

HABITAT USE, MOVEMENTS, AND ECOLOGY OF FEMALE MOTTLED DUCKS
ON THE GULF COAST OF LOUISIANA AND TEXAS

A Dissertation

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by

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ABSTRACT

Mottled ducks (*Anas fulvigula*) are the most abundant breeding waterfowl in the coastal marshes of Louisiana and Texas. Mottled ducks are non-migratory and heavily dependent on coastal marsh habitats; they must satisfy all of their annual resource needs from within the Gulf Coast region. Coastal marsh habitats are being rapidly lost or degraded in Louisiana and Texas. The hydrology of many coastal marsh habitats has been altered by anthropogenic activity and natural factors. Parameters related to Mottled Duck habitat use and movements in this altered environment are poorly understood, and managers need information on vital rates of Mottled Ducks in coastal Louisiana and Texas. Information on use of habitats, breeding pair densities, and movements of female Mottled Ducks could benefit managers charged with conservation of Mottled Ducks and coastal marsh habitats and be used to guide resource allocation for restoration and conservation in this region. Additionally, information on breeding propensity would satisfy a need to establish vital rates used for population modeling. I employed radio-telemetry techniques to evaluate use of habitats and movements by female Mottled Ducks in the Gulf Coast region. I used a transect survey as an index to pair densities in different habitats, and evaluated examination of postovulatory follicles as a method to assess breeding propensity in Mottled Ducks. Mottled Ducks used fresh and intermediate marsh heavily and pair densities were greatest in fresh marsh habitats. Mottled ducks had low movement distances and moved inland away from storm surge caused by hurricanes. Macroscopic examination of postovulatory follicles was not appropriate for evaluation of breeding propensity in Mottled Ducks. Conservation of natural coastal marsh habitats in Louisiana and Texas will benefit Mottled Ducks in the Western Gulf Coast region.

CHAPTER 1. INTRODUCTION

Mottled ducks are the most abundant breeding waterfowl in the coastal marshes of Louisiana and Texas (Stutzenbaker 1988). Mottled ducks are non-migratory and consequently must satisfy all of their annual resource needs from within a smaller geographic range than do most North American waterfowl (Stutzenbaker 1988, Bellrose 1976).

Coastal marsh habitats are being lost or degraded at 100 km²/year in Louisiana (Walker et al. 1987); in Louisiana, 487,695 hectares of coastal lands were lost between 1932 and 2010 (Couvillion et al. 2011). In Texas, approximately 320,000 hectares of coastal marsh have been lost since the 1950s and palustrine emergent wetlands have decreased 29% (Moulton et al. 2000). The hydrology of many coastal marsh habitats has been altered by the construction of canals and associated spoil banks that alter natural hydrology and allow saltwater inundation of marsh habitats (Kinnish 2001). Estuarine habitats are being lost due to natural subsidence; in portions of the Gulf Coast subsidence rates may exceed 25 mm/year (Shinkle and Dokka 2004). Subsidence may be accelerated by the withdrawal of oil and gas (Moulton et al. 2000). Deterioration of coastal marsh habitats is compounded by the combined factors of subsidence and anthropogenic changes (Salinas et al. 2006). In some places, freshwater emergent marsh habitats have been converted to rice or other agriculture uses in the gulf coast region. Further, fragmentation of marsh habitats has occurred due to development and urban sprawl (Miller and Hobbs 2002).

Spring and breeding season likely represent an important portion of the Mottled Duck life cycle; in temperate nesting Mallards, variations in breeding parameters were

reported to be the largest factors affecting population growth (Hoekman et al. 2002). Mottled Ducks may initiate nests from February through July in gulf coast habitats; median nest initiation dates were reported to vary as much as 68 days in one study in coastal Texas (Grand 1992). Current information on habitat use of female Mottled Ducks during spring and breeding season to assess and direct management and conservation activities may benefit wetland managers.

Major weather events can have immediate impacts on coastal marsh habitats and potentially degrade these habitats. In the event of large storm events, Mottled Ducks may move inland to habitats not impacted by the storm surge.

Counts from simple line transects may provide a way to estimate Mottled Duck abundance. Transect surveys from airboats could be used as an index to habitat use or as a means for correction of fixed wing counts for missed ducks.

Breeding propensity is defined as the proportion of mature females that lay ≥ 1 egg during a given breeding season. Not surprisingly, variation in breeding propensity could dramatically influence estimates of production (Johnson et al. 1992, Hoekman et al. 2002), yet this component is the least well studied aspect of waterfowl production in even the most well studied species. Breeding propensity has never been studied in Mottled Ducks, but a potential technique to evaluate breeding propensity has been recently developed for Mallards; postovulatory follicles remain identifiable by macroscopic examination (examination without sectioning) for ≥ 60 d after egg laying occurs in Mallards (Lindstrom et al. 2006). Because Mottled Ducks are similar to Mallards, I expect development and regression of follicles will be similar among these species. If macroscopic examination of postovulatory follicles proves to be a successful technique

for determination of laying status in female Mottled Ducks, this technique could be used to ascertain estimates of breeding propensity, an important vital rate for Mottled Ducks.

I employed radio-telemetry techniques to develop estimates of proportional use of habitats by female Mottled Ducks in coastal Louisiana and Texas in marshland and adjacent agricultural lands and to estimate movements of Mottled Ducks among gulf coast habitats. I established rates of use and estimated variation in those rates due to annual and intra-seasonal variation. I conducted surveys of breeding pairs in conjunction with aerial transects flown in Louisiana as an index to pair densities and to establish visibility correction factors for surveys conducted via fixed-wing aircraft. I examined postovulatory follicles in Mottled Ducks known to have bred to evaluate the efficacy of examination of postovulatory follicles for estimation of breeding propensity in Mottled Ducks.

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CHAPTER 2. HABITAT USE BY FEMALE MOTTLED DUCKS IN LOUISIANA AND TEXAS

Mottled ducks are the most abundant breeding waterfowl in the coastal marshes of Louisiana and Texas (Stutzenbaker 1988). Mottled ducks are nonmigratory and consequently must satisfy all of their annual resource needs from within a smaller geographic range than do most North American waterfowl (Stutzenbaker 1988, Bellrose 1976).

Coastal marsh habitats are being lost or degraded at 100 km²/year in Louisiana (Walker et al. 1987); in Louisiana, 487,695 hectares of coastal lands were lost between 1932 and 2010 (Couvillion et al. 2011). In Texas, approximately 320,000 hectares of coastal marsh have been lost since the 1950s and palustrine emergent wetlands have decreased 29% (Moulton et al. 2000). The hydrology of many coastal marsh habitats has been altered by the construction of canals and associated spoil banks that alter natural hydrology and allow saltwater inundation of marsh habitats (Kinnish 2001). Estuarine habitats are being lost due to natural subsidence; in portions of the Gulf Coast, subsidence rates may exceed 25 mm/year (Shinkle and Dokka 2004). Subsidence may be accelerated by the withdrawal of oil and gas (Moulton et al. 2000). Deterioration of coastal marsh habitats is compounded by the combined factors of subsidence and anthropogenic changes (Salinas et al. 2006). In some places, freshwater emergent marsh habitats have been converted to rice or other agriculture uses in the gulf coast region. Further, fragmentation of marsh habitats has occurred due to development and urban sprawl (Miller and Hobbs 2002). Remaining marsh habitats occupy a strip of varying width along coastal Louisiana and Texas (Figures 2.1 and 2.2).

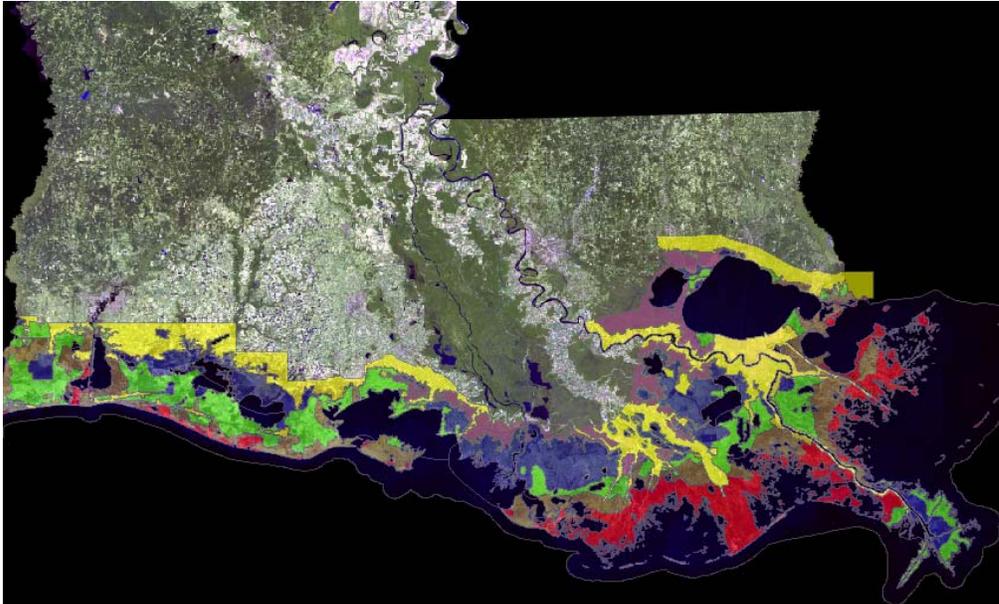


Figure 2.1. Marsh classification map adapted from Sasser et al. (2008) for coastal Louisiana. Habitat types are defined by predominant vegetation communities; red indicates saline marsh, brown indicates brackish marsh, green indicates intermediate marsh, light blue indicates fresh marsh, and yellow indicates non-marsh habitats.

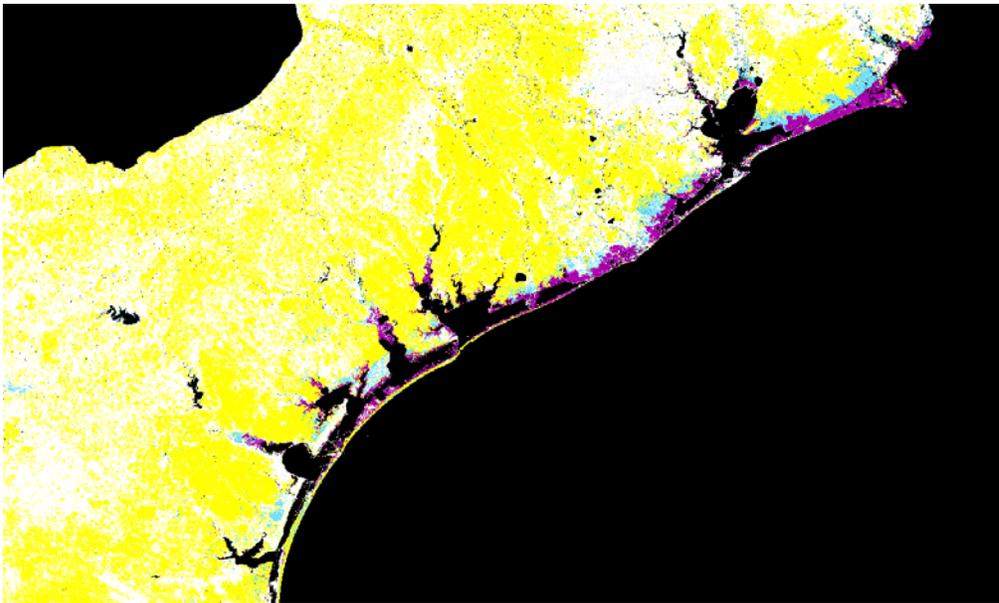


Figure 2.2. Marsh classification map adapted from C-CAP imagery for coastal Texas. Purple indicates estuarine emergent marsh, light blue indicates palustrine emergent marsh, and yellow indicates agricultural habitats (including pasture and hay production).

Habitat management along the gulf coast has focused on protection of remaining marsh habitats and restoration of degraded marsh habitats. However, agricultural land use may provide alternative or additional habitats for many wetland obligate species when natural marsh habitat is not available or reduced in availability.

Spring and breeding season represent an important portion of the Mottled Duck life cycle. In temperate nesting Mallards, variations in breeding parameters were reported to be the largest factors affecting population growth (Hoekman et al. 2002). Nesting season among Mottled Ducks is more protracted than it is in temperate nesting duck species; Mottled Ducks commonly initiate nests from February through July and median nest initiation dates were reported to vary as much as 68 days in one study in coastal Texas (Grand 1992).

Puddle ducks have been reported to utilize brackish, intermediate, and fresh marsh habitats in southwest Louisiana (Palmisano 1972), but species-specific use of marsh habitats by Mottled Ducks has not been examined. Wetland managers need current information on habitat use of female Mottled Ducks during spring and breeding season to better inform habitat management plans and actions and other conservation activities. However, waterfowl researchers lack unbiased estimates of the distribution and habitat use of Mottled Ducks use across the western Gulf Coast. I employed radio-telemetry techniques to estimate proportional use of habitats by female Mottled Ducks in coastal Louisiana and Texas in marshland and adjacent agricultural lands. My primary objective was to estimate the proportional use of habitats by female Mottled Ducks in Louisiana and Texas; secondarily, I sought to explain variation in these rates due to annual variation and timing within each sampling period. I determined whether marked

females (sampling units) used habitats differently among years and weeks within my sampling period. Because precipitation varied markedly in the gulf coast region during the 3 years of my study (National Climatic Data Center 2012), I was able to test hypotheses relating to weather related annual variation. I tested the hypotheses that: 1) females alter use of habitats in the gulf coast region as breeding season progresses and wing molt begins; and 2) that proportional use of habitats by females differed among years of the study.

STUDY AREA

Capture sites in Louisiana included the Atchafalaya Delta Wildlife Management Area (WMA), Cameron Prairie National Wildlife Refuge (NWR), Rockefeller State Wildlife Refuge (SWR), Marsh Island SWR, and 2 sites on private lands in Cameron and Vermillion parishes. Capture sites in Texas included Anahuac NWR, Aransas NWR, Mad Island WMA, McFaddin NWR, lands on the Katy Prairie Conservancy, and areas on private lands in Jackson, Orange, and Jefferson Counties. Capture sites were selected based on access and presence of molting female Mottled Ducks. To assess locations of radio-marked females, I searched the study area using aerial telemetry techniques by flying 28 transects perpendicular to the coast and 1 transect parallel to the coast in Texas (Figure 2.3).

METHODS

I marked 590 female Mottled Ducks in conjunction with fall (pre-hunting season) banding efforts conducted by state and federal wildlife agencies (Louisiana Department of Wildlife and Fisheries, Texas Parks and Wildlife Department, and United States Fish and Wildlife Service), including 182 in 2007, 182 in 2008, and 226 in 2009. I marked

females using 20-g abdominally implanted radiotransmitters with external antennae (Korshgan 1996). Transmitters had an expected battery life of 435 days. Substantial sample size reduction occurred between marking and the breeding season tracking period in each year of the study due to mortality of females and radio-failure. In breeding season 2008, I monitored 25 radio-marked females in Louisiana and 17 females in Texas. In breeding season 2009, I monitored 39 and 29 radio-marked female Mottled Ducks in Louisiana and Texas, respectively. In breeding season 2010, I monitored 63 and 36 radio-marked female Mottled Ducks in Louisiana and Texas, respectively.

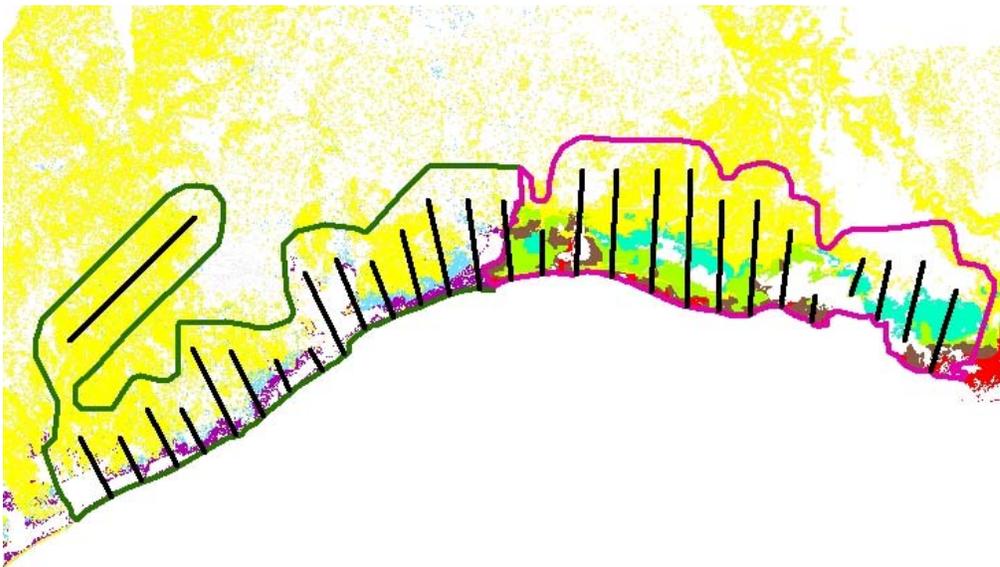


Figure 2.3. Map depicts transects (black lines) flown for aerial telemetry estimation of habitats; Pink and green polygons depict study area boundaries used for determinations of habitat availabilities in Louisiana and Texas, respectively. Transects have been overlaid on C-CAP data for Texas and the Crop Data Layer and Marsh Classification layer in Louisiana.

To assess use of habitats, I searched for marked females on my study area weekly during Feb-July (hereafter, breeding season) of each year using aerial telemetry

techniques (Gilmer et al. 1981). I searched the transects weekly during the breeding seasons following fall marking efforts; transects were perpendicular to the gulf coast and spaced 20 km apart to maximize coverage of the study area given the initial range of our radio transmitters (Figure 2.3). Transects extended inland from the coast varying distances based on kernel densities (Rodgers and Kie 2007) derived from band recoveries for 30 years of band returns. Because additional females were marked outside of this transect coverage in Texas, I flew an additional transect parallel to the coast to cover these areas in Texas. Due to weak signal strength from many transmitters, I developed an alternate set of transects by shifting the original 28 transects that were perpendicular to the coast west or southwest 10 km and used this alternate set of transects instead of my original transects every other week. This enabled me to find and sample radio-transmitters with poor quality signals at least once every 2 weeks; these individuals may have been otherwise excluded from the sample if they remained in an area where they were out of range from my original transects. Upon detection from the airplane, I flew off transect towards the direction of the radio-signal and estimated locations as described by Gilmer et al. (1981) then returned to the transect line before continuing the survey.

To gain more precise estimates of locations than those possible using aerial telemetry techniques, I ascertained locations of Mottled Ducks using triangulation from truck mounted null-peak antenna systems where habitats allowed access by roads. Radio-marked females were tracked using two vehicles equipped with roof mounted 4-element, null-peak antenna systems (Mech 1983), GPS units, and laptop computers with Location of a Signal software (LOAS 3.0.4; Ecological Software Solutions 2004). Truck antenna systems were equipped with electronic compasses (Cox et al. 2002) and

calibrated empirically to known locations of beacon transmitters within 0.5 degree of accuracy. I estimated point locations for each female based on a maximum-likelihood estimator (Lenth 1981) with a bearing standard deviation of 3 degrees. Plots of estimated locations were examined in the field and obvious erroneous bearings were discarded immediately. Locations of tracking vehicles were estimated using Global Positioning Systems. I acquired a minimum of 3 azimuths for each female. I analyzed location data separately for Louisiana and Texas due to differing availability of geospatial data.

Classification of Habitats in Louisiana

The Louisiana Gulf Coast contains a complex mosaic of coastal marsh habitat types (Figure 2.1). The most useful classification of habitats in Louisiana's marsh zone is based on the predominant vegetation present and identifies habitats as salt marsh, brackish marsh, intermediate marsh, fresh marsh, open water, or other habitats including agricultural lands (Sasser et al. 2008). I classified locations of radio-marked females in Louisiana according to the marsh types described by Sasser et al. (2008) and as described above as BRACK, INTERMED, FRESH, WATER, or OTHER, respectively. For locations outside of the marsh zone and for locations in areas classified as OTHER by Sasser et al. (2008), I further classified location data based on a cropland data layer that identified the crop or agricultural practice present when the location was estimated.

Classification of Habitats in Texas

Available habitat layers allowed better delineation of marsh types in Louisiana than in Texas; I was able to classify coastal marsh to 4 habitat types for Louisiana, but I was limited to 2 classifications of coastal marsh in Texas. I classified marshland locations in Texas using Coastal Change Analysis Program (C-CAP, NOAA 2012) land

cover data. For locations in areas classified by C-CAP as crop, I further classified location data based on the cropland data layer by the crop or agricultural practice present. I used classifications from the C-CAP data to identify habitats classed by C-CAP as palustrine emergent or aquatic beds as PALUS, estuarine habitats as ESTU, crop (including tilled and areas used for hay or livestock) as CROP, or all other habitats as OTHER.

Data Analyses

To eliminate bias caused by locations in areas which were easier to sample, I limited analysis to 1 location for each marked female per week. Because locations derived via truck triangulation are more accurate than those possible from aerial telemetry, I prioritized locations used for analysis by using locations from triangulations if they were available. If multiple locations of the same accuracy level were available within a sampling period (week), I used the first location of the female taken within that week for analysis.

I determined proportional use of habitats in each state based on compositional analyses of location data collected from February through July of each year. I calculated proportional use of each female in every habitat. I replaced zero values with 0.002 (an order of magnitude lower than the lowest non-zero proportion of a habitat used by any female; Aebischer et al. 1993). To remove the unit sum constraint, I constructed 5 log-ratios by dividing proportional use of SALT, FRESH, INTERMED, BRACK, WATER, and OTHER by proportional use of INTERMED and used natural logarithms of these ratios as response variables in my analyses (Aitchison 1986). Choice of habitat used as a denominator does not alter results (Aebischer et al. 1993), but does allow direct

comparison of each habitat with the habitat used as a denominator. I used INTERMED as the denominator for analysis of data collected in Louisiana, and used OTHER as the denominator for analysis of data collected in Texas.

I used repeated measures, split-plot, multivariate analysis of covariance (PROC GLM; SAS Institute 2004) to test for overall effects of year (2008, 2009, or 2010), week, and individual female. I used variation due to individual females as the error term to test for effects of year and residual error to test the effects of week. I initially analyzed full models and then used backward, stepwise procedures to eliminate nonsignificant ($P > 0.050$) terms (Wolfinger 1992). In the presence of significant effects in my multivariate analysis, I tested whether or not parameter estimates for effects on univariate responses in my final model differed from 0 using ANCOVA.

I calculated a value for Ivlev's electivity index (hereafter, IV) as a measure of habitat preference for habitats used by female Mottled Ducks (Ivlev 1964). This index produces values ranging from -1.0 to 1.0; positive values indicate preference, negative values indicate avoidance, and 0 values indicate random use of habitats. Ivlev's value follows the equation:

$$IV = (\% \text{ Use} - \% \text{ Availability}) / (\% \text{ Use} + \% \text{ Availability})$$

Calculation of IV requires a measure of availability. To determine availability of habitats in each state, I buffered the aerial transects by 20 km, excluding the open waters of the Gulf of Mexico and produced a polygon corresponding to the study area in each state (Figure 2.3). I then determined the composition of habitats within this polygon, and I used these compositions to determine % availability in calculation of IV.

I determined use of croplands based on compositional analyses of locations in agricultural landscapes using data pooled across states where locations were initially classified as CROP or OTHER in my previous analyses. I fit models for use of crop lands using methods similar to those described for modeling use of habitats and using rice as a denominator.

RESULTS

Use of Habitats in Louisiana

My final fitted MANCOVA indicated habitat use varied by week (Wilks' Lambda = 0.9859; $F = 3.29$; 5, 1150 df; $P = 0.006$) and among females (Wilks' Lambda = 0.093; $F = 5.68$; 615, 5752 df; $P < 0.001$). I was unable to detect differences in habitat use among years (Wilks' Lambda = 0.935; $F = 0.81$; 10, 238 df; $P > 0.616$). Females in Louisiana used INTERMED most frequently (Table 2.1). The ratio of use of OTHER to use of INTERMED increased during breeding season in Louisiana ($T = 2.38$, $P = 0.018$; Figure 2.4). Marked females in Louisiana showed highest preference for INTERMED and avoided WATER.

Use of Habitats in Texas

My final fitted MANCOVA indicated habitat use varied among females (Wilks' Lambda = 0.149; $F = 4.53$; 234, 1197.5 df; $P < 0.001$). I was unable to detect differences in habitat use among years (Wilks' Lambda = 0.972; $F = 0.73$; 3, 75 df; $P > 0.539$) or weeks (Wilks' Lambda = 0.981; $F = 2.45$; 3, 399 df; $P > 0.063$). Females in Texas used ESTU most frequently (Table 2.2). Marked females in Texas showed strong preference for PALUS and ESTU.

Table 2.1. Proportional use of habitats expressed as an average across birds (\bar{x}), \pm Standard Error (SE), proportion of study area in each habitat, and Ivlev's Value (IV) for radio-marked female Mottled Ducks during spring and breeding season 2008, 2009, and 2010 along the Gulf Coast of Louisiana.

Vegetation Code	Proportional Use of Habitats		Proportion of Study Area	Habitat Preference (IV)
	\bar{x}	SE		
Fresh Marsh	0.210	.025	0.113	0.300
Intermediate Marsh	0.348	.033	0.119	0.490
Brackish Marsh	0.142	.024	0.076	0.303
Salt Marsh	0.020	.007	0.022	-0.048
Other habitats	0.202	.028	0.558	-0.468
Open Water	0.078	.015	0.112	-0.612

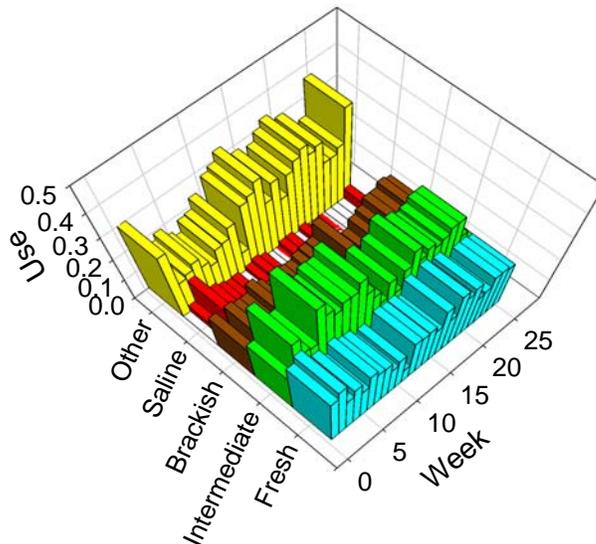


Figure 2.4. Proportional use of marsh habitat types by week expressed as an average across birds for radio-marked female mottled ducks during February-July 2008, 2009, and 2010 along the Gulf Coast of Louisiana.

Table 2.2. Proportional use of habitats expressed as an average across birds (x-bar), ± Standard Error (SE), proportion of study area in each habitat, and Ivlev's Value (IV) for radio-marked female Mottled Ducks during spring and breeding season 2008, 2009, and 2010 along the Gulf Coast of Texas.

Habitat Code	Proportional Use of Habitats		Proportion of Study Area	Habitat Preference (IV)
	x-bar	SE		
Palustrine Marsh	0.247	0.037	0.0490	0.669
Estuarine Marsh	0.417	0.045	0.0542	0.769
Other	0.141	0.023	0.5107	-0.567
Crop	0.190	0.038	0.4253	-0.382

Use of Croplands in Louisiana and Texas

Eighty females (39% of the females included for habitat use analyses) used cropland habitats during the study. My final fitted MANCOVA indicated crop use varied among females (Wilks' Lambda = 0.095; $F = 2.38$; 316, 934 df; $P < 0.001$). I was unable to detect differences in crop use among years (Wilks' Lambda = 0.971; $F = 0.56$; 4, 75 df; $P > 0.690$) or weeks (Wilks' Lambda = 0.975; $F = 1.48$; 4, 233 df; $P > 0.208$).

Among females using croplands, proportional use of rice was 31%; females used hay, fallow agricultural fields, aquaculture, and other agricultural habitats less frequently (Table 2.3).

DISCUSSION

I observed high proportional use of INTERMED and ESTU marsh in Louisiana and Texas, respectively (Tables 2.1 and 2.2). Changes in habitat use over weeks in Louisiana may have reflected changing habitat conditions within breeding seasons or

shifts in preference; Mottled Ducks moved away from INTERMED and into habitats classified as OTHER as breeding season progressed. Habitats classified as OTHER are largely made up of agricultural areas and increased use of these habitats supports my hypothesis that Mottled Ducks will use habitats differently in late breeding season. I suspect that habitats in agricultural areas, especially rice, offer better water conditions than do natural marsh habitats in dry years; shifts in the ratio of use of INTERMED to OTHER may reflect changing habitat conditions.

Table 2.3. Proportional use of crop and other habitats expressed as an average across birds for radio-marked female Mottled Ducks during spring and breeding season 2008, 2009, and 2010 along the Gulf Coast of Louisiana and Texas.

Habitat Code	Proportional Use of Crops	
	x-bar	SE
Rice	0.314	0.042
Fallow	0.127	0.028
Hay-Pasture	0.203	0.039
Aquaculture	0.064	0.023
Other	0.173	0.036

Precipitation varied markedly in the Gulf Coast region during the 3 years of my study; the Palmer drought severity index (Palmer 1968) values show coastal areas in Louisiana and Texas were near average wetness in 2008, dryer than average in 2009, and average to above average wetness in 2010 (data from National Climatic Data center 2012). Despite differing water conditions over the duration of study, I was unable to detect changes in habitat use among years. It appears that variability in water levels

during my study was not large enough to alter the distribution of Mottled Ducks; thus my hypothesis that Mottled Ducks would use habitats in different proportions in drier years was unsupported. In years with extremely wet or dry conditions proportional use may change, but my estimates should reflect habitat use within the normal range of conditions.

My estimates of proportional habitat use contrast with apparent distribution of Mottled Duck pair densities in the Louisiana marsh zone of the gulf coast derived from transect surveys (see Chapter 4). For example, I reported the highest pair densities in FRESH habitats, but proportional use of INTERMED was higher than use of FRESH in Louisiana for radio marked females. These differences may reflect differences in habitat availability and preference among Mottled Ducks; FRESH habitats may be more ephemeral than are INTERMED habitats in Louisiana and may be less likely to contain adequate water for survey; densities estimated from an airboat survey could be biased high because airboats could only survey wet portions of the marsh. Pair densities derived from transects surveyed via airboat in marsh habitats in Louisiana reflect pair densities for only wet portions of the marsh where the airboat could be operated (see Chapter 4); thus, density estimates from these transect surveys may be biased.

Radio-marked females showed preference for INTERMED, BRACK, and FRESH in Louisiana and PALUS and ESTU in Texas in my study. These coastal marsh habitats are undoubtedly important to Mottled Ducks; however, interpretation of preference values should be approached cautiously. Johnson (1980) cautioned that preference values are dependent on proper determination of availability, and that this information must be arbitrarily determined by the researcher. Similarly, researchers must arbitrarily consider accessibility of an area to an animal when determining preference (Beyer et al. 2010).

Indeed, Mottled Ducks have the ability to travel distances greater than the confines of my study area and determining availability is an arbitrary exercise.

I was able to better delineate coastal marsh types in Louisiana than in Texas. I classified coastal marsh to 4 habitat types in Louisiana, but I was limited to 2 classifications of coastal marsh in Texas. INTERMED received the highest use in Louisiana, but in Texas, habitats that may have been classified as INTERMED in Louisiana were pooled with BRACK and saline marsh habitats and classified as PALUS. Considerable variation in marsh habitats may exist within the PALUS classification; a wide variety of plants with differing food values for waterfowl may grow within the PALUS zone (Cramer et al. 2011). Improved classification of marsh habitats in Texas would allow more refined classification of habitat use data. Use of FRESH and agricultural habitats was similar between states.

Much freshwater marsh has been replaced by rice agriculture in many areas of coastal Louisiana and Texas. Radio-marked female Mottled Ducks used rice agriculture more than OTHER agricultural habitats in the region. Continued loss and degradation of marsh habitats in Louisiana and Texas may lead to displacement of female Mottled Ducks away from natural habitats and towards rice agricultural habitats. These rice agricultural habitats could become increasingly important to Mottled Ducks if continued loss of marsh occurs.

MANAGEMENT IMPLICATIONS

My results document the importance of marsh habitats to female Mottled Ducks in Louisiana and Texas. Data collected in this study could be used to adjust Habitat Suitability Index models for Mottled Ducks (Rorbaugh and Zwank 1983). Increased

conservation of marsh habitats in coastal Louisiana and Texas may provide useful habitats for Mottled Ducks in this area. Considering the resources that agricultural habitats provide to Mottled Ducks, protection and restoration of rice habitats appears to be of benefit to Mottled Duck populations and should receive consideration as a high priority management option. In areas where restorations of natural marsh habitats are incompatible with current land uses, artificial flooding of agricultural landscapes could augment available habitats for Mottled Ducks.

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CHAPTER 3. MOVEMENTS OF FEMALE MOTTLED DUCKS IN LOUISIANA AND TEXAS

Mottled ducks are the most abundant breeding waterfowl in the coastal marshes of Louisiana and Texas. Mottled ducks are nonmigratory and consequently must satisfy all of their annual resource needs from within a smaller geographic range than do most North American waterfowl (Stutzenbaker 1988, Bellrose 1976).

Coastal marsh habitats are being lost or degraded at 100 km²/year in Louisiana (Walker et al. 1987); in Louisiana, 487,695 hectares of coastal lands were lost between 1932 and 2010 (Couvillion et al. 2011). In Texas, approximately 320,000 hectares of coastal marsh have been lost since the 1950s and palustrine emergent wetlands have decreased 29% (Moulton et al. 2000). The hydrology of many coastal marsh habitats has been altered by the construction of canals and associated spoil banks that alter natural hydrology and allow saltwater inundation of marsh habitats (Kinnish 2001). Estuarine habitats are being lost due to natural subsidence; in portions of the Gulf Coast subsidence rates may exceed 25 mm/year (Shinkle and Dokka 2004). Subsidence may be accelerated by the withdrawal of oil and gas (Moulton et al. 2000). Deterioration of coastal marsh habitats is compounded by the combined factors of subsidence and anthropogenic changes (Salinas et al. 2006). In some places, freshwater emergent marsh habitats have been converted to rice or other agriculture uses in the gulf coast region. Further, fragmentation of marsh habitats has occurred due to development and urban sprawl (Miller and Hobbs 2002).

Management practices in coastal habitats and management of Mottled Duck populations may differ among states. Coastal habitats in Texas generally receive less rainfall than do those in Louisiana (Stutzenbaker 1988). Use of water resources for crop

irrigation may be restricted in Texas (Schultz 1996); this could potentially impact the amount of wet habitat available for use by Mottled Ducks. The extent and frequency of Mottled Duck movements across the Texas-Louisiana border are unknown; consequently, resource managers are uncertain about how management activities in one state or the other may impact the Western Gulf Coast Mottled Duck population.

Hurricanes and tropical storms can have immediate impacts on coastal marsh habitats and substantially alter these habitats. Storm surge can inundate coastal marshes and destroy marsh vegetation. Salinities in impacted areas can be increased by storm surge waters to the point that these habitats are no longer useful to Mottled Ducks. In the event of large storm events, Mottled Ducks may move inland to habitats not impacted by the storm surge. Peak storm frequency in Louisiana and Texas occurs in late breeding season and coincides with the conclusion of wing molt by Mottled Ducks. It is difficult to differentiate between movements occurring due to the hurricane from those occurring as a natural post-molt movement. Individual Mottled Ducks may move about during the annual cycle to meet resource needs, avoid predators, and find mates.

My primary objective was to assess several parameters related to movements by radio-marked female Mottled Ducks throughout the annual cycle. Specifically, I provide estimates of the frequency of Mottled Duck movements among states, movement distances away from capture sites and distances moved away the coast by radio-marked females. Considering that annual precipitation varied markedly throughout the study and that 2 hurricanes impacted portions of the study area in one year of the study, I was presented a unique opportunity to evaluate the effects of major weather events and annual variation on movement parameters. Accordingly, I tested whether marked individuals

moved between states similarly in years with markedly differing weather patterns and hypothesized that Mottled Ducks would be less likely to move in wet years than in dry years. Similarly, I examine maximum distances moved by female Mottled Ducks and hypothesize that females will move less distance in a wet year than in dry years. Distances of these movements may vary due to proximity of other preferred habitats; I hypothesize that maximum movement distances may vary among females marked at different capture sites. Finally, I examined distances from the coast and distances from capture sites for females immediately after hurricanes impacted the coast and compare among years without hurricane impacts. I hypothesize that marked females moved greater distances from their capture sites and away from the coast in the year impacted by the hurricane.

STUDY AREA

Capture sites in Louisiana included the Atchafalaya Delta Wildlife Management Area (WMA), Cameron Prairie National Wildlife Refuge (NWR), Rockefeller State Wildlife Refuge (SWR), Marsh Island SWR, and 2 sites on private lands in Cameron and Vermillion parishes. Capture sites in Texas included Anahuac NWR, Aransas NWR, Mad Island WMA, McFaddin NWR, lands on the Katy Prairie Conservancy, and areas on private lands in Jackson, Orange, and Jefferson Counties. Capture sites were selected based on access and presence of molting female Mottled Ducks. To assess locations of radio-marked females, I searched the study area using aerial telemetry techniques by flying 28 transects perpendicular to the coast and 1 transect parallel to the coast in Texas (Figure 3.1).

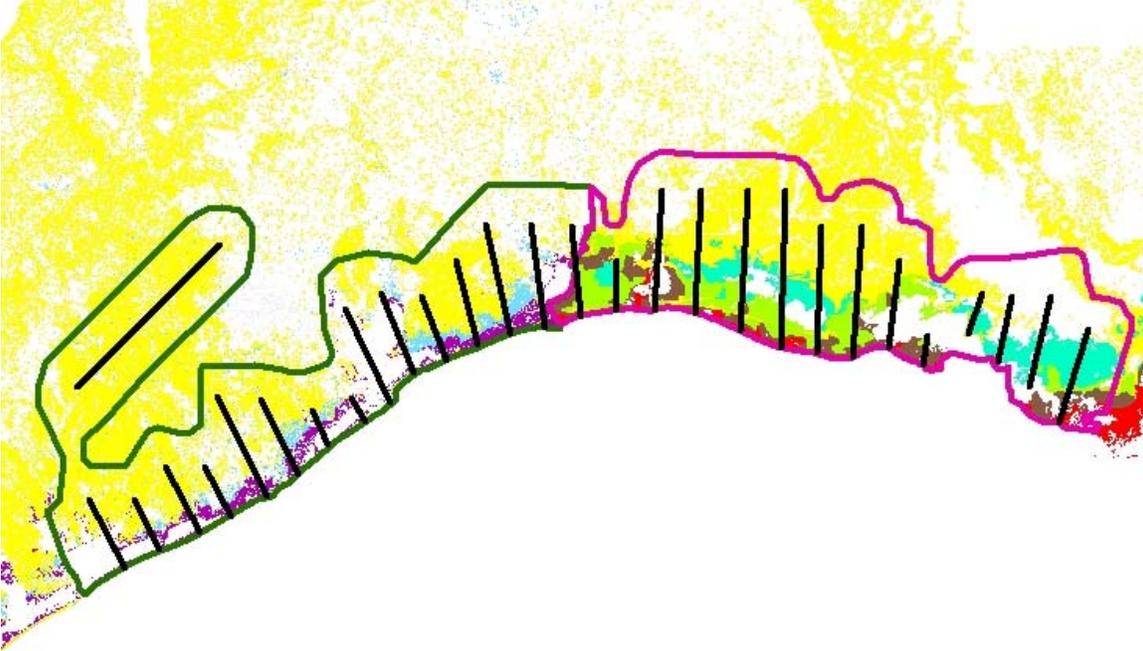


Figure 3.1. Map depicts transects (black lines) flown for aerial telemetry estimation of habitats; Pink and green polygons depict study area boundaries in Louisiana and Texas, respectively. Transects have been overlaid on C-CAP data for Texas and the Crop Data Layer and Marsh Classification layer in Louisiana.

METHODS

I marked 590 female Mottled Ducks in conjunction with fall (pre-season) banding efforts conducted by state and federal wildlife agencies (LDWF, TPWD, and USFWS); this included 182 in 2007, 182 in 2008, and 226 in 2009. I marked females using 20-g abdominally implanted radio-transmitters with external antennae (Korshgan 1996). Transmitters had an expected battery life of 435 days.

To assess movements of Mottled Ducks, I searched for marked females on my study area weekly during Feb-July (hereafter, breeding season) of each year using aerial telemetry techniques (Gilmer et al. 1981). I searched the transects weekly during the breeding seasons following fall marking efforts; transects were perpendicular to the gulf coast and spaced 20 km apart to maximize coverage of the study area given the initial

range of our radio transmitters (Figure 3.1). Transects extended inland from the coast varying distances based on kernel densities (Rodgers and Kie 2007) derived from band recoveries for the previous 30 years of band returns. Because additional females were marked outside of this transect coverage in Texas, I flew an additional transect parallel to the coast to cover these areas in Texas. Due to weak signal strength from many transmitters, I developed an alternate set of transects by shifting the original 28 transects that were perpendicular to the coast west or southwest 10 km and used this alternate set of transects instead of my original transects every other week. This enabled me to find and sample radio-transmitters with poor quality signals at least once every 2 weeks; these individuals may have been otherwise excluded from the sample if they remained in an area where they were out of range from my original transects. Upon detection from the airplane, I flew off transect towards the direction of the radio-signal and estimated locations as described by Gilmer et al. (1981) then returned to the transect line before continuing the survey.

During breeding seasons, I ascertained locations of Mottled Ducks using triangulation from truck mounted null-peak antenna systems where habitats allowed access by roads. Radio-marked females were tracked using two vehicles equipped with roof mounted 4-element, null-peak antenna systems (Mech 1983), GPS units, and laptop computers with Location of a Signal software (LOAS 3.0.4; Ecological Software Solutions 2004). Truck antenna systems were equipped with electronic compasses (Cox et al. 2002) and calibrated empirically to known locations of beacon transmitters within 0.5 degree of accuracy. I estimated point locations for each female based on a maximum-likelihood estimator (Lenth 1981) with a bearing standard deviation of 3 degrees. Plots

of estimated locations were examined in the field and obvious erroneous bearings were discarded immediately. Locations of tracking vehicles were estimated using Global Positioning Systems. I acquired a minimum of 3 azimuths for each female. I attempted to attain aerial telemetry locations every 2 weeks during the remainder of the year; however, ground tracking via trucks was discontinued outside of breeding season.

Statistical Procedures

Propensity to Change States

I examined whether marked females moved out of the state in which they were marked. To assess this, I coded a binary response for whether each observation was in the state where the bird had been marked. When females were located out of the state in which they were marked, I coded the response variable as 1. When females did not change states, I coded the response variable as 0. I used repeated measures, logistic regression with a logit link (PROC GENMOD; SAS Institute 2004; Stokes et al. 2000) to assess effects of several explanatory variables on the probability that females switched habitats. For this analysis, I included the year of marking and state of marking as potential explanatory variables in my full model. PROC GENMOD invokes the generalized estimating equation (hereafter, GEE) approach (Liang and Zeger 1986) to account for the correlation structure of repeated measures (Stokes et al. 2000). I specified the correlation structure of repeated measures on individual females as exchangeable; GEE methods are robust to assigned correlation structure (Stokes et al. 2000, pp. 474-480). I initially analyzed the full model and then used backward, stepwise procedures to eliminate nonsignificant ($P > 0.050$) terms (Stokes et al. 2000). I subsequently

summarized data by the explanatory variables in the final model and present the frequency of birds moving from 1 state to another.

Maximum Distance Moved Between Marking and Subsequent Locations

I calculated distances moved between marking locations and subsequent locations and used these distances as the response variable in my analysis. I assessed effects of year of marking and capture locations on the maximum distance moved by females during the study using ANOVA (PROC GENMOD; SAS Institute 2004). Initially, I analyzed the full model and then used backward, stepwise procedures to eliminate nonsignificant ($P > 0.0500$) terms (Wolfinger 1992). I present averages of maximum movement distances among years.

Movement after Hurricanes

I examined distances of locations from the coast and distances of locations from capture sites for marked female Mottled Ducks after hurricanes and during a similar time period in years where the coast was not impacted by hurricane activity. I attained distances using spatial joins in ARCGIS. I limited analyses to 1 location for each animal during the sampling period. If multiple locations of the same animal were available, I used the first location of the female.

I assessed effects of year of marking and capture locations on distances of locations from the coast for females located during mid-September to early-October of each year using ANOVA (PROC GENMOD; SAS Institute 2004). Initially, I analyzed the full model and then used backward, stepwise procedures to eliminate nonsignificant ($P > 0.050$) terms (Wolfinger 1992). Similarly, I assessed effects of year of marking and capture locations on distances of locations from the capture sites for females located

during mid-September to early-October of each year using ANOVA (PROC GENMOD; SAS Institute 2004). I present means of distances of locations from the coast and distances of locations from capture sites based on explanatory variables remaining in my final fitted models.

RESULTS

Propensity to Change States

My analysis of propensity to change states was based on 5710 observations on 398 radio-marked females. My final fitted model indicated that changing states varied among years ($P = 0.0331$). I failed to detect significant effects of capture state ($P = 0.448$).

Females were most likely to change states during the hurricane year, but likelihood of changing states was low in all years. Of the 5710 observations examined, 2.3%, 5.5%, and 4.4% occurred in states other than where the female was marked for females marked in 2007, 2008, and 2009, respectively. I found that 6.9%, 18.1%, and 13.3% of females were detected at least once in states other than where they were marked for females marked in 2007, 2008, and 2009, respectively.

Maximum Distance Moved Between Marking and Subsequent Locations

My analysis of maximum movement distance was based on 5710 observations on 398 radio-marked females. My final fitted model indicated that distances moved varied by capture location and among years ($P_s < 0.001$). I failed to detect significant effects of capture state on maximum movement distances (all $P = 0.451$). The median of the maximum distances moved by individual females was 49.3 km; the median of maximum

movement distances was lowest in the first year of the study and lowest for females marked on Justin Hurst WMA in mid-coast Texas (Tables 3.1 and 3.2).

Table 3.1. Medians of maximum distances moved by females marked in 2007, 2008, and 2009.

Marking year	mean (km)	median (km)	std error (km)
2007	44	22.2	9.4
2008	105.5	55.9	11.1
2009	81.2	66.3	5.0

Table 3.2. Means, medians, and standard error (SE) of maximum distances moved by females marked at each capture site and 2009.

Capture site	state	Mean (km)	Median (km)	SE (km)
Anahuac NWR	TX	53.8	30.7	8.3
Atchafalaya WMA	LA	67.2	31.8	19.4
Big Burn	LA	45.5	23.7	9.9
Cameron Priarie NWR	LA	74.3	70.3	16.4
Aransas (F-W) NWR	TX	66.5	43.1	21.3
Justin Hurst WMA	TX	55.1	11.3	17.5
Katy Prairie Conservancy	TX	105.9	154.8	19.3
Mad Island WMA	TX	88.7	47.6	17.3
Marsh Island SWR	LA	126.6	89.3	17.2
McFaddin NWR	TX	83.6	40.7	13.0
Miller Property	LA	36.4	32.1	6.6
J.D. Murphree WMA	TX	137.9	67.4	31.2

Movement after Hurricanes

My analyses of movement distance during mid-September through early-October period were based on observations of 294 radio-marked females. My final fitted model indicated that distance to the coast for locations collected mid-September through early-October varied among capture locations ($P < 0.001$), but I was not able to detect differences among years for this response ($P = 0.122$). Distance from capture sites for locations collected mid-September through early-October varied among capture locations and years ($P_s < 0.001$; Figures 3.2-3.4).

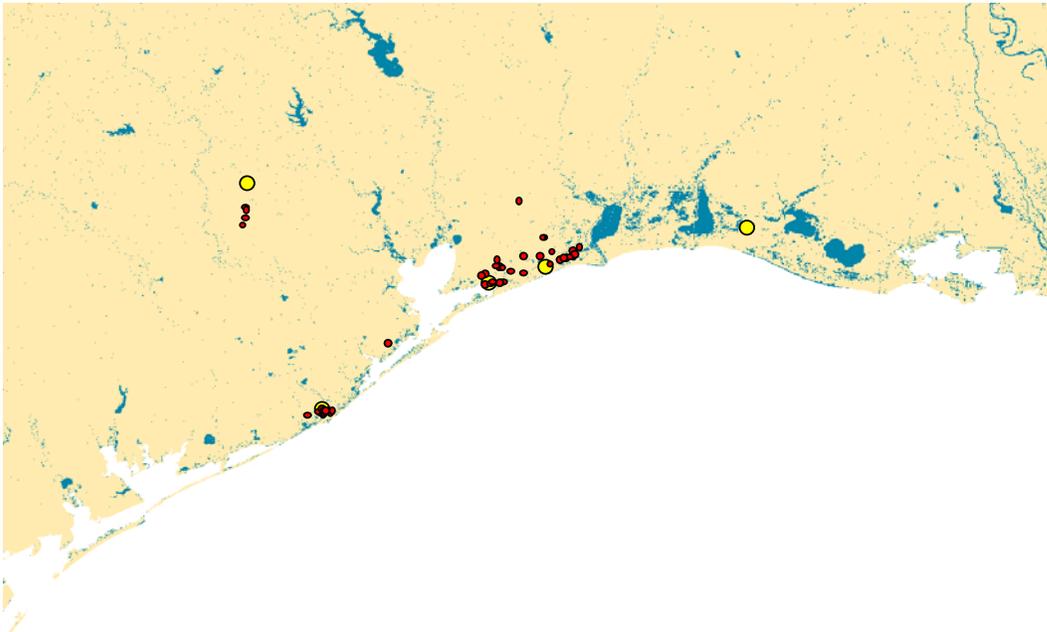


Figure 3.2. Locations (red dots) of radio-marked females in coastal Louisiana and Texas in mid-September – early-October 2007. Capture locations are displayed in yellow.

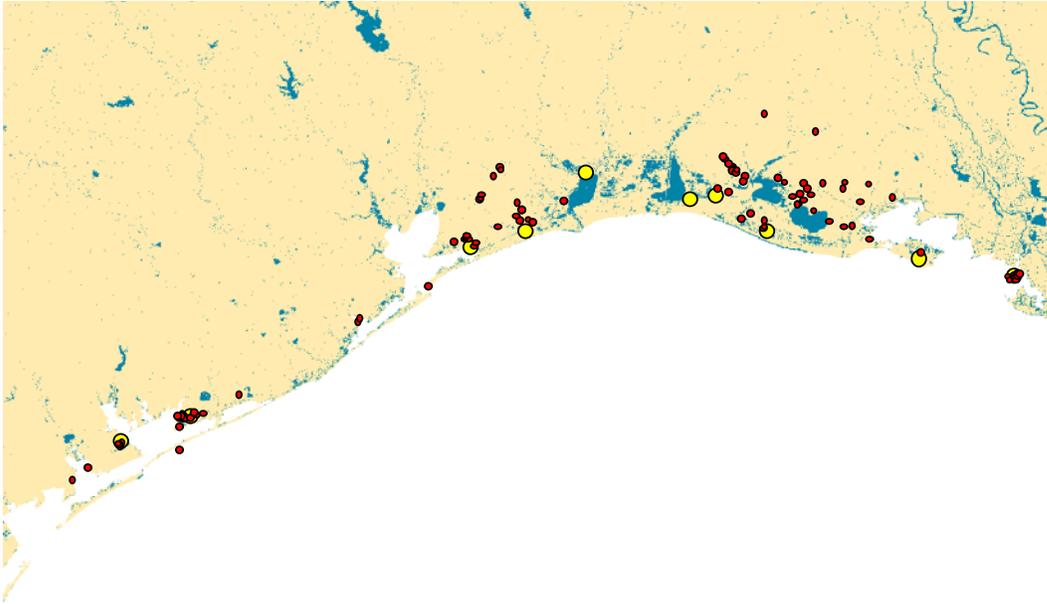


Figure 3.3. Locations (red dots) of radio-marked females in coastal Louisiana and Texas in mid-September – early-October 2008. Capture locations are displayed in yellow.

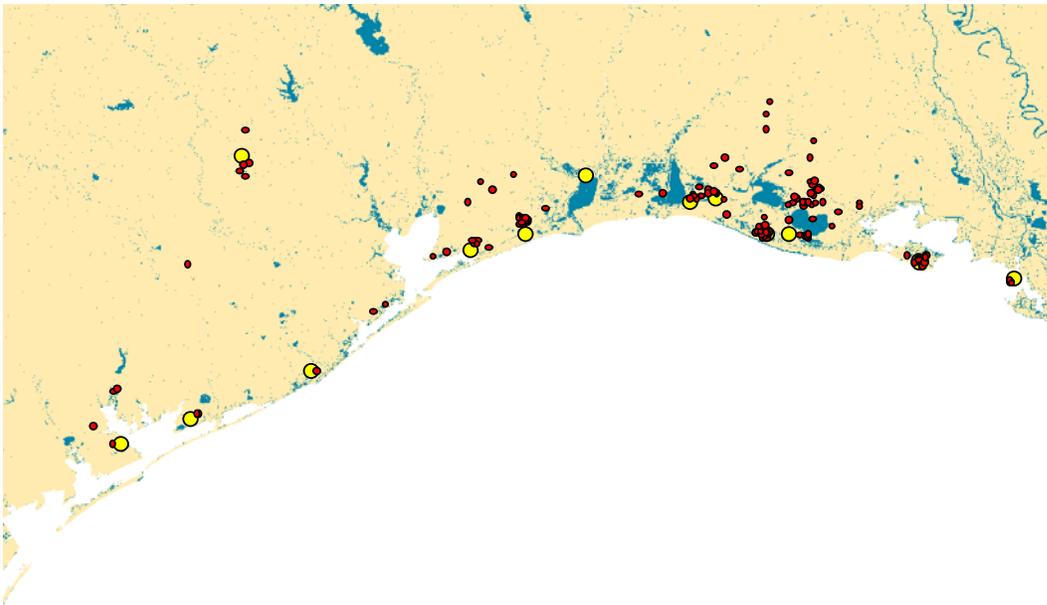


Figure 3.4. Locations (red dots) of radio-marked females in coastal Louisiana and Texas in mid-September – early-October 2009. Capture locations are displayed in yellow.

DISCUSSION

During the first year of my study (August 2007- August 2008) there were no direct hurricane impacts in our study area and conditions in winter and spring were relatively wet; the Palmer drought severity index (Palmer 1968) values show coastal areas in Louisiana and Texas were near average wetness in 2008, dryer than average in 2009, and average to above average wetness in 2010 (data from National Climatic Data Center 2012). In 2008-2009 the study area was impacted by Hurricane Gustav and Hurricane Ike followed by a dry winter and spring. In 2009-2010, our study area was not impacted by hurricanes.

Potential impacts of hurricanes were highly variable across the study area. Hurricane Ike had a much stronger and more widespread storm surge than did Hurricane Gustav and was centered much closer to the Texas-Louisiana border (the center of my study area). In general, Hurricane Gustav had minimal impacts on areas inhabited by radio-marked females.

The least switching of states occurred during the wettest year of the study and females were most likely to change states in the hurricane year. This supported my hypothesis that females would be least likely to switch habitats in wet years. Further, it appears that major weather disturbances result in more switching of states among females. Overall, the relative probability of switching states was low; this suggests that managers should consider that management activities and regulations have a greater impact on local Mottled Duck populations than do management and regulations at a regional scale.

Similarly, females moved least during the wettest year of the study. This supports the hypothesis that movement distances will be lowest during wet years; further, maximum movement distances varied among capture sites.

Distances from the coast of marked females in mid-September – early-October were similar among all years of the study; this did not support my hypothesis that females were more likely to move inland during a hurricane impacted year than in non-hurricane impacted years. However, distance from capture sites did vary among years and capture sites, suggesting that females at some capture sites were already in favorable locations when hurricanes impacted the coast. Establishment and protection of managed inshore wetland habitats areas, away from potential hurricane impacts may be beneficial to Mottled Ducks.

Visual inspection of movement data from 2008 revealed what appear to be inconsistent reactions to potentially catastrophic weather events (Figs. 3.2 – 3.4). The majority of females marked at Marsh Island SWR moved off of the island and to the northwest after Hurricane Gustav and the remainder moved northwest after Hurricane Ike. Females marked in other areas of Louisiana generally moved little after hurricane Gustav, but apparently moved northward due to Hurricane Ike and its strong storm surge. Post-Ike telemetry flights found about 20 radio-marked females using Lacassine NWR and the immediately surrounding lands. Very few radio-marked females were using this area before Hurricane Ike affected the region. By late October 2009, all but 1 marked female moved inland from Marsh Island, most females marked on Rockefeller SWR and on private lands in southwest Louisiana moved inland, and no females marked on the Atchafalaya Delta WMA made substantial movements.

MANAGEMENT IMPLICATIONS

In years when severe storms alter coastal marshes, presence of suitable inland marsh habitats may be of extreme importance along the western Gulf Coast.

Juxtaposition of managed freshwater habitats may be an important management consideration to ensure available marsh habitats for Mottled Ducks in years of severe weather.

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CHAPTER 4. AN AIRBOAT-BASED SURVEY CONDUCTED IN LOUISIANA MARSH HABITATS FOR ESTIMATION OF PAIR DENSITIES AND VISIBILITY CORRECTION OF FIXED-WING SURVEYS

Mottled Ducks (*Anas fulvigula*) are the most abundant breeding waterfowl in coastal marshes of Louisiana and Texas (Stuzenbaker 1988). In Louisiana, 487,695 hectares of coastal lands were lost between 1932 and 2010 (Couvillion et al. 2011). Wetland managers need current information on pair densities of Mottled Ducks to assess and direct management and conservation activities. Waterfowl researchers lack unbiased estimates of Mottled Duck abundance along the Gulf Coast during spring. Population indexes could be established for the area using data from transects flown via fixed wing aircraft, but techniques to correct these counts for visibility and extrapolate these indices to attain population estimates have not been attempted.

Counts from simple line transects likely provide inaccurate estimates of numbers of animals present during a survey because observers miss substantial numbers of animals while conducting surveys (Caughley 1974). Helicopter counts can be used to correct visibility bias of fixed wing aircraft surveys for Mottled Ducks by flying an exhaustive search pattern (Johnson et al. 1989). The ability of helicopters to fly over habitats very slowly or hover in place until complete counts are attained makes them useful for these counts. In this chapter, I evaluate airboats as a means for correction of fixed wing counts for missed ducks. The number of missed animals predictably increases with distance from the transect line, and the subsequent population estimates can be adjusted to attain unbiased estimates of population density if the sighting distance from the transect line can be estimated (Caughley et al. 1976, Buckland et al. 2001).

My objectives were to 1) estimate densities of indicated breeding pairs in each marsh type using transects completed by airboat, 2) to compare the number of indicated

breeding pairs estimated using PROGRAM DISTANCE on airboat transects with the number of indicated breeding pairs detected via helicopter, and 3) to establish visibility correction factors for fixed wing transects using airboat transects.

METHODS

I used transects established by the Louisiana Department of Wildlife and Fisheries (LDWF) as a sampling framework for this data set (Fig. 4.1). The purpose of LDWF's annual survey is to provide an index to the number of breeding Mottled Ducks in coastal Louisiana. Fixed wing transects were divided into 6 nautical mile segments for helicopter survey by United States Fish and Wildlife Service (USFWS) and LDWF personnel. Segments of fixed wing transects were selected for survey via airboat and helicopter 1-2 d after survey from the fixed wing aircraft in southwest Louisiana; portions of 10 and 9 transects were surveyed via both airboat and helicopter in 2009 and 2010, respectively. We sampled portions of these segments via airboat where we could attain permission for access and water conditions permitted use of an airboat (Figs. 4.2 and 4.3). Airboat transects were completed 7-8 April 2009 and 13-14 April 2010; timing of this survey was chosen to coincide with the timing of fixed wing transects flown in southwest Louisiana. LDWF personnel attempt to time these surveys such that peak nesting activity for Mottled Ducks is underway each spring.

Helicopter Surveys

Pair surveys were conducted via helicopter following flights of fixed wing transects in 2009 and 2010, by the U.S. Fish and Wildlife Service and Louisiana Department of Wildlife and Fisheries. A helicopter was flown in a zigzag pattern within 200 meters of transect lines in an attempt to attain a complete count in the 400 meter

wide strip. Two observers visually searched for Mottled Ducks and recorded detections via an audio device connected to a laptop with an integrated GPS unit; detections were geo-referenced simultaneously while they were recorded.

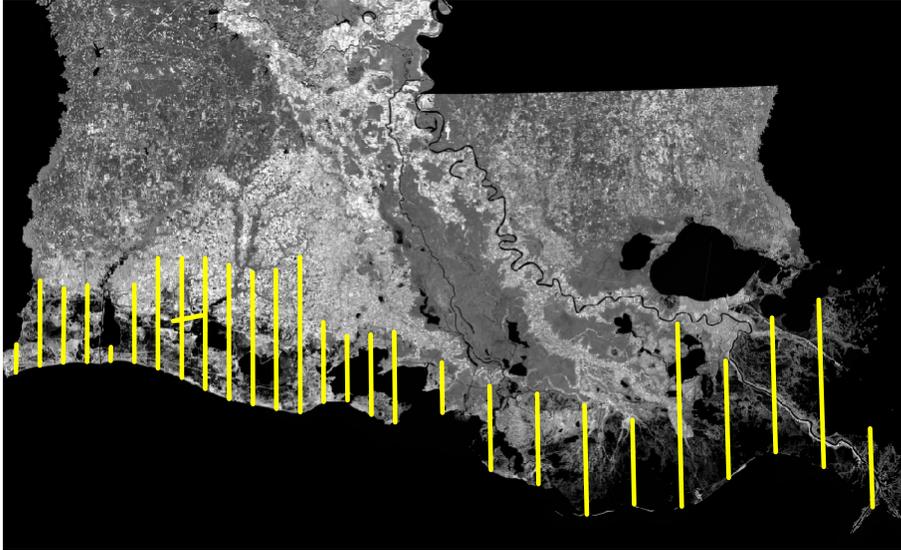


Figure 4.1. Fixed wing transects (yellow lines) for spring Mottled Duck survey in coastal Louisiana areas established by LDWF.

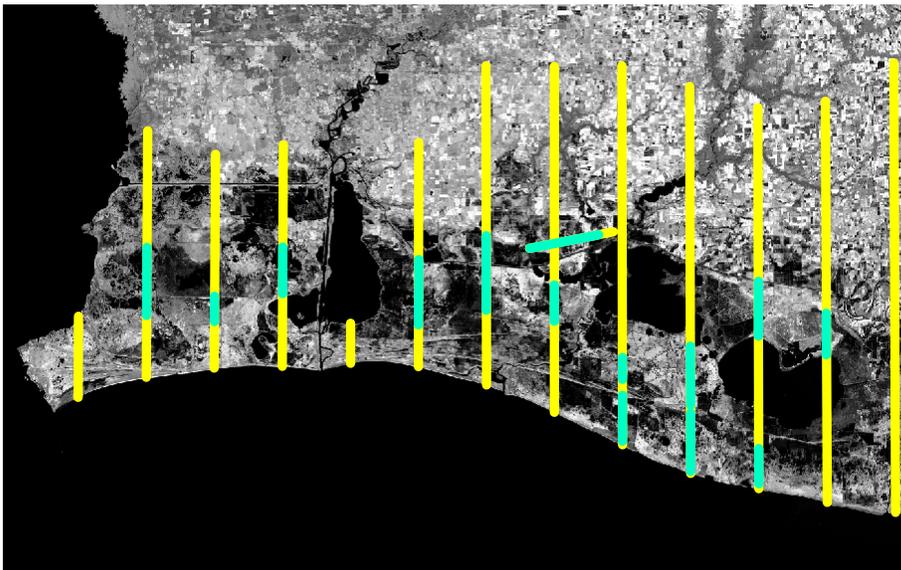


Figure 4.2. Transects surveyed via airboat (blue segments) on portions of fixed wing transects (yellow lines) in coastal areas of southwest Louisiana during 7-8 April 2009.

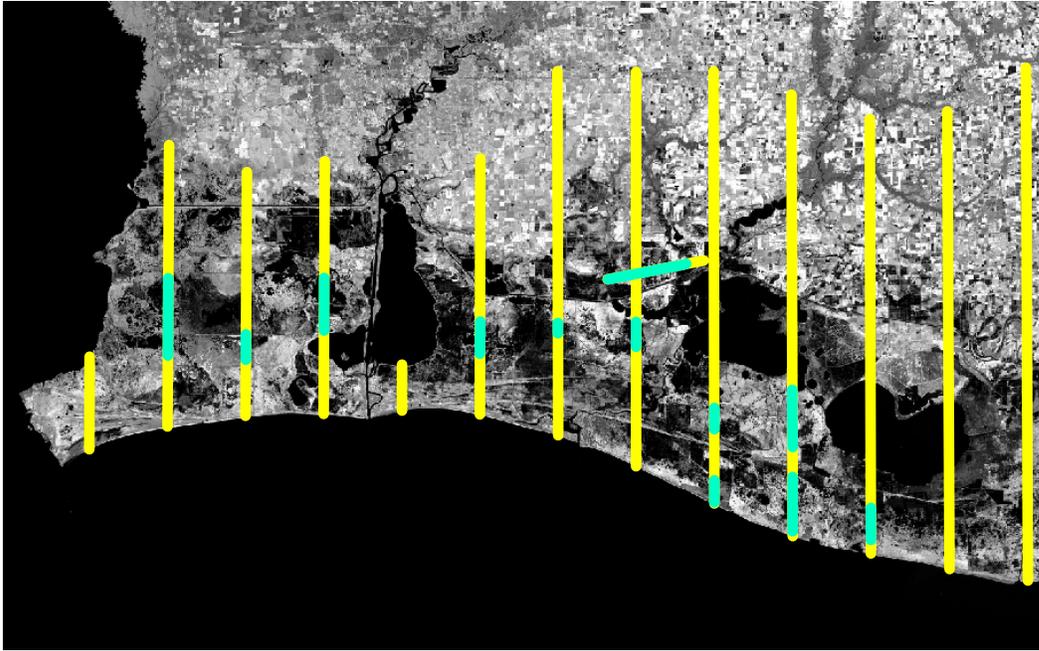


Figure 4.3. Transects surveyed via airboat (blue segments) on portions of fixed wing transects (yellow lines) in coastal areas of southwest Louisiana during 13-14 April 2010.

Airboat Surveys

I conducted pair counts on straight line transects from an airboat 1 to 2 days after fixed wing transects were flown. I recorded pairs, lone birds, or groups of Mottled Ducks flushing or on the water within 200 meters of the airboat. I recorded my location and an ocular estimate of the perpendicular distance from the line transect to the detected animal or group of animals each time a detection was made.

Data Analysis

Pair Density

To estimate densities of indicated breeding pairs in each marsh type via airboat transects, I considered each detected pair, lone male, lone female, or brood as an indicated breeding pair. I conservatively estimated the number of indicated breeding pairs from groups of any size by dividing group size by 2 and rounding to the nearest

integer. The Louisiana marsh zone is divided into fresh, intermediate, brackish, and saline habitat types according to classifications established by Sasser *et al.* (2008). I post-stratified data by habitat type (Buckland et al. 2001) and considered each portion of a segment within a marsh type a separate sampling unit for this analysis; this yielded 28 and 21 samples for analysis in 2009 and 2010, respectively. Mean length of the sampling unit was 4274 meters; transect length ranged from 320 to 12241 meters.

I used PROGRAM DISTANCE to estimate habitat specific densities of indicated breeding pairs in each marsh type (strata; Buckland et al. 2001). I estimated densities of indicated breeding pairs separately for 2009 and 2010. I estimated variances of densities empirically for each habitat type sampled in 2009, but assumed a Poisson distribution of the data in 2010. Due to dry conditions in 2010, I could only sample one transect in fresh marsh habitat, thus empirical estimates of variance were not possible for this habitat type in 2010.

Comparisons of Helicopter and Airboat Data

For this comparison, I estimated pair densities from airboats for each transect segment separately using PROGRAM DISTANCE. I did not divide transects among habitat types for this analysis. I compared the indicated breeding pair densities generated using PROGRAM DISTANCE for airboat transects with the numbers of indicated breeding pairs observed directly from the helicopter using a paired T-Test, and restricted comparison to portions of transect segments where both airboat and helicopter surveys were completed.

Estimation of Visibility Correction Factor from Airboat

To estimate visibility correction factors (VCFs), I restricted analysis to portions of transect segments where both airboat and helicopter surveys were completed. I calculated indicated breeding pair densities for each transect segment surveyed via airboat separately using PROGRAM DISTANCE. I regressed the calculated number of pairs on the count data from the fixed wing data and estimated 95% confidence intervals on the intercept and slope of this line. The slope of the regression is equal to the estimated VCF.

RESULTS

Airboat Surveys

Pair counts conducted via airboat indicated extensive use of fresh marsh habitats. In 2009, I recorded 147 detections on approximately 37 km of transects in fresh marsh, 82 detections on approximately 60 km of transects in intermediate marsh, 31 detections on approximately 16 km of transects in brackish marsh, and 6 detections on approximately 7 km of transects in saline marsh. In 2010, I recorded 62 detections on approximately 12 km of transects in fresh marsh, 87 detections on approximately 52 km of transects in intermediate marsh, 20 detections on approximately 12 km of transects in brackish marsh, and 14 detections on approximately 7 km of transects in saline marsh. Detections of indicated breeding pairs decreased with distance from the transect lines (Figs. 4.4 and 4.5). Estimates of pair density produced using distance sampling analysis techniques were highest in fresh marsh habitats (Tables 4.1 and 4.2). Ratios of sighted pairs to sighted lone males were 201:64 and 94:68 in 2009 and 2010, respectively; these

measures may give an indication chronology of the breeding season (Cowardin et al. 1995).

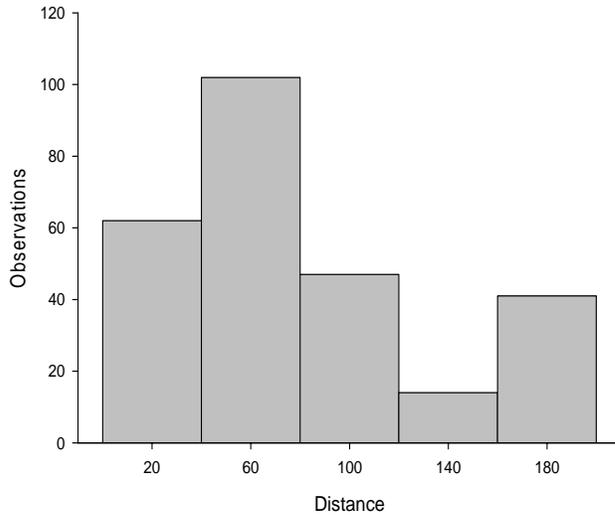


Figure 4.4. Observations of indicated breeding pairs by estimated distance from transect line for transects completed via airboat on 7-8 April 2009.

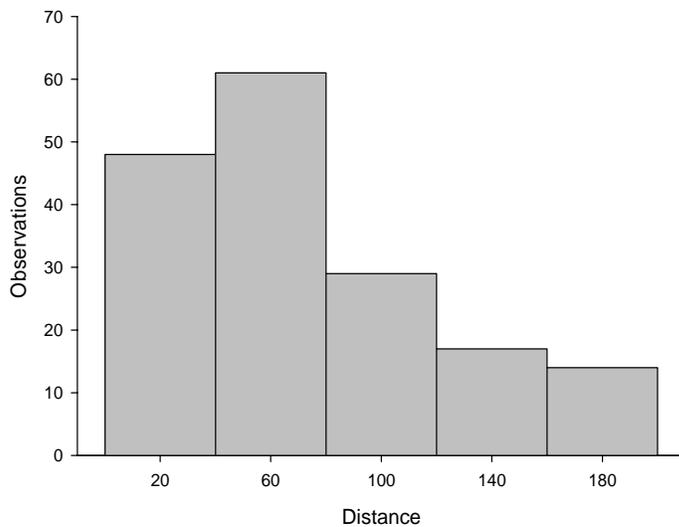


Figure 4.5. Observations of indicated breeding pairs by estimated distance from transect line for transects completed via airboat on 13-14 April 2010.

Table 4.1. Pair density estimates produced using PROGRAM DISTANCE for line transects surveyed 7-8 April 2009; Data have been post-stratified by habitat types.

Vegetation Code	Pair Density (pairs/km ²)	Lower 95% CL	Upper 95% CL	km ² of marsh habitats in southwest Louisiana	km ² of marsh habitats in Louisiana
Fresh	13.716	6.499	28.950	921.6	3901.2
Intermediate	4.716	2.674	8.317	1720.3	4221.9
Brackish	6.452	2.886	14.428	922.7	3093.5
Salt	3.011	0.203	44.689	290.6	3435.7

Table 4.2. Pair density estimates produced using PROGRAM DISTANCE for line transects surveyed 13-14 April 2010; Data have been post-stratified by habitat types.

Vegetation Code	Pair Density (pairs/km ²)	Lower 95% CL	Upper 95% CL	km ² of marsh habitats in southwest Louisiana	km ² of marsh habitats in Louisiana
Fresh	20.059	15.049	26.738	921.6	3901.2
Intermediate	5.719	4.412	7.412	1720.3	4221.9
Brackish	6.505	4.082	10.366	922.7	3093.5
Salt	6.592	3.632	32.000	290.6	3435.7

Comparisons of Helicopter and Airboat Data

Estimated densities of indicated breeding pairs derived from the airboat survey did not differ from counts produced using a helicopter ($P = 0.4361$). Estimated densities derived from the airboat were directly related to counts produced using a helicopter (Pearson correlation coefficient = 0.95985; Figure 4.6).

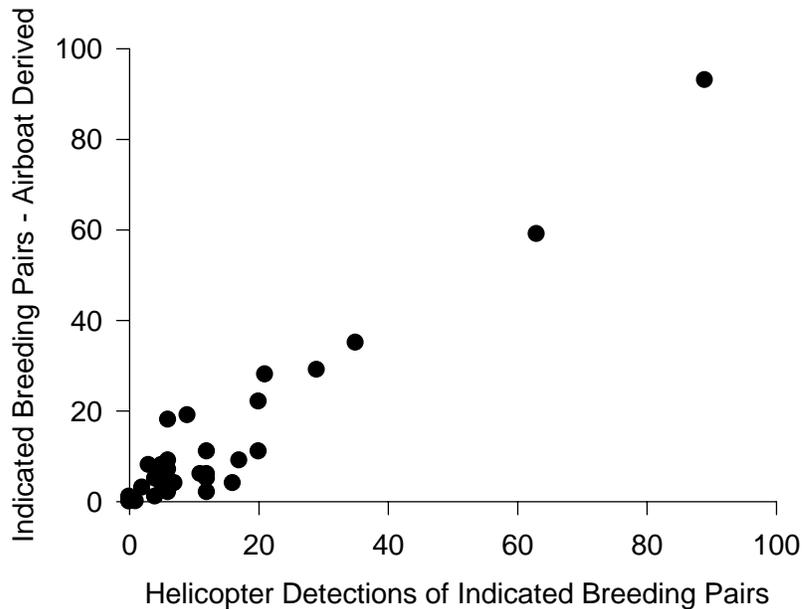


Figure 4.6. Scatter plot of indicated breeding pairs derived from distance sampling from an airboat by the number of detections of indicated breeding pairs seen from transect flown in a helicopter.

Estimation of VCF from Airboat

The fixed wing counts explained 38.6% of the variation in the airboat survey (Figure 4.7). We estimated that for each unit increase in fixed wing count data, true total count increased by a factor of 2.525 (± 0.541) and that the intercept of the VCF equation was 3.676 (± 3.152), yielding a VCF equation of:

$$\text{Corrected count} = (\text{fixed wing count} * 2.525) + 3.676$$

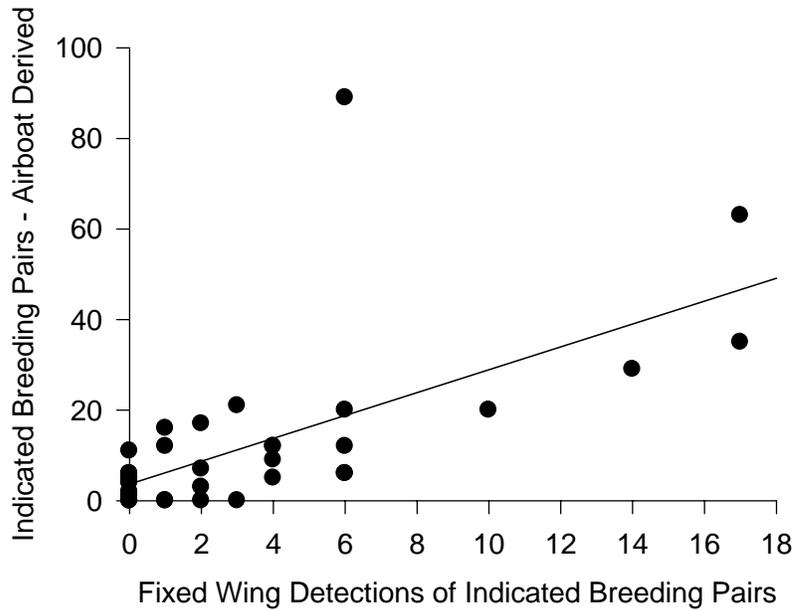


Figure 4.7. Regression of indicated breeding pairs derived from distance sampling from an airboat on the number of detections of indicated breeding pairs seen from transect flown in fixed wing aircraft.

DISCUSSION

Among marsh habitats surveyed using the airboat, estimated densities of indicated breeding pairs were highest in fresh marsh habitats. Fresh marsh habitats comprise about 25% of the coastal marsh habitat in Louisiana and include 3900 km² of habitat (Sasser et al 2008). Salt water intrusion into fresh marsh habitats causes degradation of marsh habitats and accelerates coastal land loss in Louisiana marshes (Walker et al. 1987). Saltwater intrusion alters plant community structure in fresh marsh habitats and may displace breeding pairs of Mottled Ducks.

If true pair densities were homogenous within each marsh type and transects surveyed using the airboat were representative, managers could simply multiply airboat derived density estimates by the area of marsh habitats on the landscape to achieve an overall estimate of the breeding population in Louisiana marshes. Some portions of

transect segments were not accessible due to dry conditions and difficulty of access with the airboat, thus, we suspect that our estimated pair densities may not be representative of the entire landscape in marsh habitat. However, our estimate of pair density should be representative of the wet portions of Louisiana marsh habitats. In future studies, it may be possible to use satellite imagery to estimate the amount of each marsh habitat that is wet and available for use by Mottled Ducks and incorporate these data to attain an accurate estimate of the breeding population of Mottled Ducks in Louisiana marshes.

Due to difficulty in attaining permission to use an airboat in unharvested rice fields, surveyed transects did not include any in rice agricultural habitats. These habitats are used by breeding Mottled Ducks (Zwank et al. 1989, Durham and Afton 2003); a study of radio-marked individuals reported that proportional use of agriculture lands by marked females was 20.2% (see Chapter 2). Thus, any population estimate of Mottled Ducks based solely on transects surveyed in marsh habitats will under-represent the total population.

Timing is an important aspect in planning waterfowl breeding surveys (Dzubin 1969); to attain an optimal index to local breeding pair densities, surveys should be timed such that the maximum number of breeding females has initiated a nest. For breeding population surveys of Mallards (*Anas platyrhynchos*) in the U.S. Prairie Pothole Region (PPR), a pair to lone male ratio of ≤ 0.50 is considered to give the optimal index of breeding pairs; my survey yielded ratios larger than this value. Because the breeding season is more protracted and variable for Mottled Ducks in the Gulf Coast than for Mallards in the PPR, synchrony of nest initiation dates among female Mottled Ducks may be less likely than in Mallards (Lokemon et al. 1990, Grand 1992). I suspect that the pair

to lone male ratio may never drop below 0.50 in this population. Further, this ratio may be biased high in our survey, because nesting females flushing due to the disturbance from the airboat may have been immediately joined by a nearby attending male and been mistakenly recorded as a pair; this error would not affect our overall density estimate of breeding pairs but would bias measurement of the pair to lone male ratio.

Counts via helicopter may be considered to be complete censuses of waterfowl populations, and differences between helicopter and traditional ground-truthing counts have been shown to be minimal (Cordts et al. 2002). Estimated densities of indicated breeding pairs derived from airboat surveys did not significantly differ from counts produced using the helicopter on the same transect segments. In wet areas of the Louisiana marsh, airboats offer a viable substitute for helicopter counts for surveying Mottled Duck breeding pairs. Drier portions of marsh habitats, inaccessible via airboat, may contain different densities of Mottled Duck pairs than do wet areas and cause a potential bias.

Analysis using PROGRAM DISTANCE allows correction of bias towards increased detection of objects nearest the transect line. Airboat transects represent a cost effective alternative to using helicopters for establishing visibility correction factors for fixed wing aircraft count data, after correction of airboat transect counts using PROGRAM DISTANCE. Airboat operation is considerably cheaper than operation of helicopters. Further, many state and federal wildlife management agencies in the gulf coast region commonly have airboats readily at their disposal, whereas, helicopters typically need to be rented to perform surveys. Operational costs of helicopters and airboats vary markedly among vendors depending on location, type of craft, fuel costs,

and other factors. Maintenance costs must also be factored in if using state or federally owned equipment to perform surveys.

In our analysis, we treated the corrected airboat counts as a census and calculated a VCF using a regression equation fitted to our corrected counts. The parameter estimate for the slope of this regression had a low standard error and lower and upper 95% confidence limits of 1.42 and 3.63, respectively. The parameter estimate for the intercept of this model had a much wider confidence interval than did the parameter estimate for the slope of the regression with lower and upper 95% confidence limits of -2.74 and 10.10, respectively; error on the intercept of the model would lead to a proportionally greater impact on index values near zero than to larger values. These standard error rates would result in an unacceptably high coefficient of variation on our VCF for some transects (Smith 1995). Considering that 56% of the transects surveyed by the airboat and the fixed wing had fixed wing counts of indicated breeding pairs ≤ 2 , population estimates derived using this corrected visibility factor will contain substantial variability.

Variation in visibility rates increases variation in VCFs and associated population estimates (Pearse et al. 2008). Differences in visibility of pairs among different habitat types are possible in these data and may lead to bias in our VCFs, thus caution is warranted in interpretation of these results (Broome 1985). Substantial variation in pair densities for each habitat type estimated in my study exists. Reduction of unexplained variation in VCFs among different types of marsh habitats may be possible with increased sample sizes.

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CHAPTER 5. USING POSTOVULATORY FOLLICLES AS AN INDICATOR OF BREEDING PROPENSITY IN MOTTLED DUCKS

Production in waterfowl is a function of numbers of breeding pairs, breeding propensity, hen success, brood size, and duckling survival. Breeding propensity is defined as the proportion of mature females that lay ≥ 1 egg during a given breeding season. Not surprisingly, variation in breeding propensity could dramatically influence estimates of production (Johnson et al. 1992, Hoekman et al. 2002), yet this component of production modeling is the least well studied aspect of waterfowl production in even the most well studied species.

Accurate estimates of breeding propensity are unknown for most waterfowl. Researchers currently estimate that 95%-100% of midcontinent Mallards (*Anas platyrhynchos*) breed when habitat conditions are favorable, but substantial bias may exist in these estimates. Breeding propensity is a difficult parameter to measure directly; some speculate that estimates of breeding propensity attained by monitoring radio-marked females are underestimated because of the negative effects of transmitters (Paquette et al. 1997). In contrast, breeding propensity may be overestimated because many studies utilizing radio-telemetry methods for monitoring breeding waterfowl use individuals captured with decoy-traps; estimates of nesting propensity derived from these studies are likely biased high because females must exhibit territorial behavior to be captured and non-breeding females are likely excluded from the sampling framework.

Postovulatory follicles are ovarian follicles that remain attached to an ovary after ovulation (Davis 1942). Presence of postovulatory follicles can be used as an indicator of egg production in many avian species (Hannon 1981). Postovulatory follicles remain identifiable by macroscopic examination (examination without sectioning) for ≥ 60 d after

ovulation occurs in Mallards (Lindstrom et al. 2006). Because Mottled Ducks are similar to Mallards, we expect development and regression of follicles will be similar among these species. If macroscopic examination of postovulatory follicles proves to be a successful technique for determination of laying status in female Mottled Ducks, this technique could be used to ascertain estimates of breeding propensity.

My primary objective was to determine whether or not macroscopic examination of ovaries could be used to identify female Mottled Ducks that had attempted to nest in the same breeding season. I tested the hypothesis that my ability to identify postovulatory follicles in female Mottled Ducks would decline with time lapsed since ovulation. Finally, I tested the hypothesis that females attending large broods would be more likely to have postovulatory follicles present than females attending smaller broods. A better understanding of breeding ecology derived through robust estimates of breeding propensity could help managers better understand the parameters influencing population dynamics in Mottled Ducks.

STUDY AREA

My capture sites included several localities on Rockefeller State Wildlife Refuge in southwest Louisiana (Figure 5.1). These locations were selected based on access and presence of high concentrations of female Mottled Ducks attending broods.

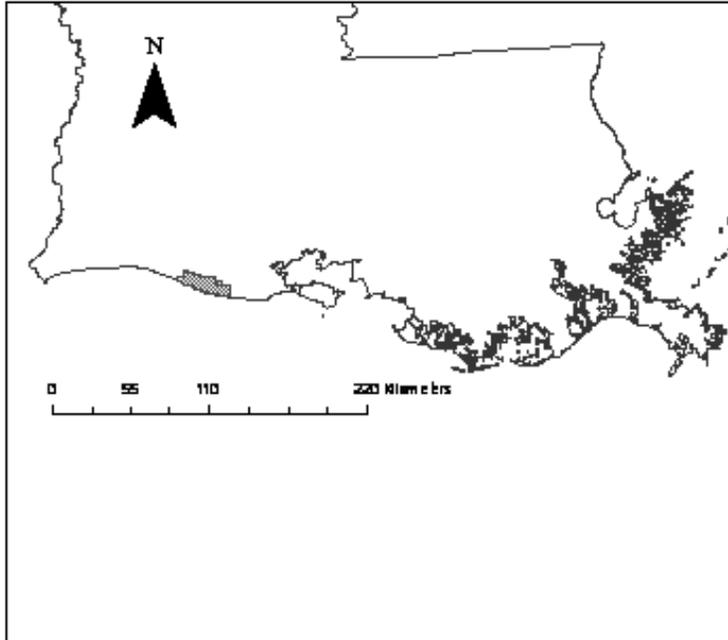


Figure 5.1. Location of Rockefeller State Wildlife Refuge (cross-hatched segment) in southwest Louisiana.

METHODS

In 2007 and 2008, I collected 22 female Mottled Ducks after capture using night-lighting techniques from an airboat (Cummings and Hewitt 1964). All collected females were attending broods and hence considered to be known breeders. I recorded the number of ducklings and duckling plumage characteristics in the field and later estimated brood ages based on these recorded plumage characteristics (Gallop and Marshall 1954). I surgically removed ovaries immediately after females were killed and placed them in a 10% buffered formalin solution (Lindstrom et al. 2006). I later examined each ovary for presence of postovulatory follicles under a dissecting microscope. Postovulatory follicles were identified as yellowed follicles with an occluded stigma. I counted the numbers of postovulatory follicles seen in each female.

I coded a binary response variable for successful determination of breeding status and classified ovaries with at least 1 identifiable postovulatory follicle as successfully determined. I tested for effects of estimated brood ages and observed number of ducklings on successful determination of laying status using logistic regression (PROC LOGISTIC, SAS Institute 2004).

RESULTS

Postovulatory follicles were identifiable via examination under dissecting microscopes in only 10 of 22 samples. I failed to detect effects of brood age or number of observed ducklings on successful determination of laying status ($P_s \geq 0.27$).

DISCUSSION

In the majority of my samples, postovulatory follicles could not be identified via examination with dissecting scopes. Our collected Mottled Duck ovaries appeared approximately 15 days or more regressed than did ovaries of mallards examined by Lindstrom et al, (2006; E Lindstrom, pers. comm.). The postovulatory follicles had apparently regressed beyond recognition in the majority of my samples. I eliminated potential observer error by having all observations checked by an experienced observer. Counts of postovulatory follicles have been used as indicators of clutch size in other avian taxa (Kennedy et al. 1989), but I observed no relationship between apparent brood size and correct classification of breeding status.

Mottled Ducks are most closely related to American Black Ducks (*Anas rubripes*) and Mexican Ducks (*Anas diazi*), and somewhat less closely related to Mallards (McCracken et al. 2000). In spite of being closely related to Mallards, Mottled Duck

ovaries appear to regress more rapidly than do ovaries in Mallards, perhaps because the latter are such prolific reneesters.

The apparent differences between Mottled Duck and Mallard ovaries may reflect differential sampling biases caused by differing methods of collection between my study and the work of Lindstrom et al. (2006). Females collected by Lindstrom et al. (2006) did not successfully hatch eggs, whereas all of the females I collected tended broods. Physiology may change after hens hatch broods (Davis 1942). In most duck species, females that successfully hatch broods are unlikely to initiate further nesting attempts, thus no longer need to retain the ability to undergo rapid follicle growth (Lofts and Murton 1973). Further, I suspect that females tending broods regress their ovaries more rapidly than do hens without broods. Sectioning of ovaries and microscopic examination could have provided better information on the laying histories of females.

I suggest that examination for postovulatory follicles is not a viable method for estimating breeding propensity in Mottled Ducks. Further research is necessary to determine whether observed differences between Mottled Ducks and Mallards could be attributed to dissimilarities in the species or were due to differences in collection methodologies. Examination of postovulatory follicles may not be effective in species of ducks other than Mallards; in a pilot study to test the efficacy of examination of Wood Duck (*Aix sponsa*) ovaries for evidence of postovulatory follicles in females after ducklings hatched, researchers were unable to identify postovulatory follicles (Semel and Sherman 1991). If females of other duck species with broods regress their ovaries in a similar fashion to that of Mottled Ducks, then examination of postovulatory follicles may be ineffective for determining breeding propensity.

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CHAPTER 6. CONCLUSIONS

My results document the importance of fresh and intermediate marsh habitats to female Mottled Ducks. Increased conservation of natural marsh habitats in coastal Louisiana and Texas may provide are warranted for Mottled Ducks. Considering the resources that agricultural habitats may provide to Mottled Ducks, protection and restoration of rice habitats appears to be of benefit to Mottled Duck populations and should be a high priority management option. In areas where restorations of natural marsh habitats are incompatible with current land uses, artificial flooding of agricultural landscapes could augment available habitats for Mottled Ducks.

In years when severe storms alter coastal marshes, presence of suitable inland marsh habitats may be of extreme importance along the western Gulf Coast. Juxtaposition of managed freshwater habitats may be an important management consideration to ensure available marsh habitats for Mottled Ducks in years of severe weather. Estimation of visibility correction factors via airboat offer an alternative method to establishment of these factors via helicopter and provide a reliable index to use of habitats in wet marsh habitats. Macroscopic examination of postovulatory follicles does not appear to be a reliable method for estimating breeding propensity in Mottled Ducks.

Further research is necessary to understand Mottled Duck vital rates, and to better understand variation in use of coastal habitats by Mottled Ducks. Research linking habitat use and movement parameters to vital rates such as hen success, brood survival, and adult survival rates across a broad spectrum of habitats and several years would benefit Mottled Duck conservation efforts. Research that incorporates substantial spatial,

temporal and habitat specific variation may allow evaluation of cross-seasonal effects and be most beneficial to Mottled Duck conservation efforts.

VITA

Bruce Edward Davis grew up in Glidden, Iowa, where he pursued wild game and fish through the younger days of his life. He attended Iowa State University from 1991 to 1996 and graduated with a Bachelor of Science degree in fisheries and wildlife biology. He spent the next 8 years working as a seasonal technician in support of research projects on various wildlife species and took a keen interest for projects concerning waterfowl in breeding, wintering, and spring-migrational habitats. He then enrolled in the graduate program at Louisiana State University and was awarded the degree of Master of Science in December 2007; his work entailed estimating the habitat use, movements, and survival of female Mallards during winter in the Lower Mississippi Alluvial Valley. Bruce will obtain the degree of Doctor of Philosophy in August 2012.