Mottled Duck Conservation Plan Update

A product of the
Gulf Coast Joint Venture
Mottled Duck Working Group
July 2023

Gulf Coast Joint Venture

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Mottled Duck Conservation Plan Update

A product of the
North American Waterfowl Management Plan

Gulf Coast Joint Venture
Mottled Duck Working Group

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North American Waterfowl Management Plan

Plan nord-américain de gestion de la sauvagine

Plan de Manejo de Aves Acuáticas de Norteamérica

Gulf Coast Joint Venture

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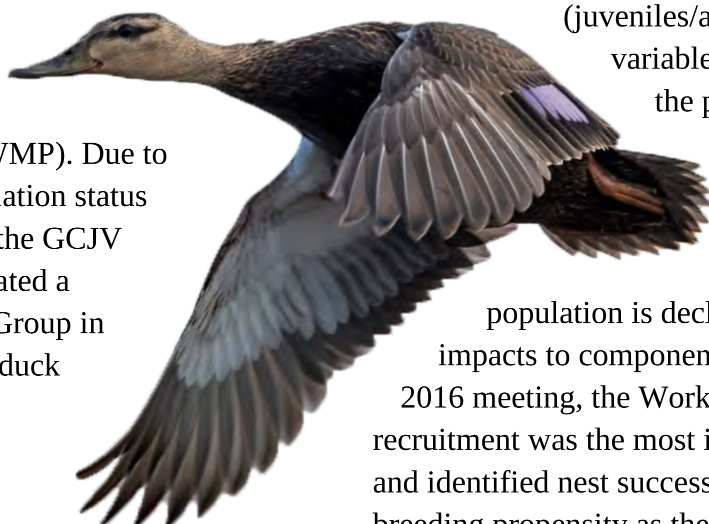
EXECUTIVE SUMMARY

The mottled duck (*Anas fulvigula*) is a resident waterfowl species found in Florida, the south Atlantic Coast of South Carolina and Georgia, and the western Gulf Coast (WGC) portions of Alabama, Mississippi, Louisiana, Texas, and northeast Mexico. WGC mottled ducks meet all life cycle requirements from their year-round home of Gulf Coast marshes and associated habitats, and their U.S. range is nearly coincident with the geographic boundaries of the Gulf Coast Joint Venture (GCJV). The GCJV is a bird conservation partnership situated in one of the priority habitat regions of the North American Waterfowl Management Plan (NAWMP). Due to concerns about the population status of WGC mottled ducks, the GCJV Management Board initiated a Mottled Duck Working Group in 2003 to provide mottled duck conservation guidance to GCJV partners. The ensuing Mottled Duck Conservation Plan (Wilson 2007) provided guidance for habitat conservation and research activities to benefit the species. As part of the iterative framework of adaptive management, the Working Group reconvened in 2016 to review contemporary scientific information, revise conservation strategies and research needs for WGC mottled ducks, and produce this updated Conservation Plan.



Nearly all population indices illustrate a slightly to moderately declining mottled duck population over long-term (i.e., 1961-2022) and contemporary (i.e., 2003-2022) periods across the WGC. Since 2003, the Texas mottled duck population appears to have stabilized albeit at lower levels, but the population has declined in Louisiana. At the 2016 meeting, the Working Group considered the WGC population slightly less stable (5.5 on a 10-point scale) than it was during the 2003 meeting (4.8), but still not near threatened with extinction.

Annual survival and recovery rates from 2000-2020 banding data are variable, but there is no directional trend. Likewise, age ratios (juveniles/adult) have become more variable but have increased in the past decade. Several estimates of a population growth rate suggest the WGC mottled duck population is declining driven mostly by impacts to components of recruitment. At the 2016 meeting, the Working Group agreed recruitment was the most important limiting factor and identified nest success, brood survival, and breeding propensity as the most important components to impact through management. WGC mottled ducks continue to face survival and recruitment stresses from a variety of direct and indirect impacts from people, associated land use changes, and environmental conditions. However, research since Wilson (2007) has revealed that hybridization is low and does not currently present a conservation concern for WGC mottled ducks.

Following recommendation of Wilson (2007) and with an operational range-wide survey, a sub-team of the Working Group revised GCJV mottled duck population objectives based on the Western Gulf Coast Mottled Duck Breeding Population

Survey. The revised range-wide and state-specific triad population objectives accentuate the relative urgency with which habitat conservation should be achieved. The definitive range-wide population objective of 211,865 is believed to be consistent with restoration of desired population objectives articulated in Wilson (2007).

Availability of spring and summer wetlands in proximity to large tracts of upland nesting cover are key to increasing components of recruitment. Several existing land uses can provide suitable conditions for breeding mottled ducks with minimal adjustments including rice cultivation, crawfish aquaculture, native and introduced pasture, and impoundments managed for wintering waterfowl. Existing and newly developed programs such as the Coastal Grassland Restoration Incentive Program (C-GRIP) are available to provide financial and technical assistance to private landowners. Decision support tools are available to identify areas where establishment and management of wetlands and grasslands can achieve the greatest impact. Meanwhile, marsh loss, coastal squeeze, urbanization, changing landowner demographics, renewable energy development, and invasive species present ongoing challenges. Achieving population objectives will require accelerated habitat delivery and likely new funding and staffing templates.

As new technology increases our understanding of nesting ecology, habitat associations, and demographic rates of WGC mottled ducks, research and conservation must advance in a manner that facilitates learning through applying the best available information. Several exemplary research efforts, conservation programs, and monitoring programs sparked by Wilson (2007) provide a framework for this advancement. Monitoring mottled duck populations and their habitats remain a priority that requires coordination and development of new programs. Research priorities are identified to refine our understanding of population limiting factors, identify management practices that alleviate limiting factors, and develop a habitat objective.

INTRODUCTION TO THE UPDATE

In June 2003, the Gulf Coast Joint Venture (GCJV) Management Board established the Mottled Duck Working Group for the purpose of assembling, discussing, and evaluating current knowledge of the status of the western Gulf Coast (WGC) population of mottled ducks and factors influencing their annual dynamics. The Working Group's findings and recommendations were adopted by the GCJV Management Board on February 1, 2006, in the form of the GCJV Mottled Duck Conservation Plan (Wilson 2007). Since publication, the Plan has provided effective guidance for habitat conservation and research activities to benefit WGC mottled ducks.

The Plan advocated an iterative framework of adaptive management to implement conservation actions based on current scientific information and refining our knowledge by monitoring population responses to conservation actions and using targeted research to address key uncertainties in mottled duck population ecology. Since the early 2000s, substantial resources have been invested in conservation and research activities for WGC mottled ducks, addressing essentially all aspects of the mottled duck annual cycle.

Periodic assessment of new information and its implications for conservation and management recommendations are necessary within the iterative framework of adaptive management (Williams et al. 2009). Accordingly, the GCJV Management Board recommended the Mottled Duck Working Group reconvene to review contemporary scientific information and revise as necessary the priority habitat conservation strategies and research needs for WGC mottled ducks as articulated in the GCJV Mottled Duck Conservation Plan.

The Mottled Duck Working Group convened March 29-31, 2016 in Winnie, TX to provide a forum for these discussions. The workshop was attended by 31 Working Group members from Louisiana, Texas, and elsewhere with responsibilities for managing mottled ducks and related habitat conservation in the WGC. The workshop was organized by a coordination team of Mike Brasher, Dan Collins, Kevin Kraai, Jena Moon, Larry Reynolds, and Barry Wilson and was facilitated by Dave Case and Rick Clawson of DJ Case and Associates. The primary goals of the workshop were to:

1) Conduct a careful and thoughtful examination of historical and contemporary scientific studies and other relevant conservation efforts, with an emphasis on contemporary information.
2) Update the current understanding of WGC mottled duck ecology, including population limiting factors and priority habitat conservation actions using contemporary and historical scientific studies.
3) Consider revising or restating GCJV population targets for mottled ducks based on information gained from new surveys for estimating the WGC mottled duck breeding population size.
4) Identify priority research and monitoring needs to address remaining gaps in WGC mottled duck ecology and further refine strategic conservation efforts to benefit mottled ducks.
5) Develop a strategy and timeline for revising the GCJV Mottled Duck Conservation Plan to reflect an updated understanding of mottled duck ecology, priority conservation and

management recommendations, and research needs.

Toward achievement of these goals, Working Group members delivered presentations with contemporary scientific information followed by open discussion by the Working Group. Turningpoint—a real-time audience response system—was used throughout the meeting to poll attendees in real time to anonymously assess group consensus and inform discussions on meeting topics. Throughout this update, summaries of audience survey responses are provided to capture attendee perspectives, and when applicable, comparisons are made to similar questions asked of meeting attendees of the 2003 Working Group meeting. Information from presentations and discussions during the 2016 meeting, follow-up meetings of sub-teams, and research results that were completed since the 2016 meeting constitute foundation for this update. Thus, some contemporary information presented in this plan was not available nor presented at the 2016 meeting and may not be reflected in Working Group responses to poll questions. The Working Group expressed a desire to maintain the general format and comprehensiveness of the 2007 Plan, thus, we have attempted to retain a similar design and composition of information included in Wilson (2007).

The GCJV mottled duck working group met in Winnie, Texas, in 2016 to review contemporary science, revise priority habitat conservation, and identify research needs.

INTRODUCTION TO THE SPECIES

The mottled duck (*Anas fulvigula*) is a resident species comprising one of three monochromatic taxa belonging to the mallard complex in North America. The primary mottled duck range is limited to the western Gulf Coast (WGC), peninsular Florida, and a translocated population in the south Atlantic (Figure 1). Population sizes are somewhat debatable, but recent estimates suggest a breeding population of approximately 53,000 in Florida (North American Waterfowl Management Plan Committee 2018), 125,000 in the WGC region of Alabama, Mississippi, Louisiana, Texas, and northeast Mexico (U.S. Fish and Wildlife Service, unpublished data), and 23,000 in the south Atlantic (Kneece 2016). There is no record of a mottled duck migrating between the WGC and Florida populations despite >10,000 recoveries of mottled ducks banded in the regions and reported recoveries from distances greater than that which separates the two populations (e.g., South Dakota, Iowa, Indiana, New Jersey). Genetically, the Florida population (*A. f. fulvigula*) is distinct from the WGC and south Atlantic populations (*A. f. maculosa*) although their recognition as separate subspecies has wavered (Peters et al. 2016). The current unoccupied range gap (i.e., Florida panhandle) appears to represent a significant barrier to gene flow between the Florida and WGC populations, and although genetic evidence suggests a few migrants may exchange per generation, the populations represent separate conservation units (Peters et al. 2016).

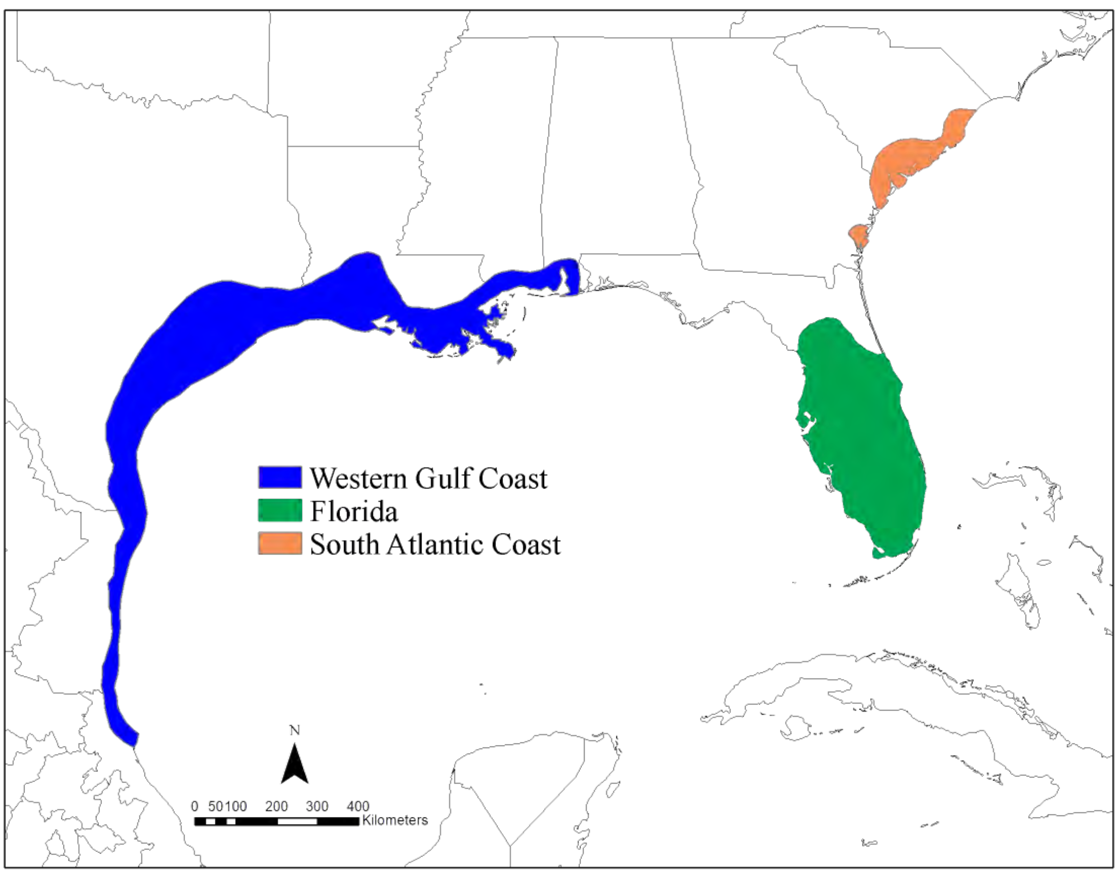


Figure 1. Mottled duck range (Bonczek and Ringelman 2022).

Consequently, this Conservation Plan Update relates only to the WGC population of mottled ducks.

Mottled ducks establish pairs relatively early (i.e., August-January) among dabbling ducks and thereafter generally isolate from other ducks, making them somewhat averse to typical waterfowl hunting situations. Regardless, WGC mottled ducks have an important economic and cultural importance to waterfowl hunters and bird watchers in Texas and Louisiana despite averaging 1% and 2.3% of statewide duck harvest, respectively (2003-2018; USFWS unpublished data). The mottled duck range is primarily restricted to coastal counties/parishes, and within those regions mottled duck harvest accounts for a greater percentage (e.g., 6%) of total duck harvest (USFWS unpublished data). WGC mottled ducks are non-migratory and must utilize resources from their year-round home of Gulf Coast marshes and associated inland habitats to satisfy all life cycle requirements. Their year-round residency imposes local population stresses that are unique among waterfowl (DeMaso et al. 2019). Resources used by mottled ducks are threatened by tropical storms, sea-level rise, saltwater intrusion, invasive species, urbanization, and myriad other factors. Special consideration is warranted to ensure that the unique needs of WGC mottled ducks are met.

THE GCJV AND MOTTLED DUCK WORKING GROUP

The Gulf Coast Joint Venture (GCJV) was established in 1988 as a conservation partnership in one of the priority habitat regions designated by the North American Waterfowl Management Plan (NAWMP). The GCJV Management Board is composed of 16 agencies and organizations that have accepted responsibility for collectively developing and attaining a common set of habitat objectives in furtherance of the NAWMP and other national or international bird plans.

The GCJV region encompasses a diversity of landcover types from coastal marsh to upland forests across Alabama to south Texas. The GCJV region is geographically subdivided into 6 planning units called Initiative Areas: Coastal Mississippi-Alabama, Mississippi River Coastal Wetlands, Louisiana Chenier Plain, Texas Chenier Plain, Texas Mid-Coast, and Laguna Madre (Figure 2). Within each Initiative Area, a habitat implementation plan guides waterfowl habitat conservation by GCJV partners via priority species population objectives, biological models to translate regional population objectives into quantitative habitat objectives that are expected to support populations at objective levels, and recommended strategies and actions to achieve and maintain habitat objectives. Biological models are developed by GCJV staff in cooperation with taxa-specific science teams composed of scientists from partnering agencies, organizations, and academic institutions. A GCJV Science Needs

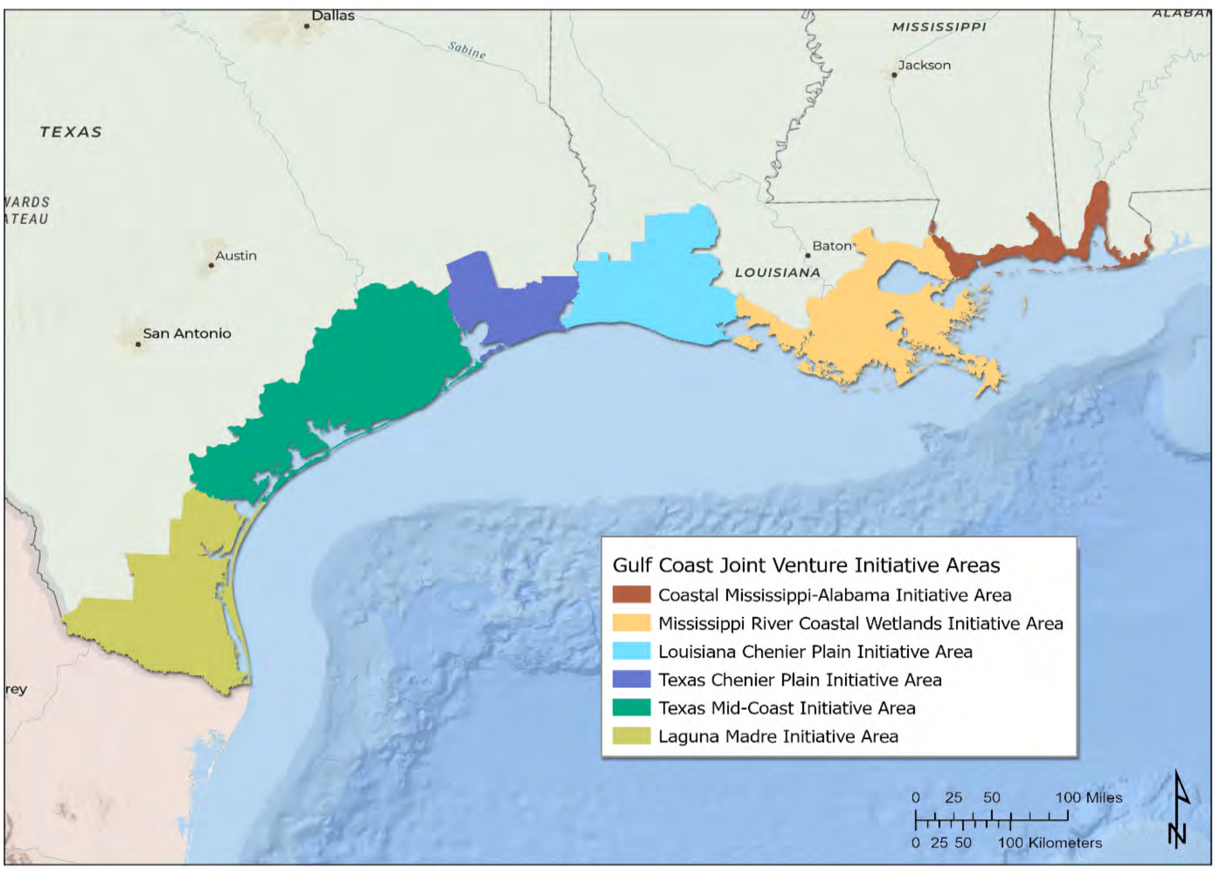


Figure 2. Initiative Areas of the Gulf Coast Joint Venture geography.

Plan identifies and prioritizes information gaps that currently constrain effective planning and archive untested assumptions made during the planning process, providing a feedback loop for adaptive refinements in biological planning.

The primary roles of the GCJV relative to continental waterfowl populations are 1) providing migration and wintering habitat to support foraging demands across 1.66 billion use-days by dabbling and diving ducks and 109 million use-days by geese (Lancaster et al. 2021), and 2) providing habitat to support breeding mottled ducks. The five Initiative Area plans that encompass Texas and Louisiana acknowledge the need to provide breeding and post-breeding habitat for mottled ducks, but do not provide specific guidance desired by the GCJV partnership. This document is intended to meet that need and provide a framework for adaptive refinements in mottled duck conservation planning.

Since inception in 2003, the GCJV Mottled Duck Working Group has met on four occasions (August 2003 in Port Arthur, TX; February 2004 in Lafayette, LA; March 2016 in Winnie, TX, and January 2022 virtually) for the primary purpose of informing the 2007 Conservation Plan and this Update. The Mottled Duck Working Group is composed of members representing the following organizations and areas of expertise: GCJV Initiative Team Chairpersons, Management Board members, the Waterfowl Working Group, and staff; regional USFWS Migratory Bird staff; Flyway Council and/or Gamebird Technical Committee members; scientists engaged in WGC mottled duck research; and state, federal, and non-governmental biologists having responsibility for habitat conservation or monitoring programs related to WGC mottled ducks.

RE-ASSESSING THE EVIDENCE I: STATUS OF THE PROBLEM

Trends in regional and range-wide mottled duck populations have been indexed through periodic and ongoing surveys since the 1960s. Wilson (2007) presented mottled duck population trajectories from available surveys conducted through 2003 which substantiated a declining mottled duck population in Texas and a stable to slightly declining population in Louisiana. Our purpose herein is to re-examine the long-term mottled duck population trajectory and contemporary trends (i.e., since 2003) in mottled duck populations using available surveys including those examined by Wilson (2007). When applicable, we display mottled duck population trajectories across the survey periods of record and relevant contemporary periods.

Range-wide

Few surveys are conducted at a scale representative of the entire western Gulf Coast (WGC) population, but several surveys are conducted across Louisiana and Texas in areas that support the majority of the WGC population. Therefore, we examined range-wide population trends using the U.S. Midwinter Survey (e.g., Sharp et al. 2002; Figure 3 and Figure 4), the Breeding Bird Survey (Sauer et al. 2020; Figure 5), harvest indices calculated from the U.S. Fish and Wildlife Service harvest and hunter activity surveys (Figure 6 and Figure 7), National Audubon Society Christmas Bird Count (National Audubon Society 2021; Figure 8), Lincoln-Peterson estimates (Lincoln 1930; Figure 9), and the WGC Mottled Duck Breeding Population Survey (USFWS Division of Migratory Bird Management, unpublished data; Figure 10).

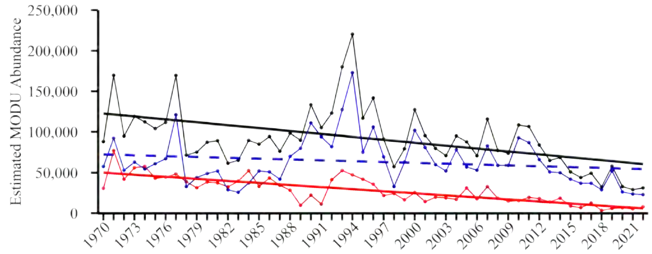


Figure 3. Estimated mottled duck abundance from the Mid-winter Waterfowl Survey for coastal Louisiana, coastal Texas, and combined total, 1970-2022.
Solid linear trend lines depict a significant trend ($P \le 0.05$), whereas the dashed linear trend lines represent non-significant trend. Incomplete 1993 and 1997 Louisiana surveys were replaced with mean of prior and subsequent years. Texas estimates exclude the south Texas brush country strata which has been surveyed only since 1997. Texas coastal survey zones and transects changed in 2000.

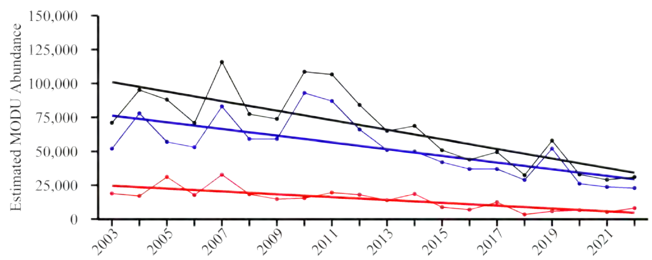


Figure 4. Estimated mottled duck abundance from the Mid-winter Waterfowl Survey in coastal Louisiana (blue), coastal Texas (red), and combined total (black), 2003-2022.
Solid linear trend lines depict a significant trend ($P \le 0.05$).

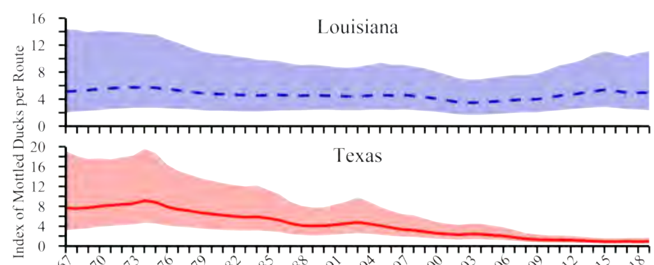


Figure 5. Index of abundance (95% CI; shaded) for mottled ducks in Louisiana (blue) and Texas (red) from the Breeding Bird Survey, 1967-2019 (Sauer et al. 2020).
A solid trend line depicts a significant trend ($P \le 0.05$), whereas a dashed trend line represents a non-significant trend over the time series presented.

Nearly all range-wide surveys depict a downward population trajectory at both long-term and more recent time periods. Long-term mottled duck population declines appear less dramatic in Louisiana than Texas, similar to Wilson (2007).

However, data recorded since Wilson (2007) demonstrates a more pronounced and significant negative trajectory of the Louisiana mottled duck population. Although the Texas population has continued to decline, the rate of decline appears to have slowed and is not significant in many cases over the contemporary time period.

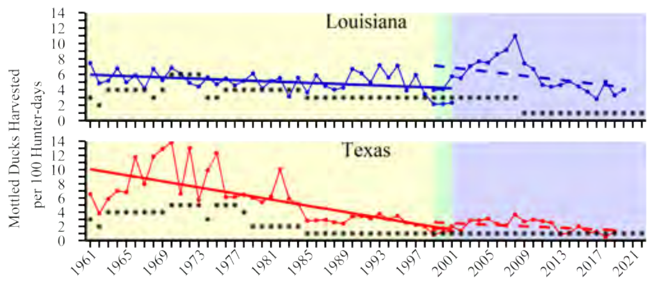


Figure 6. Estimated mottled duck harvest per 100 hunter days in Louisiana (blue) and Texas (red), 1961-2019.
Rates calculated using harvest and hunter effort from the Mail Questionnaire Survey (yellow/green regions; Fronczak 2003, Kruse 2009) and Harvest Information Program (green/blue regions; Dubovsky 2020, Fronczak 2021). Daily mottled duck bag limit shown by black asterisk. Solid linear trend lines depict a significant trend (P ≤ 0.05), whereas dashed linear trend lines represent non-significant trend.

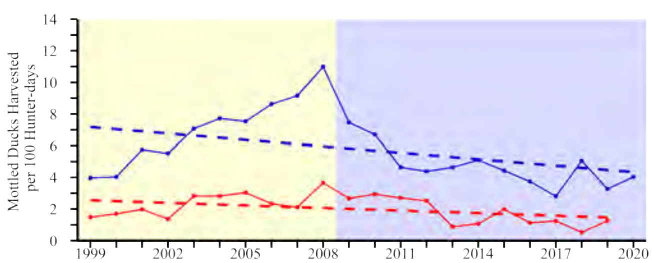


Figure 7. Estimated mottled duck harvest per 100 hunter days in Louisiana (blue) and Texas (red), 1999-2019.
Rates calculated from harvest and effort from the Harvest Information Program (Dubovsky 2020, Fronczak 2021). Prior to 2009 (yellow region) the bag limit was 3 in Louisiana and 1 in Texas. Beginning in 2009 (blue region), the bag limit was 1 in Louisiana and harvest was prohibited during the first 5 days of the 74-day duck season in Texas. Dashed linear trend lines depict a non-significant trend (*P* > 0.05).

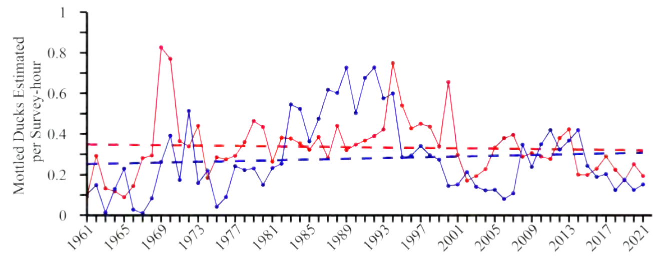


Figure 8. Average number of mottled ducks estimated per survey hour during the Christmas Bird Count in Louisiana (blue) and Texas (red), 1961-2021 (National Audubon Society 2021).
Dashed linear trend lines depict a non-significant trend (*P* > 0.05).

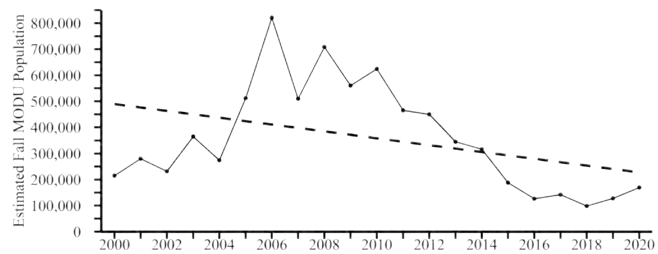


Figure 9. Estimated post-breeding mottled duck population size for Texas and Louisiana combined derived from Lincoln Peterson estimation, 2000-2020 (J. Lancaster, unpublished data).
Estimated with annual direct band recovery rates and harvest from the Harvest Information Program (e.g., Alisauskas et al. 2014). Dashed linear trend lines depict a non-significant trend (*P* > 0.05).

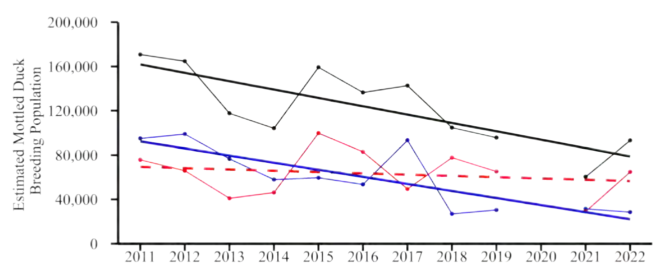


Figure 10. Estimated mottled duck population from the Western Gulf Coast Mottled Duck Breeding Population Survey in Louisiana (blue), Texas (red) and total survey area (black), 2011-2021.
The survey was not flown in 2020 due to COVID-19. Solid linear trend lines depict a significant trend (*P* ≤ 0.05), whereas dashed linear trend lines represent non-significant trends.

Regional

In addition to the state-specific components of range-wide surveys, several regional or state-specific indices of mottled duck populations were available for examination, including the Texas Gulf Coast NWR breeding pair survey (1985-2015; Figure 11), the Louisiana Department of Wildlife and Fisheries (LDWF) Coastal Refuges and Wildlife Management Area Survey (2003-2020; Figure 12), and the LDWF winter waterfowl survey (1969-2021; Figure 13). These smaller scale surveys show more variation in annual indices during contemporary periods, but still indicate strong negative population trajectories in Louisiana and Texas.

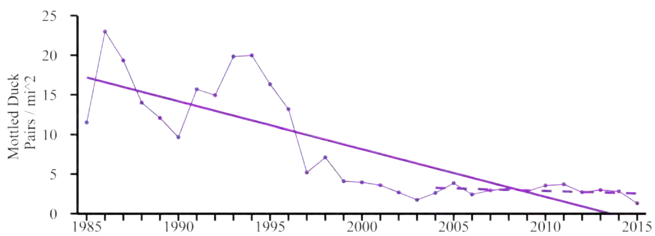


Figure 11. Estimated mottled duck breeding pairs/mi[2] on upper Texas Gulf Coast National Wildlife Refuges, 1985-2015.
Estimates include surveys from Anahuac, Big Boggy, Brazoria, San Bernard, and Matagorda Island National Wildlife Refuges across all years, and McFaddin and Texas Point since 2005. Linear trends shown for 1985-2015 and 2003-2015. Solid linear trend lines depict a significant trend ($P \leq 0.05$), whereas dashed linear trend lines represent non-significant trends.

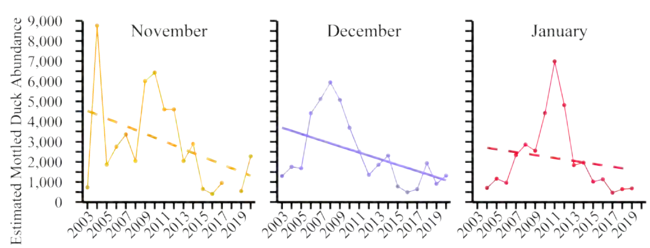


Figure 12. Estimated monthly mottled duck abundance on Louisiana Department of Wildlife and Fisheries coastal refuges and wildlife management areas, 2003-2020.
Solid linear trend lines depict a significant trend ($P \leq 0.05$), whereas dashed linear trend lines represent non-significant trends.

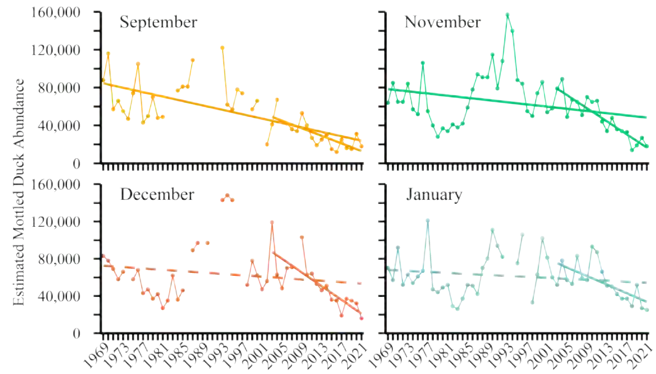


Figure 13. Monthly mottled duck abundance from coastal Louisiana aerial waterfowl surveys, 1969-2021 (LDWF, unpublished data).
Separate linear trends are shown for entire period (1969-2021) and contemporary period (2003-2021). Solid linear trend lines depict a significant trend ($P \leq 0.05$), whereas dashed linear trend lines represent non-significant trends.

Degree of confidence and concern

Attendees of the 2016 Mottled Duck Working Group Meeting (Appendix A) were asked a series of questions regarding their assessment of current mottled duck population status, population trajectory, and accuracy among available datasets. Attendees had greatest confidence that the WGC Mottled Duck Breeding Population Survey reflected true population size (Figure 14) and population trajectory (Figure 15) over the period of record. Respondents perception was that the WGC mottled duck population was neither stable nor faced with extinction, but in-between (Figure 16). Respondent rated the current population status similarly on day 1 ($\bar{x}$ = 5.8) and day 2 ($\bar{x}$ = 5.5), but on average, 2016 meeting participants considered the species to be less stable than attendees at the 2003 Mottled Duck Working Group meeting ($\bar{x}$ = 4.8; Wilson 2007). Meeting attendees expressed variable response regarding the trajectory of state-specific and WGC mottled duck populations with the majority indicating a "slightly declining" to "stable" population in Louisiana, and a "steeply declining" to "slightly declining” population in Texas (Figure 17). Respondents expressed greater confidence that the Texas population was in decline than their confidence that the Louisiana population was stable or only slightly declining (Figure 17).

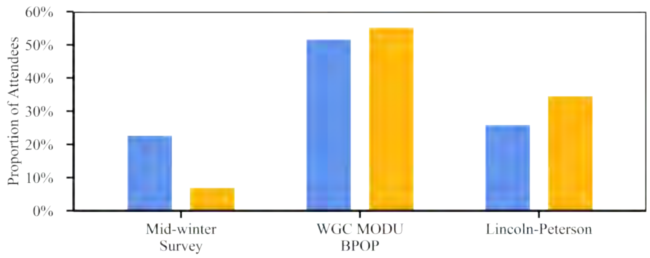


Figure 14. Day 1 (blue; *n* = 31) and day 2 (yellow; *n* = 28) mottled duck working group assessment of which dataset they are confident reflects the true population size of western Gulf Coast (WGC) mottled ducks?

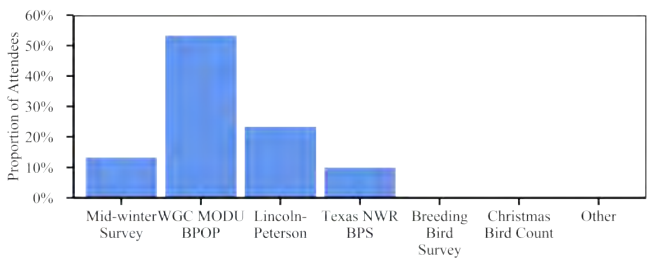


Figure 15. Mottled duck working group (*n* = 30) assessment of which dataset they have most confidence reflects the true population trajectory of western Gulf Coast (WGC) mottled duck over the period of record.

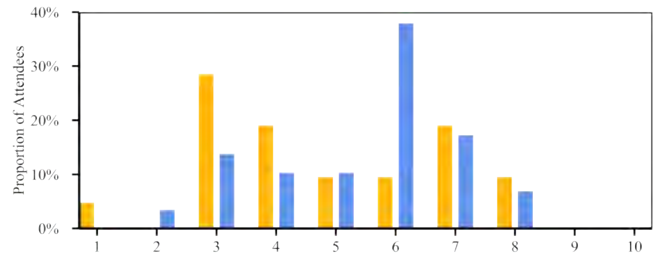


Figure 16. Comparison of 2016 (blue; *n* = 29; $\bar{x}$ = 5.5) and 2003 (yellow; *n* = 21; $\bar{x}$ = 4.8) mottled duck working group rating of the current population status of western Gulf Coast mottled ducks.

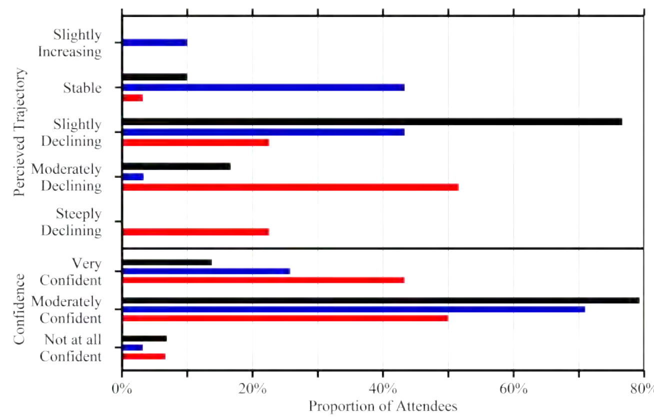
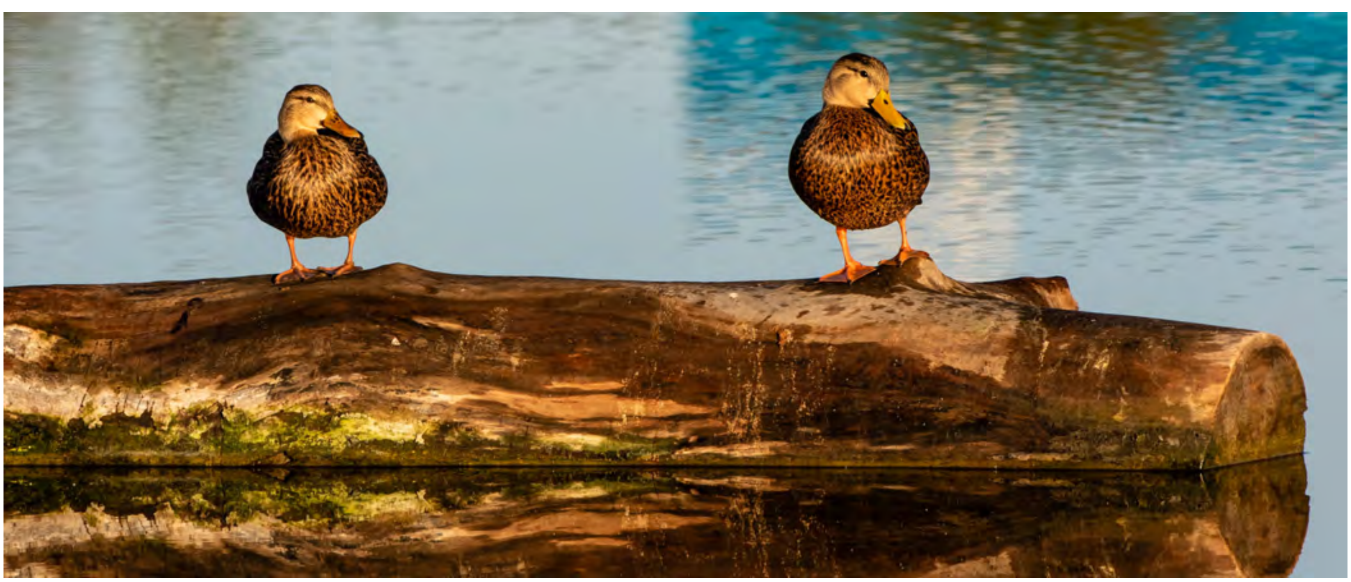


Figure 17. Mottled duck working group (*n* = 30) assessment of the mottled duck population trajectory (top) in Texas (red), Louisiana (blue), and the western Gulf Coast (black) during 1985-2016 and their confidence in the trend (bottom).
None of the mottled duck working group members identified the perceived mottled duck population trajectory as “Moderately Increasing” or “Steeply Increasing.”



RE-ASSESSING THE EVIDENCE II: IDENTIFYING THE LIMITING FACTORS

The WGC population of mottled ducks has declined in recent decades. Factors limiting the WGC population of mottled ducks can be related to limitations in seasonal and annual survival or recruitment (i.e., the addition of fledged young to the population). Recovery of WGC mottled ducks banded since 1994 (Table 1) and recent telemetry studies provide estimates of annual and seasonal survival which can be compared across regions and with other dabbling duck species (Table 2).

Table 1. Pre-season (June-September) mottled duck banding totals by year and state, 1994-2020.

Year	LA	TX	Total
1994	1,958	0	1,958
1995	3,809	0	3,809
1996	3,452	0	3,452
1997	1,914	1,978	3,892
1998	706	1,331	2,037
1999	910	2,167	3,077
2000	2,619	2,532	5,151
2001	1,024	1,474	2,498
2002	1,309	1,037	2,346
2003	2,246	842	3,088
2004	2,063	1,502	3,565
2005	2,430	1,605	4,035
2006	3,991	1,742	5,733
2007	1,966	1,114	3,080
2008	2,545	1,832	4,377
2009	1,121	2,914	4,035
2010	293	2,156	2,449
2011	588	1,712	2,300
2012	331	2,083	2,414
2013	953	1,689	2,642
2014	1,784	1,028	2,812
2015	2,814	1,041	3,855
2016	849	772	1,621
2017	1,053	352	1,405
2018	1,976	475	2,451
2019	1,316	370	1,686
2020	1,948	726	2,674

In general, annual WGC mottled duck survival rates vary by age and sex, where adult males tend to have higher survival rates than other age- and sex-classes (Table 2). Overall, annual mottled duck survival (0.39-0.64) tends to be slightly lower than ranges reported for mallards (adult female: 0.54-0.59, adult male: 0.62-0.68, juvenile female: 0.46-0.61, juvenile male: 0.48-0.63) (Baldassarre 2014). Available seasonal survival rates for mottled ducks are limited to individually marked females and estimates suggest survival is lowest during waterfowl hunting season, including the special September teal hunting season when mottled duck harvest is restricted (Table 3). Seasonal survival tends to be greatest during post-breeding and late winter, which encompass less demanding periods outside of breeding, molting, or waterfowl hunting season (Table 3).

The only range-wide recruitment data for WGC mottled ducks are age ratios (juveniles/adult) derived from wings sent in by randomly selected hunters as part of the U.S. Waterfowl Parts Collection Survey (e.g., Fronczak 2021). Because there is little movement (Moon et al. 2015, Bonczek 2022) or gene flow (Ford 2015) between Texas and Louisiana, age ratios in the Mississippi and Central Flyways should represent an index of local production. Harvest age ratios (immatures per adult) have both increased and become more variable between the periods 2000-2009 and 2010-2020 (Figure 18).

Table 2. Annual survival rates of mottled ducks based on pre-season banding and telemetry.

Location	Years	Class	Survival ± SE	Method	Reference
Texas and Louisiana	1994-2000	Males	0.56	Banding	Wilson et al. 2003
		Females	0.50		
Texas and Louisiana	1997-2012	Adult female	0.53 ± 0.02	Banding	Haukos 2015
		Adult male	0.62 ± 0.01		
		Juv. female	0.52 ± 0.03		
		Juv. male	0.43 ± 0.02		
Upper Texas Coast	2004-2015	Adult female	0.50 ± 0.05	Banding	McClinton et al. 2019
		Adult male	0.64 ± 0.04		
		Juv. female	0.39 ± 0.07		
		Juv. male	0.53 ± 0.09		
Texas and Louisiana	2000-2020	Adult female	0.54 ± 0.01	Banding	Lancaster (unpub.)
		Adult male	0.64 ± 0.01		
		Juv. female	0.44 ± 0.03		
		Juv. male	0.56 ± 0.02		
Texas and Louisiana	2006-2010	Adult female	0.48 ± 0.03	Telemetry	Wehland 2012
		Juv. female	0.40 ± 0.04		
Texas	2009-2011	Adult female	0.12-0.38	Telemetry	Moon et al. 2017
Louisiana	2017-2020	Adult female	0.60-0.64	Telemetry	Bonczek et al. 2022
North Florida	2000-2013	Adult female	0.44 ± 0.17	Banding	Bielefeld et al. 2020
		Adult male	0.53 ± 0.18		
		Juv. female	0.33 ± 0.15		
		Juv. male	0.25 ± 0.13		
South Florida	2000-2013	Adult female	0.44 ± 0.12	Banding	Bielefeld et al. 2020
		Adult male	0.62 ± 0.12		
		Juv. female	0.63 ± 0.12		
		Juv. male	0.61 ± 0.12		
South Carolina	2008-2017	Adult female	0.57 ± 0.04	Banding	Kneece et al. 2020
		Adult male	0.60 ± 0.03		
		Juv. female	0.44 ± 0.13		
		Juv. male	0.32 ± 0.07		

Table 3. Weekly seasonal survival rates of mottled ducks marked with transmitters.

Region	Years	Age	Season	Season Dates*	Weekly Survival ± SE	Reference
Upper TX Coast	2006-2008	Adult	Breeding	1 Feb - 30 June	0.986 ± 0.006	Rigby and Haukos 2012
Upper TX Coast	2009-2012	Adult	Non-Hunting	30 Jan - 10 Sep, 27 Sep - 31 Oct, & 29 Nov - 10 Dec	0.98 ± 0.007	Moon et al. 2017
			Hunting	11 - 26 Sep, 1 - 28 Nov, & 11 Dec - 29 Jan	0.957 ± 0.015	
Texas and Louisiana	2007-2010	Juv.	Post-breeding	15 July - 31 Oct	0.989 ± 0.002	Wehland 2012
			Hunting	1 Nov - 28 Jan	0.973 ± 0.005	
			Late Winter	29 Jan - 28 Feb	0.976 ± 0.008	
		Adult	Breeding	1 Mar - 14 Jul	0.985 ± 0.002	
			Post-breeding	15 July - 31 Oct	0.992 ± 0.001	
			Hunting	1 Nov - 28 Jan	0.981 ± 0.002	
			Late Winter	29 Jan - 28 Feb	0.983 ± 0.002	
South Florida	2008-2011	Adult	Post-breeding	1 Aug - 18 Nov	0.996 ± 0.002	Varner et al. 2014*a*
			Hunting	19 Nov - 31 Jan	0.989 ± 0.002	
			Late Winter	1 Feb - 28 Feb	0.997 ± 0.002	
			Breeding	1 Mar - 31 Jul	0.984 ± 0.003	
East-Central Florida	1999-2002	Adult	Post-breeding	1 Aug - 18 Nov	0.976 ± 0.004	Bielefeld and Cox 2006
			Hunting	19 Nov - 31 Jan	0.994 ± 0.005	
			Late Winter	1 Feb - 28 Feb	1.00 ± 0.00	
			Breeding	1 Mar - 31 Jul	0.993 ± 0.006	
TX Mid-Coast	2000-2003	Adult	Breeding	3 Feb - 20 Jul	0.988 ± 0.003	Finger et al. 2003
Southwest Louisiana	2017-2020	Adult	Non-Hunting	21 Jan - 3 Feb, 1 Oct - 4 Nov, & 4 - 10 Dec	0.986 ± 0.004	Bonczek et al. 2022
			Breeding	4 Feb - 15 Jul	0.994 ± 0.002	
			Molt	16 Jul - 9 Sep	0.995 ± 0.002	
			Teal	10 - 30 Sep	0.976 ± 0.007	
			Hunt 1	5 Nov - 3 Dec	0.979 ± 0.007	
			Hunt2	11 Dec - 20 Jan	0.996 ± 0.003	

Season are generalized to correspond with distinctive life-history periods; dates typically varied by a few days across years.

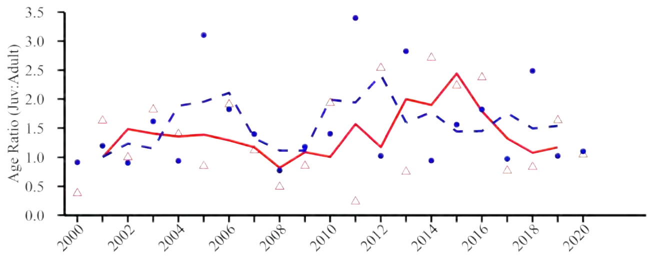


Figure 18. Mottled duck age ratios from hunter harvest derived from the U.S. Fish and Wildlife Service Parts Collection Survey, 2000-2020 (Dubovsky 2020, Fronczak 2021).

Across all three Flyways where mottled ducks occur, average age ratios have increased in the past decade (Table 4). Parts Collection Survey data are useful for visualizing temporal trends in age ratios of harvested mottled ducks but requires an assumption that the age-specific harvest vulnerability is constant across the period of interest. Adjusting harvest age ratios with annual age-specific recovery rates (i.e., relative vulnerability) provides a value that more accurately represents the proportion of juveniles in the post-breeding population (Johnson 2009). Age ratios adjusted for harvest vulnerability averaged 0.81 (range 0.38-1.90) in the Mississippi Flyway and 0.79 (range 0.14-1.56) in the Central flyway from 2001-2020.

Components of recruitment including nesting propensity, nest success, and duckling survival are believed to be the most important mottled duck population limiting factors.

Table 4. Age ratio (juv:adult) and number of wings submitted of harvested mottled ducks from U.S. Fish and Wildlife Service Parts Collection Survey.

Decade	Central[a]		Mississippi[b]		Atlantic[c]	
	Ratio	Wings	Ratio	Wings	Ratio	Wings
1961–1970	1.08	(2,189)	1.25	(1,074)	1.41	(2,477)
1971–1980	1.34	(2,214)	1.42	(990)	1.92	(1,364)
1981–1990	1.13	(1,144)	1.67	(1,136)	1.76	(1,610)
1991–2000	1.02	(1,183)	1.45	(1,908)	1.41	(1,206)
2001–2010	1.30	(1,076)	1.39	(919)	1.13	(415)
2011–2020	1.69	(325)	1.69	(868)	1.80	(901)
Mean	1.26		1.48		1.57	

[a] Central Flyway (Dubovsky 2020), [b] Mississippi Flyway (Fronczak 2021), [c] Atlantic Flyway (Roberts 2022).

Since the 2007 Plan, abundant research has been conducted to derive reliable estimates of individual components of recruitment and better understand the factors influencing their variability (Table 5). Bonczek and Ringelman (2021) summarized results of breeding ecology research since 1950, and presented estimates for nesting propensity, clutch size, nest success, re-nesting propensity, and duckling survival.

Understanding the relationship between vital rates and population growth is instrumental to identifying priorities for population and habitat management for WGC mottled ducks. Estimates of annual population change (N_t/N_{t-1}) from the WGC Mottled Duck Breeding Population Survey suggest a slightly declining (0.96) population since 2012 (Figure 19).

Table 5. Estimates of components comprising mottled duck recruitment.

Region	Years	Nesting Propensity	Clutch Size	Nest Success	Renesting Propensity	Duckling Survival
Upper TX Coast[a]	2006-2008	15-63%	–	–	–	57%
TX Mid-Coast[b]	2000-2002	31-77%	8.6 ± 0.2	9-62%	38%	41%
Southwest LA[c]	2017-2020	18-25%	8.8 ± 1.3	28%	0-75%	–
LA and TX[d]	2019-2020	100%	–	–	–	–
Atchafalaya Delta[e]	2012-2013	–	–	16%	–	–
Upper St. Johns River[f]	1999-2002	25-56%	8.5 ± 0.3	28%	–	–
South FL[f]	2009-2011	36-31%	7.5 ± 0.3	28%	–	–
ACE Basin SC[g]	2011-2014	–	8.9 ± 0.2	12%	–	–

[a] Rigby and Haukos 2012, 2015; [b] Finger et al. 2003, [c] Bonczek 2022, [d] Ringelman et al. 2022, [e] Caillouet 2015, [f] Varner et al. 2013, [g] Kneece 2016.

Figure 19. Annual population change (N_t/N_{t-1}) for Louisiana (blue), Texas (red) and the WGC (black) estimated from the WGC Mottled Duck Breeding Population Survey.

Sensitivity analyses are useful for identifying the relative importance of individual vital rates across the species life cycle and guiding habitat management to address factors most likely to limit population growth (Hoekman et al. 2002). Several attempts have been made to quantify the mottled duck population growth rate and examine its sensitivity to component vital rates. Johnson (2009) reported a declining WGC mottled duck population with a mean growth rate of 0.79 (0.49 – 1.15 [min-max]) from 1994-2005. Variation in adult and juvenile survival contributed to 60% of the variation in population growth compared to 40% attributed to recruitment (Johnson 2009). Rigby and Haukos (2014) estimated a population growth rate of 0.54 (0.37 – 0.91[min-max]) using data available through 2010. Recruitment contributed to 68% of the variation in population growth with breeding propensity (27%) and nest success (20%) being single factors that explained the most variation (Rigby and Haukos 2014). Moon (2014) calculated a population persistence rate of 100% with a mean population growth rate of 0.44-0.82 over the next 50-100 years. Elasticity of the population growth rate was captured primarily by factors related to the recruitment process including clutch size, nest success, and breeding propensity (Moon 2014).

Following a presentation of available data on survival and recruitment of mottled ducks, attendees of the 2016 meeting responded to several poll questions addressing the relative likelihood that survival or recruitment currently limited mottled duck populations and the relative importance of components of those population parameters. When asked to allot 10 points to represent the relative likelihood that survival or recruitment currently limited mottled duck populations, the group on average identified recruitment as being nearly two times more important than survival, a slight increase in the relative likelihood of survival than assigned by attendees of the 2003 meeting (Figure 20). Two-thirds of attendees were either unsure or would not rank the relative importance of survival and recruitment differently if asked about separate sub-regions of the GCJV geography (Figure 21).

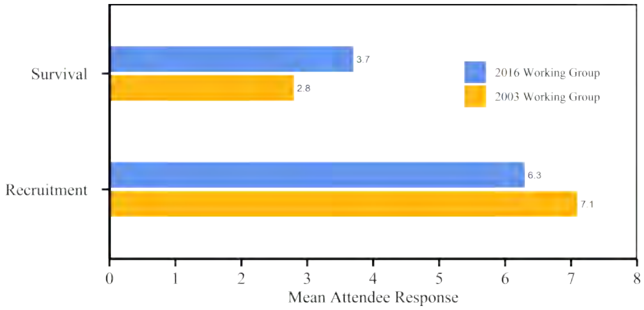


Figure 20. Relative importance of survival and recruitment to limiting western Gulf Coast mottled duck populations assessed by the 2003 (yellow; *n* = 25) and 2016 (blue; *n* = 30) mottled duck working groups.

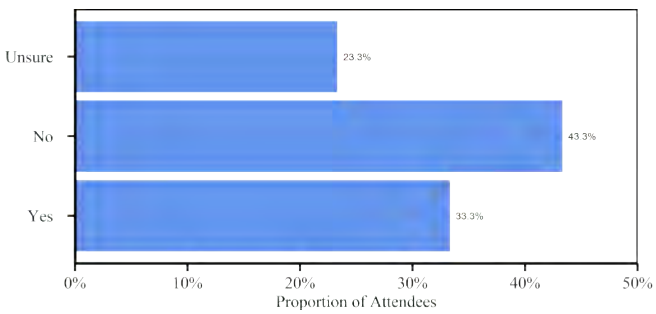


Figure 21. Mottled duck working group (*n* = 30) response to whether they would rank the relative importance of survival and recruitment differently for sub-regions of the GCJV geography (i.e., states or Initiative Areas).

The three most important components of recruitment thought to limit mottled duck populations were similar to those ranked highest by the 2003 working group (i.e., nest success, brood survival, and breeding propensity), yet 2016 meeting attendees assigned greater weight to breeding propensity (Figure 22). Of the ranked recruitment factors, working group confidence was high that their ranking reflected true importance, except for the breeding propensity parameter which the group was only moderately confident their rank reflected true importance (Figure 23).

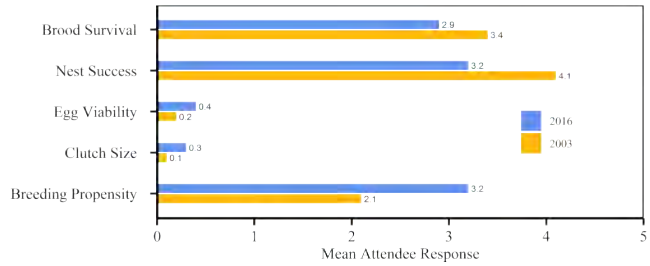


Figure 22. Mottled duck working group assessment of the relative importance of components of recruitment potentially limiting mottled duck populations at the 2003 (yellow; *n* = 25) and 2016 (blue; *n* = 30) meetings.

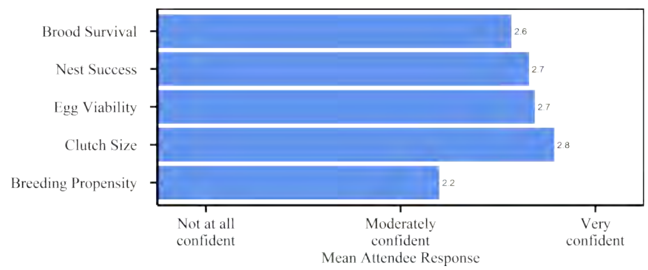


Figure 23. Mottled duck working group attendee (*n* = 30) confidence that ranks reflect true importance of components of recruitment limiting populations.

The relative importance of survival components was more varied and attendees recognized adult female mortality from predation during the spring and summer as the most important followed by harvest mortality (Figure 24). There was slightly less confidence that attendee rankings reflected true importance of components limiting survival, though participants were still moderately confident (Figure 25).

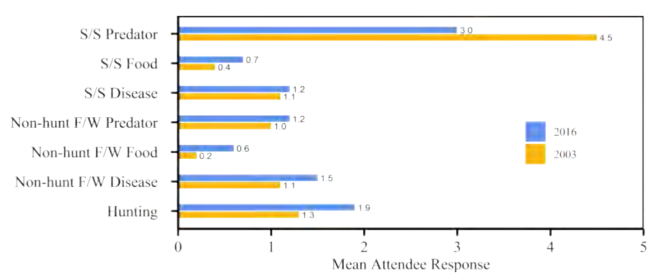


Figure 24. Mottled duck working group assessment of the relative importance of components of survival that potentially limit mottled duck populations at the 2003 (yellow; *n* = 25) and 2016 (blue; *n* = 30) meetings. S/S = spring/summer; F/W = fall/winter.

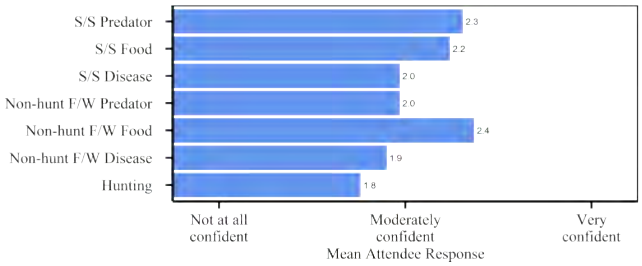


Figure 25. Mottled duck working group meeting attendee (*n* = 30) confidence that their ranks reflect the true importance of components of survival limiting mottled duck populations. S/S = spring/summer; F/W = fall/winter.

Attendees overwhelmingly identified the breeding and brood-rearing periods as seasons within the mottled duck annual cycle that should be priority for improvement of the mottled duck population status (Figure 26). Attendees identified the pre-breeding period as a season with the most uncertainty about its relative priority for improving mottled duck population growth (Figure 27). The majority (62%) of attendees believed seasonal priorities should differ between sub-regions of the GCJV and that the dividing line should be located at Galveston Bay (83%) over the Sabine River (17%). However, when asked to prioritize seasons of the annual cycle for regions east and west of Galveston Bay, attendees' response was similar to the earlier WGC range-wide question with only minor differences between regions (Figure 28).

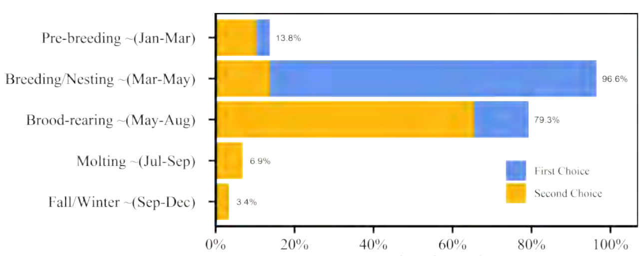


Figure 26. Mottled duck working group meeting attendee (*n* = 29) response to which season should partners focus on to improve mottled duck population status.

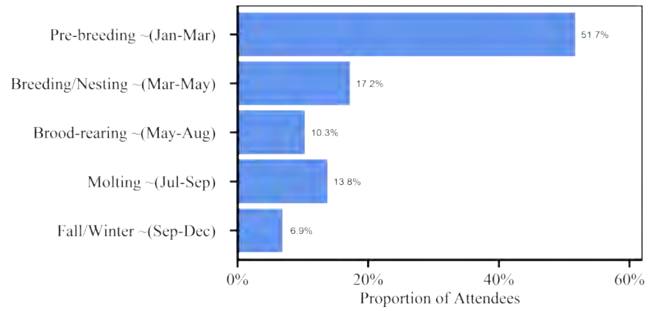


Figure 27. Mottled duck working group meeting attendee (*n* = 29) response to which season of the annual cycle they are most uncertain about when identifying its relative priority regarding the population status of mottled ducks.

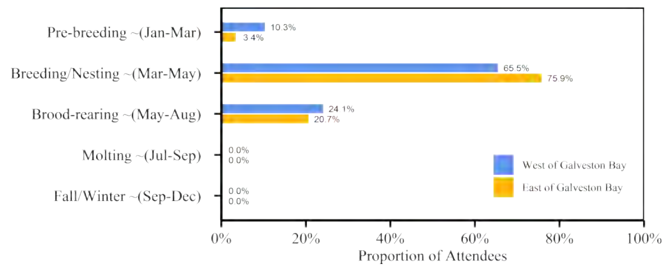


Figure 28. Mottled duck working group meeting attendee (*n* = 29) assessment of which season of the annual cycle they feel partners should focus on to improve mottled duck population status east (yellow) and west (blue) of Galveston Bay.

Factors potentially limiting survival and/or recruitment

Survival and/or recruitment of mottled ducks could be limited by harvest, predation, disease, or severe storms, the effects of which may be exacerbated against a backdrop of habitat loss and degradation, disturbance, lead exposure, and climate change. In the following sections we explore available research and data that may be useful in identifying population limiting factors.

Harvest – Since the 2007 Plan, Louisiana and Texas modified mottled duck harvest opportunities with an overall goal of reducing harvest by 30%. Beginning with the 2009 hunting season, Louisiana reduced their daily mottled duck bag limit from 3 to 1 and Texas maintained a bag limit of 1 dusky duck (i.e., mottled duck, black duck and their hybrids, or Mexican-like duck), but restricted mottled duck harvest during the first 5 days of the duck season. There has been a 23% decline in the estimated number of mottled ducks harvested in Texas and Louisiana between 1999-2008 ($\bar{x}$ = 47,962) and 2009-2018 ($\bar{x}$ = 36,936), however, age- and sex-specific harvest rates have remained relatively unchanged over the same time period (Figure 29).

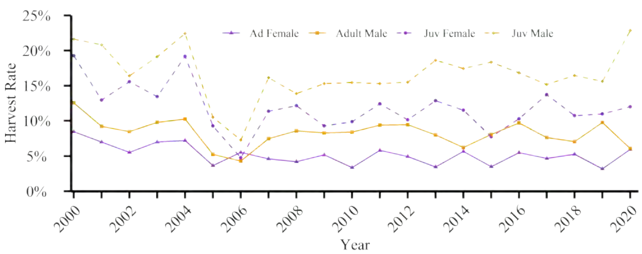


Figure 29. Age- and sex-specific annual harvest rate of mottled ducks banded in Texas and Louisiana, 2000-2020. Calculated using methods of Kneece et al. (2020) and assuming a 20% crippling rate and 65% band reporting rate.

The crude harvest rate index (total harvest/MWS estimate) presented in the 2007 Plan additionally suggests a continued decline in harvest rates from 1970-2020 (Figure 30), and steady to declining rates from 2000-2020 (Figure 31). Estimated harvest mortality from 2000-2020 is similar to and in some cases slightly lower than age- and sex-specific estimates from 1994-2000 presented in the 2007 Plan (Figure 32). While the GCJV defers any judgements regarding impacts of harvest regulations to partners charged with that responsibility, assessment of available data continues to suggest that reductions in natural mortality may result in greater increases in annual survival, especially for adult females. Improvements in habitat or other environmental variables within the purview of the GCJV partnership should remain a priority focus.

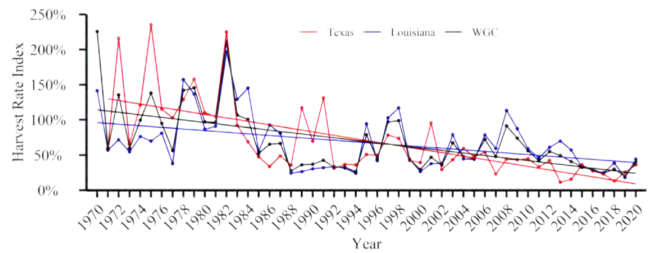


Figure 30. Annual mottled duck harvest as a proportion of the Mid-winter Waterfowl Survey estimates as a crude index of harvest rate, 1970-2020.
Solid line indicates significant linear trend ($P \leq 0.05$).

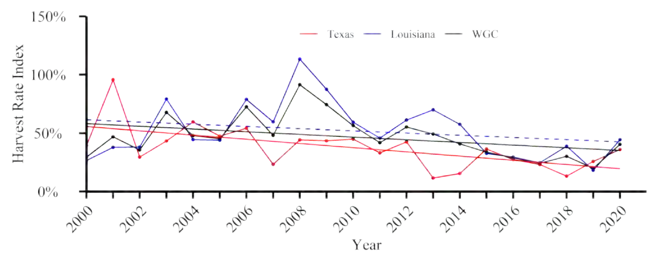


Figure 31. Annual mottled duck harvest as a proportion of the Mid-winter Waterfowl Survey estimates as a crude index of harvest rate, 2000-2020.
Solid linear trend lines depict a significant trend ($P \leq 0.05$), whereas dashed linear trend lines represent non-significant trend.

Predation – Like other dabbling ducks, mottled ducks are particularly susceptible to nest predation, which is the most common cause of nest failure along the WGC. Most mottled duck nests are found in upland areas, where they are subject to predation from raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), American mink (*Neogale vison*), coyotes (*Canis latrans*), snakes (e.g., rat snake [*Elaphe obsolete*]), armadillos (*Dasypus novemcinctus*), and corvids (Corvidae; reviewed in Bonczek and Ringelman 2021). Mottled ducks have also been observed to construct nests over water in vegetated marsh (Bonczek and Ringelman 2019) where they are subject to additional predation risk from alligators (*Alligator mississippiensis*) and river otters (*Lontra canadensis*).

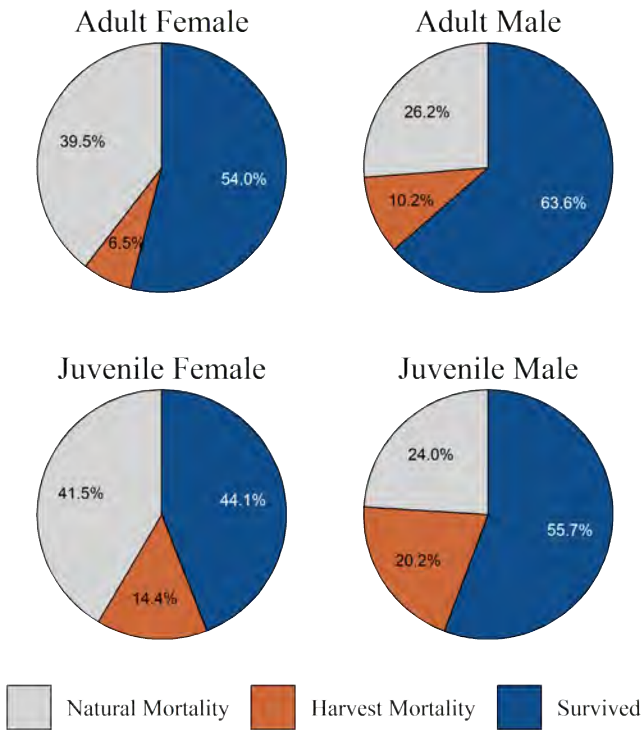


Figure 32. Annual Fate of banded Western Gulf Coast mottled ducks, 2000-2020.
Calculated using methods of Kneece et al. (2020) and assuming a 20% crippling rate and 65% band reporting rate. There was no support for state-specific estimates, thus data were combined for Texas and Louisiana.

Egg predation by raccoons and other mammals, birds, and reptiles is the most common cause of mottled duck nest failure.

Recent trail camera evidence from simulated mottled duck nests baited with chicken eggs emphasized the importance of racoons, alligators, and snakes as nest predators, but also increases the suite of potential avian predators to include rails and gallinules (Rallidae) that have been observed destroying eggs (Dopkin and Ringelman 2021). Predation rates of adult ducks and predator identity are difficult to evaluate, but raptors and alligators are both known to depredate adult mottled ducks, and trail cameras have repeatedly documented alligators lying in wait at simulated mottled duck nests. The duckling predator community is also diverse and likely includes the same suite of predators previously mentioned plus some although identification of duckling predators has not been quantified. Alligators are considered the prominent predator of all post-hatch life stages (Stutzenbaker 1988, Elsey et al. 2004). Estimates of alligator nest abundance, which is a proxy for alligator population size, continues to increase in Louisiana (Figure 33), signaling a growing source of predation risk for mottled ducks. Moreover, approximately 41,000 alligators between 0.9 and 1.8 meters have been released annually since 1994 to mimic natural survival rates of eggs collected and hatched to support alligator farms (Figure 34). Beginning in 2022, the proportion of juvenile alligators hatched from collected eggs required to be returned to the wild will decline from 10% to 5% in response to the substantial increase in alligator nest abundance. This action may reduce the supplemental abundance of alligators in the size range most likely to consume mottled ducks (1.5 - 1.7m; Elsey et al. 2004).

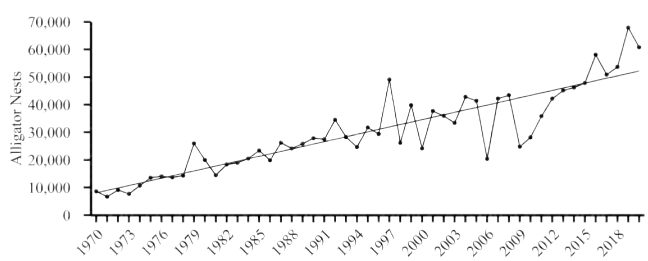


Figure 33. Annual alligator nest abundance, a proxy for alligator population in coastal Louisiana, 1970-2020.
Solid line indicates a significant ($P \leq 0.05$) linear relationship. (LDWF, 2021 Alligator Program Annual Report).

Alligators are among the chief natural predator of mottled ducks for all post-hatch life stages.

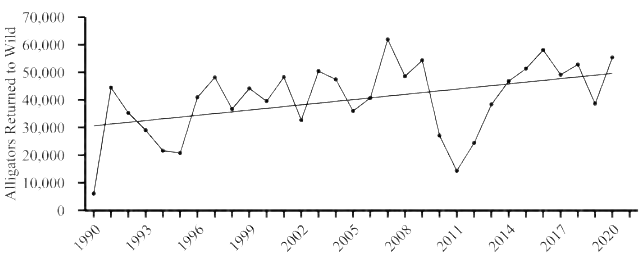


Figure 34. Annual number of 1-2 year-old alligators hatched in captivity and released at sites near where eggs were collected, 1990-2020.
Solid line indicates a significant ($P \leq 0.05$) linear relationship. (LDWF, 2021 Alligator Program Annual Report).

Lead exposure – Prolonged or repeated exposure to lead is known to cause morbidity and mortality in waterfowl. Moreover, exposure above background levels can cause sub-lethal impacts to reproductive performance, offspring viability, or vulnerability to predation (Pain et al. 2019). Despite a nationwide ban on the use of lead shot for waterfowl hunting, lead toxicity has continued to be a factor of concern for WGC mottled ducks and has prompted additional research since the 2007 Plan. McDowell et al. (2015) examined blood lead concentrations of live-captured (summer) and hunter-harvested (winter) mottled ducks in southeast Texas during 2010-2012 and found evidence for potential seasonal shifts in blood lead concentration. Of mottled ducks captured during summer, no locally produced (i.e., flightless juvenile) individuals contained blood concentrations above levels indicative of exposure (≥200 ug/L), whereas 13% of juvenile and 23% of adult birds had lead concentrations indicative of exposure, but not toxicity (≥500 ug/L). In contrast, among hunter-harvested birds, 72% of juveniles and 24% of adults exceeded lead concentrations indicative of exposure. For those identified as being exposed, the geometric mean exceeded levels indicative of toxicity and several individuals had lead concentrations exceeding potentially lethal levels (≥1 mg/L). McDowell (2015) also measured lead concentrations at Anahuac and McFaddin National Wildlife Refuges in soils (19.1 mg/kg), vegetation (6.9 mg/kg), roots (8.4 mg/kg), seeds (2.4 mg/kg), widgeon grass (9.2 mg/kg), and invertebrates (1.07 mg/kg) but generally found mean lead concentrations to be within natural concentrations identified by the Environmental Protection Agency (i.e., <50 mg/kg). Two lead pellets were collected from soil samples, resulting in a crude extrapolated estimate of 60,000 pellets/ha which is a 96% decrease from 1970s estimates (1.5 million/ha; Fisher et al. 1986). Only one lead pellet was recovered from soil samples collected in production rice fields in Texas and Louisiana (Marty et al. 2017). Kearns et al. (2019) developed and overlaid a mottled duck habitat suitability map on interpolated soil lead concentrations and found that areas used by mottled ducks frequently corresponded to areas of greater lead concentrations.

Lead exposure continues to impact mottled ducks. Seventy-two percent of sampled hunter harvested juveniles had lead concentrations above background levels.

Kearns (2015) examined lead isotope ratios from mottled duck blood and found consistencies with isotope ratios found in samples of lead shot, particularly lead shot produced in the 1980s. There has not been a recent examination of lead shot ingestion by mottled ducks, but recent estimates from wintering waterfowl on the Gulf Coast indicate low levels of lead ingestion for northern pintails (*Anas acuta*; 3%, *n* = 226; Huck et al. 2016), green-winged teal (*Anas carolinensis*; 0%, *n* = 98, Garrison et al. 2011) and northern shovelers (*Spatula clypeata*; 1%, *n* = 84, Garrison et al. 2011). Although wintering waterfowl spend only a portion of their annual cycle on the Gulf Coast, these are lower than estimates of lead ingestion prior to the 1999 ban on lead shot specifically for waterfowl hunting, suggesting that the availability of lead pellets on the landscape has declined. Nevertheless, lead contamination, whether from legacy lead shot or contemporary illegal activities, remains a concern, and there is an ongoing need to investigate the effects of short- and long-term exposure to modern lead concentrations on mottled duck vital rates.

Habitat loss and degradation – WGC mottled ducks are generally associated with coastal marsh and inland agricultural lands including pasture. The WGC has experienced substantial loss of coastal marsh in the last century and is projected to lose millions more acres in the coming decades (Osland et al. 2017, Moon et al. 2022). Moon et al. (2021) examined habitat selection of mottled ducks and projected impacts of sea-level rise and urbanization on future habitat quality for mottled ducks in portions of coastal Texas and Louisiana (see inset page 50). The coverage of fresh and irregularly flooded marsh, which are considered high-quality habitat for WGC mottled ducks, are projected to decrease 82% by 2100 across the region (i.e., Texas Mid-coast, Texas and Louisiana Chenier Plain, and western Mississippi Coastal Wetlands Initiative Areas). Coastal marsh in Texas is predicted to fare better than that in Louisiana, but mottled duck habitat in Texas is at greater risk from urbanization. Across the region there is a projected 72% increase in developed land by 2100 (Moon et al. 2021). In Florida, some mottled ducks readily use urban environments throughout the year in response to ongoing wetland loss, seasonal habitat conditions, or avoidance of disturbance (Bielefeld and Cox 2006). Western Gulf Coast mottled ducks are less likely to use urban environments, but continued wetland loss and urban expansion may result in established urban populations similar to those in Florida. Moreover, expansion of urban environments may potentially exacerbate issues of hybridization with local mallards (Varner et al. 2014*b*).

Inland rice agricultural systems have provided a somewhat stable source of freshwater wetlands for mottled ducks, especially during drought. However, rice agriculture has declined markedly in the Gulf Coast region and is projected to further decline (Baldwin et al. 2011; Figure 35). Many rice producers in Louisiana have integrated crawfish aquaculture into their rice rotation for economic gains, which provides additional surface water during a portion of the mottled duck breeding season (Figure 36). However, the extent to which mottled ducks utilize crawfish aquaculture during the breeding season is unknown, and drawdowns following crawfish harvest (i.e., June-July) may create an ecological trap if alternate brood-rearing habitat is unavailable nearby.

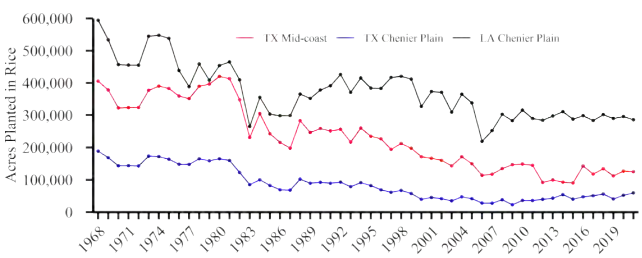


Figure 35. Acres of rice planted annually in Gulf Coast Joint Venture Initiative Areas, 1968-2021.

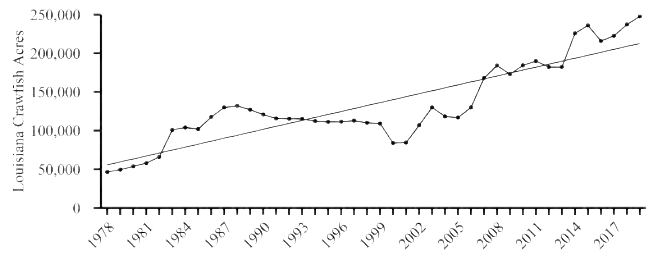


Figure 36. Louisiana crawfish aquaculture acres, 1978-2019.

Moreover, rice farmers are becoming reluctant to flood idle fields due to presence of exotic, invasive apple snails (*Pomacea maculate*), as they have become a nuisance to crawfish harvest and can potentially destroy rice crops (Lucero and Wilson 2023). Alternative rice-growing practices have the potential to further reduce the amount of flooded habitat available during the mottled duck breeding season. For example, furrow-irrigated rice—a practice where rice is grown on hilled rows and irrigated between rows—has already become a popular practice in northern Louisiana to reduce greenhouse gas emissions and overall cost associated with conventional rice-field flooding. This practice does not require water be held on rice fields and thus reduces their functioning as surrogate wetlands. Additionally, the practice of alternate wetting and drying during the period of active rice growth is another method designed to reduce overall water consumption and greenhouse gas emission over conventional continuous flood practices. However, this practice too has the potential to reduce the availability of surface water during the mottled duck breeding season. Neither practice is yet being used widely along the Gulf Coast, but increased pressure


Rice agriculture can provide a reliable freshwater source during the mottled duck breeding season. However, rice acreage has declined across the gulf coast.

for reduced water usage and greenhouse gas emissions and expanded eligibility for federal crop insurance coverage will likely result in expansion of these agricultural practices.

Suitability of coastal marsh for mottled ducks is driven predominantly by flood frequency and salinity with preference for irregularly flooded fresh marsh. Haukos et al. (2010) found mottled duck pairs were 11.7, 12.2, and 2.6 times more likely to select fresh marsh than intermediate, brackish, or saline marsh, respectively in Texas. Moreover, female mottled ducks have been shown to select wetlands of lower salinity, especially during the breeding and brood-rearing periods (Davis 2012, Moon 2014, Moon et al. 2021). Perhaps the most direct impact of salinity on recruitment is through the survival of ducklings, where reported negative impacts on growth and survival of mottled duck ducklings occurs at >9ppt (Moorman et al. 1991). Salinization of fresh marsh occurs through numerous processes including, saltwater intrusion, reductions in downstream freshwater flow, storm surge, and anthropogenic alteration of coastal geomorphology.

Disturbance – Disturbance likely has indirect impacts on mottled duck populations (DeMaso et al. 2019), but has not been a point of conservation emphasis for WGC mottled ducks because many areas of south Louisiana and Texas have a low human population density. Nevertheless, roads, oil and gas activity, and other human development have the potential to impact mottled ducks as documented in closely related species (Skaggs et al. 2020). Moreover, standard land management and agricultural practices, such as burning and plowing upland areas, occur frequently during the mottled duck nesting season (March-June) (Dopkin and Ringelman 2021) and are undoubtedly contributing to nest loss, albeit at unknown levels. During winter, the effects of disturbance are much less clear, although mottled ducks in Louisiana may alter their behavior to avoid hunters, and accordingly have relatively high survival rates as waterfowl hunting season progresses (Bonczek et al. 2022).

Environmental Conditions – Mottled ducks are subject to mortality, displacement, and habitat degradation from hurricanes that have become both more frequent and intense with climate change (Knutson et al. 2013, 2015). Because the Atlantic hurricane season overlaps critical events in the annual cycle of mottled ducks, including nesting, brood-rearing, and molting, increasingly frequency and severity of tropical storms may pose a local risk to populations beyond their indirect impact on habitat. Although mottled ducks should be evolutionarily well-adapted to these risks, Ringelman et al. (2021) documented ~40% mortality of GPS marked female mottled ducks when Hurricane Laura made landfall in southwest Louisiana in 2020. The resultant habitat destruction and degradation was widespread and had the knock-on effect of displacing regional cattle grazing operations to any remaining grasslands that may have functioned as suitable nesting areas, thus further increasing risks to

Drought conditions during the breeding season can reduce wetland availability leading to negative impacts on breeding propensity, nest success, and duckling survival.

nesting mottled ducks. The impacts of hurricanes are exacerbated by regionally high rates of relative sea-level rise and declines in marsh resilience; posing a significant threat to coastal mottled duck habitats.

Wetland availability during the pre-breeding and breeding season can impact mottled duck recruitment through its impacts on breeding propensity, nest success, and brood survival (Johnson 2009, Rigby and Haukos 2012, Ross et al. 2018). Johnson (2009) found a positive relationship between environmental moisture and population growth rates for male mottled ducks, whereas population growth of females varied little with environmental moisture. The lack of an effect for females may be due to a trade-off of decreased female survival during wet periods associated with the ecological cost of increased breeding (Johnson 2009). The Palmer Drought Severity Index (PDSI) is a reliable indicator of wetland conditions (Sorenson et al. 1998) that may index annual breeding conditions that relate to breeding propensity of mottled ducks (Rigby and Haukos 2012). In general, moisture indices from 1970-1995 were near average to slightly above average, however, since 1995, moisture indices have become more variable with a greater frequency of moderate (<-2) or severe drought (<-3) during the mottled duck breeding season (March-July; Figure 37).

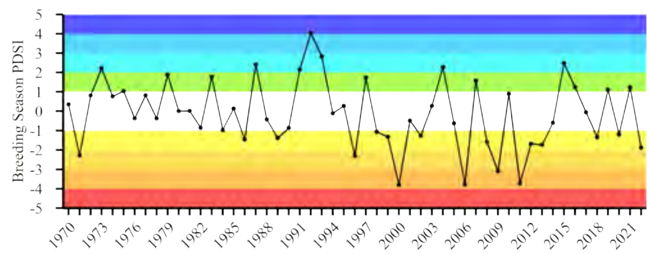
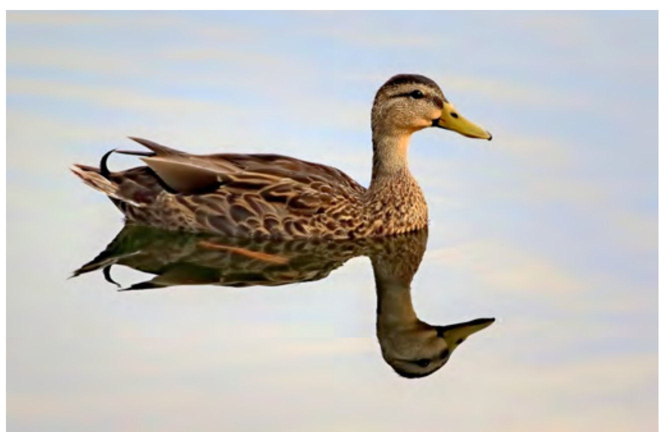


Figure 37. Average breeding season (March-July) Palmer Drought Severity Index (PDSI) value across the Texas and Louisiana Coast, 1970-2022.
Magnitude of values indicate deviation from normal soil moisture conditions with positive values indicating wetter conditions and negative values indicating drier conditions.

Hybridization – Hybridization with feral game-farm mallards is a concern for Florida mottled ducks, with hybridization rates estimated at ~9% (Williams et al. 2005). Releases of game-farm mallards have historically been less common across the WGC, but there is concern that coastal marsh loss may force mottled ducks further inland where they may be more likely to encounter and hybridize with mallards in urban or suburban areas. Ford et al. (2017) estimated levels of mallard-mottled duck hybridization at 5-8% in the WGC, although they were unable to determine whether hybrid genetics were derived from local game-farm or wild migratory mallards. Current levels of hybridization in the region are low overall and is probably a low conservation concern, although any expansion of game-farm mallard operations could be disastrous for the species (Lavretsky et al. 2020). Convergence of expanding Mexican duck (*Anas diazi*) and mottled duck populations in south Texas may be resulting in a hybrid zone that is the topic of ongoing research, but it is unknown what impacts this may



Mottled duck x mallard hybridization rates in the western Gulf Coast are currently of low conservation concern but should be reevaluated periodically.

have on WGC mottled duck populations (Lavretsky, University of Texas El Paso, unpublished).

After reviewing available data on factors potentially limiting mottled duck survival and recruitment, attendees of the 2016 meeting responded to questions regarding their interpretation of current and future population limiting factors. Attendees identified habitat quality and quantity as the most important priorities for the GCJV partnership to focus on mitigating (Figure 38). Hybridization was identified as the lowest priority, whereas predation, lead exposure, and disturbance were ranked in the middle (Figure 38). In the next 20 years, attendees identified the availability and reliability of freshwater for wetland management as the greatest threat, followed by sea-level rise and urban growth (Figure 39). Similar threats predominated as greatest threats over the next 100 years, with sea-level rise surpassing other threats (Figure 39). Hybridization, lead exposure, and the decline in rice agriculture were not identified as significant threats among the options provided at either timeline (Figure 39).

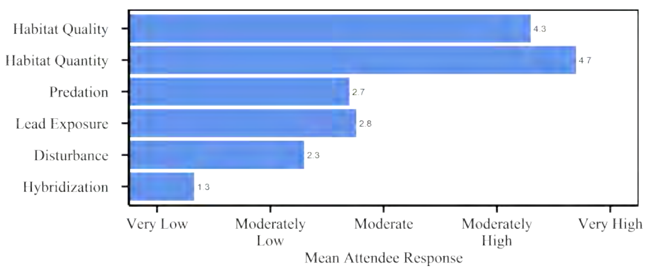


Figure 38. Mottled duck working group (*n* = 30) prioritization of issues potentially related to mottled duck population decline.

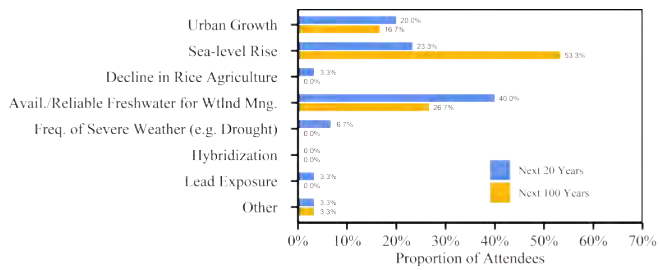
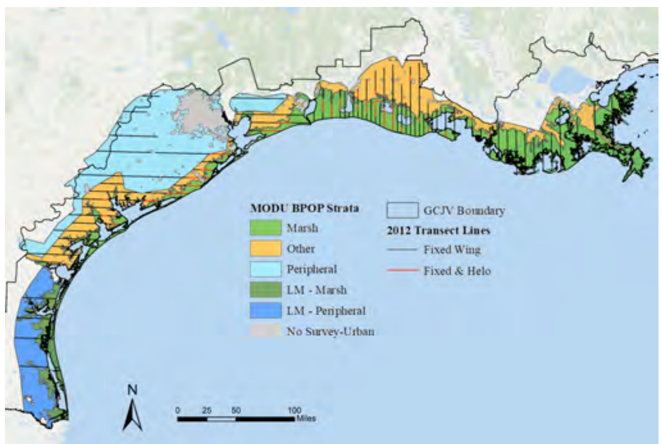


Figure 39. Mottled duck working group (*n* = 30) assessment of which threat has greatest potential to negatively impact MODU in the next 20 (blue) and 100 (yellow) years.

POPULATION TARGET

Mottled duck population objectives serve four primary functions: 1) inspire partners around common conservation goals; 2) facilitate efficient communication about desired conservation outcomes; 3) enable establishment of quantitative habitat objectives through development of population-habitat models; and 4) enable evaluation of conservation success. The 2007 Plan established regional mottled duck population objectives for the western Gulf Coast (105,816; Texas, Louisiana, Mississippi, and Alabama), Texas (35,322) and Louisiana (70,132) using the long-term average (1971-2004) of Midwinter Waterfowl Survey (MWS) estimates. Acknowledging the limitations of the MWS (e.g., uncorrected for visibility bias, disparate effort, and spatial coverage; Eggeman and Johnson 1989) and other data available at the time, population objectives were established while advocating for an improved and operational range-wide survey capable of reliably assessing trends in mottled duck populations. The 2007 Plan recommended that population objectives be revisited and the derivation process updated as new monitoring programs became established and confidence gained in their reliability. Two options emerged as potential replacements for the MWS as the basis for mottled duck population objective establishment and tracking and were explored by the mottled duck working group.

A collaboration between the U.S. Fish and Wildlife Service Division of Migratory Bird Management, Texas Parks and Wildlife Department, and the Louisiana Department of Wildlife and Fisheries resulted in a novel mottled duck population survey being initiated in 2008. The Western Gulf Coast Mottled Duck Breeding Population Survey (hereafter BPOP) is a transect-based, fixed-wing aircraft survey flown in early April across much of the mottled duck range in Texas and Louisiana. Transects are stratified among regions to reflect differences in vegetation communities and presumed differences in mottled duck density. A subsequent helicopter-based survey is flown in a “beat-out” pattern on select transect segments to calculate a visibility correction factor (VCF) which is used to adjust the fixed-wing survey estimate for visibility bias (e.g., Smith 1995). Annual population estimates are reported as total indicated birds (TIBs), which accounts for an undetected mate for each bird counted alone. The BPOP survey underwent several years of revisions but has remained unchanged since the addition of the Laguna Madre strata in 2011.



Implemented in 2008, the Western Gulf Coast Mottled Duck Breeding Population Survey has been flown annually in early April to provide a visually corrected estimate of the population during the breeding season.

Given the increasing difficulty of conducting human-occupied aerial surveys due to costs and concern over observer safety, the working group expressed interest in exploring other options for population estimation, and in turn the basis for population objectives. One such approach is

Lincoln-Peterson (LP) estimation, a mathematical method that uses annual direct recovery rates from banded mottled ducks and total mottled duck harvest to estimate autumn population size. In many cases, abundance estimates obtained through LP analyses are substantially greater than those from traditional survey techniques, and this often creates skepticism in estimation reliability from those unfamiliar with the method (see Alisauskas et al 2014). Higher estimates are at least partially due to LP estimates being a post birth-pulse survey (i.e., includes adults and young), whereas traditional breeding survey estimates are pre-birth-pulse (i.e., only adults). Lincoln Peterson estimation requires a robust annual banding effort across the mottled duck range, an open harvest season, and reliable estimate of total mottled duck harvest.

At the 2016 Mottled Duck Working Group meeting, following a presentation of survey alternatives, attendees were asked which dataset they believe should form the basis for development of updated mottled duck population objectives. There was overwhelming support for establishment of mottled duck population objectives based on the BPOP survey (Figure 40), but there was a desire to make a connection between the existing MWS-based population objectives and those based on the BPOP survey. A series of linear regressions were presented to attendees showcasing the relationship between paired annual MWS-based estimates and BPOP-based estimates for Louisiana and Texas as one option for conversion. The paired surveys showed moderate correlation (r = 0.52) across 2009-2015 in Louisiana, where similar transects are flown for the MWS and BPOP. In Texas, the regression included only 2011-2015 data and excluded MWS data outside of the Gulf Coast Prairies and Marshes strata to limit comparisons to similar spatial scales. The correlation was moderate (r = 0.48) in Texas, but the negative relationship was contradictory, prompting censoring of paired 2015 data which resulted in a stronger (r = 0.73) positive relationship. However, when polled, none of the 2016 meeting attendees were content with the conversion process and instead favored postponing conversion of the MWS-based objective to a BPOP-based objective until several more paired years of data were available regardless of the resulting correlation (Figure 41). Later in the meeting, attendees were asked which population objective setting option had a fatal flaw and should not be considered further (Figure 42). Attendee responses exposed some discomfort in objective establishment based on the existing BPOP survey and highlighted support for establishment of a population objective without connection to the existing MWS objective. Discomfort with the existing BPOP survey related to spatial coverage in Texas which excludes portions of the Sandplains and Brush Country regions where "dusky ducks", presumably mottled ducks had been counted during the MWS in recent years.

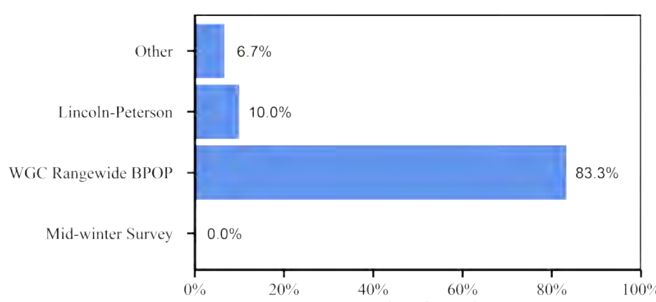


Figure 40. Mottled duck working group (n = 30) assessment of which dataset should form the basis of population objective development to achieve stated purposes.

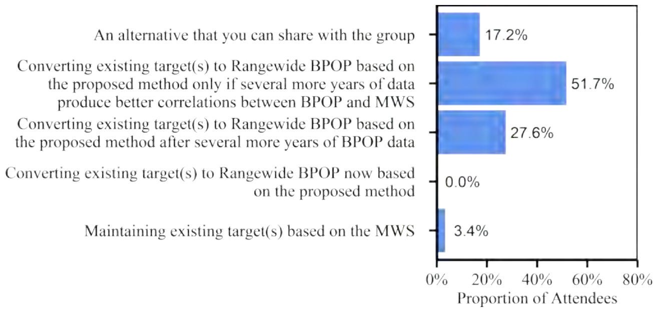


Figure 41. Mottled duck working group (*n* = 29) assessment of which process they favored to convert from MWS-based to BPOP-based population objectives after viewing 2010-2015 correlations.

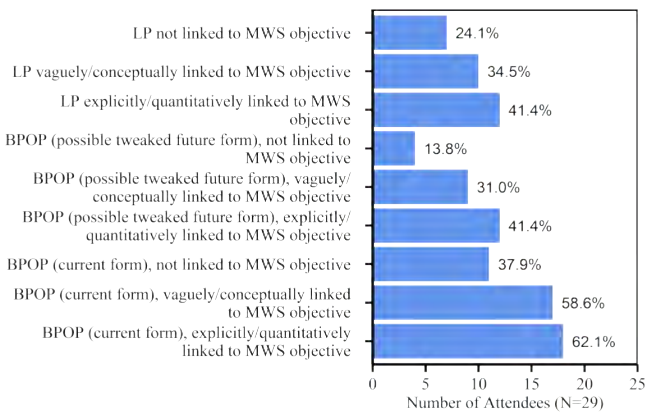


Figure 42. Mottled duck working group (*n* = 29) assessment of which option(s) have a 'fatal flaw' such that the MODU Population Objectives Sub-team does not spend any time exploring them.
LP – Lincoln-Peterson, MWS – Midwinter Survey, BPOP – WGC Mottled Duck Breeding Population Survey.

A population objective sub-team was formed to continue exploring options for population objective establishment. The sub-team met in summer 2016 advancing discussions and identifying data needs to inform advancement on the topic, but was dormant until revitalization of the Conservation Plan Update in 2022. The revived sub-team began revisiting available mottled duck survey data and narrowed their focus to three options for establishing a new WGC mottled duck population objective: 1) Lincoln Peterson based; 2) BPOP based translated from the 2007 Plan's MWS-based objective; or 3) BPOP based with no connection to the existing MWS-based objective. The group first focused on identifying which dataset to base population objectives. Several desirable traits were identified in the LP approach: 1) its estimation warrants a robust banding effort across the mottled duck range, 2) it provides some leverage to maintain an open hunting season, 3) it provides an estimate of total population, and 4) it does not rely on manned aerial surveys. The group also identified numerous concerns related to component assumptions of LP estimation process, including: 1) uncertainty and potentially dynamic band reporting rates, 2) the challenge of deriving a band reporting rate without also influencing harvest rate, 3) discomfort with estimation of total harvest using data obtained through the Harvest Information Program, 4) a limited annual sample of mottled duck wings from the parts collection survey from which to calculate total harvest, and 5) the assumption that no death occurs between banding and harvest (Cooch et al. 2021). Additional concern revolved around current uncertainty regarding necessary banding efforts and whether robust banding efforts are annually achievable, the general reliance on maintaining harvest opportunity when harvest decisions are outside our control, and further population decline may result in hunting season closure for WGC mottled ducks. After discussion, the sub-team unanimously eliminated the LP approach from further consideration in favor of further exploring establishment of a BPOP-based objective. Sub-team members expressed greater confidence in BPOP estimation techniques, that consistent methodology would produce reliable estimates into the future, recognition that significant time and effort has gone into developing the BPOP survey for this very purpose, and a desire to establish the BPOP survey as the definitive survey of WGC mottled ducks.

The population sub-team transitioned discussion to the two options identified for setting a population objective based on the WGC BPOP survey. The group explored updated MWS and BPOP correlation graphs that incorporated paired survey data across 2010-2021 for Louisiana (Figure 43) and Texas (Figure 44). There were mixed thoughts about the utility of the conversion of the existing MWS-based objective to one on the BPOP scale. On the one hand, the MWS-based objective had already undergone scrutiny by the GCJV Mottled Duck Working Group and Management Board. However, the sub-team expressed concerns over generally poor correlations that had not improved with additional data and a seemingly unjustified need to censor several years of data in Texas to increase correlation and produce a positive relationship (Figure 44). Thus, the group concluded that population objectives should be calculated from extant BPOP estimates from 2011-2021 instead of converting from previous MWS-based objectives. Despite indication from attendees of the 2016 Working Group Meeting of a desire to establish BPOP-based objectives on an updated survey design/extent, the population objective sub-team concluded that delaying the population objective update until sufficient data were available to calculate such an objective was unfavorable.

Exploratory BPOP surveys were flown in the Brush Country and Sandplains strata in 2019, but additional analysis of transect placement and understanding the genetic make-up of “dusky ducks” in surveyed regions have precluded operational status. Thus, the sub-teams decision excluded the Brush Country and Sandplain strata from any further consideration, thus limiting BPOP-based population objective establishment to the existing survey area (Figure 45). Should these strata become operational in the future, the GCJV will communicate with neighboring JVs regarding a process to establish population objectives in those geographies which fall predominantly outside the GCJV geography.

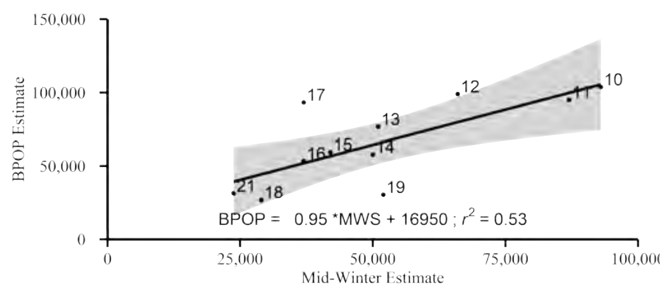


Figure 43. Relationship between paired Mid-winter Waterfowl Survey (MWS) and Western Gulf Coast Mottled Duck Breeding Population Survey (BPOP) estimates in Louisiana, 2010-2021.

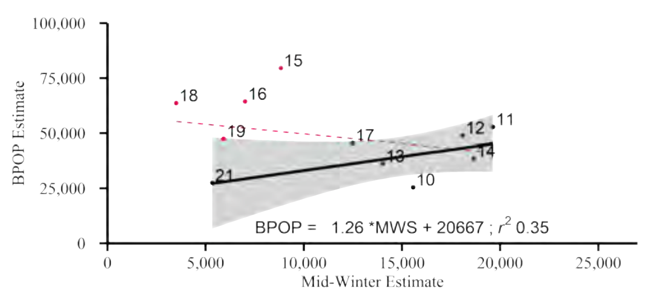


Figure 44. Relationship between paired Mid-winter Waterfowl Survey (MWS) and Western Gulf Coast Mottled Duck Breeding Population Survey (BPOP) estimates in Texas, 2010-2021.
Surveys from 2015, 2016, 2018, and 2019 were excluded from the linear regression to avoid an illogical negative relationship (red dashed line).

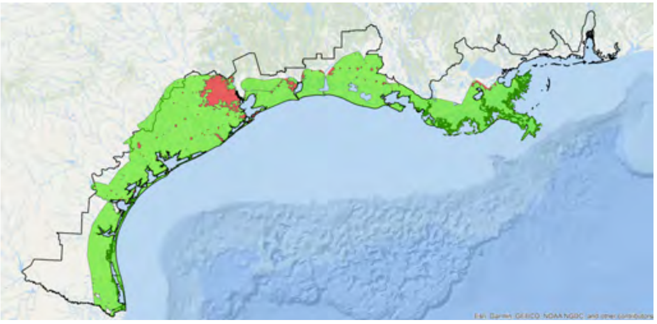


Figure 45. Western Gulf Coast Mottled Duck Breeding Population Survey extent (green) for which updated WGC Mottled Duck population objectives are applicable. Non-surveyed urban areas are shown in red and the Gulf Coast Joint Venture geography is outlined in black.

BPOP-based Population Objective Establishment

The sub-team discussed alternative options for establishment of a population objective from the available WGC BPOP data. Recognizable calculation options included the average or 80th percentile calculated across survey years which corresponded with dual NAWMP objectives implemented for other continental duck populations (Figure 46; NAWMP 2014). At the time of discussions, 10 years of consistently collected WGC BPOP data were available for the BPOP survey area (Figure 45) from the period of 2011-2021 excluding 2020 when the survey was canceled due to Covid-19. There was general agreement within the sub-team that in the short term the population objective should reflect a goal of stabilizing the current negative population trajectory with an objective equivalent to the average across the 2011-2021 period. However, the group acknowledged that while achievement of such an objective would be celebrated, populations would remain below those witnessed when the BPOP survey began and would be well below historic abundances that we felt better aligned with societal desires and values. Given the relationship of the mottled duck population from the MWS over the 2011-2022 time period relative to the long-term average (1970-2022), setting an objective that fell within the range of 2011-2021 BPOP estimates did not seem aspirational enough (Figure 47). Although there was slight discomfort setting an objective outside the range of existing BPOP survey estimates, members were confident in the sensitivity of the BPOP survey to track population losses and gains. Moreover, amending the population objective upward in response to achieved objectives was seen as undesirable which resulted in consideration of establishing multiple objectives that reflected current knowledge of populations and societal desires (NAWMP 2014).

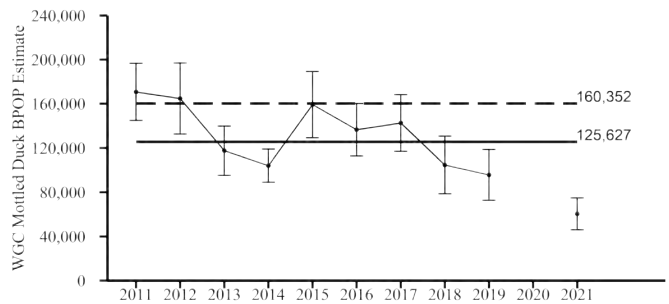


Figure 46. Long term average (solid line) and 80th Percentile (dashed line) of 2011-2021 WGC Mottled Duck Breeding Population Survey estimates for consideration of setting population objectives.

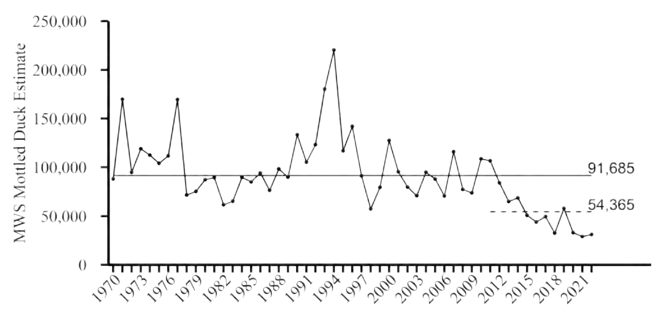


Figure 47. Disparity between the long-term average (1970-2022; solid line) and a contemporary average (2011-2022; dashed line) of mottled duck abundance from the Midwinter Waterfowl survey.

Population Objectives

The following statement represents new WGC mottled duck population objectives given current and historical abundance information followed by brief guidance for their functional application.

> ***Maintain spring mottled duck populations at an average (2011-2021 WGC Mottled Duck Breeding Population Survey) of 125,627 and periodically exceed 160,352 (80th percentile of 2011-2021 BPOP) with increased frequency and magnitude until the population sustains 211,865 (69% greater than 2011-2021 BPOP average) within the survey range.***

The mottled duck population objective statement characterizes a triad of objectives that accentuate the relative urgency with which habitat conservation for the species should be achieved. As a metric to evaluate population health and response-based success of all conservation measures, all 3 objectives are relevant, with a 5-year moving average being a desired assessment metric that minimizes impacts of short-term environmental perturbations.

Average – 125,627

The 2011-2021 average represents a minimal threshold below which population status is undesirable, indicating that habitat conservation should be pursued with the highest possible level of urgency. Given the timing of objective establishment at a time of declining mottled duck abundance to record lows, reversing the trajectory and rebounding populations to this level is moderately aspirational in the short term.

80th Percentile – 160,352

The 80th percentile represents a desired population status that is more aspirational than the average while remaining within the range of abundance observed in the last decade. Population sizes below this objective, but above the average, indicate that habitat conservation should remain a very high priority. Given variability in annual population estimates over the past decade, achieving populations that equilibrate around the average should result in periodic abundance above the 80th percentile. As habitat conservation gains expand, achieving the 80th percentile more often and exceeding by a greater amount until average populations maintain at that level is aspirational over middle term.

Aspirational – 211,865

The most aspirational objective exceeds populations witnessed by the WGC MODU BPOP but is believed to be consistent with restoration of desired population levels articulated in the 2007 Plan, consistent with the historic (1970-2022 MWS) long-term average, thus fully representing conservation success. Populations below this level, but above the 80th percentile objective, are indicative that habitat conservation should remain a high priority, whereas levels above the threshold indicate that habitat conservation attention should be sufficient to maintain that status.

Triad objectives were intended to be inspirational, communicable, and allow appraisal of conservation status and success. As we continue to better understand the population-habitat relationship we will translate the population objective into a habitat objective. However, we do not advocate that the triad be used to develop respective habitat objectives. We intend that a single habitat objective be established using the aspirational population objective in unison with stakeholder desires.

State-specific Population Objectives

Attendees of the 2016 Mottled Duck Working Group Meeting were ambivalent regarding mottled duck population objective development for individual states (Figure 48). The population objective sub-team had additional discussion on the tradeoffs and reached consensus to calculate state-specific population objectives. State-specific objectives maintain applicability to state wildlife action plans, flyway councils, and USFWS regions. Moreover, establishment of state-specific population objectives will be helpful for eventual translation of population objectives to habitat demand at the Initiative Area scale.

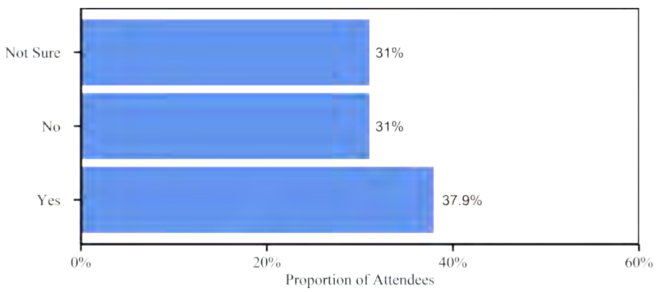
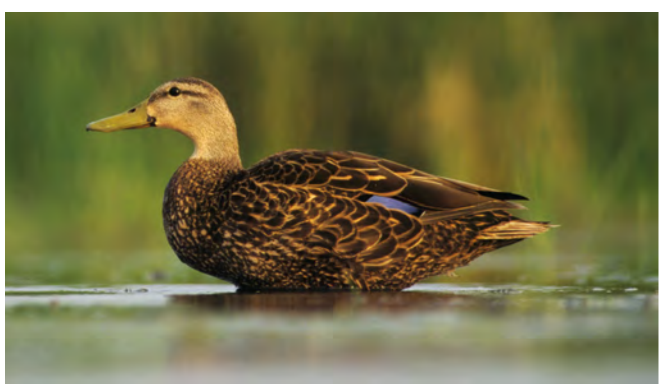


Figure 48. Mottled duck working group (*n* = 29) opinion of whether state-specific population objectives were essential.

Calculation of state-specific objectives followed a top-down approach such that WGC population objectives (outlined above) were first calculated using the entire WGC BPOP dataset and then state-specific objectives were derived using the mean proportional contribution of each state to the WGC BPOP across the 2011-2021 time period (Table 6). The resulting triad population objectives in Texas are 64,324; 82,104; and 108,480 (Figure 49) and in Louisiana 61,303; 78,248; and 103,385 (Figure 50). The WGC population objective established in the 2007 Plan was developed using MWS data that included estimates from coastal Mississippi and Alabama. However, the BPOP Survey only includes coastal portions of Louisiana and Texas (Figure 45). Therefore, extending BPOP-based WGC population objectives to Mississippi and Alabama would require extrapolated estimates using relative mottled duck abundance among states (Lancaster et al. 2021). Given there would be no survey data to evaluate population status relative to an objective and Mississippi and Alabama contain a relatively small portion of the entire WGC population, we did not pursue methodology to extrapolate population objectives to Mississippi and Alabama. If the lack of mottled duck population objectives for the Coastal Mississippi-Alabama Initiative area or its respective states becomes perceived as a significant barrier in the future, we will revisit the decision.

Table 6. Proportional distribution of mottled duck abundance from the 2011-2021 Western Gulf Coast (WGC) Mottled Duck Breeding Population Survey.

Year	TX	LA	WGC	TX%	LA%
2011	75,798	94,964	170,762	44.4%	55.6%
2012	65,830	98,915	164,745	40.0%	60.0%
2013	40,970	76,605	117,575	34.8%	65.2%
2014	46,257	57,850	104,107	44.4%	55.6%
2015	99,737	59,517	159,254	62.6%	37.4%
2016	82,968	53,494	136,462	60.8%	39.2%
2017	49,369	93,237	142,606	34.6%	65.4%
2018	77,729	26,949	104,678	74.3%	25.7%
2019	65,179	30,459	95,638	68.2%	31.8%
2021	28,980	31,460	60,440	47.9%	52.1%
			Average	51.2%	48.8%



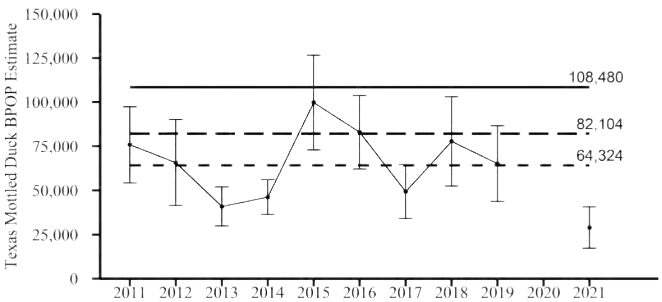


Figure 49. Annual Western Gulf Coast Mottled Duck Breeding Population Survey estimates for Texas with state-specific triad population objectives.

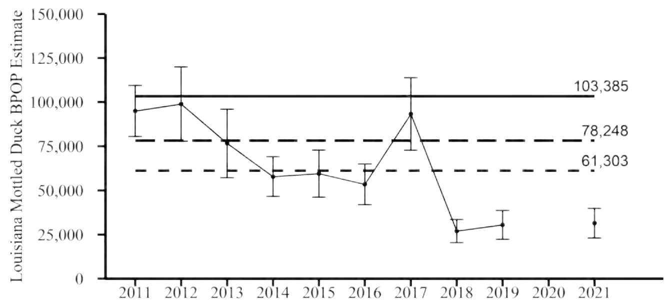


Figure 50. Annual Western Gulf Coast Mottled Duck Breeding Population Survey estimates for Louisiana with state-specific triad population objectives.

HABITAT CONSERVATION AND MANAGEMENT FOR MOTTLED DUCKS

Mottled ducks require a diversity of upland and wetland types to satisfy their annual cycle needs. Wetlands are vital for meeting foraging demands, providing areas for pair formation and isolation, stimulating annual breeding efforts, serving as brood-rearing and molting habitats, and otherwise providing areas for refugia, loafing, and other activities. Mottled ducks primarily construct their nests on the ground, and thus rely on uplands, including grasslands and infrequently flooded coastal vegetation, as the primary source of nesting habitat. Within these two broad categories of habitat types—wetlands and uplands—site selection and habitat use by mottled ducks varies across periods of the annual cycle and in response to local- and landscape-scale characteristics. Among the different resources provided by habitats used by mottled ducks, those that most directly affect recruitment are considered to be of highest priority for conservation and management.

Mottled ducks rely on a diversity of upland and wetland habitat across the annual cycle to survive and reproduce.

The loss and conversion of expansive native prairie and coastal wetlands from the Western Gulf Coast landscape has severely reduced its capacity to support a robust population of mottled ducks. Thus, protecting and managing the remaining grasslands and wetlands to provide high quality habitat for mottled ducks must be a priority for regional waterfowl managers and state and federal wildlife agencies. Additionally, because public land represents only a small percentage of the WGC landscape, sustaining a healthy population of mottled ducks requires programs and activities that encourage and enable conservation on private lands.

This chapter describes the current understanding of preferred habitat characteristics that support annual cycle requirements of mottled ducks and recommends conservation and management actions likely to benefit mottled ducks. In a previous chapter, we detailed potential population limiting factors impacting survival and recruitment with supporting citations, however, we limited our use of citations in this chapter to increase readability. Mottled duck habitats of the WGC occur primarily in two broad landscapes: 1) permanent or semipermanent palustrine and estuarine coastal marsh (hereafter coastal marsh), and 2) inland regions dominated by agriculture, pasturelands, seasonal wetlands, and intensively managed wetlands (hereafter agricultural landscape). Because of differences in habitat characteristics, conservation challenges, and management options between these landscapes, descriptions and recommendations in this chapter are presented separately for coastal marsh and agricultural landscapes. Also included is a discussion of existing conservation programs and potential new opportunities for conserving and enhancing habitats to support mottled ducks.

Wetlands

Wetland types most frequently used by WGC mottled ducks include fresh and intermediate coastal marsh ponds, natural or intensively managed freshwater wetlands, and agricultural-based wetlands associated with rice production and permanent crawfish aquaculture. While wetlands satisfy a diversity of resource requirements throughout the annual cycle, their role in supporting breeding activities should be the primary basis for conservation and management decisions. Thus, recommended wetland characteristics and actions herein reflect current knowledge of mottled duck habitat use during the pre-breeding and breeding periods and are those believed to be important for enhancing breeding propensity, nest success, renesting, and brood survival.

Within both coastal and agricultural landscapes, there are several basic requirements to provide quality wetlands for breeding mottled ducks, beginning with availability of suitable wetlands at times and locations to stimulate breeding. Breeding propensity is believed to vary in relation to wetland availability during late winter and spring as pairs prepare for nesting, and hens may forego nesting altogether when wetland conditions are poor, such as that caused by widespread drought. Mottled ducks begin prospecting for suitable nest sites as early as late February or early March, so managers should seek to ensure abundant surface water is available during this time span and continuing through the breeding season to ensure habitat remains available for brood-rearing and molting. Salinity is an important determinant of wetland suitability, as mottled ducks prefer freshwater wetlands, whether in coastal marsh or agricultural landscapes, although they will also use intermediate and brackish coastal marsh ponds. While broods have been observed using intermediate and brackish wetlands, salinity levels above 9 ppt may impair duckling growth. Thus, managers should promote salinity levels < 9 ppt where water management infrastructure allows. Proximity of wetlands to suitable nesting habitat is also an important consideration for promoting breeding activities and reducing mortality risks from extensive overland travel by newly hatched broods. Although broods may successfully travel >2 miles

Quality mottled duck brood-rearing wetlands are within 1-mile of nesting habitat, are shallow with salinity <9 ppt, contain emergent or submerged aquatic vegetation to support invertebrate production, and contain patches of dense emergent vegetation for escape cover.

from nest site to their first brood wetlands, shorter travel distances are generally considered to present fewer risks. It is currently recommended that breeding pair and brood-rearing wetlands be within 0.25 – 1 mile of upland nesting habitat (see upland section).

Wetlands for breeding pairs and broods should generally be characterized by shallow water (< 18”) with emergent vegetation covering 30–70% of the water surface. However, shallower depths (< 6”) may be more beneficial during the brood-rearing stage, especially in the coastal marsh landscape, by reducing places where aquatic predators (e.g., alligators) could hide. During the brood-rearing period, wetlands containing mudflats, submerged aquatic vegetation that supports an abundance of aquatic invertebrates, and patches of dense escape cover are considered ideal. Specific characteristics of wetlands to support mottled ducks during the breeding season, including pre-breeding, nesting, and brood-rearing are presented in Table 7.

Table 7. Recommended characteristics for wetlands to support mottled ducks during the breeding season, including pre-breeding, nesting, and brood-rearing.

Wetland Characteristics for Breeding Mottled ducks
Seasonal, semi-permanent or permanent wetlands, coastal marsh, flooded rice field, or permanent crawfish pond
Surface water available mid-February–July
Within 1 mile of nesting habitat
Salinity less than 9 ppt
Water depths <18” with short (<12”) emergent vegetation covering 30–70% of water surface or submerged aquatic vegetation supporting abundant aquatic invertebrates
Patches of dense emergent vegetation to provide escape cover for ducklings

Wetlands are also essential for providing safe habitat for mottled ducks while undergoing wing molt during late summer. During this period, mottled ducks are flightless for approximately 27 days, and are vulnerable to mortality from aquatic predators. Characteristics of wetlands used for molting are similar to those used during other periods of the breeding season, including permanent or semi-permanent water regimes with water depths of 6–18 inches, emergent and submerged aquatic vegetation to support aquatic invertebrate populations, and areas of dense emergent vegetation that serves as escape cover from predators. Wetlands should be free from deep water areas that might provide habitat for aquatic predators. During drought, natural and managed wetland sites that hold water through late summer are particularly valuable as large numbers of molting mottled ducks may concentrate in response to decreased wetland availability. Survival during molt has not been shown to be a limiting factor for mottled duck population growth, and thus should not be the primary determinant of wetland conservation and management for WGC mottled ducks.

Uplands

While wetlands provide abundant resources needed by mottled ducks throughout the annual cycle, nesting occurs primarily in infrequently flooded coastal marsh and uplands near wetlands. Mottled ducks have a protracted breeding season with most nesting occurring March – May, although annual variation results from differences in temperature and precipitation. Events that occur during the breeding season are thought to have the greatest impact on population growth rates, making quality nesting habitat a conservation priority.

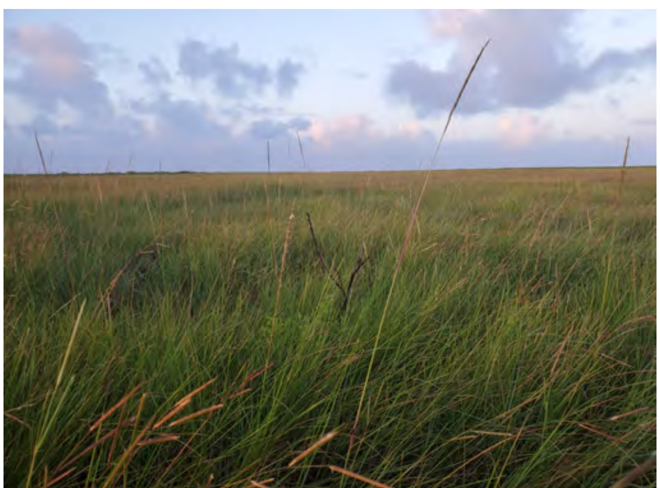
Mottled ducks nest in dense herbaceous vegetation in coastal and inland regions of the western Gulf Coast.

Mottled ducks nest in numerous landcover types across their range including spoil islands, river levees and canal banks, cattle pastures, deltaic islands, old fields, emergent marshes, idle rice fields, and crawfish aquaculture levees. Important characteristics of selected nest sites include vegetation structure and composition, patch size, and proximity to suitable wetlands for pairs and broods. Nest sites appear to be selected to reduce effects of the predominant causes of mottled duck nest failure—depredation and flooding. The mottled duck nest predator community is diverse and includes mammals, birds, and reptiles, though raccoons are the most common predator of mottled duck nests. Mottled ducks avoid nesting in locations subject to regular tidal inundation, but nests located in other low-lying areas are subject to flooding from heavy rainfall or untimely water management decisions. In some instances, females may add material to elevate the nest and avoid flooding from elevated water levels. Mottled ducks in southwestern Louisiana have been documented nesting successfully in fresh marsh by creating overwater platforms in dense clumps of giant cutgrass (*Zizaniopsis miliacea*). It is unclear how widespread this nesting strategy is, but it is considered rare. Given widespread availability of emergent marsh, this phenomenon should not form the basis for habitat conservation and management actions.

Priority conservation and management actions in uplands can increase the availability of suitable landcover types containing vegetation structure that improve nest success. Actions that are likely to reduce predation include maintaining large patches of dense herbaceous vegetation of moderate height that provide overhead concealment of nest sites. In inland remnant prairie, successful mottled duck nests have been attributed to a diversity of vegetation species that

Large tracts of grassland containing a diverse mix of moderately dense herbaceous vegetation approximately knee high with little to no woody enchroachment is ideal for mottled duck nesting.

increase nest concealment through vertical and horizontal layering of interlaced live and dead vegetation. Native bunch grasses provide horizontal and vertical structure while leaving space at ground level allowing broods to efficiently travel from nest site to brood-rearing wetlands. Large tracts of homogenous landcover with a high species and structural diversity are ideal, but small fields containing suitable vegetation structure may still be used. Bonczek (2022) reported mottled duck nests in a range of patch sizes (0.6–2,831 ha; avg 515) but found the average patch size of old fields, the most selected landcover type by nesting mottled ducks in southwestern Louisiana, was only 14 ha (35 ac). Regardless, greater patch size reduces predation risk by limiting predator search efficiency and allowing female mottled ducks to select preferred microhabitats to establish nest sites (Table 8).



Marshhay cordgrass (*Spartina patens*) is a quality nesting habitat in coastal environments.

Topography within nesting patches may be an important upland component that allows females to select nest sites at elevated locations that are less flood prone. Durham and Afton (2003) found mottled duck females selected pastures with knolls over similar flat landcover types, suggesting females selected for higher elevation sites. Bonczek (2022) reported elevations between 0–6m at nest sites across used landcover types, but elevation at nest sites was similar to reference sites. In coastal marsh, minor differences in elevation influence the frequency and duration of flooding, which also impacts the vegetation community. Elevated ridges in coastal environments that do not receive periodic inundation or other forms of disturbance can become dominated by woody vegetation. In the Atchafalaya and Mississippi River Deltas, mottled ducks did not avoid nesting in areas containing woody vegetation but experienced reduced nest success. However, ideal marsh ridges and uplands habitats are absent of or have a minimal coverage of woody plants.

Table 8. Recommended nesting habitat characteristics for mottled ducks in coastal and agricultural landscapes of the Western Gulf Coast.

Coastal	Inland
Irregularly flooded high marsh or prairie ridges within fresh, intermediate, or slightly brackish complexes and early successional deltaic or spoil islands	Permanent native pasture, rangeland, and idled or old rice fields
Herbaceous cover (e.g., *Spartina patens*, *Spartina spartinae*, *Distichlis spicata*, *Borrichia frutescens*); prairie ridges may contain species similar to inland	Abundant mixture of bunch grasses (e.g., *Paspalum* sp., *Schizachyrium scoparium*, *Andropogon* sp., *Dichanthelium acuminatum*)
Within 1 mile of a suitable brood-rearing wetland(s)	
Moderately dense mix of living and senescent herbaceous cover, knee to waist high ($\geq$20”), that doesn’t impede walking	
Patch size of 500–1000 acres are ideal, preferably no smaller than 40 acres	
Absent or minimal dispersed woody plants (less than 5% coverage, 1-m tall)	

Exemplar Mottled Duck Breeding Landscapes

Landscapes that contribute to mottled duck recruitment contain large tracts of nesting habitat and brood-rearing wetlands within 1-mile of each other. The following aerial photos depict quality breeding landscapes found within the western Gulf Coast. Each example is depicted with an oblique optical image on the left and areas of quality nesting and brood-rearing habitat are highlighted on the right.

Legend:

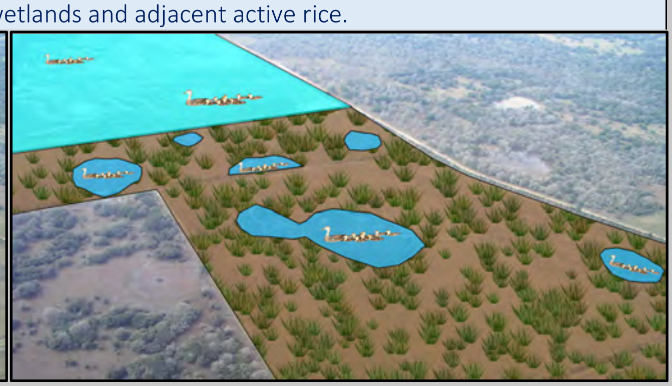

Nesting habitat


Wetland brood-rearing habitat


Riceland brood-rearing habitat

Deltaic islands with adjacent emergent wetlands in the Atchafalaya Delta, Louisiana.


Old rice field with embedded wetlands and adjacent active rice.

Coastal prairie with embedded wetland.

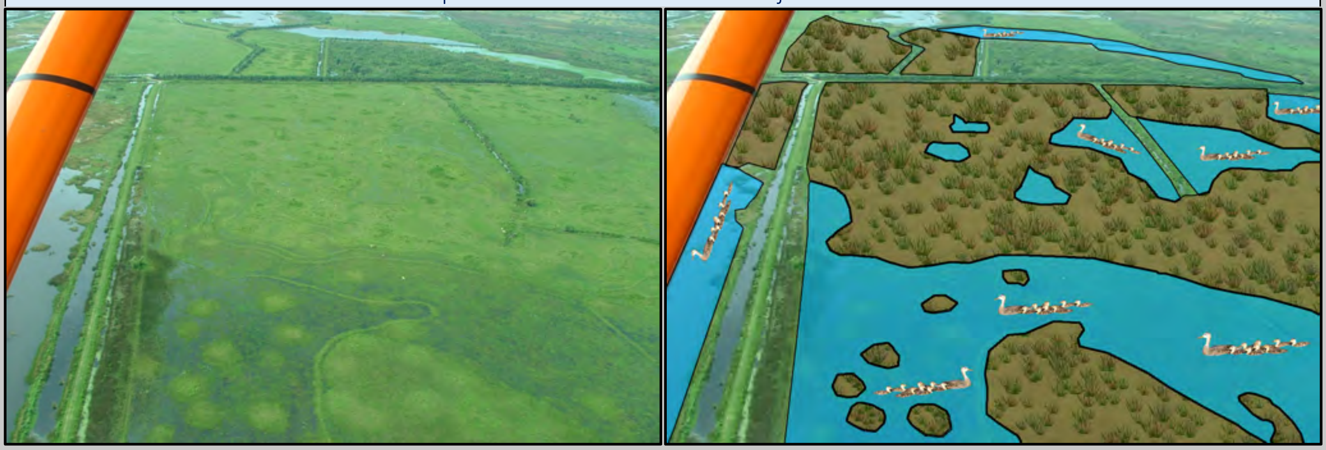

Legend:


Nesting habitat

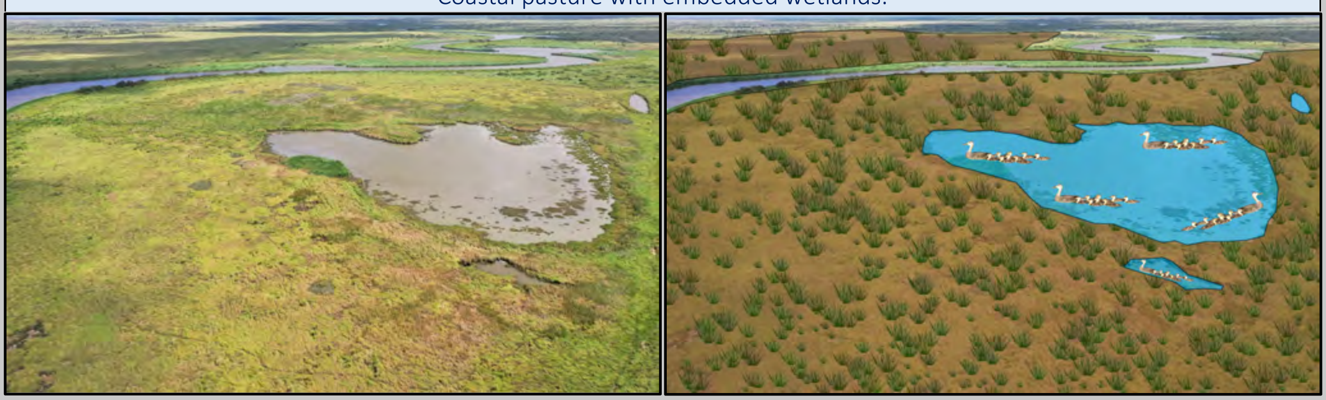

Wetland brood-rearing habitat


Riceland brood-rearing habitat

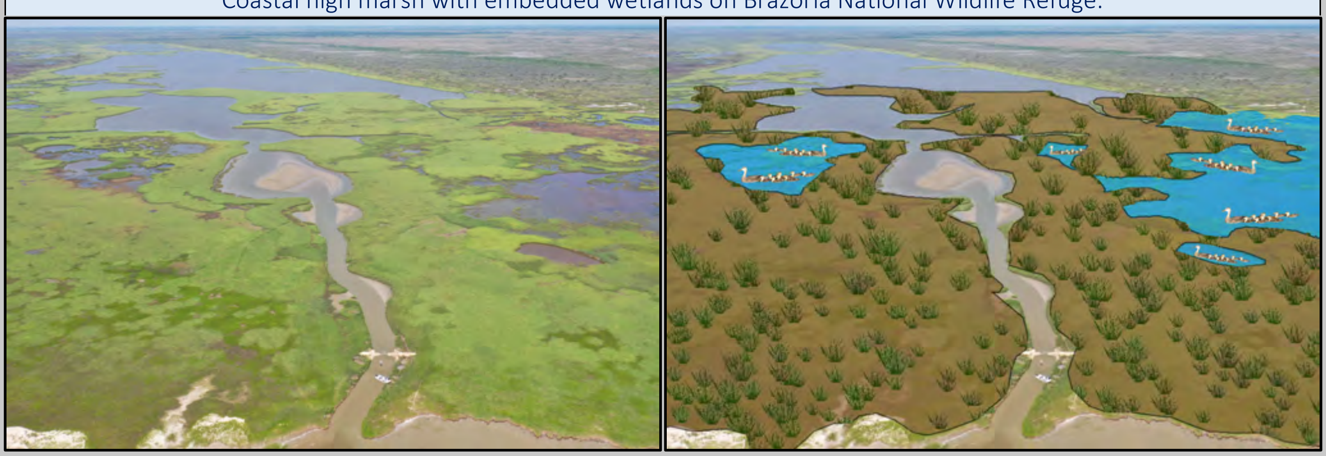
Cattle pasture with embedded and adjacent wetlands.



Coastal pasture with embedded wetlands.



Coastal high marsh with embedded wetlands on Brazoria National Wildlife Refuge.



Compatibility with Existing Land Use

Continuous management for mottled ducks may not be practical in all situations, but opportunities exist to increase habitat availability when and where land use conflicts are minimal. Within existing land use such as rice cultivation, cattle production (native and permanent pasture), and impoundments managed for wintering waterfowl, minor adjustments in management practices can increase suitability for breeding mottled ducks.

Rice Cultivation – Rice production on the Texas Coast generally follows a 2- or 3-year rotation. That is, a field cultivated for rice in one growing season is planted in an alternative row crop, grazed, or left fallow the following 1 to 2 growing seasons. In Louisiana, rice production follows a 2-year rotation and similar practices are implemented during fallow years with the addition of crawfish production (see next section). The spatial arrangement of rice fields in varying stages of rotation can provide a complex of vegetative conditions that benefit mottled ducks. Active rice fields provide surface water from April through mid-July, which can serve as surrogate wetlands for mottled duck pairs and broods. Grasses and forbs growing in dried fallow fields can provide nesting cover of moderate quality (especially the 2nd fallow year) if activities that manipulate vegetation (e.g., disking) are delayed through July. Grazing of rice fields after harvest should be delayed initially to allow for establishment of nesting cover (grasses) and then cattle may be introduced at a low stocking rate outside of the primary nesting season. Although mottled duck nests have been located in idle rice fields in Louisiana, the traditional 2-year rice rotation reduces the quality of idled fields as nesting habitat because there is less time for grasses to grow and provide adequate visual obstruction (Bonczek 2022).

Fallow rice can provide moderate quality nesting vegetation, especially in the second year.

Crawfish Aquaculture – Commercial crawfish production is commonplace in the Louisiana Chenier Plain (~250,000 acres) and to a lesser extent the Texas Chenier Plain (~9,500 acres). Crawfish production strategies vary, but generally include crawfish in rotation with rice or monocropping crawfish in dedicated fields. In a rotation system, rice is grown and harvested as usual, and fields are reflooded to promote rice regrowth which forms the forage base for crawfish. Farmers may grow soybeans or leave fields fallow following crawfish harvest, or in limited cases, rice may be grown annually. Flood regimes vary by production strategy, but crawfish fields are generally flooded from November through April at a minimum (Sep.-Jun. in a crawfish monocrop, Sep.-Apr. in rice-crawfish-rice rotation, and Oct.-Jun. in rice-crawfish-soybean/idle rotation). Crawfish harvest activities may limit the quality of impoundments for mottled ducks, although scientific evidence is currently lacking. Crawfish harvest typically occurs 2-4 days per week from Dec.-Feb. and 3-7 days/week from Mar.-Jun. depending on crawfish catch rates and markets. Flooded crawfish impoundments may encourage breeding in landscapes with suitable nesting habitat, and mottled ducks have been documented nesting on crawfish pond levees. However, some crawfish impoundments are dewatered in mid-summer, which may create an ecological trap for broods if other wetlands are unavailable nearby. Flooded rice fields or other wetlands available nearby may lessen any adverse effects of this activity if females can move broods a short distance to an alternative wetland. Some monocropped crawfish impoundments remain flooded annually and resemble persistent emergent marsh with vegetation and open water ratios well suited for mottled duck brood-rearing. Crawfish ponds are typically flooded 8-24 inches deep with the upper threshold exceeding that preferred for brood-rearing habitat. However, the seasonal nature of most crawfish impoundments probably limits residency by alligators, a primary driver of the shallow wetland recommendation.

Semi-permanent crawfish ponds form dense emergent vegetation and hydroperiod that can provide quality mottled duck brood-rearing habitat.

Pasture Lands – Permanent cattle pasture, comprised of native or introduced vegetation, is a prominent land use along the western Gulf Coast. Pasture lands that are adjacent to or contain wetlands suitable for pre-breeding and brood-rearing have potential to provide nesting habitat for mottled ducks. The quality of nesting cover is greatest in pastures that are lightly grazed or have been deferred for a period before and during the mottled duck nesting season. Thus, appropriate stocking rates and rotating cattle among pastures that allow for periods of rest between grazing can sustain healthy forage conditions and promote quality mottled duck nesting cover. Additionally, native warm-season grasses are adapted to grazing, are resilient to periods of drought, and do not require fertilizer, making them cheaper to maintain than introduced non-native grasses. Appropriate brush management can increase foraging area for cattle while also improving conditions for mottled duck nesting, reducing predation risk, and providing habitat for other grassland species. For hay fields where mottled ducks are suspected to nest, cutting should be delayed until mid-June or July when most mottled ducks have completed nesting and broods have moved to nearby wetlands.

Deferred grazing or low stocking rates can produce grassland vegetation density and height that improves the quality of mottled duck nesting habitat.

Managed Impoundments – Developed wetland units, which are generally managed to benefit migratory waterfowl in winter, have potential value for breeding mottled ducks.

However, the common practice is to drain wetland units at the end of winter as migratory waterfowl depart the region. Keeping water control structures closed and maintaining water levels through spring can provide wetlands for mottled duck pairs during the early part of the breeding season. Where impoundments are adjacent to suitable nesting habitat, land managers should consider capturing water from rainfall through mid-summer to continue providing habitat for ducklings. Managing spring and summer water for mottled ducks can be rotated (every other year or every 2 years) with traditional moist-soil management practices during the growing season for migratory waterfowl. Incorporating topographic diversity has the potential to sustain flooded habitat for mottled ducks in a portion of the impoundment even as the remainder is seasonally dewatered to induce moist-soil vegetation.

Programmatic Habitat Delivery

Wetland and upland conservation for breeding mottled ducks necessitates a collective effort across public and private lands in the western Gulf Coast. Although several existing conservation strategies have proven useful, additional novel approaches will likely be needed to increase the quantity and quality of mottled duck breeding habitats at meaningful scales. On private lands, cost-share or incentive-based programs provide important assistance to landowners for restoring and maintaining uplands and wetlands in suitable condition. For example, achieving suitable vertical and horizontal grass cover in currently overgrazed pastures would require a reduction in grazing pressure and resting certain pastures on a rotational basis during the mottled duck breeding season. Thus, landowners will likely need to be compensated for economic opportunity costs (i.e., lowered stocking rate) incurred by implementing management practices that increase habitat quality for breeding mottled ducks.

Partner Priorities – At the 2016 Mottled Duck Working Group meeting, participants recognized the need for accelerated mottled duck conservation efforts in the western Gulf Coast. Most participants have seen greater recognition of mottled duck conservation needs within their organizations over the past 15 years, but only half have increased implementation of practices that focus on conservation of the species (Figure 51). Still, about one-third of participants suggested that their organization does not devote sufficient attention to mottled duck conservation issues (Figure 52).

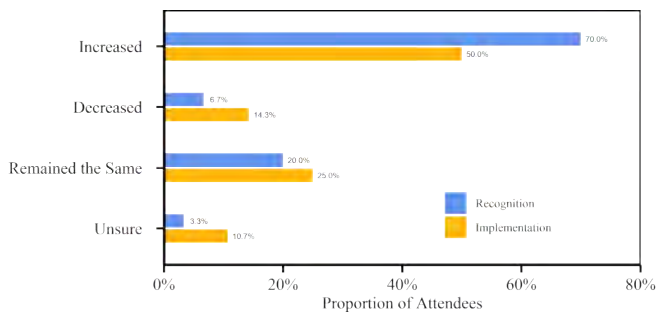


Figure 51. Mottled duck working group (n = 30) assessment of the recognition (blue) and implementation (yellow) of mottled duck conservation needs over the past 15 years within their organization.

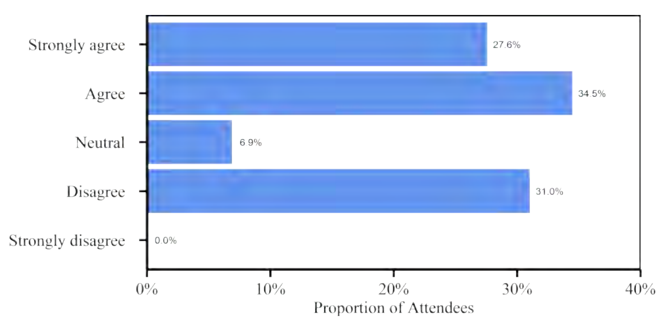


Figure 52. Mottled duck working group (n = 28) appraisal that their organization gives appropriate attention to mottled duck conservation in the western Gulf Coast.

Existing Conservation Programs – Numerous voluntary assistance programs are available to private landowners or managers to increase the quantity and quality of mottled duck breeding habitats on working and recreational lands. These programs provide technical and financial assistance for implementing conservation practices and activities that improve ecosystem function and wildlife habitat quality while typically improving agricultural operations or recreational opportunities.

Several conservation programs use cost-share agreements to focus on expanding, preserving, and improving grassland conditions across the WGC, including the Gulf Coast Joint Venture's Coastal Grasslands Restoration Incentive Program (C-GRIP) and the Natural Resources Conservation Service's (NRCS) Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP). Among conservation practices, the ones most applicable to improving mottled duck breeding habitat include those that (re-)establish grassland cover (e.g., native warm season grasses) or encourage and enable seasonally appropriate prescribed fire, prescribed grazing, and mechanical or herbicidal brush management. The Farm Service Agency's Grassland Conservation Reserve Program (CRP; formerly Grassland Reserve Program) uses 10-15-year conservation easements to protect grassland and pastureland at greatest risk for conversion while continuing to allow grazing. Additionally, lands enrolled in the grassland CRP can continue using cost-share practices to protect and maintain the health of the grassland or pastureland for the duration of the easement.

Increased availability of mottled duck brood-rearing wetlands can be achieved through several conservation programs including Ducks Unlimited's Texas Prairie Wetlands Project, Louisiana Waterfowl Project, Louisiana Mottled Duck Project, and the Natural Resource Conservation Services' EQIP and Wetlands Reserve Easement (WRE). The Texas Prairie Wetlands Project and Louisiana Waterfowl Project are chiefly aimed at improving water management capabilities and assisting landowners with new or repaired infrastructure, whereas the Louisiana Mottled Duck Project is a novel conservation program that incentivizes landowners to manage wetland units to provide mottled duck brood-rearing habitat during summer. The WRE has been infrequently implemented in the GCJV geography but can be used to establish 30-year or perpetual conservation easements and cost-share restoration of private farmland or previously converted wetlands. Most existing wetland conservation programs, with exception of the Louisiana Mottled Duck Project, assist with infrastructure but do not incentivize holding water during the mottled duck breeding season.

Several programs have provisions for conserving wetlands and uplands, including the USFWS's Partners for Fish and Wildlife and

The Texas Prairie Wetlands Project improves wetlands on private lands for mottled duck brood-rearing when implemented within 1 mile of grassland nesting habitat.

Coastal Programs and the Texas Rice Coalition for the Environment (TX R.I.C.E). All three programs have a history of working on public and private lands. Texas R.I.C.E. has worked with public and private landowners to increase management capabilities on active and abandoned rice fields for wetlands management while also reestablishing native grassland on former coastal tallgrass prairie. In addition to voluntary private landowner incentive programs, other strategies have been successful in restoring and protecting existing mottled duck breeding habitats. For example, conservation partners can seek funding through a Regional Conservation Partnership Program (RCPP) grant to co-invest in the delivery of NRCS practices on private lands to address specific local resource concerns. RCPPs sometimes include special allowances such as removal of adjusted gross income cap that can increase landowner eligibility, and the dedicated funding can accelerate delivery of conservation practices in programs that currently have long waiting lists. For habitats in peril, fee title acquisition or establishment of conservation easements can perpetually protect a habitat from conversion.

Habitat Risk and Challenges to MODU Conservation Delivery

Landscape changes threaten the quality and persistence of habitats that support breeding mottled ducks in the WGC. Sea-level rise and urbanization are directly impacting the quantity and quality of breeding habitat, and these are expected to continue in the future. Moreover, additional factors such as changing landowner demographics, renewable energy development, invasive species, and future population status will create new challenges to conserving and managing for mottled ducks.

Sea-level rise is projected to have profound effects on the extent of freshwater coastal marsh preferred by breeding mottled duck across much of the WGC (Moon et al. 2021). Projected conversion and loss of irregularly flooded marsh habitats at a minimum will force mottled ducks inland and may negatively affect landscape carrying capacity for the species. One of the most important regions for mottled ducks, the Chenier Plain, is expected to suffer the greatest loss of preferred marsh types. Significant loss of fresh and irregularly flooded marsh will likely occur as sea-levels rise and few opportunities are available for marsh zones to migrate inland. This phenomenon, known as coastal squeeze, occurs when intertidal habitats are lost due to the high-water mark being fixed by a defense or structure and the low water mark migrating landward in response to sea-level rise (Pontee 2013).

The Gulf of Mexico coast has the fastest growing population of any coastal region in the United States, experiencing a 26% population increase from 2000-2017. Coastal population growth in the WGC has brought with it expansive urban development and increased fragmentation of remaining working lands. Texas' population increased 48% from 1997-2017, with largest increases in urban centers such as Houston, which alone increased 59% (U.S. Census Bureau 2018). The growth of Houston resulted in an additional >2,000 km^2 of development between 1997-2017 at the expense of forest, cultivated crops, grasslands and pasture, and wetlands (Hakkenberg et al. 2018). Beyond direct impacts from habitat loss and degradation, urbanization has increased surrounding land values, which makes conservation easements and fee title acquisitions increasingly expensive, thereby increasing the risk of conversion.

As a result of population growth, urban expansion, and record levels of intergenerational land ownership transfer, there has been an overall decrease in farm size and increase in smaller acreage farms in Texas (Smith et al. 2019). Because landowners with more acreage generally experience greater profitability, they are likely in better financial position to undertake conservation practices on a portion of their property with less economic cost. With 40% of landowners >65 years of age, there will likely be an even greater intergenerational land transfer in the next decade. This occurrence may increase conservation challenges as first-time farmers and ranchers often lack experience or a connection with the land, which may lead to decisions that reduce the quantity and quality of wildlife habitat. On the other hand, opportunities may exist to expand engagement with first-time farmers and ranchers through government assistance programs (e.g., EQIP) which now contain special funds and other provisions for historically underserved or first-time farmers and ranchers.

Portions of the western Gulf Coast are undergoing substantial expansion of renewable energy development due to suitable wind and solar conditions and proximity to large population centers. Along the Texas coast, solar facilities capable of producing more than 23,700 megawatts (MW) of energy were proposed as of September 2022 (Electric Reliability Council of Texas 2022;Figure 53). The likelihood of construction for proposed projects is varied, but in the past, more proposed solar projects have been canceled or became inactive than gained ultimate approval (Morse et al. 2022). Regardless, with an estimated 5-10 acres of panels and associated equipment required per MW generated (Ong et al. 2013), 118,000-237,000 acres are at risk of conversion from existing land use practices to solar farms, with pastureland as the landcover most likely to be impacted. It is unknown whether mottled ducks would use wetlands and grasslands for nesting or brood-rearing within land converted to renewable energy development. In many cases, solar facilities are fenced, which may restrict brood movements to adjacent wetlands. Wind turbine farms may also pose a risk to mottled duck breeding habitats. While research on potential consequences of wind generation to mottled ducks is lacking, studies from the Prairie Pothole Region of North and South Dakota found an average 21% reduction in duck breeding pair density on wetlands in sites with wind energy development (Loesch et al. 2013). Moreover, wind farm development decreased redhead abundance by 77% on freshwater wetlands adjacent to the Laguna Madre (Lange et al. 2018). Landowner incentives for incorporating renewable energy development make it extremely difficult for conservation programs to compete in the current market.

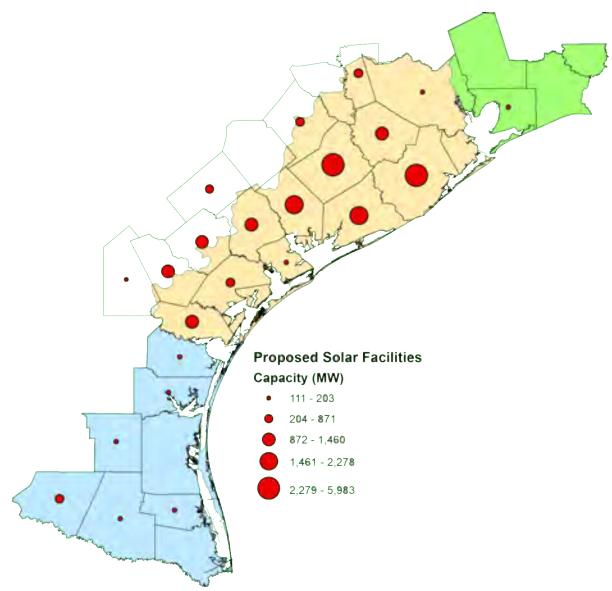


Figure 53. Relative megawatt (MW) capacity of proposed solar photovoltaic facility grid connections in Texas Gulf Coast Joint Venture Initiative Areas, September 2022 (Electric Reliability Council for Texas 2022).

Invasive species reduce habitat quality, discourage landowner participation in conservation activities, and increase costs and complexity of maintaining habitat conditions for breeding mottled ducks. In Louisiana, rice producers prefer that idled fields remain dry (as opposed to providing spring/summer brood-rearing habitat) over concerns that summer flooded fields harbor and proliferate apple snails and promote growth of aquatic weeds. Apple snails have been documented to decimate rice seedlings, though predominant planting practices in Louisiana have thus far limited apple snail impacts on rice production. However, for producers that rotate crawfish production, apple snails consume vegetation intended for crawfish and disrupt trapping efforts sometimes to an extent that fishing must be terminated and ponds drained early in the season. Water hyacinth (*Eichhornia crassipes*), alligatorweed (*Alternanthera philoxeroides*), and giant salvinia (*Salvinia molesta*) choke freshwater waterways and prevent growth of submersed aquatic vegetation that reduces suitability of wetlands for brood-rearing. Chinese tallow (*Triadica sebifera*) quickly invades coastal prairies and abandoned rice fields in Texas and Louisiana, displacing native vegetation and preventing restoration of historic prairie conditions. Deep rooted sedge (*Cyperus entrerianus*) is another invasive plant that invades disturbed areas and can rapidly spread to natural areas where it displaces native vegetation communities. Tools exist to combat these invasive species including pesticides, periodic disturbance (e.g., fire), biological control (e.g., Salvinia weevil), or a combination of these. However, combating invasive species once established can be difficult and costly, so efforts should also focus on preventing their spread and establishment.


Chinese tallow quickly invades abandoned rice fields and other recently disturbed areas, and its rapid growth reduces quality and eventually eliminates habitat for nesting mottled ducks.

Private lands represent a significant proportion of the WGC landscape, making voluntary habitat conservation, either through technical or financial assistance, essential for achieving mottled duck population objectives. Motivations for landowner participation in conservation programs are varied and generally include financial benefit, a desire to improve wildlife habitat quality, or a desire to increase yield of hunted species (Allen and Vandever 2003, Pfrimmer et al. 2017). Numerous barriers to landowner participation in conservation programs also exist, and we should recognize that increased protection of mottled ducks, such as through harvest closure or proposed for listing under the Endangered Species Act, would likely decrease landowner participation in voluntary conservation programs or possibly create perverse incentives to reduce habitat quality or quality (Lueck and Michael 2003, Langpap and Wu 2017, Byl 2019). Thus, future status decisions should be carefully considered and evaluated to ensure conservation measures are not negatively impacted.

Informed Conservation Delivery

The 2007 Mottled Duck Conservation Plan offered guidance on scientific research and development of tools to inform decisions on mottled duck habitat conservation and management. Two geospatial planning products were developed to assist managers in this regard, and herein we briefly introduce the tools and provide some guidance for their application.

Projected impact of sea-level rise and urbanization – Moon et al. (2021) modeled female mottled duck resource selection during the breeding season in association with projected sea-level rise and urbanization scenarios to visualize the quantity, quality, and distribution of future habitat for female mottled ducks in 20-year time steps out to 2100. Conversion of preferred freshwater marsh to salt marsh and eventually to open water was identified as a primary cause of mottled duck habitat loss. Although the model predicted a substantial increase in land development across the region, only in the Texas Mid-Coast did urbanization appear to be a significant threat to existing coastal wetlands. Overall, as coastal marshes become saltier and freshwater marsh attempts to migrate inland, they are likely to be impeded by modern infrastructure (e.g., risk reduction levees, roads, and navigational waterways). Loss of coastal fresh marsh will increase mottled duck reliance on inland seasonal and agricultural wetlands for breeding. **The geospatial tool should be used by managers to identify long-term conservation options to preserve current breeding habitat at high risk of loss or development.** The resist-adapt-direct (RAD) framework may be useful to prioritize areas where conservation actions have the greatest ecological effect on the quantity and quality of mottled duck habitat given often limited financial availability. The spatial layers depicted in Moon et al. (2021) may be particularly useful in identifying location for expansion of existing public lands (e.g., NWRs, State WMAs) and identifying other inland habitats to protect through easement or fee-title acquisition.

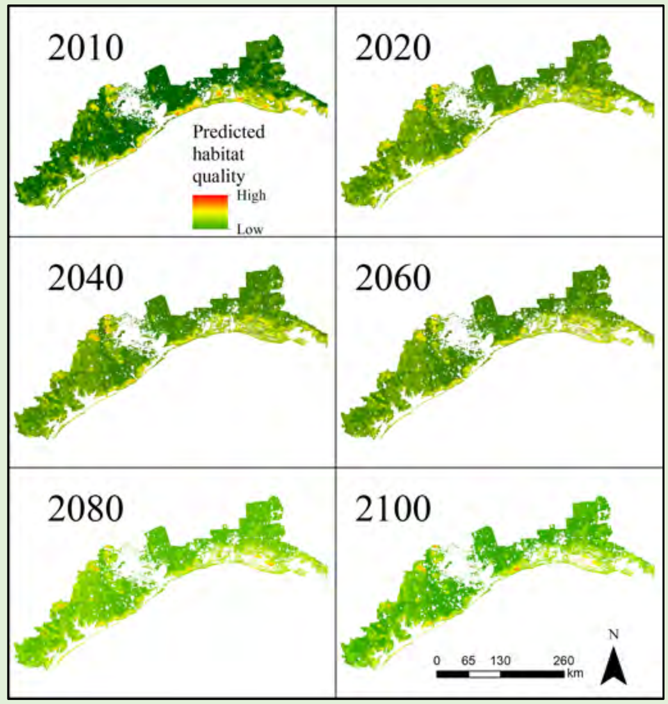


Figure 54. Projected habitat quality for female mottled ducks. Reproduced from Moon et al. (2021).

Access Moon et al. (2021) layers here.

Mottled duck decision support tool (DST) – Krainyk et al. (2019) developed a geospatial decision support tool incorporating current and historic remote sensing data to prioritize areas where management efforts can increase the quantity and quality of nesting and brood-rearing habitat for mottled ducks. The tool includes four spatial layers, including prioritization of; a) currently suitable nesting habitat, b) currently suitable brood-rearing habitat, c) wetland basins for freshwater enhancement, and d) areas for grassland establishment.

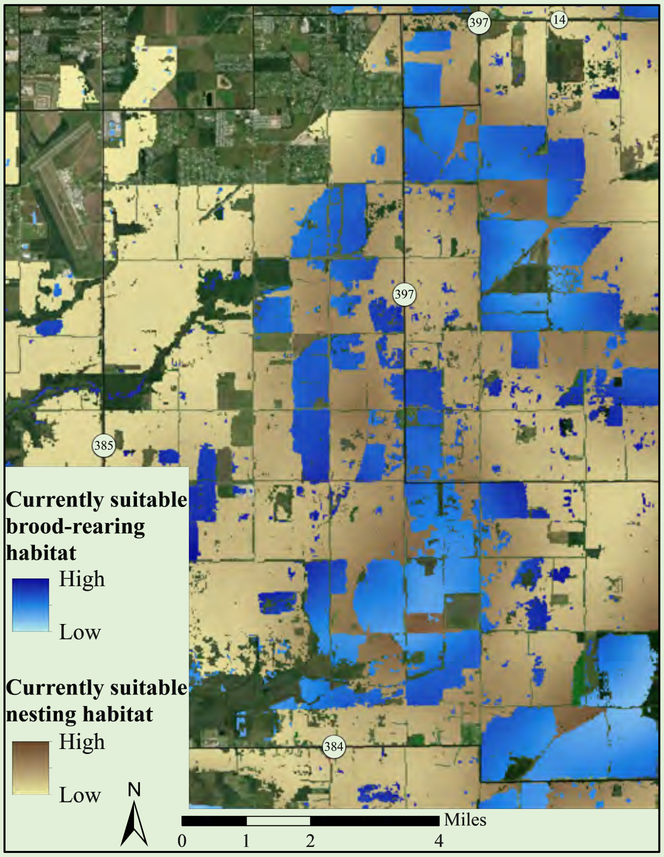


Figure 55. Currently suitable nesting and brood-rearing habitat southeast of Lake Charles, Louisiana identified by the mottled duck decision support tool.
Lake Charles Regional Airport located in top left of image.

In-field assessments of the tool by GCJV staff and partners revealed that the *currently suitable brood-rearing* layer and *wetland basins for freshwater enhancement* layers were generally an accurate depiction of current conditions. However, in nearly all cases, areas prioritized by the tool as *currently suitable nesting habitat* were determined to need active management of some form to enhance existing conditions. Specifically, most areas identified by the DST as *currently suitable nesting habitat* were considered too dense, overgrazed, or contained excessive woody vegetation. **The greatest utility of the DST is therefore to use the two currently suitable layers to identify areas where management actions (e.g., prescribed fire and reduced grazing pressure) could be focused to increase site conditions for mottled duck breeding.** The DST was deemed of limited utility in coastal areas where much of the *currently suitable nesting habitat* was also identified as wetland in need of enhancement.

Some areas visited that were not prioritized as *currently suitable grassland* or *areas for grassland enhancement* by the DST may be restored to quality nesting habitat with limited effort. One example included former grassland now infested with running live oak (*Quercus virginiana*) where herbicide (Spike) treatment followed by prescribed fire resulted in conditions suggestive of quality breeding habitat. In summary, the DST should not be expected to identify all sites relevant for conservation actions to benefit breeding mottled ducks, nor should it be used to inform delivery actions without competent field assessments of existing conditions.

Many areas identified by the mottled duck decision support tool as suitable nesting habitat are overgrazed and would require managing grazing pressure to increase vegetation height and density to support mottled duck nesting.

Access Krainyk et al. (2019) layers here.

Habitat Delivery Focus Areas

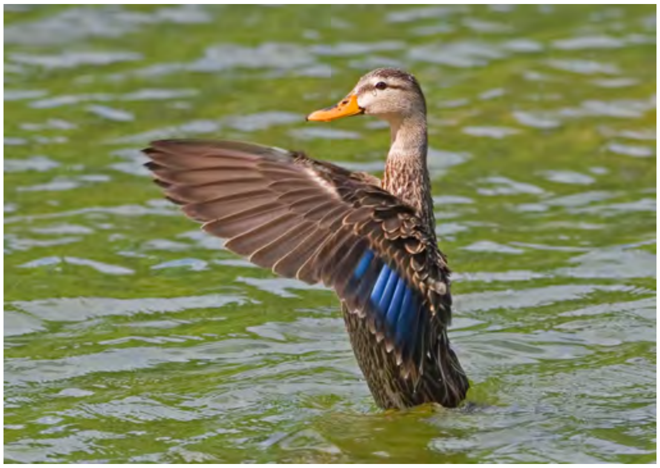
The current capacity to fund and deliver conservation for breeding mottled ducks is inadequate to maintain and enhance existing habitat, let alone restore lost habitat. Beyond the biologically based guidance offered by the decision support tools outlined above, the GCJV does not intend to identify focal areas for mottled duck conservation delivery. However, we acknowledge that in the development of specific conservation programs, partners may desire to identify focal areas to increase the efficiency of project delivery or to evaluate program success through an adaptive management framework (see next chapter). Thus, we provide some thoughts on sources of data that could be used to prioritize areas for program delivery. The currently suitable wetlands and nesting habitat layers from the mottled duck DST identify sites with requisite wetland and proximal grasslands that could be enhanced with limited financial investment. One approach would be to classify the currently suitable layers into percentiles and identify regions with the greatest densities of the high percentage pixels. Average abundance distribution from the WGC Mottled Duck Breeding Population Survey could also be used as a biological foundation for focal area development (Howell et al. 2022). Restoration cost and opportunity are also important considerations that may go into the selection of a program focal area. Thus, conservation planners looking to establish focal areas may consider regions that contain large amounts of perpetually protected land or locate regions with low ownership fragmentation which may improve landowner willingness to participate in conservation delivery programs. Moreover, program developers may choose to exploit synergies with conservation delivery efforts for species that share common desired landscape conditions, such as Attwater's' prairie chicken (*Tympanuchus cupido attwateri*), northern aplomado falcon (*Falco femoralis septentrionalis*), whooping crane (*Grus americana*), eastern black rail (*Laterallus jamaicensis*), and northern bobwhite (*Colinus virginianus*).

Accelerating habitat delivery

Staffing – Numerous conservation programs are already available to assist landowners with practices to improve site conditions for breeding mottled ducks. Accelerating conservation delivery and reversing the negative population trend will require a greater focus on practices and sites having greater likelihood of benefiting mottled ducks. Relying on existing programs and staff is unlikely to achieve the accelerated rate of delivery required. Instead, deliberate advocacy for and dedication to management actions that are not traditionally implemented across the WGC are needed. Leveraging conservation program delivery in coastal marshes may be more synergistic with other species conservation, but restoration of inland habitats requires dedicated staff. The Texas Prairie Wetlands Program provides an example where a dedicated staff member works nearly exclusively on securing funding and delivering targeted habitat for non-breeding waterfowl, and we believe this offers a useful model for hiring and supporting staff to work exclusively on habitat conservation to satisfy the annual cycle needs of mottled ducks.

Funding – Accelerated habitat delivery will require conservation funding in addition to the traditional sources that have been instrumental to mottled duck conservation to date (e.g., NAWCA, NRCS, state agency, and private industry). Opportunities for new funding may be available from recent federal funding bills, including America the Beautiful, Inflation Reduction Act, Infrastructure Investment and Jobs Act, and Partnership for Climate Smart Commodities. Tapping into these novel funding pools will require identifying climate friendly practices, resilient habitats, and invasive species removal that could simultaneously improve habitat for mottled ducks. Most available funding is derived from federal sources, creating additional considerations and potential limitations to landowner involvement. Thus, sources of non-federal funds will also be important as match for federal grants and to expand programs that rely on availability of non-federal funds, such as the C-GRIP in Texas and Louisiana. One possible approach is to establish a conservation endowment aimed at providing dedicated funding for a mottled duck delivery specialist and operationally supporting a mottled duck conservation program on a perpetual basis. The delivery specialist would be responsible for securing additional funding and working with landowners to deliver conservation programs and management activities that benefit mottled ducks.

Other – Many wetland and grassland management techniques require specialized equipment (e.g., roller-chopper, marsh master, chemical sprayers, etc.) that may not be readily available to private landowners. Private land cooperatives may have access to shared equipment, but most landowners are forced to use contract services for such techniques, which may limit their participation in cost-share programs. Providing specialized equipment to landowners through a co-op and a subsidized rental could eliminate a potential barrier and may increase implementation of beneficial practices on private land. Developers of such programs should ensure access to equipment is a regional limiting factor before investing in establishment of an equipment cache program.



Several cost-share programs offset expenses of prescribed fire, but in most cases, the landowner is responsible for completion of the prescribed fire. Landowners can consult lists of prescribed fire contractors available in their state, but providing landowners the skills to conduct fire themselves is more likely to increase the frequency of prescribed fire across the region. Limitations typically include prescribed fire equipment, knowledge and training, and legal protection. In Louisiana, the LSU AgCenter hosts prescribed burn workshops in conjunction with the Louisiana Department of Agriculture and Forestry in which individuals can become certified as a Louisiana Certified Prescribed Burner. Beyond gaining training and experience with prescribed fire, the certification includes certain legal protection when conducting prescribed fire on private lands in Louisiana. Texas has a prescribed burn alliance of Texas that oversees several regional prescribed burn associations composed of landowners and citizens that assist, train, and promote the use of prescribed fire as a management tool on private lands. Expansion of prescribed burn associations in Texas may increase landowner usage of fire as a management tool. Defraying costs associated with these innovative ideas would require access to additional funding, but this is not a unique challenge and could be pursued through many of the same aforementioned novel funding approaches.

Habitat Management

Availability of spring and summer water and upland nesting cover are key requirements for mottled duck breeding. However, periodic management of wetlands and grasslands is necessary to restore site conditions to the appropriate state for mottled duck production. Prior to human alteration, early successional grassland and marsh conditions resulted from periodic natural disturbances, such as drought, flooding, fire, and grazing. Without this ecological reset, wetlands become less productive and upland grasslands or old fields give way to woody plant encroachment. Today, managers implement several habitat management practices that mimic natural disturbance to maintain productive wetlands and grasslands for livestock and wildlife. The following management practices are commonly used to create and maintain wetland and grassland conditions preferred by mottled ducks.

Water-level Management – Mottled ducks prefer shallow isolated wetlands to access food resources and avoid aquatic predators throughout the year. Wetland units managed for migratory waterfowl through seasonal fall and winter flooding can provide excellent habitat conditions for mottled ducks through prolonged spring flooding. These managed wetlands typically have existing water control structures to manipulate water levels. Maintaining shallow water depths into summer on managed units can provide maximum benefits for mottled ducks where freshwater coastal marsh and other natural wetlands are absent. Managing spring and summer water for mottled ducks can be rotated with moist-soil management to produce early successional seed-bearing species for wintering migratory waterfowl. Where multiple managed wetlands exist as a complex, spring and summer water management for mottled ducks can be applied in rotation on different wetlands or group of wetlands annually, thereby maximizing benefits for both mottled ducks and migratory waterfowl. Assistance programs are available to repair levees, add or replace water control structures, or plug ditches to create and enhance water-level management capabilities across the region.

Supplemental Water – Nesting activity in mottled ducks is influenced by the availability of surface water from late winter through spring, and females may forego breeding when water is scarce on the landscape, whether caused by drought or water management challenges. Additionally, low-salinity (i.e., < 9ppt) wetlands in spring and summer improve duckling growth and survival. Management actions that deliver supplemental water to natural and impounded wetlands offer the highest potential rate of return for mottled ducks, especially when drought conditions limit natural wetland availability. Maintaining water levels <18" from late winter through summer will support breeding activities and increase mottled duck production. Providing supplemental water during drought can offer significant benefits for local populations of mottled ducks. Solar or alternatively powered wells are a good option to maintain water in small (<10 acres) wetlands near suitable grasslands, especially during drought. Although setup costs of solar wells may be high, a relatively constant water supply can be achieved with minimal operating costs.

Solar wells can be used to maintain flooding in small wetlands, especially during drought.

Vegetation Management – Mottled ducks are generally attracted to shallow wetlands having open water and interspersed emergent vegetation on the wetland edge or scattered in small clumps. Emergent vegetation should cover roughly 30-70% of the wetland during the brooding season providing escape cover for females and broods. These conditions can be achieved with wetland management practices that periodically disturb vegetation and soil. Without periodic disturbance, wetland suitability can be reduced if dense vegetation dominates the wetland or it transitions to open water. Vegetation management also may be needed to control growth of non-native or invasive plants. Grasslands require management to maintain quality nesting cover. Periodic disturbance reduces woody encroachment that would otherwise hinder use by nesting mottled ducks or increase the likelihood of predation. Disturbance also increases vegetation diversity and may promote native bunchgrass species that reduce understory density making it easier for ducklings to travel from the nest site to nearby wetlands. Timing of vegetation management is particularly important. Managers should avoid summer prescribed fire but may burn early enough in the dormant season to allow vegetation to grow prior to the nesting season. It may take 2-3 years following prescribed fire for vegetation conditions to become suitable for mottled duck nesting. Thus, burns should be conducted in rotation across years to ensure uplands of desirable vegetation condition are available each year. Management practices commonly used to control vegetation in wetlands and grasslands and the appropriate application timing are presented in Table 9 & Table 10.

Prescribed fire can be used every 3-5 years to reduce woody encroachment and vegetation density and improve quality of mottled duck nesting habitat.

Predator Management – Nesting female mottled ducks, eggs, and ducklings are consumed by predators and high rates of predation can be a concern because population growth is determined by the number of adults and young that survive and breed the following year. Removing predators to reduce encounters with mottled ducks may improve breeding production at a local scale if habitat is managed to provide optimal conditions and predator removal efforts can be sustained over multiple years. Best practices for predator removal to increase mottled duck production are to: 1) apply removal efforts to local areas of high nest density or on islands or other isolated habitats where removal efforts are aided by barriers to predator recolonization, 2) sustain management activities for several years, and 3) target known hen and egg predators. Predator management has traditionally not been applied as a management tool for improving mottled duck recruitment.

Table 9. Timing of management activities to increase habitat quality for breeding mottled ducks.

	January	February	March	April	May	June	July	August	September	October	November	December
Key Annual Cycle Event	Breeding season (breeding territory establishment, nest site selection, egg laying, incubation, & brood-rearing)								Pair formation			
Key Annual Cycle Event			Peak nest initiation				Peak wing molt					
Wetland Management Recommendation	Manage water levels	Delay drawdown of impoundments and maintain water levels and salinity levels <9 ppt							Manage water levels for migratory waterfowl and non-breeding mottled ducks			
Wetland Management Recommendation	Roller chop dense veg.					Disk or shred managed wetland impoundments as they dry out					Roller chop dense vegetation	
Wetland Management Recommendation							Treat invasive vegetation with chemical herbicide					
Nesting Cover Management Recommendations	Avoid manipulation of pasture and hayfields where nesting may occur								Lightly disk or shred nesting cover as necessary if prescribed burning is not an option			
Nesting Cover Management Recommendations	Reduce grazing pressure	Rest or lightly graze pasture where nesting may occur								Reduce grazing pressure or begin resting pasture where nesting may occur next spring		
Nesting Cover Management Recommendations	Prescribed burning		Delay cutting hay where nesting is suspected					Prescribed burning to control woody vegetation and promote native bunch grass diversity (~every 4th to 5th year)				
Nesting Cover Management Recommendations							Treat woody vegetation with chemical herbicide					

Table 10. Management techniques to increase wetland and grassland quality for breeding mottled ducks.

Practice	Wetland	Grassland
Disking	Controls unwanted plant species and encourages growth of emergent plants that produce abundant seeds and provide habitat for aquatic invertebrates. Promotes an even balance of open water and short, emergent plant cover. Recommended at least once every 3-4 years. Late summer or fall application will prepare the site and promote conditions beneficial for mottled ducks the following breeding season but can be done whenever the wetland is dry.	Generally not necessary to maintain good nesting cover conditions. However, light application in winter may be necessary to manipulate vegetation density when other means cannot be used. Important to prepare a site prior to seeding new vegetation when restoring prairie. Avoid disturbing grassland cover March-June.
Shredding	Before flooding, use to achieve desired 30-70% open water conditions in a wetland. May be needed annually; thus, not as effective as disking. May be needed for rank vegetation prior to disking. May be necessary during non-disk years.	Can reduce density of cover from woody plants; however, it does not kill the root stock, and other practices are necessary to kill the plant. Can add plant litter and maintain appropriate density of grasses. Avoid during March-June.
Roller-chopping	When a wetland is flooded, may be necessary to provide and maintain open water areas when vegetation becomes too dense. Conduct in fall and winter before onset of pairing or March through early April before peak of hatching to provide small, open areas for ducklings.	Rarely used for managing nesting cover.
Livestock grazing	Can be used as an alternative to mechanical disturbance in certain instances. Can induce trampling of the ground in dry wetlands that mimics impact of light disking. A risk of this application is that livestock will eat many of the plants that produce food eaten by mottled ducks. Applying high stocking rates over a short period of time (dependent on wetland size) can achieve the desired effect without detriment to habitat.	Light and rotational application on native grasses can be beneficial in promoting good nesting cover. Avoid heavy application that results in loss of nesting cover, especially before and during the nesting season (March-June). Reducing stocking rates or rest pasture during drought to ensure availability of nesting cover the following year. Additional fencing may be necessary.
Prescribed fire	Efficiently reduces rank and dead vegetation and controls invasive woody plants in dry wetlands. Can achieve a mixture of open water and short, emergent vegetation when the wetland is flooded. Adequate fire breaks and specific weather conditions are required to use fire safely and effectively.	Effective at controlling most woody plants and reduces vegetation density in future growing seasons. Can be applied late summer and into winter when conditions are dry. Apply once every 4-5 years. Rotational application is ideal to avoid complete loss of nesting cover the following spring, as conditions for nesting may not return until the 2nd growing season after a burn. Adequate fire breaks and specific weather conditions are required to use fire safely and effectively.

<table>
<tr><th>Practice</th><th>Wetland</th><th>Grassland</th></tr>
<tr><td>Flooding and drawdown</td><td>Flooding can be an effective method to reduce cattail and phragmites after manipulation by disking, shredding, burning or herbicide spraying.
Occasional drawdown mimics the natural cycle of seasonal wetlands and ensures that productivity (food, cover) remains high.
Drawdown may be necessary to enable other desired management practices.
Avoid deep (>18”) flooding or drawdown treatments during the breeding season (January-July) that will prevent use by mottled ducks.</td><td>Not applicable for managing nesting cover.</td></tr>
<tr><td>Chemical herbicide</td><td colspan="2">Can be used to control unwanted vegetation over large areas or individual plants.
Perhaps the most effective means of controlling large stands of non-native plants, such as Chinese tallow, water hyacinth, Macartney rose, and deep-rooted sedge.
Vegetation may require manipulation using other practices before or after application of chemical herbicide to increase success.
Herbicide product and method of application depends on type and condition of target vegetation, presence of desirable plants and size of area to be treated.
Timing of application is generally late growing season when the foliage is still green (July-September), but optimal timing some chemical herbicide products may differ.
Always consult product labels and manufacturer representatives for proper methods, application timing and rates, and tank mixtures.</td></tr>
</table>

ADAPTIVE IMPLEMENTATION

Conservation of WGC mottled ducks and their habitat remains a high priority across the western Gulf Coast (WGC) amid current and future population limiting factors such as lead poisoning, predation, climate change, and reduction in the quality and quantity of nesting and brood-rearing habits to urban expansion, coastal marsh loss, grassland/pastoral degradation, and a decline in rice agriculture. The 2007 Plan sparked several research endeavors, refinement of limiting factors, establishment of new monitoring programs, development and implementation of new conservation programs, and identification of novel research and monitoring needs. As the development and refinement of technologies are increasing our understanding of nesting ecology, habitat associations, and demographic rates of WGC mottled ducks, it is necessary to continue to advance research and conservation in a manner that facilitates learning through application of the best available information. In this section, we recap research and conservation programs that were developed in response to guidance in the 2007 Plan, present ongoing and novel monitoring needs, and identify research needs that will advance our understanding of mottled duck ecology and guide habitat conservation into the future.

Implementation of 2007 Plan Guidance

Research – Identifying priority landscapes for conservation and management that achieve the greatest impact on mottled duck populations was an important need identified in the 2007 Plan. Through engagement with stakeholders, Krainyk et al. (2019) developed four mottled duck decision support tool (DST) layers that identified currently suitable wetlands and grasslands and those in need of conservation to improve the availability of quality nesting and brood-rearing habitat. Beyond highlighting the continued loss of mottled duck breeding habitat to urbanization, coastal wetland loss, and the decline in rice agriculture, the DST layers highlighted the important co-occurrence of wetlands and grassland and identified landscapes that could become suitable with management for the missing component. This tool has become important to identifying sites for conservation work through the Texas Prairie Wetland Project and Louisiana Waterfowl Project and has been a key reference in identifying and ranking potential benefits of proposed activities on mottled ducks in the evaluation of NAWCA proposals.

Since the 2007 Plan, numerous research projects have recorded location and habitat association information on female mottled ducks across the WGC. Moon et al. (2021) combined location data from several projects to develop a habitat suitability map that identified currently suitable habitat and projected future habitat quality and quantity in the face of urbanization and sea-level rise through 2100 (Figure 54). The resulting landscape conservation design product is available for visualizing future impacts and steering land conservation and stewardship to the most important and sustainable habitats for mottled ducks along the Gulf Coast. Wehland (2012) analyzed seasonal survival rates of 503 female mottled ducks across Texas and Louisiana from 2006-2010. She found that seasonal survival was greatest during the post-breeding period contrasting estimates for mottled ducks in Florida (Bielefeld and Cox 2006). Evidence from Wehland (2012) minimized the emphasis of molting season survival on improving mottled duck populations in this plan.

Hybridization with feral mallards has been considered the greatest threat facing Florida mottled ducks, but the extent of hybridization in the WGC was unknown (Wilson 2007). Mallard-like plumage characteristic in mottled ducks were presumed indicative of mallard x mottled duck hybrids which sparked concern among managers. Ford et al. (2017) provided a genetic baseline estimate of mallard x mottled duck hybridization for the WGC and established that current hybridization rates do not pose a significant threat to the WGC mottled duck population. Moreover, in development of a phenotypic classification key, Bielefeld et al. (2016) found that certain mallard-like plumage traits in mottled ducks alone do not identify a specimen as a hybrid.

The 2007 Plan identified management actions to improve nest success and brood survival as the highest priority but little was known about habitat characteristics that increase these vital rates. The ability to locate an adequate sample of active nests has been a limitation to reliable estimation of breeding season vital rates and effectiveness of assessing management actions. Bonczek (2022) utilized advancements in GPS transmitter technology to locate nests within days of nest initiation by female mottled ducks and derived estimates of breeding propensity, nest success, brood movements, and nest site characteristics across SW LA. Her research led to the first documentation of over-water nesting by mottled ducks which appeared to be a rare but successful strategy. In response to the low breeding propensity estimates revealed in GPS telemetry research, Ringelman et al. (2022) deployed geolocators on molt-captured mottled ducks as a lower-impact way to assess breeding propensity. Return rates of geolocators were lower than expected, and breeding season data were available for only three units; nevertheless, each geolocator showed one or more breeding attempts.

Geolocators can be used to gather breeding propensity rates but require recapture or indirect harvest to retrieve stored data.

Conservation – The 2007 Plan identified numerous avenues to improve the quality and quantity of habitats important to breeding mottled ducks. This guidance has led to the development or modification of several partnership programs to deliver grassland or wetland habitats in areas identified as suitable by the Krainyk et al. (2019) mottled duck decision support tool.

The Coastal Grassland Restoration Incentive Program (C-GRIP)

The Coastal Grassland Restoration Incentive Program (C-GRIP) is a partnership program modified from the Oaks and Prairies Joint Venture GRIP and has been implemented in five focal areas on the central Texas coast since 2018 and five focal areas in southwest Louisiana established in 2022 (Figure 56). The program is modeled after the Natural Resource Conservation Service's Environmental Quality Incentives Program and incentivizes voluntary landowners to address the quality of grassland bird habitat on their properties through active management. Specifically, the C-GRIP provides a set payment rate for brush management, prescribed burning, native grass reseeding, and prescribed grazing practices in an effort to improve grassland condition for species like northern bobwhite (*Colinus virginianus*), loggerhead shrike (*Lanius ludovicianus*), and mottled ducks. Landowners are required to maintain improved site conditions for 5 years following treatment. The program has already improved nearly 50,000 acres of grassland habitat in Texas between 2019-2022.

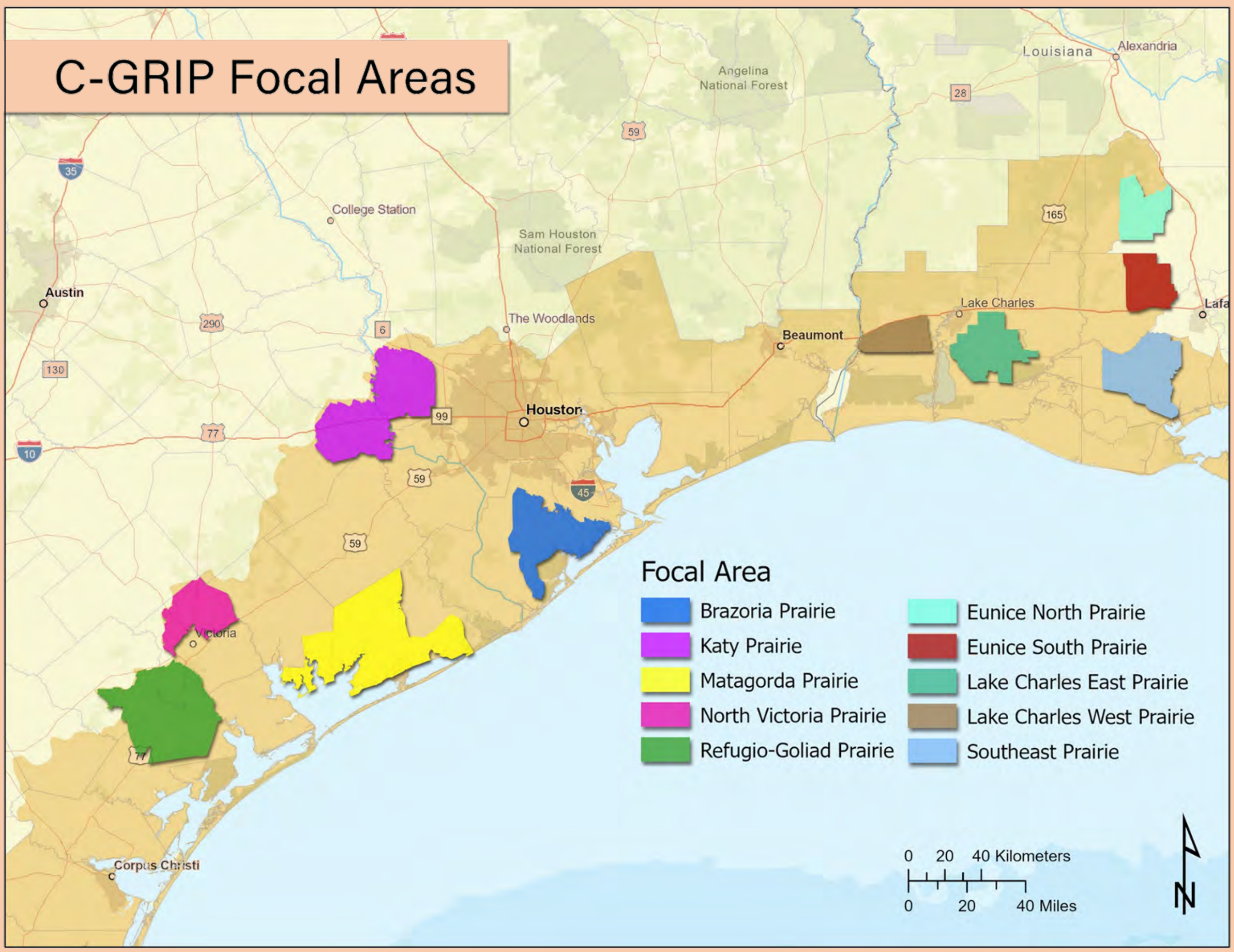
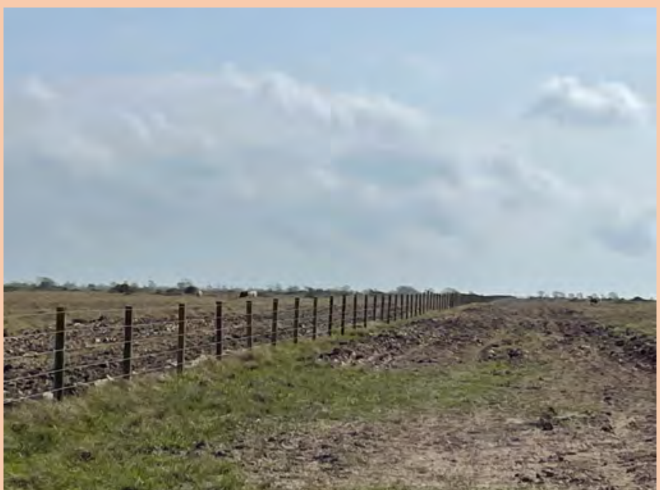


Figure 56. Focal areas for grassland enhancement through the Coastal Grassland Restoration Incentive Program.

C-GRIP Management Examples

Herbicide application to control woody vegetation and restore a desired grassland plant community.

Prescribed burning to control undesirable vegetation or improve plant production and quality.



Establishment of cross-fencing and firebreaks to allow prescribed grazing and burning activities, respectively.

Deferred or prescribed grazing practices to achieve plant height, density, and diversity that improves nesting habitat quality.

C-GRIP Partners

More information about C-GRIP

Since 1991, the Texas Prairie Wetlands Program (TPWP) has provided technical and cost-share assistance to private landowners for wetland development in a 28-county area on the Texas coast. The program was initiated to increase wetland availability for migrating and wintering waterfowl to achieve habitat objectives established under the North American Waterfowl Management Plan. It was recognized that wetland restoration and spring/summer flooding within proximity to suitable grassland nesting cover could increase breeding propensity and provide brood-rearing habitat otherwise unavailable. Beginning in 2016, a portion of project funds allocated from Texas Parks and Wildlife Migratory Game Bird Stamp funds were dedicated to enhance wetland availability proximal to suitable nesting cover to increase habitat availability for breeding mottled ducks. Landowners enter a ≥10 year Wetland Development Agreement to provide surface flooding during April-July. To date, the TPWP has delivered >19 mottled duck projects totaling more than 1,200 acres. An evaluation of April-July flooding found that ~80% of mottled duck sites contained some annual flooding during 2019-2021 with 19% of the project area flooded on average (Parr and Wilson 2021).

Monitoring – Establishment of range-wide and state-specific mottled duck population objectives in the 2007 Plan were limited by the reliability of existing range-wide population monitoring data. Thus, the 2007 Plan called for an improved range-wide survey that could reliably assess changes in populations. The WGC Mottled Duck Breeding Population survey was developed and piloted in 2008 across the Louisiana and Texas Gulf Coasts. Several survey refinements (e.g., helicopter segments, transect placement) were implemented in the first few years (Fleming and Otto, unpublished), but since 2011 the survey has become a reliable source for mottled duck abundance information and now forms the basis for the WGC mottled duck population objective.

Monitoring Priorities

BPOP abundance – The BPOP survey has been instrumental in providing population trends and visibility bias corrected annual abundance estimates at the WGC and state-specific scale. However, the surveys have the ability to provide additional information that has yet to be harnessed. The dataset should be investigated to determine potential sources of variation in regional mottled duck abundance, improve survey design, and evaluate the impact of spatial and temporal metrics (e.g., rainfall) on mottled duck occupancy and abundance. Research is ongoing to investigate and reduce sources of variation in visual correction factors, evaluate the appropriateness of the current spatial coverage of the survey, evaluate whether transect placement is representative of strata composition, and options for transect establishment in the Sandplain and Brush Country ecoregions of south Texas. Given this Plan Update establishes WGC mottled duck population objectives based on the BPOP survey, advancements in survey design must ensure that abundance estimates are calculable for the strata used during the 2011-2021 surveys. Advancements that increase precision within strata estimates through additional transects but do not directionally impact abundance estimates would be welcomed. Additional work investigating an expansion of the BPOP survey into the Texas Brush Country will be important for tracking abundance trends and distribution of the WGC mottled duck population, but the strata lie mostly outside of the GCJV geography as it pertains to future habitat conservation.

Banding, survival, harvest rates – An ongoing effort to band mottled ducks annually is important to monitoring trends in survival and harvest rates and identify sources of variation. Between 2000-2022, 3,000 mottled ducks have been banded annually in the WGC with efforts being relatively opportunistic regarding banding location and age- and sex-class distribution of birds captured and banded. Based on previous band deployment, a recent banding needs assessment suggests that 4,500 mottled ducks should be banded annually to achieve a goal of banding at least 750 individuals of each age- and sex-class (Collins et al. 2023). Banding goals are split equally among Texas and Louisiana. Despite a consistent mottled duck banding effort, the current banding distribution has been primarily limited to the Chenier Plain of Louisiana and Texas (Figure 57). Moreover, the distribution of WGC mottled duck banding has become more centralized since 2010 with 81% of bands deployed in the Louisiana and Texas Chenier Plains. There may be some concern over hybrid status of mottled ducks in the Laguna Madre given potential hybridization with Mexican ducks in that region. Therefore, a combination of banding and genetic analysis may be necessary.

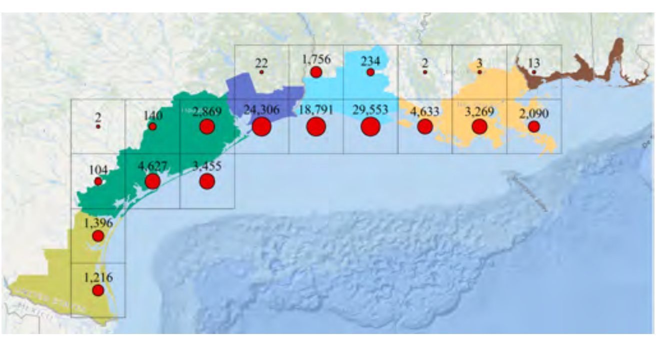


Figure 57. Distribution of mottled ducks banded by degree block, 1994-2020.


Annual mottled duck banding is an important monitoring tool that will require an increased effort to achieve the banding goal of 4,500 individuals.

Recovery rates (f) estimated from banding analyses are the product of three separate event probabilities; 1) the probability a banded bird is killed by a hunter (K), 2) the probability the banded bird is retrieved by the hunter (c), and 3) the probability that the hunter reports the band to the bird banding lab (λ). Because harvest rates (Kc) are typically unobservable, unbiased estimates of reporting probability and recovery rates are required. Since 1994, WGC mottled ducks have been banded with five primary band material and inscription combinations; aluminum with original address (i.e., Avise; 1994-1997), aluminum with new address (1995-1997), aluminum with toll-free (1996-2016), aluminum with web address (2008-2017) and incoloy with web address (2018-present). Most contemporary survival and recovery analyses have constrained band type to include only toll-free and web address combinations because of the substantial increases in reporting rate following implementation of the toll-free inscription in 1996 (Arnold et al. 2020). The only reporting probability estimate for WGC mottled ducks is from a reward band study conducted in Louisiana and Texas during 2007-2008 (Garrettson, unpublished). A sample of 1,772 aluminum web address reward bands and 1,769 control bands were deployed with a resulting reporting rate of 65%. The mottled duck reporting rate was lower than estimates for mallards in the Mississippi (81%) and Central (70%) Flyways and for mallards, wood ducks and black ducks (73%) in the eastern United States during the 2000s (Boomer et al. 2013, Garrettson et al. 2014). Temporal trends in reporting probability are necessary for correcting annual recovery rates for estimation of population abundance using the Lincoln Peterson approach. Calculating annual reporting probability for mottled ducks may be infeasible, however, Arnold et al. (2020) conducted a meta-analysis of over 300 reward band studies and provides annual reporting rate estimates for mallards from 1948-2010 that may be a useful reference. They found a 0.58% increase in reporting rate per year between 1998-2010. WGC mottled ducks have been banded with incoloy material bands since 2018 because of its superior resistance to wear in saltwater environments. Kneece et al. (2021) found no evidence for a difference in recovery rates of mottled ducks banded with aluminum or incoloy bands in South Carolina suggesting that material type nor inscription legibility impact reporting rate.

Habitat conditions – A high priority moving forward will be to establish a formal link between habitat conditions and population limiting factors to enable the development of habitat objectives needed to achieve and maintain regional and range-wide WGC population objectives. Once established, periodic monitoring should be performed to identify regional habitat availability in relation to objectives. Based on available science, availability of grassland nesting habitat within 1.6 km of fresh-intermediate wetlands is foundational to suitable breeding areas for WGC mottled ducks. Initial estimates of the amount and distribution of those habitats were elucidated in the Krainyk et al. (2019) decision support tool. Although we currently lack explicit habitat objectives, the sustainability and enhancement of existing grasslands is paramount to achieving mottled duck population objectives, and several aspects should be monitored to quantify existing suitability, identify management opportunities, and evaluate the efficacy of management practices for achieving desired vegetation conditions. Other potential grassland monitoring topics include urbanization threats, grazing practices, fire seasonality and frequency, rice and other agricultural practices, and invasive species distribution (e.g., running live oak, Chinese tallow).

Mottled ducks rely on wetlands throughout the year, but increasing mottled duck recruitment requires a sufficient abundance and distribution of wetlands during the protracted breeding season to increase breeding propensity and provide brood-rearing and adult molting habitat. Numerous threats to wetland availability and suitability can impact mottled duck recruitment and should be monitored, including wetland hydrology and seasonal availability, salinity, upslope freshwater availability/flow, rice and crawfish aquaculture practices, and aquatic invasive species (e.g., giant salvinia, apple snails). In addition to monitoring hydrological conditions, widespread threats to wetland sustainability such as marsh accretion or subsidence rates and eustatic sea-level rise should continue to be monitored. Evaluating the opportunity for fresh-intermediate wetlands and high marsh habitats to migrate inland in the face of sea-level rise and identifying barriers that inhibit wetland migration resulting in loss of high marsh habitat is also important. Range-wide monitoring should be conducted periodically through remote sensing of satellite derived imagery when feasible using existing methods.

Lead concentrations – Lead is not going away, but it does seem to be taking other forms in the environment (e.g., soil and vegetation) which may lessen the overall impact to mottled ducks as direct contamination through ingestion of lead shotshell pellets is reduced. The latest large-scale wing-bone analysis was done in 1998-1999 (Merendino et al. 2005) and should likely be repeated across the WGC mottled duck range to determine contemporary lifetime lead accumulations. Because blood lead concentrations exhibit a relatively recent picture of lead ingestion, monitoring blood lead concentrations through the fall/winter may elucidate the time period when mottled ducks are most likely to encounter lead in the environment. Randomized collection techniques should be used when possible to reduce potential bias introduced through harvest susceptibility. Moreover, expanding blood lead concentration collections across the WGC mottled duck range would identify any regional differences in accumulation. Blood monitoring on live captures should be closely coordinated with banding managers to ensure that blood draws do not detract from banding quotas given many banding analyses exclude non-normal banding codes (e.g., 318 or 385). Additional monitoring of environmental samples (e.g., soil, vegetation) should be considered to track changes in indirect sources of lead contamination in mottled ducks.

Hybridization rate – Although current hybridization rates are of minimal concern for WGC mottled duck conservation, periodic assessment of hybridization rates are recommended to monitor potential directional shifts that may trigger enhanced response. The phenotypic classification key developed for identification of mottled ducks and their hybrids in Florida (Bielefeld et al. 2016) was 97% successful in identifying mottled ducks and hybrids in the WGC (Ford 2015). Hunter check stations may be the most logical place to employ the classification key because it requires precise examination and measurement of feather characteristics that may be difficult or prolong handling time during traditional live capture events. However, the key does include classification options that utilize only contour feathers, thus it is possible to classify individuals captured during remigial molt. Ford et al. (2017) also recommended periodic genetic analysis to monitor the proportion of mottled ducks containing hybrid genetics. Moreover, recently developed techniques (i.e., ddRAD-seq) provide the ability to differentiate the lineage of hybrid genetics to determine the source of mallard genetics (i.e., game farm or wild) which could be used to targeting the source of hybridization and implementing programs to reduce co-occurrence of congeners (Lavretsky et al. 2020). The urban-suburban interface is hypothesized to be where the greatest rates of mottled duck x mallard hybridization will occur. Hunter harvest samples are unlikely to occur in these areas, therefore, alternate strategies may be necessary to identify potential hybridization hot spots which may require additional conservation efforts to reduce hybridization potential.

Genetic sampling of dusky ducks is ongoing in southeast Texas to determine the distribution of mottled ducks and hybridization rate with Mexican ducks. Determining the full geographic range of mottled ducks will be important to expanding the extent of the WGC BPOP survey into the Brush Country ecoregion. Moreover, high probabilities of genetically vetted mottled ducks within the Laguna Madre region of the GCJV geography will verify that it is indeed mottled ducks that are being counted during the BPOP and may trigger increased efforts to band mottled ducks in these regions.

Demographic rates – All current indications are that breeding season demographic rates (nesting propensity, nest survival, renesting intensity, brood survival) are limiting WGC mottled duck populations, but due to logistical and financial limitations, there are no long-term monitoring programs evaluating trends in these rates. Rough estimates of productivity (i.e., age ratios) are derived from the Parts Collection Survey, but small sample sizes limit inferences at smaller spatial scales. New efforts to measure mottled duck breeding season vital rates could include larger scale geolocator studies (especially if units could be deployed immediately preceding the breeding season), or regular and standardized monitoring of broods via uncrewed aerial vehicles (*sensu* Bushaw et al. 2021 for prairie ducks).

Preliminary efforts using drone-mounted thermal sensors suggest applicability to locate and monitor mottled duck broods. Thermal sensor (left) is used to locate the brood and zoomed optical camera (right) helps identify the mottled duck hen and ten class IIc ducklings.

Hunter-check stations – Several monitoring priorities would benefit from opportunities to examine birds in-hand, which could be obtained through hunter harvest. Numerous research studies utilized hunter-harvested birds to examine lead exposure and concentrations, body condition, hybrid status, etc. Staffing at hunter check stations or mobile sampling efforts would allow regional sampling from hunter-harvested birds. Examples of data that could be obtained include blood, tissues, gizzards, or bone to examine lead exposure and concentration, determine hybrid status, utilize plumage characteristics to calculate regional age- and sex-ratios, and examine body condition using morphometric measurements. It is important to acknowledge that several variables may be impacted by harvest vulnerability (e.g., body condition) but results would be an index comparable to historical studies that utilized similar data types.

Response to habitat delivery – One of the greatest ongoing monitoring needs is to evaluate the impact of habitat management techniques on breeding season vital rates. Habitat management guidelines suggested in the previous chapter are based on the best available information but are generally based on limited samples sizes or derived from local scale studies. Regardless, the adaptive management process allows for refinement and learning through the application of management techniques informed by available science. Currently, two examples of monitoring to inform the adaptive management process are ongoing to investigate breeding mottled duck abundance at local and landscape scales in response to habitat management. Both monitoring protocols were developed with substantial insight from biologists and researchers but are in their first years of data collection. Firstly, the research team on the National Oceanic and Atmospheric Administration (NOAA) RESTORE Science funded project entitled "Fire effects in Gulf of Mexico marshes; historical perspectives, management, and monitoring of mottled ducks and black and yellow rails" have developed a repeated point-count survey to monitor the impacts of vegetation and fire return interval in high marsh habitats on mottled duck breeding abundance across the Texas and Louisiana coasts (Firebird Project Field Procedures). The research will elucidate optimal dormant season prescribed fire return intervals to maintain high marsh habitat in a suitable state for mottled duck nesting. Secondly, GCJV staff and partners have developed and implemented a monitoring protocol to evaluate landscape scale impacts of grassland enhancement through the C-GRIP on grassland bird density. Density estimates of mottled ducks and other grassland birds are quantified along established ~30 mile roadside point count routes in the 5 focal areas and corresponding control areas. Two routes are surveyed within each focal and corresponding control areas annually. The first year of C-GCRIP monitoring resulted in only 1 mottled duck detection. Although the monitoring program is aimed to detect landscape scale changes in grassland bird density through time, preliminary evidence may suggest a need for increased effort and that collecting sufficient mottled duck detections for analysis requires local scale surveys at improved and unimproved sites to assess the impact of management decisions.


Point count surveys are used to estimate mottled duck pair density as part of the NOAA RESTORE funded Firebird project.

Additional programs are needed to monitor breeding season vital rates (e.g., breeding propensity, nest success, and brood survival) beyond abundance or density in response to habitat management. Behavioral cues such as drop flights, landing in vegetation, and chase flights (i.e., where a territorial male chases an intruding pair from a wetland) are generally indicative of breeding activity, but themselves have not correlated with nest abundance (Baker et al. 1984). Thus, it is likely that more rigorous, direct measures of nest abundance and nest and brood monitoring will be required to advance our understanding of the impact of management on vital rates. In the past, locating active mottled duck nests to monitor has required substantial search effort in difficult terrain or capture and tracking of females. Observations of drop flights or hens returning to their nest have been useful in determining nest locations or to refine search efforts, but there is an opportunity to explore and refine the use of new technologies to aid in detection of nest sites and broods. Generally, unmanned aerial vehicle (UAV) platforms have not been as reliable as traditional nest searching techniques for upland nesting ducks, but UAV automation techniques can substantially decrease search time in difficult terrain. UAVs outfitted with dual thermal and normal color cameras have been shown to increase detection rates of duck broods in prairie pothole region of North America (Bushaw et al. 2021). Lower temperature differential between ambient temperatures and ducks and high relative humidity may make the same technology difficult to use in the WGC, but recent pilot work has successfully detected mottled duck broods (K. Ringelman, personal observation).

Research Priorities

Substantial progress has been made in past decades to reduce biological uncertainties associated with WGC mottled duck conservation. Additional targeted research and monitoring is needed to continue refining our understanding of population limiting factors, identify management practices that alleviate limiting factors, and develop a habitat objective. The following research priorities were identified by the original 2007 Plan, the 2012 GCJV Waterfowl Science Needs Plan, and discussions at the 2016 Mottled Duck Working Group Meeting (Figure 58). This list is not intended to be comprehensive regarding mottled duck conservation needs, but outlines highest priorities expected to have the greatest impact on GCJV planning over the next 5-10 years. Additional research priorities are excluded from the list because research is underway to address the topic.

1. Estimate means and variances for priority vital rates for WGC mottled ducks, and identify factors (e.g., environmental, habitat-based) responsible for variation.
   A. Breeding propensity, nest survival, and brood survival are high priorities, especially breeding propensity which may be highly variable and is poorly known.
   B. Survival during breeding and molting are high priorities for understanding drivers of adult survival.
2. Estimate cause-specific mortality for WGC mottled ducks during different periods of the annual cycle, including agents of mortality for nests and broods.
3. Establish a connection between population size and habitat, which is required to quantify the amount of habitat needed to achieve population objectives.
4. Evaluate the effectiveness of wetland and grassland management strategies (e.g., burning, grazing, salinity management) at elevating mottled duck vital rates.
5. Determine the suitability of crawfish aquaculture to provide wetland habitat during the pre-breeding, breeding, and brood-rearing periods.
6. Determine the prevalence and regional variation of sub-lethal effects of lead poisoning and sources of exposure.

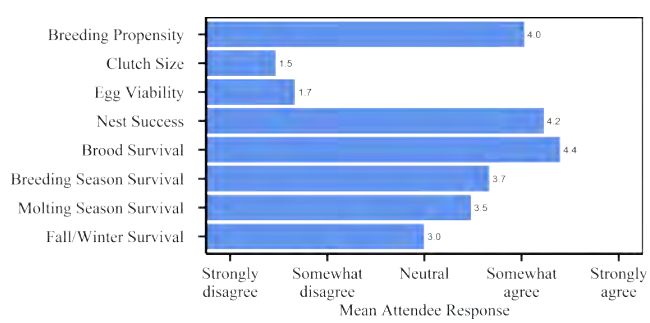


Figure 58. Mean working group meeting attendee response regarding whether each vital rate should be a high priority for additional research.

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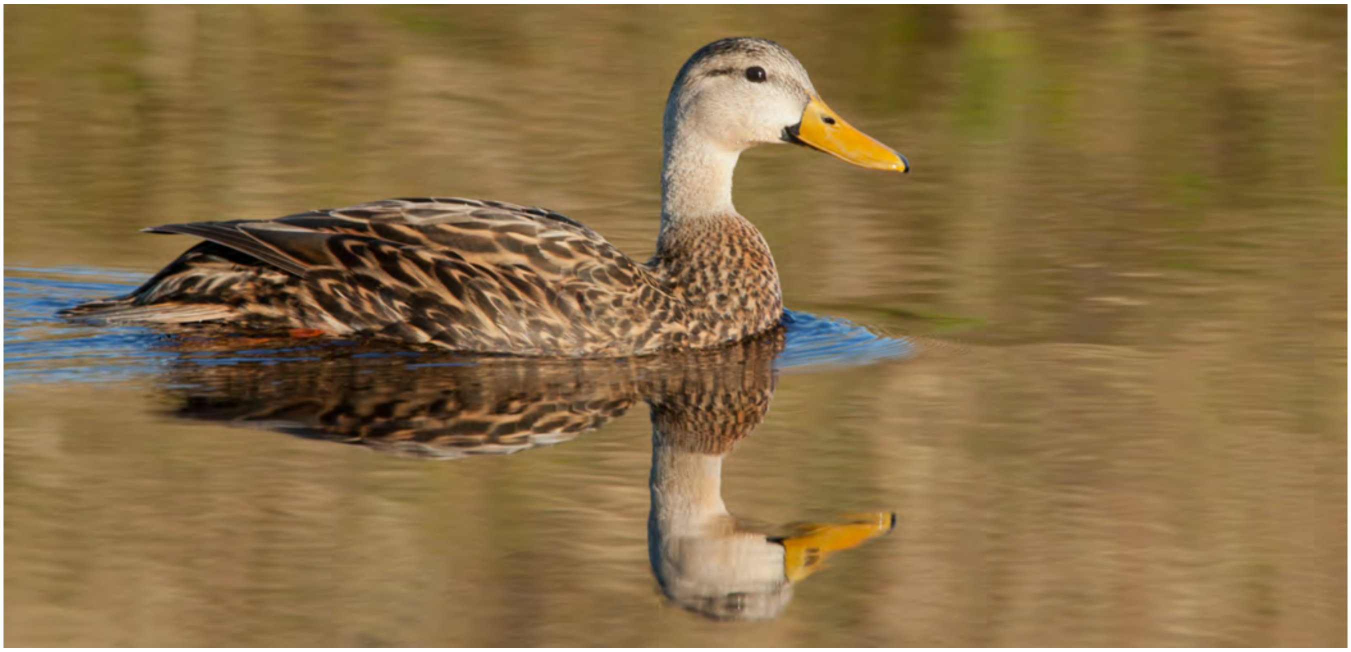

APPENDICES

APPENDIX A – PARTICIPANT LIST 2016 MOTTLED DUCK WORKING GROUP MEETING

Name	Organization
Barry Wilson	Gulf Coast Joint Venture
Jon Hayes	Gulf Coast Joint Venture
Mike Brasher	Gulf Coast Joint Venture
Larry Reynolds	Louisiana Department of Wildlife and Fisheries
Kevin Kraai	Texas Parks and Wildlife Department
Kevin Hartke	Ducks Unlimited
Samantha Collins	Louisiana Department of Wildlife and Fisheries
James Whitaker	Louisiana Department of Wildlife and Fisheries
Jeff Raasch	Texas Parks and Wildlife Department
Glenn Harris	U.S. Fish and Wildlife Service
Keith Westlake	U.S. Fish and Wildlife Service
Paul Link	Louisiana Department of Wildlife and Fisheries
Patrick Walther	U.S. Fish and Wildlife Service
Dan Collins	U.S. Fish and Wildlife Service
Tim Anderson	U.S. Fish and Wildlife Service
Stephen LeJeune III	U.S. Fish and Wildlife Service
Douglas Head	U.S. Fish and Wildlife Service
Jena Moon	U.S. Fish and Wildlife Service
Warren Conway	Texas Tech University
Stephen McDowell	Texas Parks and Wildlife Department
Clay Shipes	Texas Parks and Wildlife Department
Mike Rezsutek	Texas Parks and Wildlife Department
Jeff Gleason	U.S. Fish and Wildlife Service
Mike Carloss	Ducks Unlimited
Cassidy Lejeune	Ducks Unlimited
Alonda McCarty	Ducks Unlimited
Bart Ballard	Caesar Kleberg Wildlife Research Institute/Texas A&M Kingsville
Dale James	Ducks Unlimited
Steve DeMaso	Gulf Coast Joint Venture
Todd Merendino	Ducks Unlimited
Kevin Ringelman	Louisiana State University


Gulf Coast Joint Venture