SURVIVAL AND POST-BREEDING HABITAT USE OF MOTTLED DUCKS IN THE WESTERN GULF COAST

A Dissertation

by

ERIN M. WEHLAND

Submitted to the College of Graduate Studies
Texas A&M University-Kingsville
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2012

Major Subject: Wildlife Science

SURVIVAL AND POST-BREEDING HABITAT USE OF MOTTLED

DUCKS IN THE WESTERN GULF COAST

A Dissertation

by

ERIN M. WEHLAND

Approved as to style and content by:

Bart M. Ballard, Ph.D.
(Dissertation Chair)

David G. Hewitt, Ph.D.
(Member of Committee)

Fidel Hernández, Ph.D.
(Member of Committee)

M. Todd Merindino, Ph.D.
(External Member of Committee)

Michael E. Tewes, Ph.D.
(Graduate Council Representative)

Mohamed Abdelrahman, Ph.D.
(Interim Associate VP for Research & Dean,
College of Graduate Studies)

August 2012

ABSTRACT

Survival, Post-breeding Habitat Use, and Fidelity of Mottled Ducks in the Western Gulf

(August 2012)

Erin Marie Wehland, B.S. University of Nebraska; M.S., Texas A&M University-Kingsville

Chair of Advisory Committee: Dr. Bart M. Ballard

Survival and post-breeding habitat use of female mottled ducks was assessed for Texas and Louisiana. Mottled duck survival was estimated by tracking and montoring 617 radio-marked mottled ducks along the WGC coast from 2006-2010. A total of 226 randomly selected wetlands and 32 wetlands used by post-breeding mottled ducks were surveyed in 2009 and 2010. Identification of used wetlands was determined presense of radio-marked birds or capture of molting ducks. The influence of habitat conditions on fidelity was investigated using 665 records of recaptured banded mottled ducks from 1967-2010.

Model-averaged annual survival was 0.48 ± 0.03 SE for after-hatch-year (AHY) females, 0.40 ± 0.04 SE for hatch-year (HY) females, and did not vary among years. For AHY birds, weekly survival was higher in the post-breeding period (0.992 ± 0.001) compared to hunting (0.981 ± 0.002) and breeding periods (0.985 ± 0.001) and similar between breeding and hunting periods. HY birds also had higher weekly survival during the post-breeding period (0.989 ± 0.002) compared to the hunting (0.973 ± 0.005) period (0.973 ± 0.005). Dry conditions in 2009, resulted in 81% of randomly selected wetlands being dry compared to 18% in 2010. The most commonly used wetland type by post-breeding mottled ducks was estuarine-intertidal-emergent wetlands which comprised about 50% of used wetlands in both years. Known-use wetlands were larger (F^{1}_{60} = 52.35, $P < 0.001$), had greater coverage of emergent vegetation (F^{1}_{141} 8.29, $P = 0.005$), and less open water habitat ($F^{1}_{141} = 6.89$, $P = 0.010$) than random wetlands Molting mottled ducks selected wetlands with approximately 35% open water and 45% emergent vegetation (cover) both years, resulting in similar water depths and amount of screening cover between years. Water salinity ($t = 3.78$, 34 df, $P < 0.001$) and amount of exposed mudflat ($t = 2.25$, 34 df, $P = 0.03$) in known-use wetlands were greater in 2009 than in 2010. Molting site-fidelity increases during drought for both male and ($F_{5,\,390}$=18.79, P =0.012) and female ($F_{5,\,267}$=6.48, P <0.001) mottled ducks. Information from this study will be useful in devising conservation plans focused on increasing mottled duck populations.

ACKNOWLEDGMENTS

This project would not have been possible without the assistance and cooperation of many wonderful people living and working in the coastal zone of Texas and Louisiana. I am grateful to the Gulf Coast Joint Venture for coordinating and funding of this project. Many thanks to the personnel of the Texas Parks and Wildlife Department, U.S. Fish and Wildlife Service, and Louisiana Department of Wildlife and Fisheries for providing housing, information, and assistance when requested. Thank you to the many landowners who provided access to their property.

I would like to thank my advisor, Dr. Bart Ballard. His guidance and support throughout this project has been invaluable and is greatly appreciated. I would also like to recognize my committee members Drs. Hernanadez, Hewitt, and Meridino. Thank you to my technicians, Robert Haley, Daniel Reed, Curt Kleist, and Taryn Balke for your hard work and positive attitudes. I want to thank Anse Windham for entertaining me through the many hours of flying with stories and informational tidbits and for all the safe flights. I thank Owen Fitzsimmons, Doug Wilmeth, Liz Bates, Shlya Rabe, Johanna Delgado, Aaron T., Andy Tri, and Kelly Corman for volunteering to help when needed. Thank you, Dr. Wester for help with the statistical analysis. I am grateful to the CKWRI support staff for their assistance and hard-work. I would like to recognize the CKWRI graduate students. I don't know what I would have done without your support. I am grateful to have met and befriended such a great group of people. I would like to thank my Aunt Gladys and Uncle Leland for their support and encouragement. Finally, I would like to thank my Mom and Dad. Thank you for your support and belief in me.

TABLE OF CONTENTS

LIST OF FIGURES

Figure

LIST OF TABLES

Table

CHAPTER 1.

SURVIVAL OF MOTTLED DUCKS ALONG THE WESTERN GULF COAST

INTRODUCTION

Mottled ducks (*Anas fulvigula*) are non-migratory dabbling ducks found in peninsular Florida and marshes along the Western Gulf Coast (WGC) from Mobile, Alabama to Vera Cruz, Mexico (Stutzenbaker 1988, Bielefeld et al. 2010). Florida and WGC populations are genetically distinct with no detectable levels of gene flow between populations (McCracken et al. 2001) and, thus, justify separate management. The WGC population of mottled duck occurs in low densities at the southwesterrn edge of its range with densities increasing with increasing latitudes and peaking in the freshwater and intermediate coastal marshes of southeast Texas and southwest Louisiana (Bielefeld et al. 2010). Mottled ducks are one of the least gregarious of all dabbling ducks (Stutzenbaker 1988, Bielefeld et al. 2010) and during fall and winter do not regularly associate with migratory ducks (Paulus 1984). Mottled ducks are usually found in pairs or small flocks of ≤ 10 birds; although rare, flocks of >1,000 may occur during fall (Bielefeld et al. 2010).

Despite comprising < 3% of the total waterfowl harvest for Texas and Louisiana (Raftovich et al. 2011), mottled ducks are considered prize game birds due to their wary nature and size. The mottled duck's popularity as a game species, combined with a restricted range, loss of preferred habitat, and declining population has prompted concerns about its future viability (Wilson 2007). To address these concerns, the Gulf

---

This chapter is written in the style of *Journal of Wildlife Management*

Coast Joint Venture (GCJV) appointed a mottled duck working group to review existing information and assess population status, factors limiting population, urgency of conservation issues, and to develop a conservation plan (Wilson 2007). Changes in hunting regulations have been implemented in recent years in an attempt to reduce mottled duck harvest in Texas and Louisiana.

Population Trends

The cryptic coloration and secretive nature of mottled ducks coupled with the inaccessibility of gulf coastal marshes make the species difficult to survey. Survey techniques have ranged from waterfowl counts by air and boat along with multispecies counts, such as the Christmas Bird Counts (Lotter and Cornwell 1969, Johnson et al. 1989, Johnson et al. 1991, Chabreck and Roberts 1993, Ballard et al. 2001). Estimates derived from local and regional indices vary depending on the data source and years of inference. For instance, the mid-winter waterfowl survey, which has no visibility correction factor, indicates a long-term (1971–2009) population decline in Texas, a stable trend in Louisiana, and an overall stable to slightly declining WGC population (Haukos 2009). Visibility corrected surveys of breeding mottled duck pairs on National Wildlife Refuges (NWR) along the Texas coast indicate a 12% annual decline from 1985-2009 (Haukos 2009); however, it is uncertain how these counts correspond to the entire region. Johnson (2009) created population matrices using band return data from 1994-2005 and estimated an average finite population change rate of 0.82 for mottled ducks in Texas and Louisiana, suggesting a rapid rate of population decline. In 2008, the U.S. Fish and Wildlife Service initiated a Western Gulf Coast (WGC) mottled duck survey. Although data from this survey is limited, it does have potential to deliver more precise estimates of mottled duck population and population trends than currently available. Advantages of this survey include visibility correction and stratified sampling of mottled duck habitat in Texas and Louisiana (Fleming and Otto 2010).

Overall, conservative results of local and regional indices indicate a declining population in Texas, stable in Louisiana, and a stable to slightly declining trend for the WGC (Wilson 2007, Bielefeld et al. 2010). These declines are likely caused by continued habitat loss and degradation, hybridization with feral mallards (*Anas platyrhynchos*), and possibly excessive sport harvest (Esslinger and Wilson 2001, Bielefeld et al. 2010).

Habitat Loss

Preferred habitats for mottled ducks are coastal wetlands and adjacent prairies, which are some of the most imperiled ecosystems in the United States (U.S. Geological Survey 1997, Grace et al. 2000). Besides supporting mottled duck populations, the coastal zone support 33% of Texas' and 47% Louisiana's human population (Brown et al. 1977, U.S. Census Bureau 2007). Coastal wetlands and prairies have been degraded or replaced by human development, agriculture, subsidence, and salt-water-intrusion. The human population is predicted to continue to grow in this region which will likely result in increased conflicts between habitat conservation and land development (Brody et al. 2004).

Coastal zones of Louisiana and Texas contain roughly 58% of all salt and brackish marshes located in the lower 48 states (Field et al. 1991), with considerable coastal wetland loss occurring in both states. Between the mid-1950s and early 1990s, coastal wetland area in Texas declined by an estimated 23 km^2/year (Moulton et al.

1997). Louisiana has the highest rate of wetland loss (90-116 km^2/year) in the nation and accounts for 90% of coastal wetland loss in the contiguous 48 states (Field et al. 1991, Barras et al. 1994, Dahl 2000). Coastal wetlands have been lost through natural forces (i.e. subsidence, hurricanes) and human modifications (i.e. draining, filling, dredging, and the creation of levees, canals, and spoil banks). Human induced habitat alterations impact wetlands directly and indirectly by changing hydrology, salinity, wetland vegetation, and sediment deposition (Chabrek 1982, Turner 1990, Kennish 2001). Levees and other flood control structures prevent rivers and their distributaries from naturally depositing sediments and nutrients onto coastal wetlands; instead pushing the sediment directly into the Gulf of Mexico (Boesch et al. 1994). Dredging of canals navigation, gas and oil operations, and pipeline installation allow salt water intrusion into fresh and intermediate marsh affecting plant communities and habitat structure as salt-intolerant vegetation perishes leaving behind large areas of open water (Chabreck 1981, McKee and Mendelssohn 1989). Subsequently, areas devoid of vegetation are more susceptible to erosion. Wetland vegetation is an important contributor to vertical accretion of wetlands through trapping of sediments suspended in the water and providing stability of substrates from dense root systems (Turner 1990). Without adequate vertical accretion, wetlands may become submerged through rising sea-levels and/or subsidence (Leonard et al. 1995).

Inland and adjacent to coastal wetlands lay the coastal prairies. Coastal prairies represent the southern tip of the tall-grass prairies and historically supported bunch-grasses such as big-bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and Indian grass (*Sorghastrum nutans*) (Gould 1975). These prairies once spanned 2.6 million ha (Allain et al. 1999) and contained numerous, small, shallow wetlands used by mottled ducks. However, < 1% of unaltered coastal prairie remains; 40 ha in Louisiana and 26,000 ha in Texas (Allain et al. 1999). Long growing seasons and fertile alluvial soils make the coastal prairies attractive for agricultural uses. As a result, much of the coastal prairie has been converted to crop production (rice, milo, and cotton) and improved pastures. Remnant prairies are further threatened by invasion by exotic plants and urban sprawl (Allain et al. 1999).

Rice fields do not fully replace the benefits of coastal prairies and associated wetlands, but they do retain many of the wetland benefits that are typically lost when lands are converted to use for row crop agriculture (Hobaugh et al. 1989). Active and fallow rice fields provide resting and foraging habitat for mottled ducks during brooding and winter (Stutzenbaker 1988, Zwank 1989, Durham and Afton 2003). Nesting mottled ducks will readily use rice fields, especially during drought, when rice fields may provide important habitat at a time when natural wetlands are dry (Stutzenbaker 1988, Durham and Afton 2003). However, rice production in the coastal prairie regions has declined. From 1980-2007, area planted in rice declined by 75% (from 239,000 ha to 59,000 ha) in Texas and by 40% (from 254,000 ha to 154,000 ha) in Louisiana (USDA-NASS 2007). This trend is likely to continue due to lower production cost of growing rice in the Mississippi Delta as well as changes in government agricultural policy (Childs and Livezey 2006). Loss of rice agriculture on the landscape may reduce the ability of this region to support current mottled duck populations.

PURPOSE OF STUDY

Coastal prairie and associated wetlands are under continued threat of being destroyed or degraded. Habitat loss coupled with declining mottled duck abundance is a primary concern among waterfowl managers in the WGC region. Certain aspects about the basic ecology of the mottled duck are unknown and vital information needed to devise effective management plans is limited. The sedentary nature mottled ducks requires the fulfillment of annual needs within a relatively restricted area. Some studies have efforts examined survival of mottled ducks, but these studies were limited to specific areas and periods within the annual cycle (i.e., Finger et al. 2003, Rigby 2008). A more comprehensive understanding of seasonal survival that identifies periods of high mortality is crucial to designing and implementing management plans aimed at increasing mottled duck survival and enhancing key habitats during critical periods. The objectives of this study were to estimate survival rates of female mottled ducks throughout the WGC and identify critical periods that may constrain population growth.

STUDY AREA

My primary study area was based on band recovery locations from 1,689 normal, wild female mottled ducks recovered over the last 30 years in Texas and Louisiana (USGS, unpublished data). A 95% adaptive kernel distribution was developed from band recovery locations to delineate the extent of the study area. This home range was considered my primary study area and extended from Calhoun County in Texas north and east to Terrebonne Parish in Louisiana and encompassed wetlands and prairies of the Texas mid-coast, the Chenier Plain of southeast Texas and southwest Louisiana, and part of the Mississippi Deltaic Plain (Fig. 1.1). The climate is humid subtropical with

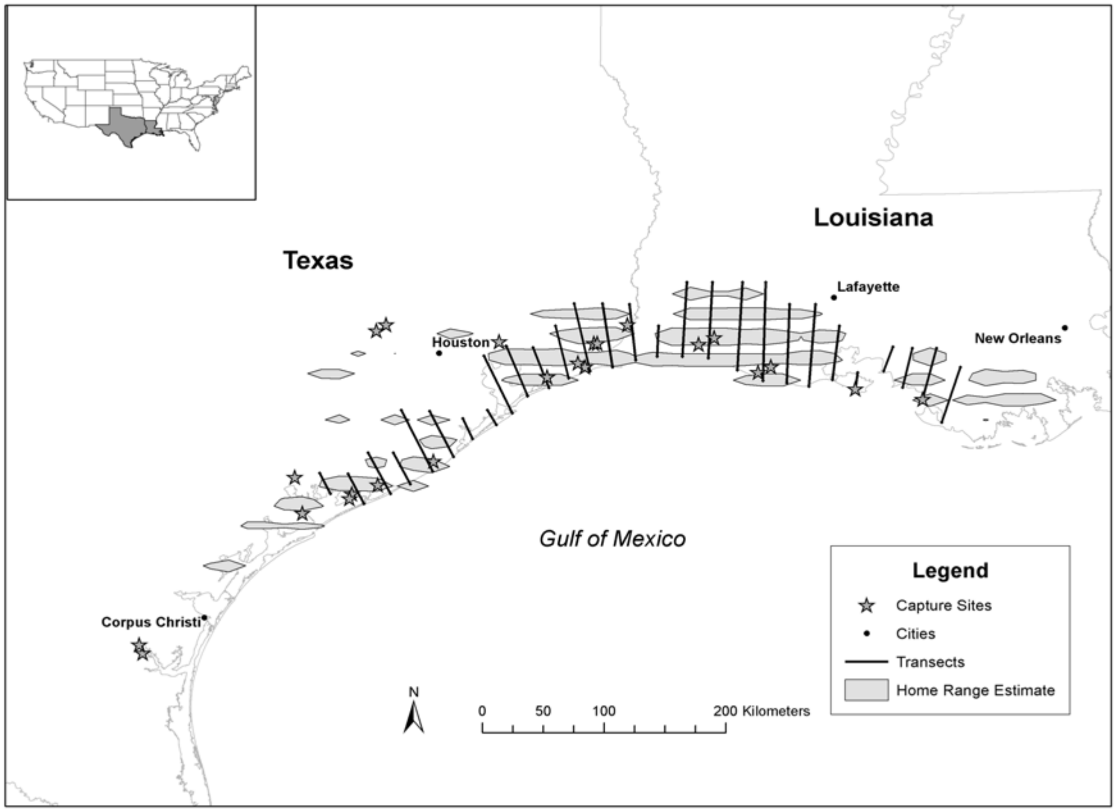

Figure 1.1. Primary study area of WGC mottled ducks with capture sites, transects, and home-range estimates derived from band return data**.**

average annual rainfall increasing from ~100 cm in the west to ~150 cm in the east (National Oceanic and Atmospheric Administration, National Climatic Data Center, http://gis.ncdc.noaa.gov/map/cdo/?thm=themeAnnual). Major habitats of mottled ducks within this area include extensive emergent estuarine marshes, emergent palustrine wetlands, and farmed wetlands; including rice fields (Stutzenbaker 1988). Coastal marshes are more extensive in the upper-coast of Texas and in southern Louisiana extending 25-80 km inland compared to the mid-coast of Texas in which coastal marshes occur along a relatively thin fringe (Tacha et al. 1993, Muehl 1994). The mid-coast region of Texas contains relatively more extensive areas of wet prairies and depressional wetlands than the upper coast of Texas and southern Louisiana. Much of the wet prairies have been converted to agricultural uses dominated by rice, soybean, and cattle production (Chabreck et al. 1989). This area has been described by previous authors (Chabreck et al. 1989, Houbaugh et al. 1989, and Stutzenbaker and Weller 1989). Capture sites were located on private and public land and based on local mottled duck abundance and accessibility. In Texas, female mottled ducks were captured on Anahuac National Wildlife Refuge (NWR), McFaddin NWR, Aransas NWR, Mad Island Marsh Preserve, Katy Prairie Conservancy, J.D. Murphree Wildlife Management Area (WMA), and Justin Hurst WMA, and on private lands in Harris, Jackson, Jefferson, Matagorda, Orange, and Kleberg County (Fig. 1.1). In Louisiana, individuals were captured at Marsh Island State Wildlife Refuge (SWR), Rockefeller SWR, Atchafalaya Delta WMA, Cameron Prairie NWR, and privately owned lands managed by Miami Corporation and owned by the M.O. Miller Estate in Cameron Parish and Vermilion Parish (Fig. 1.1).

METHODS

I captured female mottled ducks during July-September 2006-2009 when most adults were undergoing wing-molt. The majority of individuals were captured using night-lighting techniques and baited rocket-nets. I also captured 13 females with bait-traps, decoy traps, and rocket-nets during March 2007 and 2008 to complete my sample. Captured females were aged as after-hatch-year (AHY) or hatch-year (HY) based upon cloacal and plumage characteristics (Carney 1992). Each bird was weighed to the nearest 5 g using a Pesola spring scale and measurements (0.1 mm) were made on central culmen, head length, tarsus, and middle toe to adjust body mass for structural size and calculate a body condition index. AHY females were assigned a stage of molt based on the percent of regrowth of primaries with 0% being retention old primaries and no regrowth, and 100% indicating complete replacement and regrowth of primaries. Each female weighing ≥ 600 g was implanted with a 21 g abdominal transmitter with percutaneous whip antennas (Advanced Telemetry Systems, Isanti, MN, USA; Holohil Systems, Ltd., Carp, Ontario, Canada; Sirtrack, North America, North Liberty, Iowa) following procedures outlined by Korschgen et al. (1996) but with different placement of the catheter cuff. In the procedures of Korschegen et al. (1996), the cuff is placed at the base of the antennae and snug against the transmitter prior to insertion into the body cavity. Once the transmitter is inserted, the cuff is located under the skin, inside the duck and stitched into place. In my study, the cuff was placed at the base of the antennae after the transmitter was inserted in the body cavity and the antennae was extending out from the dorsal side of the duck; the cuff rested outside of the body. Super glue was applied to the cuff to keep it in place. These modifications were recommended by licensed veterinarian familiar with the surgical procedure.

During the study, concerns were raised about the possibility of the altered Dacron cuff placement affecting survival and detection of the transmitters. To test any potential effects resulting from cuff placement, 50.4% (114 of 226) of the radio-marked birds in 2009 had cuffs placed inside the body following Korschgen et al. (1996) procedures and the remaining 49.6% had Dacron cuffs placed on the outside of the body as done in previous years.

Transmitters had an expected battery life of 435 days. Each transmitter was equipped with a mortality sensor; a temperature-regulated sensor in 2006–07 that was activated when temperature of the transmitter fell below 30˚C, and a motion-sensitive sensor in 2008–09 that was activated if the transmitter was motionless for ≥8 hours. Range of the transmitters was approximately 10 km at an altitude of 1,000 m. Females were held for ≥ 4 hours after completion of surgery to allow recovery. All radio-marked females were banded with size 7A aluminum bands (USGS banding permit #21314) and released at the area of capture during daylight. These procedures were reviewed and approved by Texas A&M University-Kingsville Institutional Animal Care and Use Committee (Approval # 2006-07-18).

Radio-marked birds were monitored weekly from Aug 2006–Sept 2010 using trucks and fixed-wing aircraft with mounted Yagi antennas. I monitored location and status (dead or alive) of all individuals upon release until assigning a known fate or until their signal was lost due to transmitter failure or movement outside the study area. Upon detection of a mortality signal, I attempted to confirm fate and location through recovery of the transmitter.

From August 2006–March 2008, weekly aerial monitoring was conducted along 4 transects running parallel to the Gulf Coast and 20 km apart and covered an area considered to be the primary range of WGC mottled ducks in Louisiana and Texas. In March 2008, sampling protocol was redesigned and the study area was determined based on the aforementioned band recovery locations and derived distribution extent. Twenty-eight aerial transects (hereafter, set 1) were established roughly perpendicular to the coast, with 14 transects in each state. Distance between transects was 20 km, based on detection range of transmitters. A second set of transects (set 2) was established parallel to set 1, and positioned 10 km south and west of each transect in set 1. Transects in set 2 were flown in lieu of set 1 in alternating weeks to increase the likelihood of detecting transmitters with weak signals. I also monitored areas in Kleberg County and the Katy prairie weekly to survey birds caught and released outside the primary study area (Fig. 1.1). Additional search flights were flown every 3 months in attempts to locate missing birds that may have emigrated from the study area. During these surveys, we searched for missing birds in areas south of the primary study area to the US-Mexico border (0-30 km inland), the Garwood and Lissie Prairies, and east of the primary study area to the Mississippi River (0-80 km inland, Fig. 1.2).

Data Analyses

I estimated annual and weekly survival of female mottled ducks using the nest survival model (Dinsmore et al. 2002) in program MARK (White and Burnham 1999). The nest survival model allows date of loss to be assigned to an interval and does not

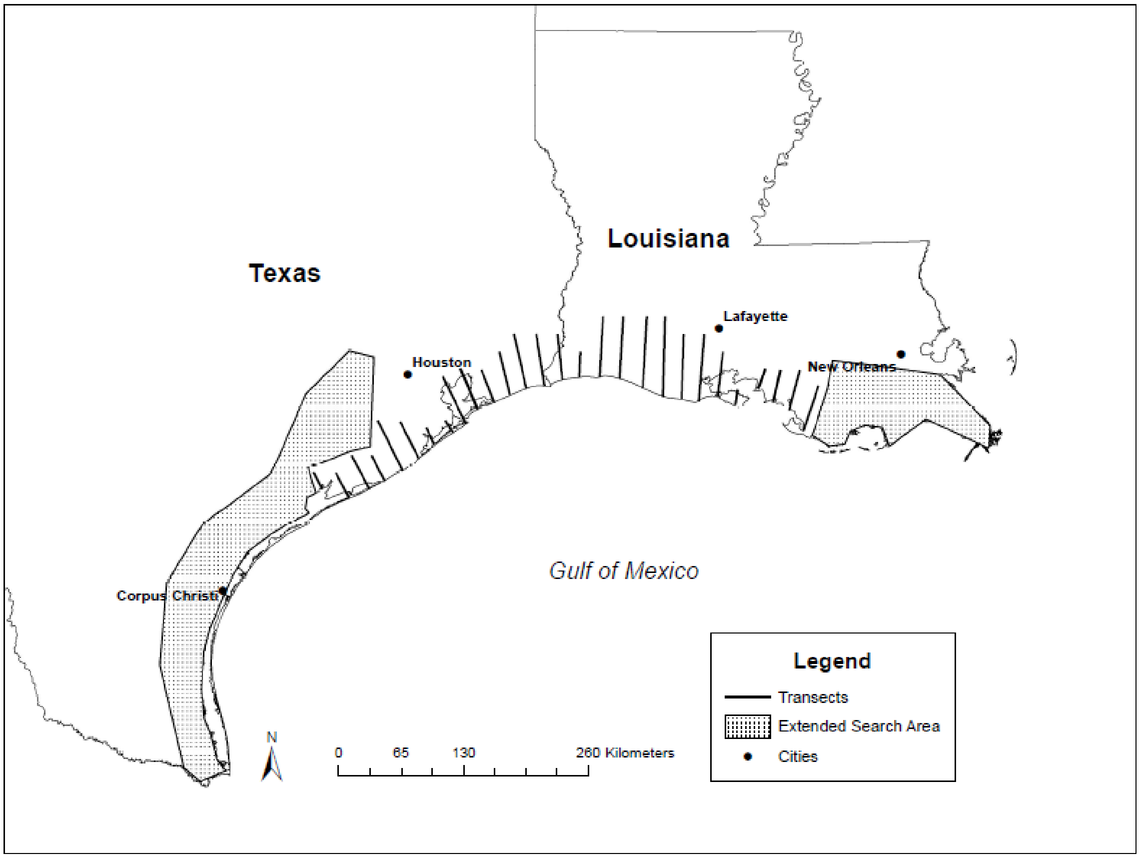

Figure 1.2. Location of transects and extended search area for radio-marked female mottled ducks along the western Gulf Coast during 2006–10.

require an assumption about the precise time when an individual is lost or result in a loss of information caused by censoring an individual following the last live sighting. My modeling approach follows the general advice of Burnham and Anderson (2002) and I used Akaike's information criterion corrected for bias due to small sample size (AIC_c, Hurvich and Tsai 1995) to select among competing models. I compared survival estimates only among top models with ΔAICc < 4, as models with ΔAICc ≤ 4 are considered to have strong to moderate support over candidate models with ΔAIC >4 (Burnham and Anderson 2002).

Survival estimation was initiated 2 weeks following release to filter potential radio effects and allow birds to acclimate to the transmitter (Gilmer et al. 1974, Migoya and Baldassarre 1995, Cox and Afton 1998). Individuals were grouped into cohorts based on year of capture and age at capture (hatch-year [HY], and after-hatch-year [AHY]). HY birds were considered AHY upon the start of the breeding season following capture. Annual survival was estimated from 15 July to 14 July the following year.

I tested the effects of 6 factors (body condition, molt stage, year of capture, age, state, and time periods) on their ability to explain variation in annual survival of female mottled ducks (Table 1.1). Body condition was examined because ducks in poorer condition have been found to have lower survival (Johnson et al. 1992, Pace and Afton 1999). Body condition can change throughout the annual cycle, so in a separate analysis, I modeled body condition to influence survival for the first 6 months following release since body condition parameters were measured only at the time of capture. Molt was considered as a factor because during molt survival may decrease due to nutritional stress

Table 1.1. List of factors included in survival analyses of female mottled ducks in the western Gulf Coast during 2006-2010.

Factor	Rationale	Reference
Body Condition	Birds in better body condition have higher survival.	Johnson et al. 1992 Pace and Afton 1999
Molt	Survival lower due to increased predation and nutritional strees.	Bielefeld and Cox 2006
Year	Environmental factors and habitat conditions vary from year to year affecting survival.	Dufour and Clark 2002
Age	Naivety of hatch-year bird results in lower survival compared to adults.	Johnson et al. 1992
State	Survival may differ between Texas and Louisiana.	Wilson 2007 Haukos 2008
Time Periods	Survival may vary during different periods within the annual cycle.	Owen and Black 1989 Johnson et al. 1992 Bielefeld and Cox 2006

and increased vulnerability to predators (Hanson 1962, Bielefeld and Cox 2006). I modeled molt stage to influence survival for the first 6 months following release since molt stage was only assessed at the time of capture. Capture year was considered because different weather patterns and habitat conditions among years may influence survival (Dufour and Clark 2002). Age was a likely factor because survival often differs between age classes of waterfowl (Johnson et al. 1992). HY individuals typically have lower survival possibly caused by inexperience or naivety of juveniles to hunters and predators (Anderson 1975, Krementz et al. 1987, Johnson 2009). State refers to the state (Texas or Louisiana) they spent most time in while being monitored. State was considered relevant because of differences in population trends between states (Wilson 2007, Haukos 2008). Biologically relevant time periods (e.g., post-breeding, hunting, late winter, and breeding, Table 1.2) were also included in survival models (Owen and Black 1989, Johnson et al. 1992, Bielefeld and Cox 2006). I delineated Mar 1 as the start of the breeding based on previous research (Finger et al. 2003). The post-breeding period started 14 days from the first release of radio-marked ducks for 2006-2007 or on July 15 for years 2008-2010. Hunting period dates in my analysis were established using the start and end dates of hunting seasons in Texas and Louisiana. Hunting seasons opened a week earlier in Texas than Louisiana but ended at the same time; earlier dates delineated the start of the hunting period. Late winter was from the end of the hunting period to the start of the breeding period. Using these factors, we developed a set of *a priori* models to examine survival rates (Table 1.3). A separate survival analysis for all birds captured in 2009 (including censored birds) was ran to determine if cuff placement influenced survival. I evaluated the importance of cuff placement on survival through its effect on model estimates.

Table 1.2. Periods and dates used to estimate seasonal survival of radio-marked female mottled ducks in Texas and Louisiana from July 2007 to October 2010. * Birds not monitored during this period.

	2006		2007		2008		2009		2010	
Period	Start	End	Start	End	Start	End	Start	End	Start	End
Post-breeding	July 15	Nov 3	July 15	Nov 2	July 15	Oct 31	July 15	Oct 30	July 15	Sep 10
Hunting	Nov 4	Jan 28	Nov 3	Jan 27	Nov 1	Jan 25	Oct 31	Jan 24	*	*
Late Winter	Jan 29	Feb 28	Jan 28	Feb 29	Jan 26	Feb 28	Jan 25	Feb 28	*	*
Breeding	*	*	Mar 1	July 14	Mar 1	July 14	Mar 1	July 14	*	*

Table 1.3. Candidate set of a priori models and corresponding Akaike's information criterion corrected for small sample size (AICc), differences in AICc from best model (ΔAICc), Akaike weight (w), model likelihood, and number of parameters (K) used to estimate survival of female mottled ducks in Texas and Louisiana during August 2006 – September 2010. Time periods are post-breeding, hunting, late winter, and breeding. Age = female age (hatch-year or after-hatch-year). State = state duck spent most time (TX or LA) Year = year of capture.

Model	AICc	Δ AICc	AICc Weights	Model Likelihood	K	Deviance
Intercept + time period + age + state	1672.68	0.00	0.65	1.00	6	1660.68
Intercept + time period + age	1674.99	2.30	0.20	0.32	5	1664.98
Intercept + time period + state	1675.84	3.15	0.13	0.21	5	1665.83
Intercept + time period	1679.95	7.27	0.02	0.03	4	1671.95
Intercept + age + state	1689.36	16.68	0.00	0.00	3	1683.36
Intercept + age	1691.07	18.39	0.00	0.00	2	1687.07
Intercept + state	1691.72	19.03	0.00	0.00	2	1687.72
Intercept + year + age + state	1694.08	21.40	0.00	0.00	7	1680.07
Intercept (constant survival)	1694.97	22.29	0.00	0.00	1	1692.97
Intercept + year + age	1695.75	23.06	0.00	0.00	6	1683.74
Intercept + year + state	1695.75	23.06	0.00	0.00	6	1683.74
Year	1699.22	26.54	0.00	0.00	5	1689.22
Age * year	1699.38	26.70	0.00	0.00	9	1681.37

RESULTS

Six-hundred-sixteen female mottled ducks were captured, radio-marked, and released on private and public lands along the WGC during the study. This included 162 HY and 454 AHY females (Table 1.4). Twenty-seven females were radio-marked in 2006, 182 in 2007, 182 in 2008, and 226 in 2009. A total of 113 birds were censored from survival analysis over the 4 year period because they were not detected beyond the censor period due to radio failure, movement out of the study area, or death within 2 weeks of being released. Therefore, seasonal and annual survival analyses included information from 503 radio-tagged mottled ducks monitored from 30 August 2006 to 12 September 2010 totaling 98,604 exposure days. Excluding censored birds, I detected 204 mortalities throughout the study period with 25 mortalities being reported hunter harvests. Two died in 2006, 53 in 2007, 58 in 2008, 89 in 2009, 2 in the post-breeding season of 2010. Most of the mortalities (52%) occurred during the hunting season, 25% occurred in the post-breeding period, 18% during breeding, and 5% during late winter. I was unable to determine the cause of most mortalities due to scavenging of carcasses. When transmitters were recovered, often little to none of the carcass could be found.

Cuff placement had little influence on survival as the survival rate was 0.36 ± 0.05 for females with interior cuffs and 0.40 ± 0.05 for females with exterior placed cuffs. Also, the beta value was small and overlapped zero (β -0.112, 95% C.I: -0.495 to 0.271).

I excluded molt state and body condition from my final models as preliminary analyses indicated weak to no influence of these factors on survival for the 6 months constant or varied among years (Table 1.3). The top model contained the additive effects

Table 1.4. Mean body condition index of female mottled ducks captured in Texas and Louisiana during July-September 2007–09 and March 2008–09.

Year	State	Age	*n*	Body Condition	(SE)
2006	LA	AHY	12	709	12.4
Aug-Sept	TX	AHY	14	701	10.5
2007	LA	AHY	75	779	9.3
July-Sept		HY	24	745	19.5
	TX	AHY	43	751	9.3
		HY	32	693	12.9
Mar-08		AHY	8	768	33.9
2008	LA	AHY	91	789	7.9
July-Sept		HY	18	707	18.0
	TX	AHY	45	788	10.51
		HY	23	717	17.5
Mar-09		AHY	5	840	44.8
2009	LA	AHY	108	803	7.0
		HY	23	692	11.0
	TX	AHY	53	785	8.8
		HY	42	681	7.9

of time periods, age, and state, and contributed 65% of the model weight. The next best approximating model ($\Delta AIC_c = 2.30$) was similar contained the additive effects of time period and age and accounted for 20% of the model weight. The third ranked model ($\Delta AIC_c = 3.15$) contained the additive effects of time periods and state and contributed 13% of the model weight. All other models had $\Delta AIC_c > 7.00$ and contributed ≤ 2% to the model weight. Time periods had strong support and were a factor in the 4 top models accounting for 100% of the cumulative AICc weight. Although the inclusion of state and age increased the strength of the model by explaining some of the variation, I found no statistical differences in mean estimates of survival between Texas and Louisiana, or between HY and AHY birds as 95% CI overlap (Table 1.5).

Survival estimates were similar among the top 3 models and compared to the overall model-averaged estimates (Table 1.6). Model-averaged annual survival was 0.48 ± 0.03 SE for AHY females and 0.40 ± 0.04 SE for HY females. For AHY birds, survival was higher in the post-breeding period compared to hunting and breeding periods (95% C.I. did not overlap, Fig. 1.3) and similar between breeding and hunting periods (95% C.I.'s overlapped). HY birds also had higher survival during the post-breeding period compared to the hunting period. Since HY birds were combined with AHY upon the start of breeding period, there are no estimates of HY survival during the breeding period. I observed less precise estimates for weekly survival in late winter likely due to the relatively short duration of this period (4 weeks) compared to the other time periods (≥14 weeks) and reduced sample sizes caused by mortalities and loss of transmitter signals resulting from movement out of the area or radio failure. As a result,

Table 1.5. Effect of estimates (β), standard errors (SE), and 95% of the 3 top models describing survival of female mottled ducks of the WGC.

Model	**Parameter**	**β**	**SE**	**95% CI**
Time period + age + state	Intercept	3.89	0.25	3.39 to 4.39
	Post-breeding	0.68	0.24	0.21 to 1.15
	Hunting	-0.20	0.20	-0.59 to 0.20
	Late Winter	-0.07	0.36	-0.78 to 0.64
	Age[1]	0.39	0.17	0.06 to 0.73
	State[2]	-0.30	0.14	-0.59 to -0.02
Time period + age	Intercept	3.70	0.23	3.24 to 4.16
	Post-breeding	0.69	0.24	0.22 to 1.16
	Hunting	-0.17	0.20	-0.57 to 0.23
	Late Winter	-0.03	0.36	-0.74 to 0.68
	Age	0.45	0.17	0.12 to 0.78
Time period + state	Intercept	4.31	0.17	3.97 to 4.66
	Post-breeding	0.54	0.23	0.09 to 0.99
	Hunting	-0.33	0.19	-0.70 to 0.05
	Late Winter	-0.20	0.35	-0.90 to 0.49
	State	-0.35	0.14	-0.63 to -0.08

[1] Coding for age: HY = 0, AHY = 1

[2] Coding for state bird spent the most time in while being monitored: LA = 0, TX = 1

Table 1.1. Weekly and seasonal estimates of survival with standard error (SE) for 4 different time periods and annual survival (SE) for female mottled ducks of the WGC.

Model	**Region**	**Age**	**Post-breeding**	**SE**	**Hunting**	**SE**	**Late Winter**	**SE**	**Breeding**	**SE**	**Annual**	**SE**
Weekly Estimates												
Time period + age												
+ state	LA	HY	0.990	0.002	0.976	0.004	0.979	0.007			0.434	0.047
		AHY	0.993	0.001	0.984	0.002	0.985	0.004	0.986	0.002	0.522	0.036
	TX	HY	0.986	0.003	0.967	0.005	0.971	0.009			0.324	0.044
		AHY	0.991	0.002	0.978	0.003	0.980	0.006	0.982	0.003	0.436	0.044
	WGC	HY	0.988	0.002	0.973	0.004	0.976	0.008			0.389	0.039
		AHY	0.992	0.001	0.981	0.002	0.984	0.005	0.985	0.002	0.480	0.030
Time period + state	LA	Pooled	0.992	0.001	0.982	0.002	0.984	0.005	0.987	0.002	0.504	0.035
	TX	Pooled	0.989	0.002	0.974	0.003	0.977	0.007	0.981	0.003	0.378	0.039
	WGC	Pooled	0.991	0.001	0.979	0.002	0.981	0.005	0.985	0.002	0.453	0.274
Time period + age	WGC	HY	0.988	0.002	0.971	0.004	0.985	0.002			0.396	0.044
		AHY	0.992	0.001	0.982	0.002	0.985	0.002	0.985	0.001	0.476	0.031
Model-averaged	WGC	HY	0.989	0.002	0.973	0.005	0.976	0.008			0.396	0.044
		AHY	0.992	0.001	0.981	0.002	0.983	0.002	0.985	0.002	0.476	0.031
Entire Season												
		HY	0.852	0.029	0.685	0.044	0.909	0.028	0.745	0.036		
		AHY	0.893	0.018	0.765	0.026	0.934	0.019	0.745	0.036		

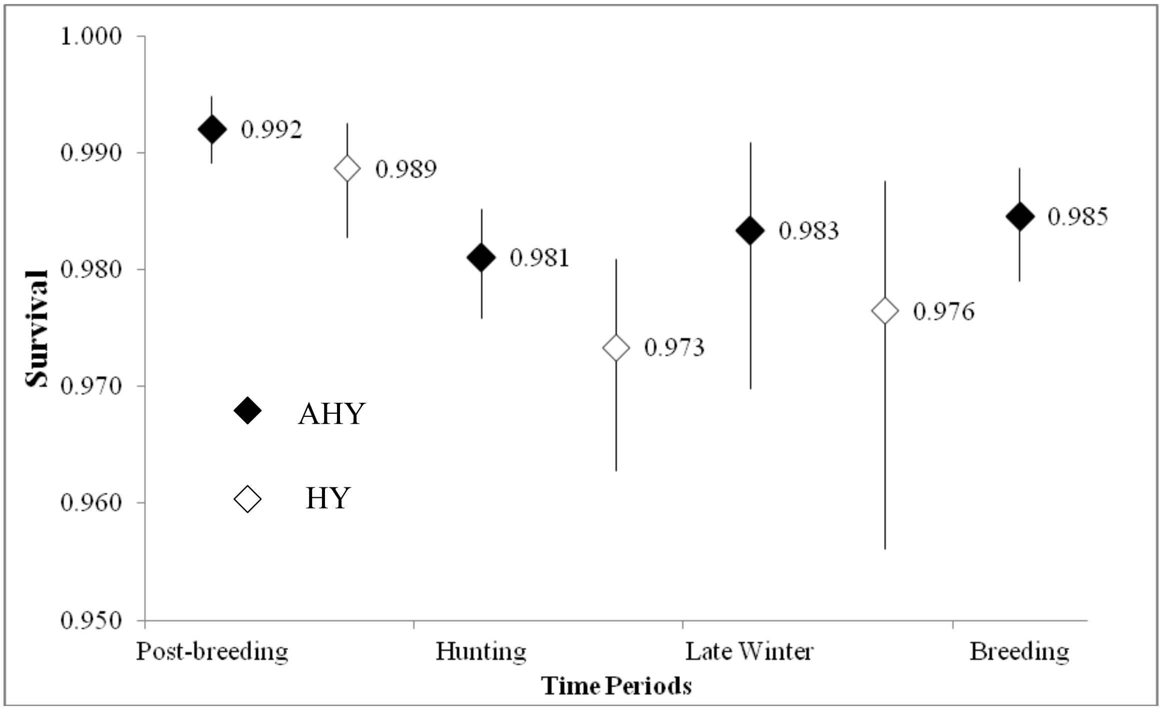

Figure 1.3. Model-averaged weekly estimates with 95% confidence intervals of survival through 4 different time periods for female mottled ducks of the Western Gulf Coast from 2006-10. HY birds were considered AHY at the start of the breeding season.

late winter was not statistically different from average weekly estimates of other time periods for AHY or HY.

DISCUSSION

My estimated annual survival of female mottled ducks is similar to survival estimates derived from banding data (Haukos 2009, Johnson 2009). Annual survival is similar with reported estimates for other dusky duck species and at the low end of the range of survival for other dabbling ducks (see Johnson et al. 1992, Krementz et al. 1997). Despite varying precipitation levels among years and the landfalls of Hurricanes Ike and Gustav in 2008, I did not detect any difference in survival among years. Mottled ducks exploit a wide-range of habitats from estuarine-emergent wetlands to freshwater wetlands enabling their persistence in an area that is subject to marked variation in habitat conditions due to weather. For example, when the storm surge associated with Hurricane Ike inundated habitats with seawater up to 25 km inland along the upper coast of Texas and southeast Louisiana (D'sa et al. 2010), radio-marked mottled ducks within this area moved to wetlands lying further inland and remained there until salinities decreased in coastal areas (Bruce Davis, unpublished data). By being mobile and able to exploit a variety of habitats, mottled ducks can adjust when habitat conditions temporarily deteriorate within part of their range.

Mottled ducks may also influence their survival by altering their behavior when habitat conditions change. For instance, female dabbling ducks may respond to drought conditions by forgoing reproduction to increase their chance of survival to breed in subsequent years (Dufour and Clark 2002). Nesting propensity of mottled ducks was low and female survival relatively high when conditions were dry along the Texas coast

(Finger et al. 2003). Precipitation and survival for adult male mottled ducks were positively related within the WGC, but not for females (Johnson 2009). Similar to Finger et al. (2003), Johnson (2009) attributed the lack of relationship between female survival and precipitation to increased nesting propensity and greater vulnerability to predation of females during wet years.

Although no difference in survival was detected across years, strong support was provided for temporal variation within the annual period. My results indicated relatively high rates of survival for mottled ducks during the post-breeding period for both HY and AHY cohorts compared to breeding and hunting periods. Model-averaged weekly survival estimates during the breeding period were similar to those reported in other studies of mottled ducks in Texas (Table 1.7). There are no other published seasonal survival estimates for mottled ducks in the WGC. To compare my survival estimates to those observed in Florida, I converted Bielefeld and Cox (2006) seasonal estimates to weekly averages using the delta method (Powell 2007). Weekly survival of AHY females in the WGC were lower than in Florida during late winter and breeding, higher during the post-breeding period, and similar during the hunting period (Bielefeld and Cox 2006; Table 1.7). Differences observed between the 2 populations may be a result of different habitat conditions between the two regions and different levels of hunting pressure and predation. For example, Bielefeld and Cox (2006) noted that during their study, rural wetlands dried out and mottled ducks moved into wetlands more associated with urban and suburban areas which had lower predation and hunting pressure than rural wetlands. Similar movements within the WGC have not been observed (Bruce Davis, unpublished data).

Table 1.7. Estimates (SE) of weekly survival for female mottled ducks during different periods in the annual cycle in the western Gulf Coast and Florida.

Year	Study Area	Age[1]	Weekly Survival		Season	Dates	Reference
1999-2002	FL	AHY	0.976	(0.002)	Post-breeding	1 Aug – mid-late Nov	Bielefeld and Cox 2006
			0.981	(0.005)	Hunting	mid-late Nov – late Jan	
			1		Late Winter	late Jan – 29 Feb	
			0.993	(0.002)	Breeding	1 Mar – 31 July	
2000-2002	Mid-coast of TX	AHY	0.988	(0.010)	Breeding	Feb–Aug	Finger et al. 2003
2006-2008	Upper-coast of TX	AHY	0.985	(0.006)	Breeding	Mid-Feb – 30 June	Rigby 2008
2007-2010	TX & LA	AHY	0.992	(0.001)	Post-breeding	15 July –late Oct/early Nov	This study
			0.981	(0.002)	Hunting	late Oct/early Nov–late Jan	
			0.983	(0.002)	Late Winter	Late Jan–29 Feb	
			0.985	(0.002)	Breeding	1 Mar–14 July	
		HY	0.989	(0.002)	Post-breeding	15 July–late Oct/early Nov	
			0.973	(0.005)	Hunting	late Oct/early Nov–late Jan	
			0.976	(0.008)	Late Winter	late Jan–29 Feb	

[1] AHY=after-hatch-year, HY = hatch-year.

Lower survival of mottled ducks during the hunting and breeding periods compared to post-breeding is a pattern observed in many North American ducks (i.e., Losito et al. 1995, Devries et al 2003). However, mottled ducks in Florida were more likely to die during the post-breeding period than during hunting or breeding periods (Bielefeld and Cox 2006). I did not detect a similar pattern for the WGC population of mottled duck, which suggests that the 2 populations are operating under different environmental factors. Although my survival estimates for the hunting and breeding periods were lower compared to the post-breeding period, they are similar to survival during hunting and breeding periods reported for American black ducks (*Anas rubripes*) and mallards (Cowardin et al. 1985, Reinecke 1987, Conroy et al. 1989, Devries et al. 2003; Table 1.8).

Ground-nesting female ducks face increased exposure to predators during nesting and brood rearing often resulting in lower survival during these periods (Johnson and Sargeant 1977, Blohm et al. 1987, Sargeant and Raveling 1992, Johnson et al. 1992). Patch size, vegetation cover, predator community, landscape composition, and proximities to other patches can influence rates of predation on females and nests (Sargeant and Arnold 1984, Clark and Nudd 1991). Ducks nesting in large habitat patches tend to experience higher rates of daily survival than individuals nesting in smaller patch sizes, probably due to lower efficiency of predators in locating nests in larger patches (Sovada et. al 2000). However, the precise relationship between patch size and predation risk is unclear because of confounding effects of different habitat conditions (e.g., number of wetlands, vegetative structure, etc.) and predator communities among studies (Clark and Nudds 1991, Sovada et al. 2000). Small increases in patch size

Table 1.8. Estimated survival (S) of female mallards, black ducks, and mottled ducks throughout North America during the breeding and hunting seasons.

Season	Species	Region	Years	Weeks	Months	Age[1]	S	SE	Reference
Breeding	Mallard	ND	1977-1980	16	Apr-Jun	AHY	0.87	(0.06)	Cowardin et al. 1985
	Mallard	Canada-Prairie Pothole Region	1993-1998	13	15 Apr-15 Jul	AHY	0.69	(0.01)	Devries et al. 2003
	Mottled Duck	WGC	2005-2009	20	Mar-Jul	AHY	0.75	(0.04)	This Study
Hunting	Mallard	MS, AR		10		AHY	0.84	NA	Reinecke 1987
		TX-Playa Lakes Region		14	21 Nov-1 Mar	AHY	0.77	(0.06)	Bergan and Smith 1993
						HY	0.76	(0.06)	
	American Black Duck	NJ and VA	1983-1985	8	19 Dec-15 Feb	AHY	0.73	(0.06)	Conroy et al. 1989
						HY	0.60	(0.05)	
	Mottled Duck	WGC		14		AHY	0.77	(0.03)	This Study
				14		HY	0.69	(0.04)	

[1] AHY=after-hatch-year, HY = hatch-year.

may have little to no effect on female survival, and patch size may need to be increased beyond a threshold before any differences in survival can be detected (Clark et al. 1991).

When land is converted to agricultural uses, small pockets of isolated wetlands and associated upland habitat can remain. Although, some benefit may be gained by increasing the density of cover on these patches, results of such efforts are mixed (see McKinnon and Duncan 1991). A more effective means to increase survival is to increase patch size and landscape connectivity through conversion of farmland to pastures (McKinnon and Duncan 1991). To maximize the benefits of converting farmland to pastures or idle fields, these areas should be placed near rice fields or wetlands to increase nesting success in farming landscapes (Durham and Afton 2003, Horn et al. 2005).

The effects of hunting on annual survival of ducks have only been investigated for a few species and remain a contentious issue. For adult male dabbling ducks, hunting mortality appears to be largely compensated by reductions in other forms of mortality (Anderson and Burnham 1976). The effect of hunting on female dabbling ducks appears to produce a more mixed set of results, particularly for HY females (Burnham et al. 1984, Krementz et al. 1987). Harvest regulations in Texas and Louisiana have been changed over the years to reduce harvest of mottled ducks. For instance, daily bag limits for mottled ducks have recently been reduced from 3 to 1 in Louisiana. From the 2006 to 2009 hunting season, Texas implemented a 3-year experimental “hunter’s choice” bag in attempts to reduce harvest on duck species of conservation concern such as the mottled duck. The hunter’s choice option allowed the daily bag to include 1 duck from a group of these species of concern. Since 1985, the daily bag limit for the mottled duck in Texas is one. Currently, Texas implements a season within a season for mottled ducks with the first day to legally harvest a mottled duck being 5 days after the opening day of the regular duck season. Historically, most mottled ducks were harvested during the first two weeks of duck season and this change was implemented to reduce mottled duck harvest by 20%. Results from the experimental regulations are currently being evaluated by federal and state agencies to establish future hunting regulations to balance mottled duck harvest with their population status.

Interspecific competition for resources between mottled ducks and migrant waterfowl during the breeding season is likely limited as most migrants have departed the WGC for northern breeding grounds by early spring. However, during autumn, arrival of migrant species and the mottled duck's anti-social behavior may cause it to shift use to more marginal habitats. The loss of wetland habitats along the WGC over the last 50 years (Moulton et al. 1997, Dahl 2000) may have influenced the mottled duck's ability to find high quality alternate habitat away from high concentrations of other waterfowl during winter. Reduced body condition and lowered survival are possible outcomes of using suboptimal habitat during winter (Hepp et al. 1986, Sillett and Holmes 2002). Additionally, waterfowl in poor body condition may be more susceptible to harvest (Greenwood et al. 1986, Hepp et al. 1986, Dufour et al. 1993). During this study, 12.2% of mortalities were known harvest which is similar to 10.2% found in mottled ducks in Florida (Belfield and Cox 2006) suggesting that other factors may be as important during the hunting period.

MANAGEMENT IMPLICATIONS

Population growth for mottled ducks is sensitive to female survival and reproduction rates (Johnson 2009). Increases in survival can potentially lead to increases in overall populations (Johnson et al. 1992, Hoekman et al. 2002). My results suggest relatively low annual survival for mottled ducks compared to other dabbling duck species. Efforts to increase preferred habitats, particularly during the breeding periods could positively female survival (Wilson 2007). Currently, most wetland management along the WGC is focused on wintering waterfowl. Drainage of managed wetlands along the WGC typically begins at the end of hunting season in mid-January, reducing the amount of habitat available to breeding mottled ducks. Habitat management should be considered at the landscape scale. Prioritizing habitat management for areas that optimize habitat connectivity should be most effective for population recovery. For example, most mottled ducks prefer nesting in tall dense grass such as in cordgrass prairies, fallow rice fields, or rangelands (Stutzenbaker 1988, Durham and Afton 2003, Finger et al. 2003). Managing for nesting habitat in close proximity to brood habitat would likely reduce predation on ducklings and nesting females (Durham and Afton 200).

Since large amounts of land in Texas and Louisiana are privately owned, it is important for agencies to build and maintain strong relationships and enlist landowners to assist with conservation efforts. The GCJV encourages these practices and currently supports several cost-share programs in Texas and Louisiana that are designed to increase wetland availability during the winter, spring, and summer (Wilson 2007). Other incentive programs are available that can be implemented to increase nesting habitat.

These programs, plus a greater focus on managing wetlands for mottled ducks along the WGC are important steps towards the conservation of the mottled duck.

CHAPTER 2.

SITE FIDELITY AND CHARACTERISTICS OF HABITAT USED BY FEMALE MOTTLED DUCKS DURING POST-BREEDING

INTRODUCTION

The non-migratory mottled duck (Anas fulvigula) is a specialist of the marshes of the Western Gulf Coast (WGC). Habitat loss, urban development, and reduction in rice farming throughout the species' range combined with declining population trends have resulted in the mottled duck being identified as a priority species for conservation (Wilson 2007). Despite its relatively sedentary nature, a paucity of information exists regarding the mottled ducks ecology; including habitat-use and site-fidelity during the post-breeding period. During the post-breeding period mottled ducks shed and replace flight feathers and are flightless for ~27 days (Stutzenbaker 1988). This is a potentially critical time as mortality may increase due to vulnerability to predators and possibly physiological stress caused by increased nutrient demand needed to grow feathers (Hanson 1962, Bielefeld and Cox Jr. 2006). While flightless, a duck's mobility is reduced and vulnerable to changes in local habitat conditions (Hohman et al. 1992). Habitats preferred by dabbling ducks during the post-breeding period are generally described as permanent, shallow wetlands with areas of open water and dense vegetation (Oring 1964, Salomonsen 1968). However, specific information about preferred habitat characteristics and structure for molting waterfowl, including those preferred by mottled ducks, is relatively unknown.

This chapter is written in the style of *Wildfowl*

Waterfowl are well known for their breeding-site fidelity (see Anderson et al. 1992), but fidelity to post-breeding or molting sites has received less attention (Hohman et al. 1992). Molt-site fidelity has been documented for the closely-related black duck (*Anas rubripes*, Bowman and Brown 1992, Bowman and Longcore 1989) and mallard (*Anas platyrhynchos,* Yarris et al. 1994), as well as waterfowl comprising a variety of different taxa including diving ducks, shelducks, and geese (Erskine 1961, Barker et al. 2005, King and Hodges 1979, Williams 1979). However, little is known about the molting sites of mottled ducks including whether they are selected based on breeding-site use or if they exhibit fidelity to previously used molting areas.

Gender, reproductive success, and environmental factors affect the timing of molt and selection of molting sites (Hohman et al 1992). Males and non-breeding females typically start molting earlier than breeding females. Small numbers of male mottled ducks will begin to molt in late June but large numbers are not observed until mid-July (Stutzenbaker 1988). Female mottled ducks do not start molt till after their brood has fledged. A small proportion of females will start molting in late June, but peak numbers of molting females are not reached until mid-August; with late nesting females molting through September or October (Stutzenbaker 1988). In other duck species, males and non-breeding females will often leave breeding sites and move to different areas to molt (Salomonsen 1968); possibly because breeding sites are not ideal molting sites (Gilmer et al. 1977). Such “molt migrations” are well established in migratory species, however, these patterns have not been observed in resident species such as the mottled duck. Breeding females often molt on or near the nesting/brood-rearing area (Oring, 1964, Salomonsen 1968). Advantages of remaining on breeding sites through the molt include better knowledge of optimal foraging areas and predator avoidance (Hohman et al. 1992). In certain years, however, food sources at breeding sites may become reduced over time leaving breeding females at a disadvantage if they remain at breeding sites to molt (Sedinger and Raveling 1986).

Fidelity tends to be positively correlated with habitat stability, with higher fidelity observed in more stable and predictable habitats (McNicholl 1975). Wetland type and availability vary throughout the WGC. The expansive fresh and intermediate marshes are more stable habitats whereas the availability of smaller, temporary, freshwater wetlands is more subject to fluctuate with varying amounts of precipitation. During wet years, mottled ducks are widely distributed and will molt in a variety of wetlands as long as they have adequate food, escape cover, and water. In dry years, mottleds ducks will move to more permanent wetlands such as tidally influenced marshes, deep marshes, or rice irrigation reservoirs to undergo molt (Stutzenbaker 1988).

Increasing our understanding of habitat selection by molting mottled ducks will aid in developing management goals to ensure proper habitat is available during a potentially critical, yet often overlooked, period in the annual cycle. The first objective of this study was to describe and quantify characteristics of wetlands used by female mottled ducks during the post-breeding period. I also estimated molt-site fidelity and tested possible factors influencing fidelity. I predicted female mottled ducks may be more sensitive to changes in habitat conditions in the spring months as females dabbling ducks tend to molt in close proximity to nesting and brooding sites. Male mottled ducks were predicted to be more sensitive to habits conditions during the summer months as males mottled ducks do not share in parental duties and should be less tied to breeding sites. This study was part of a larger study investigating survival, habitat use, and movements of mottled ducks along the WGC.

Study Area

The study area included wetlands located within 80 km inland from the WGC from the Texas-Mexico border north and east to the Mississippi River Delta. This area encompassed coastal wetlands and prairies of the Texas lower and mid-coast, the Chenier Plain of southeast Texas and southwest Louisiana, and part of the Mississippi Deltaic Plain (Fig. 2.1). Major habitats of mottled ducks within this area include extensive emergent estuarine marshes, emergent palustrine wetlands, and farmed wetlands; including rice fields (Bielefeld et al. 2010). The climate varies from semi-arid in the lower-coast of Texas to sub-tropical humid in the central-coast of Texas north and east through southern Louisiana. Annual precipitation ranges from 55 cm in the lower coast of Texas with a gradient that increases to about 150 cm in southeastern Louisiana (National Oceanic and Atmospheric Administration, National Climatic Data Center, http://gis.ncdc.noaa.gov/map/cdo/?thm=themeAnnual). The WGC is affected by the El Nino-La Nina-Southern Oscillations which influences precipitation patterns varying from wet to dry periods (Ropelewski and Halpert1986, 1996). These alternating precipitation patterns affect wetland availability as shallower more ephemeral wetlands disappear during drought periods. Salinities in coastal marshes also vary with precipitation and will increase during times of drought as freshwater inflows are reduced (Tolan 2007). The WGC is vulnerable to major storm events and associated tidal surges which can inundate low lying coastal marshes with seawater (Chabreck 1972). Tropical storms occur ~1 per 5

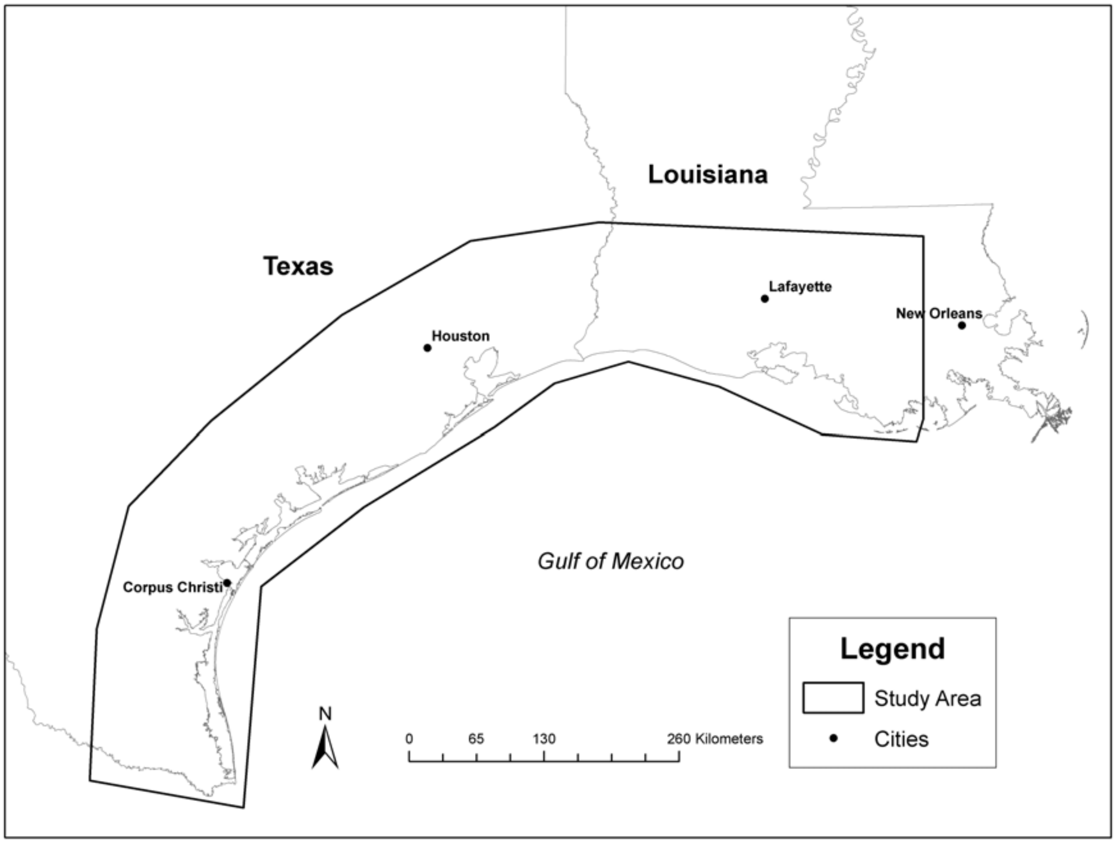

Figure 2.1. Study area for habitat use of post-breeding mottled ducks in Texas and Louisiana during 2009 and 2010.

years and hurricanes occur ~1 every 10 years (Keim et al. 2007). Hurricanes occur most often in the months of August and September.

Precipitation and climatic patterns differed between the 2 years of this study, especially for Texas. Dry to severe drought conditions were observed in Louisiana and Texas prior and through the sampling period (late July-Sept) of 2009 (Fig. 2.2). After the sampling period through the beginning of 2010, wetter conditions were observed. By the second sampling period conditions in Texas were near normal while Louisiana experienced dry to moderate drought conditions.

Wetland type and distribution varies across the study area. Estuarine wetlands are the most abundant wetland type in lower-Texas coast (Muehl 1994). This area has limited freshwater flows from mainland drainages and evaporation rates can exceed precipitation rates causing hyper-saline conditions in the Laguna Madre (McMahan 1968; Tunnel 2002). Inland landscapes are dominated by sandy plains and coastal prairies.

The mid-coast region is dominated by extensive areas of wet prairies and depressional wetlands. Coastal marshes are restricted to a thin fringe bordering the coast and bays. Much of the wet prairies have been converted to agricultural uses dominated by rice, soybean, and cattle production (Chabreck et al. 1989).

The coastal marshes of the Chenier and Mississippi Deltaic Plains extend up to 80 km inland and are extensive compared to those along the mid-coast and lower-coasts of Texas (Tacha et al. 1993, Muehl 1994, Chabreck et al. 1989). The Chenier plain contains a series of sand ridges running parallel to the coast and serve as natural levees bordering coastal marshes limiting tidal exchanges to inlets and river mouths. These ridges formed as sediment from the Mississippi river was discharged into the Gulf,

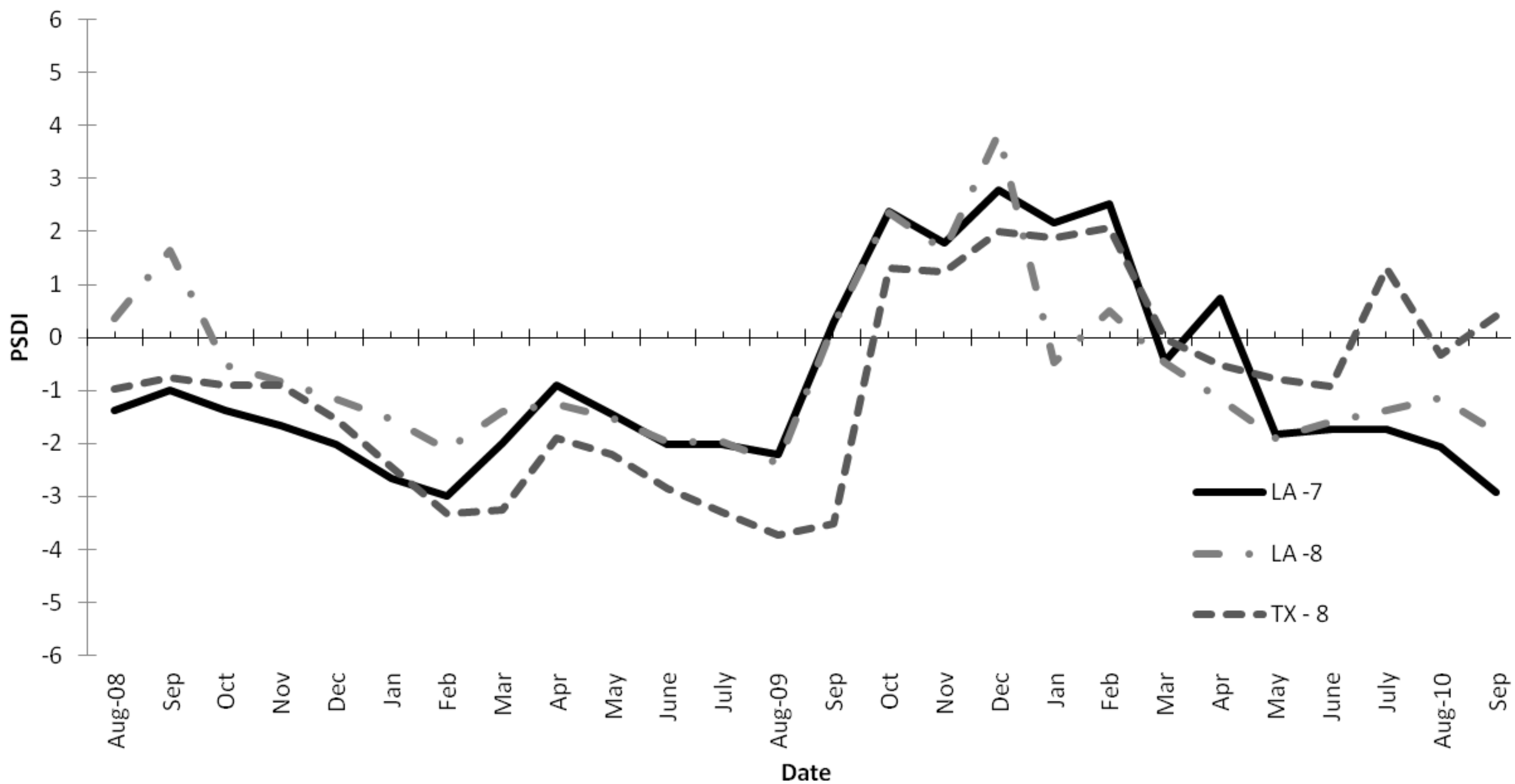

Figure 2.2. Palmer Drought Severity Index values for climatic zones 7 and 8 in Louisiana and zone 8 in Texas for August 2008-September 2010.

carried by currents, and deposited on the shoreline (Coleman 1966, Chabreck 1972). The Mississippi Deltaic Plain is characterized by its irregular shoreline and large bays. The marshes of the Deltaic Plain were also formed by sedimentation from the Mississippi river, and are described as unstable, and degrading (Gagliano et al. 1981, Chabreck et al. 1989).

Habitat throughout the area has been degraded and lost through anthropomorphic means (agriculture, channelization, canal creation, urbanization, reduced freshwater inflows (Chabreck et al. 1989, Stutzenbaker and Weller 1989). In addition to losing natural wetlands, rice production has declined throughout the area (USDA-NASS 2007). The coastal zone of Texas and Louisiana support 33% and 47% of each state's human population (Brown et al. 1977, U.S. Census 2007). Human populations are predicted to continue to grow in this region which will likely result in increased conflict between habitat conservation and land development (Brody et al. 2004).

METHODS

Capture

I captured female mottled ducks during July-September 2006-2009 when most adults were undergoing wing-molt. The majority of individuals were captured using night-lighting techniques and baited rocket-nets. I also captured 13 females with bait-traps, decoy traps, and rocket-nets during March 2007 and 2008 to complete my sample. Captured females were aged as after-hatch-year (AHY) or hatch-year (HY) based upon cloacal and plumage characteristics (Carney 1992). Each female weighing ≥ 600 g was implanted with a 21 g abdominal transmitter with percutaneous whip antennas (Advanced Telemetry Systems, Isanti, MN, USA; Holohil Systems, Ltd., Carp, Ontario, Canada;

Sirtrack, North America, North Liberty, Iowa) following procedures outlined by Korschgen et al. (1996). Transmitters had an expected battery life of 435 days. Each transmitter was equipped with a mortality sensor; a temperature-regulated sensor in 2006–07 that was activated when temperature of the transmitter fell below 30˚C, and a motion-sensitive sensor in 2008–09 that was activated if the transmitter was motionless for ≥8 hours. Range of the transmitters was approximately 10 km at an altitude of 1,000 m. Females were held for ≥ 4 hours after completion of surgery to allow recovery. All radio-marked females were banded with size 7A aluminum bands (USGS banding permit #21314) and released at the area of capture during daylight. These procedures were reviewed and approved by Texas A&M University-Kingsville Institutional Animal Care and Use Committee (Approval # 2006-07-18).

Radio Tracking

To estimate habitat use during molt, I initiated tracking of radio-marked female mottled ducks during the molting period the year following their initial capture. I waited until the following year to allow radio-marked females to select sample wetlands and to reduce potential bias associated with using only habitats that banding crews searched which is based on accessibility and previous banding success. However, the number of transmitters implanted in 2008 that were still functioning during the molting period in 2009 was low (n = 2) so I augmented my sample with birds that were captured in the current year, but were captured prior to wing molt (n=7); all ducks were located in Texas. In 2010, 6 ducks were tracked in Texas and 3 in Louisiana. Radio-marked mottled ducks were located with truck-mounted null-peak systems at 4-6 hour intervals for a length of 24-48 hours during late-July through September 2009 and 2010.

Habitat Sampling

Locations of individual females were estimated using program LOAS (Location of a Signal, Ecological Software Solutions LLC). For each radio-marked female, I used 3-10 estimated locations to estimate a 95% minimum convex polygon of use. For each polygon, I used Generate Random Points in Hawth's Analysis Tools for ArcGIS (Beyer 2004) to generate a random starting point for a 100-m transect. The number of transects per use polygon ranged from 1-8 and was related to the size of the polygon. At 25-m intervals along each transect (i.e., 5 sampling points per transect) I measured percent vegetation cover within a 1-m quadrat, and measured screening cover, water depth, and vegetation height using a Robel pole. I also measured water salinity at each sampling point with a YSI model 30 probe. I estimated size and classified each sampled wetland using Cowardin et al. (1979) classification system. To boost sample size, an additional 8 wetlands were sampled where molting mottled ducks were captured during federal and state banding operations.

I randomly selected 75 wetlands in Texas during 2009 and in selected a different set of 156 random wetlands in Texas and Louisiana during 2010. These random wetlands represented availability of wetland types in the landscape. For my selection process, I used data from the National Wetland Inventory and excluded all open water lakes, riverine, and marine systems, as well as deep water estuarine wetland types within our study area to limit our sampling to wetlands of probable use by post-breeding mottled ducks. I then randomly selected wetlands contained within the coastal zone of Texas for 2009 and the coastal zone for Texas and Louisiana in 2010 using the Create Random Selection option of the Hawthe's Tools extension of ARCGIS. Random wetlands were classified based on Cowardin et al. (1979) descriptions and salinity readings were taken when possible.

Molt-Site Fidelity

To investigate molt site fidelity, I compiled records of all wild banded mottled ducks captured from 1967-2010 in Texas and Louisiana. I obtained all original banding records from Texas Parks and Wildlife Department, Louisiana Department of Wildlife and Fisheries, and the Bird Banding Lab (BBL) and reviewed each record for recaptures. I recorded sex, age at initial capture, and date and location of initial capture and recapture for each record. I restricted my analyses to birds banded and recaptured during the months of Jun-Sep and recaptured ≥ 1 year after banding. Fidelity was defined as the individual being recaptured at its original banding site (TX and LA state data) or within the original 10-minute block of capture (BBL data). I also compiled data from the Palmer Drought Severity Index (PDSI, http://www.ncdc.noaa.gov/temp-and-precip/time-series/) for April and July. The PSDI is a measure of soil moisture conditions derived from moisture supply versus demand and is used as an index of relative drought (i.e., wetland habitat conditions). Birds were matched with PDSI values from the same month and climatic zone of initial capture and recapture locations. I selected PDSI values from April because peak nesting for mottled ducks typically occurs during this month (Ballard et al. 2001). Since female mottled ducks molt immediately following completion of breeding activities (Gilmer et al. 1974, Oring 1964, Salomonsen 1968), habitat conditions during nesting may be important in habitat selection during the post-breeding period. However, if molting site selection is not strongly influenced by nesting and brood-rearing locations, then wetland conditions during the summer may have a stronger influence on molting-site selection. I chose PDSI conditions for July because the peak number of males molting occurs during July and molting females are commonly observed during this month (Stutzenbaker 1988).

I also obtained age ratio data for mottled ducks for Texas and Louisiana from the U.S. Fish and Wildlife Service's Waterfowl Parts Collection Survey. Average age ratios from the fall-winter following date of initial capture and for the state of initial capture were used as an index to habitat conditions. Age ratios are well known to be positively correlated with breeding habitat conditions (Anderson 1975, Heitmeyer and Fredrickson 1981, Kaminski and Gluesing 1987).

Statistical Analysis

Habitat Sampling

I compared mean wetland size, salinity, % emergent vegetation, % submergent vegetation, and % open water between used and randomly selected wetlands with a one-way ANOVA (unpaired t-test) for response variables that satisfied assumptions of a parametric test. Normality of errors was tested with the Shapiro-Wilk (1965) test, and homogeneity of variances was tested with Levene's (1960) test and with a Wilcoxon test when assumptions were violated.

I summarized wetland characteristics (% emergent vegetation, % submergent vegetation, and % open water habitat) and vegetation and water characteristics (vegetation height, screening cover, salinity, and water depth) of known-use wetlands using descriptive statistics. I used student's t-tests to compare habitat characteristics between years.

Molt-site Fidelity

I analyzed 3 different models to test for association between fidelity and both change in habitat conditions and age. Males and females were analyzed separately because of differences in timing of molt. Males may respond to conditions more in the summer, whereas females molt following completion of breeding activities and are thought to molt at or near breeding sites (Oring 1964, Gilmer et al. 1977). Age was included as an explanatory variable because lower fidelity has been observed for hatch-year ducks than for adults (Anderson et al. 1992). Using PDSI values, I classified habitat conditions for the months of capture and recapture as dry (PDSI < -1), normal ($-1 \leq$ PDSI $\leq +1$), and wet (PDSI $> +1$, Palmer 1965). I compared classified PDSI values between capture and recapture years to determine if habitat conditions differed between years. I assigned a value of change (CH) when PSDI varied (dry to normal, dry to wet, normal to dry, normal to wet, wet to dry, wet to normal) between years and a value of no change (NC) when values remained the same. The first model included the dependent variables (i) age, and CH or NC in PSDI for (ii) April and for (iii) June (all as classification variables); this analysis tested for an association between fidelity and change in habitat conditions in a model that accounted for age (juvenile or adult) at initial capture. For the second model, I wanted to determine if positive changes in PSDI (wetter conditions during recapture) affected fidelity differently than negative changes in PSDI (drier conditions during recapture). For this model, I classified habitat change into 3 classes of drier (D), no change (NC), and wetter (W); age was also included. The third model included age and the change in age ratios from year of capture and recapture (a continuous variable).

For each analysis, I used PROC GLIMMIX (SAS, version 9.2) to fit a generalized linear model to test the effects of the explanatory variables on fidelity. Effects of explanatory variables in each model were assessed using *F*-values in Type III test.

RESULTS

I sampled 32 (10 in 2009, 22 in 2010) wetlands of known-use by radio-marked female mottled ducks, and 225 (70 in 2009, 156 in 2010) randomly selected wetlands of unknown use. Dry conditions in 2009, resulted in 81% of randomly selected wetlands being dry compared to 18% in 2010 (Table 2.1). Three of 10 wetland types were observed holding water during 2009 due to the drought. The most available wetland type was palustrine unconsolidated bottom, which accounted for 83% of randomly selected wetland basins holding water. These were deeper wetland types often represented by dugout ponds used as water sources for cattle and often fed by windmills.

The most commonly used wetland type by post-breeding mottled ducks in our study was estuarine-intertidal-emergent wetlands which comprised about 50% of used wetlands in both years (Table 2.1). No wetlands of this type were randomly selected for sampling in 2009. Freshwater vegetated wetlands were generally not available as post-breeding sites during the dry conditions in 2009. Wetlands of this type used by mottled ducks in 2009 were typically located near more permanent water sources such as canals.

About half of the wetland characteristics compared between used and randomly selected wetlands violated statistical assumptions regarding homogeneity of variance and normal distribution. However, comparison of ANOVA and non-parametric analyses yielded the same results, so I reported results of the ANOVA analysis (Table 2.2). Salinity and percent submergent vegetation were similar between known-use and

Table 2.1. Number of each wetland type randomly selected, number with inundated basins (%), and number used (%) by molting mottled ducks along the Gulf Coast of Texas and Louisiana during August through September 2009-2010. Numbers in parentheses are percent of total wetlands of used or randomly selected wetlands for that year.

	2009			2010		
	Randomly selected			Randomly selected		
Wetland Type	Total	Available	Used	Total	Available	Used
Estuarine						
Subtidal-unconsolidated bottom	0	0 (0)	2 (20.0)	3	3 (1.9)	0
Intertidal-emergent	0	0 (0)	5 (50.0)	19	15 (9.6)	12 (54.6)
Intertidal-unconsolidated bottom	1	0 (0)	0	21	20 (12.8)	0
Lacustrine						
Limnetic-unconsolidated bottom	1	1 (1.4)	0	1	1 (0.6)	1 (4.6)
Littoral-aquatic bed	0	0	0	2	2 (1.3)	0
Palustrine						
Aquatic bed	3	2 (2.9)	0	5	4 (2.6)	0
Emergent	34	0	2 (20.0)	47	38 (24.4)	7 (31.8)
Forested	11	0	0	24	16 (10.3)	0
Scrub/shrub	6	0	0	5	4 (2.6)	0
Unconsolidated bottom	14	10 (14.3)	1 (10.0)	29	25 (16.0)	2 (9.1)

Table 2.2. Mean (SE) estimates, test statistics, and p-values comparing habitat characteristics between wetlands randomly selected and wetlands used by radio-markedmottled ducks along the Western Gulf coast during August through September 2009-2010.

					ANOVA			Non-parametric		
Selection	Variable	N	Mean	SE	*F* -value	df	*p*	χ2	df	*p*
Random	Size*	133	1.48	0.17	52.35	161	<.0001	102.56	37	< 0.001
Used		30	55.79	0.47						
Random	Salinities	30	5.39	2.11	2.87	60	0.096	50.59	39	0.096
Used		32	10.19	1.91						
Random	Open water	141	61.31	2.65	6.89	171	0.010	73.85	53	0.03
Used		32	45.13	5.55						
Random	Emergent vegetation	141	24.87	2.32	8.29	171	0.005	42.77	20	0.02
Used		32	40.66	5.29						
Random	Submerged vegetation*	141	5.64	1.17	3.78	171	0.053	40.25	35	0.25
Used		32	11.56	3.82						

* Violated statistical assumptions of normal distribution and equal variance assumptions.

randomly selected wetlands both years. Known-use wetlands were larger (F^{1}_{60} = 52.35, *P* < 0.001), had greater coverage of emergent vegetation (F^{1}_{141} 8.29, *P*= 0.005), and less open water habitat (F^{1}_{141} = 6.89, *P*= 0.010) than random wetlands. Molting mottled ducks selected wetlands with approximately 35% open water and 45% emergent vegetation (cover) both years, resulting in similar water depths and amount of screening cover between years (Fig. 2.3, Table 2.3). Water salinity (t = 3.78, 34 df, P < 0.001) and amount of exposed mudflat (t= 2.25, 34 df, P = 0.03) in known-use wetlands were greater in the dry year of 2009 than in 2010 (Table 2.3). I observed 34 different plant species in known-use wetlands in 2009 and 28 species in 2010, with 14 plants being observed both years (Fig 2.4). However, 18 and 12 plant species from 2009 and 2010 each contributed <1% of the total plant composition of known-use wetlands. *Spartina patens* was the most common plant species in both years comprising > 18% of vegetation cover, but was more common in 2010. The next most common plant species in 2009 were *S. alterniflora*, *Scirpus americanus, and S. robustus* compared to *Ruppia martima*, *Distichlis spicata*, and *Scirpus americanus* in 2010.

I extracted 665 records of recaptured mottled ducks from all banded mottled ducks in Texas and Louisiana. Of these, 273 were females and 392 were males (Table 2.4). Overall, 49.8% of recaptured females and 38.2% of recaptured males displayed site fidelity. The influence of age was not significant factor explaining molt-site fidelity in males or females in any model ($F \leq 1.60$, $P \geq 0.207$) (Table 2.5). No effect of Δ April or Δ July was detected for either sex 0.54 $\leq$1.60, $P \geq 0.638$). In the final model, a significant negative correlation of Δ AR on fidelity was detected for males ($F_{1,\,389}$ = 13.07 P < 0.001) and females ($F_{1,267}$ = 9.13, P = 0.003).

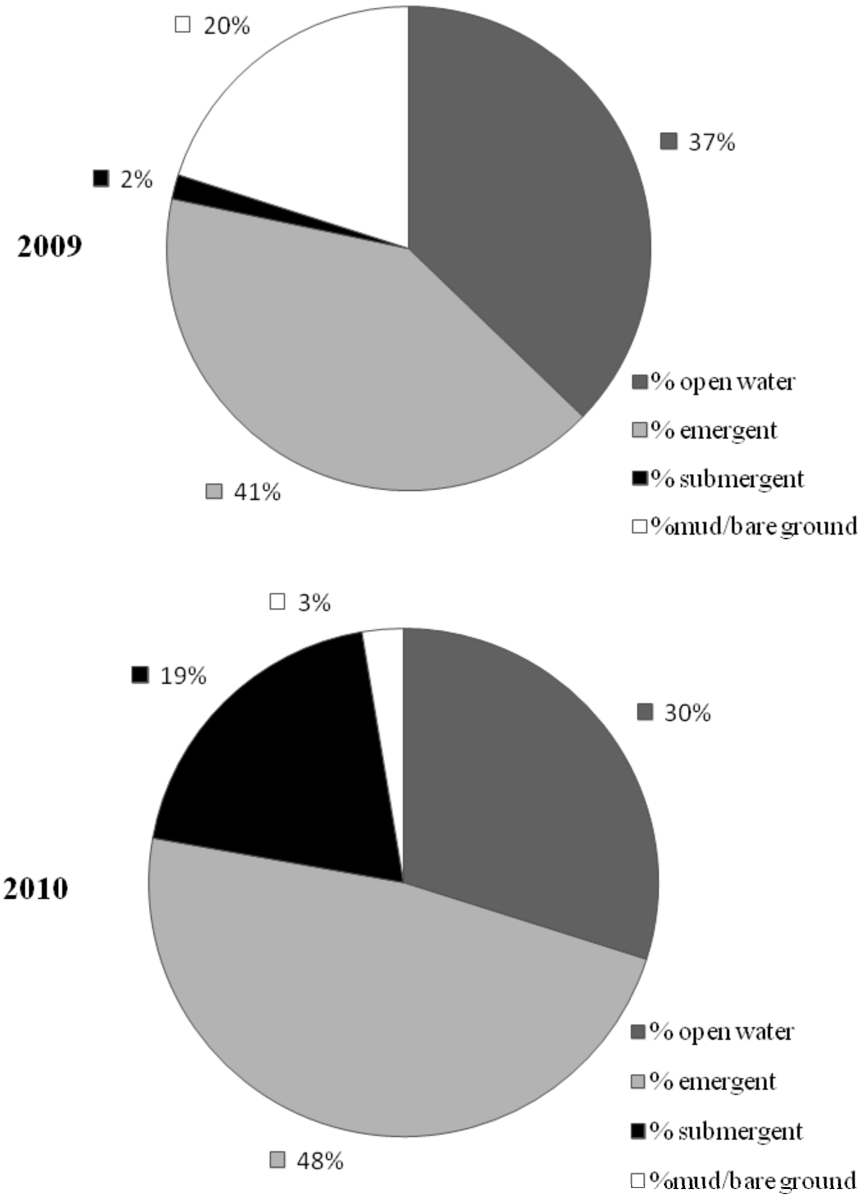

Figure 2.3. Habitat composition of wetlands used by radio-marked female mottled ducks in Texas and Louisiana during July-Sep 2009 and 2010.

Table 2.3. Mean (SE) habitat characteristics of wetlands used by radio-marked female mottled ducks in the Western Gulf Coast during August-September of 2009 and 2010. * Indicates significant difference between years.

Year	Salinity* (ppt)	Water Depth (cm)	Screening Cover (cm)	Vegetation Height * (cm)
2009	18.4 (2.9)	12.7 (3.3)	18.6 (4.6)	87.0 (15.2)
2010	6.6 (1.5)	14.3 (2.2)	12.4 (3.9)	49.1 (8.8)

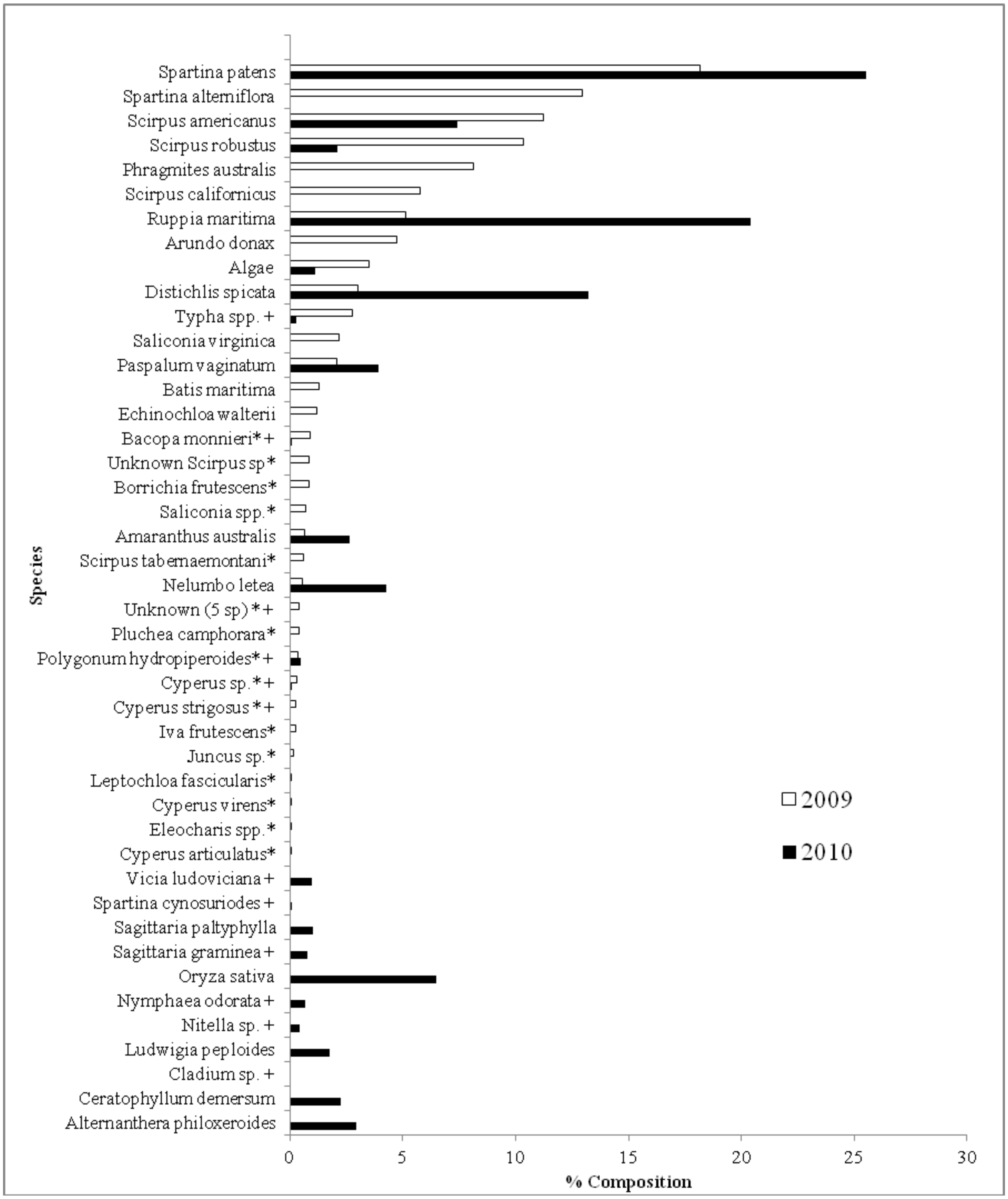

Figure 2.4. Percentage of wetland plants observed in wetlands used by radio-marked female mottled ducks in the Western Gulf Coast during August-September of 2009 and 2010. * Species comprises <1% of observed species for 2009. + Species comprises <1% of observed species for 2010.

Table 2.4. Number of banded mottled ducks (by age and sex) recaptured during June-September in Texas and Louisiana from 1967-2010.

	State Banded		
	TX	LA	Total
AHY			
Males	43	214	257
Females	19	107	126
HY			
Males	32	103	135
Females	43	104	147
Total	137	528	665

Table 2.5. Explanatory variables used to analyze molt site fidelity of banded mottled ducks in Texas and Louisiana.

Model	Sex	Variable	df	*F* Values	*P*
1	Females	Age	266	0.01	0.923
		Δ April		0.01	0.914
		Δ July		0.08	0.780
2		Age	266	0.00	0.969
		Δ April		0.96	0.385
		Δ July		1.40	0.248
3		Age	267	0.17	0.682
		Δ age ratios		6.48	0.012
1	Male	Age	389	0.05	0.479
		Δ April		0.02	0.895
		Δ July		0.17	0.681
2		Age	387	0.54	0.462
		Δ April		0.45	0.638
		Δ July		0.13	0.882
3		Age	390	1.60	0.207
		Δ age ratios		13.39	< 0.001

Δ April and Δ July for model 1 represent if classified PDSI were different between capture and recapture years. Δ April and Δ July for model 2 represent if moisture conditions were drier, no, change, or wetter between capture and recapture years. Δ age ratios was the difference in age ratios between capture and recapture year.

DISCUSSION

Wetland use by mottled ducks during the post breeding period is influenced by habitat conditions along the WGC. Much of our study area experienced a drought in 2009 which resulted in only 19% of randomly selected wetlands to be available during the post-breeding period. Those wetlands that remained available tended to be deepwater wetlands with little vegetation cover. Most mottled ducks used estuarine habitats where water levels fluctuate less due to drought. Estuarine wetlands typically occur in relatively large expanses along the coast, and their high use by radio-marked mottled ducks resulted in the observed difference in size between used and randomly selected wetlands. A few mottle ducks were located in vegetated freshwater habitat during the dry year despite this wetland type's limited availability. These habitats were located adjacent to or surrounded more permanent wetlands (e.g. lakes and canals).

The greater vegetation height in habitats used in 2009 was related to the more robust vegetation that grows in deeper wetlands with longer hydroperiods (e.g., *Phragmites australis*, *Scirpus spp.*), as those were the only wetland types that remained available during the drought. When conditions were wetter in 2010, wetlands used by radio-marked mottled ducks had higher proportions of submerged aquatic vegetation than during the dry conditions of 2009. Submerged aquatic vegetation is known to support diverse invertebrate communities which are an important source of protein needed for feather development (Ringleman 1990). In addition, seeds and the vegetative parts of submergents such as *R. maritime,* which was the second most common plant species in 2010, are consumed by mottled ducks (Chamberlain 1959).

Even though the types of wetlands used by mottled ducks changed between years due to availability, the physiognomic structure of used wetlands remained relatively similar (e.g., percent emergent vegetation, percent open water, screening cover, water depth). Thus, mottled ducks used structurally similar wetlands each year, but due to differences in habitat conditions, used different wetland types to find such structure.

Like most post-breeding dabbling ducks, mottled ducks in this study selected stable wetlands (e.g. coastal marshes) with areas of open water interspersed with dense emergent vegetation (Kortegaard 1974, Anderson and Low 1976, Courcelles and Bedard 1979). Because mottled ducks experience a complete wing molt and become flightless for 2-3 weeks, they are quite vulnerable to changes in habitat conditions. Selection of more stable wetlands would enhance the likelihood that wetlands remain flooded throughout the molting period. Flooded emergent vegetation selected by dabbling ducks is important for avoiding and escaping predators. For example, flightless male mottled ducks used dense emergent vegetation as loafing cover and molting female mottled ducks forage while remaining hidden in emergent vegetation (Paulus 1984).

I was unable to detect any relationship between my classified PSDI values on fidelity to support my predictions about the influence of spring or summer conditions on molt site fidelity. However, I did find that age ratios of the harvest did influence the probability of post breeding fidelity, suggesting that breeding habitat conditions may be important. My predictions about the influence of breeding conditions on fidelity was based on the assumption that molting sites would be in close proximity to sites selected for breeding (Gilmer et al. 1974, Oring 1964, Salomonsen 1968). Harvest age ratios of dabbling ducks have been linked to habitat conditions during the previous breeding periods (Heitmeyer and Fredrickson 1981, Kaminski and Gluesing 1987). The negative correlation between molt-site fidelity and harvest age ratios indicates molting mottled ducks are more likely to return to previously used molting sites when conditions become drier. Mottled ducks typically nest in close proximity to more permanent wetland types (Stutzenbaker 1998, Durham and Afton 2003, Rigby 2008). Therefore, drier years with later nest initiation dates (Finger et al. 2003) may result in high molt-site fidelity, particularly if females already inhabit the best available habitat.

Male and female mottled ducks exhibited the same relationship between molt-site fidelity and age ratios at harvest. However, the parameters I used to index habitat conditions (PSDI and age ratios) are only available at very large scales and may be too course to tease out relationships when habitat conditions vary at a much smaller scale. Thus, a more precise metric of wetland conditions may provide greater insights to factors affecting fidelity of mottled ducks to molting sites.

Molt side-fidelity may also be a product of the sedentary nature of the mottled duck. Stutzenbaker (1988) reported that 82% of birds banded during the post-hunting period in Texas were later shot in subsequent years within the same county of banding. In another study, mottled ducks banded in the upper coast of Texas from 1997-2001 were recovered within ~80km from the center of the 10-min block of banding (Haukos et al. 2005 as cited in Bielefield et al. 2010). The stability and quality of the coastal marshes along the WGC likely enables the sedentary behavior (Stuzenbaker 1988). However, mottled duck movements have been noted when habitat quality declines due to drought or increased salinity levels (Rigby 2008); although mottled ducks typically do not to travel more than 60 km to find available wetlands (Stutzenbaker 1988).

Coastal marshes of the WGC provide important habitat for post-breeding mottled ducks. Most waterfowl management along the coast is geared towards meeting the needs of wintering waterfowl. This includes drawing down wetlands after hunting season limiting wetlands available for post-breeding mottled ducks. A greater emphasis on managing wetlands for mottled ducks could benefit the species. Wetlands used by flightless mottled ducks should be maintained throughout the molting period, especially during drought. Mottled ducks usually reside usually within a constrained area throughout the entire lifecycle. Therefore, conservation projects aimed at increasing habitat connectivity (i.e. placement of brood habitat near molting habitat) should be given priority.

The fate of the mottled duck is linked with the future of wetlands of the WGC. Like many coastal regions, the WGC is heavily impacted by anthropomorphic activities (e.g. channelization, canal creation, dredging, flood control, and urbanization) that have greatly altered hydrology of these wetlands (Chabrek 1982, Turner 1990, Kennish 2001). Restoration of hydrological features of WGC wetlands on a landscape scale will be needed to conserve important mottled duck habitat (Bielefeld et al. 2010). To accomplish this objective, cooperative efforts between government and non-government agencies, private organizations, and citizens will be needed. Human populations in the region are projected to grow through the foreseeable future which will increase human impacts on coastal wetlands. Water use issues will need to be addressed in order to meet the demands of a growing population while maintaining adequate inflows into coastal wetlands.

REFERENCES

Allain, L., M. Vidrine, V.Grafe, C. Allen and S. Johnson. 1999. Paradise lost? The coastal prairie of Louisiana and Texas. U.S. Fish and Wildlife Service and U.S. Geological Survey. 39 pp.

Anderson, D. R. 1975. Optimal Exploitation Strategies for an Animal Population in a Markovian Environment: A Theory and an Example. Ecology 56:1281.

Anderson, D. R., and Burnham, K.P. 1976. Population ecology of the mallard. VI. The effect of exploitation on survival. U.S. Fish and Wildlife Service Resource Publication 128. Washington, D.C.

Anderson, M. G., and J. B. Low. 1976. Use of sago pondweed by waterfowl on the Delta Marsh, Manitoba. The Journal of Wildlife Management 40:233–242.

Anderson M.G., J. M. Rhymer, and F. C. Rohwer. 1992. Philopatry, dispersal and the genetic structure of waterfowl populations. Pages 365-395 In B. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankeny, D. H. Johnson, J. A. Kadlec and G. L. Krapu, editors. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis Minnesota, USA.

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

Barker, R. J., T. Caithness, and M. Williams. 2005. Survival rates of Australasian shoveler ducks in New Zealand. Journal of Wildlife Management 69:1508–1515.

Barras, J.A., Bourgeois, P.E., and Handley, L.R., 1994, Land loss in coastal Louisiana 1956-90: National Biological Survey, National Wetlands Research Center, Open File Report 94-01.

Bergan, J. F. and Smith, L. M. 1993. Survival rates of female mallards wintering in the Playa Lakes region. Journal of Wildlife Management 57:570–577.

Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. Available at http://www.spatialecology.com/htools.

Bielefeld, R.R., and R. R. Cox Jr. 2006. Survival and cause-specific mortality of adult female mottled ducks in east-central Florida. Wildlife Society Bulletin 34:388–394.

Bielefeld, Ronald R., Michael G. Brasher, T. E. Moorman and P. N. Gray. 2010. Mottled duck (*Anas fulvigula*), The Birds of North America Online. A. Poole, editor. Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/081. Accessed 25 June 2011.

Blohm, R. J., R. E. Reynolds, J. P. Bladen, J. E. Nichols, J. E. Hines, K. H. Pollock, and R. T. Eberhardt. 1987. Mallards mortality rates on key breeding and wintering areas. Transactions of North American Wildlife and Natural Resources Conference. 52:246-257.

Boesch, D. F., M. N. Josselyn, A. J. Mehta, J. T. Morris, W. K. Nuttle, C. A. Simenstad, and D. J. P. Swift. 1994. Scientific assessment of coastal wetland loss, restoration and management in Louisiana. Journal of Coastal Research special issue 20:1-103.

Bowman, T. D., and P. W. Brown. 1992. Site fidelity of male black ducks to a molting area in Labrador. Journal of Field Ornithology 63:32–34.

Bowman, T. D., and J. R. Longcore. 1989. Survival and movements of molting male black ducks in Labrador. Journal of Wildlife Management 53:1057–1061.

Brody, S. D., W. Highfield, S. Arlikatti, D. H. Bierling, R. M. Ismailova, L. Lee, and R. Butzler. 2004. Conflict on the coast: using geographic information systems to map potential environmental disputes in Matagorda Bay, Texas. Environmental Management 34:11–25.

Brown, L. F., J. H. McGowen, Evans, T.J., C. G. Groat, and W. L. Fisher. 1977. Environmental Geologic Atlas of the Texas Coastal Zone: Kingsville Area. Bureau of Economic Geology, University of Texas at Austin, Austin, Texas, USA.

Burnham, K. P., G. C. White, and D. R. Anderson. 1984. Estimating the effect of hunting on annual survival rates of adult mallards. Journal of Wildlife Management 48:350-361.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer Verlag. New York, New York, USA.

Carney, S. M. 1992. Species, age, and sex identification of ducks using wing plumage. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Chabreck, R. H. 1972. Vegetation, Water and Soil Characteristics of the Louisiana Coastal Region. Louisiana State University, Agricultural Experiment Station Bulletin No. 664.

Chabreck, R. H. 1981. Freshwater inflow and salwater barriers for management of coastal wildlife and plants in Louisiana. Pages 125-138 *in* R. D. Cross and D. L. Williams, editors. Proceeding of the national symposium on freshwater inflow to estuaries, volume 2. U.S. Fish and Wildlife Service. Washington DC, USA. FWS/OBS-81/04.

Chabreck, R. H. 1982. The effect of coastal alteration on marsh plants. Pages 92-98 *in* D.F. Boesch, editor. Proceedings of the Conference on Coastal Erosion and Wetland Modification in Louisiana: Causes, Consequences and Options. U. S. Fish and Wildlife Service, Office of Biological Services, FWS/OBS-82..

Chabreck, R. H, T. Joanen, and S. L. Paulus. 1989. Southern coastal marshes. Pages 249-277 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press. Lubbock, Texas, USA.

Chabreck, R., and S. Roberts. 1993. Evaluation of aerial transect surveys of mottled ducks. Northeast Gulf Science 13:43-51.

Chamberlain, J. L. 1959. Gulf Coast Marsh Vegetation as Food of Wintering Waterfowl. The Journal of Wildlife Management 23:97–102.

Childs, N., and J. Livezey. 2006. Rice backgrounder. Outlook Report from the Economic Research Service, United States Department of Agriculture. RCS-2006–01 .

Clark, R. G., and T. D. Nudds. 1991. Habitat patch size and duck nesting success: the crucial experiments have not been performed. Wildlife Society Bulletin 19:534-543.

Clark, R. G., T. D. Nudds, and R. O. Bailey. 1991 Populations and nesting success of upland-nesting ducks in relation to cover establishment. Canadian Wildlife Service Progress Notes 193.

Conroy, M. J., G. R. Constanzo, and D. B. Stotts. 1989. Winter survival of female American black ducks on the Atlantic Coast. Journal of Wildlife Management 53:99-109.

Courcelles, R., and J. Bédard. 1979. Habitat selection by dabbling ducks in the Baie Noire marsh, southwestern Quebec. Canadian Journal of Zoology 57:2230–2238.

Cowardin, L. M. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service. Washington, D.C., USA.

Cowardin, L. M., M., D. S. Gilmer, and C. W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildlife Monographs 92:1.

Cox Jr, R. R., and A. D. Afton. 1998. Effects of capture and handling on survival of female northern pintails. Journal of Field Ornithology 69:276-287

D'sa, E. J., M. Korobkin, and D. S. Ko. 2010. Effects of Hurricane Ike on the Louisiana–Texas coast from satellite and model data. Remote Sensing Letters 2:11–19.

Dahl, T. E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of Interior, Fish and Wildlife Service, Washington, DC.

Devries, J. H., J. J. Citta, M. S. Lindberg, D. W. Howerter, and M. G. Anderson. 2003. Breeding-season survival of mallard females in the prairie pothole region of Canada. Journal of Wildlife Management 67:551–563.

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

Dufour, K. W., C. Davison Ankney, and P. J. Weatherhead. 1993. Condition and Vulnerability to Hunting among Mallards Staging at Lake St. Clair, Ontario. The Journal of Wildlife Management 57:209–215.

Dufour, K. W., and R. G. Clark. 2002. Differential survival of yearling and adult female mallards and its relation to breeding habitat conditions. Condor 104:297–308.

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

Erskine, A. J. 1961. Nest-site tenacity and homing in the Bufflehead. The Auk 78:389–396.

Esslinger, C.G., and B.C. Wilson. 2001. Gulf Coast Joint Venture: Chenier Plain Initiative, North American Waterfowl Management Plan, Albuquerque, New Mexico, USA.

Field, D. W., A. J. Reyer, P. V. Genovese, and B. D. Shearer. 1991. Coastal wetlands of the United States: an accounting of a valuable natural resource. Strategic Assessment Branch, Ocean Assessments Division, Office of Oceanography and Marine Assessment, National Ocean Service, National Oceanic and Atmospheric Administration, Washington, DC.

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

Fleming, K, and M. Otto. 2010. Review of survey design and double sampling methods in the Western Gulf Coast mottled duck survey. U.S. Fish and Wildlife Service, Regional Migratory Bird Office, Albuquerque, New Mexico, USA.

Gagliano, S. M., K. J. Meyer-Arendt, and K. M. Wicker. 1981. Land loss in the Mississippi River deltaic plain. Transactions of the Gulf Coast Association of Geological Societies 31:295–300.

Gilmer, D. S., I. Ball, L. M. Cowardin, and J. H. Riechmann. 1974. Effects of radio packages on wild ducks. Journal of Wildlife Management 38:243–252.

Gilmer, D. S., R. E. Kirby, I. J. Ball, and J. H. Riechmann. 1977. Post-breeding activities of mallards and wood ducks in north-central Minnesota. The Journal of Wildlife Management 41: 345–359.

Gould, F. W. 1975. Grasses of Texas. Texas A&M University Press. College Station, Texas, USA.

Grace, J. B., L. Allain, and C. Allen. 2000. Factors associated with plant species richness in a coastal tall-grass prairie. Journal of Vegetation Science 11:443-452.

Greenwood, H., R. G. Clark, And P. J. Weatherhead. 1986. Condition bias of hunter-shot mallards. Canadian Journal of Zoology. 64:599-601.

Anderson, D.R. and K.P. Burnham. 1976. Population ecology of the mallard. VI. The effect of exploitation on survival. U.S. Fish and Wildlife Service.

Hanson, H. C. 1962. The dynamics of condition factors in Canada Geese and their relation to seasonal stresses. Arctic Institute of North America. Technical Paper 12.

Haukos, D.A. 2008. Analyses of selected midwinter waterfowl data (1955-2008) in Region 2 (Central Flyway portion). U.S. Fish and Wildlife Service, Regional Migratory Bird Office, Albuquerque, New Mexico, USA.

Haukos, D.A. 2009. The status of mottled ducks on the western Gulf Coast. U.S. Fish and Wildlife Service, Regional Migratory Bird Office, Albuquerque, New Mexico, USA. 34pp.

Hepp, G. R., R. J. Blohm, R. E. Reynolds, J. E. Hines, and J. D. Nichols. 1986. Physiological condition of autumn-banded mallards and its relationship to hunting vulnerability. The Journal of Wildlife Management 50:177–183.

Heitmeyer, M. E., and L. H. Fredrickson. 1981. Do wetland conditions in the Mississippi Delta hardwoods influence mallard recruitment? Transactions of the North American Wildlife and Natural Resources Conferences 46:44-57.

Hobaugh, H.C., C.D. Stutzenbaker, and E.L. Flickinger. 1989. The rice prairies. Pages 367-383 In L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, Texas, USA.

Hoekman, S. T., L. S. Mills, D. W. Howerter, J. H. Devries, and I. Ball. 2002. Sensitivity analyses of the life cycle of midcontinent mallards. The Journal of wildlife management 66:883–900.

Hohman, W. L., C. D. Ankney, and D. H. Gordon. 1992. Ecology and management of postbreeding waterfowl. Pages 128-189 in B. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankeny, D. H. Johnson, J. A. Kadlec and G. L. Krapu, editors. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis, Minnesota, USA.

Horn, D. J., M. L. Phillips, R. R. Koford, W. R. Clark, M. A. Sovada, and R. J. Greenwood. 2005. Landscape composition, patch size, and distance to edges: interactions affecting duck reproductive success. Ecological Applications 15:1367–1376.

Hurvich, C. M., and C. L. Tsai. 1995. Model selection for extended quasi-likelihood models in small samples. Biometrics 51:1077–1084.

Johnson, J. D. and A. B. Sargeant. 1977. Impact of red fox predation on the sex ratio of prairie mallards. U.S. Fish and Wildlife Service Wildlife Resource Repoport 6. 56 pp.

Johnson, D. H., J. D. Nichols, and M. D. Schwartz. 1992. Population dynamics of breeding waterfowl. Pages 446-485 *In* B. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankeny, D. H. Johnson, J. A. Kadlec and G. L. Krapu, editors. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis Minnesota, USA.

Johnson, F. A., K. H. Pollock, and F. Montalbano III. 1989. Visibility bias in aerial surveys of mottled ducks. Wildlife Society Bulletin 17:222–227.

Johnson, F. A., F. Montalbano III, J. D. Truitt, and D. R. Eggeman. 1991. Distribution, abundance, and habitat use by mottled ducks in Florida. Journal of wildlife Management 55:476–482.

Johnson, F.A. 2009. Variation in population growth rates of mottled ducks in Texas and Louisiana. Report to the U.S. Fish and Wildlife Service, USGS Administrative Report, 26 pp.

Kennish, M. J. 2001. Coastal salt marsh systems in the US: a review of anthropogenic impacts. Journal of Coastal Research 17:731–748.

Kaminski, R. M., and E. A. Gluesing. 1987. Density-and habitat-related recruitment in mallards. The Journal of wildlife management 51:141–148.

Keim, B. D., R. A. Muller, and G. W. Stone. 2007. Spatiotemporal patterns and return periods of tropical storm and hurricane strikes from Texas to Maine. Journal of Climate 20:3498–3509.

King, J. G., and J. I. Hodges. 1979. A preliminary analysis of goose banding on Alaska's arctic slope. Management and Biology of Pacific Flyway Geese. Oregon State University Bookstores, Corvallis , Oregon, USA.

Korschgen, C. E., K. P. Kenow, A. Gendron-Fitzpatrick, W. L. Green, and F. J. Dein. 1996. Implanting intra-abdominal radiotransmitters with external whip antennas in ducks. Journal of Wildlife Management 60:132–137.

Kortegaard, L. 1974. An ecological outline of a moulting area of Teal, Vejlerne, Denmark. Wildfowl 2:134-142.

Krementz, D. G., M. J. Conroy, J. E. Hines, and H. F. Percival. 1987. Sources of variation in survival and recovery rates of American black ducks. Journal of Wildlife Management 51:689-700.

Krementz, D. G., R. J. Barker, and J. D. Nichols. 1997. Sources of Variation in Waterfowl Survival Rates. The Auk 114:93–102.

Leonard, L.A., A.C. Hine, M.E. Luther, R.P. Stumpf, and E.E. Wright. 1995. Sediment transport processes in a west- central Florida open marine marsh tidal creek; the role of tides and extra-tropical storms. Estuarine Coastal and Shelf Science 41: 225-248.

Levene, H. 1960. Robust t test for equality of variances. Pages 278-292. In I. Olkin, S. G. Ghurye, W. Hoeffding, W. G. Madow, and H. B. Mann, editors. Contributions to probability and statistics: Essays in honor of Harold Hotelling. Standford University Press. Standford, Califoria, USA.

Losito, M. P., G. A. Baldassarre, and J. H. Smith. 1995. Reproduction and survival of female mallards in the St. Lawrence River Valley, New York. Journal of Wildlife Management 59:23–30.

Lotter, C., and G. Cornwell. 1969. Comparison of airplane, air-boat and helicopter for censusing Florida ducks, Anas platyrhynchos fulvigula . *in* Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 23:97-101.

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

McKee, K. L., and I. A. Mendelssohn. 1989. Response of a freshwater marsh plant community to increased salinity and increased water level. Aquatic Botany 34:301-316.

McKinnon, D. T., and D. C. Duncan. 1999. Effectiveness of dense nesting cover for increasing duck production in saskatchewan. Journal of Wildlife Management 63:382-389.

McMahan, C. A. 1968. Biomass and salinity tolerance of shoalgrass and manateegrass in Lower Laguna Madre, Texas. Journal of Wildlife Management 32:501-506.

Migoya, R., and G. A. Baldassarre. 1995. Winter survival of female northern pintails in Sinaloa, Mexico. Journal of wildlife management 16–22.

Moulton, D., T. Dahl, and D. Dall. 1997. Texas coastal wetlands; status and trends, mid-1950s to early 1990s. U.S. Department of the Interior, Fish and Wildlife Service, Albuquerque, New Mexico, USA.

Muehl, G. T., T C. Tacha, and J. T. Anderson. 1994. Distribution and abundance of wetlands in coastal Texas. Texas Journal of Agriculture and Natural Resources.7:85-106.

McNicholl, M. K. 1975. Larid Site Tenacity and Group Adherence in Relation to Habitat. Auk 92:98–104.

Oring, L. W. 1964. Behavior and ecology of certain ducks during the postbreeding period. The Journal of Wildlife Management 28:223–233.

Owen, M. and J. M. Black. 1989. Factors affecting the survival of Barnacle Geese on migration from the breeding grounds. Journal of Animal Ecology 603–617.

Pace, R. M. and A. D. Afton. 1999. Direct recovery rates of lesser scaup banded in northwest Minnesota: sources of heterogeneity. Journal of Wildlife Management 63:389-395.

Paulus, S. L. 1984. Behavioral ecology of mottled ducks in Louisiana. Ph.D. Thesis. Auburn University, Auburn, Alabama, USA.

Powell, L. A. 2007. Approximating variance of demographic parameters using the delta method: a reference for avian biologists. The Condor 109:949–954.

Raftovich, R. V., S. S. Williams, H. L. Spriggs, and K. D. Richkus. 2011. Migratory bird hunting activity and harvest during 2009 and 2010. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Reinecke, K. J., C. W. Shaiffer, and D. Delnicki. 1987. Winter survival of female mallards in the lower Mississippi Valley. Transactions of the North American Wildlife and Natural Resources Conference 52:258‑263.

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

Ringelman, J. K. 1990. 13.4. 4. Habitat Management for Molting Waterfowl. U.S. Fish and Wildlife Service. Fish and Wildlife Leaflet 13.4.4.

Ropelewski, C. F. and M. S. Halpert, 1986: North American precipitation and temperature patterns associated with the El Niño/Southern Oscillation (ENSO).Monthly Weather Review 114:2352–2362.

Ropelewski, C. F. and M. S. Halpert. 1996: Quantifying Southern Oscillation—precipitation relationships. Journal of Climate 9:1043–1059.

Salomonsen, F. 1968. The moult migration. Wildfowl 195-24.

Sargeant, A. B. and P. M. Arnold. 1984. Predator management for ducks on waterfowl production areas in the northern plains. Proceedings of the Eleventh Vertebrate Pest Conference. Paper 31.

Sargeant, A. B. and D. H. Raveling. 1992. Mortality during the breeding season. Pages 396-422 *In* B. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankeny, D. H. Johnson, J. A. Kadlec and G. L. Krapu, editors. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis Minnesota, USA.

Sedinger, J. S., and D. G. Raveling. 1986. Timing of nesting by Canada Geese in relation to the phenology and availability of their food plants. Journal of Animal Ecology 55: 1083–1102.

Shapiro, S. S., and M. B. Wilk. 1965. An analysis of variance test for normality (complete samples). Biometrika 52:591–611.

Sillett, T. S., and R. T. Holmes. 2002. Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology 71:296–308.

Sovada, M. A., M. C. Zicus, R. J. Greenwood, D. P. Rave, W. E. Newton, R. O. Woodward, and J. A. Beiser. 2000. Relationships of habitat patch size to predator community and survival of duck nests. Journal of Wildlife Management 64:820-831.

Stutzenbaker, C. D. 1988. The mottled duck: it's life history, ecology and management. Texas Parks and Wildlife, Austin, Texas, USA.

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

Tacha, T.C., A.M. Holzen, and D.W. Bauer. 1992. Changes in freshwater wetlands and waterfowl distribution in the Chenier Plain of Texas, 1970-90. Final Report, U.S. Department of the Interior, U.S. Fish and Wildlife Service (R2) Cooperative Agreement, 14-16-002-91-252.

Tolan, J. M. 2007. El Niño-Southern Oscillation impacts translated to the watershed scale: Estuarine salinity patterns along the Texas Gulf Coast, 1982 to 2004. Estuarine, Coastal and Shelf Science 72:247–260.

Turner, R. E. 1990. Landscape development and coastal wetland losses in the Northern Gulf of Mexico. American Zoologist 30:89-105.

Tunnel, J. W. 2002. Geography, climate, and hydrology. in The Laguna Madre of Texas and Tamaulipas Texas A&M University Press, College Station, Texas, USA.

U.S. Census Bureau. 2007. Annual Estimates of the Population for Counties: April 1, 2000 to July 1, 2006. (Coastal parish population total was calculated based on the sum of the populations of the 20 coastal parishes: Ascension, Assumption, Calcasieu, Cameron, Iberia, Jefferson, Lafourche, Livingston, Orleans, Plaquemines, St. Bernard, St. Charles, St. James, St. John the Baptist, St. Martin, St. Mary, St. Tammany, Tangipahoa,Terrebonne, and Vermilion.) Internet URL: http://www.census.gov/popest/counties/tables/CO-EST2006-01-22.xls.

U.S. Geological Survey. 1997 . Coastal wetlands and global change: Overview. USGS Fact Sheet FS-089-97.

USDA-NASS, 2007. Census of agriculture. US Department of Agriculture. Washington, DC. http://www. agcensus. usda. gov/Publications/2007/index. asp (accessed June 9, 2011) .

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird study 46:120–139.

Williams, M. 1979. The moult gatherings of paradise shelduck in the Gisborne-east coast district. Notornis 26:369–390.

Wilson, B.C. 2007. North American waterfowl management plan, Gulf Coast Joint Venture: mottled duck conservation plan. North American Waterfowl Management Plan, Albuquerque, New Mexico, USA.

Yarris, G. S., M. R. McLandress, and A. E. H. Perkins. 1994. Molt migration of postbreeding female Mallards from Suisun Marsh, California. Condor 96: 36–45.

Zwank, P. J., P. M. McKenzie, and E. B. Moser. 1989. Mottled duck habitat use and density indices in agricultural lands. Journal of Wildlife Management 53: 110-114.

VITA

Erin Marie Wehland attended Fairmont Public School, Fairmont, Nebraska. She graduated in 1999 from the University of Nebraska-Lincoln with a B.S. in Natural Resources. Upon graduation she worked as a conservation technician for several years with the Nebraska Game and Parks Commission. She moved to Texas in 2004 and enrolled as a graduate student at Texas A&M University-Kingsville and researched population genetics of northern bobwhites. She graduated in in 2006 with a M.S. in Range and Wildlife Management. During the following year, she worked as a project manager for USDA/APHIS/Wildlife Services and Caesar Kleberg Wildlife Research Institute monitoring feral pig populations in south Texas for the prevalence of avian influenza. In 2007, she entered her Ph.D. program at Texas A&M University-Kingsville.