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Habitat use, movements, and survival of radio-marked female mallards in the lower Mississippi Alluvial Valley

Bruce Edward Davis

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HABITAT USE, MOVEMENTS, AND SURVIVAL OF RADIO-MARKED FEMALE
MALLARDS IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The School of Renewable Natural Resources

by
Bruce Edward Davis
B. S., Iowa State University, 1996
December 2007

To my father, Dean Davis; he introduced me to the pursuits of hunting and fishing when I was very young. He helped to spark an interest in me that has turned into an obsession and a career with wildlife.

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ABSTRACT

Mallard (*Anas platyrhynchos*) populations in the Lower Mississippi Alluvial Valley (LMAV) historically averaged 1.6 million and represented the largest concentrations of wintering mallards in North America. Effective management of this wintering population requires current information on use of habitats, movements, and survival of female mallards. I used radio-telemetry techniques to assess these parameters during winters 2004-2005 and 2005-2006. Radio-marked female mallards used forested wetland habitats extensively during diurnal and nocturnal sampling periods. Proportional use of habitats varied inconsistently among time periods defined by hunting seasons and winters. Proportional use of forested wetlands ranged from 0.464 to 0.816 and from 0.280 to 0.764 during diurnal and nocturnal sampling periods, respectively. Movement distances (\pm SE) between diurnal and nocturnal locations averaged 2524 ± 150.1 meters and varied inconsistently by date among habitat types. The product-limit survival rate of radio-marked female mallards was 0.542 for the 140 day tracking season. Interval survival rates varied among time periods defined by hunting seasons and ranged from 0.721 to 0.981. Cause-specific mortality rates (\pm SE) for the tracking period were 0.177 ± 0.041 and 0.342 ± 0.119 for hunting and non-hunting sources of mortality, respectively. Continued restoration and establishment of forested wetland habitats should benefit wintering mallards in the LMAV. Finally, waterfowl managers may want to consider management actions to improve survival of female mallards in the LMAV.

CHAPTER 1. INTRODUCTION

The Mississippi Flyway is the most important flyway for mallards (*Anas platyrhynchos*) and the Mississippi Alluvial Valley (hereafter MAV) is the most significant mallard wintering area within this flyway (Bellrose 1976). Mallard populations in the lower MAV (LMAV) historically averaged 1.6 million and represented the largest concentrations of wintering mallards in North America (Bartonek et al. 1984). However, landscapes in the LMAV have been altered due to flood-control projects and agricultural drainage, causing extensive wetland losses and degradation (Goldstein 1988). Fragmentation of remaining forested wetlands has been widespread, and less than 25% of native bottomland hardwood habitats remain in the LMAV (Wolf et al. 1986).

Considerable habitat restoration efforts have been undertaken and are ongoing in this region (Forsythe and Gard 1980, Reinecke et al. 1989, King and Keeland 1999). Additional research is needed to refine habitat restoration and management programs. In particular, managers need current information on habitat use, movements, and survival of female mallards using this area to better understand how mallards have been affected by this altered landscape.

Understanding use of habitats by female mallards should provide information to guide habitat restoration activities. Food available in harvested agricultural fields, particularly rice fields, has declined in recent years (Stafford et al. 2006). Patterns of habitat use have not been examined in light of these recent data on declining food value of agricultural habitats to waterfowl. Opportunities exist to restore forested wetlands, moist soil wetlands, and agricultural wetlands; thus, habitat use data could provide

direction for conservation programs geared towards restoring habitats most frequently used by mallards.

Information on movements of female mallards could provide valuable insight to the daily activity patterns of these birds. Refuging theory predicts that congregated individuals will increase distances moved between roosting and foraging areas over time, as resources are depleted near roosting areas (Hamilton and Watt 1970). Refuging theory and foraging resource depletion have been used to explain movements and use of foraging habitats by other waterfowl during winter (e.g. Frederick et al. 1987, Vickery et al. 1995, Cox and Afton 1996, Borbach-Jaene and Kruckenberg 2002). Daily movement distances probably are proportional to energy expenditure and potential exposure to mortality. These increased costs associated with movements by individuals often are predicted to be outweighed by potential benefits (Hamilton and Watt 1970).

Previous radio-telemetry studies have indicated relatively high winter survival rates for mallards in the LMAV. Reinecke et al. (1987) reported a winter survival rate of 0.82 for radio-marked female mallards during the early to mid 1980s. Dugger et al. (1994) reported no deaths for radio-marked females marked after hunting seasons during 1988 and 1989. Previous radio-telemetry and reward band studies indicated that hunting was the primary mortality agent for mallards within the LMAV and for mallards in central California, (Reinecke et al. 1987, Fleskes et al. 2007). Conversely, in the Playa Lakes region of Texas, hunting mortality was lower than non-hunting mortality (Bergan and Smith 1993).

I used radio-telemetry to investigate habitat use, movements, and survival of female mallards in the LMAV, and examined variation in these estimates due to several

explanatory variables. In chapter 2, I provide estimates of proportional use by female mallards in relation to habitat types. In chapter 3, I provide estimates of daily movement distances and daily switching of habitat types by radio-marked female mallards and discuss movement distances in the context of refuging theory. In chapter 4, I provide survival estimates and information on cause-specific mortality. Finally, in chapter 5, I summarize the major results of my study,

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CHAPTER 2. HABITAT USE OF FEMALE MALLARDS IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY

The Mississippi Flyway is the most important flyway for mallards (*Anas platyrhynchos*), and the Mississippi Alluvial Valley (hereafter MAV) is the most significant mallard wintering area within this flyway (Bellrose 1976). Mallard populations in the lower MAV (LMAV) historically averaged 1.6 million and represented the largest concentrations of wintering mallards in North America (Bartonek et al. 1984).

Landscapes in the LMAV have been greatly altered due to flood-control projects and agricultural drainage, causing extensive wetland losses and degradation (Goldstein 1988). Fragmentation of remaining forested wetlands has been widespread, and less than 25% of native bottomland hardwood habitats remain in the LMAV (Wolf et al. 1986). Consequently, considerable habitat restoration efforts have been undertaken in this region; (Forsythe and Gard 1980, Reinecke et al. 1989, King and Keeland 1999). The Wetlands Reserve Program (WRP) has provided incentives for increased restoration and reforestation of habitats in the LMAV, but evaluations of WRP program impacts on wildlife populations are limited (King et al. 2006).

The acreage of timberland recently has increased in some portions of the LMAV (Faulkner et al. 1995); thus, availability of forested wetland habitats should be increasing for mallards. The dynamic nature of bottomland hardwood ecosystems during winter floods provides a diversity of resources for mallards (Heitmeyer 2006). However, little information is available regarding how mallards use this highly fragmented, altered, and dynamic landscape in the LMAV.

Previous research on mallards in the MAV has focused on estimating survival, diets, and body condition (Delnicki and Reinecke 1986, Heitmeyer 1988, Reinecke et al.

1987, Dugger et al. 1994, Dabbert and Martin 2000). Waterfowl habitat management within the LMAV has focused on agricultural and moist-soil habitats. However, information is lacking regarding use of these habitats relative to that of forested wetlands. Previous estimates of habitat use in the LMAV were derived from aerial surveys (e.g. Dell et al. 1987), but visibility biases preclude accurate abundance estimates from aerial count data in some habitats (Smith et al. 1995).

Winter precipitation in the MAV may effect distribution of mallards (Nichols et al. 1983). Similarly, precipitation on wintering areas may also impact winter habitat use. Weather varied markedly in the LMAV during the 2 winters of my study; 2004-2005 was a very wet winter and 2005-2006 was a very dry winter (data from National Climatic Data Center, NOAA).

Areas closed to hunting (by statute or governmental authority) may reduce disturbance by humans and provide opportunities for information sharing (Ydenberg et al. 1983). Some dabbling ducks increase their use of closed areas in response to hunting (Cox and Afton 1997, Migoya et al. 1994), but relative use of closed areas by mallards, in relation to hunting seasons, has not been investigated in the LMAV. Further, little is known about nocturnal habitat use of mallards, although habitats used nocturnally may serve as important feeding and roosting areas for dabbling ducks (Guillemain et al. 2002). Accordingly, I employed radio-telemetry techniques to provide unbiased estimates of proportional habitat use during day and night by mallards wintering in the LMAV.

Some heterogeneity in proportional habitat use by ducks may be explained by female age. Reinecke et al. (1987) reported age specific survival rates for radio-marked

female mallards in the LMAV, but age specific use of habitats and closed areas have not been examined.

I provide here estimates of proportional use of various habitat types and of closed areas. I test whether marked individuals (sampling units) use habitats similarly among time periods defined by hunting by testing for an effect of individual female in each analysis. Further, I examine variation in diurnal and nocturnal habitat use due to winter of study, time periods defined by hunting seasons, and female age.

STUDY AREA

I trapped mallards on 5 sites within the Mollicy Unit of Upper Ouachita National Wildlife Refuge (NWR), 19.5 kilometers (km) east and 5 km north of Marion, Louisiana (Figure 2.1). Upper Ouachita NWR is a 14,973 hectare (ha) area encompassing the floodplain of a 29 km length of the Ouachita River. The Mollicy Unit is a 6475 ha tract of Upper Ouachita NWR located on the east side of the Ouachita River. The unit was enclosed by a levee and cleared for agriculture in the 1960's; it presently is undergoing extensive reforestation. Reforestation tracts include 3817 ha on the Mollicy Unit; the remainder currently is in rice agriculture or left fallow and dominated by moist-soil vegetation.

We tracked radio-marked mallards on all lands within 80 km of our trap sites. This area encompassed a portion of the LMAV in northeastern Louisiana and southeastern Arkansas (Figure 2.1). This area included five publicly owned areas managed by the U.S. Fish and Wildlife Service: D'Arbonne NWR, Black Bayou Lake NWR, Handy Brake NWR, Felsenthal NWR, and Overflow NWR. My tracking area also included Bayou Macon Wildlife Management Area (WMA), Russell Sage WMA, and

Ouachita WMA managed by Louisiana Department of Wildlife and Fisheries, as well as, Beryl Anthony WMA, Cut Off Creek WMA, Seven Devils WMA, and several tracts of Casey Jones WMA managed by Arkansas Game and Fish Department.

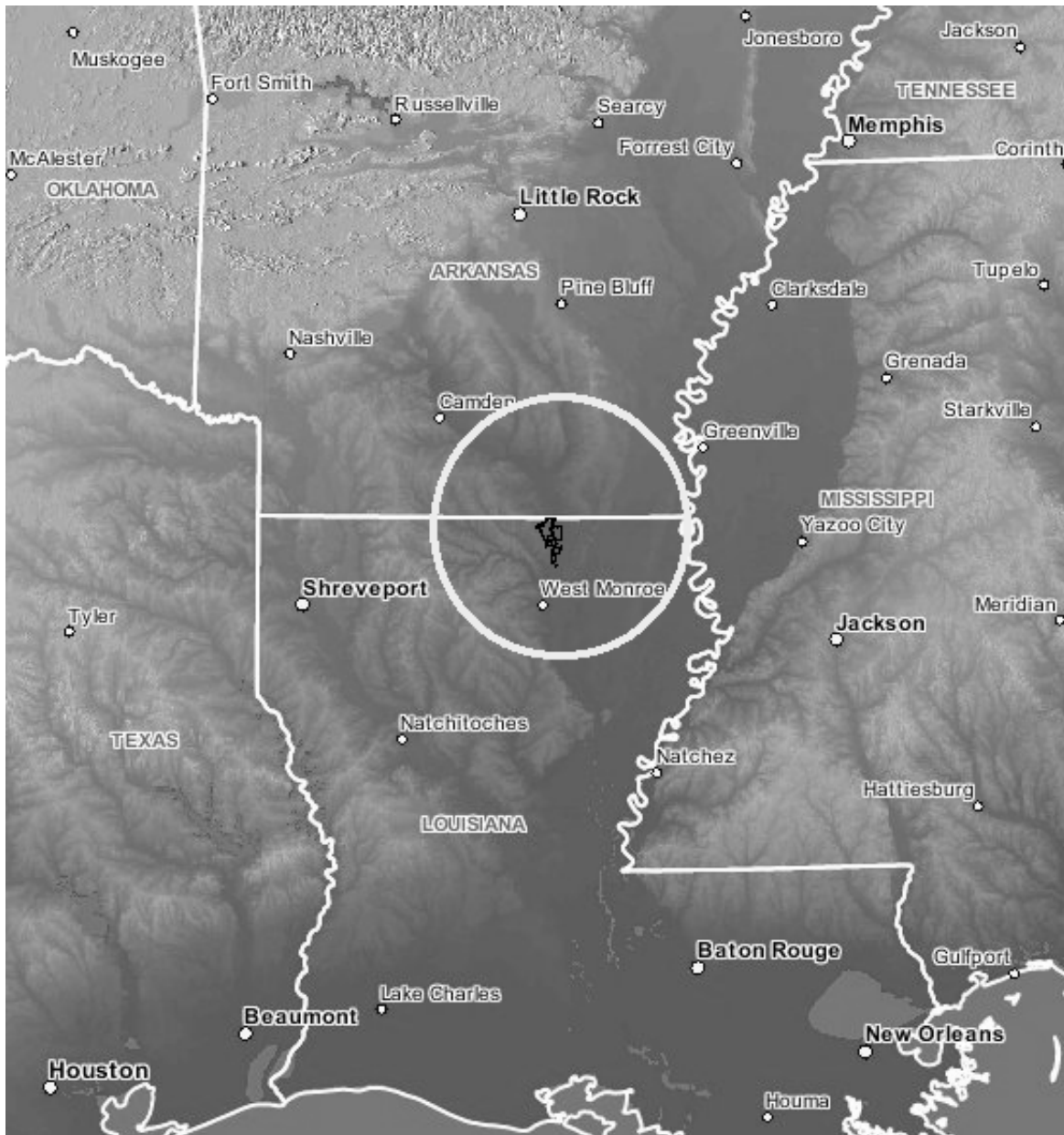


Figure 2.1. Tracking area (heavy white circle) with trapping area at Upper Ouachita NWR (black polygon) shown in center.

METHODS

Field Methodology

I captured and radio-marked 91 (61 adult and 30 immature) and 98 (51 adult, 46 immature, and 1 unknown age) female mallards from 27 November through 15 December 2004 and from 19 November through 22 November 2005, respectively. I captured females using swim-in traps adapted from those described by Mauser and Mensik (1992) or with rocket nets fired from portable platforms (Dill and Thornberry 1950, Cox and Afton 1994), all which were baited with a mixture of rice, wheat, corn, and sweet potatoes. In 2004, 57 of 91 radio-marked females were caught using swim in traps; the remainder was captured using rocket nets. In 2005, all females were captured using rocket nets.

All captured females were banded and aged as immature (hatched during year of capture) or adult (hatched prior to year of capture) according to wing plumage characteristics (Carney 1992). I instrumented females with 21-g, harness-type transmitters (Dwyer 1972; Advanced Telemetry Systems; Isanti, MN). When the number of females captured exceeded available number of transmitters, I randomly selected females for radio-marking from the captured sample. Transmitters pulsed at 50 beats per minute and were coded to pulse double on every tenth beat to distinguish them from other transmitters with similar frequencies. Transmitters had an expected battery life of 160 days and were equipped with mercury-type mortality switches, which caused their pulse rates to double if they remained motionless for > 4 hours. I provided food and water *ad libitum* for all captured ducks while held for instrumentation and measurements (LSU ACUC protocol # 04-108). I released females simultaneously with accompanying males

at capture sites <24 hours after capture to minimize potential handling effects (Cox and Afton 1998).

My technicians and I tracked radio-marked females from four vehicles equipped with roof mounted 4-element, null-peak antenna systems (Mech 1983), GPS units, and laptop computers with Location of a Signal software (LOAS 3.0.4; Ecological Software Solutions 1999). Truck antenna systems were equipped with electronic compasses (Cox et al. 2002) and calibrated empirically to known locations of beacon transmitters within 0.5 degree of accuracy. Prior to data collection, I trained technicians by having them triangulate on beacon transmitters until each technician was able to maintain a bearing standard deviation of ≤ 3 degrees.

To facilitate tracking in areas frequently used by mallards but inaccessible by trucks, I erected 2, 9.1-m telemetry towers near the north edge of the Mollicy Unit of Upper Ouachita NWR, and accessed them by ATV or on foot. I placed towers on top of a 12 m levee to maximize their effective range. Each tower was equipped with a single 9-element antenna on a rotating center mast. Towers were equipped with a compass rosette and pointer at the bottom of the mast set so that I could read an azimuth to peak signals heard through the tower antenna. I calibrated tower systems empirically using beacon transmitters in known locations.

My technicians and I avoided flushing females with telemetry vehicles whenever possible, to minimize investigator disturbance. To avoid sampling bias towards habitats that were accessible by trucks, I restricted habitat use analyses to days and nights that aircraft could be used, or when the entire pre-selected random sample of females could be located via trucks and towers.

When the tracking area contained more radio-marked females than could be tracked during a sampling period, I collected locations on a subsample of females, which were randomly selected without replacement. When day and night tracking could be completed on the same day, I tracked the same females during the two sampling periods to estimate individual daily movement distances (see Chapter 3).

I aurally searched for females that could not be located from trucks and towers and relayed their general locations to ground crews who subsequently attempted to triangulate on them. I applied aerial telemetry techniques to locate radio-marked females from fixed-wing aircraft (Gilmer et al. 1981); GPS coordinates and distance and direction to nearby landmarks were recorded. Flights were conducted at 1200-3000 m above ground level because Cox and Afton (2000) could reliably detect similar transmitters at distances of 80 km from this altitude. I also monitored for female mallards that were radio-marked in southwest Louisiana during a concurrent study when they were missing from that study area. I added newly arrived females from the southwest Louisiana study area to my sample for habitat-use estimates ($n = 7$ females during 2004-2005, $n = 4$ females during 2005-2006). I used aurally derived locations (12% of all locations) or locations derived from 2 bearings (6% of all locations) to estimate habitat-use when triangulation (a location using 3 or more bearings; 82% of all locations) by ground crews was not possible, as occurred in large areas without passable roads. When multiple triangulations were attained for an individual female within a tracking period, I used the initial triangulation collected.

My technicians and I estimated point locations for each female based on a maximum-likelihood estimator (Lenth 1981) with a bearing standard deviation of 3

degrees. Plots of estimated locations were examined in the field and apparent erroneous bearings were discarded immediately. I estimated locations of tracking vehicles and towers using Global Positioning Systems (Garmin, GPS76) with selective availability removed (using no intentionally degraded satellite signals). My technicians and I attempted to take a minimum of 3 azimuths for each female, and we continued to shoot azimuths until error ellipses fell within one habitat type or until available vantage points were exhausted. I used azimuths from the telemetry towers in combination with those from trucks for location estimates.

Habitat data and crop types for each point estimate were discerned by visual inspection, contact with land owners or land managers, or from Farm Service Agency records. I grouped habitats based on vegetative similarity and also to minimize zero values in my analyses. All locations in established stands of trees were classified as FOREST, whereas, those in areas involved in replanting (< 10 years past initial replanting) of trees or enrolled in the Wetland Reserve Program were classified as REFOR. I classified locations on lands managed for moist-soil plants (through water level management or soil disturbance) and all agricultural lands which had been left fallow for the previous growing season as MSIDLE. I classified locations on agricultural lands according to the crops grown on them during the preceding growing season. All locations in rice agriculture were classified as RICE, whereas locations in soybeans, cotton, corn, sweet potatoes, other crops, and open water impoundments were combined as OTHER.

I used GIS overlays available from local, state, and federal land managers to determine whether each estimated location was on private or publicly owned land

available for hunting, or on publicly owned land closed to hunting by statute or governmental authority. All locations on lands closed to duck hunting by statute or local regulation during the regular duck seasons in Louisiana or Arkansas were then classified as CLOSED; and all other locations were classified as OPEN.

Statistical Procedures

As an index to water conditions on my study area, I summarized data from a weather station at Bastrop, LA near the center of my study area (data from National Climatic Data Center, NOAA). I calculated the 30 year average precipitation by summing average daily totals from monthly averages for 1971-2000 for each day beginning with 1 August. Similarly, I calculated cumulative precipitation totals by summing the daily precipitation totals starting on 1 August in each winter of my study.

I performed 4 major analyses; I evaluated use of habitat types separately during diurnal and nocturnal sampling periods and examined use of CLOSED relative to use of OPEN separately for diurnal and nocturnal sampling periods. I analyzed 2710 observations on 146 radio-marked females and 682 observations on 115 radio-marked females to assess diurnal and nocturnal models, respectively.

I divided winters (2004-2005 or 2005-2006) into 4 time periods defined by duck hunting seasons in Arkansas and Louisiana. Each day was considered to be in an open hunting season (FIRST or SECOND) if regular duck season was open in either Louisiana's east zone or in Arkansas, or in a closed season (SPLIT or POST) when hunting seasons were closed in both areas. I was unable to collect diurnal or nocturnal data during the FIRST and SPLIT for the first winter of the study (Tables 2.1 and 2.2),

Table 2.1. Numbers of females monitored (n), total locations (Locs), and mean (Avglocs/bird), median (Medlocs/bird), standard error (SE), and range (Min-max) in number of diurnal locations per female by age, time period, and winter.

Winter	Time period	Age	<i>n</i>	Locs	Avglocs/bird	Medlocs/bird	SE	Min-max
2004-2005	FIRST	A	-	-	-	-	-	-
		I	-	-	-	-	-	-
	SPLIT	A	-	-	-	-	-	-
		I	-	-	-	-	-	-
	SECOND	A	56	191	3.4	4	0.2	1-5
		I	28	110	3.9	4	0.1	2-6
	POST	A	49	367	7.5	8	0.5	1-14
		I	26	260	10.0	10	0.5	4-13
2005-2006	FIRST	A	28	28	1.0	1	0.0	1-1
		I	28	28	1.0	1	0.0	1-1
	SPLIT	A	42	97	2.3	2	0.1	2-3
		I	34	69	2.0	2	0.1	1-3
	SECOND	A	27	454	16.8	20	1.3	1-21
		I	24	331	13.8	20	1.9	1-22
	POST	A	21	605	28.8	33	2.1	6-38
		I	17	392	23.1	28	3.3	1-38

Table 2.2. Numbers of females monitored (n), total locations (Locs), and mean (Avglocs/bird), median (Medlocs/bird), standard error (SE), and range (Min-max) in number of of nocturnal locations per female by by age, time period, and winter.

Winter	Time period	Age	<i>n</i>	Locs	Avglocs/bird	Medlocs/bird	SE	Min-max
2004-	FIRST	A	-	-	-	-	-	-
		I	-	-	-	-	-	-
2005	SPLIT	A	-	-	-	-	-	-
		I	-	-	-	-	-	-
	SECOND	A	45	102	2.3	2	0.1	1-3
		I	28	61	2.2	2	0.1	1-3
	POST	A	16	16	1.0	1	0.0	1-1
		I	10	10	1.0	1	0.0	1-1
2005-	FIRST	A	15	15	1.0	1	0.0	1-1
		I	10	10	1.0	1	0.0	1-1
2006	SPLIT	A	-	-	-	-	-	-
		I	-	-	-	-	-	-
	SECOND	A	22	186	3.9	4	0.1	2-4
		I	15	58	3.9	4	0.1	3-4
	POST	A	21	209	10.0	11	0.7	2-13
		I	16	140	8.8	11	1.1	1-13

due to later capture of females in 2004-2005. I also was unable to collect nocturnal data during SPLIT in 2005-2006 (Table 2.2). Therefore, I tested for variation in use of habitats and in use of CLOSED using only data collected during the SECOND and POST.

Use of Habitats – Diurnal

For my first analysis, I calculated diurnal proportional use of each female in every habitat during SECOND and POST. I replaced zero values with 0.002 (an order of magnitude lower than the lowest non-zero proportion of a habitat used by any female diurnally; Aebischer et al. 1993). To remove the unit sum constraint (Aitchison 1986), I constructed 4 log-ratios by dividing proportional use of FOREST, REFOR, MSIDLE, and OTHER by proportional use of RICE and used napierian logarithms of these ratios as response variables in my analysis. I used split-plot multivariate analysis of variance (PROC GLM; SAS Institute 2004) to test for overall effects of age (Immature or Adult), winter of capture and tracking (2004-2005 or 2005-2006), time period (SECOND or POST), individual female, and all potential interactions of these effects on response variables. I used variation due to individual females as the error term to test for effects due to age, winter and their interaction, and residual error to test for individual female and time period effects and all other interactions. I initially analyzed full models and then used backward, stepwise procedures to eliminate nonsignificant ($P > 0.0500$) terms, beginning with the highest order interactions (Wolfinger 1992).

I compared use of each habitat to use of RICE, within levels of significant explanatory variables in final models, by testing whether least-square means of log-ratios

differed from zero as in Cox and Afton (1997, Aebischer et al. 1993). I used orthogonal contrasts to compare use of each habitat relative to rice for various combinations of explanatory variables when MANOVA indicated a significant interaction (SAS Institute 2004).

I present estimates of proportional use of each habitat as averages across females from the untransformed data to facilitate biological interpretation within levels of significant ($P > 0.0500$) explanatory variables from my final fitted model. Each female was treated as a sampling unit and all sampling units were weighted equally. I also present estimates of proportional use for all levels of significant explanatory variables, even though some levels could not be formally tested within my model due to missing cells in the data.

Use of Habitats – Nocturnal

In the second analysis, I calculated nocturnal proportional use of each female in the same manner as for my diurnal analysis. I tested for effects of the same explanatory variables after replacing zero values with 0.008 (an order of magnitude lower than the lowest non-zero proportion of a habitat used by any female nocturnally), and constructing log-ratios as described above.

Use of Areas Closed to Hunting– Diurnal

For my third analysis, I calculated diurnal proportional use of CLOSED and OPEN areas for each female during SECOND and POST. I replaced zero values with 0.003 (an order of magnitude smaller than the lowest non-zero proportion of CLOSED use by any female during the diurnal sampling period). I constructed log-ratios by dividing the proportional use of CLOSED by the proportional use of OPEN, and then

used the napierian logarithm of this ratio as a response variable in my models. I used mixed model analysis of variance with maximum likelihood estimation (PROC MIXED; SAS Institute 2004) to test for fixed effects of female age, winter of study, time period, and all potential interactions of these effects, as well as the random effect of individual female. I fit models and present data summaries using error terms and procedures as outlined for my previous analyses. In the presence of significant interactions, I tested for differences in least squares means among levels of explanatory variables using Fisher's LSD (SAS Institute 2004).

Use of Areas Closed to Hunting – Nocturnal

In the fourth analysis, I calculated nocturnal proportional use of CLOSED and OPEN areas for each female during SECOND and POST. I tested for effects of the same explanatory variables as above, using identical procedures, after replacing zero values with 0.009 (an order of magnitude lower than the lowest non-zero use of closed areas during the nocturnal sampling period) and constructing log-ratios as above.

RESULTS

Precipitation varied markedly in the LMAV during the 2 years of my study; cumulative precipitation was above the 30 year average in 2004-2005 but below the 30 year average in 2005-2006 (Figure 2.2).

Use of Habitats – Diurnal

My final fitted MANOVA model indicated that diurnal use of habitats varied inconsistently among time periods and winters (time period by winter interaction; Wilks' Lambda = 0.6844; $F = 11.18$; 4, 97 df; $P < 0.0001$) and among females (Wilks' Lambda = 0.0045; $F = 1.95$; 576, 390.82 df; $P < 0.0001$). I failed to detect significant effects of

other interactions and age (all $P_s \geq 0.7104$). FOREST received high diurnal use, with proportional use of ranging from 0.475 to 0.816 during the SECOND and POST for the two winters of my study (Table 2.3).

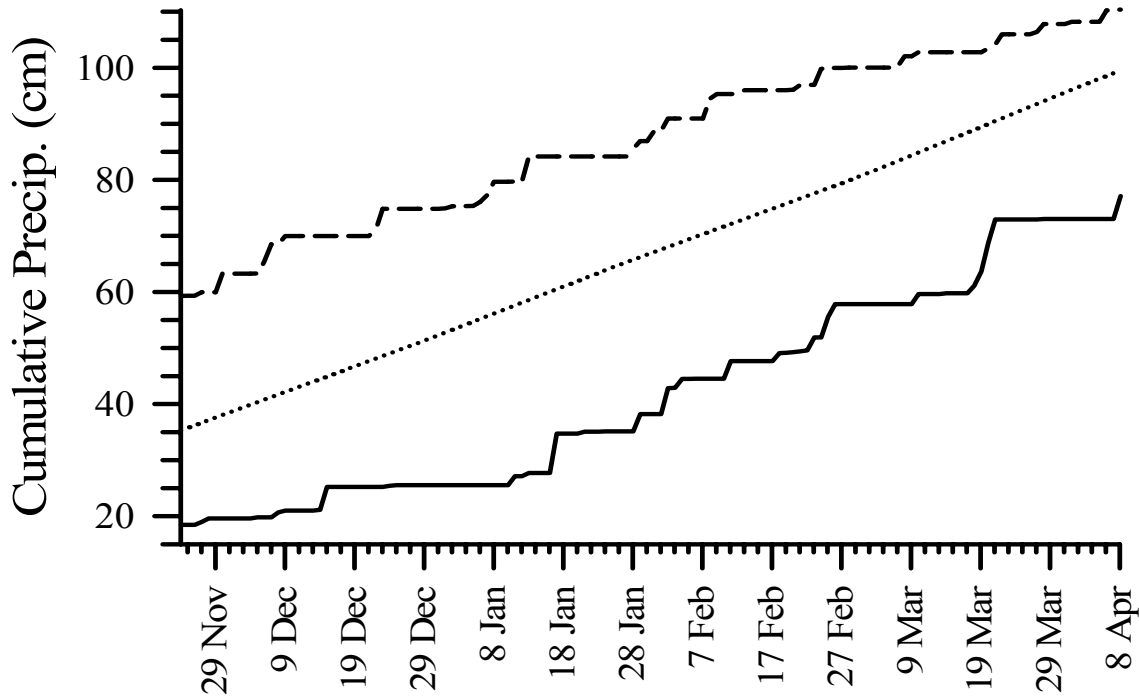


Figure 2.2. Cumulative precipitation after 1 August on my study area. Dotted line represents the 30 year average precipitation for 1971-2001. Long dashes represent precipitation for 2004-2005 and the solid line represents precipitation in 2005-2006.

In both winters, use of FOREST exceeded use of RICE during the SECOND and POST (all $P_s < 0.0001$). In 2004-2005, use of OTHER was lower than use of RICE during the SECOND ($P < 0.0001$) but did not differ from use of RICE during the POST ($P = 0.6595$). In 2005-2006, use of OTHER was lower than use of RICE during the SECOND and POST ($P_s < 0.0184$). In 2004-2005, use of REFOR was higher than use of RICE during the SECOND ($P < 0.0001$) but use of REFOR did not differ from use of RICE during the POST in 2004-2005 or during the SECOND or POST in 2005-2006 (all

Table 2.3. Diurnal proportional use of habitats by female mallards by time periods during winters 2004-2005 and 2005-2006.

Winter	Time Period	n^a	FOREST		MSIDLE		OTHER		REFOR		RICE	
			\bar{X}	SE	\bar{X}	SE	\bar{X}	SE	\bar{X}	SE	\bar{X}	SE
2004-05	SECOND	84	0.597	0.039	0.064	0.017	0.000	0.000	0.237	0.034	0.102	0.022
	POST	75	0.816	0.036	0.037	0.011	0.040	0.017	0.058	0.020	0.048	0.016
2005-06	FIRST ^b	56	0.464	0.067	0.018	0.018	0.000	0.000	0.054	0.030	0.464	0.067
	SPLIT ^b	76	0.583	0.046	0.013	0.009	0.057	0.018	0.029	0.017	0.318	0.041
	SECOND	51	0.798	0.039	0.015	0.006	0.045	0.016	0.044	0.013	0.097	0.026
	POST	38	0.475	0.055	0.069	0.021	0.096	0.020	0.158	0.041	0.202	0.045

^a Sample sizes represent number of radio-marked females tracked in each time period.

^b Models were fit without FIRST and SPLIT due to missing data during the first winter of the study (see methods)

$P_s \geq 0.1818$). In 2004-2005, use of MSIDLE did not differ from use of RICE ($P_s \geq 0.0689$); however, in 2005-2006 use of MSIDLE was lower than use of RICE during SECOND and POST ($P_s = 0.0005$).

Use of FOREST relative to RICE was lower during the POST in 2005-2006 than during the POST in 2004-2005 ($P < 0.0001$), but did not differ among winters during the SECOND ($P = 0.5859$). Use of FOREST relative to RICE increased between SECOND and POST in 2004-2005 ($P = 0.0038$) and decreased between SECOND and POST during 2005-2006 ($P = 0.0005$). Use of OTHER relative to RICE increased between SECOND and POST during 2004-2005 ($P = 0.0008$), but did not differ between SECOND and POST in 2005-2006 or among winters in either time period ($P_s \geq 0.0841$). Use of REFOR relative to RICE was higher in SECOND during 2004-2005 than in SECOND during 2005-2006 ($P = 0.0001$), but did not differ among winters in the POST ($P = 0.2702$). Use of REFOR relative to RICE was higher in the SECOND during 2004-2005 than in the SECOND during 2005-2006 ($P = 0.0044$), but did not differ among winters during the POST ($P = 0.2702$). Use of IDLE relative to RICE was higher during the POST in 2004-2005 than during the POST in 2005-2006 ($P = 0.0002$), but did not differ among winters during the SECOND ($P = 0.0876$). Use of IDLE relative to RICE increased between SECOND and POST during 2004-2005 ($P = 0.0192$), but did not differ among time periods in 2005-2006 ($P = 0.5472$).

Use of Habitats – Nocturnal

My final fitted model indicated that nocturnal habitat use varied inconsistently among time periods and winters (time period by winter interaction; MANOVA; Wilks' Lambda = 0.8266; $F = 2.78$; 4, 53 df; $P = 0.0360$) and among females (Wilks' Lambda =

0.0060; $F = 1.23$; 452, 214.81 df; $P = 0.0412$). I failed to detect significant effects of other interactions and age (all $P_s \geq 0.0966$). FOREST received high nocturnal use, with proportions ranging from 0.428 to 0.764 during the SECOND and POST for the two winters of my study (Table 2.4).

In 2004-2005, use of REFOR exceeded use of RICE during the SECOND ($P = 0.0134$), but did not differ from use of RICE during the POST ($P = 0.8425$). In 2005-2006, use of REFOR did not differ from use of RICE during the SECOND or POST ($P_s \geq 0.0830$). In each winter, use of FOREST exceeded use of RICE during the SECOND and POST (all $P_s \leq 0.0033$). In 2004-2005, use of OTHER was less than use of RICE during SECOND and POST ($P_s \leq 0.0454$), but did not differ among SECOND and POST during 2005-2006 ($P_s \geq 0.4758$). Use of MSIDLE did not differ from use of RICE during the SECOND or POST in either winter (all $P_s \geq 0.791$).

Use of FOREST relative to RICE decreased from SECOND to POST in 2005-2006 ($P = 0.0036$), but did not differ among time periods in 2004-2005 or among winters in SECOND or POST (all $P_s \geq 0.0776$). Use of REFOR relative to RICE was higher in 2004-2005 than in 2005-2006 during the SECOND ($P = 0.0053$), but did not differ among winters during the POST ($P = 0.3043$). Use of REFOR relative to use of RICE increased from the SECOND to POST in 2005-2006 ($P = 0.0238$), but did not differ among SECOND and POST in 2004-2005 ($P = 0.2185$). I detected no differences in use of OTHER or use of MSIDLE relative to RICE among time periods in either winter or among winters during the SECOND or POST (all $P_s \geq 0.1302$).

Table 2.4. Nocturnal proportional use of habitats by female mallards by time periods during winters 2004-2005 and 2005-2006.

Winter	Time Period	n^a	FOREST		MSIDLE		OTHER		REFOR		RICE	
			\bar{X}	SE	\bar{X}	SE	\bar{X}	SE	\bar{X}	SE	\bar{X}	SE
2004-05	SECOND	73	0.708	0.044	0.025	0.012	0.014	0.010	0.174	0.035	0.080	0.027
	POST	26	0.654	0.095	0.038	0.038	0.000	0.000	0.154	0.072	0.154	0.074
2005-06	FIRST ^b	25	0.280	0.092	0.000	0.000	0.000	0.000	0.000	0.000	0.720	0.092
	SECOND	37	0.764	0.062	0.047	0.027	0.047	0.021	0.027	0.016	0.115	0.039
	POST	37	0.428	0.063	0.122	0.042	0.093	0.024	0.208	0.041	0.149	0.040

^a Sample sizes represent number of radio-marked females tracked in each time period.

^b Models were fit without FIRST time period due to missing data during the first winter of the study (see methods)

Use of Areas Closed to Hunting– Diurnal

My final fitted mixed model indicated that diurnal use of CLOSED varied inconsistently among time periods and winters (time period by winter interaction; $F = 11.08, 1, 100; P = 0.0012$) and among females ($P < 0.0001$). I failed to detect significant effects of the 3-way interaction, age by winter and age by time period interactions, and age (all $P_s \geq 0.2245$). Proportional use of CLOSED ranged from 0.183 to 0.423 among SECOND and POST during the two winters of my study (Table 2.5).

Table 2.5. Diurnal proportional use of CLOSED by time period for winters 2004-2005 and 2005-2006.

Winter	Time period	n^b	Use of CLOSED ^a	
			\bar{X}	SE
2004-05	SECOND	84	0.423	0.041
	POST	75	0.183	0.031
2005-06	FIRST ^c	56	0.732	0.060
	SPLIT ^c	76	0.447	0.045
	SECOND	51	0.207	0.044
	POST	38	0.262	0.052

^a Proportional use of OPEN is 1-proportional use of CLOSED and standard errors are equal to standard errors for use of CLOSED.

^b Sample sizes represent number of radio-marked females tracked in each time period.

^c Models were fit excluding FIRST and SPLIT time periods due to missing data for these periods during the first winter of the study.

Diurnal use of CLOSED decreased from SECOND to POST in 2004-2005 ($P < 0.0001$), but did not differ among time periods in 2005-2006 ($P = 0.4487$). Diurnal use of CLOSED was higher during 2004-2005 than 2005-2006 for SECOND ($P = 0.0075$), but did not differ among winters during the POST ($P = 0.2634$).

Use of Areas Closed to Hunting – Nocturnal

My final fitted model indicated that nocturnal use of CLOSED varied inconsistently among ages and time periods (age by time period interaction; $F = 8.88$, 1, 56; $P = 0.0043$) and among ages and winters (age by winter interaction; $F = 3.96$, 1, 111; $P = 0.0491$). I failed to detect significant effects of other interactions or fixed effects (all $P_s \geq 0.0875$).

Immature females increased nocturnal use of CLOSED from SECOND to POST ($P = 0.0002$), but use of CLOSED by adult females did not differ among time periods ($P = 0.8946$). Use of CLOSED was greater for immature females than adult females during POST ($P = 0.0074$), but did not differ among ages during the SECOND ($P = 0.3107$). During the SECOND and POST time periods in 2004-2005, adult females used CLOSED more than immature females ($P = 0.0113$), but use of CLOSED did not differ among ages in 2005-2006. Use of CLOSED during the SECOND and POST was lower for immature females in 2004-2005 than in 2005-2006 ($P = 0.0238$), but did not differ among winters for adults ($P = 0.7360$). Overall, nocturnal proportional use of CLOSED ranged between 0.211 and 0.800 among ages and time periods (Tables 2.6 and 2.7).

DISCUSSION

As typical in telemetry studies, I assumed that sampling units (radio-marked individuals) were independent. Effects of individual female were statistically significant in three of my four major analyses; I interpret these results as reasonably strong evidence that proportional use of habitats by individual females were similar among time periods.

I observed high proportional use of FOREST during all combinations of time periods and winters during both diurnal and nocturnal sampling periods (Tables 2.3 and

2.4). My diurnal habitat use estimates contrast with previous estimates for the LMAV based solely on aerial surveys. For example, Dell et al. (1987) reported high densities of mallards using wet agricultural and open water habitats and low densities of mallards in flooded timber habitats in northeast Louisiana. These differences may reflect differences in methodology between the studies, changes in habitat use over time, or both.

Table 2.6. Nocturnal proportional use of CLOSED by age and time period.

Time period	Age	n^b	Use of CLOSED ^a	
			\bar{X}	SE
FIRST ^c	Adult	15	0.667	0.126
	Immature	10	0.800	0.133
SECOND	Adult	67	0.256	0.043
	Immature	43	0.211	0.052
POST	Adult	37	0.246	0.059
	Immature	26	0.445	0.082

^a Proportional use of OPEN is 1-proportional use of CLOSED and standard errors are equal to standard errors for use of CLOSED.

^b Sample sizes represent number of radio-marked females tracked by age within each time period.

^c Models were fit excluding FIRST time period due to missing data for this time period during the first winter of the study.

Table 2.7. Nocturnal proportional use of CLOSED by age for winters 2004-2005 and 2005-2006.

Winter	Age	n^b	Use of CLOSED ^a	
			\bar{X}	SE
2004-05	Adult	46	0.248	0.050
	Immature	28	0.348	0.072
2005-06	Adult	31	0.356	0.066
	Immature	22	0.411	0.081

^a Proportional use of OPEN is 1-proportional use of CLOSED and standard errors are equal to standard errors for use of CLOSED.

^b Sample sizes represent number of radio-marked females tracked by age within each winter during SECOND and POST.

In other portions of the mallard wintering range, females pair by mid December or January, and paired females are observed in smaller flocks (Heitmeyer 1988, Johnson and Rohwer 1998). Scrub habitats which are a component of FORESTS may provide areas where small flocks can remain isolated. Further, forested wetlands may provide important food resources for female mallards. Dabbert and Martin (2000) reported that only 4% of mallards collected in their study contained agricultural seeds even though crop fields were in close proximity to their collection sites.

I captured and marked all females in non-forested areas; thus, any potential bias associated with capture site should inflate estimates of habitat use for non-forested habitats. Accordingly, my estimates for proportional use of FOREST may be minimum estimates of these proportions. Moreover, since I captured all females on CLOSED, my estimated use of CLOSED may be a maximum estimate for females wintering within my study area.

My radio-marked female mallards did not increase use of CLOSED in response to hunting seasons as did pintails on the Louisiana coast and in Mexico (Migoya et al. 1994, Cox and Afton 1997). In 2005-2006, use of CLOSED increased after all hunting seasons had ended. Dry conditions in 2005-2006 may have precluded use of many CLOSED areas for much of the winter on several areas with intensively managed vegetation (i.e. WMAs and NWRs); however, by late winter these areas accumulated sufficient water to make them available to female mallards.

Diurnal use of CLOSED did not decrease coincidentally with the end of hunting seasons as might be expected if hunting were the primary factor influencing use of

CLOSED areas. High use of areas open to duck hunting suggests that CLOSED, as currently managed, are not overly important for wintering mallards on my study area, and that specific habitat types may be more important to wintering mallards than the amount of CLOSED available.

MANAGEMENT IMPLICATIONS

Given the relatively high use of areas open to hunting by females during hunting seasons, establishment of additional CLOSED may not be a high priority in my study area. Increasing FOREST within CLOSED may result in increased use by female mallards and provide greater protection from hunting. Heitmeyer and Fredrickson (1981) speculated that abundance and quality of winter wetlands affects subsequent recruitment. My results document the importance of forested wetlands as mallard habitat in my study area. Therefore, increased long-term enrollment in the Wetland Reserve Programs or other programs that restore forested wetlands in my study area may provide important wintering habitat for mallards and subsequently increase breeding success.

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CHAPTER 3. DAILY MOVEMENT DISTANCES AND HABITAT SWITCHING BY FEMALE MALLARDS IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY

Refuging theory predicts that congregated individuals will increase distances moved between roosting and foraging areas over time as food resources are depleted near roosting areas (Hamilton and Watt 1970). Refuging theory and forage depletion have been used to explain movements and use of habitats by waterfowl during winter (e.g. Frederick et al. 1987, Vickery et al. 1995, Cox and Afton 1996, Borbach-Jaene and Kruckenberg 2002). Daily movement distances probably are proportional to energy expenditure and potential exposure to mortality. Assuming these movements are adaptive, costs and risks associated with increased movements are predicted to be outweighed by potential fitness benefits to individuals (c.f. Hamilton and Watt 1970).

Female age may affect movements and flight distance to foraging areas. For example, Cox and Afton (1996) reported that female northern pintails (*Anas acuta*) increased their flight distances from a refuge in southwest Louisiana as winter progressed and that distances moved varied among age groups. When food resources are limited, adult females may out-compete immature females in nearby, less energetically costly foraging habitats.

Refuging theory typically is applied only to animals originating from large congregations and moving to other habitats to forage. The key premise of refuging theory is dependent on having concentrations of animals large enough to deplete foraging resources near a central point. Thus, daily movement distances for females using refuge habitats may differ from females using nonrefuge habitats, if concentrations of waterfowl differ on refuge and nonrefuge areas.

Daily movement distances could be affected by habitat types used by females. Frederick et al. (1987) extended refuging theory to models of spatial use by snow geese relative to habitat management treatments and reported that models were sensitive to proportions of available foraging fields. Movement distances changed in response to available waste grain at foraging sites for mallards (*Anas platyrhynchos*) wintering in Nebraska (Jorde et al. 1983). Thus, females using various habitats may vary their daily movement distances differently over time.

Females may not need to forage in habitats away from their roosting habitats if dietary needs and roosting requirements can be met in a single habitat type. Dabbert and Martin (2000) reported that only 4% of mallards collected in a greentree reservoir in southeastern Arkansas had consumed agricultural seeds even though flooded agricultural habitats were nearby. Conversely, some habitats may lack sufficient foraging resources and, thus, females may need to travel to other habitats to find sufficient food resources. Available waste rice declines as winter progresses (Stafford et al. 2006); thus, females using rice may be relatively more likely to switch habitats to meet foraging requirements.

In this chapter, I first estimate distances moved between diurnal and nocturnal locations recorded within a 24-hour period for radio-marked female mallards wintering in the lower Mississippi Alluvial Valley. I then examine variation in distances moved in relation to date within winter, female age, hunting regime (OPEN or CLOSED) of diurnal locations, habitat type of diurnal locations, and among individual females. Finally, I examine the probability of habitat switching between diurnal and nocturnal locations in relation to date, female age, and diurnal habitat type.

STUDY AREA

I trapped and marked female mallards within the Mollicy Unit of Upper Ouachita National Wildlife Refuge (NWR), 19.5 kilometers (km) east and 5 km north of Marion, Louisiana (Figure 2.1). Upper Ouachita NWR is a 14,973-hectare (ha) area encompassing the floodplain of a 29-km length of the Ouachita River. The Mollicy Unit is a 6475-ha tract of Upper Ouachita NWR located on the east side of the Ouachita River. The unit was enclosed by a levee and cleared for agriculture in the 1960's but presently is undergoing extensive reforestation. Reforestation tracts include 3817 ha on the Mollicy Unit; the remainder currently is in rice agriculture or left fallow and dominated by moist-soil vegetation.

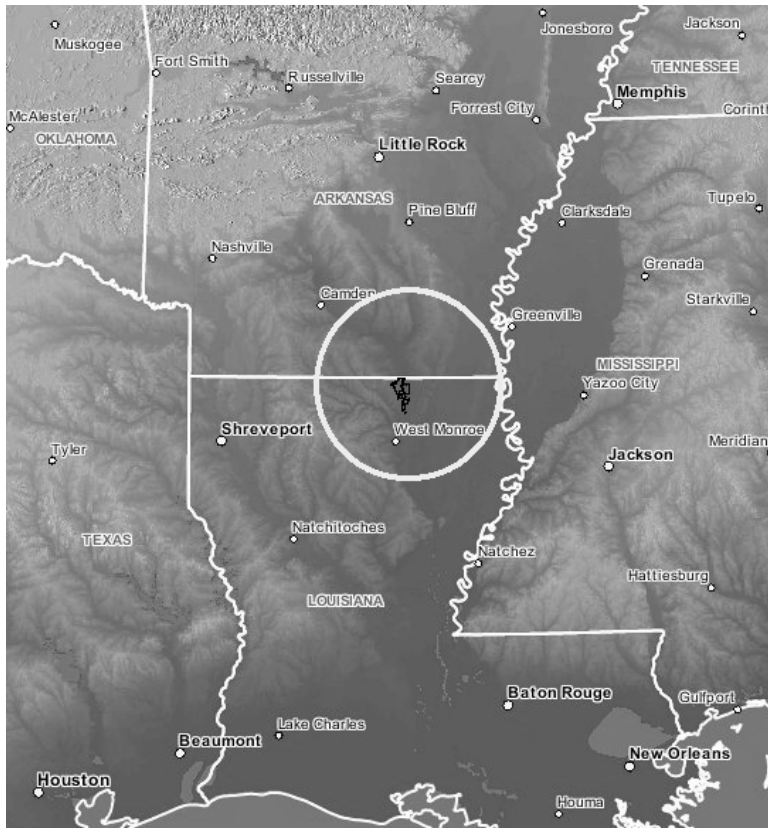


Figure 3.1. Tracking area (heavy white circle) with Upper Ouachita NWR (black polygon) shown in center.

I tracked radio-marked females on all land within 80 km of my trap sites. This area encompassed a portion of the Lower Mississippi Alluvial Valley (hereafter LMAV) in northeastern Louisiana and southeastern Arkansas (Figure 3.1), and was assumed to be representative of the LMAV. This area included five publicly owned areas managed by the U.S. Fish and Wildlife Service: D'Arbonne NWR, Black Bayou Lake NWR, Handy Brake NWR, Felsenthal NWR, and Overflow NWR. My tracking area also included Bayou Macon Wildlife Management Area (WMA), Russell Sage WMA, and Ouachita WMA managed by Louisiana Department of Wildlife and Fisheries, as well as Beryl Anthony WMA, Cut Off Creek WM-A, Seven Devils WMA, and several tracts of Casey Jones WMA managed by Arkansas Game and Fish Commission.

METHODS

Data Collection

I captured and radio-marked 91 (61 adult and 30 immature) and 98 (51 adult, 46 immature, and 1 unknown age) female mallards from 27 November through 15 December 2004 and from 19 November through 22 November 2005, respectively. I captured females using swim-in traps adapted from those described by Mauser and Mensik (1992) or rocket nets fired from portable platforms (Dill and Thornberry 1950, Cox and Afton 1994), both of which were baited with a mixture of rice, wheat, corn, and sweet potatoes. In 2004, 57 of 91 radio-marked females were caught using swim in traps; the remainder was captured using rocket nets. In 2005, all females were captured using rocket nets.

I banded captured females and aged them as either immature (hatched during year of capture) or adult (hatched prior to year of capture) according to wing plumage

characteristics (Carney 1992). I instrumented females with 21-g, harness-type transmitters (Dwyer 1972; Advanced Telemetry Systems; Isanti, MN). When the number of females captured exceeded the available number of transmitters, I randomly selected females from the captured sample for radio-marking. Transmitters pulsed at 50 beats per minute and were coded to pulse double on every tenth beat to distinguish them from other transmitters with similar frequencies. Transmitters had an expected battery life of 160 days and were equipped with mercury-type mortality switches that caused their pulse rates to double if they remained motionless for > 4 hours. I provided food and water *ad libitum* to all captured ducks held for instrumentation and measurements (LSU ACUC protocol # 04-108). I released females simultaneously with accompanying males at capture sites <24 hours after capture to minimize potential handling effects (Cox and Afton 1998).

My technicians and I tracked radio-marked females from four vehicles equipped with roof mounted 4-element, null-peak antenna systems (Mech 1983), GPS units, and laptop computers with Location of a Signal software (LOAS 3.0.4; Ecological Software Solutions 1999). Truck antenna systems were equipped with electronic compasses (Cox et al. 2002) and calibrated empirically to known locations of beacon transmitters within 0.5 degree of accuracy. Prior to data collection, I trained technicians by having them triangulate on beacon transmitters until each technician was able to maintain a bearing standard deviation of ≤ 3 degrees.

To facilitate tracking in areas frequently used by mallards but inaccessible by trucks, I erected 2, 9.1-m telemetry towers near the north edge of the Mollicy Unit of Upper Ouachita NWR, and accessed them by ATV or on foot. I placed towers on top of

a 12-m levee to maximize their effective range. Each tower was equipped with a single 9-element antenna on a rotating center mast. Towers were equipped with a compass rosette and pointer at the bottom of the mast set so that I could read an azimuth to peak signals heard through the tower antenna. I calibrated tower systems empirically using beacon transmitters at known locations.

My technicians and I avoided flushing females with telemetry vehicles to minimize investigator disturbance whenever possible. To avoid sampling bias towards habitats that were accessible by trucks, I restricted sampling to days and nights that aircraft could be used, or when the entire pre-selected random sample of females could be located via trucks and towers.

When the tracking area contained more radio-marked females than could be tracked during a sampling period, I collected locations for a subsample of females that were randomly selected without replacement. When day and night tracking could be completed within 24 hours, I tracked the same females during the two sampling periods to facilitate estimation of individual daily movement distances.

I aurally searched for females that could not be located from the trucks and towers and relayed their general locations to ground crews who subsequently attempted to triangulate on them. I applied aerial telemetry techniques to locate radio-marked females from fixed-wing aircraft (Gilmer et al. 1981); GPS coordinates and distance and direction to nearby landmarks were recorded. Flights were conducted at 1200-3000 m above ground level because Cox and Afton (2000) could reliably detect similar transmitters at distances of 80 km from this altitude. I also monitored for female mallards radio-marked during a concurrent study in southwest Louisiana when they were missing

from that study area. I added newly arrived females ($n = 3$) from the southwest Louisiana study area to my monitored sample immediately after detection on my study area. I used aerially derived locations (10 % of diurnal locations and 9 % of nocturnal locations) or locations derived from 2 bearings (1 % of diurnal locations and 2 % of nocturnal locations) to estimate habitat-use when triangulation (a location using 3 or more bearings; 89 % of both diurnal and nocturnal locations) by ground crews was not possible, as occurred in large areas without passable roads. When multiple triangulations were attained for an individual female within a tracking period, I used the initial triangulation data.

My technicians and I estimated point locations for each female based on a maximum-likelihood estimator (Lenth 1981) with a bearing standard deviation of 3 degrees. Plots of estimated locations were examined in the field and apparently erroneous bearings were discarded immediately. I estimated station locations of tracking vehicles using Global Positioning Systems (Garmin, GPS76) with selective availability removed (using no intentionally degraded satellite signals). My technicians and I attempted to take a minimum of 3 azimuths for each female, and we continued to shoot azimuths until error ellipses fell within one habitat type or until available vantage points were exhausted. I used azimuths from the telemetry towers in combination with those from trucks for location estimates. I recorded coordinates for all location estimates using the Universal Transverse Mercator system.

I used GIS overlays available from state and federal land managers to discern whether estimated locations were on private or publicly owned land available for hunting, or on publicly owned land closed to hunting by statute or governmental authority.

Locations on lands closed to duck hunting by statute or local regulation during the regular duck seasons in Louisiana or Arkansas were then classified as CLOSED; and all other locations were classified as OPEN.

I discerned habitat data and crop types for each location by visual inspection, contact with land owners or managers, or from Farm Service Agency records. For analysis, I grouped habitats based on vegetative similarity. All locations in established stands of trees were classified as FOREST, whereas, those in areas involved in replanting (< 10 years past initial replanting) of trees or enrolled in the Wetland Reserve Program were classified as REFOR. I classified locations on lands managed for moist-soil plants (through water level management or soil disturbance) and all agricultural lands which had been left fallow for the previous growing season as MSIDLE. I classified locations on agricultural lands according to the crops grown on them during the preceding growing season. All locations in rice agriculture were classified as RICE, whereas locations in soybeans, cotton, corn, sweet potatoes, other crops, and open water impoundments were combined as OTHER.

Statistical Procedures

Distance Moved between Diurnal and Nocturnal Locations

For my first analysis, I calculated distances moved between diurnal and nocturnal location coordinates using the Pythagorean Theorem. I used a natural-log transformation to normalize these distances and used the transformed distances as the response variable in my analysis. I combined data over the two winters of my study because of the large difference in length of sampling spans among winters (see Results). I used a repeated measures mixed-model ANCOVA with maximum likelihood estimation (PROC MIXED;

SAS Institute 2004) to assess effects of several explanatory variables on the transformed distances. I used number of days after 19 November (earliest date a female was instrumented, hereafter date) as the covariate. I included female age (immature or adult), hunting regime (CLOSED or OPEN) of diurnal locations, habitat type (FOREST, REFOR, MSIDLE, RICE, or OTHER) of diurnal locations as fixed effects, and individual female as a random effect. I elected to examine effects of habitat parameters (hunting regime and habitat type) from diurnal locations rather than nocturnal locations in my models. I used variation due to individual females as the error term to test for effects due to age and used residual error to test for all other effects and interactions. The full model included all 2-way interactions including those with date as well as all main effects. I used AIC values from overall fit of 3 iterations of the full model with restricted maximum likelihood estimation to evaluate the symmetry of the matrix structure of repeated measures as simple, compound, or first order autoregressive, and maintained appropriate matrix structure throughout model fitting (Wolfinger 1992).

I initially analyzed the full model and then used backward, stepwise procedures to eliminate nonsignificant ($P > 0.0500$) terms, beginning with 2-way interactions (Wolfinger 1992). In the presence of significant interactions with date, I tested whether estimated slopes differed from 0 (NOINT and SOLUTIONS options PROC MIXED; SAS Institute 2004).

Habitat Switching

For my second analysis, I examined switches in habitat types within diurnal and nocturnal location pairs. I used the binary response of whether each observation included a switch of habitat types between diurnal and nocturnal locations as the response variable

in this analysis. When females switch habitat types, I coded the response variable as 1. When females did not switch habitats, I coded the response variable as 0. I used repeated measures ANCOVA with a logit link (PROC GENMOD; SAS Institute 2004; Stokes et al. 2000) to assess effects of several explanatory variables on the probability that females switched habitats. For this analysis, I used date as the covariate, and included female age, habitat type of diurnal locations, and the interaction of date with habitat type of diurnal locations as explanatory variables in my full model. PROC GENMOD invokes the generalized estimating equation (hereafter, GEE) approach (Liang and Zeger 1986) to account for the correlation structure of repeated measures (Stokes et al. 2000). For this analysis, I specified the correlation structure of repeated measures on individual females as exchangeable; GEE methods are robust to assigned correlation structure (Stokes et al. 2000, pp. 474-480). I initially analyzed the full model and then used backward, stepwise procedures to eliminate nonsignificant ($P > 0.0500$) terms, beginning with the 2-way interaction (Stokes et al. 2000). I subsequently compared parameter estimates from GEEs among levels of significant explanatory variables from the final fitted model. The GENMOD procedure (SAS Institute 2004) provides comparisons for each level of explanatory variables with the last sorted level of that explanatory variable in the model (Stokes et al. 2000); I ran iterations of the final fitted model to allow comparisons among all levels of significant explanatory variables.

RESULTS

Distance Moved between Diurnal and Nocturnal Locations

I collected 47 observations on 39 radio-marked female mallards from 14 January 2005 to 18 January 2005 and 420 observations on 41 radio-marked female mallards from

2 January 2006 to 29 March 2006. For this data set, I collected nocturnal locations following diurnal locations on 406 occasions, and diurnal locations following nocturnal on 61 occasions, all within a 24 hour period. Mean (\pm SE), median, and range of distances between paired diurnal and nocturnal locations were 2524 ± 150.1 m, 1501.25 m, and 19-25,806 m, respectively.

My analysis of movement distance was based on 467 observations on 80 radio-marked females (282 observations on 50 adults and 185 observations on 30 immatures). My final fitted model indicated that distances moved varied inconsistently by date among habitat types (date by habitat type interaction; $F = 5.27$, 4, 378; $P = 0.0004$) and among individual females ($P = 0.0062$). I failed to detect significant effects of other explanatory variables or interactions (all P s ≥ 0.1008). First order autoregression provided a better fit to the matrix structure of repeated measures than did compound or simple symmetry (Δ AIC from full models = 3.8 and 1.8, respectively).

Distance moved increased with date for females diurnally located in RICE ($P = 0.0342$), whereas it decreased with date for females diurnally located in FOREST ($P = 0.0002$; Figure 3.2). Distances moved were not correlated with date for females diurnally located in REFOR, OTHER, or MSIDLE (P s = 0.0580, 0.1992, and 0.8837, respectively).

Habitat Switching

My analysis of habitat switching was based on the same 467 observations on 80 radio-marked females as was my analysis of movement distances. My final fitted model indicated that switching varied among diurnal habitat types used by females ($P = 0.0060$).

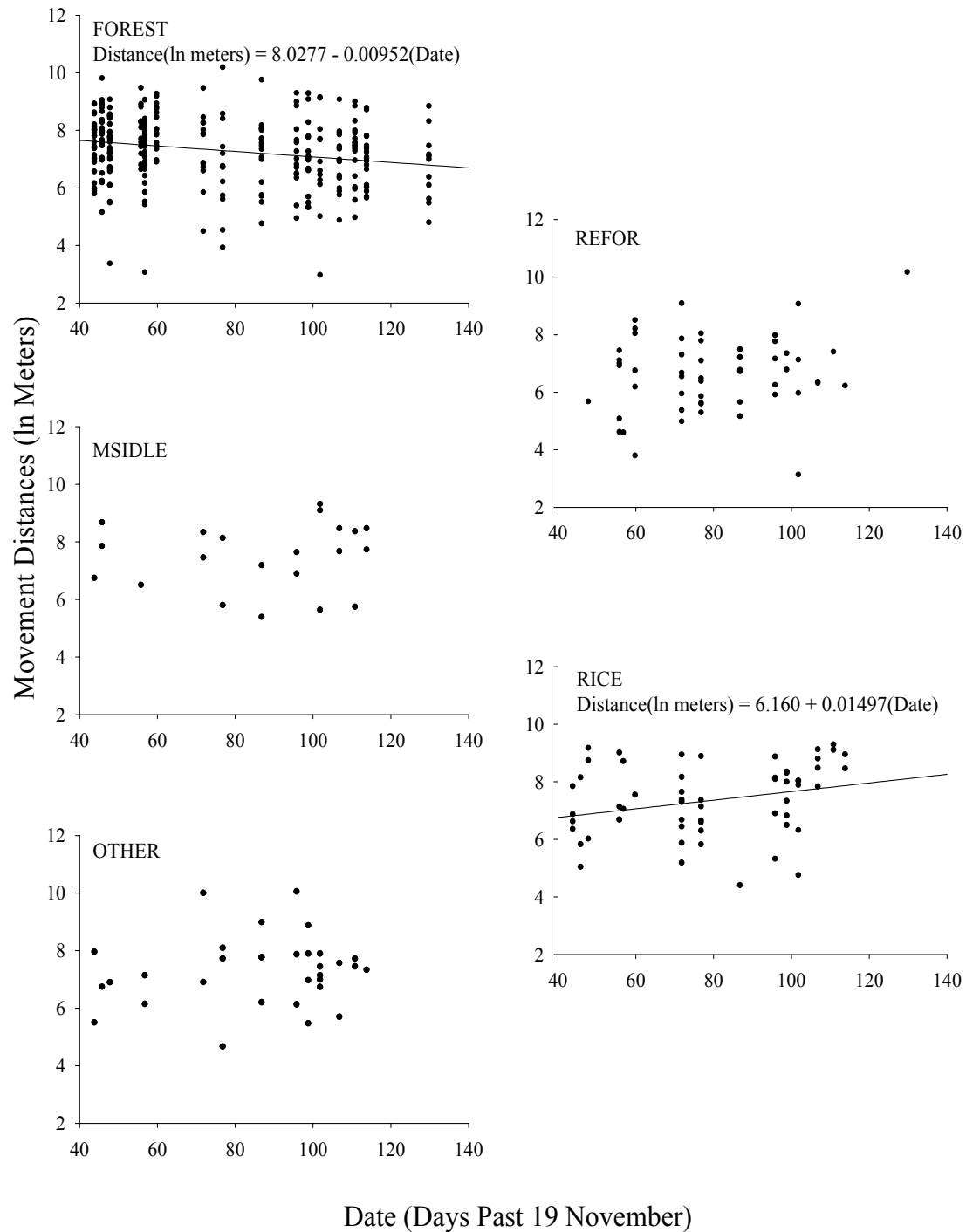


Figure 3.2. Movement distances (natural log m) by date (days past 19 November) for each diurnal habitat type. Habitats depicted with a line were significantly correlated with date; equations and lines depicted on graphs are based on estimated intercepts and slopes provided by the final mixed model ANCOVA.

I failed to detect significant effects of other explanatory variables or the interaction (all P s ≥ 0.0634). Females diurnally located in FOREST and REFOR were less likely to switch habitats than were those in RICE (P s = 0.0001 and 0.0053, respectively), whereas habitat switching did not differ for females diurnally located in MSIDLE or OTHER from those in RICE (P s = 0.1085 and 0.8746, respectively). Females diurnally located in OTHER and MSIDLE were more likely to switch habitats than were those in REFOR (P s = 0.0060 and < 0.0001 , respectively), whereas habitat switching did not differ for females diurnally located in FOREST from those located in REFOR ($P = 0.6170$). Females diurnally located in FOREST were less likely to switch habitats than were those in OTHER ($P = 0.0002$), whereas habitat switching did not differ for females diurnally located in MSIDLE from those in OTHER ($P = 0.0583$). Females diurnally located in FOREST were less likely to switch habitats than were those in MSIDLE ($P = 0.0002$).

Females located diurnally in FOREST or REFOR frequently were located in the same habitats at night, indicating that habitat switching was very low for these two habitats (Table 3.1). Females located diurnally in RICE were located in the same habitat at night less frequently than females located diurnally in FOREST or REFOR.

Table 3.1. Number of nocturnal locations in each habitat type by their corresponding diurnal locations for paired observations within a 24-hour period.

		Nocturnal Habitat Type ^a					Total ^b
		FOREST	MSIDLE	OTHER	REFOR	RICE	
Diurnal Habitat Type	FOREST	245 (81)	14 (5)	6 (2)	20 (7)	17 (6)	302
	MSIDLE	4 (19)	5 (24)	4 (19)	3 (14)	5 (24)	21
	OTHER	4 (13)	4 (13)	15 (47)	4 (13)	5 (16)	32
	REFOR	7 (13)	1 (2)	0 (0)	42 (78)	4 (7)	54
	RICE	15 (26)	6 (10)	3 (5)	8 (14)	26 (45)	58

^a Numbers in parentheses indicate the percentage of females located nocturnally in each habitat type for each row of corresponding diurnal habitat type.

^b Row percentages sum to 100 % across columns, exclusive of rounding error.

DISCUSSION

My results indicate that distances moved by radio-marked females generally were short, and may reflect close proximity of habitats used during day and night. The observed increase in movement distances with date for females diurnally located in RICE and decrease for those diurnally located in FOREST may reflect differing food availability in these habitats. Available waste rice declines as winter progresses due to granivory, germination, and decomposition; thus, leaving few seeds available for foraging waterfowl (Stafford et al. 2006). Accordingly, females diurnally located in RICE may be responding to declining rice within my study area. Conversely, seeds available in forested wetlands may be more persistent. For example, Neely (1956), reported that decomposition rates of acorns reached only 4% after 90 days of flooding.

Females located diurnally in FOREST seemingly roost and forage within this habitat and may have little need to move. Fredrickson and Heitmeyer (1988) suggested that females in forested wetlands may find increased food sources in late winter, because invertebrates increase as winter progresses in southern forested wetlands. However, Wherle et al. (1995) found that invertebrates decreased as winter progressed in one of their study sites while increasing on another site. The observed low incidence of habitat switching for females using forested habitats is consistent with Dabbert and Martin's (2000) suggestion that few mallards in forested wetlands forage in agricultural habitats.

Overall, my results suggest that females using forested wetlands may have energetic and survival advantages over females using rice agriculture. Decreased movement distances and less frequent habitat switching could result in decreased energy expenditures and decreased exposure to risks for females using forested habitats. My

results further document the importance of forested wetlands to mallards wintering in the LMAV. Accordingly, the Wetland Reserve Program and other conservation programs that protect or restore forested wetland habitats may help provide important wintering habitat for mallards in the LMAV.

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CHAPTER 4. WINTER SURVIVAL OF FEMALE MALLARDS IN THE LOWER MISSISSIPPI ALLUVIAL VALLEY

Approximately 40% of the Mississippi Flyway's mallard (*Anas platyrhynchos*) population winters in the lower Mississippi Alluvial Valley (hereafter LMAV; Bellrose 1976). Mallards are a highly desired species for Arkansas and Louisiana duck hunters. During the 2004-2005 and 2005-2006 hunting seasons, mallards comprised 49 and 43 percent of the Arkansas duck harvest and 10 and 12 percent of the Louisiana duck harvest, respectively (Padding et al. 2006). Given the large number of mallards wintering in this region, survival of females in the LMAV potentially could influence continental mallard populations.

Previous radio-telemetry studies have reported relatively high winter survival rates for mallards in the LMAV. Reinecke et al. (1987) reported a winter survival rate of 0.82 for radio-marked female mallards during the early to mid 1980s. Dugger et al. (1994) reported no deaths for radio-marked females marked after hunting seasons during 1988 and 1989. Previous radio-telemetry and reward band studies indicated that hunting was the primary mortality agent for mallards within the LMAV, (Reinecke et al. 1987, Dugger et al., 1994). Conversely, for mallards in the Playa Lakes region of Texas, non-hunting mortality was higher than hunting mortality (Bergan and Smith 1993).

Several studies have examined effects of female age, body condition, winter of study, and time periods within winters on winter survival of mallards. Data from previous radio telemetry and banding studies have indicated that adults survive at higher rates than do immatures (Reinecke et al. 1987, Blohm et al. 1987). Further, Blohm et al. (1987) suggested that age effects did not diminish during hunting seasons. Survival is

positively correlated with early season body condition during winter (Bergan and Smith 1993, Jeske et al. 1994). Annual variation in regional water conditions did not affect survival in previous radio-telemetry studies of mallards; however, annual variation in water conditions may not have been extreme in these studies. My study included one extremely wet and one extremely dry winter; thus, detection of a significant effect of winter on survival could indicate a response to regional water conditions among winters. Reinecke et al. (1987) reported that daily survival rates increased after hunting seasons had closed in the LMAV, and Dugger et al. (1994) reported high survival rates for females marked in late winter after hunting seasons. Effects of timing within the hunting season on survival of female mallards have not been studied. Moreover, current estimates of survival and cause-specific mortality rates would be useful to managers.

My objectives were to estimate survival rates for female mallards in the LMAV and document and compare cause-specific mortality factors. Specifically, I examined variation in survival due to the following explanatory variables: female age, body condition at time of capture, winter of study, time periods defined by hunting seasons (hereafter, hunt periods), and timing within hunt periods where duck seasons were open. I also estimated specific survival rates for hunting and non-hunting related mortalities. Finally, I examined the effects of timing within hunt periods open to duck hunting on survival from hunting-related mortality.

STUDY AREA

My trap sites were located on the Mollicy Unit of Upper Ouachita National Wildlife Refuge (NWR), 19.5 kilometers (km) east and 5 km north of Marion, Louisiana (Figure 4.1). Upper Ouachita NWR is a 14,973-hectare (ha) area encompassing the

floodplain of a 29-km length of the Ouachita River. The Mollicy Unit is a 6475-ha tract of Upper Ouachita NWR located on the east side of the Ouachita River. The unit was enclosed by a levee and cleared for agriculture in the 1960's, and presently is undergoing extensive reforestation. Reforestation tracts include 3817 ha on the Mollicy Unit; the remainder currently is in rice agriculture or left fallow and dominated by moist-soil vegetation.

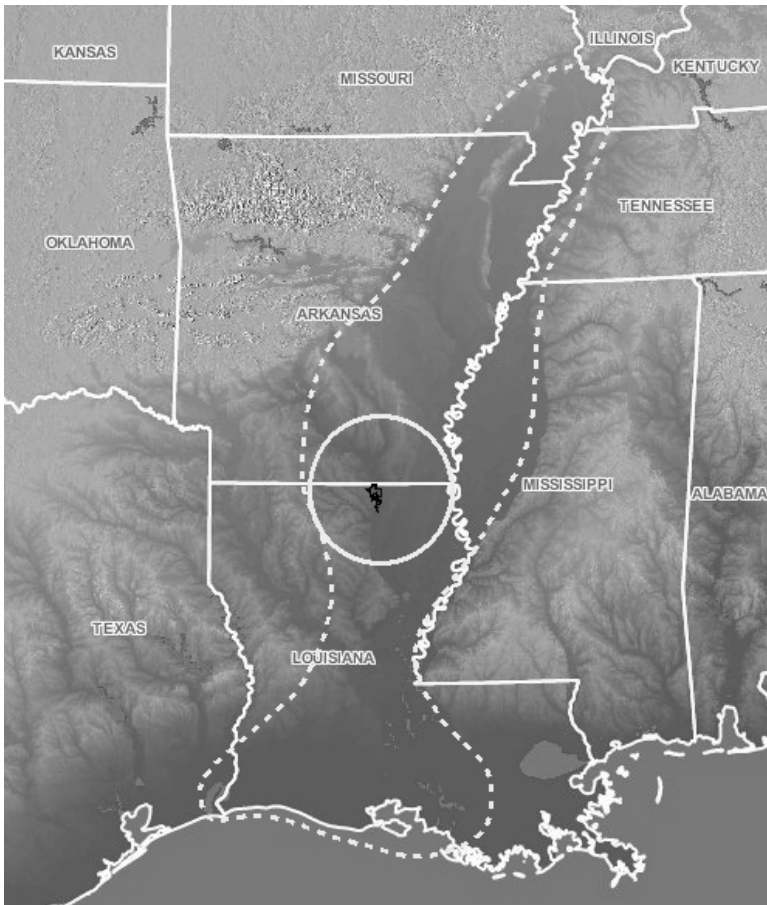


Figure 4.1. Core tracking area (heavy light circle) and extended search area (dashed light circle) with trapping areas at Upper Ouachita NWR (black polygon) noted in center.

My core tracking area included all lands within 80 km of my trap sites. This area encompassed a portion of the MAV in northeastern Louisiana and southeastern Arkansas (Figure 4.1) and was assumed to be representative of the LMAV. This area included five

publicly owned areas managed by the U.S. Fish and Wildlife Service: D'Arbonne NWR, Black Bayou Lake NWR, Handy Brake NWR, Felsenthal NWR, and Overflow NWR. The core tracking area also included Bayou Macon Wildlife Management Area (WMA), Russell Sage WMA, and Ouachita WMA managed by Louisiana Department of Wildlife and Fisheries, as well as Beryl Anthony WMA, Cut Off Creek WMA, Seven Devils WMA, and several tracts of Casey Jones WMA managed by Arkansas Game and Fish Department.

My extended search area included all of the LMAV and a portion of southwest Louisiana (Figure 4.1). The LMAV has been described in detail by Delnicki and Reinecke (1986). I used searches in the extended tracking area to help differentiate between females emigrating from the core tracking area and those whose transmitters failed.

METHODS

Field Methodology

I captured and radio-marked 91 (61 adult and 30 immature) and 98 (51 adult, 46 immature, and 1 unknown age) female mallards from 27 November through 15 December 2004 and from 19 November through 22 November 2005, respectively. I captured females using swim-in traps adapted from those described by Mauser and Mensik (1992) or rocket nets fired from portable platforms (Dill and Thornberry 1950, Cox and Afton 1994), all of which were baited with a mixture of rice, wheat, corn, and sweet potatoes. In 2004, 57 of 91 radio-marked females were caught using swim in traps, and the remainder was captured using rocket nets. In 2005, all females were captured using rocket nets.

I banded captured females and aged them either as immature (hatched during year of capture) or adult (hatched prior to year of capture) according to wing plumage (Carney and Geis 1960). I also recorded mass (± 10 g), flattened and natural wing chord (± 1 mm), and total tarsus, head length, culmen, and middle toe to (± 0.05 mm, Dzubin and Cooch 1992). I palpated each females neck and scored the esophageal contents of each female immediately prior to weighing and marking as full (containing a large amount of grain), medium (containing some grain), or empty (containing little or no grain). I failed to record age or morphological measurements for 2 radio-marked females; these females were excluded from all analyses.

I instrumented females with 21-g, harness-type transmitters (Dwyer 1972; Advanced Telemetry Systems; Isanti, MN). When the number of females captured exceeded available number of transmitters, I randomly selected females for radio-marking from the captured sample.

Transmitters pulsed at 50 beats per minute and were coded to pulse double on every tenth beat to distinguish them from other transmitters with similar frequencies. Transmitters had an expected battery life of 160 days and were equipped with mercury-type mortality switches that caused their pulse rates to double if they remained motionless for > 4 hours. I provided food and water *ad libitum* for all captured ducks while held for instrumentation and measurements (LSU ACUC plan # 04-108). I released females simultaneously with accompanying males at capture sites < 24 hours after capture to minimize potential handling effects (Cox and Afton 1998). Each radio transmitter carried a label on the underside offering a reward (pencil-sketch art print) to

hunters for contacting project personnel and providing information about the bird (date, time, and location where bird was killed).

Data Analysis

I excluded the first four days of exposure (hereafter, adjustment period) for each female from all analyses to avoid bias due to stress from capture and handling (Cox and Afton 1998). I subsequently assigned daily status for each female into 1 of 3 categories for each day of the tracking period: 1) alive inside the core study area, 2) dead inside the core study area, or 3) dead or alive outside the core study area. When I was not able to determine bird status directly for a given day (i.e. was unable to complete a search of the entire study area and had not found the bird on a partial search), I interpolated status based on days where status was known. If status was the same for consecutive tracking events, I assumed it to be constant for the days between them. When exact date of a mortality event was unknown, I estimated it as the midpoint between the last day the bird was known to be alive and the first indication of its death (Cox and Afton 1998).

Mortality events initially were classified as caused by hunting, avian, mammalian, or unknown sources based on hunter reports or evidence gathered at recovery sites, including damage to transmitters (e.g. bite marks), carcass condition, location of carcasses or transmitters, or tracks in the vicinity as have others (e.g. Reinecke et al 1987, Bergan and Smith 1993, Cox and Afton 1998, Fleskes et al. 2007). I classified mortality events as unknown when evidence for cause of death was inconclusive.

I subsequently classified mortality events as either caused by hunting or non-hunting related factors (including mortalities from avian, mammalian, and unknown

sources). I elected to include mortalities from unknown sources in my non-hunting mortality estimate as have others (e.g. Bergan and Smith 1993, Cox and Afton 1998).

I used data collected on search flights in my extended tracking area to attain emigration information. I excluded (right censored) birds after they emigrated from the study area, their radio-transmitters failed, or I lost contact with them. When the exact date of an emigration event was unknown, I estimated it by randomly assigning the event to a day in the interval containing the true possible emigration event (Cox and Afton 2000). I included emigrating females which returned to the study area after they re-entered.

Louisiana and Arkansas utilize a split hunting season, with two open periods of hunting separated by a closed season. In addition, the duck season in Arkansas was closed on 25 December of each year and reopened on 26 December. Days were included in the hunt periods assigned to the open hunting seasons (FIRST or SECOND) if regular duck season was open in either Louisiana's east zone or in Arkansas, or to a closed season (SPLIT or POST) when hunting seasons were closed in both areas. This resulted in unequal interval lengths, with POST being the longest hunt period in the analysis.

Statistical Procedures

Body Condition at Capture

Whyte and Bolen (1984) suggested that individual variation in lipid stores and structural size should be accounted for by condition indices. Thus, I first performed principal components analysis (PROC PRINCOMP; SAS Institute 2004) on 5 morphological measurements (natural wing chord, total tarsus, head length, culmen, and middle toe; Dzubin and Cooch 1992) and then used the first principal component score as

a measure of body size for each marked female. I subsequently used analysis of covariance (PROC GLM; SAS Institute 2004) to test for a relationship of body mass to body size and esophageal content score; I treated body size as the continuous covariate and esophageal content score as a categorical explanatory variable with three levels. Finally, I adjusted body mass of each female for her body size and esophageal content score by adding the overall mean body mass of females to her residual from the model and used adjusted body mass as an index of body condition (Ankney and Afton 1988, Dufour et al. 1993).

Survival Based on All Sources of Mortality

I used proportional hazards regression (PROC PHREG; SAS Institute 2004) to test for differences in survival relative to female age, female body condition at time of capture, winter, hunt period, and all potential 2-way interactions (Cox 1972, Allison 1995). This survival analysis requires that the user determine a point in time where analysis will start and that time thereafter is treated as a continuous variable (Allison 1995, pp. 22-25). For my analysis, I reset the continuous time variable to the origin at the beginning of each hunt period. I used backward step-wise procedures to eliminate nonsignificant ($P > 0.05$) terms, beginning with 2-way interactions.

I present product-limit survival estimates (Kaplan and Meier 1958) (\pm SE) based on significant effects in my final fitted model. Hazard ratios (Allison 1995) are presented for comparisons among levels of significant explanatory variables. When effects of hunt periods were significant, I provide survival rates for each hunt period (interval survival rates). For comparison with previous studies, I also present survival estimates derived using MICROMORT (Heisey and Fuller 1985).

Cause-specific Mortality

I estimated cause-specific survival rates by estimating separate product-limit survival rates for hunting and non-hunting mortality. Cause-specific mortality rates are computed as 1-cause specific survival rates. For comparison with previous studies, I also present cause-specific mortality estimates derived using MICROMORT (Heisey and Fuller 1985).

Survival Considering Only Hunting Mortalities

For these analyses, I estimated survival based exclusively on hunting related mortality for the core study area, and included exposure days during the FIRST and SECOND hunt periods only for each winter. Females dying from non-hunting causes were right censored on the day of their mortality event. I excluded females temporarily emigrating from the core tracking area while they were absent, but included them again when they returned. I used proportional hazards regression to test for differences in survival relative to female age, body condition at time of capture, winter, hunt period, and all potential 2-way interactions (Cox 1972, Allison 1995).

To assess the effect of timing within the hunt period, I examined intervals within the FIRST and SECOND in a separate model containing only this effect. Maximum length of hunt periods was 45 days in each winter. To maintain a minimum of 1 death in each interval while maximizing the number of equal length intervals in the analysis, I subjectively divided hunt periods into 9-day intervals. I treated these 9-day intervals as a categorical explanatory variable with 5 levels, and examined their effects on survival from hunting using proportional hazards regression (Cox 1972) with the continuous time variable reset to the origin at the beginning of each 9-day interval (Allison 1995). Days

from both the FIRST and SECOND hunt periods were included in the first two 9-day intervals.

RESULTS

Body Condition at Capture

The combination of body size and esophageal content score explained 35% of the overall variation in body mass among radio-marked females. Body mass was positively related to body size ($F = 75.79$, 1, 174 df; $P < 0.0001$) and varied significantly among esophageal content scores ($F = 3.88$, 2, 174 df; $P = 0.0226$). The equations for body condition (adjusted body mass) were:

Empty esophagei: Body condition (g) = $1121.91 + 40.03$ (body size)

Medium esophagei: Body condition (g) = $1140.01 + 40.03$ (body size)

Full esophagei: Body condition (g) = $1196.34 + 40.03$ (body size)

Survival Based on All Sources of Mortality

This analysis included 11,912 exposure days on 174 radio-marked female mallards. The analysis included 60 adults and 30 immature females in 2004-2005 and 45 adults and 39 immature females in 2005-2006. The number of females included for analysis varied throughout each winter, and declined in late winter (Figure 4.2). Thirteen of 187 available radio-marked females were excluded from this analysis because they either died, their transmitters failed, I lost contact with them, or they emigrated from the core tracking area during the first four days of exposure. My final fitted model included only effects of hunt period ($P = 0.0103$). All other explanatory variables, including interactions were not significant ($P_s \geq 0.0899$).

The interval survival rate was highest during SPLIT (Table 4.1). Hazard ratios indicate that female mallards were 5.6 (95% CI 1.4 - 21.9) times and 4.4 (95% CI 1.5 - 12.4) times more likely to die on any given day in the FIRST or SECOND, respectively, than they were on any given day in the POST. The product-limit survival estimate through the entire tracking period was 0.542 ± 0.101 (Figure 4.3). Overall survival estimated using MICROMORT (Heisey and Fuller 1985) was 0.670 ± 0.043 .

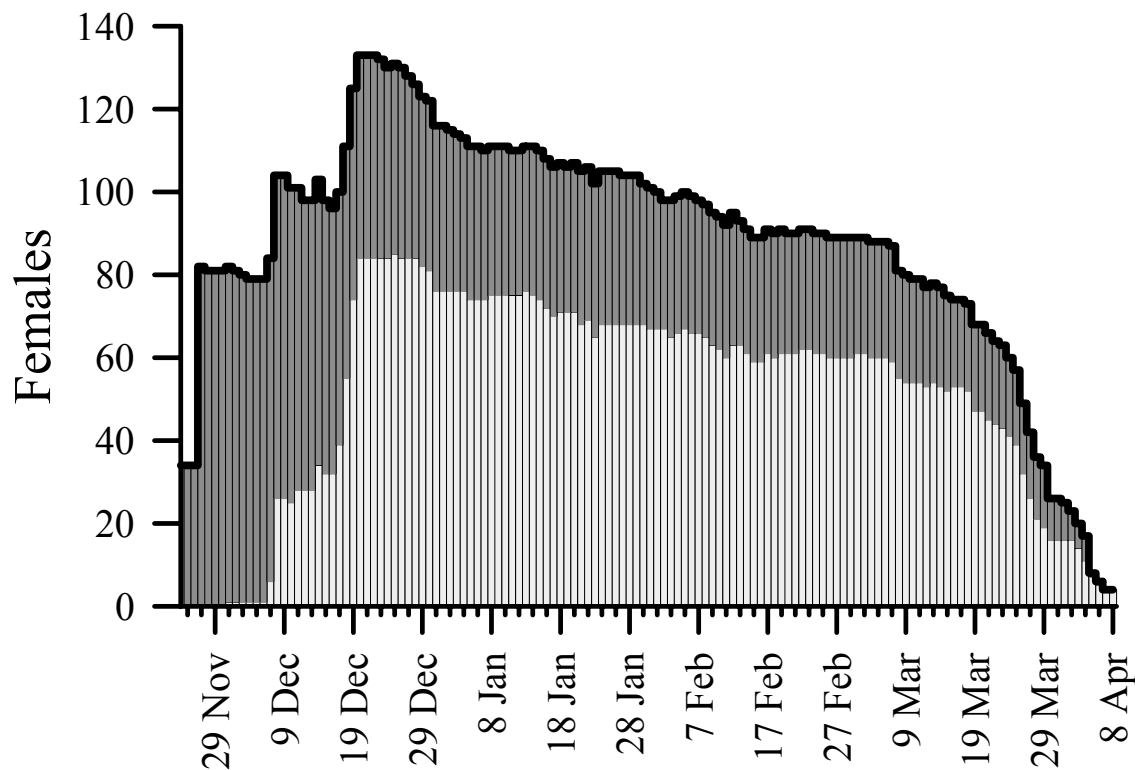


Figure 4.2. Total number of radio-marked females included in sample for survival estimation on core tracking area by date as shown by heavy line. The lighter section of each bar represents number of females tracked in winter 2004-2005 and the darker section of each bar represents number of females tracked in winter 2005-2006.

Although the effect of female body condition was removed from my final model, there was weak evidence that female body condition affected survival ($P = 0.0899$). The predicted overall survival rate for the highest condition female exceeded the predicted seasonal survival rate for the lowest condition female by a factor of 2 (Figure 4.4).

Table 4.1. Interval survival rates, standard errors, and duration by hunt period for winters 2004-2005 and 2005-2006 combined.

Hunt period ^a	Duration (days) ^b	Survival Rate	
		\hat{S}_i	SE
FIRST	12	0.89554	0.04332
SPLIT	10	0.98058	0.01353
SECOND	46	0.82960	0.03374
POST	68	0.72147	0.14864

^a Days were included in FIRST or SECOND if hunting seasons were open in either winter of the study for that day.

^b Duration reflects number of days that radio-marked females were exposed during each hunt period.

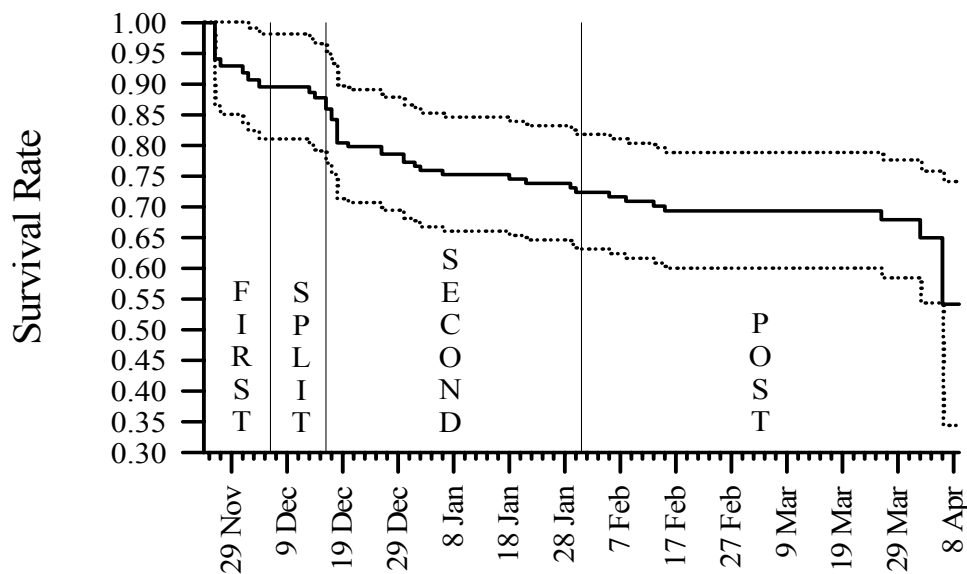


Figure 4.3. Seasonal product-limit survival rate (solid line) on core tracking area with confidence limits (dotted lines) by date for both winters combined. Vertical reference lines indicate the start of each hunt period.

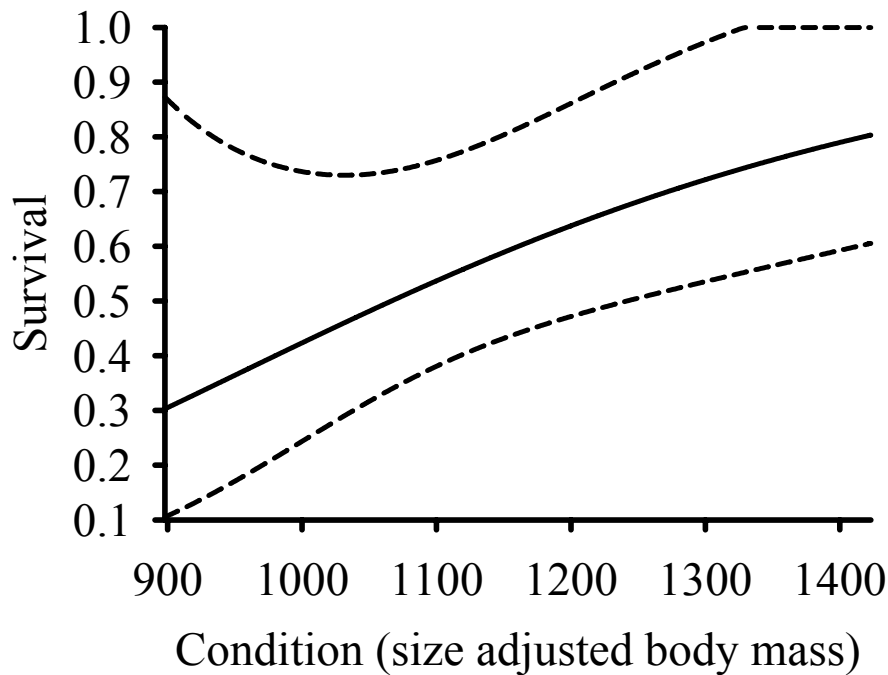


Figure 4.4. Predicted survival through entire tracking period by female body condition at time of capture (solid line) with confidence limits (dashed lines).

Cause-specific Mortality

I detected 36 mortalities on the core tracking area after excluding the first four days of exposure for each female; equal numbers of deaths were attributed to hunting and non-hunting mortality. Non-hunting mortalities included those from avian ($n = 9$), mammalian ($n = 2$), and unknown ($n = 7$) sources. Nine deaths attributed to non-hunting causes occurred when all hunting seasons were closed, of which four were from unknown sources and occurred during POST (10, 17, 56, and 67 days after all hunting seasons were closed). Three deaths initially attributed to unknown causes occurred during SECOND.

Cause-specific mortality rates (\pm SE) for the entire tracking period were 0.177 ± 0.041 and 0.342 ± 0.119 for hunting and non-hunting sources of mortality, respectively. Cause-specific mortality rates estimated using MICROMORT (Heisey and Fuller 1985) were 0.156 ± 0.035 and 0.173 ± 0.038 , for hunting and non-hunting mortalities, respectively.

Survival Considering Only Hunting Mortalities

This analysis included 5849 exposure days on 172 birds. The analysis included 59 adults and 30 immature females in 2004-2005 and 44 adults and 39 immature females in 2005-2006. Mean, median, minimum, and maximum number of exposure days beyond the 4-day adjustment period for the 18 females which died from hunting were 19.8, 20, 1, and 43 days, respectively. My final fitted model indicated that none of the explanatory variables, including interactions, were significant (all P s ≥ 0.1496). Survival, considering hunting mortality only, on the core tracking area, was 0.814 ± 0.0429 .

My model examining timing within hunt periods open to hunting indicated that 9-day intervals were significant ($P = 0.0303$) predictors of survival. Survival was lowest during the first nine days of open hunting seasons (Table 4.2). Hazard ratios indicate that females were 7.7 (95% CI 1.0 – 60.6) times as likely to be shot on any given day in the first 9-day portion of an open hunting period as they were in the last 9-day portion an open hunting period.

Table 4.2. Interval survival with standard errors on the core tracking area when considering only hunting during each 9-day portion of an open hunting season.

Day	Survival Rate	
	\hat{S}_i	SE
1-9	0.91958	0.02429
10-18	0.96698	0.01486
19-27	0.99099	0.00893

28-36	0.99038	0.00952
37-45	0.99038	0.00952

DISCUSSION

Choice of a survival estimator is a critical step in any survival analysis. Estimation methods outlined by Heisey and Fuller (1985) (hereafter H-F method) assume that daily survival rates remain constant among days within hunt periods. The H-F method is not sensitive to sample size reductions within each hunt period, but does account for changing sample sizes between hunt periods. I used the product-limit (Kaplan and Meier 1958) survival estimator, which makes no assumptions about constancy of daily survival probabilities within hunt periods and accounts for changing sample sizes among days. I favor the product-limit estimator because of its advantages in handling decreasing sample sizes over time and inconsistent survival rates among days as documented in my analysis of survival among 9-day periods within open hunting seasons. However, I also present H-F method survival estimates to allow direct comparisons with Reinecke's (1987) results.

My survival estimates may be subject to potential biases which overestimate or underestimate survival. Daily survival estimates were derived from a sample of females which generally decreased as winter progressed; thus, mortalities near the end of my tracking season have a larger impact on survival estimates than mortalities near the beginning of my tracking period and introduce decreased precision (increased standard errors). In one banding study, male mallards banded on areas closed to waterfowl hunting seemingly survived at higher rates than those banded on areas open to hunting (Blohm et al. 1987). Given that my entire sample was marked on areas closed to hunting,

survival probabilities for female mallards in my study area may be overestimated if this effect occurs in my study area. However, females use areas closed to hunting only 21 – 42 percent of the time during diurnal sampling periods (see Chapter 2).

My survival estimate for radio-marked females is lower than that reported by Reinecke et al. (1987) for similarly marked female mallards elsewhere in the LMAV. Unfortunately, differences in study areas and analysis methodology confound direct comparisons between studies. Direct comparison of H-F method survival rates among studies indicates a lower survival rate during my study compared to previous estimates without the confounding effects of different estimation methodologies.

My results are consistent with Bergan and Smith (1993) but contrast with those of Reinecke et al. (1987) and Fleskes et al. (2007) in that non-hunting mortality rates were higher than hunting mortality rates. Due to consumption of carcasses, hunting could not be completely ruled out as a contributing factor to deaths classified as non-hunting mortality in my study. Further, all mortalities originally classified as unknown were categorized as non-hunting for analyses, which may have potentially inflated my non-hunting mortality estimate. Considering 4 mortalities classified as unknown occurred during POST and ≥ 10 days after hunting seasons closed, it seems less likely that these deaths were related to hunting than non-hunting causes. Alternately, females wounded by predators could have been more vulnerable to hunting. Dugger et al. (1994) reported no deaths in late winter for female mallards marked after hunting seasons, whereas I documented 7 deaths (19 % of my total detected mortalities) after hunting seasons closed in my study. Thus, my results indicate that non-hunting mortality is more prevalent now than during earlier studies in the LMAV. The overall difference in survival between my

study and previous studies in the LMAV seemingly is due to increased non-hunting mortality.

I found weak evidence for an effect of body condition on female survival, which is consistent with results of Bergan and Smith (1993). Body condition could only be measured once for each female, four days prior to her entry into the dataset, so it is unknown how much body conditions changed during the wintering period. Hepp et al. (1986) reported hunter killed mallards were lighter, on average, than mallards in the population, but I detected no effect of body condition on survival from hunting. Thus, my weak evidence for a condition effect on survival may have been driven by a condition effect on non-hunting mortality.

I failed to detect differences in survival rates due to either female age or winter of study. My failure to find an effect of female age may in part be due to the relatively late capture of females in my study. Immature females that survived until arrival in my study area may have gained experience that enabled them to survive as well as adults during winter in my study area. Weather and water conditions often are considered a major factor influencing survival rates in wintering populations of waterfowl. Weather varied greatly between the two winters of my study; 2004-2005 was extremely wet, and 2005-2006 was very dry (see Chapter 2). Failure to find effects of winter on survival of female mallards in my core tracking area despite considerable differences in weather patterns may have been due to changes in emigration rates between the two years of the study. For the majority of the tracking period, fewer females remained on my core tracking area in 2005-2006 than in 2004-2005 (Figure 4.2). Thus, some females may have emigrated to other areas with better water conditions in 2005-2006.

Hunting seasons were 60 days long during each winter of my study and timing within the hunting season apparently influenced survival. Survival from hunting did not differ among hunt periods; however hunting mortality was highest during the first 9 days of open hunting seasons. Considering that females which were shot were exposed, on average 18 days beyond their initial 4 day adjustment period, it is unlikely that this result is entirely an artifact of a short adjustment period.

MANAGEMENT IMPLICATIONS

If increasing female mallard survival is a management objective, several management strategies might be implemented to decrease non-hunting and hunting mortality. Management practices which reduce predator abundance or vulnerability of mallards to predators in wintering areas may decrease non-hunting mortality. Hunting mortality potentially could be decreased by manipulating habitats or closed zone boundaries to include habitats which are more frequently used by female mallards in this area (see Chapter 2). Louisiana and Arkansas both implement split regular duck hunting season utilizing two periods of open hunting. Since female mallards may be more susceptible to hunting near the beginning of hunting seasons, a continuous season, without splits might result in lower hunting mortality.

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CHAPTER 5. SUMMARY

Mallard (*Anas platyrhynchos*) populations in the Lower Mississippi Alluvial Valley (LMAV) historically averaged 1.6 million and represented the largest concentrations of wintering mallards in North America. Effective management of this wintering population requires current information on habitat use, movements, and survival of female mallards. I used radio telemetry techniques to assess these parameters during winters 2004-2005 and 2005-2006.

I found that radio-marked female mallards used forested wetland habitats extensively during day and night. Proportional use of habitats varied inconsistently among time periods defined by hunting seasons and winters. Proportional use of forested wetlands ranged from 0.464 to 0.816 and from 0.280 to 0.764 during diurnal and nocturnal sampling periods, respectively.

Mean movement distances (\pm SE) between diurnal and nocturnal locations were 2524 ± 150.1 meters and varied inconsistently by date among habitat types. Females often used the same habitat types during the day and at night and were less likely to switch habitats when diurnally located in forested habitats than in rice.

The product-limit survival rate of radio-marked female mallards through the 140-day tracking season was 0.542. Interval survival rates varied among time periods defined by hunting seasons and ranged from 0.721 to 0.981. Rates of non-hunting related mortality were higher than that historically estimated for female mallards in the LMAV.

The observed habitat use and movements demonstrates the importance of forested wetlands to female mallards in the LMAV. Continued restoration and establishment of forested wetland habitats should benefit wintering mallards in the LMAV. Finally,

waterfowl managers may want to consider management actions that could improve survival of female mallards in the LMAV.

VITA

Bruce Edward Davis grew up in Glidden, Iowa. He has spent a good portion of his childhood and adult life in pursuit of wild game and fish. He attended Iowa State University from 1991 to 1996 and graduated with a Bachelor of Science degree in fisheries and wildlife biology. He spent the next 8 years primarily working as a seasonal technician in support of research projects on waterfowl in breeding, wintering, and spring-migrational habitats. He then enrolled in the graduate program at Louisiana State University. The degree of Master of Science will be awarded to Bruce in December 2007.