not the presence of the transmitter itself may negatively affect the parameter of interest, i.e., survival, thus violating one of the key assumptions (Brownie et al. 1985).

The GoMAMN Waterfowl Working Group identified adult female survival for species other than Mottled Ducks, during the fall/winter period as an important avian response metric or parameter of interest. In addition, the group identified adult female survival of Mottled Ducks during the breeding season and molt (Figure 9.1), as well as duckling or brood survival (from hatch to fledging; Flint et al. 1995) for Mottled Ducks is also very important. Clearly, estimating such a relevant demographic parameter is highly valued by this group, as this particular avian response variable seems to be a reasonable and robust indicator for evaluating both management actions (i.e., habitat manipulations, wetland and grassland restorations, predator removal, etc.) and ecological processes (i.e., changes in hydrological or climatic processes that influence wetland availability and salinity levels) (Tables 9.2–9.3). In the case of Mottled Ducks specifically, the Waterfowl Working Group sees the value in marking adult female hens with transmitters in an effort to address data gaps related to structural characteristics of grasslands that are selected for by Mottled Ducks during nesting at both larger spatial scale and nest-site selection scale, as well as habitat selection and specific wetland and vegetation characteristics associated with females and their ducklings during brood-rearing. Lastly, a better understanding of spatial and temporal variation in Mayfield nest success (Shaffer 2004, Jones and Geupel 2007) or daily survival rates of marked nests (Dinsmore et al. 2002, Rotella et al. 2004, Dinsmore and Dinsmore 2007; but see Thompson et al. 2001, Streby et al. 2014) for Mottled Ducks is a high priority. Due to the challenges of locating nests of female Mottled Ducks, many of the studies to date have suffered due to small sample sizes and/or limited geographic or spatial footprints (e.g., Holbrook et al. 2000, Durham and Afton 2003, 2004).

At this point, it seems appropriate to provide a recommendation. We strongly encourage those conducting any form of 'survival' monitoring or analyses to consider employing Program MARK (Cooch and White 2014) and the appropriate models or routines identified therein, rather than estimating survival using some other readily available analytical technique/procedure (e.g., Kaplan-Meier model or Cox Proportional Hazards model, etc.). Program MARK includes a diverse suite of available models, allows one to simultaneously incorporate and evaluate main effects, covariates, and interactions that potentially influence survival, is robust to simultaneously testing multiple competing hypotheses (Lebreton et al. 1992), and uses an information theoretic approach (Anderson et al. 2000, Burnham and Anderson 2002), rather than traditional null hypothesis testing (Johnson 1999, 2002a) to evaluate amongst competing models (Lukacs et al. 2007, Doherty et al. 2012). Specifically, there are major advantages of estimating daily survival rates of marked nests (Rotella 2014) versus calculating either apparent or Mayfield nest success (Klett et al. 1986).

Waterfowl movements during the fall/winter period were briefly discussed previously. This remains a major information gap for wintering waterfowl. Broad-scale movements of a target species of wintering waterfowl may best be achieved using satellite telemetry (Krementz et al. 2011, 2012; Beatty et al. 2014). Whereas finer-scale movements of target species of wintering waterfowl are probably best addressed using VHF transmitters with Yagi antennas on boats or vehicles, VHF transmitters with Yagi antennas affixed to aircraft, VHF transmitters with Yagi antennas and receivers at remote stations, GPS tags, or nanotags with MOTUS stations (Taylor et al. 2017), or some combination of these techniques. Smaller spatial scale movements, in particular, diurnal versus nocturnal use of "refuges" or similar areas relatively free of disturbance, and movements between these areas and foraging sites is an important data gap, at least for some species (Davis et al. 2018). In particular, are there areas on the landscape within the GoMAMN geography (Figure 1.2) where it would be beneficial to wintering waterfowl to establish additional "refuges" as a function of distance between these diurnal disturbance-free areas (i.e., day roosts) to nocturnal foraging sites (e.g., Northern Pintail- Cox and Afton 1996, 1997, 1998)? Information on species-specific movements between known refuges and foraging areas would be valuable from a conservation planning and habitat delivery perspective (Davis et al. 2018). A common question related to Gulf-funded bird habitat restoration projects (DHNRDAT 2016) is, "Are we just moving birds around?" More specifically, are birds simply redistributing (i.e., emigration-immigration) on the landscape given this novel habitat provided by a restoration project? This is an important question if the objective is to "replace" a given number of individuals for a species that was injured by the oil spill (DHNRDAT 2016, 2017). Addressing this and related questions is particularly amenable to telemetry monitoring, but which specific technology should be used depends on a number of factors including project-specific objectives and hypotheses. Questions like those above could potentially be addressed for any of the waterfowl species targets identified herein via a large spatial scale telemetry study given the appropriate attention to survey design, elucidation of explicit objectives, sampling, and attention to minimum sample sizes (Hayward et al. 2015). Clearly, there are some advantages of a telemetry-based marking technique, in that information gain per marked bird is very high when compared to legband-only or legband plus color-mark (i.e., color legband or neckcollar).

However, the cost per bird for any transmitter-type is considerably higher than for either legband-only or legband plus color-mark. In addition, there are concerns for at least some species of waterfowl that the attachment site, attachment type and procedures, transmitter type, and transmitter weight and shape may potentially negatively affect behavior and survival of marked birds (Kesler et al. 2014). Research to date on potential transmitter effects on transmittered ducks has provided variable results (review by Lameris and Kleyheeg 2017). In addition, a recent meta-analysis on tracking devices suggests tags >1% of an individual bird's body mass may negatively affect survival (Bodey et al. 2018). It is becoming increasingly clear that external packages and attachments may negatively affect transmittered individuals of diving duck species (Robert et al. 2006). There is a large volume of scientific literature on this topic as it relates to various species of waterfowl, and we suggest that those interested in telemetry studies of wintering waterfowl consult the literature, the GoMAMN CoP, and members of the GoMAMN Waterfowl Working Group.

Though we have provided some recommendations and suggestions in this section, it is beyond the scope of this document to provide explicit recommendations for a specific transmitter type, specific attachment technique, and specific monitoring protocols to track marked individuals across species identified as monitoring priorities. Finally, it is beyond the scope of this document to provide explicit guidance, protocols, and specific recommendations for a specific technology, i.e., nano tags, GPS transmitters, VHF transmitters, satellite transmitters, etc. (reviews by Robinson et al. 2010, Bridge et al. 2011). We recognize and understand that the decision of whether or not to employ a given technology type for monitoring bird movements (and survival) can be a daunting and extremely complex process, and is not strictly limited to the interaction between available funding and maximizing sample size.

Though we obviously recognize and understand the value and importance of non-avian covariates in monitoring, for brevity purposes, a decision was made to not provide a separate section here. In addition, examples were described previously in text within the management actions, status and trends assessment, and ecological processes sections. Lastly, it is beyond the scope of this chapter to attempt to explicitly describe every potential combination of non-avian response variables and the where, when, and how they may be relevant and appropriate given the range of potential waterfowl-related monitoring and research projects across the Gulf of Mexico. Rather, we suggest that those interested in monitoring wintering waterfowl use this chapter and the references herein as a stepping stone or starting point.

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LITERATURE CITED

Adair, S. E., J. L. Moore, W. H. Kiel. 1996. Wintering diving duck use of coastal ponds: An analysis of alternative hypotheses. Journal of Wildlife Management 60:83-93.

Afton, A. D., M. G. Anderson. 2001. Declining scaup populations: A retrospective analysis of long-term population and harvest survey data. Journal of Wildlife Management 65:781-796.

Alisauskas, R. T., C. D. Ankney. 1992. The cost of egg laying and its relationship to nutrient reserves in waterfowl. Pages 30-61 in B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, G. L. Krapu (Eds.), Ecology and Management of Breeding Waterfowl. University of Minnesota Press, Minneapolis, MN, USA.

Alston, J. M., P. G. Pardey, S. Wood, L. You. 2000. Strategic technology investments for LAC agriculture: A framework for evaluating the local and spillover effects of R&D. International Food Policy Research Institute, Washington, D.C., USA.

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29:1294-1297.

Anderson, D. R., K. P. Burnham, W. L. Thompson. 2000. Null hypothesis testing: Problems, prevalence, and an alternative. Journal of Wildlife Management 64:912-923.

Anderson, J. T. 2008. Survival, habitat use, and movements of female northern pintails wintering along the Texas coast. Thesis, Texas A&M University, Kingsville, TX.

Andersson, K., C. A. Davis, G. Harris, D. A. Haukos. 2015. An assessment of non-breeding waterfowl surveys on national wildlife refuges in the central flyway. Wildlife Society Bulletin 39:79-86.

Andersson, K., C. A. Davis, G. Harris, D. A. Haukos. 2018. Nonbreeding duck use at Central Flyway National Wildlife Refuges. Journal of Fish and Wildlife Management 9:45-64.

Ankney, C. D., C. D. MacInnes. 1978. Nutrient reserves and reproductive performance of female Lesser Snow Geese. Auk 95:459-471.

Anteau, M. J., A. D. Afton. 2008. Using plasma-lipid metabolites to index changes in lipid reserves of free-living lesser scaup (*Aythya affinis*). Auk 125:354-357.

Anteau, M. J., A. D. Afton. 2009. Lipid reserves of lesser scaup (*Aythya affinis*) migrating across a large landscape are consistent with the "spring condition" hypothesis. Auk 126:873-883.

Anteau, M. J., A. D. Afton. 2011. Lipid catabolism of invertebrate predator indicates widespread wetland ecosystem degradation. PLoS ONE 6: e16029.

Anteau, M. J., J.-M. DeVink, D. N. Koons, J. E. Austin, C. M. Custer, A. D. Afton. 2014. Lesser Scaup (*Aythya affinis*). In P. G. Rodewald (Ed.), The Birds of North America, Version 2.0. Cornell Lab of Ornithology, Ithaca, NY, USA.

Austin, J. E., A. D. Afton, M. G. Anderson, R. G. Clark, C. M. Custer, J. S. Lawrence, J. B. Pollard, J. K. Ringelman. 2000. Declining scaup populations: Issues, hypotheses, and research needs. Wildlife Society Bulletin 28:254-263.

Baker, O. E. 1983. Nesting and brood rearing habitats of the mottled duck in the coastal marsh of Cameron Parish, Louisiana. Thesis, Louisiana State University, Baton Rouge, LA.

Baldassarre, G. A. 2014. Ducks, geese, and swans of North America. Wildlife Management Institute, Johns Hopkins University Press, Baltimore, MD, USA.

Baldassarre, G. A., E. G. Bolen. 1994. Waterfowl Ecology and Management. First Edition. John Wiley and Sons, Inc., New York, NY, USA.

Baldwin, K., E. Dohlman, N. Childs, L. Foreman. 2011. Consolidation and structural change in the U.S. rice sector. RCS-11D-01, U.S. Department of Agriculture, Economic Research Service, Washington, D.C., USA.

Ballard, B. M., J. D. James, R. L. Bingham, M. J. Petrie, B. C. Wilson. 2010. Coastal pond use by redheads wintering in the Laguna Madre, Texas. Wetlands 30:669-674.

Ballard, B. M., M. T. Merendino, R. H. Terry, T. C. Tacha. 2001. Estimating abundance of breeding mottled ducks in Texas. Wildlife Society Bulletin 29:1186-1192.

Ballard, B. M., J. E. Thompson, M. J. Petrie, M. Checkett, D. G. Hewitt. 2004. Diet and nutrition of northern pintails wintering along the southern coast of Texas. Journal of Wildlife Management 68:371-382.

Barron, D. G., J. D. Brawn, P. J. Weatherhead. 2010. Meta-analysis of transmitter effects on avian behaviour and ecology. Methods in Ecology and Evolution 1:180-187.

Beatty, W. S., E. B. Webb, D. C. Kesler, A. H. Raedeke, L. W. Naylor, D. D. Humburg. 2014. Landscape effects on mallard habitat selection at multiple spatial scales during the non-breeding period. Landscape Ecology 29: 989-1000.

Bellrose F. C. 1980. Ducks, Geese and Swans of North America. Stackpole Books, Harrisburg, PA, USA.

Benedetti-Cecchi, L. 2003. The importance of the variance around the mean effect size of ecological processes. Ecology 84:2335-2346.

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

Bielefeld, R. R. 2006. Mottled Duck survey redesign final report. Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Gainesville, FL, USA.

Bielefeld, R. R., M. G. Brasher, T. E. Moorman, P. N. Gray. 2010. Mottled Duck (*Anas fulvigula*). In P. G. Rodewald (Ed.), The Birds of North America, Version 2.0. Cornell Lab of Ornithology, Ithaca, NY, USA.

Bjorndal, K. A., B. W. Bowen, M. Chaloupka, L. B. Crowder, S. S. Heppell, C. M. Jones, M. E. Lutcavage, D. Policansky, A. R. Solow, B. E. Witherington. 2011. Better science needed for restoration in the Gulf of Mexico. Science 331:537-538.

Block, W. M., L. A. Brennan. 1993. The habitat concept in ornithology: Theory and applications. Current Ornithology 11:35-91.

Block, W. M., A. B. Franklin, J. P. Ward Jr., J. L. Ganey, G. C. White. 2001. Design and implementation of monitoring studies to evaluate the success of ecological restoration on wildlife. Restoration Ecology 9:293-303.

Bodey, T. W., I. R. Cleasby, F. Bell, N. Parr, A. Schultz, S. C. Votier, S. Bearhop. 2018. A phylogenetically controlled meta-analysis of biologging device effects on birds: Deleterious effects and a call for more standardized reporting of study data. Methods in Ecology and Evolution 9:946-955.

Boomer, G. S., F. A. Johnson. 2007. A proposed assessment and decision-making frame-work to inform scaup harvest management. Unpublished Report. U.S. Department of the Interior, Fish and Wildlife Service, Laurel, MD, USA.

Borchert, S. M., M. J. Osland, N. M. Enwright, K. T. Griffith. 2018. Coastal wetland adaptation to sea-level rise: Quantifying the potential for landward migration and coastal squeeze in northern Gulf of Mexico estuaries. Journal of Applied Ecology.

Brasher, M. G., J. D. James, B. C. Wilson. 2012. Gulf Coast Joint Venture priority waterfowl science needs. Gulf Coast Joint Venture, Lafayette, LA, USA.

Brasher, M. G., B. C. Wilson, M. W. Parr, B. M. Allston, N. M. Enwright, S. J. DeMaso, W. G. Vermillion, Gulf Coast Joint Venture Waterfowl Working Group. 2018. Contemporary refinements to Gulf Coast Joint Venture population and habitat objectives and landscape assessments for wintering waterfowl. Gulf Coast Joint Venture, Lafayette, LA, USA.

Brewer, J. 1984. Measuring inefficiencies of federal acreage reduction programs. Honors Project (Paper 96), Illinois Wesleyan University, Bloomington, IL, USA.

Bridge, E. S., K. Thorup, M. S. Bowlin, P. B. Chilson, R. H. Diehl, R. W. Flééron, P. Hartl, R. Kays, J. F. Kelly, W. D. Robinson, M. Wikelski. 2011. Technology on the move: Recent and forthcoming innovations for tracking migratory birds. BioScience 61:689-698.

Brownie, C., D. R. Anderson, K. P. Burnham, D. S. Robson. 1985. Statistical inference from band recovery data—A handbook. U. S. Department of the Interior, Fish and Wildlife Service, Resource Publication 156, Washington, D.C., USA.

Burger, J. 2017. Avian resources of the northern Gulf of Mexico. Pages 1353-1488 in C. H. Ward (Ed.), Habitats and Biota of the Gulf of Mexico: Before the Deepwater Horizon Oil Spill, Volume 2: Fish Resources, Fisheries, Sea Turtles, Avian Resources, Marine Mammals, Diseases and Mortalities. Springer Science and Business Media LLC, New York, NY, USA.

Burger, J. 2018. Birdlife of the Gulf of Mexico. Harte Research Institute for the Gulf of Mexico Studies Series, Texas A&M University Press, College Station, TX, USA.

Burnham, K. P., D. R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, 2nd Edition. Springer Science, New York, NY, USA.

Chabreck, R. H., T. Joanen, S. L. Paulus. 1989. Southern coastal marshes and lakes. Pages 249-277 in L. M. Smith, R. L. Pederson, R. M. Kaminski (Eds.), Habitat Management for Migrating and Wintering Waterfowl in North America. Texas Tech University Press, Lubbock, TX, USA.

Clark, R. G., J. P. Fleskes, K. L. Guyn, D. A. Haukos, J. E. Austin, M. R. Miller. 2014. Northern Pintail (*Anas acuta*). In P. G. Rodewald (Ed.), The Birds of North America, Version 2.0. Cornell Lab of Ornithology, Ithaca, NY, USA.

Coastal Protection and Restoration Authority of Louisiana (CPRA). 2012. Louisiana's comprehensive master plan for a sustainable coast. Coastal Protection and Restoration Authority of Louisiana. Baton Rouge, LA, USA.

Coastal Protection and Restoration Authority of Louisiana (CPRA). 2017. Louisiana's comprehensive master plan for a sustainable coast. Coastal Protection and Restoration Authority of Louisiana, Baton Rouge, LA, USA.

Conroy, M. J., M. C. Runge, J. D. Nichols, K. W. Stodola, R. J. Cooper. 2011. Conservation in the face of climate change: The roles of alternative models, monitoring, and adaptation in confronting and reducing uncertainty. Biological Conservation 144:1204-1213.

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

Cooch, E. G., M. Guillemain, G. S. Boomer, J.-D. Lebreton, J. D. Nichols. 2014. The effects of harvest on waterfowl populations. Wildfowl (Special Issue No. 4):220-276.

Cooch, E. G., G. C. White. 2014. Program MARK: A gentle introduction. Retrieved on March 8, 2018 from http://www.phidot.org/software/mark/docs/book.

Cooke, F., R. F. Rockwell, D. B. Lank. 1995. The Snow Geese of La Perouse Bay: Natural Selection in the Wild. Oxford University Press, Oxford, UK.

Cornelius, S. E. 1977. Food and resource utilization by wintering Redheads on lower Laguna Madre. Journal of Wildlife Management 41:374-385.

Couvillion, B. R., J. A. Barras, G. D. Steyer, W. Sleavin, M. Fischer, H. Beck, N. Trahan, B. Griffin, D. Heckman. 2011. Land area change in coastal Louisiana from 1932 to 2010. U.S. Geological Survey Scientific Investigations Map 3164.

Cowardin, L. M., R. J. Blohm. 1992. Breeding population inventories and measures of recruitment. Pages 423-445 in B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, G. L. Krapu (Eds.), Ecology and Management of Breeding Waterfowl. University of Minnesota Press, Minneapolis, MN, USA.

Cox Jr., R. R. 1996. Movements, habitat use, and survival of female northern pintails in southwestern Louisiana. Dissertation, Louisiana State University, Baton Rouge, LA.

Cox Jr., R. R., A. D. Afton. 1996. Evening flights of female northern pintails from a major roost site. Condor 98:810-819.

Cox Jr., R. R., A. D. Afton. 1997. Use of habitats by female northern pintails wintering in southwestern Louisiana. Journal of Wildlife Management 61:435-443.

Cox Jr., R. R., A. D. Afton. 1998. Use of mini-refuges by female northern pintails wintering in southwestern Louisiana. Wildlife Society Bulletin 26:130-137.

Craig, N. J., R. E. Turner, J. W. Day Jr. 1979. Land loss in coastal Louisiana. Pages 227-254 in J. W. Day Jr., D. D. Culley Jr., R. E. Turner, A. J. Mumphrey Jr. (Eds.), Proceedings of the Third Coastal Marsh and Estuary Management Symposium. Louisiana State University, Baton Rouge, LA, USA.

Craigmiles, J. P. 1975. Advances in rice—through research and application. Pages 1-8 in J. E. Miller (Ed.), Six decades of rice research in Texas. Texas Agricultural Experiment Station Research Monograph 4, Texas A&M University, College Station, TX, USA.

Dahl, T. E., S. M. Stedman. 2013. Status and trends of wetlands in the coastal watersheds of the conterminous United States 2004 to 2009. U.S. Department of the Interior, Fish and Wildlife Service and National Oceanic and Atmospheric Administration National Marine Fisheries Service, Washington, D.C., USA.

Davis, J. B., M. Guillemain, R. M Kaminski, C. Arzel, J. M. Eadie, E. C. Rees. 2014. Habitat and resource use by waterfowl in the northern hemisphere in autumn and winter. Wildfowl (Special Issue No. 4):17-69.

Davis, J. B., M. G. Brasher, H. A. Hagy. 2018. Managed sanctuary for migrating and wintering waterfowl: A brief synthesis and insights for conservation planning. White Paper. Gulf Coast Joint Venture and Lower Mississippi Valley Joint Venture Waterfowl Working Group Meeting, Mississippi State University, Starkville, MS, USA.

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

Deepwater Horizon Natural Resource Damage Assessment Trustees (DHNRDAT). 2016. Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement.

Deepwater Horizon Natural Resource Damage Assessment Trustees (DHNRDAT). 2017. Deepwater Horizon Oil Spill Natural Resource Damage Assessment: Strategic Framework for Bird Restoration Activities.

Devries, J. H., R. W. Brook, D. W. Howerter, M. G. Anderson. 2008. Effects of spring body condition and age on reproduction in mallards (*Anas Platyrhynchos*). Auk 125:618-628.

Dinsmore, S. J., J. J. Dinsmore. 2007. Modeling avian nest survival in Program MARK. Studies in Avian Biology 34:73-83.

Dinsmore, S. J., G. C. White, F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476-3488.

Doherty K. E., A. J. Ryba, C. L. Stemler, N. D. Niemuth, W. A. Meeks. 2013. Conservation planning in an era of change: State of the U.S. Prairie Pothole Region. Wildlife Society Bulletin 37:546-563.

Doherty, K. E., J. S. Evans, J. Walker, J. H. Devries, D. W. Howerter. 2015. Building the foundation for international conservation planning for breeding ducks across the U.S. and Canadian border. PLoS ONE 10: e0116735.

Doherty, P. F., G. C. White, K. P. Burnham. 2012. Comparison of model building and selection strategies. Journal of Ornithology 152:317-323.

Dooley, J. L., T. A. Sanders, P. F. Doherty Jr. 2010. Effects of hunting season structure, weather and body condition on overwintering mallard *Anas platyrhynchos* survival. Wildlife Biology 16:357-366.

Drever, M. C., T. D. Nudds, R. G. Clark. 2007. Agricultural policy and nest success of prairie ducks in Canada and the United States. Avian Conservation and Ecology 2(2): 5.

Dubovsky, J. A. 2017. Central Flyway harvest and population survey data book. U. S. Department of the Interior, Fish and Wildlife Service, Lakewood CO, USA.

Dubovsky, J. A., R. M. Kaminski. 1994. Potential reproductive consequences of winter-diet restriction in mallards. Journal of Wildlife Management 58:780-786.

Ducks Unlimited (DU). 1997. Ducks Unlimited's International Conservation Plan. Retrieved on March 6, 2018 from https://www.ducks.org/media/Conservation/Conservation%20Plan/_documents/a_ICP2004%20final%208.05.pdf.

Dunn, E. H., C. M. Francis, P. J. Blancher, S. R. Drennan, M. A. Howe, D. Lepage, C. S. Robbins, K. V. Rosenberg, J. R. Sauer, K. G. Smith. 2005. Enhancing the scientific value of the Christmas Bird Count. Auk 122:338-346.

Durham, R. S., A. D. Afton. 2003. Nest-site selection and success of mottled ducks on agricultural lands in southwest Louisiana. Wildlife Society Bulletin 31:433-442.

Durham, R. S., A. D. Afton. 2004. Breeding biology of mottled ducks on agricultural lands in southwestern Louisiana. Southeastern Naturalist 5:311-316.

Dzubin, A., E. G. Cooch. 1992. Measurements of geese: General field methods. California Waterfowl Association, Sacramento, CA, USA.

Eberhardt, L. L. 1978. Appraising variability in population studies. Journal of Wildlife Management 42:207-238.

Eberhardt, L. L. 1988. Testing hypotheses about populations. Journal of Wildlife Management 52:50-56.

Eberhardt, L. L., J. M. Thomas. 1991. Designing environmental field studies. Ecological Monographs 61:53-73.

Eggeman, D. R., F. A. Johnson. 1989. Variation in effort and methodology for the midwinter waterfowl inventory in the Atlantic Flyway. Wildlife Society Bulletin 17:227-233.

Enwright, N. M., K. T. Griffith, M. J. Osland. 2016. Barriers to and opportunities for landward migration of coastal wetlands with sea-level rise. Frontiers in Ecology and the Environment 14:307-316.

Enwright, N. M., S. B. Hartley, B. R. Couvillion, M. G. Brasher, J. M. Visser, M. K. Mitchell, B. M. Ballard, M. W. Parr, B. C. Wilson. 2015. Delineation of marsh types from Corpus Christi Bay, Texas, to Perdido Bay, Alabama, in 2010. U. S. Geological Survey Scientific Investigations Map 3336.

Environmental Protection Agency (EPA). 1999. Considering ecological processes in environmental impact assessments. U.S. Department of the Interior, Environmental Protection Agency, Washington, D.C., USA.

Field, S. A., A. J. Tyre, H. P. Possingham. 2005. Optimizing allocation of monitoring effort under economic and observational constraints. Journal of Wildlife Management 69:473-482.

Finger, R. S., B. M. Ballard, M. T. Merendino, J. P. Hurst, D. S. Lobpries, A. M. Fedynich. 2003. Habitat use, movements, and survival of female mottled ducks and ducklings during brood rearing. Texas Parks and Wildlife Department, Austin, TX, USA.

Flint, P. L., K. H. Pollock, D. Thomas, J. S. Sedinger. 1995. Estimating pre-fledging survival: allowing for brood mixing and dependence among brood mates. Journal of Wildlife Management 59:448-455.

Ford, R. J., W. Selman, S. S. Taylor. 2017. Hybridization between Mottled Ducks (*Anas fulvigula maculosa*) and Mallards (*A. platyrhynchos*) in the western Gulf Coast region. Condor 119:683-696.

Fournier A. M. V, R. R. Wilson, J. E. Lyons, J. Gleason, E. Adams, L. Barnhill, J. Brush, F. Chavez-Ramirez, R. Cooper, S. DeMaso, M. Driscoll, M. Eaton, P. Frederick, M Just., M. Seymour, J. Tirpack, M. Woodrey. (In Press). Structured decision making and optimal bird monitoring in the Northern Gulf of Mexico. U.S. Geological Survey, Open File Report.

Fronczak, D. L. 2017. Mississippi Flyway harvest and population survey data book. U. S. Department of the Interior, Fish and Wildlife Service, Bloomington, MN, USA.

Gilroy, J. J., T. Virzi, R. L. Boulton, J. L. Lockwood. 2012. A new approach to the "apparent survival" problem: Estimating true survival rates from mark-recapture studies. Ecology 93:1509-1516.

Glick, P., J. Clough, A. Polaczyk, B. Couvillion, B. Nunley. 2013. Potential effects of sea-level rise on coastal wetlands in southeastern Louisiana. Journal of Coastal Research 63:211-233.

Gosselink, J. G., J. M. Coleman, R. E. Stewart Jr. 1998. Coastal Louisiana. Pages 385-436 in M. J. Mac, P. A. Opler, C. E. Puckett-Haecker, P. D. Doran (Eds.), Status and Trends of the Nation's Biological Resources, Volume 1. U.S. Department of Interior, U.S. Geological Survey, Reston, VA, USA.

Grand, J. B. 1988. Habitat selection and social structure of mottled ducks in a Texas coastal marsh. Dissertation, Texas A&M University, College Station, TX, USA.

Gray, J. M. 2010. Habitat use, movements, and migration chronology and corridors of female gadwalls that winter along the Louisiana Gulf Coast. Thesis, Louisiana State University, Baton Rouge, LA, USA.

Gregory, R. D., D. W. Gibbons, P. F. Donald. 2004. Bird census and survey techniques. Pages 7-55 in W. J. Sutherland, I. Newton, R. E. Green (Eds.), Bird Ecology and Conservation: A Handbook of Techniques. Oxford University Press, New York, NY, USA.

Guillemain, M., J. Elmberg, C. Arzel, A. R. Johnson, G. Simon. 2008. The income–capital breeding dichotomy revisited: Late winter body condition is related to breeding success in an income breeder. Ibis 150:172-176.

Guillemain, M., J. Elmberg, M. Gauthier-Clerc, G. Massez, R. Hearn, J. Champagnon, G. Simon. 2010. Wintering French mallard and teal are heavier and in better body condition than 30 years ago: Effects of a changing environment? Ambio 39:170-180.

Hamilton, C. M., M. Baumann, A. M. Pidgeon, D. P. Helmers, W. E. Thogmartin, P. J. Heglund, V. C. Radeloff. 2016. Past and predicted future effects of housing growth on open space pathways and habitat connectivity around National Wildlife Refuges. Landscape Ecology 31:2175-2186.

Handley, L., D. Altsman, R. DeMay (Eds.). 2007. Seagrass status and trends in the northern Gulf of Mexico: 1940–2002. U.S. Department of the Interior, U.S. Geological Survey Scientific Investigations Report 2006-5287 and Environmental Protection Agency 855-R-04-003.

Handley, L., K. Spear, E. Taylor, C. Thatcher. 2015. Corpus Christi, Nueces, and Aransas Bays: Emergent wetlands status and trends. U.S. Department of the Interior, U.S. Geological Survey and Environmental Protection Agency.

Harmon, B. G. 1962. Mollusks as food of lesser scaup along the Louisiana coast. Transactions of the North American Wildlife and Natural Resources Conference 27:132-138.

Haukos, D. A. 2012. The status of mottled ducks on the western Gulf Coast. U.S. Department of the Interior, Fish and Wildlife Service, Regional Migratory Bird Office, Albuquerque, New Mexico. USA.

Haukos, D. A. 2015. Survival and recovery rates of mottled ducks banded in Texas and Louisiana. Journal of the Southeastern Association of Fish and Wildlife Agencies 2:214-220.

Haukos D. A., S. Martinez, J. Heltzel. 2010. Characteristics of ponds used by breeding mottled ducks on the Chenier Plain of the Texas Gulf Coast. Journal of Fish and Wildlife Management 1:93-101.

Hayward, M. W., L. Boitani, N. D. Burrows, P. J. Funston, K. U. Karanth, D. I. MacKenzie, K. H. Pollock, R. W. Yarnell. 2015. Ecologists need robust survey designs, sampling and analytical methods. Journal of Applied Ecology 52:286-290.

Heitmeyer, M. E. 1995. Influences of age, body condition, and structural size on mate selection by dabbling ducks. Canadian Journal of Zoology 73:2251-2258.

Hestbeck, J. B., D. H. Rusch, R. A. Malecki. 1990. Estimating population parameters for geese from band-recovery and mark-recapture data. Transactions of the North American Wildlife and Natural Resources Conference 55:350-373.

Heusmann, H. W. 1999. Let's get rid of the midwinter waterfowl inventory in the Atlantic Flyway. Wildlife Society Bulletin 27:559-565.

Higgins, K. F., D. E. Naugle, K. J. Forman. 2002. A case study of changing land use practices in the Northern Great Plains, USA: An uncertain future for waterbird conservation. Waterbirds 25:42-50.

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

Holbrook, R. S., F. C. Rowher, W. P. Johnson. 2000. Habitat use and productivity of mottled ducks on the Atchafalaya River Delta, Louisiana. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 54:292-303.

Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54:187-211.

Hutto, R. L., R. T. Belote. 2013. Distinguishing four types of monitoring based on the questions they address. Forest Ecology and Management 289:183-189.

Johnson, C. J., M.-H. St.-Laurent. 2011. Unifying framework for understanding impacts of human developments on wildlife. Pages 27-54 in D. E. Naugle (Ed.), Energy Development and Wildlife Conservation in Western North America. Island Press, Washington, D.C., USA.

Johnson, D. H. 1999. The insignificance of statistical significance testing. Journal of Wildlife Management 63:763-772.

Johnson, D. H. 2002a. The role of hypothesis testing in wildlife science. Journal of Wildlife Management 66:272-276.

Johnson, D. H. 2002b. The importance of replication in wildlife science. Journal of Wildlife Management 66:919-932.

Johnson, D. H. 2008. In defense of indices: The case of bird surveys. Journal of Wildlife Management 72:857-868.

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

Johnson, D. H., J. D. Nichols, M. D. Schwartz. 1992. Breeding dynamics of waterfowl. Pages 446–485 in B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, G. L. Krapu (Eds.), Ecology and Management of Breeding Waterfowl. University of Minnesota Press, Minneapolis, MN, USA.

Johnston, C. A. 2014. Agricultural expansion: Land use shell game in the U.S. Northern Plains. Landscape Ecology 29:81-95.

Jones, S. L., G. R. Geupel (Eds.). 2007. Beyond Mayfield: Measurements of Nest-survival Data. Studies in Avian Biology 34. CRC Press, Boca Raton, FL.

Kaminski, R. M., A. D. Afton, B. W. Anderson. D. G. Jorde, J. R. Longcore. 1988. Workshop summary- habitat selection. Pages 399-404 in L. M. Smith, R. L. Pederson, R. M. Kaminski (Eds.), Habitat Management for Migrating and Wintering Waterfowl in North America. Texas Tech University Press, Lubbock, TX, USA.

Kaminski, R. M., E.A. Gluesing. 1987. Density- and habitat related recruitment in mallards. Journal of Wildlife Management 51:141-148.

Kesler, D. C., A. H. Raedeke, J. Foggia, W. S. Beatty, E. B. Webb, D. D. Humburg, L. W. Naylor. 2014. Effects of satellite transmitters on captive and wild mallards. Wildlife Society Bulletin 38:557-565.

Kinney, S. D. 2004. Estimating the population of greater and lesser scaup during winter in off-shore Louisiana. Thesis, Louisiana State University, Baton Rouge, LA, USA.

Kirwan, M. L., J. P. Megonigal. 2013. Tidal wetland stability in the face of human impacts and sea-level rise. Nature 504:53-60.

Kirwan, M. L., S. Temmerman, E. E. Skeehan, G. R. Guntenspergen, S. Fagherazzi. 2016. Overestimation of marsh vulnerability to sea-level rise. Nature Climate Change 6:253-260.

Klett, A. T., H. F. Dubbert, C. A. Faanes, K. F. Higgins. 1986. Techniques for studying nest success of ducks in upland habitats in the Prairie Pothole Region. U. S. Department of the Interior, Fish and Wildlife Service, Resource Publication Number 158, Washington, D.C., USA.

Koneff, M. D., J. A. Royal, M. C. Otto, J. S. Wortham, J. K. Bidwell. 2008. A double-observer method to estimate detection rate during aerial waterfowl surveys. Journal of Wildlife Management 72:1641-1649.

Koons, D. N., G. Gunarsson, J. A. Schmutz, J. J. Rotella. 2014. Drivers of waterfowl population dynamics: from teal to swans. Wildfowl (Special Issue No. 4):169-191.

Koons, D. N., J. J. Rotella, D. W. Willey, M. Taper, R. G. Clark, S. Slattery, R. W. Brook, R. M. Corcoran, J. R. Lovvorn. 2006. Lesser scaup population dynamics: What can be learned from available data? Avian Conservation and Ecology 1(3).

Krainyk, A., B. M. Ballard. 2015. Decision support tool: prioritization of Mottled Duck (*Anas fulvigula*) habitat for conservation and management in the Western Gulf Coast. Final Report. Texas A&M University-Kingsville, Kingsville, TX, USA.

Krapu, G. L. 1981. The role of nutrient reserves in mallard reproduction. Auk 98:29-38.

Krapu, G. L., K. J. Reinecke. 1992. Foraging ecology and nutrition. Pages 1-29 in B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, G. L. Krapu (Eds.), Ecology and Management of Breeding Waterfowl. University of Minnesota Press, Minneapolis, MN, USA.

Krementz, D. G., K. Asante, L. W. Naylor. 2011. Spring migration of mallards from Arkansas as determined by satellite telemetry. Journal of Fish and Wildlife Management 2:156-168.

Krementz, D. G., K. Asante, L. W. Naylor. 2012. Autumn migration of Mississippi Flyway mallards as determined by satellite telemetry. Journal of Fish and Wildlife Management 3:238-251.

Kunkel, K. E, L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, C. E. Konrad, II, C. M. Fuhrman, B. D. Keim, M. C. Kruk, A. Billet, H. Needham, M. Schafer, J. G. Dobson. 2013. Regional climate trends and scenarios for the U. S. National Climate Assessment. Part 2. Climate of the southeast U. S. National Oceanic and Atmospheric Administration, NOAA Technical Report NESDIS 142-2, Silver Spring, MD, USA.

Kuvlesky, W. P., L. A. Brennan, M. L. Morrison, K. K. Boydston, B. M. Ballard, F. C. Bryant. 2007. Wind energy development and wildlife conservation: Challenges and opportunities. Journal of Wildlife Management 71:2487-2498.

Lameris, T. K., E. Kleyheeg. 2017. Reduction in adverse effects of tracking devices on waterfowl requires better measuring and reporting. Animal Biotelemetry 5:24.

Lange, C. J. 2014. Impacts of wind energy developments on wintering redheads along the Lower Texas Coast. Thesis, Texas A&M University-Kingsville, Kingsville, TX, USA.

Lange, C. J., B. M. Ballard, D. P. Collins. 2018. Impacts of wind turbines on redheads in the Laguna Madre. Journal of Wildlife Management 82:532-537.

Larsen, J. K., M. Guillemette. 2007. Effects of wind turbines on flight behaviour of wintering common eiders: Implications for habitat use and collision risk. Journal of Applied Ecology 44:516-522.

Leberg, P. L. 2017. Mottled Duck (*Anas fulvigula*) Habitat Suitability Index Model. 2017 Coastal Master Plan: Attachment C3-8, Coastal Protection and Restoration Authority, Baton Rouge, LA, USA.

Lebreton, J.-D., K. P. Burnham, J. Clobert, D. R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: A unified approach with case studies. Ecological Monographs 62:67-118.

LeSchack, C. R., S. K. McKinght, G. R. Hepp. 1997. Gadwall (*Mareca strepera*). In P. G. Rodewald (Ed.), The Birds of North America, Version 2.0. Cornell Lab of Ornithology, Ithaca, NY, USA.

Lindenmayer, D. B., G. E. Likens. 2010a. Effective Ecological Monitoring. CSIRO Publishing, Washington, D.C., USA.

Lindenmayer, D. B., G. E. Likens. 2010b. The science and application of ecological monitoring. Biological Conservation 143:1317-1328.

Link, P. A., A. D. Afton, R. R. Cox Jr., B. E. Davis. 2011. Daily movements of female mallards wintering in southwestern Louisiana. Waterbirds 34:422-428.

Loesch, C. R., J. A. Walker, R. E. Reynolds, J. S. Gleason, N. D. Niemuth, S. E. Stephens, M. A. Erickson. 2013. Effect of wind energy development on breeding duck densities in the Prairie Pothole Region. Journal of Wildlife Management 77:587-598.

Loges B. W., B. G. Tavernia, A. M. Wilson, J. D. Stanton, J. H. Herner-Thogmartin, J. Casey, J. M. Coluccy, J. L. Coppen, M. Hanan, P. J. Heglund, S. K. Jacobi, T. Jones, M. G. Knutson, K. E. Koch, E. V. Lonsdorf, H. P. Laskowski, S. K. Lor, J. E. Lyons, M. E. Seamans, W. Stanton, B. Winn, L. C. Ziemba. 2014. National protocol framework for the inventory and monitoring of nonbreeding waterbirds and their habitats, an integrated waterbird management and monitoring initiative (IWMM) approach. Version 1. Natural Resources Program Center, Fort Collins, CO, USA.

Lukacs, P. M., W. L. Thompson, W. L. Kendall, W. R. Gould, P. F. Doherty Jr., K. P. Burnham, D. R. Anderson. 2007. Concerns regarding a call for pluralism of information theory and hypothesis testing. Journal of Applied Ecology 44:456-460.

Lyons, J. E., M. C. Runge, H. P. Laskowski, W. L. Kendall. 2008. Monitoring in the context of structured decision-making and adaptive management. Journal of Wildlife Management 72:1683-1692.

MacKenzie, D. I., J. D. Nichols. 2004. Occupancy as a surrogate for abundance estimation. Animal Biodiversity and Conservation 27:461-467.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, J. E. Hines. 2006. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence. Elsevier/Academic Press, Burlington, MA, USA.

MacKenzie, D. I., J. A. Royle. 2005. Designing occupancy studies: General advice and allocating survey effort. Journal of Applied Ecology 42:1105-1114.

Marcot, B. G., J. D. Steventon, G. D. Sutherland, R. K. McCann. 2006. Guidelines for developing and updating Bayesian belief networks applied to ecological modeling and conservation. Canadian Journal of Forest Research 36:3063-3074.

Martin, S. R., C. P. Onuf, K. H. Dunton. 2008. Assessment of propeller and off-road vehicle scarring in seagrass beds and wind-tidal flats of the southwestern Gulf of Mexico. Botanica Marina 51:79-91.

Martinuzzi, S., V. C. Radeloff, J. V. Higgins, D. P. Helmers, A. J. Plantinga, D. J. Lewis. 2013. Key areas for conserving United States' biodiversity likely threatened by future land use change. Ecosphere 4(5):58.

Martinuzzi, S., J. C. Withey, A. M. Pidgeon, A. J. Plantinga, A. A. McKerrow, S. G. Williams, D. P. Helmers, V. C. Radeloff. 2015. Future land-use scenarios and the loss of wildlife habitat in the southeastern U.S. Ecological Applications 25:160-171.

Marty, J. R. 2013. Seed and waterbird abundances in ricelands in the Gulf Coast Prairies of Louisiana and Texas. Thesis, Mississippi State University, Starkville, MS, USA.

McCracken, K. G., W. P. Johnson, F. H. Sheldon. 2001. Molecular population genetics, phylogeography, and conservation biology of the mottled duck. Conservation Genetics 2:87-102.

Michot, T. C., A. J. Nault. 1993. Diet differences in Redheads from nearshore and offshore zones in Louisiana. Journal of Wildlife Management 57:238-244.

Michot, T. C., M. C. Woodin, A. J. Nault. 2008. Food habits of redheads (*Aythya americana*) wintering in seagrass beds of coastal Louisiana and Texas, USA. Acta Zoologica Academiae Scientarum Hungaricae 54:239-250.

Mitchell, C. A., T. W. Custer, P. J. Zwank. 1994. Herbivory on shoalgrass by wintering Redheads in Texas. Journal of Wildlife Management 58:131-141.

Mitchell, M. K., B. M. Ballard, J. M. Visser, M. G. Brasher, E. J. Redeker. 2014. Delineation of coastal marsh types along the central Texas coast. Journal of Wildlife Management 34:653-660.

Moon, J. A., D. A. Haukos. 2006. Survival of female Northern pintails wintering in the Playa Lakes Region of northwestern Texas. Journal of Wildlife Management 70:777-783.

Moon, J. A., D. A. Haukos. 2009. Factors affecting body condition of northern pintails wintering in the playa lakes region. Waterbirds 32:87-95.

Moon, J. A., D. A. Haukos, W. C. Conway. 2017. Seasonal survival of adult female mottled ducks. Journal of Wildlife Management 81:461-469.

Moon, J. A., D. A. Haukos, L. M. Smith. 2007. Changes in body condition of pintails wintering in the Playa Lakes Region. Journal of Wildlife Management 71: 218-221.

Moorman, A. M., T. E. Moorman, G. A. Baldassarre, D. R. Richard. 1991. Effects of saline water on growth and survival of mottled duck ducklings in Louisiana. Journal of Wildlife Management 55:471-476.

Morrison, M. L., W. M. Block, M. D. Strickland, B. A. Collier, M. J. Peterson. 2010. Wildlife Study Design, 2nd Edition. Springer, New York, NY, USA.

Moulton, D. W., T. E. Dahl, D. M. Dall. 1997. Texas coastal wetlands status and trends, mid-1950s to early 1990s. United States Department of the Interior, Fish and Wildlife Service Southwest Region, Albuquerque, NM, USA.

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

Naugle, D. E., R. R. Johnson, T. R. Cooper, M. M. Holland, K. F. Higgins. 2000. Temporal distribution of waterfowl in eastern South Dakota: Implications for aerial surveys. Wetlands 20:177-183.

Newton, I. 1998. Population Limitation in Birds. Academic Press, London, UK.

Newton, I. 2006. Advances in the study of irruptive migration. Ardea 94:433-460.

Nichols, J. D. 1991. Extensive monitoring programmes viewed as long-term population studies: The case of North American waterfowl. Ibis 133:89-98.

Nichols, J. D., B. K. Williams. 2006. Monitoring for conservation. Trends in Ecology and Evolution 21:668-673.

Niven, D. K., G. S. Butcher. 2011. Status and trends of wintering coastal species along the northern Gulf of Mexico, 1965–2011. American Birds 65:12-19.

North American Waterfowl Management Plan (NAWMP). 1986. North American Waterfowl Management Program: A strategy for cooperation. Canadian Wildlife Service and U.S. Fish and Wildlife Service.

Notaro, M., M. Schummer, Y. Zhong, S. Vavrus, L. Elsen, J. Coluccy, C. Hoving. 2016. Projected influences of changes in weather severity on autumn-winter distributions of dabbling ducks in the Mississippi and Atlantic Flyways during the twenty-first century. PloS ONE 11: e0167506.

Nudds, T. E. 1983. Niche dynamics and organization of waterfowl guilds in a variable environment. Ecology 64:319-330.

Nudds, T. E. 1992. Patterns in breeding duck communities. Pages 540–567 in B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, G. L. Krapu (Eds.), Ecology and Management of Breeding Waterfowl. University of Minnesota Press, Minneapolis, MN, USA.

Nyman, J. A., R. H. Chabreck. 2012. Managing coastal wetlands for wildlife. Pages 133–156 in N. J. Silvy (Ed.), The Wildlife Management Techniques Manual, 7th Edition. John Hopkins University Press, Baltimore, MD, USA.

Onuf, C. P. 1996. Biomass patterns in seagrass meadows of the Laguna Madre, Texas. Bulletin of Marine Science 58:404-420.

Osland, M. J., N. M. Enwright, R. H. Day, C. A. Gabler, C. L. Stagg, J. B. Grace. 2016. Beyond just sea-level rise: Considering macroclimatic drivers within coastal wetland vulnerability assessments to climate change. Global Change Biology 22:1-11.

Osnas, E. E., M. C. Runge, B. J. Mattsson, J. Austin, G. S. Boomer, R. G. Clark, P. Devers, J. M. Eadie, E. V. Lonsdorf, B. G. Tavernia. 2014. Managing harvest and habitat as integrated components. Wildfowl (Special Issue No. 4): 305-328.

Paulus, S. L. 1982. Feeding ecology of gadwall in Louisiana in winter. Journal of Wildlife Management 46:71-79.

Partners in Flight (PIF). 2017. Avian Conservation Assessment Database, version 2017. Retrieved on February 7, 2018 from http://pif.birdconservancy.org/ACAD.

Pearce, J. L., M. S. Boyce. 2006. Modelling distribution and abundance with presence-only data. Journal of Applied Ecology 43:405-412.

Pearse, A. T. 2007. Design, evaluation, and applications of an aerial survey to estimate abundance of wintering waterfowl in Mississippi. Dissertation, Mississippi State University, Starkville, MS, USA.

Pearse, A. T., S. J. Dinsmore, R. M. Kaminski, K. J. Reinecke. 2008a. Evaluation of an aerial survey to estimate abundance of wintering ducks in Mississippi. Journal of Wildlife Management 72:1413-1419.

Pearse, A. T., P. D. Gerard, S. J. Dinsmore, R. M. Kaminski, K. J. Reinecke. 2008b. Estimation and correction of visibility bias associated with aerial surveys of wintering ducks. Journal of Wildlife Management 72:808-813.

Péron, G., C. A. Nicolai, D. N. Koons. 2012. Demographic response to perturbations: The role of compensatory density dependence in a North American duck under variable harvest regulations and changing habitat. Journal of Animal Ecology 81:960-969.

Petrie, M., M. Brasher, D. James. 2014. Estimating the biological and economic contributions that rice habitats make in support of North American Waterfowl. The Rice Foundation, Stuttgart, AR, USA.

Phillips, E. H. 1951. The Gulf Coast rice industry. Agricultural History 25:91-96.

Pollock, K. H., W. L. Kendall. 1987. Visibility bias in aerial surveys: A review of estimation procedures. Journal of Wildlife Management 51:502-510.

Pollock, K. H., H. D. Marsh, I. R. Lawler, M. W. Alldredge. 2006. Estimating animal abundance in heterogeneous environments: An application to aerial surveys for dugongs. Journal of Wildlife Management 70:255-262.

Pollock, K. H., J. D. Nichols, T. R. Simons, G. L. Farnsworth, L. L. Bailey, J. R. Sauer. 2002. Large-scale wildlife monitoring studies: Statistical methods for design and analysis. Environmetrics 13:105-119.

Quammen, M. L., C. P. Onuf. 1993. Laguna Madre: Seagrass changes continue decades after salinity reduction. Estuaries 16:302-310.

Raabe, E.A., R. P. Stumpf. 2016. Expansion of tidal marsh in response to sea-level rise: Gulf Coast of Florida, USA. Estuaries and Coasts 39:145-157.

Rashford, B. S., J. A. Walker, C. T. Bastian. 2011. Economics of grassland conversion to cropland in the Prairie Pothole Region. Conservation Biology 25:276-284.

Reinecke, K. J., C. D. Ankney, G. L. Krapu, R. B. Owen, H. H. Prince, D. G. Raveling. 1988. Workshop summary: Nutrition, condition, and ecophysiology. Pages 299-303 in M. W. Weller (Ed.), Waterfowl in Winter. University of Minnesota Press, Minneapolis, MN, USA.

Reinecke, K. J., M. W. Brown, J. R. Nassar. 1992. Evaluation of aerial transects for counting wintering mallards. Journal of Wildlife Management 56:515-525.

Reynolds, J. H., M. G. Knutson, K. B. Newman, E. D. Silverman, W. L. Thompson. 2016. A road map for designing and implementing a biological monitoring program. Environmental Monitoring and Assessment 188:399.

Reynolds, R. E., C. R. Loesch, B. Wangler, T. L. Shaffer. 2007. Waterfowl response to the conservation reserve program and swampbuster provisions in the Prairie Pothole Region, 1992–2004. U.S. Department of Agriculture RFA 05-IA-04000000-N34, Bismarck, ND, USA.

Rigby, E. A. 2008. Recruitment of mottled ducks (*Anas fulvigula*) on the upper Texas Gulf Coast. Thesis, Texas Tech University, Lubbock, TX, USA.

Rigby, E. A., D. A. Haukos. 2012. Breeding season survival and breeding incidence of female mottled ducks on the upper Texas Gulf Coast. Waterbirds 35:260-269.

Rigby, E. A., D. A. Haukos. 2014. A matrix population model for mottled ducks (*Anas fulvigula*) of the Western Gulf Coast. Southeastern Naturalist 13(Special Issue 5):26-40.

Rigby, E. A., D. A. Haukos. 2015. Duckling survival, fecundity, and habitat selection of mottled duck broods on the Upper Texas Gulf Coast. Journal of the Southeastern Association of Fish and Wildlife Agencies 2:156-163.

Ringelman, J. K., M. R. Szymczak. 1985. A physiological condition index for wintering mallards. Journal of Wildlife Management 49:564-568.

Robel, R. J., J. N. Briggs, A. D. Dayton, L. C. Hulbert. 1970. Relationship between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Robert, M., B. Drolet, J.-P. L. Savard. 2006. Effects of backpack radio-transmitters on female Barrow's goldeneyes. Waterbirds 29:115-120.

Robinson, R. A., C. A. Morrison, S. R. Baillie. 2014. Integrating demographic data: Towards a framework for monitoring wildlife populations at large spatial scales. Methods in Ecology and Evolution 5:1361-1372.

Robinson, W. D., M. S. Bowlin, I. Bisson, J. Shamoun-Baranes, K. Thorup, R. H. Diehl, T. H. Kunz, S. Mabey, D. W. Winkler. 2010. Integrating concepts and technologies to advance the study of bird migration. Frontiers in Ecology and the Environment 8:354-361.

Rohwer, F. C., W. P. Johnson, E. R. Loos. 2002. Blue-winged Teal (*Spatula discors*). In P. G. Rodewald (Ed.), The Birds of North America, Version 2.0. Cornell Lab of Ornithology, Ithaca, NY, USA.

Rorabaugh, J. C., P. Zwank. 1983. Habitat suitability index models: Mottled duck. U.S. Department of the Interior, Fish and Wildlife Service, FWS/OBS-82/10.52, Washington, D.C., USA.

Ross, B. E., D. A. Haukos, P. Walther. 2018. Quantifying changes and influences on mottled duck density in Texas. Journal of Wildlife Management 82:374-382.

Rotella, J. 2014. Nest survival models. Pages 17-1–17-20 in E. G. Cooch, G. C. White (Eds.), Program MARK: a gentle introduction. Retrieved on March 8, 2018, from http://www.phidot.org/software/mark/docs/book.

Rotella, J. J., S. J. Dinsmore, T. L. Shaffer. 2004. Modeling nest-survival data: A comparison of recently developed methods that can be implemented in MARK and SAS. Animal Biodiversity and Conservation 27:187-205.

Royle, J. A., J. D. Nichols. 2003. Estimating abundance from repeated presence–absence data or point counts. Ecology 84:777-790.

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

Sæther, B.-E., O. Bakke. 2000. Avian life history variation and contribution of demographic traits to the population growth rate. Ecology 81:642-653.

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

Sanderlin, J. S., W. M. Block, J. L. Ganey. 2014. Optimizing study design for multi-species avian monitoring programmes. Journal of Applied Ecology 51:860-870.

Sargeant, A. B., R. J. Greenwood, M. A. Sovada, T. L. Shaffer. 1993. Distribution and abundance of predators that affect duck production-Prairie Pothole Region. Resource Publication 194. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Sargeant, A. B., D. G. Raveling. 1992. Mortality during the breeding season. Pages 396-422 in B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, G. L. Krapu (Eds.), Ecology and Management of Breeding Waterfowl. University of Minnesota Press, Minneapolis, MN, USA.

Sauer, J. R., S. Droege. 1990. Survey designs and statistical methods for the estimation of avian population trends. Biological Report Number 90. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Sauer, J. R., J. E. Fallon, R. Johnson. 2003. Use of North American Breeding Bird Survey data to estimate population change for bird conservation regions. Journal of Wildlife Management 67:372-389.

Sauer, J. R., M. G. Knutson. 2008. Objectives and metrics for wildlife monitoring. Journal of Wildlife Management 72:1663-1664.

Sauer, J. R., W. A. Link. 2011. Analysis of the North American Breeding Bird Survey using hierarchical models. Auk 128:87-98.

Sauer, J. R., W. A. Link, J. E. Fallon, K. L. Pardieck, and D. J. Ziolkowski, Jr. 2013. The North American Breeding Bird Survey 1966–2011: Summary analysis and species accounts. North American Fauna 79:1-32.

Sayler, R. D. 1992. Ecology and evolution of brood parasitism in waterfowl. Pages 290-322 in B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, G. L. Krapu (Eds.), Ecology and Management of Breeding Waterfowl. University of Minnesota Press, Minneapolis, MN, USA.

Schamber, J. L., D. Esler, P. L. Flint. 2009. Evaluating the validity of using unverified indices of body condition. Journal of Avian Biology 40:49-56.

Schummer. M. L., A. D. Afton, S. S. Badzinski, S. A. Petrie, G. H. Olsen, M. A. Mitchell. 2018. Evaluating the waterfowl breeding population and habitat survey for scaup. Journal of Wildlife Management 82:1252-1262.

Schummer, M. L., R. M. Kaminski, A. H. Raedeke, D. A. Graber. 2010. Weather-related indices of autumn–winter dabbling duck abundance in middle North America. Journal of Wildlife Management 74: 94-101.

Sedinger, J. S., R. T. Alisauskas. 2014. Cross-seasonal effects and the dynamics of waterfowl populations. Wildfowl (Special Issue No. 4):277-304.

Sedinger, J. S., M. P. Herzog. 2012. Harvest and dynamics of duck populations. Journal of Wildlife Management 76:1108-1116.

Shaffer, T. L. 2004. A unified approach to analyzing nest success. Auk 121:526-540.

Shaffer, T. L., D. H. Johnson. 2008. Ways of learning: Observational studies versus experiments. Journal of Wildlife Management 72:4-13.

Sharp, D. E., K. L. Kruse, P. P. Thorpe. 2002. The midwinter waterfowl survey in the Central Flyway. U.S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Denver, CO, USA.

Sklar, F. H., J. A. Browder. 1998. Coastal environmental impacts brought about by alterations to freshwater flow in the Gulf of Mexico. Environmental Management 22:547-562.

Smith, G.W. 1995. A critical review of the aerial and ground surveys of breeding waterfowl in North America. Biological Science Report 5. U.S. Department of the Interior, National Biological Service, Washington, D.C., USA.

Soulliere, G. J., B. W. Loges, E. M. Dunton, D. R. Luukkonen, M. W. Eichholz, K. E. Koch. 2013. Monitoring waterfowl in the Midwest during the non-breeding period: Challenges, priorities, and recommendations. Journal of Fish and Wildlife Management 4:395-405.

Sovada, M. A., R. M. Anthony, B. D. J. Batt. 2001. Predation on waterfowl in arctic tundra and prairie breeding areas- a review. Wildlife Society Bulletin 29:6-15.

Stephens, S. E., D. N. Koons, J. J. Rotella, D. W. Willey. 2004. Effects of habitat fragmentation on avian nesting success: A review of the evidence at multiple spatial scales. Biological Conservation 115:101-110.

Stephens, S. E., J. J. Rotella, M. S. Lindberg, M. L. Taper, J. K. Ringleman. 2005. Duck nest survival in the Missouri Coteau of North Dakota: Landscape effects at multiple spatial scales. Ecological Applications 15:2137-2149.

Stephens, S. E., J. A. Walker, D. R. Blunck, A. Jayarman, D. E. Naugle, J. K. Ringelman, A. J. Smith. 2008. Predicting risk of habitat conversion in native temperate grasslands. Conservation Biology 22:1320-1330.

Streby, H. M., J. M. Refsnider, D. E. Andersen. 2014. Redefining reproductive success in songbirds: moving beyond the nest success paradigm. Auk 131:718-726.

Stutzenbaker, C. D. 1988. The mottled duck: Its life history, ecology and management. In S. L. Beasom (Ed.), Texas Parks and Wildlife Department. Austin, TX, USA.

Stutzenbaker, C. D., M. W. Weller. 1989. The Texas coast. Pages 385-405 in L. M. Smith, R. L. Pederson, R. M. Kaminski (Eds.), Habitat Management for Migrating and Wintering Waterfowl in North America. Texas Tech University Press, Lubbock, TX, USA.

Taylor, P. D., T. L. Crewe, S. A. Mackenzie, D. Lepage, Y. Aubry, Z. Crysler, G. Finney, C. M. Francis, C. G. Guglielmo, D. J. Hamilton, R. L. Holberton, P. H. Loring, G. W. Mitchell, D. Norris, J. Paquet, R. A. Ronconi, J. Smetzer, P. A. Smith, L. J. Welch, B. K. Woodworth. 2017. The Motus Wildlife Tracking System: A collaborative research network to enhance the understanding of wildlife movement. Avian Conservation and Ecology 12(1):8.

Texas Parks and Wildlife Department (TPWD). 2011. Waterfowl Strategic Plan-spring 2011: A look to the future. Final Report. Texas Parks and Wildlife Department, Austin, TX, USA.

Thompson, B. C., G. E. Knadle, D. L. Brubaker, K. S. Brubaker. 2001. Nest success is not an adequate comparative estimate of avian reproduction. Journal of Field Ornithology 72:527-536.

U.S. Fish and Wildlife Service (USFWS). 2010. Northern Pintail Harvest Strategy. U.S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Washington, D.C., USA.

U.S. Fish and Wildlife Service (USFWS). 2015. Economic impact of waterfowl hunting in the United States: Addendum to the 2011 national survey of fishing, hunting, and wildlife-associated recreation, Report 2011-6. U.S. Department of the Interior, Fish & Wildlife Service, Washington, D.C., USA.

U.S. Fish and Wildlife Service (USFWS). 2016. Western Gulf Coast Mottled Duck Survey. U. S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Laurel, MD, USA.

U.S. Fish and Wildlife Service (USFWS). 2017. Waterfowl Population Status. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

U.S. Fish and Wildlife Service (USFWS). 2018. Adaptive Harvest Management: 2019 Hunting Season. U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C., USA.

Walker, J., J. J. Rotella, C. R. Loesch, R. W. Renner, J. K. Ringelman, M. S. Lindberg, R. Dell, K. E. Doherty. 2013. An integrated strategy for grassland easement acquisition in the Prairie Pothole Region, USA. Journal of Fish and Wildlife Management 4:267-279.

Walker, J., P. D. Taylor. 2017. Using eBird data to model population change of migratory bird species. Avian Conservation and Ecology 12(1):4.

Watson, A., J. Reece, B. E. Tirpak, C. K. Edwards, L. Geselbracht, M. Woodrey, M. LaPeyre, P. S. Dalyander. 2015. The Gulf Coast Vulnerability Assessment: Mangrove, tidal emergent marsh, barrier islands, and oyster reef. Mississippi State University, Starkville, MS, USA.

Weller, M. W. 1964. Distribution and migration of the redhead. Journal of Wildlife Management 28:64-103.

Williams, B. K. 2001. Uncertainty, learning, and the optimal management of wildlife. Environmental and Ecological Statistics 8:269-288.

Williams, B. K. 2003. Policy, research, and adaptive management in avian conservation. Auk 120:212-217.

Williams, B. K. 2011. Adaptive management of natural resources- framework and issues. Journal of Environmental Management 92:1346-1353.

Williams, B. K., J. D. Nichols, M. J. Conroy. 2002. Analysis and Management Of Animal Populations. Academic Press, San Diego, CA, USA.

Williams, B. K., R. C. Szaro, C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, D.C.

Williams, C. K., B. D. Dugger, M. G. Brasher, J. M. Coluccy, D. M. Cramer, J. M. Eadie, M. J. Gray, H. M. Hagy, M. Livolsi, S. R. McWilliams, M. Petrie, G. J. Soulliere, J. M. Tirpak, E. B. Webb. 2014. Estimating habitat carrying capacity for migrating and wintering waterfowl: Considerations, pitfalls and improvements. Wildfowl (Special Issue No. 4):407-435.

Williams, C. L., R. C. Brust, T. T. Fendley, G. R. Tiller Jr., O. E. Rhodes Jr. 2005. A comparison of hybridization between Mottled Ducks (*Anas fulvigula*) and Mallards (*A. platyrhynchos*) in Florida and South Carolina using microsatellite DNA analysis. Conservation Genetics 6:445-453.

Wilson, B.C. 2007. North American Waterfowl Management Plan, Gulf Coast Joint Venture: Mottled Duck Conservation Plan. U.S. Department of the Interior, Fish and Wildlife Service, Migratory Bird Program, Albuquerque, NM, USA.

Wilson, B. C., C. G. Esslinger. 2002. North American Waterfowl Management Plan, Gulf Coast Joint Venture: Texas Mid-Coast Initiative. North American Waterfowl Management Plan, Albuquerque, NM, USA.

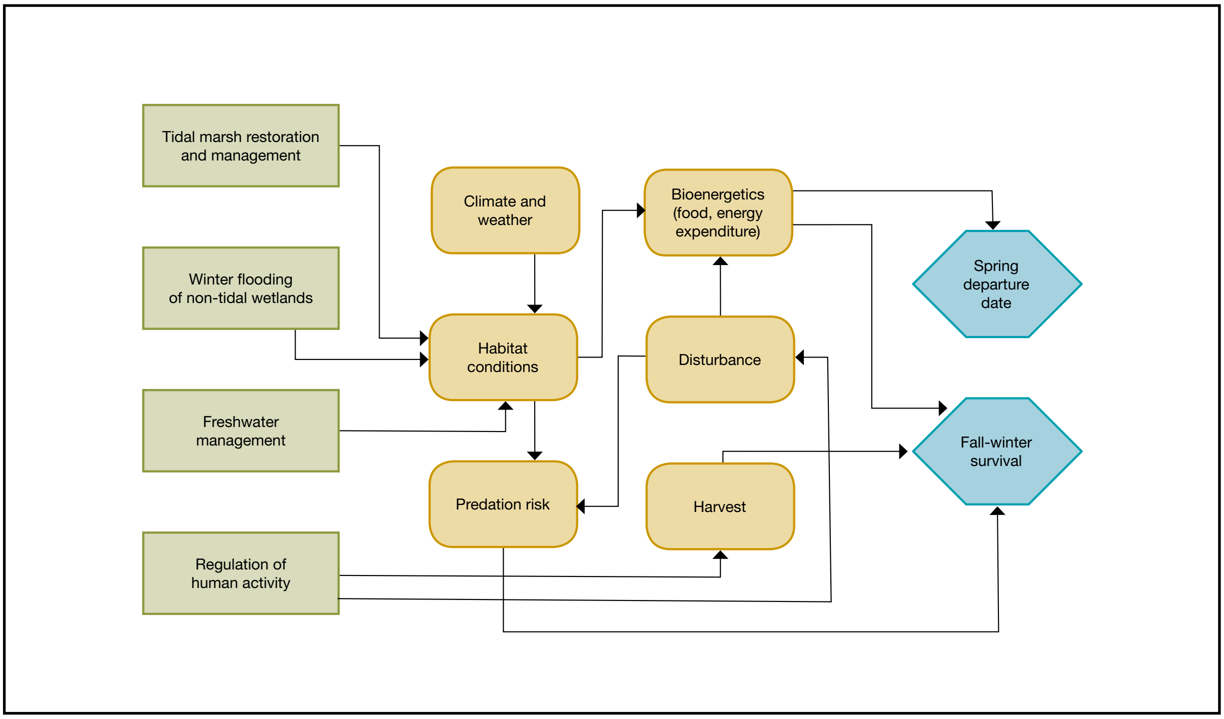
Wintle, B. A., M. C. Runge, S. A. Bekessy. 2010. Allocating monitoring effort in the face of unknown unknowns. Ecology Letters 13:1325-1327.

Woodin, M. C., T. C. Michot. 2002. Redhead (*Aythya americana*). In P. G. Rodewald (Ed.), The Birds of North America, Version 2.0. Cornell Lab of Ornithology, Ithaca, NY, USA.

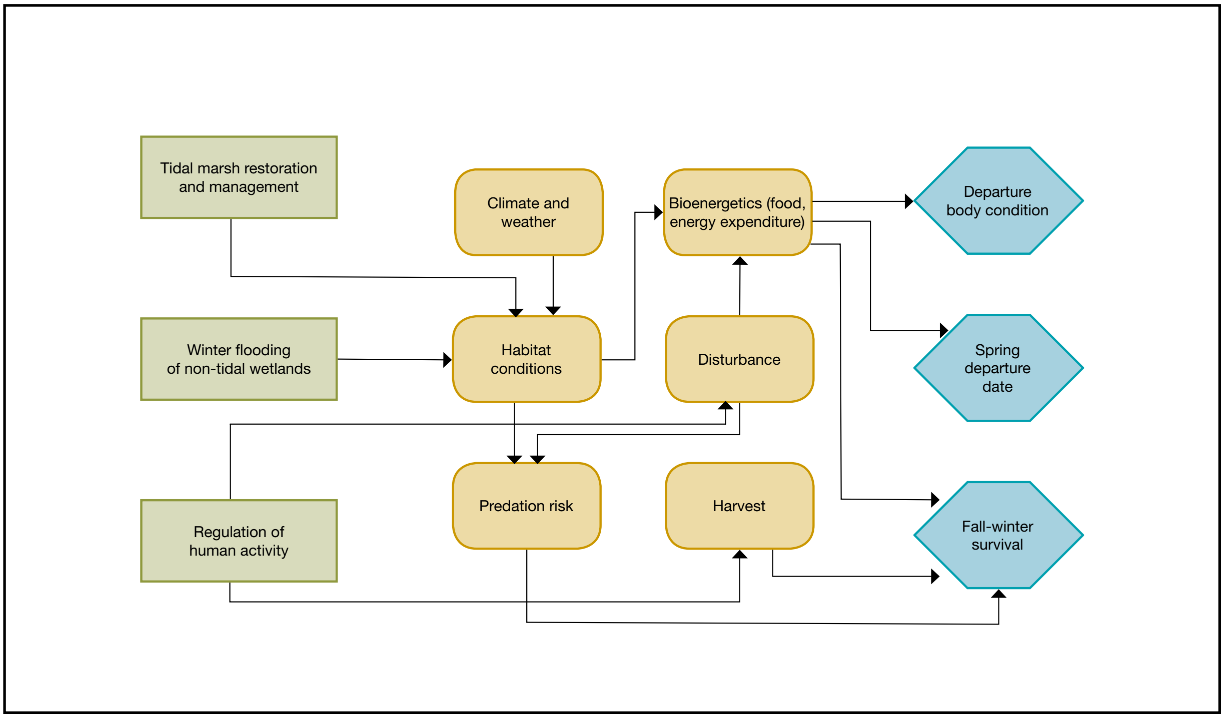
Wright, C. K., M. C. Wimberly. 2013. Recent land use change in the Western Corn Belt threatens grasslands and wetlands. Proceedings of the National Academy of Sciences 110: 4134-4139.

APPENDIX 9

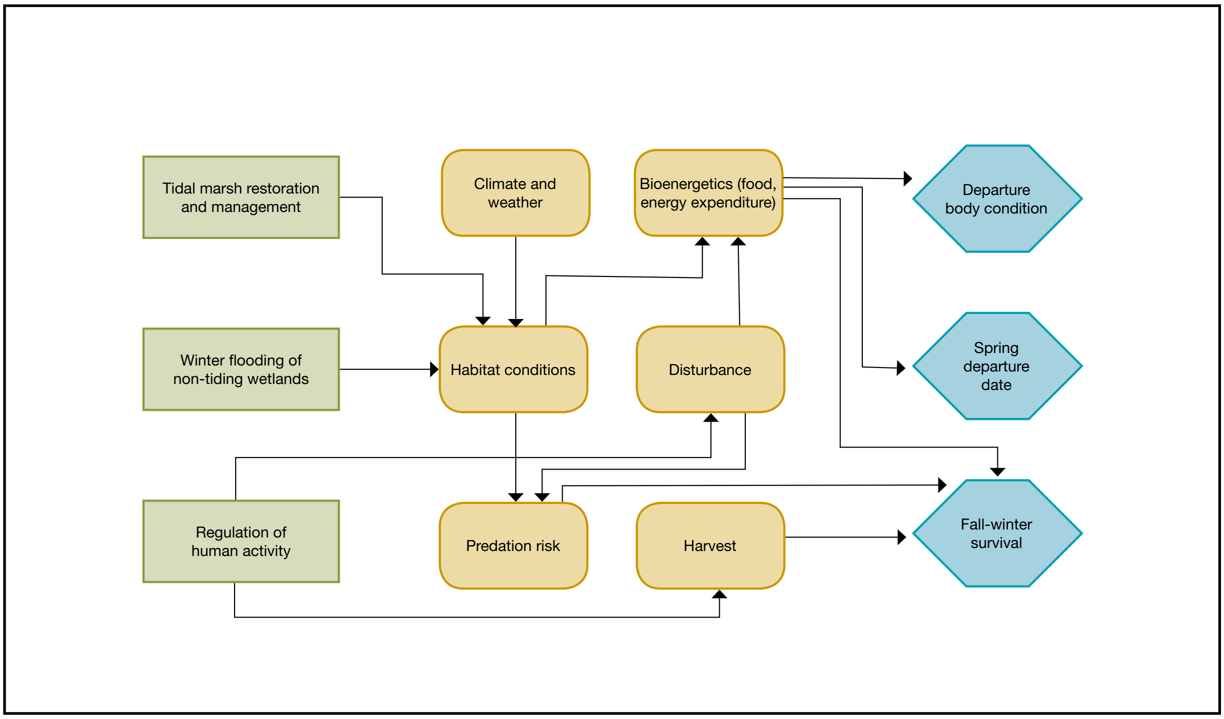
Supplementary influence diagrams depicting mechanistic relationships between management actions and population response of waterfowl.



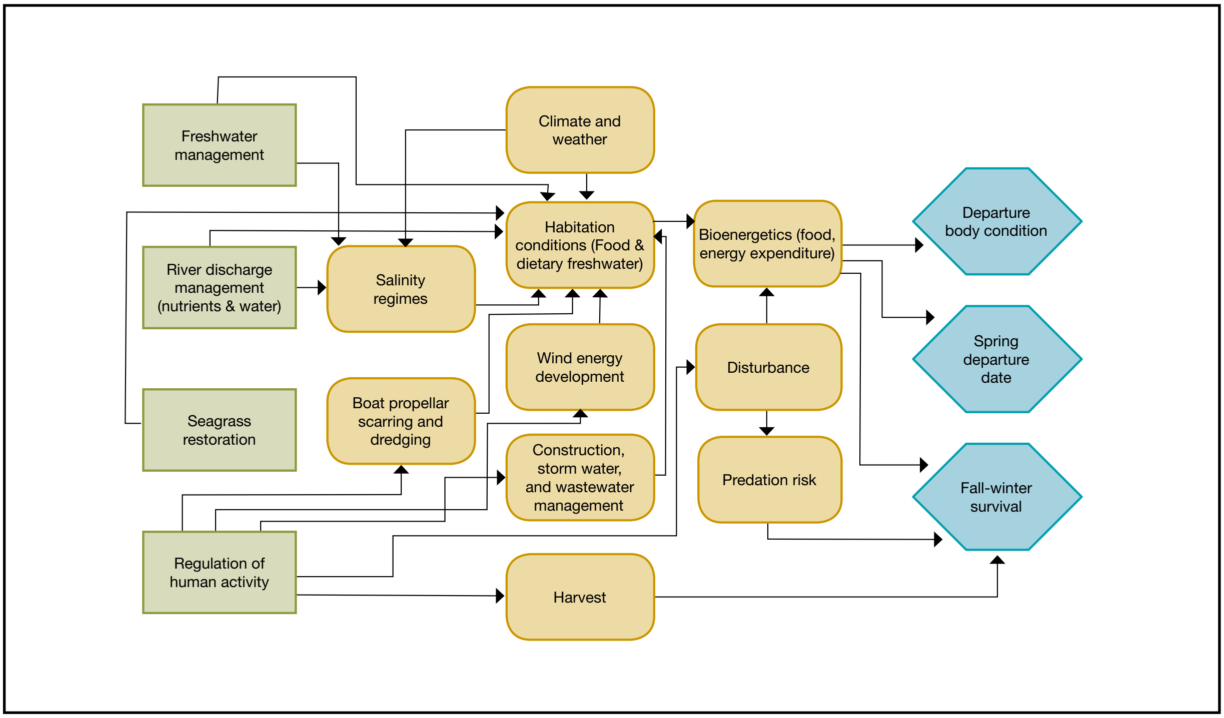
*Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population (metrics) size (blue hexagons) for the **Blue-winged Teal** (Spatula discors) within the Gulf of Mexico Region.*



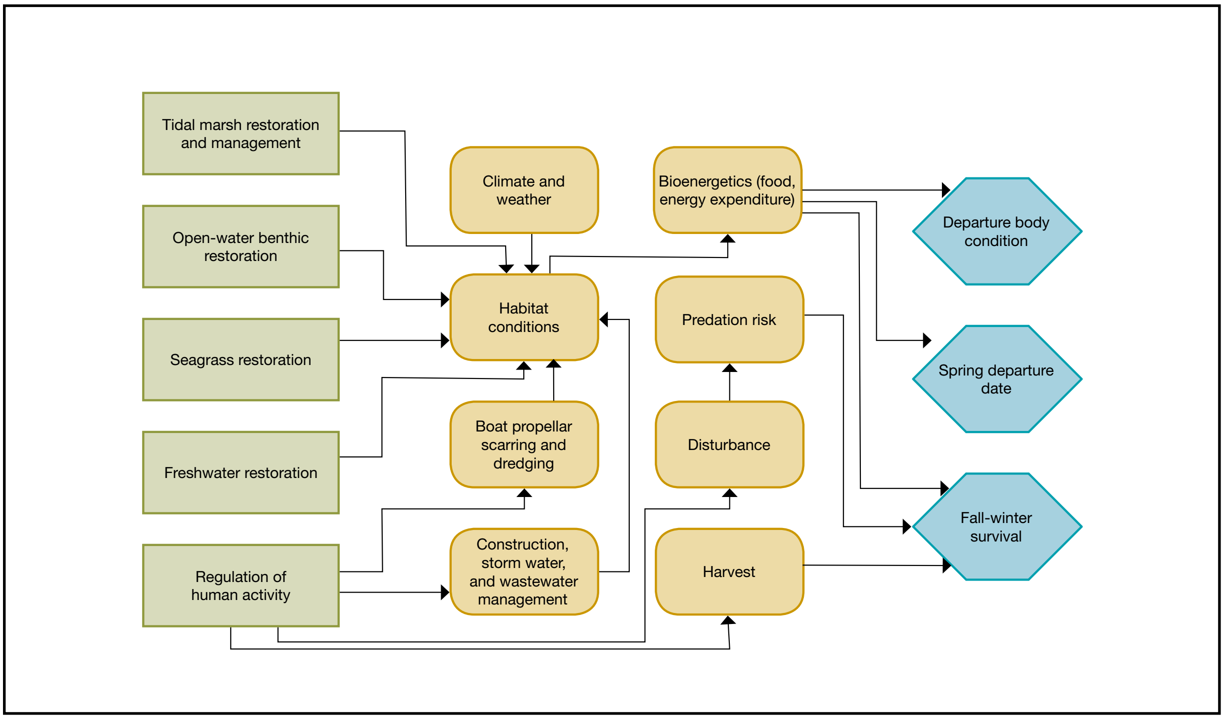
Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population (metrics) size (blue hexagons) for the ***Gadwall*** *(Mareca strepera) within the Gulf of Mexico Region.*



Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population (metrics) size (blue hexagons) for the ***Northern Pintail*** *(Anas acuta) within the Gulf of Mexico Region.*



Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population (metrics) size (blue hexagons) for the ***Redhead*** *(Aythya americana) within the Gulf of Mexico Region.*



Influence diagram of the relationship between management actions (green boxes), intermediate processes (gold boxes) and population (metrics) size (blue hexagons) for the ***Lesser Scaup*** *(Aythya affinis) within the Gulf of Mexico Region.*