HABITAT USE, MOVEMENTS, AND SPRING MIGRATION CHRONOLOGY AND CORRIDORS OF FEMALE GADWALLS THAT WINTER ALONG THE LOUISIANA GULF COAST

A Thesis

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DEDICATION

This work is dedicated in memory of my grandmother, Jean Gray. Grandma enriched everyone's life more than she ever realized. She understood it was important for boys to spend time outdoors, and raised her four sons that way. My father and his brothers helped me learn how to hunt, fish, and trap the woods and waters of Ohio, which has gotten me as far as I am today.

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ABSTRACT

The Louisiana Gulf Coast is an important wintering area for North American gadwall (*Anas strepera*). Conservation of winter habitat is a top priority of the Gulf Coast Joint Venture. Quantitative estimates of habitat use by wintering gadwall would help improve energetic demand models and subsequent estimates of habitat requirements.

I used satellite telemetry (PTTs) to estimate winter habitat and refuge uses, spring migration chronology and corridors, as well as inter- and intra-regional winter movements of females. I used a split-plot MANOVA to evaluate the effects of individual females, female age, winter, hunt periods within winter, time of day, and all possible interactions among these explanatory variables on habitat use. I used a mixed model ANOVA to evaluate the effects of individual females, female age, winter, hunt periods within winter, time of day, and all possible interactions of these explanatory variables on refuge use. I used mixed models to evaluate the effects of hunt periods within winter, refuge use, winter, individual female, female age, and body condition at time of capture on intra-regional movements. Finally, I used a MANOVA to evaluate the effects of female age, spring of tracking, and body condition at time of capture on several spring migration parameters.

I found that habitat use in winter 2007-08 was dominated by intermediate marsh, whereas habitat use during winter 2008-09 showed an increased dependence on freshwater marsh ($P = 0.0001$). Use of non-hunted refuges by adult females was greater when hunting season was open than when closed ($P = 0.0061$).

I found no significant relationships among the explanatory variables and intra-regional movements (all Ps > 0.09). Peak migratory departure from the Louisiana Gulf

Coast Chenier Plain occurred during late-March to early-April. HY females traveled a greater total migratory distance, spent more days migrating, used more stopovers, and arrived at inferred breeding locations later than did AHY females (all Ps ≤ 0.061).

My results suggest that intermediate marsh is important for wintering gadwall; however, freshwater marsh may become important after tidal surge events. Finally, my migration data provides habitat managers with quantitative information to consider when implementing conservation programs and management practices.

CHAPTER 1. INTRODUCTION

Habitat and Refuge Uses

The Gulf Coast is an important wintering area for gadwall (*Anas strepera*), with approximately 75% of the North American population wintering in Louisiana alone (Bellrose 1980). Gadwall are the most saline tolerant of the dabbling ducks (Jehl 2005) and previously have been assumed to rely heavily on coastal marsh habitats during winter. Quantitative habitat use estimates for gadwall would help improve energetic demand models and subsequent estimates of foraging habitat needs. Because of the large number of gadwall wintering along the Gulf Coast, this information may have a substantial effect on habitat conservation objectives. This information should help improve the efficiency of wetland conservation and management practices aimed at providing quality habitat for waterfowl wintering along the Louisiana Gulf Coast.

Gadwall consume predominantly herbaceous aquatic vegetation such as widgeongrass (*Ruppia maritima*), watermilfoil (*Myriophyllum spicatum*), pondweed (*Potamogeton spp.*), and algae (*Chaetophoraceae*) (Serie and Swanson 1976, Paulus 1982, Mcknight and Hepp 1998). Due to the relatively low nutritional value of aquatic vegetation, gadwall spend approximately 64% of their time feeding in order to maintain body condition on the wintering grounds (Paulus 1982). Therefore, gadwall have relatively less time available to occupy habitats that do not provide adequate foraging opportunity and probably do not use separate foraging and loafing areas, as reported for other dabbling ducks that winter within the Louisiana Gulf Coast Chenier Plain (Cox and Afton 1997, Link 2007).

Hunting disturbance affects habitat use and distribution of wintering waterfowl (Cox et al. 1998, Miller et al. 1995, Paulus 1984). Paulus (1984) speculated that hunting pressure forced gadwall to leave optimal foraging habitats, whereas those in non-hunted areas rarely left optimal foraging habitats during day or night. Furthermore, Gaston (1991) documented that lipid reserves of gadwall were lower during hunting periods than in non-hunting periods in Louisiana. Female gadwall rely heavily on lipid reserves during reproduction (Ankney and Alisauskas 1991). Body condition of nesting hens is positively correlated with reproductive investment and success in some waterfowl (Devries et al. 2008). Therefore, winter habitat use by females and concomitant body condition may effect reproduction (Paulus 1982). Moreover, habitat conservation efforts in wintering areas and along migration corridors probably are crucial for waterfowl management.

Hurricane Ike made landfall on 14 September 2008, a little more than a month before gadwall began arriving at the Louisiana Gulf Coast. Post-hurricane winter habitat conditions (2008-09) were very different than habitat conditions during the previous winter (2007-08). The resulting storm surge inundated the majority of the coastal marsh zone within the Louisiana Gulf Coast Chenier Plain. The storm surge drastically increased marsh salinities and killed large stands of aquatic vegetation, subsequently reducing the amount of potential forage throughout the area affected by the storm surge (J. Gray, personal observation). This habitat alteration may have caused gadwall to settle in areas unaffected by the storm surge, or forced those that settled in affected areas to make more frequent movements in search of adequate foraging habitats.

Movements

Understanding waterfowl movements and factors influencing them are crucial components for effective management of winter habitats (Cox et al. 1998). Wintering waterfowl may increase flight distance from concentration areas over time as nearby food resources are reduced, as predicted by refuging theory (Hamilton and Watt 1970, Cox and Afton 1996). Habitats differ in the quantity of energy per unit area produced and waterfowl presumably move within and among habitats in response to forage availability (Fredrickson and Taylor 1982, Miller 1987).

Northern pintails (*Anas acuta*; hereafter pintails; Cox and Afton 1996; Cox and Afton 2000) and mallards (*Anas platyrhynchos;* Link 2007) wintering along the Gulf Coast Chenier Plain (GCCP) made distinct movements from diurnal roost sites to nocturnal foraging areas. Furthermore, pintails wintering in the Louisiana GCCP made large inter-regional movements during winter, often leaving the Gulf Coast and moving to more northerly areas in response to weather events or hunting pressure (Cox and Afton 2000).

Spring Migration

Most species of North American waterfowl are highly migratory, breeding in temperate to sub-arctic regions and wintering from the southern half of the United States to the tropics. Waterfowl migration generally occurs along a series of narrow intermingled corridors and is energetically demanding (Bellrose 1980). Therefore, migrating birds must find suitable habitats for resting and refueling along migration corridors (Moore et al. 1990). For many years, migration habitat was thought to have a nominal effect on waterfowl populations (Reinecke et al. 1989). However, a better understanding of the interdependence of waterfowl requirements throughout the annual cycle has led to increased conservation efforts along major migratory pathways (Reinecke et al. 1989).

We have little understanding of how proximate factors influence spring migration chronology in waterfowl (Dugger 1997). The Staggered Event Hypothesis (SEH) predicts that the relative timing of life-history events within the annual cycle are dependant on physiological condition (Dugger 1997; modified from Heitmeyer 1988, Lovvorn and Barzen 1988). Based on the progression of winter life history events in most waterfowl (endogenous lipid storage > pair formation > initiation of prebasic molt > pre-migration lipid storage; Heitmeyer 1988) the SEH provides testable predictions about how female age, body condition, and concomitant molt status may affect spring migration chronology. Under the SEH, females in better physiological condition are predicted to migrate earlier. In many species, after hatch-year (AHY) females should out compete hatch-year (HY) females for limited resources (Heitmeyer 1988, Paulus 1984), and migrate earlier than do HY females (Dugger 1997).

I used satellite telemetry (PTTs) to estimate habitat and refuge use, spring migration chronology and corridors, as well as inter- and intra-regional winter movements of female gadwall. The timing of my study allowed for a comparison of habitat use and movements between pre- and post-hurricane winters. In Chapter 2, I estimate habitat and refuge use by female gadwall wintering within the Louisiana GCCP. In Chapter 3, I estimate inter- and intra- regional movements by females during winter. In Chapter 4, I describe the migration chronology and corridors used by females during spring migration. Finally, chapters 2-4 are organized as separate manuscripts for submission to scientific journals; thus, some duplication of text occurs in the study area and methods sections.

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CHAPTER 2. HABITAT AND REFUGE USE BY FEMALE GADWALLS WINTERING WITHIN THE COASTAL MARSH ZONE OF THE LOUISIANA CHENIER PLAIN.

The Gulf Coast is an important wintering area for North American waterfowl, historically supporting up to 75% of the continental dabbling duck population (Palmisano 1973) and 67% of the Mississippi Flyway waterfowl population (Bellrose 1980). Approximately 75% of the continental gadwall (*Anas strepera*) population winters in Louisiana, primarily along the Gulf Coast (Bellrose 1980).

Coastal marshes in the Mississippi Flyway cover >1 million ha and comprise 42% of the coastal marshes in the continental United States (Chabreck et al. 1989). Louisiana's coastal mashes account for 96% of the coastal marshes in the Mississippi Flyway. Unfortunately, coastal marshes in Louisiana are subsiding rapidly. Marsh loss estimates for Louisiana are as high as 100 km^2/yr (Gagliano et al. 1981), with a corresponding total coastal marsh loss of 3,900 km^2 (Boesch et al. 1994). Factors contributing to marsh loss include: altered wetland hydrology by canals, loss of river sediment deposition on wetlands caused by the construction of flood control levees, an overall decline in the amount of suspended sediments in the Mississippi River, saltwater intrusion, hurricanes, and sea level rise (Day et al. 2000, Chabreck et al. 1989).

Gadwall are the most saline tolerant of the dabbling ducks (Jehl 2005) and are assumed to rely heavily on coastal marsh habitats during winter. Quantitative habitat use estimates for gadwall would help improve energetic demand models and subsequent estimates of foraging habitat needs. Because of the large numbers of gadwall wintering along the Gulf Coast, this information may have a substantial effect on habitat conservation objectives.

Gadwall consume predominantly herbaceous aquatic vegetation, such as widgeongrass (*Ruppia maritima*), watermilfoil (*Myriophyllum spicatum*), pondweed (*Potamogeton spp.*), and algae (*Chaetophoraceae*) (Serie and Swanson 1976, Paulus 1982, Mcknight and Hepp 1998). Due to the relatively low nutritional value of aquatic vegetation, gadwalls spend approximately 64% of their time feeding to maintain body condition on the wintering grounds (Paulus 1982). Therefore, gadwall have relatively less time available to occupy habitats that do not provide adequate foraging opportunity and probably do not use separate foraging and loafing areas as reported for other dabbling ducks that winter within the Louisiana Gulf Coast Chenier Plain (Cox and Afton 1997, Link 2007).

Hunting disturbance affects habitat use and distribution of wintering waterfowl (Cox et al. 1998, Miller et al. 1995, Paulus 1984). Paulus (1984) speculated that hunting pressure forced gadwall to leave optimal foraging habitat, whereas those in non-hunted areas rarely left optimal foraging habitats during day or night. Gaston (1991) documented that gadwall had lower lipid reserves during hunting periods than in non-hunting periods in Louisiana. Female gadwall rely heavily on lipid reserves during reproduction, with 78% of lipids deposited in eggs coming from reserves (Ankney and Alisauskas 1991). Body condition of nesting hens is positively correlated with reproductive investment and success in some waterfowl (Devries et al. 2008). Consequently, habitat quality and the concomitant body condition of gadwall leaving the wintering areas maybe important to future reproduction (Paulus 1982). Therefore, knowing which habitats are most utilized by wintering waterfowl and how anthropogenic disturbances effect habitat use is an important concern of Gulf Coast waterfowl managers.

Our current understanding of gadwall habitat use along the Gulf Coast is based on diurnal aerial surveys. This type of survey methodology may not accurately estimate the distribution of waterfowl among coastal marsh habitat types. Detectability in certain habitat types is lower than in others (Smith et al. 1995; Pearse et al. 2007), and repeated low passes by aircraft may cause birds to redistribute across the landscape without regard for preferred habitat type. Also, the importance of habitats used during diurnal periods may be overestimated; telemetry studies of other dabbling ducks in the Louisiana Gulf Coast Chenier Plain (GCCP) have shown differential habitat use during diurnal and nocturnal time periods (Cox and Afton 1997, Link 2007).

Studies of radio-marked birds seemingly provide unbiased estimates of habitat use (Petrie et al. 2002) that can be incorporated into habitat objectives and help improve the efficiency of conservation efforts (Wilson 2003). Quantitative habitat use information would increase the efficiency of wetland conservation and management practices aimed at providing quality habitat for waterfowl wintering along the Louisiana Gulf Coast.

I used satellite telemetry to estimate proportional habitat and refuge uses by female gadwall wintering within the Louisiana GCCP. My objectives were to quantify: 1) proportional use among coastal marsh habitat types; 2) potential affects of hunting disturbance on habitat and refuge uses by comparing proportional use between hunted and non-hunted time periods; 3) potential effects of time of day on habitat use by comparing diurnal and nocturnal proportional habitat use; and 4) potential effects of female age on habitat and refuge uses.

Study Area

My study area included the coastal marsh zone within the GCCP in southwestern Louisiana (Figure 2.1). The GCCP is a series of beach ridges and mud flats, which became marsh, formed by westward drift of river sediments (Day et al. 2000). The GCCP ecosystem extends along 322 km of coastline from Vermillion Bay, Louisiana to East Bay, Texas and extends inland from the Gulf of Mexico for distances ranging from 60 to 110 km encompassing more than 2.5 million ha (Chabreck et al. 1989). Within the coastal marsh zone of the Louisiana GCCP, salinity progressively declines along a gradient moving inland from the Gulf of Mexico, causing marsh types generally to occur in bands parallel to the coast (Figure 2.2). Coastal marsh is comprised of four distinct marsh types; salt, brackish, intermediate, and fresh (Chabreck et al. 1989, Sasser et al. 2008).

Methods

Trapping

I captured gadwall using rocket nets fired with remote detonators (Sharp and Lokemoen 1980) from portable platforms (Cox and Afton 1992) during the winters of 2007-08 and 2008-09. These methods have been effective in capturing gadwall and other waterfowl in coastal marsh habitats (Cox and Afton 1992, Link 2007).

During both winters, I attempted to capture gadwall on Rockefeller State Wildlife Refuge, Cameron Prairie National Wildlife Refuge, and White Lake Conservation Area. I chose these sites because of the limited disturbance and prohibition of hunting there allowed me to use baited trap sites. I assumed that these trap locations were representative of the Louisiana GCCP.

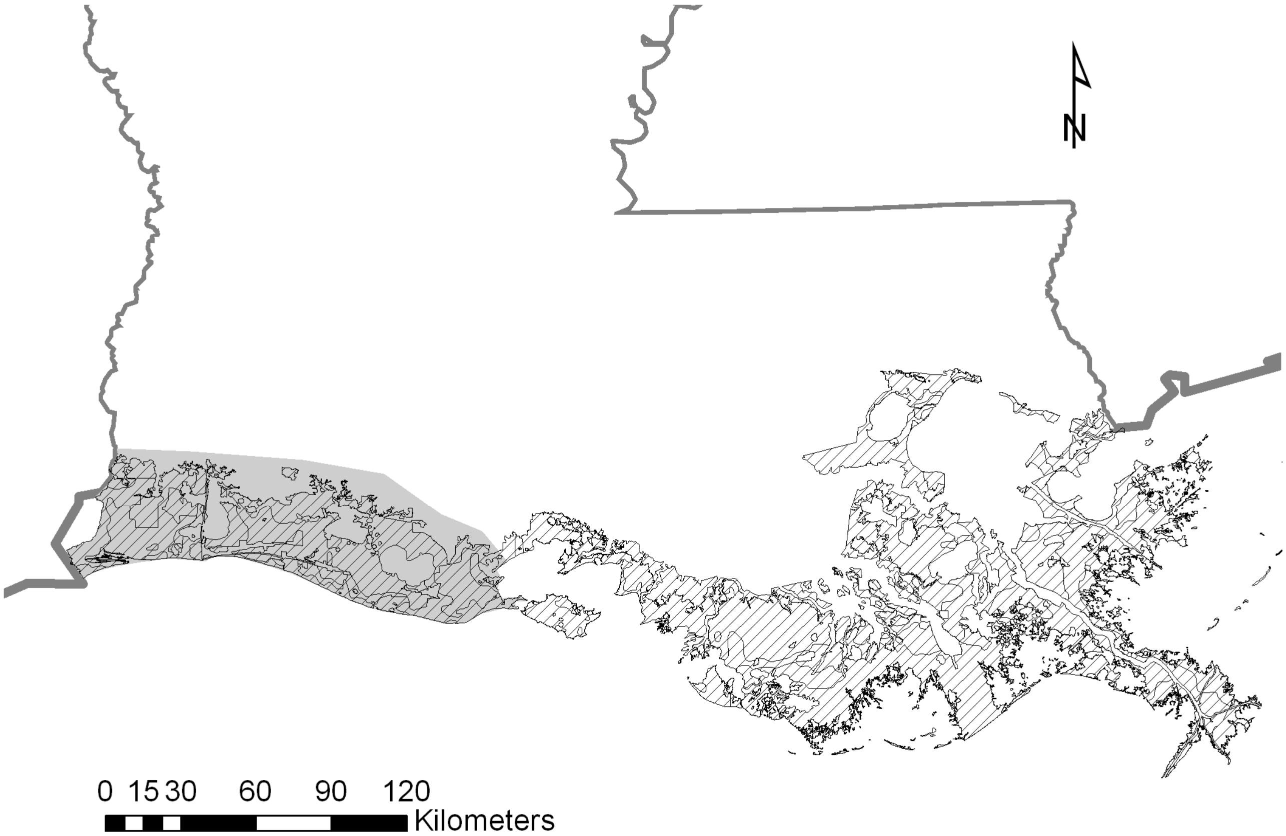

Figure 2.1 Location of the study area which encompassed the coastal marsh zone (hatched area) within the Louisiana Gulf Coast Chenier Plain (solid gray area).

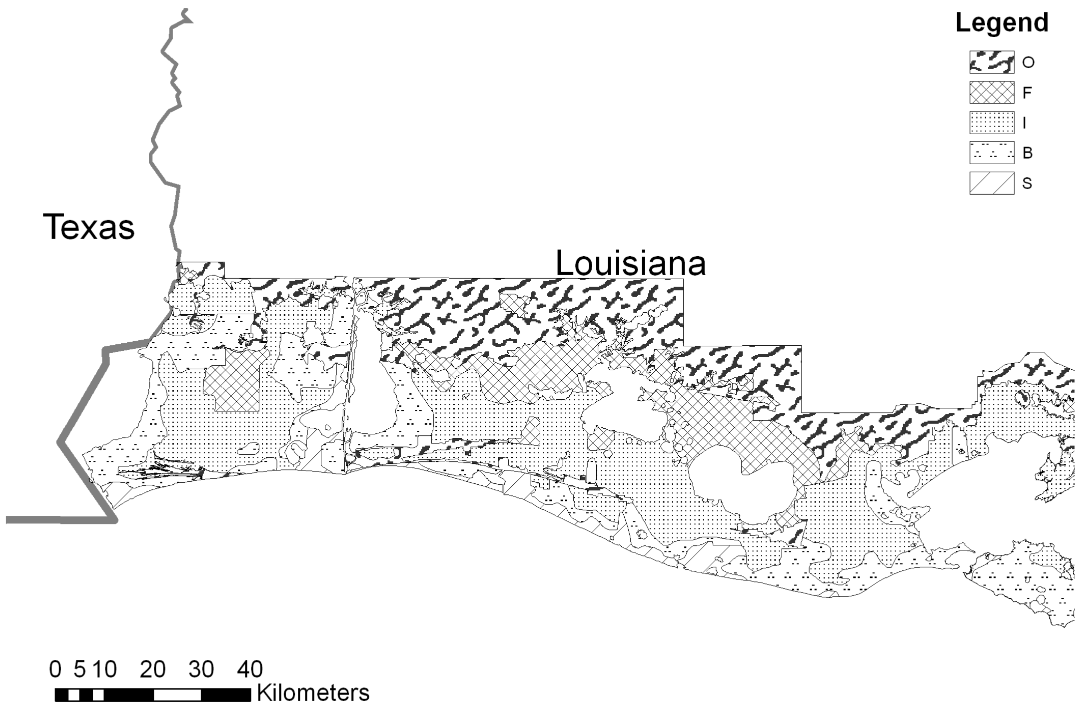

Figure 2.2 Marsh types within the Louisiana Gulf Coast Chenier Plain according to Sasser et al. 2007: S= salt marsh, B= brackish marsh, I= intermediate marsh, F= freshwater marsh, and O= all non-marsh habitats.

I used unbaited and baited rocket net sites to capture gadwall. I used baited rocket nets in large open water areas, where I had permission to use bait. I baited trap sites with a mixture of barley, corn, milo, wheat, oats, rice, peas, and oyster shells. I selected other unbaited trap sites in smaller, more secluded areas where concentrations of gadwall were observed. I used existing marsh vegetation at unbaited sites to hide rocket nets and then waited for gadwall to get into the throw of the net without the use of any attractant or hazing. I initiated trapping as soon as gadwall arrived on my study area, which was the last week of October during both winters and continued trapping until all satellite transmitters (hereafter PTTs) had been deployed. I terminated trapping in early-January and mid-December during winters 2007-08 and 2008-09, respectively.

Marking

I placed captured gadwall into catch boxes and transported them to a laboratory on Rockefeller State Wildlife Refuge for subsequent implantation of PTTs. I provided food and water *ad libitum* during the banding and marking process (LSU Agricultural Center Institutional Animal Care and Use Protocol #A2007-10 and U.S. Geological Survey Banding Permit # 08810). I determined female age as hatch-year (HY) and after hatch-year (AHY) based on wing plumage characteristics (Carney 1964). I recorded body mass (±5g) and measured (±0.1mm) natural wing cord, total tarsus length, culmen length, and head length on all captured females (Dzubin and Cooch 1992). I only implanted PTTs in females that weighed >700g to reduce potential transmitter effects. I marked females with a standard USFWS leg band and an auxiliary leg band containing my contact information. I used auxiliary leg bands so that hunters could potentially contact me immediately after harvest, which would allow me to evaluate body condition.

Transmitter implantation.— In the lab, captured females were induced under anesthesia with isoflurane delivered by facemask at a delivery rate of 5% isoflurane per 1 liter/minute of oxygen flow. Once females lost consciousness, the facemask was removed, and the bird was intubated with a 3-0 to 4-0 outside diameter endotracheal tube. Females were maintained at 2-3% isoflurane at a flow rate of 1 liter/minute of oxygen. Birds were positive-pressure ventilated during the procedure every ten seconds. An anesthetist monitored heart rate with a stethoscope through out the duration of the surgery.

Females were surgically prepped at two sites: 1) the junction of the dorsal synscarum and the pubis, and 2) the ventral abdominal body wall. The dorsal site was prepped first, followed by the ventral site. Sterile surgical preparation was done using a 1% betadine solution and sterile saline. The dorsal site was prepped and covered with a 2×2 inch sterile gauze pad, and the bird then was placed in dorsal recumbency to prep the abdominal site. After surgical preparation, a clear surgical drape was placed over the bird.

The ventral abdominal incision was made through the skin and rectus abdominis with a #15 scalpel blade. Once the celomic cavity was opened, the right abdominal airsac was manually deflated. The antenna of the PTT was placed into a blunt trochar and guided around the viscera to the pubic-spinal juncture where the trochar was pushed through the skin and out the dorsum of the bird. The antenna then was sterilely removed from the trochar by manipulating it through the clear drape, and the trochar was removed. The PTT then was inserted into the celomic cavity along the right side of the body wall.

The incision in the body wall was closed with 4-0 polydioxanone suture (PDS; Ethicon, Somerville, NJ USA) using a simple continuous pattern. The skin was closed with a 4-0 PDS using a simple continuous pattern. A single interrupted suture (4-0 PDS) was passed through the skin and the Dacron® collar at the base of the antennae to anchor the PTT.

Once the procedure was completed, the isoflurane was turned off and females were recovered on 1 liter/minute oxygen. Once birds had regained their righting reflex and had been extubated, they were held in a warm quiet area for a minimum of two hours before being released at the capture location.

During winter 2007-2008, surgeries were performed by Mark Mitchell D.V.M. (n=8) and David Guzman D.V.M. (n=6). During winter 2008-2009, I performed all surgeries (n=46), after training by Mark Mitchell D.V.M. and Jim Lacour D.V.M.

Tracking

PTTs were programmed to run on a continuous duty cycle of 6 hours "on" and 32 hours "off". This duty cycle allowed for 4-6 transmissions per week and produced a theoretical transmitter life of approximately 7 months (Microwave Telemetry, Inc., Columbia, MD, USA). Transmission periods varied by time of day to allow collection of nocturnal and diurnal locations.

Service Argos delineates each location into location classes (LC) which serve as an index of accuracy. Locations fall into two broad categories: 1) standard and 2) auxiliary. Standard class locations (3, 2, 1) have an estimated 1-sigma error radius of 250, 500, and 1500m, respectively (Argos User Manual accessed online 15 October 2009). Auxiliary locations (0, A, B, Z) have highly variable locational accuracy and are not assigned an error radius by Service Argos. Initial data processing was preformed by Argos, and data subequently were sent to me in daily e-mails in both DIAG and DS format. I stored all data on my computer hard drive and backed-up data daily on an external hard drive. I also used an online Satellite Tracking and Analysis Tool for additional data back-up and easier day-to-day monitoring (Coyne and Godly 2005).

Locational Accuracy Validation

I checked the accuracy of all locations with the Douglas Argos-Filter Algorithm V7.03 (Douglas 2006). The Douglas Argos-Filter assesses the plausibility of every Argos location using two methodologies based on: 1) distance between consecutive locations; and 2) rates and bearings among consecutive movement vectors, both of which can be defined by the user. I assigned the following values to the important user defined parameters: minoffh = 8, maxredun = 0.5, minrate = 30, ratecoef = 15, keep_lc = 2, rankmeth = 2, xmigrate = 2, and xoverrun = 1.5. Details on these parameters are provided in Douglas (2006:5-13). For analysis I used the best location per transmission period as determined by the Douglas Argos-Filter Algorithm.

I used the sigma-1 error term provided by Argos and the relationship of radius to chi-square distribution to calculate a 95% error ellipse around each PTT location. I determined the 95% error ellipses had a radius of 411m and 817m for class 3 and 2 locations, respectively. Using the PBS mapping package (Schnute et al. 2008) within Program R (R Development Core Team 2009), I generated 1000 random points following a bivariate normal distribution within the 95% error ellipse for each estimated PTT location to account for potential habitat misclassification as a result of triangulation error (Samuel and Kenow

1992). I included these random points with the original PTT locations and used the merged data set in my analysis of habitat and refuge uses.

Habitat Use

For this analysis, I classified habitat use locations by hunt periods for both winters as either open or closed. Locations during the open waterfowl season in southwestern Louisiana for each winter of the study were classified as open. Locations during the closed split between waterfowl hunting seasons and after the waterfowl hunting season in southwestern Louisiana were classified as closed. I classified habitat use locations occurring between one-half hour after sunset to one-half hour before sunrise as nocturnal, whereas locations occurring between one-half-hour before sunrise to one-half hour after sunset were classified as diurnal. I aged each individual female and classified them as either as hatch-year (HY) or after hatch-year (AHY).

I excluded the first 14 days post-release from my habitat use analysis to help reduce post-surgical effects on survival and behavior (Mulcahy and Esler 1999). I assumed that all birds surviving beyond the 14 day post-release censor period were healthy, and that subsequent habitat use data were not biased as a result of radio-marking.

Finally, I categorized all locations within the coastal marsh into five habitat types; 1) freshwater marsh, 2) intermediate marsh, 3) brackish marsh, 4) salt marsh, and 5) non-marsh, according to Sasser et al. (2008).

Refuge Use

For this analysis, I classified all locations on lands closed to duck hunting by statue or governmental authority during the regular duck season in southwest Louisiana as refuge and all other locations as non-refuge. I divided each winter into hunted or non-hunted time periods as described earlier. I also categorized time of day as previously described. Finally, I excluded the first 14 days post-release from refuge use analysis as previously described (Mulcahy and Esler 1999). I aged each individual female and classified them as either as hatch-year (HY) or after hatch-year (AHY).

Statistical Analysis

Habitat Use

I estimated compositional use of each female in every habitat, during each hunt period (open or closed), for each time of day (diurnal or nocturnal). I then replaced zero values with 0.000031 (an order of magnitude smaller than the lowest nonzero habitat use recorded for any bird in either hunt period [Aebischer et al. 1993a]). To remove the unit sum constraint (Aitchison 1986), I constructed 4 log-ratios by dividing the proportional use of freshwater marsh, intermediate marsh, brackish marsh, and salt marsh by the proportional use of non-marsh, and used napierian logarithms of these ratios as response variables in analysis.

I then used the transformed proportional habitat use data in a split-plot MANOVA (PROC GLM, SAS Institute 2009)) to evaluate the effects of individual females, female age, winter, hunt periods within winter, time of day, and all possible interactions among these explanatory variables on compositional habitat use (Aebischer et al. 1993a). I used variation due to individual female as the error term to test for effects of female age, winter, and their interaction, and residual error to test for effects of individual female, hunt period, time of day, and all other interactions.

I began with a full model and used backward, step-wise procedures to eliminate non-significant ($P > 0.05$) terms, beginning with highest order interactions. Once the final model was determined, I compared use of habitats relative to non-marsh by testing whether least-square means of log-ratios differed ($P < 0.05$) from zero (Aebischer et al. 1993b) as described by Cox and Afton (1997). I used orthogonal contrasts to compare use of each habitat relative to non-marsh for all possible combinations of explanatory variables after the MANOVA indicated a significant interaction (SAS Institute 2009).

Refuge Use

I estimated compositional refuge use by constructing 2 log-ratios by dividing the proportional use of non-refuge by proportional use of refuge, and used napierian logarithms of these ratios as response variables in my analysis. I replaced zero values with 0.001961 (an order of magnitude smaller than the lowest nonzero refuge use recorded for any bird in either hunt period [Aebischer et al. 1993a]). I used a mixed model ANOVA (PROC MIXED; SAS Institute 2009) to evaluate the effects of individual females, female age, winter, hunt period within winter, time of day, and all possible interactions of these explanatory variables on refuge use (Aebischer et al. 1993a). I used the residual error of individual females to test for main effects and all interaction among the explanatory variables. I began with a full model and used backward, step-wise procedures to eliminate non-significant ($P > 0.05$) terms, beginning with highest order interactions. Once the final model was determined, I compared use of areas among levels of significant effects using least squares means (Aebischer et al. 1993b).

Results

During two winters (2007-08, 2008-09), I estimated habitat and refuge uses of 41 marked females along the Louisiana Gulf Coast. I have presented the distribution of the original locations across hunt periods and time of day in Appendix A.

Habitat Use

I found a significant interaction among hunt periods and winters (hunt period × winter interaction; Wilks' $\lambda = 0.809$; $F_{4, 107} = 6.27$; $P = 0.0001$) and significant individual female effect (Wilks' $\lambda = 0.009$; $F_{156, 429} = 6.29$; $P < 0.001$). I failed to detect significant effects of any other interaction or time of day and age ($P \geq 0.08$ for all tests).

Use of intermediate marsh was approximately 45% greater during the open waterfowl hunting season in winter 2007-08 than in the open and closed waterfowl hunting seasons during winter 2008-09 (Figure 2.3). Use of freshwater marsh was 52% and 37% greater during the 2008-09 open and closed waterfowl hunting seasons, respectively, than during the open and closed waterfowl hunting seasons during winter 2007-08, respectively (Figure 2.3). During winter 2007-08, overall habitat use was dominated by intermediate marsh (53%) and non-marsh (23%) was the next most used habitat. During winter 2008-09, the two most used habitats were freshwater marsh (48%) and intermediate marsh (31%), which had relatively similar usage.

Refuge Use

I found significant interactions among hunt periods and winters (hunt period × winter interaction; $F_{1, 109} = 14.78$; $P = 0.0002$), and among female ages and hunt periods (age × hunt period interaction; $F_{1, 109} = 7.84$; $P = 0.0061$). I failed to detect significant effects of other interactions or time of day ($P \geq 0.10$ for all tests).

AHY females used refuge more during open waterfowl hunting season (42%) than during closed waterfowl hunting season (29%). In contrast, refuge use by HY females did not vary between open and closed waterfowl hunting seasons (Figure 2.4).

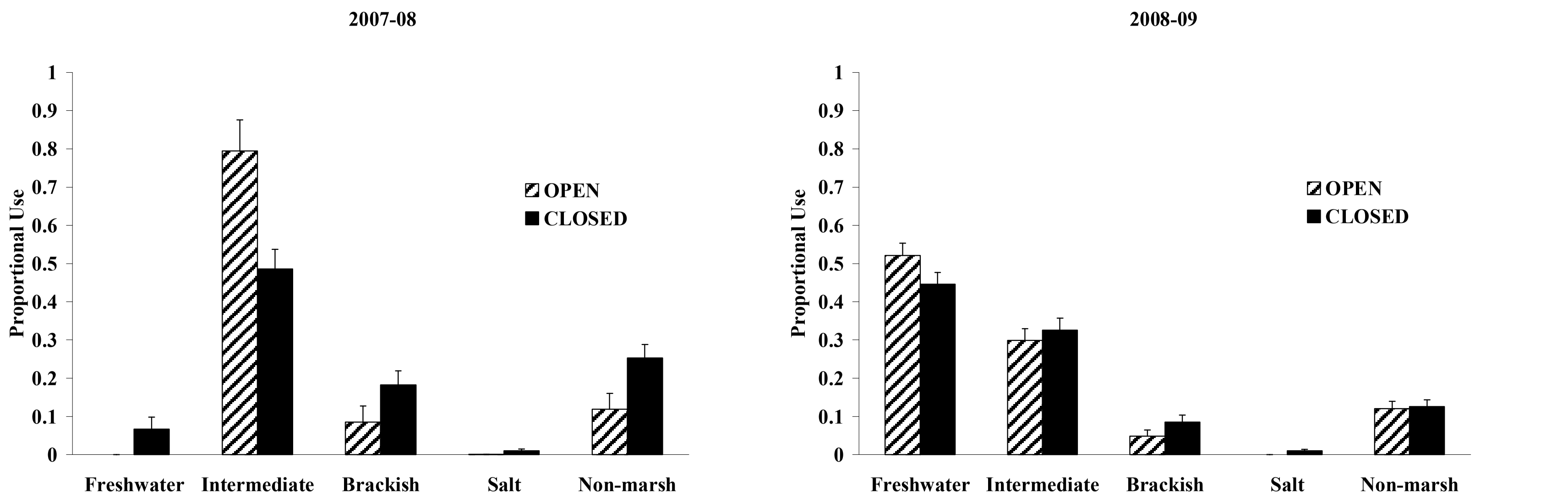

Figure 2.3 Proportional use of habitats by PTT marked female gadwall (2007-08, n=9 females; 2008-09, n=32 females) during hunted (open) and non-hunted (closed) time periods in southwest Louisiana during winters 2007-08 and 2008-09, respectively.

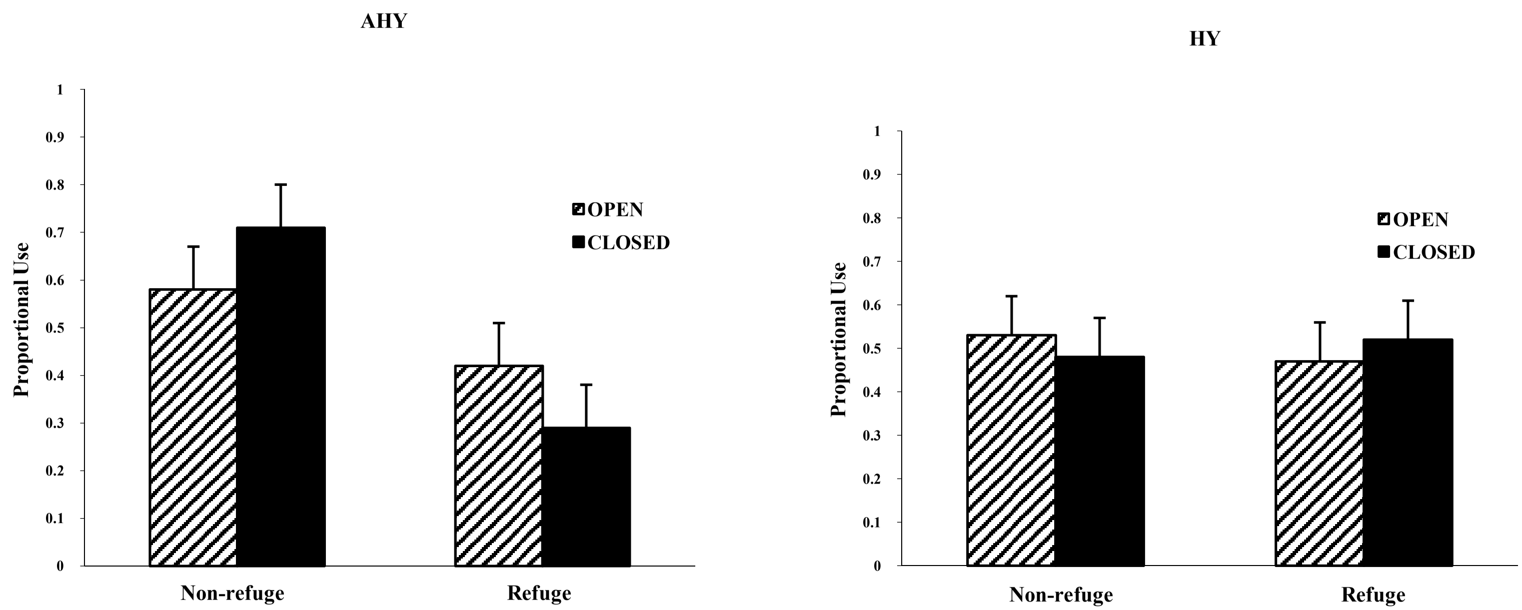

Figure 2.4 Proportional use of refuge and non-refuge areas by female age (AHY=after hatch-year, n=28 females; HY=hatch-year, n=13 females) for PTT marked gadwall during hunted (open) and non-hunted (closed) time periods in southwest Louisiana for winters 2007-08 and 2008-09 combined.

During winter 2007-08, refuge use was greater during open waterfowl hunting season (64%) than during the closed waterfowl hunting season (34%). In contrast, refuge use during winter 2008-09 did not vary between open or closed waterfowl hunting season (Figure 2.5). Time of day had no effect on the use of refuge or non-refuge areas (P= 0.4342).

Discussion

Habitat Use

My habitat use estimates may have been confounded by capture location, habitat alteration due to the hurricane storm surge, and the interaction of capture location and hurricane induced habitat alteration. In mid-September 2008, one month prior to capturing gadwall tracked in winter 2008-09, Hurricane Ike produced a large storm surge that inundated the coastal marsh zone in southwest Louisiana. This caused increased marsh salinity and killed submerged aquatic vegetation within most of the intermediate marsh in southwest Louisiana (J. Gray, personal observation.). The affected area included Rockefeller State Wildlife Refuge, where all gadwall tracked during winter 2007-08 had been captured. Such habitat alteration possibly influenced the distribution of gadwall upon arrival to the Louisiana GCCP coastal marsh and ultimately dictated where I could capture female gadwall.

Annual surveys by the Louisiana Department of Wildlife and Fisheries indicated fewer gadwall were using Rockefeller State Wildlife Refuge in winter 2008-09 than in winter 2007-08 (Table 2.1). This decrease in the number of gadwall using Rockefeller Refuge coincided with an increase in the number of gadwall counted on White Lake Conservation Area in winter 2008-09 (Table 2.1). White Lake Conservation Area is

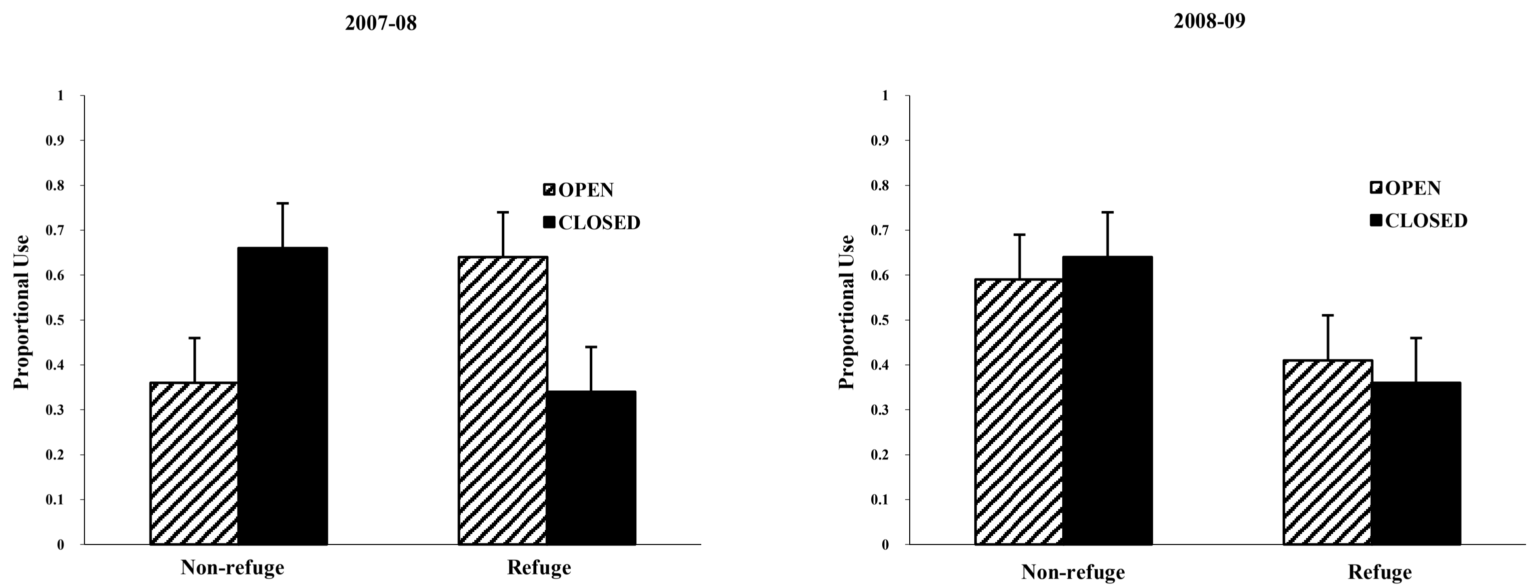

Figure 2.5 Proportional use of refuge and non-refuge areas by PTT marked female gadwall during hunted (open) and non-hunted (closed) time periods in southwest Louisiana during winters of 2007-08 and 2008-09, respectively.

Table 2.1 Number of gadwall counted before the waterfowl hunting season (Pre-season) and between the waterfowl hunting seasons (Split) on two state owned areas within the Louisiana Gulf Coast Chenier Plain during winters 2007-08 and 2008-09. Rockefeller State Wildlife Refuge is in the intermediate marsh zone and is closed to hunting. White Lake Conservation Area is in the freshwater marsh zone and includes some areas open to hunting.

	2007-08		2008-09	
Survey	Rockefeller State Wildlife Refuge	White Lake Conservation Area	Rockefeller State Wildlife Refuge	White Lake Conservation Area
Pre-season[b]	116,852	5,358	55,160	560
Split[c]	51,441	3,080	10,577	30,500

[a] Annual survey data from the Louisiana Department of Wildlife and Fisheries (L. Reynolds, LDWF; unpublished data).

[b] Pre-season survey dates were November 7, 2007 and November 6, 2008.

[c] Split survey dates were December 8, 2007 and December 8, 2008.

freshwater marsh and was unaffected by the hurricane storm surge. Although PTTs were not evenly deployed across marsh types (see below), the distribution of PTT deployment may have reflected the distribution of wintering gadwall across marsh types during winter 2008-09.

Interestingly, all gadwall tracked during winter 2007-08 were captured in intermediate marsh, and intermediate marsh accounted for the highest use that winter. In 2008-09, I captured 40 of 46 gadwall in freshwater marsh, yet use of intermediate marsh was still comparable to use of freshwater marsh in that winter. Therefore, I conclude that intermediate marsh is an important habitat for wintering female gadwall in coastal Louisiana, and that freshwater marsh may become increasingly important when salinities in intermediate marsh increase after tidal surge events.

Unlike northern pintails (*Anas acuta* hereafter pintails; Cox and Afton 1997) and mallards (*Anas platyrhynchos* Link 2007) within the Gulf Coast Chenier Plain, I found no evidence that habitat use of female gadwall differed between diurnal and nocturnal time periods. Female mallards and pintails were using marsh or managed refuge habitats during diurnal periods and switched to habitats outside of the costal marsh zone (i.e. rice and idle agricultural fields) during nocturnal periods. Mallards and pintails forage on food items that are high in nutritional value such as seeds and tubers (Checkett et al. 2002, Hoffman and Bookhout 1985). Conversely, gadwall feed almost exclusively on submerged aquatic vegetation and algae which are low in nutritional value when compared to other waterfowl foods (Paulus 1984). Accordingly, gadwall must spend more time foraging than do mallards and pintails (Paulus 1984). Paulus (1984) documented that gadwall rarely left foraging areas during day or night except when disturbed and after closure of hunting season, which allowed increased access to the most suitable habitats. I speculate that gadwall forage in areas of low disturbance, such as refuges and other areas, where they can forage undisturbed throughout the day. However, as habitat quality in undisturbed areas decreases (i.e., food resources decrease), gadwall may move in search of more optimal foraging habitats within the marsh during nocturnal periods that otherwise would be unavailable to them during diurnal times because of disturbance. Gadwall may move to more optimal foraging areas within the same habitat type during nocturnal periods, which would not be detectable in my habitat use analysis.

Refuge Use

My estimates of refuge use could be biased high if birds marked on refuge areas tend to use refuge areas more so than do those marked on non-refuge areas (Blohm et al. 1987). I found that AHY females used refuge areas significantly more during the open hunting season than during the closed season. However, unlike pintails and mallards, I did not detect differential use of refuge and non-refuge areas between diurnal and nocturnal periods. I speculate that these species differences are related to foraging ecology. Time budget studies have shown that gadwall spend more time foraging than do mallards and pintails (Jorde et al. 1984, Miller 1985, Paulus 1984, Rave and Cordes 1993). Therefore, because mallards and pintails spend significantly less time foraging they may be to utilize refuge areas for sanctuary and loafing sites before moving off the refuges to forage at night. Cox and Afton (1997) and Link (2007) documented differential refuge use between diurnal and nocturnal periods by pintails and mallards, respectively. Conversely, gadwall spend all of their time in foraging habitats (Paulus 1984). My results indicate gadwall use refuge areas similarly between diurnal and nocturnal periods. These results coupled with gadwall time activity budgets from the Louisiana GCCP (Paulus 1984) lead me to believe that gadwall are unable to utilize refuge areas for sanctuary only and refuge use by gadwall may be limited by forage availability.

Management Implications

Female gadwall primarily used intermediate and freshwater marshes during my study. During winter 2008-09, Hurricane Ike drastically altered the salinity within the coastal marsh zone. Use of other coastal marsh types and all other habitats remained relatively low during both winters. Thus, I conclude that preserving the current salinity gradient within the coastal marsh zone is important for wintering gadwall. Maintaining the hydrologic integrity of the freshwater inputs to the Louisiana GCCP (i.e., the Mermentau, Calcasieu, and Sabine Rivers along with associated watersheds) and other conservation practices that address saltwater intrusion within the coastal marsh zone may benefit wintering gadwall and other species of waterbirds that winter within the Louisiana GCCP by providing quality foraging habitats. Managers also may want to consider the importance of providing alternative quality wintering habitat after tidal surge events and possibly implement conservation practices and marsh management in areas less likely to be influenced by hurricane storm surge.

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CHAPTER 3. WINTER MOVEMENTS OF FEMALE GADWALLS WITHIN THE GULF COAST CHENIER PLAIN.

Movements and spatial distribution of individual ducks within or among regions during winter is poorly understood (Cox and Afton 2000). Understanding waterfowl movements and factors influencing them are crucial components for the effective management of winter habitats (Cox et al. 1998). Wintering waterfowl may increase flight distance from concentration areas over time as nearby food resources are depleted, as predicted by refuging theory (Hamilton and Watt 1970, Cox and Afton 1996). Additionally, waterfowl habitats differ in the quantity of energy per unit area produced and in the number of waterfowl that can be supported (Fredrickson and Taylor 1982, Miller 1987).

Movements of some dabbling duck species (Northern Pintails *Anas acuta;* Mallards *Anas platyrhynchos*) along the Louisiana Gulf Coast Chenier Plain (GCCP) are affected by hunting pressure (Cox and Afton 2000), time of day, and age (Cox and Afton 1996, Link 2007). These species exhibit distinct movements between areas utilized during diurnal and nocturnal time periods. Pintails also make large inter-regional movements during winter, often leaving the Gulf Coast and moving to more northerly areas in response to weather events or hunting pressure (Cox and Afton 2000). Based on observational data collected in southwestern Louisiana, Paulus (1984) suggested that hunting pressure forced gadwall to leave optimal foraging habitat, whereas those in non-hunted areas rarely left optimal foraging habitat during day or night.

Body condition affects survival (Bergan and Smith 1993), initiation of prebasic molt (Duggar 1997, Heitmeyer 1988), and nest initiation (Devries et al. 2008, Reynolds

1972) in waterfowl. Therefore, I tested for potential effects of body condition at time of capture on movement distances.

Anecdotal observations of waterfowl suggest that winter distributions of gadwall may have changed recently. Considerable speculation exists concerning movements of gadwall among coastal marshes and more inland habitat types such as seasonally flooded agricultural areas (i.e. rice fields) and forested wetlands (Gulf Coast Joint Venture, unpublished report).

Understanding intra- and inter-regional movements would be helpful to conservation planners, habitat managers, and waterfowl hunters. Information involving large-scale movements (hereafter inter-regional movements) would help ensure conservation and management practices are being implemented at appropriate spatial scales to provide adequate habitat for wintering waterfowl. Quantitative information concerning movements of females within the coastal marsh zone (hereafter; intra-regional movements) would help Gulf Coast waterfowl managers better understand the potential effects of hunting season on gadwall movements, and how gadwall move between refuge and non-refuge areas.

I used satellite telemetry to document the frequency of mid-winter inter-regional movements to areas outside the coastal marsh zone by female gadwall, after their arrival on the Gulf Coast. I also evaluated the potential effects of hunting season, refuge use, female age, winter, and body condition at time of capture on intra-regional movements within the coastal marsh zone.

Study Area

My study area included the coastal marsh zone within the GCCP of southwestern Louisiana (Figure 3.1), but ultimately was dictated as the area containing wintering locations from PPT marked female gadwalls. The GCCP is a series of beach ridges and mud flats formed by westward drift of river sediments which later became marsh (Day et al. 2000). The GCCP ecosystem extends along 322 km of coastline from Vermillion Bay, Louisiana to East Bay, Texas and extends inland from the Gulf of Mexico for distances ranging from 60 to 110 km encompassing more than 2.5 million ha (Chabreck et al. 1989). See Chapter 2, page 13 for a study area map.

Methods

Trapping, Marking, and Tracking

I previously described trapping, marking, and tracking in Chapter 2.

Movements

Inter-regional.— I classified inter-regional movements as movements to regions ≥20 km outside of the coastal marsh zone, as defined by Sasser at al. (2008), which occurred prior to migratory departure date. I defined migratory departure date for each individual female as the median date between the last location within the coastal marsh zone and the first location >40 km north of the coastal marsh zone after 1 January of each year. I defined departure date for females outside the coastal marsh zone on 1 January as the first movement of > 40 km after 1 January.

Locations during the open waterfowl season in southwestern Louisiana for each winter of the study were classified as open; all other locations were classified as closed.

I excluded the first 14 days post-release from analysis to help reduce post-surgical affects on survival and behavior (Mulcahy and Esler 1999). I assumed that all birds surviving beyond the 14 day post-release censor period were healthy and their subsequent movements were not biased.

Intra-regional.— I evaluated the effects of individual female, hunt period, refuge use, winter, body condition, and female age on intra-regional movements of marked females. I classified intra-regional movements as movements that occurred within the coastal marsh zone, as defined by Sasser et al. (2008), prior to migratory departure date. I defined migratory departure date as previously described. I calculated movement distances with the Douglas Argos-Filter Algorithm V7.03 (Douglas 2006) between paired locations from consecutive transmission periods. I analyzed movement distances as a response to refuge classification and hunt period at location from where the movement originated (i.e. starting location). I classified hunt periods for both winters as previously described. I classified all locations on lands closed to duck hunting by statue or governmental authority during the regular duck season in southwest Louisiana as refuge and all other locations as non-refuge. Finally, I adjusted female body mass for size as a measure of condition for each individual as described by Alisauskas and Ankney (1987).

Statistical Analysis

Locational Accuracy Validation

I checked the accuracy of all locations with the Douglas Argos-Filter Algorithm V7.03 (Douglas 2006). The Douglas Filter assesses the plausibility of every Argos location using two methodologies based on: 1) distance between consecutive locations;

and 2) rates and bearings among consecutive movement vectors, both of which can be defined by the user.

I assigned the following values to the important user defined parameters: minoffh = 8, maxredun = 0.5, minrate = 30, ratecoef = 15, keep_lc = 2, rankmeth = 2, xmigrate = 2, and xoverrun = 1.5. Details on these parameters are provided in Douglas (2006: 5-13). For analysis I used the best location per transmission period as determined by the Douglas Argos-Filter Algorithm.

Movements

I did not statistically analyze inter-regional movements because only one inter-regional movement was documented during the two winters of study. To analyze intra-regional movements, I used mixed models (PROC MIXED, SAS Institute 2009) to examine the effects of individual females, hunt period, refuge use, winter, body condition at time of capture, and female age on intra-regional movement distances. I used the residual error of individual females to test for main effects and all interaction among the explanatory variables. I calculated the mean distance moved for each bird within each year, hunt period and refuge use category and used these distances as a response variable in my mixed model. I tested the symmetry of the data and determined first-order autoregressive was the best fit and defined symmetry in the full model. I began with a full model and used backward, step-wise procedures to eliminate non-significant ($P > 0.05$) terms, beginning with highest order interactions.

Results

During the 2 winters of study, I collected movements data on 41 marked females (2007-08 AHY=2, HY=6; 2008-09 AHY=26, HY=7). Gadwall capture dates ranged from

12 December 2007 – 9 January 2008 and 25 October 2008 – 17 December 2008 during winters 2007-2008 and 2008-2009, respectively.

Inter-regional movements.— During the two winters, 1 HY female made an inter-regional movement from the coastal marsh zone to freshwater wetlands near Jonesville, LA. The female left the coastal marsh zone on 19 December 2008, 34 days after her capture at Cameron Prairie National Wildlife Refuge. The female remained near Jonesville, LA for 79 days, during which she spent time on the north end of Catahoula Lake and in the flooded agricultural fields of Delta Plantation and the surrounding area.

Intra-regional movements.— I performed this analysis on 1739 intra-regional movements of 41 marked females. My final mixed model showed no effects of individual female, hunt period, winter, refuge use or body condition on intra-regional movement distances ($P > 0.09$ for all tests). I found the mean inter-regional movement distance to be just under 4 km ($\bar{X} = 3.77$ km; Median 2.77 km; SE= 1.21) with a range from 0 to 125 km.

Discussion

Inter-regional movements.— During the two winters studied, only one female made a pre-migratory inter-regional movement to an area outside of the coastal marsh zone. Gadwall typically arrive on the Louisiana GCCP in late-October to mid-November. Most PTT marked females were captured >2 weeks after first arrival of gadwall to my trapping sites. Thus, some gadwall may have arrived on the Gulf Coast, stayed for a short period and then made an inter-regional movement and thus could not be captured. However, Cox and Afton (2000) documented pintails making inter-regional movements during mid-winter. I had several females marked before and during mid-winter and only observed one inter-regional movement. Pintails moved in response to weather and concomitant changes in habitat availability (Cox and Afton 2000). Because gadwall predominantly forage on submerged aquatic vegetation in permanent wetland habitats, gadwall would not be expected to make inter-regional movements in response to the same proximal cues as do pintails.

Intra-regional movements.— My findings indicate that wintering gadwall do not make frequent long distance movements within the coastal marsh zone and that most winter movements are $\leq$5 km. However, my data may be biased by 1) the potential effects of implant transmitters on female movements, 2) triangulation error on calculated movement distances, and 3) movements measured during a period of >24 hours. Alternately, gadwall may be able to fulfill daily requirements within a relatively small area because of the continuity within preferred coastal marsh habitats found in the Louisiana GCCP.

My PTT duty cycle was programmed for a 32 hour "off" period followed by a 6 hour "on" period. To more accurately track small scale intra-regional movements, more frequent tracking such as a minimum of two locations within 24 hours would have been optimal. Paired locations from diurnal and nocturnal periods have been used to analyze flight distances in response to diurnal and nocturnal time periods (Cox and Afton 1996, Davis 2007, Link 2007). Time of day has a significant effect on waterfowl movements in some species (Cox and Afton 1996, Davis 2007, Link 2007). Unfortunately, I was unable to test for the effects of diurnal and nocturnal time periods on movement distances, because the duty cycle of my PTTs overlapped both nocturnal and diurnal periods between locations.

Satellite telemetry provides useful information concerning large-scale movements (>50 km) and migration (Miller et al. 2005, Phillips et al. 2006, Oppel et al. 2008). Although satellite telemetry is well suited for tracking large-scale movements (>50 km), with an appropriate duty cycle, it does suffer from a lack of precision (Keating et al. 1991). Therefore, locational accuracy should be an important consideration, when studying small-scale animal movements (Hayes et al. 2001). Therefore, if additional research to ascertain more detailed information about inter-regional movements is undertaken, I recommend researchers consider the use of GPS or VHF transmitters that produce ≥2 accurate (>200 m) locations per 24 hour period.

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CHAPTER 4. SPRING MIGRATION CHRONOLOGY, CORRIDORS, AND INFERRED BREEDING LOCATIONS OF FEMALE GADWALLS THAT WINTERED WITHIN THE COASTAL MARSH ZONE OF THE LOUISIANA CHENIER PLAIN.

Most species of North American waterfowl are highly migratory, breeding in temperate to sub-arctic regions and wintering from the southern half of the United States to the tropics. Waterfowl migration generally occurs along a series of narrow intermingled corridors (Bellrose 1980). Migration is energetically demanding; therefore, migrating birds must find suitable habitats for resting and refueling along migration corridors (Moore et al. 1990). For many years, migration habitat was thought to have a nominal effect on waterfowl populations (Reinecke et al. 1989). However, a better understanding of the interdependence of waterfowl requirements throughout the annual cycle has led to increased conservation efforts along major migratory pathways (Reinecke et al. 1989).

We have little understanding of the proximate factors that influence spring migration chronology in waterfowl (Dugger 1997). The Staggered Event Hypothesis (SEH) predicts that the relative timing of life-history events within the annual cycle is dependant on physiological condition (Dugger 1997; modified from Heitmeyer 1988, Lovvorn and Barzen 1988). Based on the progression of winter life history events in most waterfowl (endogenous lipid storage > pair formation > initiation of prebasic molt > pre-migration lipid storage; Heitmeyer 1988) the SEH provides testable predictions about how female age, body condition and concomitant molt status may affect spring migration chronology. Under the SEH, females in better physiological condition are predicted to migrate earlier. In many species, after hatch-year (AHY) females should out compete hatch-year (HY) females for limited resources (Heitmeyer 1988, Paulus 1984), and migrate earlier than do HY females (Dugger 1997).

During fall migration, North American gadwall (*Anas strepera*) follow migratory corridors through the Great Plains (Dakotas, Nebraska, Kansas, and Okalahoma) and the Mississippi Alluvial Valley (Louisiana, Mississippi, Arkansas, Missouri), which leads to the Gulf Coasts of Louisiana and Texas (Bellrose 1980). Observational data during spring, indicates that gadwall numbers along the Gulf Coast begin decreasing in late-February with the greatest decline in March and most birds departing by April (Bellrose 1980, Leschack et al. 1997). However, spring migration routes do not necessarily retrace autumn routes (Bellrose 1980, Wege and Raveling 1983, Ely et al. 1997).

Information regarding gadwall migration corridors and stopovers has been based on observations of unmarked birds. This information has been useful in determining important stopover areas and provides general information about migratory corridors. However, descriptions of migratory pathways and stopovers based on observational data are limited because departure dates, migratory flight distances, stopover duration, number of stopovers, total migratory distances, and arrival dates of known individuals can not be estimated. Furthermore, the wintering and breeding area affiliation of unmarked waterfowl cannot be determined.

I used satellite telemetry to describe migratory corridors and estimate departure date, migratory flight distances, stopover duration, number of stopovers, total migratory distance, arrival date to breeding areas, and inferred breeding locations of individual females that wintered along the Louisiana Gulf Coast. Information about gadwall departure dates from the Louisiana Gulf Coast would help managers better estimate duck use days to incorporate into habitat management plans. Information describing spring migration routes and chronology of gadwall would ensure current conservation and management strategies are implemented at appropriate spatial and temporal scales to provide maximum benefit to migrating waterfowl. Also, information regarding breeding area affiliation among gadwall that winter along the Gulf Coast is of interest to waterfowl managers.

Study Area

My general study area was comprised a large portion of the mid-continent region of North America and ultimately was determined as the area containing all locations obtained from satellite transmitter (hereafter PTT) marked females during spring migration. This region included the Louisiana Gulf Coast, Mississippi Alluvial Valley and the Great Plains.

The Louisiana Gulf Coast is comprised of the Chenier and Deltaic Plains. The Chenier Plain is located in southwestern Louisiana and is a mosaic of beach ridges and marsh which was formed by river sediments discharged into the Gulf of Mexico and carried westward by currents (Day et. al 2000). The Deltaic Plain is in southeastern Louisiana and comprises three fourths of Louisiana's coastal region. The coastal marsh is comprised of four distinct marsh types; salt, brackish, intermediate, and fresh (Chabreck et al. 1989, Sasser et al. 2008).

The Mississippi Alluvial Valley (MAV) is >800km long and ranges from 32-128km in width comprising approximately 10 million ha (Reinecke et al. 1989). The MAV is comprised of seasonally flooded hardwood bottomlands with managed moist soil wetlands and other riverine influenced wetlands.

The Northern Great Plains are comprised of three major wetland regions: 1) Prairie Pothole Region, extends from south central Canada into the north central U.S. covering 777,000km^2, 2) Nebraska Sandhills Region, located in north central Nebraska covering 51,000 km^2 , and 3) Rainwater Basin Region, located in south central Nebraska covering 6,720 km^2 (Pederson et al. 1989). There are several major reservoirs and other wetland habitats associated with the Platte and Missouri Rivers that provide important waterfowl habitat within the Northern Great Plains.

Methods

Trapping, Marking, and Tracking

I previously described trapping, marking, and tracking in Chapter 2.

Migration Parameters

I examined variation in seven migratory parameters: 1) departure date, 2) migratory flight distances, 3) number of stopovers, 4) stopover duration, 5) total migratory distance, 6) arrival date, and 7) migration duration of PTT marked female. These parameters comprised my response variables and were analyzed in relation to size adjusted body mass (hereafter condition) at time of capture, spring of tracking, and female age. I determined female age as hatch-year (HY) and after hatch-year (AHY) based on wing plumage characteristics (Carney 1964). I included all females, with active PTTs, that departed the Louisiana coastal marsh zone or other wintering area in my analysis of departure date. I included only females that had been monitored throughout the entire spring migration in my analyses of migratory parameters.

I estimated body condition at time of capture for each PTT marked female by adjusting body mass for size as described by Alisauskas and Ankney (1987). I defined wintering area as the coastal marsh zone described by Sasser et al. (2008) or, if outside the coastal marsh zone, the wintering area was the location of the female on 1 January of each year. I defined departure dates for each individual female as the median date between the first location >30 km north of the wintering area. Once a female had departed the wintering area, stopovers were defined as an area where a female stopped during migration between movements ≥40 km from the previous location. I defined stopover duration as the number of days between the median date of arrival and median date of departure at each stopover location during migration.

Migratory flight distances were calculated using the Douglas Argos-Filter Algorithm V7.03 (Douglas 2006) as the distance between the last location at the previous stopover and the first location at the next stopover. The total migration distance was the sum of the distances between stopovers; smaller movements (≤40 km) of gadwall while at stopover locations were not included in the total migration distance.

I estimated migration duration as the number of days between the estimated departure date and the estimated arrival date. I estimated arrival as the date in which the female arrived and stayed continuously at the inferred breeding location. Inferred breeding location was estimated as the location of a female within ±2 days of the overall mean nest initiation date for gadwalls (8 June) as reported in Hines and Mitchell (1983).

Statistical Analysis

Locational Accuracy Validation

I checked locational accuracy of all locations with the Douglas Argos-Filter Algorithm V7.03 (Douglas 2006). The Douglas Filter assesses the plausibility of every Argos location using two methodologies based on: 1) distance between consecutive locations; and 2) rates and bearings among consecutive movement vectors both of which can be defined by the user.

The following are the values I assigned to the important user defined parameters; minoffh = 8, maxredun = 30, minrate = 70, ratecoef = 15, keep_lc = 1, rankmeth = 2, xmigrate = 2, and xoverrun = 1.5. Details on these parameters are provided in Douglas (2006:5-13). For analysis, I used the best location per transmission period as determined by the Douglas Argos-Filter Algorithm.

<u>Migration</u>

Migratory corridors.— I documented and plotted the migratory corridors used by PTT-marked females. I only present complete migratory corridors used by females with PTTs which remained active throughout the duration of migration. This not only allowed for description of corridors used but also provided information on specific migratory parameters.

Departure date, number of stopovers, total migratory distance, arrival date, and migration duration.— I used a MANOVA (PROC GLM, SAS Institute 2009) to evaluate effects of spring of tracking, female age, and condition on departure date, number of stopovers, total migratory distance, arrival date, and migration duration. I used residual error individual females to test for main effects and all interactions among the explanatory variables. I began with a full model and used backward, step-wise procedures to eliminate non-significant ($P > 0.10$) terms, beginning with highest order interactions.

Migratory flights and stopover duration.— I used mixed models (PROC MIXED, SAS Institute 2009) with the symmetry of best fit to evaluate the effects of female age and condition on migratory flight distance and stopover duration. I used the residual error of individual females to test for main effects and all interaction among the explanatory variables. I tested the symmetry of the data and determined first-order autoregressive was the best fit and defined symmetry in the full model. I began with a full model and used backward, step-wise procedures to eliminate non-significant ($P >$ 0.10) terms, beginning with highest order interactions.

Inferred breeding location.— I used a t-test (PROC TTEST, SAS Institute 2009) to test for significant ($P <$0.10) effects of female age on latitude of inferred breeding locations.

Results

For both springs combined, I estimated departure dates for 33 females (AHY n=24, HY n=9) and documented the complete spring migration and inferred breeding locations of 25 females (AHY n=20, HY n=5).

Migratory corridors.— Satellite tracking revealed that females wintering along the Louisiana Gulf Coast migrated north through the Lower Mississippi Alluvial Valley before passing through the Central and Northern Great Plains States and then settled in the Prairie Pothole Region within the United States and Canada (Figure 4.1). Kansas, Arkansas, Nebraska, Iowa, and Missouri were states outside of the Prairie Pothole Region (PPR) which were utilized by ≥5 females as stopover locations (Figure 4.2). Among states within the PPR, South Dakota was the most utilized with 19 of 25 females stopping there during migration (Figure 4.2). Interestingly, 3 females arrived in South Dakota in ≤48 hours and possibly could have flown there non-stop from more southerly locations. Furthermore, 10 additional marked females were located in South Dakota on their second

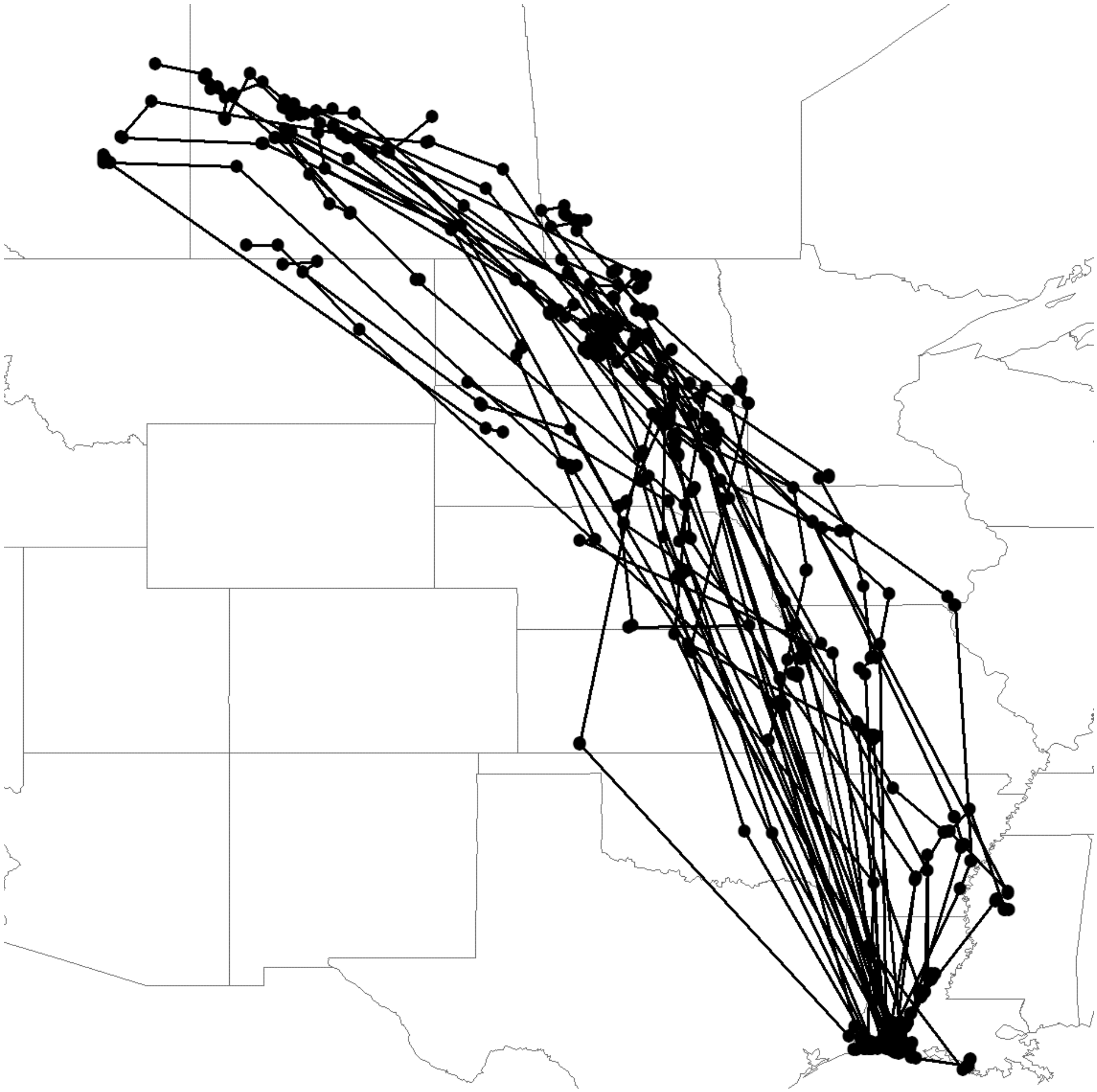

Figure 4.1 Combined 2008 and 2009 spring migration corridors of 25 female gadwalls, which were marked with PTTs within the Louisiana Gulf Coast Chenier Plain.

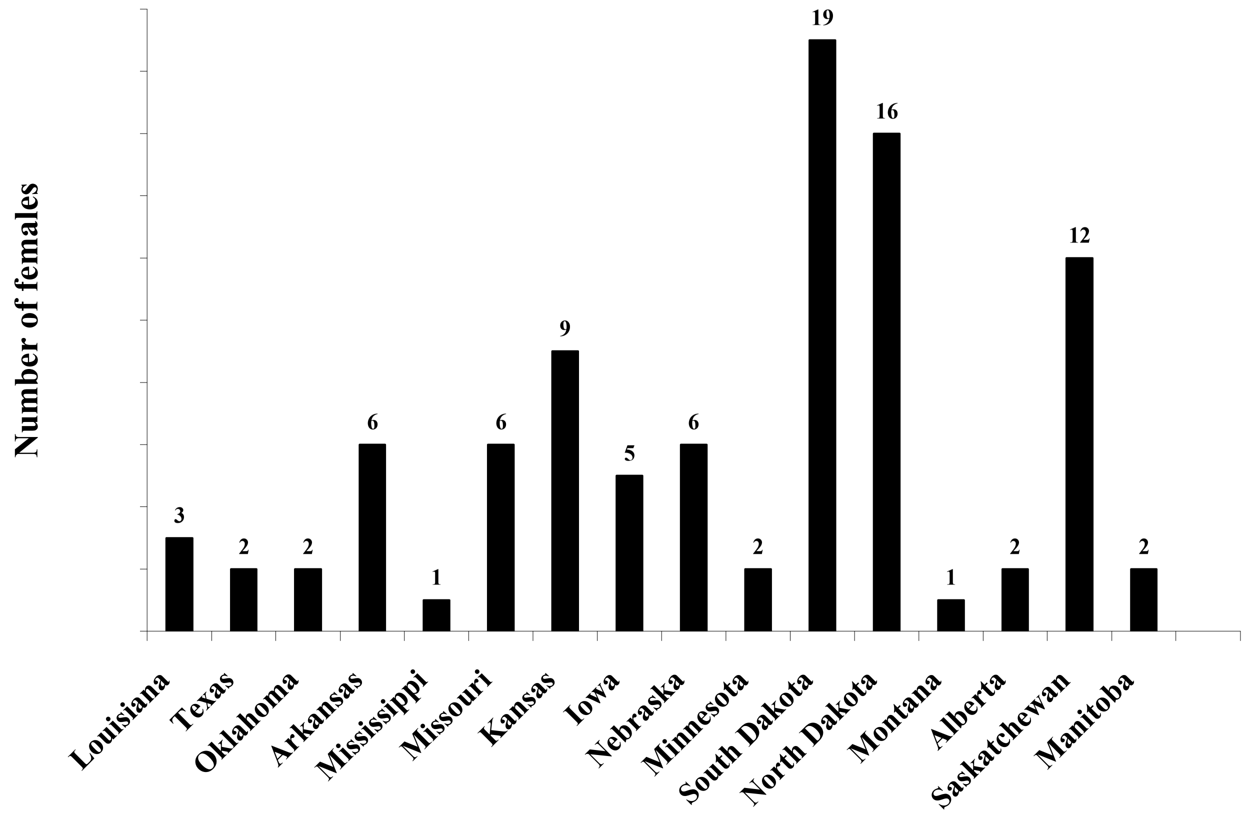

Figure 4.2 Distribution of stopover locations by state/province for 25 female gadwalls, which were marked with PTTs within the Louisiana Gulf Coast Chenier Plain, for spring migrations 2008 and 2009 combined.

stopover with the median stopover duration being 3 days. Although South Dakota was important as a migratory stopover location, only 3 females had inferred breeding locations there (Figure 4.3). North Dakota (n=10) and Saskatchewan (n=9) accounted for 76% of inferred breeding locations and also were heavily utilized for migratory stopovers as females approached their inferred breeding locations. Manitoba (n=2) and Alberta (n=1) also contained inferred breeding locations (Figure 4.3).

Departure date, number of stopovers, total migratory distance, arrival date, and migration duration.— My analysis showed no significant effects condition at time of capture, or spring of tracking, on departure date, number of stopovers, total migratory distance, arrival date, and migration duration ($P > 0.49$). I found a significant effect of female age ($P = 0.061$) on number of stopovers, total migratory distance, arrival date, and migration duration (Table 4.1), but not on departure date ($P = 0.54$; Table 4.2). HY females spent more days migrating, traveled further, used more stopovers, and arrived later at inferred breeding locations than did AHY females.

Estimated departure dates of females from the Gulf Coast Chenier Plain ranged from late-January through early-May, with peak departure during late-March (Table 4.2). After departing the Gulf Coast, females generally moved up the western edge of the Mississippi Alluvial Valley and then passed through the lower plains states, and ending up in the prairie pothole region of the United States and Canada (Figure 4.1).

Inferred breeding location.— A t-test indicated that latitude of the inferred breeding locations differed by female age. Inferred breeding locations were scattered throughout the prairie pothole region. HY females settled further north ($P = 0.096$) on the breeding grounds than did AHY females (Figure 4.2).

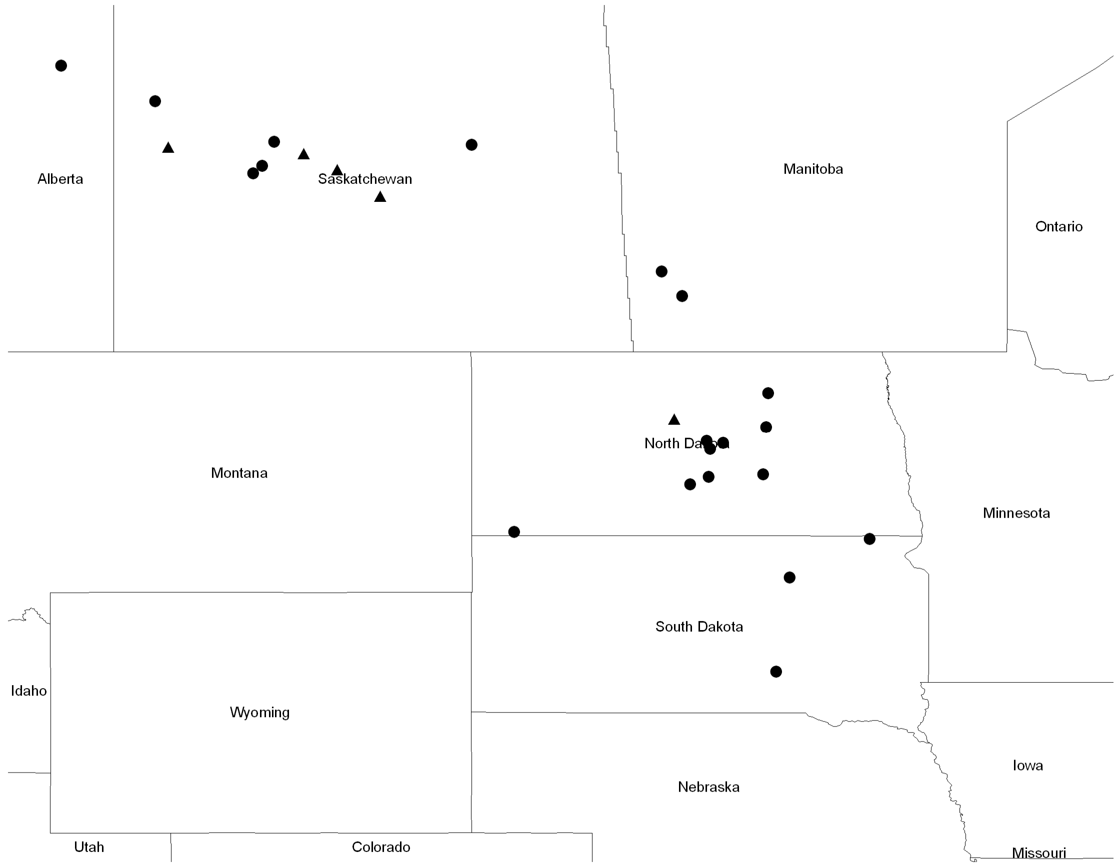

Figure 4.3 Locations of inferred breeding sites of 25 PTT marked female gadwall for springs 2008 and 2009 combined (AHY =●; HY =▲).

Table 4.1 Summary statistics for selected migration parameters by female age (AHY n=20, HY n=5) for the 2008 and 2009 spring migrations combined.

Migration Parameter	*P*	Age	Mean	Median	Std. Error
Number of stopovers	0.025	AHY	4.100	4	0.542
		HY	7.000	6	1.049
Total migratory distance (km)	0.002	AHY	2428.450	2370	101.221
		HY	3287.000	2897	303.310
Arrival date (Julian date)	0.04	AHY	136.500	136	3.027
		HY	150.800	154	3.484
Migration duration (days)	0.06	AHY	47.300	48	5.004
		HY	70.800	72	13.211

Table 4.2 Summary statistics for selected migration parameters for the 2008 and 2009 spring migrations combined.

Migration Parameter	N [a]	Mean	Median	Std. Error
Departure date (Julian date)	33	86.180	85	4.040
Migratory flight distance (km)	25	451.014	338	32.802
Stopover duration (days)	119	10.387	5	1.018

[a] Departure dates were estimated for 8 females without complete migration data, therefore, the number of females (N) was larger for departure date than migratory flight distance and stopover duration. Stopover duration was a repeated measures analysis on 119 stopovers by 25 migrating females.

Migratory flights and stopover duration.— My final mixed model showed no effects of spring of tracking, female age, or body condition on migratory flight distances ($P > 0.23$ for all tests) or stopover duration ($P > 0.27$ for all tests); however, both parameters varied among females ($P < 0.001$ for both tests). I found female gadwall traveled an average of 451 km between stopovers and spent an average of 10.4 days at a stopover location (Table 4.2).

Discussion

Interestingly, my satellite tracking revealed that females followed corridors similar to those we suspect are used during autumn based on observational data. South Dakota was the most important stopover state and was utilized by 76% of marked females. South Dakota probably is an important stopover area because it is the first area along the migratory corridor that contains a high density of permanent wetlands offering quality foraging habitat for migrating gadwall.

Estimating condition of females in early to mid-winter for use as a predictor in spring migration chronology may not be informative because the physiological condition of waterfowl is known to fluctuate during winter (Loesch et al. 1992, Reinecke et al. 1982). Changes in physiological condition resulting from changes in forage availability and the energetic demands of the prebasic molt may explain the lack of association between body condition at time of capture and migration chronology (Duggar 1997). Also, the potential effect of implanted transmitters on female gadwall physiological condition has not been quantified. I found no association of age with departure date, which is consistent with Dugger (1997).

Female gadwall have relatively high homing rates to natal breeding areas (Gates 1962, Blohm 1979, and Lokemoen et al. 1990). As did Lokemoen et al (1990), I found that arrival date at inferred breeding locations varied by age, with AHY females arriving before HY females. Lokemoen et al. (1990) also found that return rates increased significantly with age, with estimated return rates of 0.087, 0.338, and 0.667 for hatch-year, second-year, and after third-year females respectively. Furthermore, 52% of hatch-year females that subsequently returned were not initially observed until their third summer of life (Lokemoen et al. 1990). Based on my data and observations of marked females by Lokemoen et al (1990), I speculate that HY females may disperse from natal breeding areas during their first breeding season. This might explain northerly distribution and later settling dates of HY females as compared to AHY females in my study.

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CHAPTER 5. SUMMARY

I used satellite telemetry to estimate and describe female gadwall habitat use, spring migration chronology and corridors as well as inter- and intra-regional winter movements. My habitat use analysis (Chapter 2) showed that female gadwall used freshwater and intermediate marsh types substantially more so than other marsh types found within the coastal marsh zone. Also, gadwall use of freshwater marsh increased after Hurricane Ike altered the natural salinity gradient within most of the coastal marsh zone. My refuge use analysis (Chapter 2) showed that AHY females used refuges areas more during the open than the closed hunting season. However, neither habitat nor refuge use by gadwalls differed by day or night as it did for mallards and pintails wintering in the Gulf Coast Chenier Plain (GCCP; Cox and Afton 1997, Link 2007). This may be because gadwall spend the majority of the day feeding (~64%; Paulus 1984) and apparently do not have separate foraging and loafing areas as do mallards and pintails.

I conclude that preserving the current salinity gradient within the coastal marsh zone is important for wintering gadwall. Maintaining the hydrologic integrity of the freshwater inputs to the GCCP (i.e. the Mermentau, Calcasieu, and Sabine Rivers along with associated watersheds) and other conservation practices that address saltwater intrusion within the coastal marsh zone may benefit wintering gadwall and other species of waterbirds that winter within the GCCP. Managers also may want to consider the importance of providing alternative quality wintering habitat after tidal surge events and possibly implement conservation practices and marsh management in areas less likely to be influenced by hurricane storm surge.

Gadwall appear to make only localized movements (~5km) after settling within the Louisiana GCCP (Chapter 3). These localized movements are probably the result of gadwall foraging ecology and the continuity of preferred habitats within Louisiana's coastal marshes.

Satellite tracking showed gadwalls wintering in the Louisiana GCCP migrate north along the western edge of the Mississippi Alluvial Valley and then pass through the central and northern Great Plains to the prairie pothole region of the United States and Canada where they nest (Chapter 4). I found that number of stopovers, total migratory distance, arrival date, and migration duration varied by female age (P =0.061). HY females spent more days migrating, traveled further, used more stopovers, and arrived later than did AHY females. However age had no effect on the estimated departure dates of females, which ranged from late-January through early-May, with peak departure during late-March. I also found latitude of inferred breeding locations varied inconsistently by female age with inferred breeding locations of HY females being further north than AHY females (P= 0.096). I speculate that HY females may disperse from natal breeding areas during their first breeding season.

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APPENDIX

Appendix A. Number of original locations from PTT marked female gadwall by winter (2007-08, 2008-09) during OPEN and CLOSED waterfowl hunting seasons and by time of day.

PTT	WINTER	AGE	OPEN	CLOSED	DIURNAL	NOCTURNAL
36348	2007-08	AHY	16	50	33	33
36354	2007-08	AHY	11	50	32	29
36358	2007-08	AHY	1	4	1	4
36345	2007-08	HY	0	51	25	26
36349	2007-08	HY	0	18	8	10
36351	2007-08	HY	12	30	22	20
36356	2007-08	HY	1	13	8	6
36360	2007-08	HY	12	42	24	30
36685	2007-08	HY	0	51	27	24
36346	2008-09	AHY	16	1	8	9
36347	2008-09	AHY	8	19	11	16
36352	2008-09	AHY	10	51	33	28
36353	2008-09	AHY	9	6	5	10
36357	2008-09	AHY	20	28	24	24
36675	2008-09	AHY	15	27	22	20
36676	2008-09	AHY	23	60	36	47
36679	2008-09	AHY	18	25	21	22
36680	2008-09	AHY	15	45	31	31
36684	2008-09	AHY	19	39	24	34
36686	2008-09	AHY	20	48	37	31
36689	2008-09	AHY	6	2	1	7
36691	2008-09	AHY	12	28	18	22
36692	2008-09	AHY	9	39	24	24
36696	2008-09	AHY	35	60	49	49
36697	2008-09	AHY	12	55	34	33
36700	2008-09	AHY	26	51	38	39
36705	2008-09	AHY	9	11	8	13
36706	2008-09	AHY	9	14	10	13
36707	2008-09	AHY	14	43	28	29
36708	2008-09	AHY	7	24	17	16
36710	2008-09	AHY	11	26	20	17
36711	2008-09	AHY	24	42	29	37
36712	2008-09	AHY	17	55	34	38
36717	2008-09	AHY	30	23	26	30
36690	2008-09	HY	5	1	4	2
36693	2008-09	HY	12	54	38	28
36699	2008-09	HY	6	8	7	7
36703	2008-09	HY	27	16	20	23
36709	2008-09	HY	13	35	28	23
36713	2008-09	HY	4	7	4	7
36715	2008-09	HY	8	4	6	6

VITA

Jacob Marshall Gray grew up near Hallsville, Ohio. He graduated from Zane Trace High School in 2002. He attended The Ohio State University from 2002-2006 and graduated with a Bachelor of Science degree in wildlife management. While at the university and immediately after graduation, he worked as a technician on several research projects. He also worked for Ducks Unlimited as a field technician in Woodworth, North Dakota during 2007. He then enrolled in the graduate program at Louisiana State University in August 2007. The degree of Master of Science will be awarded to Jacob in May 2010.