

SURVIVAL, HABITAT USE, AND MOVEMENTS OF FEMALE
MALLARDS WINTERING IN SOUTHWESTERN LOUISIANA

A Thesis

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DEDICATION

This work is dedicated to my father,

Thomas Link.

He always made time to take me hunting and fishing. The times together were the best of my life and I look forward to many more. It was through our relationship that I learned to appreciate and respect wild things and places.

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Abstract

Little information is available concerning survival, habitat use, and movements of mallards (*Anas platyrhynchos*) wintering on the Gulf Coast Chenier Plain (GCCP). Quantitative data on these parameters would be useful in making effective management decisions by GCCP waterfowl managers. Accordingly, I radio-marked 135 female mallards during winters 2004-2005 and 2005-2006 in southwestern Louisiana. My estimated survival rate for both winters combined was 0.68 ± 0.06 and did not differ by female age. Hazard ratios indicated that radio-marked females were 21-24 times more likely to die during hunted time periods than during non-hunted time periods. Hunting and non-hunting mortality rates were 0.279 and 0.067, respectively, and did not differ between winters. Estimated product limit survival rates were 0.81 ± 0.05 (\pm SE) and 0.54 ± 0.09 (\pm SE) for HIGH and LOW condition birds, respectively. I found that diurnal and nocturnal use of areas closed to hunting was greater during hunted time periods than during non-hunted time periods, and that diurnal use of areas closed to hunting was greater in winter 2005-2006 than during winter 2004-2005. Diurnally, use of MARSH was 3.3 times greater than that of other habitats during both winters. RICE and IDLE appeared to be related to availability of these habitats within the core study area. RICE acreage and use was greater in winter 2004-2005 than in winter 2005-2006, whereas IDLE acreage and use was greater in winter 2005-2006 than in winter 2004-2005. Female mallards used freshwater marsh habitats extensively; brackish or salt marsh was used much less frequently. Diel movements of female mallards generally were short ($\bar{x} \pm$ SE = 5.0 ± 0.2 km) and mean flight distances of individual females (n = 141) ranged from 3-15 km. My results suggest that mallards wintering in this area would benefit from programs and activities that target freshwater marsh for restoration and management.

Management activities that increase mallard foraging habitats on areas closed to hunting may decrease hunting mortality rates and possibly increase female body condition.

Chapter 1. Introduction

One-fourth of the North American dabbling duck population (Palmisano 1973) and two-thirds of the Mississippi Flyway waterfowl population historically wintered in coastal marshes of Louisiana (Bellrose 1980). However, Louisiana coastal marshes are disappearing at an alarming rate; Gagliano et al. (1981) reported marsh losses at 100 km²/yr.

The primary goal of the Gulf Coast Joint Venture is to provide winter habitat for waterfowl and ensure that they survive and return to breeding areas in good condition (Eslinger and Wilson 2001). Previous radio-telemetry studies of mallards within the Mississippi Alluvial Valley reported low non-hunting mortality (Reinecke et al. 1987) and high post-hunting season survival (Dugger et al. 1994). Other than northern pintails (*Anas acuta*), little is known about winter survival of Gulf Coast Chenier Plain (GCCP) dabbling ducks (Cox et al. 1998). Consequently, current estimates of hunting and non-hunting mortality rates for mallards would be useful in making effective management decisions by GCCP waterfowl managers.

Current habitat objectives for the GCCP largely are based on diurnal observations of waterfowl (Wilson 2003). However, the importance of certain diurnal habitats may be overestimated without information concerning nocturnal habitat use. Other than northern pintail, use of habitats by dabbling ducks has received little study in the GCCP (Cox and Afton 1997).

Distribution and movements of wintering waterfowl often are influenced by the juxtaposition of sanctuary and hunted lands (Raveling 1978, Frederick and Klaas 1982, Humburg et al. 1985, Fleskes et al. 2002). Understanding movement parameters of waterfowl is crucial to managing winter habitats, especially along the GCCP where hunting pressure is high (Cox et al. 1998). Except for northern pintails (Cox and Afton 1996), little is known about diel movements of dabbling ducks wintering on the GCCP.

Hurricane Rita, the most intense tropical cyclone ever observed in the Gulf of Mexico (Johnson 2006), came ashore in southwestern Louisiana on 24 September 2005 as migrating waterfowl began arriving on the GCCP. The ensuing storm surge greatly affected the quantity and quality of freshwater marsh (Neyland 2007) and agricultural habitats (LSU AgCenter 2005). Thus, my study allowed a comparison of survival, habitat use, and movements of mallards between pre- and post hurricane winters.

I used radio telemetry to estimate survival rates, habitat use, and movements of female mallards wintering in southwestern Louisiana. I studied females because males outnumber females and hence do not limit production (Johnson and Sargeant 1977, Johnson et al. 1987). In Chapter 2, I estimate winter survival of adult (after hatch year) and immature (hatch year) female mallards and test for variation in survival rates in relation to female age, winter, body condition at time of capture, and hunt periods. In Chapter 3, I describe proportional use of areas closed and open to hunting, and also quantify habitats used by female mallards wintering in southwestern Louisiana. In Chapter 4, I estimate flight distance between paired diurnal and nocturnal locations within a 24-hr period. Chapters II-IV are organized as separate scientific manuscripts; thus, some duplication occurs in study area and methods sections.

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Chapter 2. Survival and Cause-Specific Mortality of Female Mallards in Southwestern Louisiana

Introduction

One-fourth of the North American dabbling duck population (Palmisano 1973) and two-thirds of the Mississippi Flyway waterfowl population historically wintered in coastal marshes of Louisiana (Bellrose 1980). However, Louisiana coastal marshes are disappearing at an alarming rate; Gagliano et al. (1981) reported marsh losses at 100 km²/yr.

Relative to other wintering areas (e.g. Texas Playa Lakes Region, Smith and Sheeley 1993; Mississippi Alluvial Valley, Reinecke et al. 1988), coastal marshes are predictable habitats and may encourage winter philopatry in waterfowl (Robertson and Cooke 1999). If mallards exhibit high winter fidelity, similar to other waterfowl species (e.g. northern pintails, *Anas acuta*; Hestbeck 1993, Reinecker 1987), low winter survival could negatively impact regional populations.

Hurricane Rita, the most intense tropical cyclone ever observed in the Gulf of Mexico (Johnson 2006), came ashore in southwestern Louisiana on 24 September 2005 as migrating waterfowl began arriving on the Gulf Coast Chenier Plain (GCCP). The ensuing storm surge greatly affected the quantity and quality of freshwater marsh (Neyland 2007) and agricultural habitats (LSU AgCenter 2005). Thus, hurricane effects could have affected survival of mallards and other wintering ducks during winter 2005-2006 in southwest Louisiana.

Adult mallards wintering in Arkansas and Mississippi had higher survival than did immatures (Reinecke et al. 1987), whereas survival was similar between age classes of mallards wintering in Texas (Bergan and Smith 1993). Survival estimates and potential age variation in survival have not been examined for mallards wintering on the GCCP.

The winter period can be energetically demanding for waterfowl. Reinecke et al. (1982) hypothesized that wintering black ducks (*Anas rubripes*) decreased the size of protein reserves to lower daily energy requirements. Lima (1986) suggested that energy reserves maintained by wintering birds were a compromise between the risks of starvation and predation. Heavier birds have a higher probability of surviving severe weather conditions; however, lean birds have lower maintenance costs and also may be more proficient in avoiding predators (Lima 1986). Ducks in poor condition generally have lower survival rates than do those in better condition (Bergan and Smith 1993, Conroy et al. 1989, Haramis et al. 1986, Hepp et al. 1986; but see Cox et al. 1998, Migoya and Baldassarre 1995, and Miller 1986) and may be more mobile as they search for more suitable habitats, thus increasing their exposure to hunters (Hepp et al. 1986).

The primary goal of the Gulf Coast Joint Venture is to provide winter habitat for waterfowl and ensure that they survive and return to breeding areas in good condition (Eslinger and Wilson 2001). A previous radio-telemetry study within the Mississippi Alluvial Valley reported low non-hunting mortality of mallards (Reinecke et al. 1987). Other than northern pintails (Cox and Afton 1998), little is known about winter survival of GCCP dabbling ducks. Consequently, current estimates of hunting and non-hunting mortality rates for mallards would be useful in making effective management decisions by GCCP waterfowl managers.

I used radio telemetry to estimate survival rates and determine cause-specific mortality of female mallards wintering in southwestern Louisiana. I studied females because males outnumber females and hence do not limit production (Johnson and Sargeant 1977, Johnson et al. 1987). I estimated winter survival of adult (after hatch year) and immature (hatch year) female mallards and tested for variation in survival rates in relation to female age, winter, body condition at time of capture, and hunt periods. My study also allowed comparison of mallard

survival before and after Hurricane Rita. Based on previous studies, I hypothesized that: (1) adult survival would be greater than that for immatures, (2) survival would be higher during winter 2004-2005 (pre-Rita) than during winter 2005-2006 (post-Rita), (3) individuals in poor condition would have lower survival than those in better condition, and (4) survival would be lower during hunted versus non-hunted time periods.

Study Area

I studied female mallards in southwest Louisiana and assumed that this area was representative of the GCCP. The Chenier Plain of southwest Louisiana extends 60 to 110 km inland from the Gulf of Mexico and encompasses more than 2.5 million ha (Chabreck et al. 1989). The two primary waterfowl habitats of the region are coastal marshes and rice agriculture, which is located immediately inland from coastal marshes (Chabreck et al. 1989).

My core study area in winter 2004-2005 (hereafter Winter 1) included all lands within 80 km of 2 capture sites: Pool 8 of Cameron Prairie National Wildlife Refuge (29°56'N, 93°02'W) and Amoco Pool (29°50'N, 92°34'W, Figure 2.1). I planned to use the same capture sites in winter 2005-2006 (hereafter Winter 2), but hurricane effects required that I capture mallards elsewhere on moist soil units on Cameron Prairie National Wildlife Refuge (29°58'N, 93°04'W) and Lacassine Pool of Lacassine NWR (29°57'N, 92°55'W). I maintained the same core study area in Winter 2 despite changing trapping locations from Amoco Pool to Lacassine NWR. The GCCP and Amoco Pool were described in detail by Chabreck et al. (1989).

My extended aerial search area extended from Matagorda Island, Texas inland 80 km, across the southern one-half of Louisiana, to Grand Isle, Louisiana (Figure 2.1). I searched the extended area as often as necessary ($\bar{x} = 4$ times per month) to locate birds emigrating from the core study area. Bruce Davis, who marked a complimentary sample of mallards in northeast

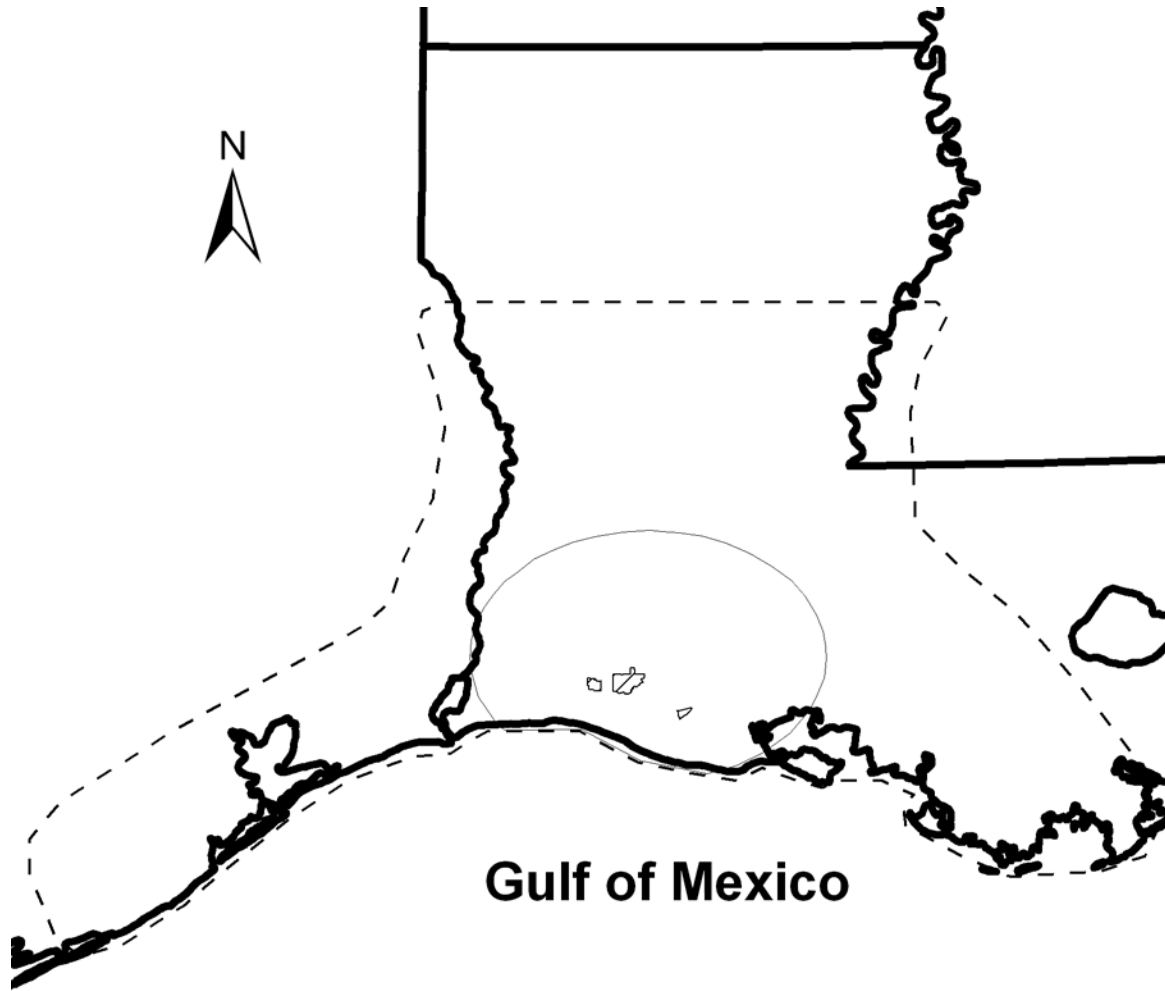


Figure 2.1. Study area in which radio-marked female mallards were monitored during winters 2004-2005 and 2005-2006. The primary study area is denoted by a solid line and extended aerial search area by a dashed line; hatched polygons are mallard capture locations (Cameron Prairie NWR, Lacassine NWR, and Amoco Pool from left to right, respectively).

Louisiana during the same period, searched for missing birds north of my extended search area. These flights helped distinguish radio failures from birds that emigrated from the core study area.

Methods

I selected potential trapping sites based on observations of concentrated waterfowl use in areas that were approved for bait-trapping by federal law enforcement agents. All trapping sites were located on areas closed to hunting and were > 1.6 km to the nearest hunting blinds. I baited sites with various combinations of unmilled rice, corn, barley, millet, sorghum, soybeans, sweet potatoes, crushed oyster shells, and sand. I captured mallards using portable rocket-net platforms (Cox and Afton 1994) and deployed nets using a remote detonator (Sharp and Lokemoen 1980).

Upon capture, female mallards were removed from nets, placed in catch boxes, and then transported to a temporary structure (screened canopy) for processing. I provided food and water *ad libitum* to captured birds during the banding and marking process (LSU Institutional Animal Care and Use Committee Protocol #04-108 and U.S. Geological Survey Banding Permit # 08810). I determined age (adult [after hatch year] or immature [hatch year]) and sex from wing plumage characteristics (Carney 1964). I weighed (± 5 g) and measured (± 0.1 mm) culmen, total tarsus, middle toe, and wing cord length of each female (Dzubin and Cooch 1992).

When numbers of females captured exceeded the number of available transmitters, I randomly selected immatures and adults so that equal numbers of each age were radio-marked. I fitted female mallards with a 21-g, harness-type transmitter (Dwyer 1972; Advanced Telemetry Systems, Inc., Isanti, MN) with an expected life of 160 days. I tightened neck and body loops such that an index finger would fit under each loop and preened feathers around the harness (Houston and Greenwood 1972). I used alligator clips while adjusting harness tension, tied double overhand knots on the final harness loop, and used purple primer and all-purpose cement

(Oatey, Cleveland, OH) on attachment points.

Each transmitter pulsed at 50 beats per minute and was coded to pulse double on every tenth beat to distinguish it from other transmitters on similar frequencies. Transmitters were equipped with mercury-type mortality switches which caused the pulse rate to double if motionless for > 4 hours. Transmitters were labeled on the underside with reporting information and an offer of a reward (pencil-sketch art print and a non-functional replacement transmitter).

I released radio-marked females in groups at capture sites from 4-14 h after capture (overnight for birds captured at dusk). I monitored radio-marked females daily for survival and investigated mortality signals immediately upon detection. I inferred cause specific mortality from evidence such as tracks, recovery location (e.g. at a boat launch or in a nest or building) collected on-site, by diagnostic necropsy, or observing a predator at the carcass (e.g. Conroy et al. 1989, Cox et al. 1998, Reinecke et al. 1987).

My technicians and I tracked radio-marked birds in 4 vehicles equipped with 4-element, null-peak antenna systems, GPS units, and laptop computers (Cochran 1980:517-518; Cox and Afton 1997, 1998). I used LOAS (Location of a Signal) software to estimate locations on site (LOAS 2003). I constructed 2, 13-m permanent towers; each tower supported a single 9-element unidirectional antenna to reduce aircraft time needed to locate birds in Amoco Pool, which was inaccessible by truck. I used aerial telemetry techniques to locate missing birds (Gilmer et al. 1981). Flights were conducted at altitudes (Range = 300 m to 3050 m) such that all radio-marked birds present on the core study area could be located.

Statistical Analysis

Because I monitored the extended search area less frequently than the core study area, the probability of detecting mortalities outside the core study area probably was lower. Thus, I

estimated survival only within the core study area.

I excluded the first 4 days post-capture from analysis to minimize effects of capture and handling on survival (Cox et al. 1998). I right-censored birds who left the core study area and included them again if they returned. When the exact date that a female left the core study area was unknown, I randomly selected a date from the interval between the last date the bird was located on the core study area and the first date a bird could not be located on the core study area or was known to be outside the core study area (Cox and Afton 1998). When inclement weather prevented some radio-marked birds from being located, I assumed that their status remained constant throughout the unmonitored time period. When the exact date of death was unknown, I selected the midpoint between the last date the bird was known to be alive and the first date of mortality detection (Cox et al. 1998).

I calculated size-adjusted body mass at capture as an index of body condition (hereafter condition). I first indexed structural size of each radio-marked female using principle components analysis (PROC PRINCOMP; SAS Inst. Inc. 2007) of the correlation matrix of the 4 morphological measures taken from capture (Cox and Afton 1998). I then used the first principle component score (PC1) as a measure of structural size for each female (SIZE, Alisauskas and Ankney 1987). I regressed (PROC GLM; SAS Inst. Inc. 2007) female body mass on PC1 and subsequently adjusted each female's body mass by adding the overall mean body mass of all females to her residual from the regression (Ankney and Afton 1988). I used 2-way ANOVA (PROC GLM; SAS Inst. Inc. 2007) to test for differences in condition in relation to female age, winter, and their interaction. Once the final model was determined, I used an ESTIMATE statement in PROC GLM (SAS Institute, 2007) to compare and estimate mean condition between years and ages.

Annual duck hunting seasons in southwest Louisiana were split into 2 periods during my study. I divided hunt periods into 4 time periods based on hunting season: (1) first hunting period ([FHUNT]; 12 Nov 2005-4 Dec 2005), (2) time between hunting periods ([SPLIT]; 5 Dec 2005-16 Dec 2005), (3) second hunting period ([SHUNT]; 24 Dec 2004-23 Jan 2005 and 17 Dec 2005-22 Jan 2006), and (4) post hunting season ([POST]; post-24 Jan 2005 and post-23 Jan 2006). Winter comparisons were limited to SHUNT and POST because I was unable to capture and radio-mark birds during FHUNT or SPLIT in Winter 1, given the later arrival of mallards on areas approved for bait trapping. Mallards were radio-marked during 21 Dec-10 Jan in Winter 1 and during 22 Nov-16 Dec in Winter 2.

I tested for differences in survival in relation to female age, winter, hunt period, and condition using Cox (1972) proportional hazards regression (PROC PHREG; SAS Institute 2007) as described by Cox and Afton (1998). I tested whether my response variable, survival, differed among the following explanatory variables: female ages, winters, hunt periods, and condition, including all 2-way interactions. Condition was a continuous covariate in my survival analysis (Cox and Afton 1998). I used backward stepwise procedures to eliminate non-significant ($P > 0.05$) terms, beginning with interactions.

I calculated product-limit survival estimates (Kaplan and Meier 1958) for significant ($P < 0.05$) effects in the final model. To summarize the observed effect of condition on survival, I partitioned birds into a HIGH condition class if they were greater than the median condition of all birds in the sample and into a LOW condition class if they were below the median condition (Conroy et al. 1989).

I conducted 2 other analyses, in which I estimated hunting mortality by censoring non-hunting mortality observations, and alternately estimated non-hunting mortality by censoring

hunting mortality observations. I conducted separate analyses because hunting mortality and non-hunting mortality cannot be summed to estimate mortality from both sources (1 - survival rate, Cox and Afton 1998). I tested for variation between hunting and non-hunting mortality rates using the same explanatory variables and procedures as previously described to identify important sources of variation related to different causes of mortality of females.

Results

I radio-marked a total of 149 females and excluded 14 females from analysis, which died ($n = 10$ from avian predation, $n = 2$ from mammalian predation) or emigrated from the core study area ($n = 2$) during the 4-day adjustment period (Cox and Afton 1998). Thus, my final sample size for the survival analysis was 135 females and included 8483 exposure days.

Body Condition Index

In the principle component analysis, PC1 explained 52.2% of the overall variation among the 4 morphometric variables. All factor loadings were positive and ranged from 0.28 (culmen length) to 0.61 (middle toe length). Female body mass showed a positive relationship to SIZE ($F = 3.34$; 1, 134 df; $P = 0.07$). The equation was:

$$\text{Mass}_{\text{adj}} = 1172.2 \pm 12.8 (\text{SIZE})$$

Two-way ANOVA indicated that female condition varied between winters ($F = 1188.45$; 1, 8219 df; $P < 0.0001$) and between ages ($F = 823.96$; 1, 8219 df; $P < 0.0001$), but the winter by age interaction was not significant ($F = 0.09$; 1, 8218 df; $P > 0.76$). Condition of females was higher ($P < 0.0001$) in Winter 2 ($\bar{x} \pm \text{SE g} = 1215.3 \pm 1.6$) than in Winter 1 ($\bar{x} \pm \text{SE g} = 1130.9 \pm 1.8$). The mean difference in condition between winters was 84.4 g and the 95% CI was 79.6 to

89.2 g. Condition of adults ($\bar{x} \pm SE$ g = 1208.9 \pm 1.5) was higher ($P < 0.001$) than that of immatures ($\bar{x} \pm SE$ g = 1137.2 \pm 1.9). The mean difference in condition between ages was 71.7 g and the 95% CI was 66.8 to 76.6 g.

Cause-Specific Mortality

Following the 4 day adjustment period (Cox and Afton (1998), I observed 28 (21%) mortalities during the study: 23 (82%) were attributed to hunting (16 retrieved by hunters, 6 unretrieved with evidence of being shot, and 1 suspected hunter discard) and 5 (18%) were inferred as due to avian predation. Of those killed by avian predators, I surmised that 3 were killed by great horned owls (*Bubo virginianus*) (2 carried to the same nest), 1 was observed being eaten by a crested caracara (*Caracara cheriway*), and 1 was killed by an unknown avian predator.

Survival

My final model indicated that condition (Wald $\chi^2 = 8.51$, 1df, $P = 0.0035$) and hunt period (Wald $\chi^2 = 9.72$, $P = 0.0078$) were important explanatory variables. I found no evidence that survival differed by female age or between winters, and none of the interactions were significant (all $P_s > 0.3$). My product-limit survival estimate for Winters 1 and 2 combined was 0.68 ± 0.06 ($\pm SE$, Figure 2.2). Estimated product limit survival rates were 0.81 ± 0.05 ($\pm SE$) and 0.54 ± 0.09 ($\pm SE$) for HIGH and LOW condition birds, respectively (Figure 2.3). Hazard ratios indicated that radio-marked females were 20.9 (95% CI = 18.0-23.7) and 24.4 (95% CI = 22.4-26.4) times more likely to die in FHUNT and SHUNT, respectively, than during POST.

My hunting mortality rate was 0.28 and did not differ between winters, age, condition, hunt period, or any of the interactions ($P_s > 0.06$). My non-hunting mortality rate was 0.07 and did not differ between winters, age, hunt period, or any of the interactions ($P_s > 0.9$). The

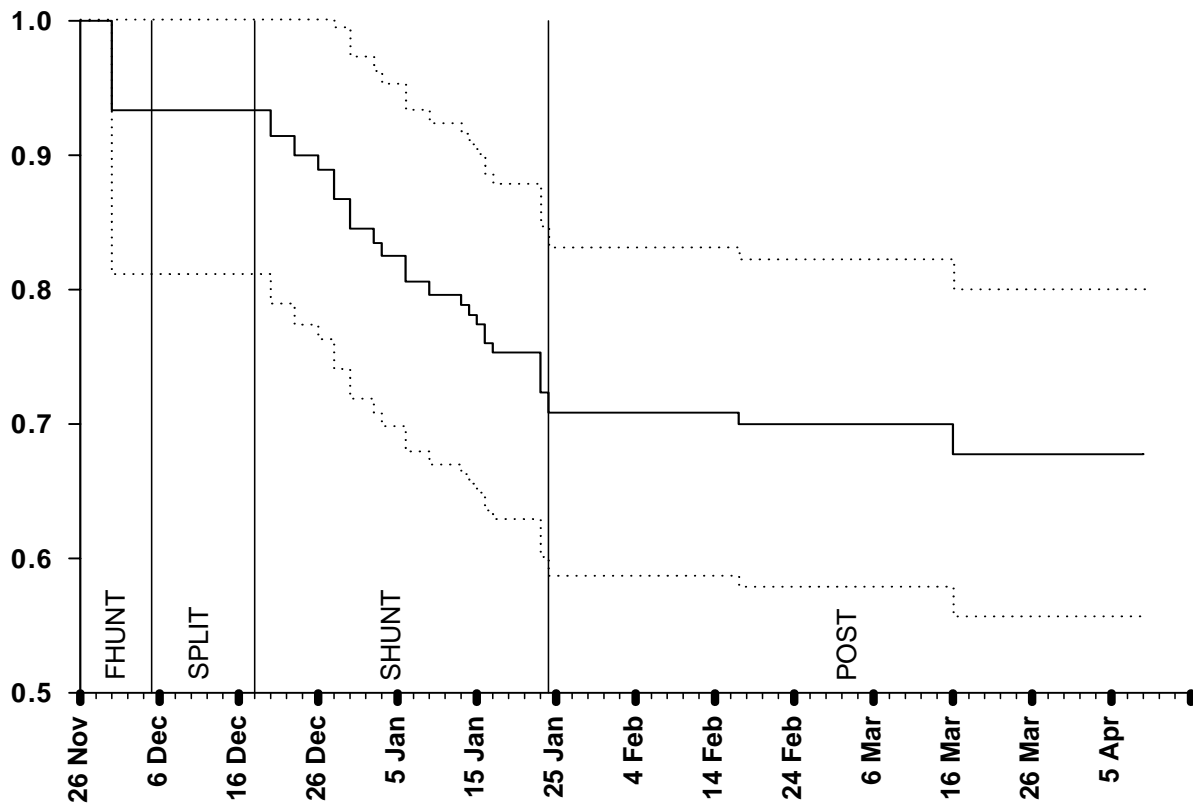


Figure 2.2. Product-limit survival rate of radio-marked female mallards during winters 2004-2005 and 2005-2006 combined in southwestern Louisiana. Note that estimates of FHUNT and SPLIT are from winter 2005-2006 only (see Methods). Dotted lines denote 95% confidence intervals. Vertical lines denote hunt periods.

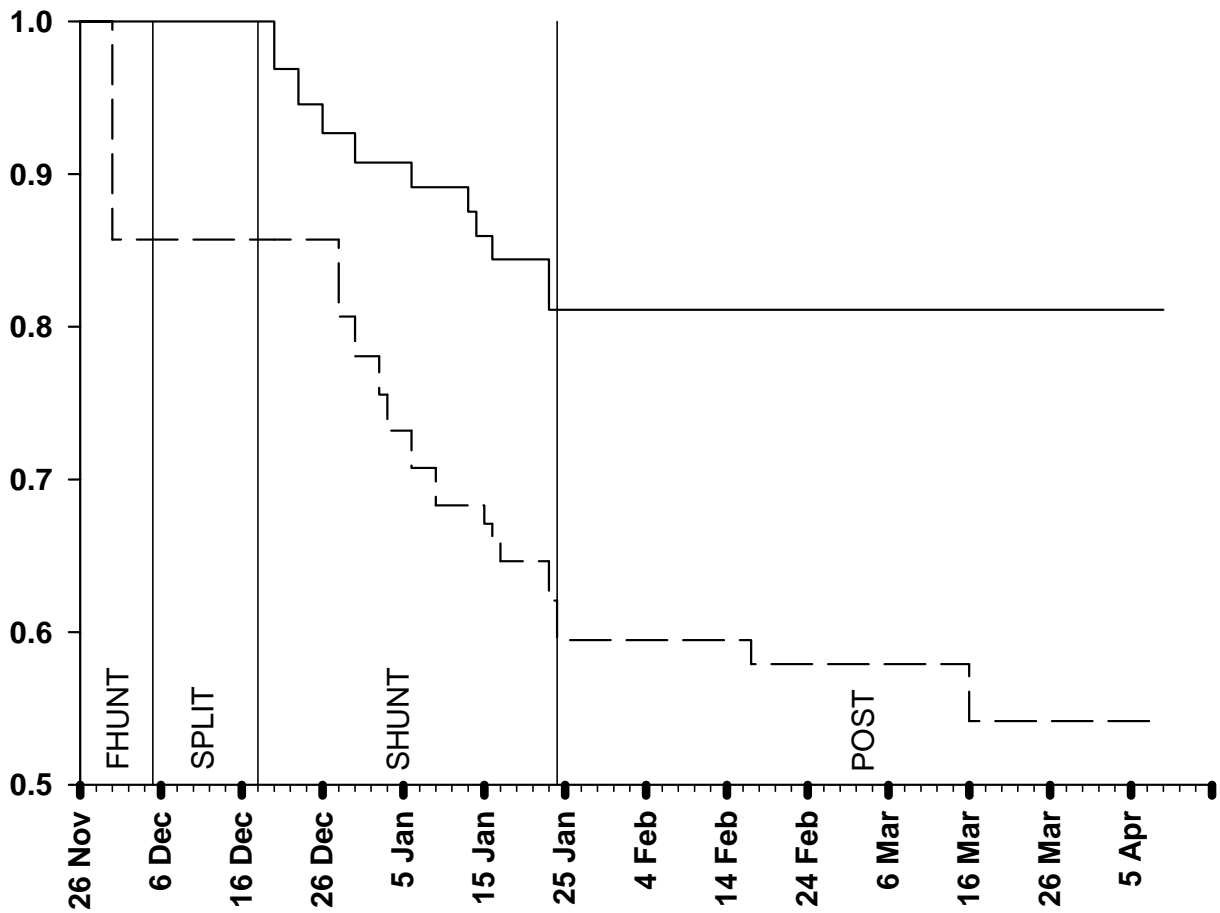


Figure 2.3. Product limit survival rate of radio-marked female mallards in relation to condition (HIGH = solid line; LOW = dashed line) for winters 2004-2005 and 2005-2006 combined in southwestern Louisiana. Vertical lines denote hunt periods. Note that estimates of FHUNT and SPLIT are from winter 2005-2006 only (see Methods).

final model of non-hunting mortality rate contained condition ($P = 0.011$).

Discussion

Despite dramatic impacts of Hurricane Rita (Neyland 2007), I found that female condition was higher in Winter 2 than in Winter 1. I radio-marked female mallards 1 month earlier in Winter 2 than in Winter 1, and mallard body condition is known to decline through winter in some areas (Whyte and Bolen 1986, Loesch et al. 1992). Thus, condition may have been higher in Winter 2 due to earlier marking of females.

Harness-type backpack transmitters (Dwyer 1972) provide relatively unbiased survival estimates (Fleskes 2003) and are widely used in studies of wintering waterfowl (Table 2.2). I observed no abnormal behavior or movement patterns of radio-marked birds after the 4-day adjustment period. Furthermore, in following years, hunters reported harvesting radio-marked birds up to 3400 km north (Saskatchewan) of my study area. Thus, I assume that transmitter effects on my survival estimates generally were small.

My estimate of winter survival could be biased high if survival of birds marked on areas closed to hunting is higher than for birds marked on areas open to hunting (Blohm et al. 1987). Blohm et al. (1987) reported that female recovery rates usually were lower for those banded on refuges than those banded off refuges; however, their results were inconclusive for females due to the small number of recoveries. As in all telemetry studies, my survival estimate may be biased high due to right censoring unreported hunter killed birds, transmitter failures, and when predators render the transmitters inoperable.

My overall product-limit survival estimate for radio-marked female mallards in southwestern Louisiana was lower than for those wintering in Mississippi and Arkansas (Reinecke et al. 1987), Texas (Bergan and Smith 1993), and Arkansas (Dugger et al. 1994) but

was higher than those wintering in northeast Louisiana and southeastern Arkansas (Davis 2007). My 134- day interval was markedly longer than many of the other studies (e.g. 70 days, 101 days, and 50 days, Reinecke et al. 1987, Bergan and Smith 1993, and Dugger et al. 1994, respectively); however, it extended later in the wintering period when survival generally was high (Table 2.1).

My estimated hunting mortality rate of female mallards in southwestern Louisiana was 0.28 and did not differ between female ages ($P = 0.96$). This rate is the highest on record for adult female dabbling ducks, and was surpassed only by the hunting mortality rate of immature northern pintails (0.315) in southwestern Louisiana (Table 2.2). My estimated non-hunting mortality rate of radio-marked female mallards was low (0.07) and similar to those wintering in Mississippi and Arkansas (0.01-0.07, Reinecke et al. 1987), but much lower than those wintering in northeastern Louisiana and southeastern Arkansas (0.34, Davis 2007).

Contrary to my prediction, I found no evidence that survival differed between female ages ($P = 0.96$). Mallards wintering in southwestern Louisiana probably have experienced considerable hunting exposure prior to arrival, which may have removed naïve birds and improved hunter and predator avoidance behavior of immatures that survived to migrate to Louisiana.

As predicted, I found that body condition at time of capture had a significant effect on survival. Birds in LOW condition survived at a much lower rate than did those in HIGH condition. Additionally, I recorded mortalities after the hunting season for LOW condition females, but not HIGH condition females (Figure 2.3). Additionally, I found no evidence that survival differed between winters ($P = 0.2961$). I hypothesize that the mobility and adaptability of mallards enabled them to locate and exploit suitable habitats (Bellrose 1988).

Table 2.1. Estimated survival, hunting mortality, and non-hunting mortality rates by hunt period for female mallards during winters 2004-2005 and 2005-2006 combined in southwestern Louisiana.

Hunt Period	Days ^a	n ^b	Survival Rate ^c		Hunting Mortality Rate		Non-Hunting Mortality Rate	
			\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
FHUNT ^d	9	19	0.933	0.062	0.067	0.062	-	-
SPLIT ^d	12	38	1	0	-	-	-	-
SHUNT	39	67	0.759	0.043	0.227	0.043	0.024	0.017
POST	74	52	0.956	0.024	-	-	0.044	0.0244
OVERALL	132	135	0.677	0.062	0.279	0.062	0.067	0.029

^aMaximum number of exposure days per hunt period in both winters.

^bMaximum number of radio-marked female mallards.

^cHunting mortality and non-hunting mortality rates cannot be summed to estimate mortality from both sources (1 - survival rate).

^dEstimate for winter 2005-2006 only; all other periods are estimates during winters 2004-2005 and 2005-2006 combined.

Table 2.2. Estimated survival, hunting mortality, and non-hunting mortality rates of female dabbling ducks during winter, based on harness type radio transmitters (Dwyer 1972).

Species	Region	Days	Age	Survival Rate	SE	Hunting Mortality Rate	Non-hunting Mortality Rate	Reference
Am. black duck	ME-NB	76	Imm	0.593	0.06	- ^a	0.306	Longcore et al. 1991
Am. black duck	NJ-VA	59	Ad	0.729	0.058	0.149	0.143	Conroy et al. 1989
			Imm	0.599	0.048	0.165	0.282	
mallard	AR	30	Ad, Imm ^b	0.993	0.014	- ^a	0.007	Dugger et al. 1994
mallard	CA	- ^a	Ad	0.71-0.83	0.07-0.08	- ^a	- ^a	Fleskes et al. 2007
			Imm	0.49-0.68	0.08-0.09	- ^a	- ^a	
mallard	LA	134	Ad, Imm ^b	0.678	0.061	0.279	0.067	This study
mallard	MS-AR	70	Ad	0.84	- ^b	0.12	0.04	Reinecke et al. 1987
			Imm	0.7	- ^b	0.19	0.011	
mallard	TX	100	Ad, Imm ^b	0.777	0.04	0.018	0.21	Bergan and Smith 1993
northern pintail	LA	146	Ad	0.714	0.045	0.165	0.145	Cox and Afton 1998
			Imm	0.55	0.068	0.315	0.196	
northern pintail	CA	216	Ad	0.756	0.034	0.199-0.249	0.078-0.1	Fleskes et al. 2002
			Imm	0.654	0.042	- ^a	- ^a	
northern pintail	CA	215	Ad	0.88-0.93	0.02-0.03	- ^a	- ^a	Fleskes et al. 2007
northern pintail	CA	180	Ad	0.874	0.03	0.041-0.087	0.013-0.076	Miller et al. 1995
northern pintail	MX	107	Ad, Imm ^b	0.911	- ^a	0.048-0.103	0-0.019	Migoya and Baldassarre 1995

^aNot reported.

^bSurvival rates were similar between adults (Ad) and immatures (Imm).

Management Implications and Research Needs

My results indicate that survival of radio-marked mallards in southwestern Louisiana was highly dependant on female condition and generally was low compared to mallards in other wintering areas (Table 2.2). If mallards are philopatric to this wintering area, the observed low survival may be a concern with regard to regional populations. If increasing winter survival is an objective, management should focus on reducing female hunting and non-hunting mortality. Increased efforts to provide mallard foraging habitats on areas closed to hunting may decrease hunting mortality rates and increase female condition. My results indicate that avian predators were responsible for all non-hunting mortality. Preston (1980) reported that availability of perch sites influenced foraging habitat use of avian predators. Thus, managers may consider discouraging raptors from areas used by ducks by removing perches, such as shelterbelts and burying telephone and electrical lines.

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Chapter 3. Use of Habitats by Female Mallards Wintering in Southwestern Louisiana

Introduction

One-fourth of the North American dabbling duck population (Palmisano 1973) and two-thirds of the Mississippi Flyway waterfowl population historically wintered in coastal marshes of Louisiana (Bellrose 1980). However, Louisiana coastal marshes are disappearing at an alarming rate; Gagliano et al. (1981) reported marsh losses at 100 km²/yr. Threats to coastal marshes include saltwater intrusion from channel dredging (Fruge 1982), hurricanes, subsidence, sea level rise, and loss of sediment and freshwater inputs from levee construction (Chabreck et al. 1989). Current wetland conservation efforts aim to reduce loss, restore, enhance, and create new marsh habitats within the region (Esslinger and Wilson 2001). Agricultural habitats in southwest Louisiana also provide habitat for wintering waterfowl (Esslinger and Wilson 2001) and primarily are dependant upon government programs.

Winter habitats and weather conditions may play an important role in sustaining waterfowl populations (Heitmeyer and Fredrickson 1981). This seems likely because mallards (*Anas platyrhynchos*): (1) arrive on the breeding grounds with much of the endogenous reserves necessary to produce a clutch of eggs (Krapu 1981), (2) have a large first clutch of eggs (Krapu and Doty 1979), and early hatching broods have higher survival (Dzus and Clark 1998, Krapu et al. 2000).

Current habitat objectives for the Gulf Coast Chenier Plain (GCCP) largely are based on diurnal observations of waterfowl (Wilson 2003). Aerial surveys often are used to estimate waterfowl populations and habitat use (Palmisano 1973, Reinecke et al. 1992). However, aerial surveys alone provide biased estimates of numbers of birds using habitats with low visibility rates (Smith et al. 1995). Additionally, the importance of certain diurnal habitats may be

overestimated without information concerning nocturnal habitat use. Other than northern pintail (*Anas acuta*, hereafter pintail), use of habitats by dabbling ducks has received little study in the GCCP (Cox and Afton 1997).

Tamisier (1976) concluded that green-winged teal (*Anas crecca*) and pintails gathered in large flocks on non-hunted areas as “more of a fundamental requirement” of wintering ducks than as a response to hunting pressure or disturbance. However, radio-marked pintails in California (Fleskes 2002), southwestern Louisiana (Cox and Afton 1997), and Mexico (Migoya et al. 1994) shifted from hunted to non-hunted areas in response to hunting pressure. Information is lacking on use of hunted and non-hunted areas by mallards wintering in the GCCP.

Chabreck et al. (1989) reported that freshwater marsh was the most important waterfowl habitat among Louisiana, Mississippi, and Alabama coastal habitats. The quantity and quality of freshwater marsh (Neyland 2007) and agricultural habitats (Table 2.7) varied markedly between winters of my study. Hurricane Rita, the most intense tropical cyclone ever observed in the Gulf of Mexico (Johnson 2006), came ashore in southwestern Louisiana on 24 September 2005 as early migrating waterfowl were arriving on the GCCP. Thus, impacts of Hurricane Rita on available habitat could have affected habitat use of mallards and other ducks.

Radio-marked birds provide an unbiased assessment of habitat use and thus can improve the accuracy of modeled habitat objectives within the GCCP (Wilson 2003). Additionally, quantitative information on habitat use of mallards would be useful in guiding refuge management and assisting in the prioritization of acquisition, protection, and management of habitats for wintering waterfowl. Accordingly, I used radio-telemetry techniques to assess proportional use of areas closed and open to hunting, and to quantify habitats used by female

mallards wintering in the GCCP. I studied females because males outnumber females and hence do not limit production (Johnson and Sargeant 1977, Johnson et al. 1987). My specific objectives were to: (1) quantify diel use of areas open and closed to hunting, (2) quantify diel use by general habitat types, (3) quantify diel use of specific marsh types, and (4) test for variation in use of areas open or closed to hunting, by habitat types, and by marsh type in relation to female age, winter, and hunt periods within winter.

Study Area

My study area was located within the GCCP in southwest Louisiana (Figure 3.1) and included all lands within Cameron, Calcasieu, Jefferson Davis, Acadia, and Vermillion Parishes. I assume that my study area was representative of the GCCP. The Chenier Plain of southwest Louisiana spans 60 to 110 km inland from the Gulf of Mexico and encompasses more than 2.5 million ha (Chabreck et al. 1989). The two primary waterfowl habitats of the region are coastal marshes and rice agriculture, which is located immediately inland from coastal marshes (Chabreck et al. 1989).

I collected habitat use data within 80 km of the following capture sites: 1) Cameron Prairie National Wildlife Refuge (29°56'N, 93°02'W), 2) Amoco Pool (29°50'N, 92°34'W), and 3) Lacassine National Wildlife Refuge (29°57'N, 92°55'W). The GCCP and Amoco Pool were described in detail by Chabreck et al. (1989).

Methods

Trapping, Marking, and Radio-tracking

I selected potential trapping sites based on observations of concentrated mallard use in areas approved for bait trapping by federal law enforcement agents. All trapping sites were

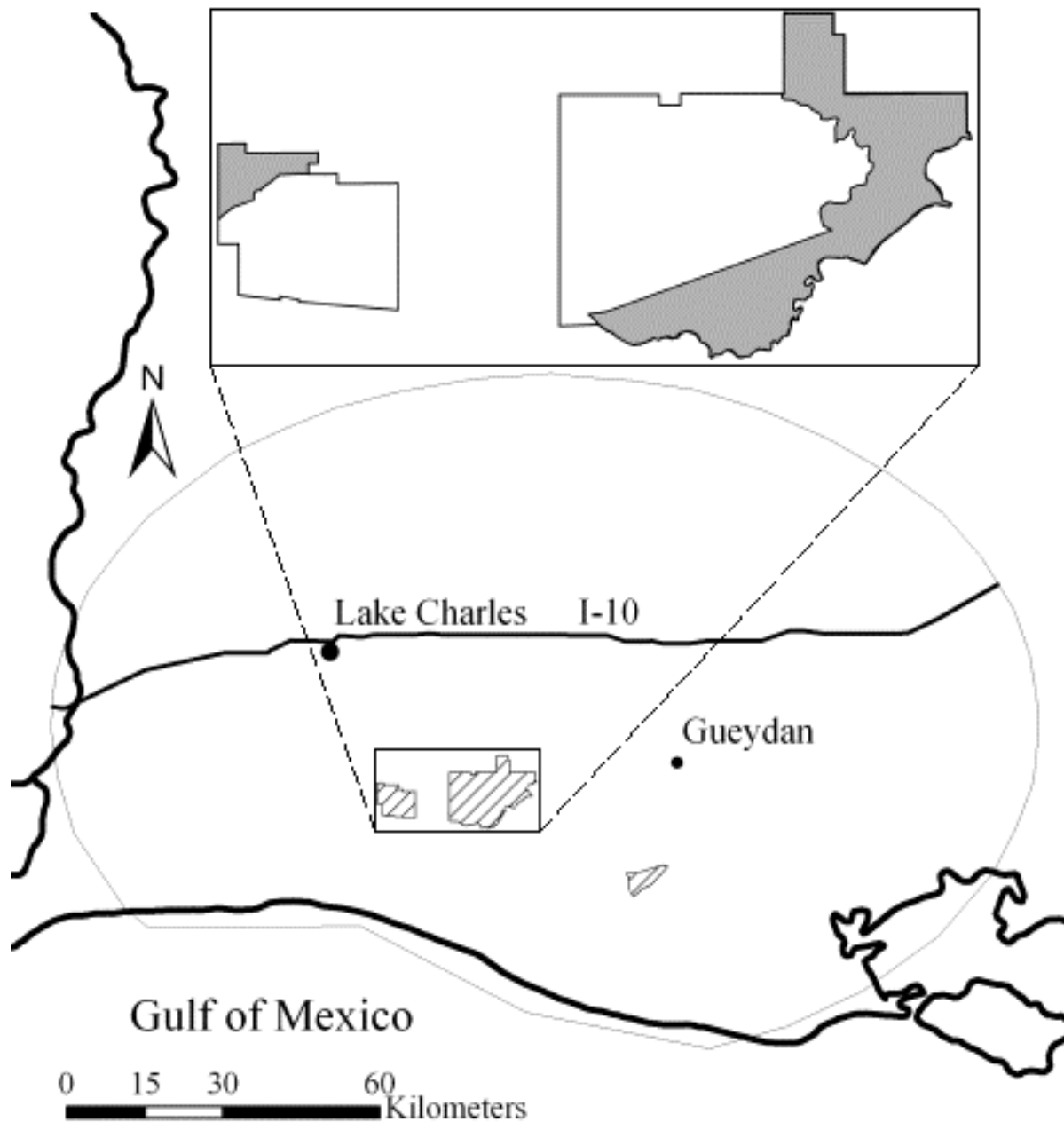


Figure 3.1. Location of core study area in southwest Louisiana. Hatched polygons are mallard capture locations (Cameron Prairie NWR, Lacassine NWR, and Amoco Pool, from left to right, respectively). Inset designates hunted portions (shaded areas) and non-hunted portions of Cameron Prairie NWR and Lacassine NWR in Winter 1. Hunting was prohibited on both refuges in Winter 2 and on Amoco Pool during both winters.

located on areas closed to hunting and were > 1.6 km to the nearest hunting blinds. I baited sites with various combinations of unmilled rice, corn, barley, millet, sorghum, soybeans, sweet potatoes, crushed oyster shells, and sand. I captured mallards using portable rocket-net platforms (Cox and Afton 1994) and deployed nets using a remote detonator (Sharp and Lokemoen 1980).

Upon capture, female mallards were removed from nets, placed in catch boxes, and then transported to a temporary structure (screened canopy) for processing. I provided food and water *ad libitum* to captured birds during the banding and marking process (LSU Institutional Animal Care and Use Committee Protocol #04-108 and U.S. Geological Survey Banding Permit # 08810). I determined age (adult [after hatch year] or immature [hatch year]) and sex from plumage characteristics or cloacal examination (Hochbaum 1942, Carney 1964). I weighed (± 5 g) and measured (± 0.1 mm) culmen, total tarsus, middle toe, and wing cord length of each female (Dzubin and Cooch 1992).

When numbers of females captured exceeded the number of transmitters, I randomly selected immatures and adults so that equal numbers of each age were radio-marked. I fitted female mallards with 21-g, harness-type transmitters (Dwyer 1972) with an expected life of 160 days. I tightened neck and body loops such that an index finger would fit under each loop and preened feathers around the harness (Houston and Greenwood 1993). I used alligator clips while adjusting harness tension, tied double overhand knots on the final harness loop, and used purple primer and all-purpose cement (Oatey, Cleveland, OH) on attachment points. I released radio-marked females in groups at capture sites 4-14 h after capture (overnight for birds captured at dusk).

Each radio pulsed at 50 beats per minute and was coded to pulse double on every tenth beat to distinguish it from other transmitters on similar frequencies. Transmitters were equipped

with mercury-type mortality switches which caused the pulse rate to double if motionless for > 4 hours. Transmitters were labeled on the underside with reporting information and an offer of a reward (i.e., pencil-sketch art print and a non-functional replacement transmitter).

My technicians and I tracked radio-marked birds in 4 vehicles equipped with 4-element, null-peak antenna systems, GPS units (GPS 76, Garmin© Corporation, Olathe, KS), and laptop computers (Cochran 1980:517-518; Cox and Afton 1997, 1998, Cox et al. 2002). Vehicle tracking systems were equipped with electronic compasses (Azimuth® 1000R, KVH Industries, Inc., Middletown, RI) and were empirically calibrated to within 0.5 degrees. I used LOAS (Location of a Signal) software to estimate locations on site (LOAS 2003) and used the Universal Transverse Mercator coordinate system for all location estimations. Prior to radio-tracking mallards, I trained technicians with beacon transmitters, placed at locations unknown to them, until each was able to maintain a bearing standard deviation of ≤ 3 degrees. I constructed 2, 13-m permanent towers; each tower supported a single 9-element unidirectional antenna to reduce aircraft time needed to locate birds in Amoco Pool, which was inaccessible by truck. My technicians and I collected a minimum of 3 azimuths for each female or until error ellipses were restricted to one habitat or marsh type. I used aerial telemetry techniques to locate birds (11% of all locations) that could not be located by vehicles or towers (Gilmer et al. 1981). Flights were conducted at altitudes (Range = 300 m to 3000 m) such that all radio-marked birds present on the core study area could be located. I also monitored for a complementary sample of female mallards radio-marked in northeast Louisiana by Bruce Davis, and included them in my habitat use analysis immediately upon detection.

Habitat Use Within Core Area

I examined variation in diurnal and nocturnal habitat use by radio-marked females in relation to individual birds, female age, winter (2004-2005 and 2005-2006), and hunt periods within winter. In 2004-2005 (hereafter Winter 1), I classified 2 hunt periods based on hunting season: (1) second hunting season ([SHUNT]; 24 Dec 2004-23 Jan 2005) and (2) post hunting season ([POST]; post-24 Jan 2005). In 2005-2006 (hereafter Winter 2), I classified 4 hunt periods based on hunting season: (1) first hunting season ([FHUNT]; 12 Nov 2005-4 Dec 2005), (2) time between hunt periods ([SPLIT]; 5 Dec 2005-16 Dec 2005), (3) second hunting season ([SHUNT]; 17 Dec 2005-22 Jan 2006), and (4) post hunting season ([POST]; post-23 Jan 2006). For analysis, comparisons between winters were limited to SHUNT and POST because birds could not be captured during FHUNT or SPLIT in Winter 1 due to later arrival of mallards on capture sites.

I classified each location as either CLOSED or OPEN to hunting. CLOSED included Amoco Pool and portions of Cameron Prairie NWR and Lacassine NWR (Figure 2.1). OPEN areas included all privately owned lands and hunted portions of Cameron Prairie NWR (units 11A, 14A, and 14B) and Lacassine NWR (units B, H, I, J, F1, F2, and F3) in Winter 1. Cameron Prairie NWR and Lacassine NWR were closed entirely to hunting in Winter 2 due to hurricane impacts.

When possible, my technicians and I identified habitats of radio-marked birds on site; otherwise I obtained this information using ground surveys, aerial photography, satellite imagery, FSA records, or mail out questionnaires to landowners. I classified habitats as: (1) MARSH, (2) tillable lands planted in rice (RICE), (3) IDLE (including: 1] moist soil, e.g. agricultural land in which water was intentionally retained, either by pumping or runoff and 2]

idle cropland, e.g. fallow agricultural land not planted to a commodity crop and not flooded); (4) tillable lands planted to native or tame grasses and maintained dry (PASTURE); and (5) OTHER (forested wetlands, soybeans, and sugarcane). I further classified MARSH locations into FRESH, INTERMEDIATE, BRACKISH, or SALT (Chabreck and Linscombe 1988). I also obtained annual acreages of RICE, IDLE, and PASTURE within the core study area from parish FSA offices.

Statistical Analysis

I excluded locations from the first 4 days post-capture for all females to minimize effects of capture and handling on habitat use (Cox et al. 1998). I performed separate models for diurnal and nocturnal locations in each of the following analyses: use of closed and open lands, use of general habitats, and use of specific marsh types.

Use of CLOSED and OPEN Lands

I compared proportional use of OPEN and CLOSED lands for each bird within the core area during each hunt period (SHUNT and POST) for diurnal and nocturnal locations separately. I calculated log-ratios by dividing the proportional use of CLOSED by the proportional use of OPEN, and then taking the napierian logarithm (Aebischer et al. 1993a) to normalize the data and remove the unit sum constraint (Aitchison 1986). I replaced zero values with 0.002 (an order of magnitude smaller than the lowest non-zero habitat recorded for any bird in any hunt period [Aebischer et al. 1993b]). I then used the transformed proportional use of OPEN and CLOSED data in a split-plot ANOVA (PROC GLM, SAS Institute 2007) to test for difference in use among the following explanatory variables: individual female, female age (adult or immature), winter (Winter 1 or Winter 2), and hunt period within winter (SHUNT or POST). I used variation due to individual females as the error term to test for effect of female age, winter,

and their interaction, and residual error to test for effect of individual female, hunt period, and all other interactions. I began with a full model (including all possible interactions) 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 relative use of OPEN and CLOSED among explanatory variables using Fisher's LSD (SAS Institute 2007) as described by Cox and Afton (1997).

Use of Habitats

I compared proportional use of habitats for each bird within the core area during each hunt period (SHUNT and POST) for diurnal and nocturnal locations separately. I calculated proportional habitat use of the 5 general habitat types (MARSH, RICE, IDLE, PASTURE, and OTHER) for each female in each hunt period, and constructed 4 log-ratios by dividing the proportional use of each habitat by proportional use of IDLE, then taking the napierian logarithm. I replaced zero values with 0.007 (an order of magnitude smaller than the lowest non-zero habitat recorded for any bird in any hunt period (Aebischer et al. 1993b)). I then used the transformed proportional habitat use data in a split-plot MANOVA (PROC GLM, SAS Institute 2007) to test for differences in use of habitat types among individual female, female age, winter, and hunt period within winter. I used variation due to individual females as the error term to test for effects of female age, winter, and their interaction, and residual error to test for effects of individual females, hunt period, and all other interactions. I began with a full model (including all possible interactions) 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 IDLE by testing whether least-square means of

log-ratios differed ($P < 0.05$) from zero (Aebischer et al. 1993a) as described by Cox and Afton (1997).

Use of Marsh Types

Brackish and salt marsh received little use (<2% and tr., respectively); thus, I pooled them (BRALT) for statistical analysis (see below) in order to eliminate a large number of zero values (Aebischer et al. 1993b). Accordingly, I classified all MARSH locations and calculated proportional use of the 3 types (FRESH, INTERMEDIATE, and BRALT) for each female in each hunt period (SHUNT and POST) for diurnal and nocturnal locations separately, and constructed 2 log-ratios by dividing the proportional use of each marsh type by proportional use of INTERMEDIATE, then taking the napierian logarithm. I replaced zero values with 0.003 (an order of magnitude smaller than the lowest non-zero marsh type recorded for any bird in any hunt period [Aebischer et al. 1993b]). I then used the transformed proportional MARSH use data in a split-plot MANOVA (PROC GLM, SAS Institute 2007) to test for differences in use of marsh types among individual females, female age, winter, and hunt period within winter. I used variation due to individual females 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, and all other interactions. I began with a full model (including all possible interactions) 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 marsh types relative to INTERMEDIATE by testing whether least-square means of log-ratios differed ($P < 0.05$) from zero (Aebischer et al. 1993a) as described by Cox and Afton (1997).

Results

Use of CLOSED and OPEN Lands

Diurnal: This analysis included 6,067 diurnal locations on 133 females (n = 80 adults, n = 53 immatures). My final fitted model contained individual female (F = 2.36; 131, 102 df; P < 0.0001), winter (F = 14.34; 1, 102 df; P = 0.0003), and a hunt period-by-winter interaction (F = 71.24; 1, 102 df; P < 0.0001) as significant explanatory variables. All other explanatory variables and interactions were not significant (P > 0.08). Use of CLOSED lands was greater (P < 0.0001) during Winter 2 than during Winter 1. Use of CLOSED lands was greater during SHUNT in Winter 2 than during SHUNT in Winter 1 (P = 0.013, Table 3.1).

Nocturnal: This analysis included 2,358 nocturnal locations on 130 females (n = 78 adults, n = 52 immatures). My final fitted model contained individual female (F = 2.62; 124, 98 df; P < 0.0001), hunt periods (F = 12.94; 1, 98 df; P = 0.0005), and age (F = 12.38; 1, 98 df; P = 0.0007) as significant explanatory variables. All other explanatory variables and interactions were not significant (P > 0.09). Use of CLOSED lands was greater (P = 0.0005) during SHUNT than during POST. Immatures (\bar{x} = 20.6%) used CLOSED lands more so than did adults (\bar{x} = 11.1%, P < 0.0006).

Use of Habitats

Diurnal: This analysis included 6,067 diurnal locations on 133 females (n = 80 adults, n = 53 immatures). My final fitted model contained individual female (F = 2.09; 395, 524 df; P < 0.0001), winter (F = 5.2; 4, 98 df; P = 0.0008), and a hunt period-by-winter interaction (F = 10.49; 4, 98 df; P < 0.0001) as significant explanatory variables. All other explanatory variables and interactions were not significant (P > 0.19). Use of RICE relative to IDLE was greater in Winter 1 than in Winter 2 (P = 0.0003), whereas use of OTHER relative to IDLE was lower in

Table 3.1. Diurnal and nocturnal use (percent^a) of CLOSED and OPEN by radio-marked female mallards by hunt period for winters 2004-2005 (Winter 1) and 2005-2006 (Winter 2) in southwestern Louisiana.

Hunt Period	n ^c	Winter 1 ^b				Winter 2				
		CLOSED		OPEN		CLOSED		OPEN		
		\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	
Diurnal										
FHUNT		-	-	-	-	14	69.4	10.9	30.6	10.9
SPLIT		-	-	-	-	37	65.3	6.2	34.7	6.2
SHUNT	63	36.0	4.0	64.0	4.0	69	52.3	3.6	47.7	3.6
POST	55	16.6	3.8	83.4	3.8	49	13.6	2.4	86.4	2.4
Nocturnal										
FHUNT		-	-	-	-	14	37.5	12.5	62.5	12.5
SPLIT		-	-	-	-	37	36.5	7.9	63.5	7.9
SHUNT	62	17.9	3.8	82.1	3.8	67	23.7	4.3	76.3	4.3
POST	50	6.4	2.6	93.6	2.6	49	7.8	2.8	92.2	2.8

^aComputed by calculating the percentage use of CLOSED and OPEN for each female in each hunt period, and then averaging over females. Data were transformed for the ANOVA and comparisons are from SHUNT and POST only.

^bNo data collected during FHUNT and SPLIT in Winter 1.

^cSample size represents number of radio-marked females monitored.

Winter 2 than in Winter 1 ($P_s < 0.001$, Table 3.2). Use of MARSH relative to IDLE was greater ($P = 0.001$) during SHUNT than during POST, whereas use of RICE relative to IDLE was greater ($P_s < 0.03$) during POST than during SHUNT (Figure 3.2).

Nocturnal: This analysis included 2,358 nocturnal locations on 130 females ($n = 78$ adults, $n = 52$ immatures). My final fitted model contained individual female ($F = 1.98$; 367, 504 df; $P < 0.0001$), female age ($F = 2.78$; 4, 123 df; $P = 0.03$), winter ($F = 2.18$; 4, 123 df; $P = 0.075$), hunt period-by-winter interaction ($F = 3.7$; 4, 91 df; $P = 0.008$), and an age-by-winter interaction ($F = 4.41$; 4, 91 df; $P = 0.003$) as significant explanatory variables. All other interactions were not significant (P 's > 0.11). Use of MARSH, RICE, PASTURE, and OTHER relative to IDLE did not differ ($P_s > 0.103$) between SHUNT and POST (Table 3.3). Immatures used MARSH and OTHER relative to IDLE more so than did adults in both winters ($P_s < 0.02$), whereas adults used RICE relative to IDLE more so than did immatures during both winters ($P_s < 0.04$, Table 3.4). Adults used MARSH ($P < 0.03$) and RICE ($P < 0.0001$) relative to IDLE more so in Winter 1 than in Winter 2 (Table 3.5). Use of PASTURE relative to IDLE did not differ ($P_s > 0.4$) between female ages.

Use of Marsh Types

Diurnal: This analysis included 3,005 diurnal locations on 133 females ($n = 80$ adults, $n = 53$ immatures). My final fitted model contained individual female ($F = 2.16$; 262, 182 df; $P < 0.0001$) and winter ($F = 137.95$; 2, 91 df; $P < 0.0001$) as significant explanatory variables. All other explanatory variables and interactions were not significant ($P > 0.08$). Use of FRESH relative to INTERMEDIATE was greater in Winter 2 than in Winter 1 ($P = 0.0001$). Use of BRALT relative to INTERMEDIATE was low (0-0.9%) in both winters.

Table 3.2. Diurnal use (percent^a) of habitats (MARSH = marsh, IDLE = tillable land not planted into a cash crop and moist soil, RICE = rice, PASTURE = cattle pasture, and OTHER = forested wetlands, soybeans, and sugarcane) by female mallards by hunt period within each winter in southwestern Louisiana.

Winter	Hunt Period	n ^b	MARSH		IDLE		RICE		PASTURE		OTHER	
			\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
2004-2005	SHUNT	63	68.7	2.1	6.6	1.7	14.2	2.9	7.7	2.1	2.7	1.3
	POST	55	48.6	4.7	10.9	3.1	26.3	4.0	11.0	2.6	3.2	1.5
2005-2006	FHUNT	14	69.4	9.9	11.2	5.6	12.2	7.3	7.1	7.1	0	0
	SPLIT	37	64.3	5.9	16.8	4.7	13.0	4.2	5.9	2.8	0	0
	SHUNT	69	66.6	3.0	11.4	1.9	12.2	2.2	5.6	1.4	4.2	1.2
	POST	49	41.5	5.0	17.6	3.6	18.4	3.5	12.7	3.1	9.8	3.2

^aComputed by calculating the percentage use of each habitat for each female in each hunt period, and then averaging over females. Data were transformed for the MANOVA and comparisons are from SHUNT and POST only.

^bSample size represents number of radio-marked females monitored.

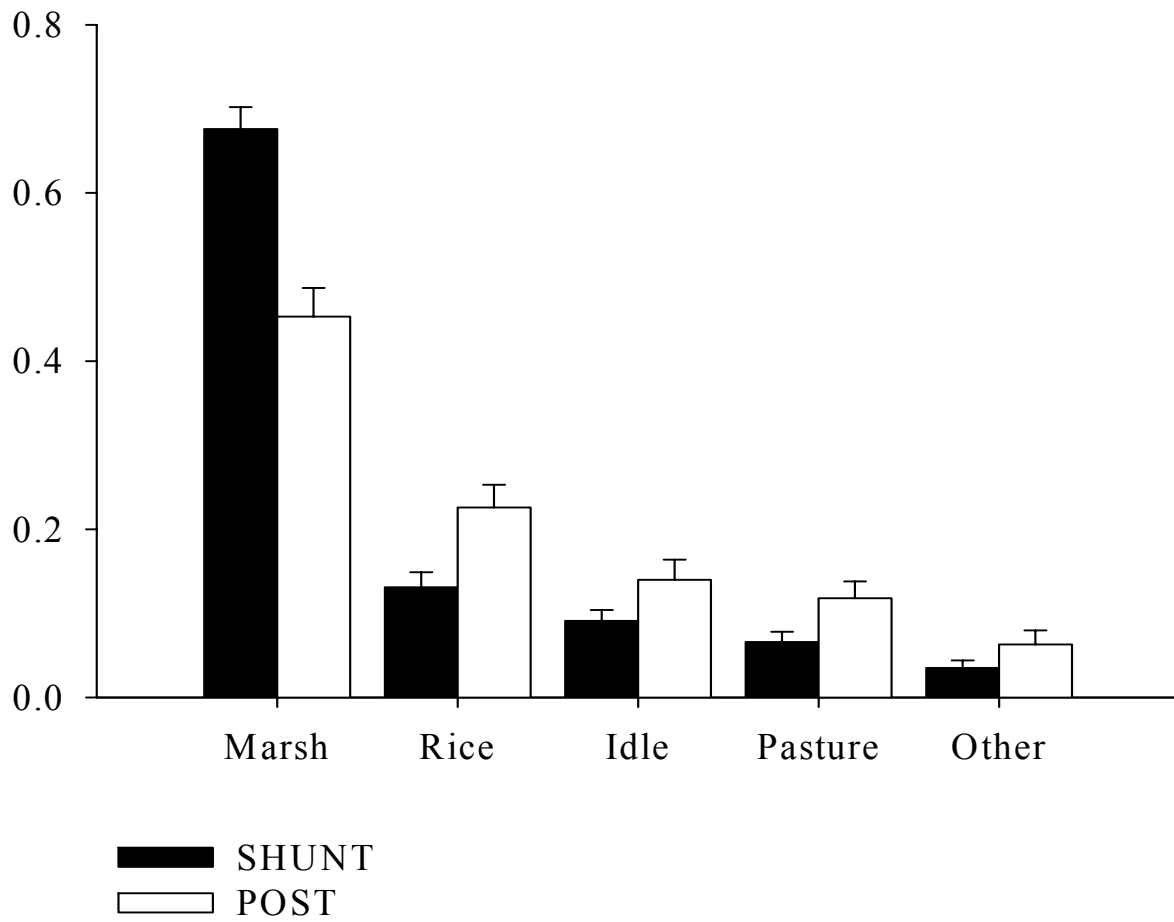


Figure 3.2. Diurnal use of habitats by female mallards by hunt period for winters 2004-2005 and 2005-2006 combined in southwestern Louisiana.

Table 3.3. Nocturnal use (percent^a) of habitats (MARSH = marsh, IDLE = tillable land not planted into a cash crop and moist soil, RICE = rice, PASTURE = cattle pasture, and OTHER = forested wetlands, soybeans, and sugarcane) by female mallards and hunt period each winter in southwestern Louisiana.

Winter	Hunt Period	n ^b	MARSH		IDLE		RICE		PASTURE		OTHER	
			\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
2004-2005	SHUNT	62	40.6	5.2	14.0	3.2	30.4	4.7	13.4	3.3	1.6	0.6
	POST	50	23.4	4.3	16.8	4.0	38.2	5.1	18.0	3.6	3.6	1.3
2005-2006	FHUNT	14	39.3	11.6	26.8	8.9	19.6	7.9	14.3	8.6	0	0
	SPLIT	37	21.6	6.6	36.5	7.4	27.0	6.9	14.9	5.4	0	0
	SHUNT	67	26.4	4.0	28.0	3.8	31.0	4.3	13.2	3.3	1.4	0.6
	POST	46	24.8	5.1	29.9	4.9	25.6	4.7	18.1	3.7	1.6	0.6

^aComputed by calculating the percentage use of each habitat for each female in each hunt period, and then averaging over females. Data were transformed for the MANOVA and comparisons are from SHUNT and POST only.

^bSample size represents number of radio-marked females monitored.

Table 3.4. Nocturnal use (percent^a) of habitats (MARSH = marsh, IDLE = tillable land not planted into a cash crop and moist soil, RICE = rice, PASTURE = cattle pasture, and OTHER = forested wetlands, soybeans, and sugarcane) by adult and immature female mallards during winters 2004-2005 and 2005-2006 combined in southwestern Louisiana.

	Adult		Immature	
	\bar{x}	SE	\bar{x}	SE
MARSH	24.9	2.8	36.1	4.0
IDLE	22.0	2.5	22.2	3.3
RICE	33.8	3.0	27.6	3.7
PASTURE	17.6	2.3	11.8	2.5
OTHER	1.8	0.5	2.2	0.6

^aComputed by calculating the percentage use of each habitat for each female in each hunt period, and then averaging over females. Data were transformed for the MANOVA and comparisons are from SHUNT and POST only.

Table 3.5. Nocturnal use (percent) of habitats (MARSH = marsh, IDLE = tillable land not planted into a cash crop and moist soil, RICE = rice, PASTURE = cattle pasture, and OTHER = forested wetlands, soybeans, and sugarcane) by adult and immature female mallards for winters 2004-2005 (Winter 1) and 2005-2006 (Winter 2) in southwestern Louisiana.

	Winter 1				Winter 2			
	Adult		Immature		Adult		Immature	
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
MARSH	31.7	4.1	36.2	7.0	15.0	3.2	36.0	4.9
IDLE	13.5	2.7	19.7	5.8	34.3	4.3	23.6	4.0
RICE	35.1	4.0	30.6	6.8	31.7	4.7	26.0	4.4
PASTURE	17.6	2.9	10.0	4.2	17.6	3.8	12.9	3.2
OTHER	2.1	0.8	3.5	1.3	1.4	0.7	1.5	0.6

^aComputed by calculating the percentage use of each habitat for each female in each hunt period, and then averaging over females. Data were transformed for the MANOVA and comparisons are from SHUNT and POST only.

Nocturnal: This analysis included 656 diurnal locations on 95 females (n = 53 adults, n = 42 immatures). My final fitted model contained individual female ($F = 2.18$; 186, 86 df; $P < 0.0001$) and winter ($F = 15.13$; 2, 92 df; $P < 0.001$) as significant explanatory variables. All other explanatory variables and interactions were not significant (P 's > 0.12). Use of FRESH relative to INTERMEDIATE was higher in Winter 2 than in Winter 1 ($P = 0.0001$, Table 3.6). Use of BRALT relative to INTERMEDIATE was low (0-1.9%) in both winters.

Discussion

My estimates of the use of CLOSED lands could be biased high if birds marked on CLOSED tend to use closed areas more so than do those marked on open areas (c.f. Blohm et al. 1987). Diurnal use of CLOSED during SHUNT in Winter 1 was relatively low (36%). My radio-marked mallards did not shift abruptly from OPEN to CLOSED (Table 2.1) in response to hunting in Winter 2 as reported for pintails in California (Fleskes 2002), Louisiana (Cox and Afton 1997), and Mexico (Migoya et al. 1994).

The higher use of CLOSED in Winter 2 may have been due to effects of Hurricane Rita rather than hunting. Lacassine Pool was one of few marsh areas that sustained minimal storm damage and my radio-marked females concentrated there in Winter 2. For example, proportional use of Lacassine Pool increased from 0.026 to 0.202 in Winter 1 and Winter 2, respectively. Additionally, 18 of 28 females captured on Cameron Prairie NWR in Winter 2 subsequently were located on Lacassine Pool. The high use of Lacassine Pool by radio-marked mallards may be partially explained by the capture of 67% of our sample there in Winter 2. However, numbers of mallards surveyed on Lacassine Pool during mid-December increased nearly 300% from Winter 1 to Winter 2 (W. Syron, Lacassine NWR, unpubl. data).

Table 3.6. Diurnal and nocturnal use (percent^a) of marsh habitats by female mallards during winters 2004-2005 (Winter 1) and 2005-2006 (Winter 2) in southwestern Louisiana.

	Winter 1		Winter 2	
	\bar{x}	SE	\bar{x}	SE
Diurnal				
FRESH	64.6	3.7	99.8	0.1
INTERMEDIATE	34.5	3.6	0.2	0.1
BRALT ^b	0.9	0.5	0.0	0.0
Nocturnal				
FRESH	66.1	5.0	99.2	0.8
INTERMEDIATE	31.9	5.0	0.8	0.8
BRALT ^b	1.9	1.4	0.0	0.0

^aComputed by calculating the percentage use of each marsh type for each female in each hunt period, and then averaging over females.

^b Brackish and Salt marsh types were combined (BRALT). Data were transformed for the ANOVA and comparisons are from SHUNT and POST only.

The few other OPEN marsh areas that were not impacted by the storm surge (e.g. Cherry Ridge and Florence Club marsh areas; both of which are north of the Intracoastal Canal) received high diurnal use by radio-marked mallards despite hunting on these areas. Paulus (1984) suggested that waterfowl could expend greater energy avoiding disturbance when using high-quality habitats. The relatively low diurnal use of CLOSED by mallards in SHUNT during Winter 1 (Table 3.1) may have occurred because high quality habitat was more abundant on OPEN lands in that winter.

Diurnal and nocturnal use of OPEN increased from SHUNT to POST in Winter 1 and throughout Winter 2. Mean use of CLOSED was higher during the day than at night during all hunt periods. These results suggest that mallards may be responding to common diurnal disturbances such as duck hunting, agricultural activities, and bird watching. Greater diurnal than nocturnal use of CLOSED during SPLIT and POST during Winter 2 may be related to disturbances other than duck hunting such as small game, goose, and deer hunting seasons, agricultural practices, and bird watching or simply a continuation of a successful strategy of returning to CLOSED prior to dawn.

Hurricane Rita directly affected habitat acreages between winters by causing high soil salinities, breached levees, and damaged farm implements. Indirect affects of Hurricane Rita also affected habitat acreages between winters, such as preventing freshwater pumping, displacing farm operators, and increasing fuel prices (USDA 2005). The most significant hurricane effect was salt burn and vegetation scouring of freshwater marsh (Neyland 2007). Despite the marked reduction in quality and quantity of freshwater marsh in Winter 2, diurnal use of MARSH was used at over twice the proportion as was the next selected habitat during both winters, thus, clearly emphasizing the importance of MARSH to wintering mallards.

Chabreck et al. (1989) reported that freshwater marsh was the most important waterfowl habitat among Louisiana, Mississippi, and Alabama coastal habitats. Of the 3 types of marsh, freshwater marsh was the most highly used by mallards (64.6-99.8% of proportional marsh use) in my study. In conclusion, my telemetry results are consistent with observations of Chabreck et al. (1989), suggesting that freshwater marsh is an important habitat for wintering mallards in southwest Louisiana.

My results also indicate that nocturnal MARSH use by mallards was high during both winters and hunt periods and use was relatively greater than that reported for northern pintails (Cox and Afton 1997). Nocturnal use of MARSH may have declined from Winter 1 to Winter 2 due to negative impacts of Hurricane Rita on the quality and quantity of freshwater marshes. The difference in use of RICE and IDLE may have been influenced by availability within the core study area (Table 3.7); RICE acreage and use was greater in Winter 1 than in Winter 2, whereas IDLE acreage and use was greater in Winter 2 than in Winter 1 (Table 3.2 and Table 3.3).

Management Implications

I found that freshwater marsh (65-99% proportional use) received the highest use by radio-marked female mallards, despite the fact that freshwater marsh comprises only 27% of northern Gulf Coast marshes (Chabreck et al. 1989). Based on my results, I conclude that freshwater marsh is an important habitat of mallards wintering along the Gulf Coast. Given that Gulf Coast marshes are disappearing at an alarming rate (Gagliano et al. 1981), my results suggest that mallards wintering in this area would benefit from programs and activities that target freshwater marsh for restoration and management.

Table 3.7. Summary of RICE, IDLE, and PASTURE (acres) by parish and winter in southwestern Louisiana.

Parish	RICE ^a			IDLE ^b			PASTURE ^b		
	2004-2005	2005-2006	% Change	2004-2005	2005-2006	% Change	2004-2005	2005-2006	% Change
Acadia	90,600	82,600	-8.8	92,000	138,000	+50.0	25,000	22,000	-13.6
Calcasieu	17,400	15,800	-9.2	90,000	128,000	+42.2	125,000	200,000	+60.0
Cameron	14,300	13,400	-6.3	55,000	63,000	+14.5	215,000	220,000	+ 2.3
Jeff Davis	86,000	82,400	-4.2	82,200	116,700	+42.0	44,500	42,000	- 6.0
Vermilion	83,200	76,400	-8.2	95,200	125,200	+32.0	63,500	76,100	+20.0
Combined	291,700	270,600	-7.2	414,400	570,900	+37.8	473,000	560,100	+18.4

^a<http://www.lsuagcenter.com/NR/rdonlyres/C68D058F-8F01-4239-849C-0D4BC0053E47/19225/2005Summary.pdf>

^bData provided by FSA offices in each parish.

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Chapter 4. Diel Movements of Female Mallards Wintering in Southwestern Louisiana

Introduction

Distributions and movements of wintering waterfowl often are influenced by the juxtaposition of sanctuary and hunted lands (Raveling 1978, Frederick and Klaas 1982, Humburg et al. 1985, Fleskes et al. 2002). Understanding movement parameters of waterfowl is crucial to managing winter habitats, especially along the Gulf Coast where hunting pressure is high (Cox et al. 1998). Except for northern pintails (*Anas acuta*, hereafter pintails, Cox and Afton 1996), little is known about diel movements of dabbling ducks wintering on the Gulf Coast Chenier Plain (GCCP).

Cox and Afton (1996, 1997) reported distinct movements of pintails from diurnal roost sites to nocturnal feeding sites (i.e., diel movements) within the GCCP. Other studies have reported increased flight distance from concentration areas over time as nearby food resources became limiting (refuging theory; Hamilton and Watt 1970, Cox and Afton 1996). If mallards exhibit similar patterns in their movements, identifying critical habitats and the role and distribution of sanctuary lands could facilitate more effective management and acquisition efforts.

Diurnal habitat types used by mallards and other ducks also could affect diel movements. Pintails spent 18% and 21% of the diurnal time period foraging on non-hunted rice fields (Miller 1985, Rave and Cordes 1993, respectively), whereas pintails spent only 5% of the diurnal time period foraging on non-hunted marsh habitats (Tamisier 1976). Additionally, waterfowl habitats differ in the quantity of energy per unit area produced and in the number of waterfowl they can support (Fredrickson and Taylor 1982, Miller 1987). Thus, foraging intensity and distances

traveled between diurnal and nocturnal sites likely is conditional upon the type of habitat and available food resources at the diurnal site.

Areas closed to hunting may differ in proximity to agricultural fields, which may be used as nocturnal foraging areas (Cox and Afton 1997). Thus, I examined variation in flight distances from diurnal locations on areas closed (Cameron Prairie NWR, Lacassine NWR, and Amoco Pool) and open to hunting.

Cox and Afton (1996) reported that flight distances between diurnal roost sites and nocturnal feeding sites varied by female age for pintails. Thus, I also examined effects of age on movement distances of female mallards.

The quantity and quality of waterfowl habitats varied markedly between winters of my study (Neyland 2007, Chapter 3). Hurricane Rita, the most intense tropical cyclone ever observed in the Gulf of Mexico (Johnson 2006), came ashore in southwestern Louisiana on 24 September 2005 as early migrating waterfowl were arriving on the GCCP. Thus, impacts of Hurricane Rita on available habitat also could have affected mallard movement distances.

Accordingly, I used radio-telemetry to investigate diel movements of female mallards in southwestern Louisiana. My objectives were to quantify flight distance between diurnal and nocturnal locations, including comparisons among: (1) individual females, (2) diurnal habitat types used, (3) birds originating on areas closed and open to hunting during diurnal periods, (4) female age, (5) winter (2004-2005 hereafter Winter 1; 2005-2006, hereafter Winter 2), and (6) date within winter.

Study Area

I studied female mallards wintering in southwest Louisiana and assumed that this area is representative of the GCCP. My study area included all lands within Cameron, Calcasieu,

Jefferson Davis, Acadia, and Vermillion Parishes (Figure 4.1). The Chenier Plain of southwest Louisiana extends 60 to 110 km inland from the Gulf of Mexico and encompasses more than 2.5 million ha (Chabreck et al. 1989). The two primary waterfowl habitats of the region are coastal marshes and rice agriculture, which is located immediately inland from coastal marshes (Chabreck et al. 1989).

I monitored diel movements within 80 km of capture sites (Cameron Prairie National Wildlife Refuge, 29°56'N, 93°02'W, Amoco Pool, 29°50'N, 92°34'W, and Lacassine National Wildlife Refuge, 29°57'N, 92°55'W). The GCCP and Amoco Pool were described in detail by Chabreck et al. (1989).

Methods

I selected potential trapping sites based on observations of concentrated waterfowl use in areas that were approved for bait-trapping by federal law enforcement agents. All trapping sites were located on areas closed to hunting and were > 1.6 km to the nearest hunting blinds. I baited sites with various combinations of unmilled rice, corn, barley, millet, sorghum, soybeans, sweet potatoes, crushed oyster shells, and sand. I captured mallards using portable rocket-net platforms (Cox and Afton 1994) and deployed nets using a remote detonator (Sharp and Lokemoen 1980).

Upon capture, female mallards were removed from nets, placed in catch boxes, and then transported to a temporary structure (screened canopy) for processing. I provided food and water *ad libitum* to captured birds during the banding and marking process (LSU Institutional Animal Care and Use Committee Protocol #04-108 and U.S. Geological Survey Banding Permit # 08810). I determined age (adult [after hatch year] or immature [hatch year]) and sex from body and wing plumage characteristics (Carney 1964).

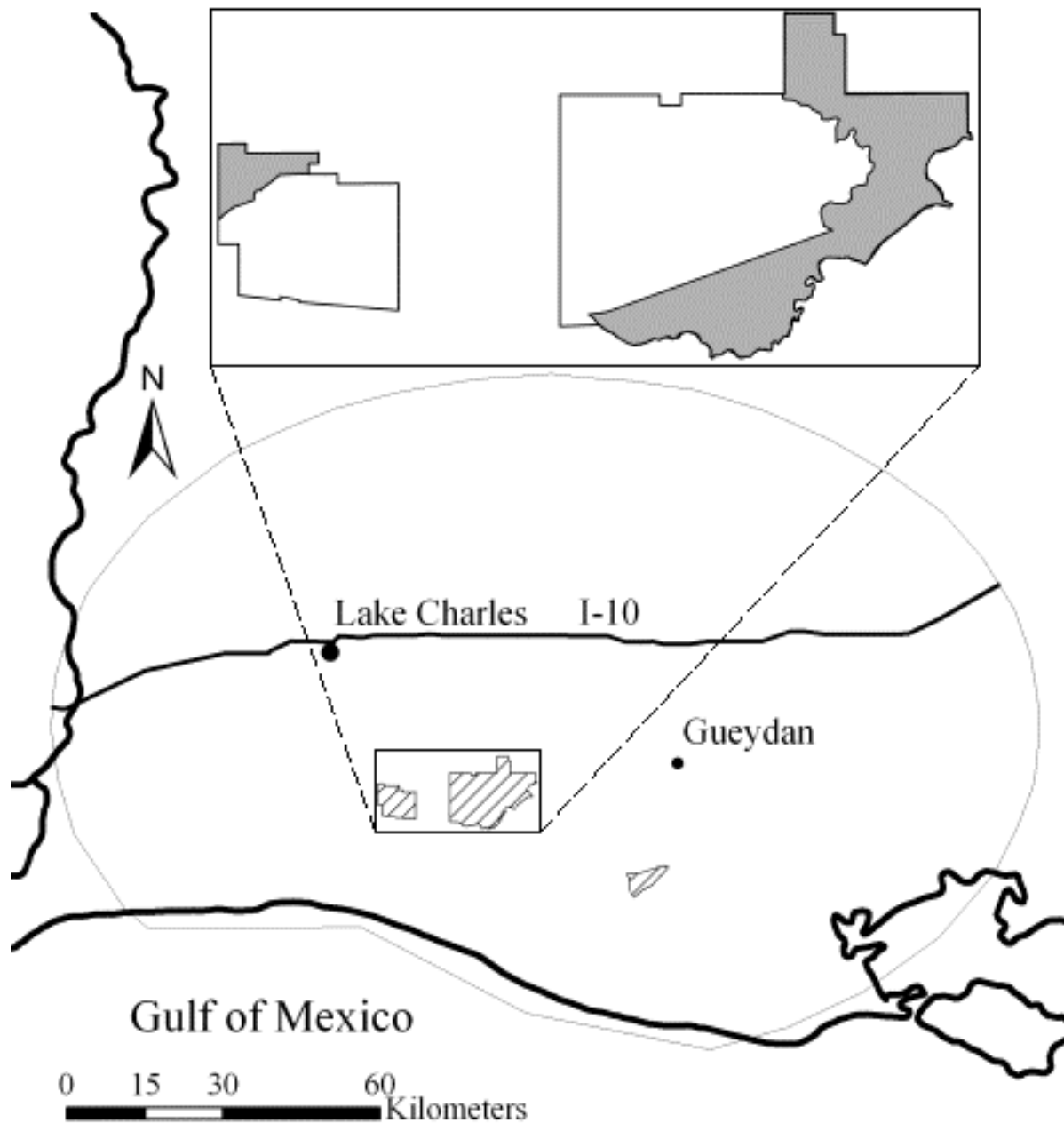


Figure 4.1. Location of core study area in southwest Louisiana. Hatched polygons are mallard capture locations (Cameron Prairie NWR, Lacassine NWR, and Amoco Pool, from left to right, respectively). Inset designates hunted portions (shaded areas) and non-hunted portions of Cameron Prairie NWR and Lacassine NWR in Winter 1. Hunting was prohibited on both refuges in Winter 2 and on Amoco Pool during both winters.

When numbers of females captured exceeded the number of available transmitters, I randomly selected immatures and adults so that equal numbers of each age were radio-marked. I fitted female mallards with a 21-g, harness-type transmitter (Dwyer 1972; Advanced Telemetry Systems, Inc., Isanti, MN) with an expected life of 160 days. I tightened neck and body loops such that an index finger would fit under each loop and preened feathers around the harness (Houston and Greenwood 1972). I used alligator clips while adjusting harness tension, tied double overhand knots on the final harness loop, and used purple primer and all-purpose cement (Oatey, Cleveland, OH) on attachment points

I radio-marked a total of 149 females ($n = 91$ adults and 58 immatures) and excluded 14 females from analysis that died ($n = 10$ from avian predation, $n = 2$ from mammalian predation) or emigrated from the core study area ($n = 2$) during an initial 4-day adjustment period (Cox and Afton 1998). I released radio-marked females in groups at capture sites from 4-14 h after capture (overnight for birds captured at dusk). I also included 6 female mallards ($n = 5$ adults and 1 immature) using my study area that were radio-marked in northeast LA by Bruce Davis. Thus, my final sample size was 141 females ($n = 87$ adults and 54 immatures).

My technicians and I tracked radio-marked birds in 4 vehicles equipped with 4-element, null-peak antenna systems, electronic compass, GPS units (GPS 76, Garmin© Corporation, Olathe, KS), and laptop computers (Cochran 1980:517-518; Cox and Afton 1997, 1998, Cox et al. 2002). Vehicle tracking systems were equipped with electronic compasses (Azimuth® 1000R, KVH Industries, Inc., Middletown, RI) and were empirically calibrated to within 0.5° . I used LOAS (Location of a Signal) software to estimate locations on site (LOAS 2003). I used the Universal Transverse Mercator coordinate system for all location estimations.

Prior to radio-tracking mallards, I trained technicians, using hidden beacon transmitters, until each technician was able to maintain a bearing standard deviation of ≤ 3 degrees. I constructed 2, 13-m permanent towers; each tower supported a single 9-element unidirectional antenna to reduce aircraft time needed to locate birds in Amoco Pool, which was inaccessible by truck. I used aerial telemetry techniques to locate missing birds (Gilmer et al. 1981). Flights were conducted at altitudes (Range = 300 m to 3050 m) such that all radio-marked birds present on the core study area could be located.

I located all birds present on the core study area daily or as often as permitted by weather and pilot availability. All movement distances were indirectly estimated from diurnal and nocturnal locations collected within the same 24-hour period. I define diurnal and nocturnal locations as those collected 0.5 hour before sunrise to 0.5 hour after sunset and 0.5 hour after sunset to 0.5 hour before sunrise, respectively. Cox and Afton (1997) reported that pintails infrequently made additional flights at night and that indirect methods could be used to collect reliable estimates of movement distance.

To test for possible effects on movement distances due to diurnal use of areas open or closed to hunting, I classified each diurnal location according to land management category as either OPEN or closed to hunting. I further tested for individual location effects on movement distance for each of the following areas closed to hunting: Amoco Pool (AMOCO) and portions of Cameron Prairie NWR (CAM) and Lacassine NWR (LAC, Figure 4.1) in Winter 1 and the entire acreage of CAM and LAC in Winter 2. Hunting programs were cancelled on CAM and LAC during Winter 2 following Hurricane Rita. OPEN areas included all privately owned lands

and hunted portions of Cameron Prairie NWR (units 11A, 14A, and 14B) and Lacassine NWR (units B, H, I, J, F1, F2, and F3) in Winter 1.

When possible, my technicians and I identified habitats of radio-marked birds immediately on site; otherwise I used ground surveys, aerial photography, satellite imagery, or FSA records and mail out questionnaires to landowners. I classified diurnal habitats as: (1) MARSH; (2) tillable lands planted in rice (RICE); (3) IDLE (including: 1] moist soil, e.g. agricultural land in which water was intentionally retained, either by pumping or runoff and 2] idle cropland, e.g. fallow agricultural land not planted to a commodity crop and not flooded); (4) tillable lands planted to native or tame grasses and maintained dry (PASTURE); and (5) OTHER (forested wetlands, soybeans, and sugarcane).

Statistical Analysis

I excluded the first 4 days post-capture from all analyses to minimize effects of capture and handling on movement distances (Cox et al. 1998). I used the Pythagorean theorem to calculate movement distances (± 1 m) between diurnal and nocturnal coordinates obtained within a 24-hour period. I normalized movement distances using a natural-log transformation and used the transformed data as a response variable in a repeated-measures, mixed model ANCOVA (PROC MIXED, SAS 2007) with maximum likelihood estimation to evaluate relationships of the transformed distances. I considered winter (Winter 1 or Winter 2), female age (immature or adult), land management category (CAM, LAC, or OPEN), and habitat (MARSH, RICE, IDLE, PASTURE, or OTHER), including all 2-way interactions, as fixed effects in the model. Individual females were included in the model as a random effect and date within wintering period. I defined date within winter as days since 26 Nov, the first date that movement data were collected (hereafter date) as the covariate. I analyzed AMOCO movement distances in a separate

model because dates that movement data were recorded differed markedly from that of other areas. I also excluded habitat as an explanatory variable from this model because all AMOCO locations were in marsh.

I used minimum AIC model selection procedures (Akaike 1981) with residual likelihood estimation to assess the matrix structure of repeated measures as either simple, compound, or first order autoregressive and maintained the appropriate structure throughout model fitting (Wolfinger 1992). I began with a full model (including all 2-way interactions) 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 least-square means of significant ($P < 0.05$) effects using Fisher's Protected LSD (PDIF option PROC MIXED; SAS 2007). I tested significant interactions involving date by testing whether slopes of regression lines differed from zero and compared slopes among levels of fixed effects (NOINT and SOLUTIONS options PROC MIXED; SAS 2007).

Results

CAM, LAC, and OPEN analysis

For this analysis, I analyzed 2,380 observations on 125 females ($n = 76$ adults and 49 immatures). I used first order autoregression ($\Delta AIC = 182.7$) for final model fitting. My final model indicated that movement distances from the various land management categories were not consistent by date (date-by-land management interaction; $F = 5.74$; 2, 2242 df; $P = 0.003$) or by winter (winter-by-land management interaction; $F = 9.65$; 2, 2242 df; $P < 0.0001$). All other explanatory variables and interactions were not significant ($P_s > 0.06$). Flight distances from LAC increased with date ($P = 0.006$), whereas flight distances from CAM and OPEN did not vary by date ($P_s > 0.11$, Figure 4.2). Flight distances from CAM during Winter 1 were greater

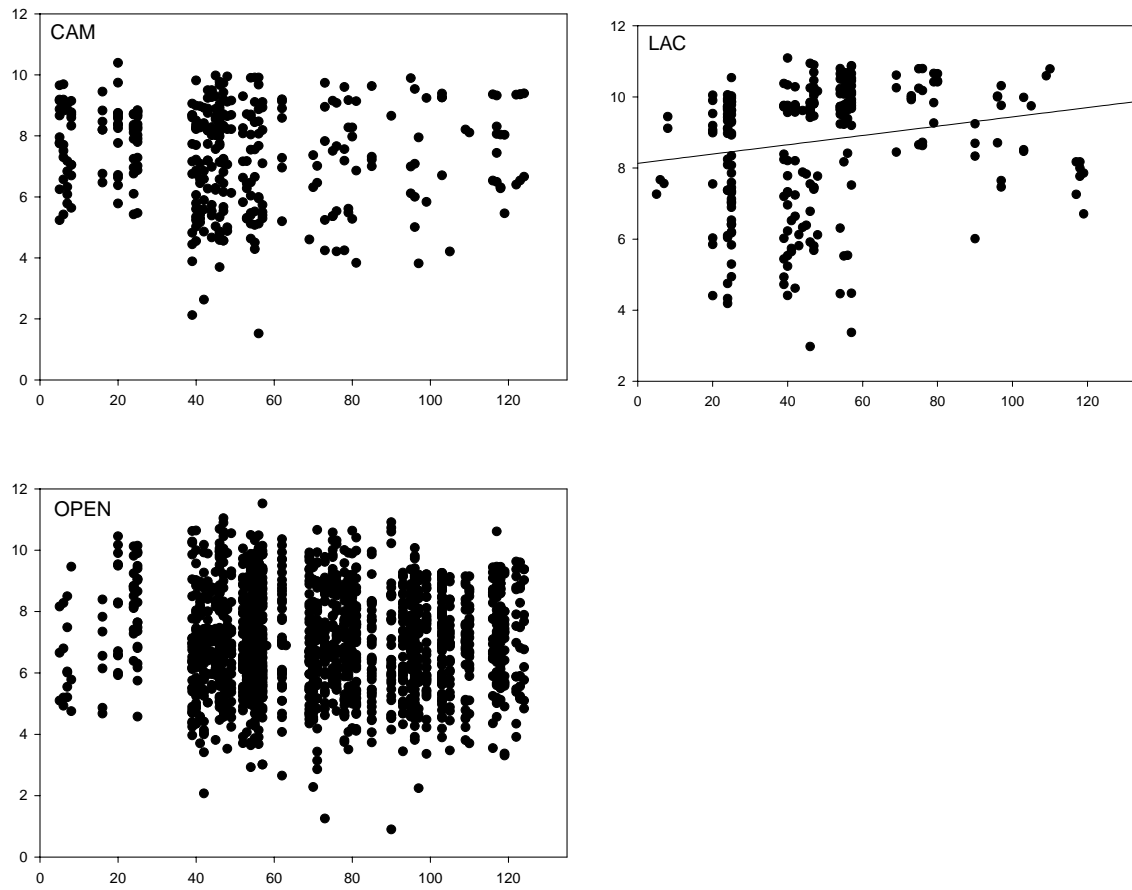


Figure 4.2. Movement distances (natural log m) by day of winter (days past 26 Nov) for each land management category (CAM, LAC, and OPEN). Flight distances from LAC were significantly correlated by date; the line depicted is based on the estimated intercept (8.1301) and slope (0.01307) from the final mixed model ANCOVA.

than those from OPEN during Winter 1 ($P < 0.0001$) and CAM during Winter 2 ($P = 0.02$; Table 4.1). Flight distances from LAC were greater in Winter 2 than in Winter 1 ($P = 0.01$; Table 4.1). Flight distances from LAC in Winter 2 were markedly greater than those from CAM ($P < 0.0001$) and OPEN ($P < 0.0001$; Table 4.1).

AMOCO analysis

For this analysis, I analyzed 75 observations (Winter 1, $n = 69$; Winter 2 $n = 6$) on 24 females ($n = 16$ adults and 8 immatures). The simple matrix structure fit the data better than did compound or first order autoregression ($\Delta AIC = 2.0$). I failed to detect effects of any explanatory variables on movement distances from AMOCO ($P_s > 0.08$). Flight distances from AMOCO ranged from 0.06-26.4 km, with a mean (\pm SE) of 11.3 ± 0.9 km, and median of 13.2 km.

Discussion

Mean flight distances of individual females varied among land management categories, ranging from 3.1 to 15.0 km. These are minimum estimates of flight distances because occasional monitoring of radio-marked females indicated that they were in flight for 20 to 90 minutes post sunset (P. Link, personal observation). During this time (within an hour after sunset), females rarely remained in one location long enough for my technicians and I to triangulate their location. Similar to pintails (Cox and Afton 1996), after finally settling, occasional monitoring by my technicians and I indicated that female mallards rarely made additional flights until pre-dawn hours.

My results from AMOCO should be viewed with caution given the small numbers of females and flights observed as well as the varying habitat conditions there between winters.

Table 4.1. Numbers of female mallards (n), flights observed (Flights), and distances ($\pm 1m$) flown from diurnal sites by land management category each winter in southwestern Louisiana. Natural-log transformations were used in the ANCOVA.

Winter	Land Mgt	n	Flights	Distance Flown			
				\bar{x}	SE	Median	Range
2004-2005	CAM	25	171	4,564	415	1,928	46-21,526
	LAC	6	24	4,387	1,371	776	82-25,790
	OPEN	62	887	3,112	169	1,053	10-42,684
2005-2006	CAM	22	179	3,442	312	2,222	5-32,579
	LAC	50	220	14,974	949	14,242	20-65,448
	OPEN	58	899	4,349	273	1,165	2-100,830

Levee maintenance on AMOCO in Winter 1 mandated that the annual spring draw down occur later than normal in that winter. As a result, forage production and subsequent waterfowl use was lower than in most years (W. Lamair, White Lake Preservation, Inc, pers. comm.).

Hurricane Rita inundated AMOCO with 2.5 m of storm surge, which was retained throughout Winter 2 (R. Helm, LDWF, pers. comm.).

Mallard flight distances varied inconsistently between winters and land management categories. Surprisingly, females originating on CAM had greater flight distances during Winter 1 than Winter 2, despite much of CAM being inundated with saltwater storm surge from Hurricane Rita and the inability to pump freshwater for moist soil management (M. Hoff, Cameron Prairie NWR, pers. comm.). The refuge hunting program and the auto tour route was closed during Winter 2, which probably reduced human disturbance and thus may have increased diel use of CAM during Winter 2.

Flight distances from birds originating on LAC were greater during Winter 2 than during Winter 1, and in Winter 2 were markedly greater than were flights from CAM or OPEN (Table 3.1). Additionally, female mallards originating on LAC increased flight distance throughout winter, which is consistent with refuging theory and previous observations for radio-marked pintails (Hamilton and Watt 1970, Cox and Afton 1996).

Numbers of mallards surveyed on LAC during mid-December increased nearly 300% from Winter 1 to Winter 2 (W. Syron, Lacassine NWR, unpubl. data) and proportional use of Lacassine Pool increased from 0.026 to 0.202 in Winter 1 and Winter 2, respectively (Chapter 2). Cox and Afton (1996) hypothesized that hunting leases and habitats managed for waterfowl hunting adjacent to LAC are flooded earlier in winter than are more distant areas. Additionally, late winter rains create additional foraging habitats farther from refuge areas (Cox and Afton

1996). Thus, Cox and Afton (1996) suggested that increased flight distances of birds from LAC may be in response to newly flooded habitats rather than food depletion. However, female mallards originating on AMOCO, CAM, or OPEN did not increase flight distance through winter. Thus, flight distances seemingly vary among waterfowl species and among specific refuges in southwestern Louisiana.

I failed to detect effects of diurnal habitat type on movement distances. Mallards are highly adaptable in their use of habitats (Bellrose 1988) and appear to use some habitats in relation to availability in the GCCP (Chapter 2). Several studies have reported that agricultural fields produce greater energy per unit area than do natural wetlands (Fredrickson and Taylor 1982, Miller 1987); however, the amount of waste grain available to wintering waterfowl has declined in recent years (Manley et al. 2004, Stafford et al. 2006). While agricultural fields may provide more food resources for a short period, natural foods are more nutritionally balanced than are those consisting of waste grains (Haukos 1991) and also provide essential nutrients that are not available from waste grains (Loesch and Kaminski 1989). Thus, despite non-agricultural habitats having lower energy per unit area than agricultural habitats, mallards may be able to acquire most of their energetic requirements from or in close proximity to non-agricultural habitats (e.g. marsh, pasture).

In conclusion, female mallards moved relatively short distances between diurnal and nocturnal sites as compared to female pintails in the same area (Cox and Afton 1996), suggesting that mallards are able to meet their daily energy requirements within a relatively small area, and thus minimize transit energy costs. Flight distances varied inconsistently among land management categories and between winters, which may be related to differences in food

resources, proximity to foraging habitats, numbers of concentrated waterfowl, or a combination of factors.

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Chapter 5. Conclusion

I used radio-telemetry techniques to estimate survival, habitat use, and movements of mallards wintering in southwestern Louisiana. My overall survival estimate for radio-marked female mallards in southwestern Louisiana was 0.68 (Chapter 2), which was lower than reported for those wintering in Mississippi and Arkansas (Reinecke et al. 1987), Texas (Bergan and Smith 1993), and Arkansas (Dugger et al. 1994), but higher than those wintering in northeast Louisiana and southeastern Arkansas (Davis 2007). My estimated hunting mortality rate of female mallards in southwestern Louisiana was 0.28 and was similar between female ages ($P = 0.9634$). This rate was the highest on record for adult female dabbling ducks, and was surpassed only by the hunting mortality rate of immature northern pintails (0.315) in southwestern Louisiana. I found that body condition at time of capture had a significant effect on survival; birds in low condition survived at a much lower rate than did those in high condition. Additionally, I recorded mortalities after the hunting season for females in low condition at time of capture, but not for females in high condition at time of capture. If increasing winter survival is an objective, management should focus on reducing female hunting and non-hunting mortality. Increased efforts to provide mallard foraging habitats on areas closed to hunting may decrease hunting mortality rates and help to increase female condition.

Diurnal use of areas closed to hunting generally was low in the absence of hurricane effects (Chapter 3). Mean use of areas closed to hunting was higher during the day than at night throughout both winters, which suggests that mallards are responding to common diurnal disturbances such as duck, small game and deer hunters, agricultural activities, and bird watchers. Diurnal use of MARSH was >2 times higher than that of the next selected habitat during both winters, thus, clearly emphasizing the importance of MARSH to wintering mallards.

Freshwater marsh received highest use of all marsh types by female mallards. My results suggest that mallards wintering in this area would benefit from programs and activities that target freshwater marsh for restoration and management.

Finally, female mallards moved relatively short distances between diurnal and nocturnal sites within a 24-hr period (Chapter 4), suggesting they are able to meet their daily energy requirements within a relatively small area, thus minimizing transit energy costs. Flight distances varied inconsistently among land management categories and between winters, which may be related to differences in food resources, proximity to foraging habitats, numbers of concentrated waterfowl, or a combination of factors.

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Vita

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