Winter ecology of radiomarked female mallards in Mississippi's Alluvial Valley

By

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Interactions between animal populations and their environment form the foundation of wildlife management, and provision of resources that enhance fitness produce effectual management. Hunting is a selective force that shapes behavior and other adaptations of harvested species and may subsequently impact diel habitat use. Moreover, linking habitat use to biological outcomes, such as survival, is needed to evidence habitat suitability because of equivocal relations among population density, habitat correlations, or energy availability to population dynamics. The mallard (*Anas platyrhynchos*) is among the most coveted and harvested waterfowl in North America and is a migratory species of ecological, economic, and social importance. The Mississippi Alluvial Valley (MAV) is an ancestral and continentally important wintering area for North American mallards despite significant anthropogenic wetland transformation. Through targeted objectives and consequence of soil and water conservation, financial assistance programs have expanded waterfowl habitat on private lands in Mississippi. I radiomarked 265 female mallards and tracked their diel habitat use in winters 2010-2015 to evaluate objectives related to their wintering ecology in the MAV of Mississippi.

Specifically, I investigated whether waterfowl hunting influenced use of some habitats during hunting season, the effectiveness of financial assistance programs in providing habitat, and habitat suitability through habitat specific survival rates. Females made greatest use of forested and emergent wetlands diurnally and emergent wetlands and flooded cropland at night. Results suggested that mallards did not avoid flooded cropland or emergent wetlands diurnally during hunting season, but conclusions were complicated by significant use of inviolate sanctuaries. Mallards used numerous incentivized conservation program wetlands, but use was less than public and privately managed wetlands. Among conservation programs, those with large enrollment and a focus on restoration (i.e., Wetlands Reserve Program) were most used by mallards. Apparent survival was independent of diurnal habitat use suggesting that mallards use of wetland complexes leads to their winter survival. Restoration of forested wetlands should be a management focus and easement programs provide such inroads on private lands. Public wetlands are an important source of habitat and inviolate sanctuary should be considered where waterfowl hunting is a predominate activity.

DEDICATION

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CHAPTER I

INTRODUCTION

The Mississippi Alluvial Valley (MAV) is a 10 million ha region extending 800 km north to south from the confluence of the Ohio and Mississippi Rivers at Cairo, Illinois to the Deltaic Plain of Louisiana (Reinecke et al. 1989). The region once was primarily forested and received dynamic inundation from runoff and overbank and backwater flooding from the Mississippi River and its tributaries. Mineral rich soils deposited during floods made the MAV ideal for crop production; thus, forests were cleared for agriculture and other anthropogenic pursuits. Frequent flooding prevented cropping much of the MAV until flood abatement facilitated drainage and clearing of 7.5 M ha of hardwood bottomlands by the late 20th century. Today, approximately 65% of the MAV is cultivated and soybean, corn, cotton, rice, and winter wheat dominate production (Reinecke et al. 1989). At nearly 20,000 km2, the Yazoo Basin is the largest of six drainage basins in the MAV (Saucier 1994). The Yazoo Basin empties the entire MAV portion of Mississippi through a series of major rivers which culminate in a single discharge, the Yazoo River, which enters the Mississippi River at Vicksburg, Mississippi (Lower Mississippi Valley Joint Venture 2002).

The mallard duck (*Anas platyrhynchos*) is a migratory species of significant ecological, economic, and social importance across North America and Europe (i.e., the Holarctic; Bellrose 1976, Baldassarre and Bolen 2006, Grado et al. 2011, Baldassarre

2014, U.S. Fish and Wildlife Service 2016). Mallards exhibit an extensive non-breeding range in North America (Baldassarre 2014). Some individual mallards remain at northern latitudes as long as adequate open water and food allow them to sustain body condition, whereas others migrate regardless of weather conditions and occupy southern latitudes early in winter (Nichols et al. 1983, Schummer et al. 2010). The MAV is a prominent ancestral wintering ground for mallards in North America, especially those in the Mississippi Flyway (Nichols et al. 1983, Reinecke et al. 1989). Mallard harvest surpasses that of all other duck species in the Mississippi Flyway, accounting for 35% of annual duck harvest between 1999 and 2015 (Fronczak 2016). In Mississippi, however, mallard composition in the total harvest has declined since 2006 establishing concern over the quantity or quality of habitat in the state (Fronczak 2016).

Despite significant transformation of wetland resources in the MAV, this region remains one of the most important for non-breeding mallards and other waterfowl in North America (Nichols et al. 1983, Davis et al. 2011, North American Waterfowl Management Plan 2012, Pearse et al. 2012, Baldassarre 2014). Historically, mallards exploited bottomland hardwood forests and associated emergent wetlands inundated by rainfall or backwater flooding. These remain important habitats for non-breeding mallards as they provide forage, cover, and refugia needed to survive and maintain pair bonds through winter (Heitmeyer 2006, Davis et al. 2009, Davis and Afton 2010). For example, Heitmeyer (2006) reported redistribution of mallards to inundated red oak (*Quercus* spp.) bottoms, hyperphagia, and initiation of pre-basic molt resulting from winter flooding in Mingo Basin, Missouri. Mallards have also adapted to exploit inundated post-harvested agricultural fields, using high-energy grains (e.g., corn, rice) to

supplement their diets of natural seeds, tubers, and aquatic invertebrates (Wright 1959, Delnicki and Reinecke 1986, Combs and Fredrickson 1996, Dabbert and Martin 2000, Davis and Afton 2010, Callicutt et al. 2011).

A central tenet of the North American Waterfowl Management Plan (NAWMP 1986) for non-breeding (e.g., wintering) Joint Venture (JV) regions in North America is that food resources limit the number of waterfowl the region can support during winter (Edwards et al. 2012, Williams et al. 2014). Accordingly, the Lower Mississippi Valley Joint Venture (LMVJV) uses energetic carrying capacity (ECC) models to establish regional habitat objectives to sustain 4.3 million non-breeding waterfowl (Reinecke and Loesch 1996). However, ECC models have several drawbacks, including the primary focus on food-producing habitats and exclusion of alternate habitat resources including provisions for thermoregulation, refugia, and protection from predation (Miller et al. 2014). Moreover, ECC model structure excludes consideration of connectivity among, and individual metrics, such as body condition, survival, and prospects for subsequent reproduction (Sedinger and Alisauskas 2014, Williams et al. 2014). Establishing this link between habitat and biological outcomes would enhance managers' abilities to assess and integrate the importance of current or alternative regional planning models for continental waterfowl populations.

A more recent and complex modeling procedure that has been integrated into waterfowl conservation includes agent based models (ABM's), which use a spatially explicit "bottom up" approach to predict biological outcomes (Williams et al. 2014). Specifically, empirical data such as feeding rates, energy expenditure, and foraging patch depletion rates are incorporated into the model thus predicting the survival or resulting

body conditions based on the dynamics of the designated landscape (Miller et al. 2014). For successful application of ABM's to waterfowl ecology, empirical data are needed to inform ABM's because they incorporate heterogeneous individual behavior and life history characteristics of a species of interest (McLane et al. 2011, Guillemain et al. 2017). Thus, investigating non-breeding mallard ecology will provide valuable information to address my proposed hypotheses regarding mallard ecology in the Yazoo Basin and provide empirical data to parameterize ABM's. My specific hypotheses are related to the following topics; investigating whether waterfowl hunting precludes use of some habitats or space by female mallards during hunting season, understanding the role of public lands and conservation easements in providing habitat for wintering mallards, and evaluating habitat suitability as measured by survival rates. Hereafter, I provide a brief justification for each of these aspects of non-breeding ecology as the focus of subsequent dissertation chapters.

Diel habitat use by female mallards in relation to waterfowl hunting and spatiotemporal covariates in Mississippi

The relationship between populations and their environment forms the foundation for wildlife management (Caughly 1977). Acknowledgment of hunting and anthropogenic impacts to this relationship is essential for management of habitats for harvested species (Block and Brennan 1993). For non-breeding waterfowl, a substantial literature base has and continues to build on estimated and spatiotemporal variability of forage availability, its energetic value among habitat types – both of which form the basis for evaluating the significance of habitats to waterfowl species (Kaminski et al. 2003, Kross et al. 2008, Foster et al. 2010, Leach et al. 2012, Olmstead et al. 2013, Foth et al.

2014, Hagy et al. 2014). Additional attempts have been made to adjust the energetic capacity of habitats on public and private lands to compensate for their reduced availability during waterfowl hunting seasons by assuming that waterfowl are ideally and freely distributed among wetlands based on food availability (Fretwell 1972, Edwards et al. 2012). However, this scenario presupposes that waterfowl seek habitats with greatest energy availability. This argument may be less realistic if waterfowl seek habitats that provide reduced predation and disturbance, albeit containing less abundant food. For example, Davis et al. (2009) recorded greatest use of forested wetlands by mallards throughout the winter in northeastern Louisiana, a habitat that provides less energy availability than other habitats such as waste rice or seasonally-flooded herbaceous wetlands (Kaminski et al. 2003). Moreover, waterfowl may alter their circadian habitat use to exploit energy rich habitats during nocturnal periods when the risk of anthropogenic disturbance and mortality are absent (Thornburg 1973; Madsen and Fox 1995; Cox and Afton 1997; Fox and Madsen 1997; Madsen 1998; Roy et al. 2013, 2014; Beatty et al. 2014; Lancaster et al. 2015). Thus, mallards may avoid preferred foraging habitats diurnally due to presence of direct or indirect effects of hunting and related disturbance. If habitat avoidance occurs, I predict greatest use of seasonal-emergent wetlands and flooded agriculture, both potentially quality foraging habitats, will predominate nocturnally during hunting season. Moreover, I would expect greater use of foraging habitats diurnally post-hunting season. Exploring mallard habitat use during and after waterfowl hunting season in the MAV will build on our understanding of important habitats, and particularly in relation to how mallards exploit habitats in response to hunting disturbance.

Female mallard use of public, private, and incentivized conservation wetlands in Mississippi's Alluvial Valley

The LMVJV recognizes waterfowl habitat provided from three primary sources: public lands, managed private lands, and natural flooding (Edwards et al. 2012). Outside of natural flooding, 75% of duck energy days, or the amount of food needed to feed one mallard-sized duck for one day, in Mississippi are provided on managed public lands including federal national wildlife refuges (NWRs) and state operated wildlife management areas (WMAs; Lower Mississippi Valley Joint Venture 2015). Managed private lands can further be classified as managed in an incentivized program (MIP) or managed outside of an incentive program (MOP); these account for 19% and 6% of duck energy days outside of natural flooding, respectively. Private landowners enrolled in an incentivized program adopt practices that conserve soil, water, and related natural resources on active or retired agricultural lands in exchange for technical and financial assistance. Most notable to waterfowl conservation in the MAV is the Wetland Reserve Program (WRP) which retires marginal farmland from production for the duration of the 30-year or perpetual easement and restores wetland and vegetative communities (King et al. 2006). As of 2013, Mississippi ranked fourth nationally for total WRP area with 71,200 ha representing > 570 easements in the state, most of which are located within the Yazoo Basin (Rooks-Barber et al. 2007, U.S. Department of Agriculture 2017). Several additional easement and financial assistance programs through federal, state, and non-governmental organizations provide habitat for non-breeding waterfowl in Mississippi. Although several studies have estimated waterfowl and other waterbird abundances on WRP easements, very little information exists on how waterfowl use WRP and other incentivized programs relative to other private or public lands at the landscape scale

(Olmstead et al. 2013, Tapp 2013, Weegman 2013, Fleming et al. 2015, Tapp et al. 2017). Understanding waterfowl use of incentivized conservation programs will allow managers to gauge the efficacy of such programs and may support the use of such programs to mitigate anthropogenic or natural disasters (Davis et al. 2014). Following the Deepwater Horizon oil spill in the Gulf of Mexico in April 2010 the USDA Natural Resources Conservation Service established the Migratory Bird Habitat Initiative (MBHI) with a goal of providing quality wetland habitats to migrating and wintering waterbirds away from oil-impacted wetlands of the Gulf Coast (Davis et al. 2014). Incentivized wetlands under easement programs such as the WRP and the conservation reserve program (CRP) may be especially important following waterfowl hunting season when private managed wetlands are promptly drained to prepare for spring planting of agricultural crops. Although incentivized private lands provide only 11% of total duck energy days in Mississippi, I hypothesize that they will be a significant habitat source for female mallards in the Yazoo basin, especially after hunting season. Thus, I predict that mallards will use incentivized private lands at equal or greater proportions than managed private and public lands throughout the non-breeding season.

Apparent daily survival of female mallards in Mississippi's Alluvial Valley

Effective management requires recognition and enhancement of resources that positively impact biological outcomes such as survival or reproduction (Leopold 1933, Ayers et al. 2013). Ornithologists have long-studied bird-habitat relationships in terms of birds' presence, abundances, or even demographic consequences of resource exploitation (Stoddard 1931, MacArthur 1958, Hilden 1965, Cody 1981, Hutto 1985, Wiens 1985, Dugger et al. 2005, Kaminski and Elmberg 2014). More recently, Pearse et al. (2012)

identified complexes of habitat and flooded landscapes in the Mississippi MAV that were linked to high densities of mallards (> 100 individuals). This linkage in habitat composition and mallard abundance has advanced our understanding of resources that may attract and retain mallards in the MAV. However, population density is not a surrogate for habitat quality (Van Horne 1983) and biological outcomes may not be accurately predicted by typical habitat correlations or by energy availability (Ayers et al. 2013). A link between habitat use and resulting demographic data is needed to truly evaluate habitat quality and identify important habitat complexes for mallards in the region (Kaminski and Elmberg 2014). Survival has been correlated with individual variation in habitat use for numerous bird species (Holmes et al. 1996, Dugger et al. 2005, Aldridge and Boyce 2008, Whitaker et al. 2008, Breininger et al. 2009). Davis and Afton (2010) advocated that forested wetlands may provide energetic and survival advantages to female mallards because females using forested wetlands were less likely to switch habitats and moved shorter distances than females in other habitats. Therefore, I hypothesize that winter survival of mallards is limited by the availability of forested wetlands and the proportion of forested wetlands in habitat complexes. I predict that females using forested wetlands will have greatest daily survival, and those using greater proportions of forested wetlands than other habitats will experience greatest survival rates over a winter. Understanding how individual mallards survive relative to their use of habitat complexes and specific habitats during winter will help identify quality habitats for continued enhancement and future restoration.

My aforementioned goals and hypotheses that form this dissertation are made possible through my study of diurnal and nocturnal space use and resource exploitation

by 241 radio-marked female mallards during 4 winters (2010-2015) in the Yazoo Basin of the MAV. The following three chapters provide additional background, study area descriptions, detailed methodology, results and discussions of them, and management implications relevant for non-breeding mallards in the Yazoo Basin. Consideration of these objectives will advance our understanding of female mallard ecology during the non-breeding period in the MAV, provide valuable information regarding management of public and private wetlands in the region, and provide empirical inputs needed for future agent based modeling (Miller et al. 2014, Lonsdorf et al. 2016).

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CHAPTER II

DIEL HABITAT USE BY FEMALE MALLARDS IN RELATION TO WATERFOWL HUNTING AND SPATIOTEMPORAL COVARIATES IN MISSISSIPPI

Hunters have been instrumental in establishment and financial support of wildlife conservation in North America since the early 1900s (Geist 1995, Organ et al. 2012, Heffelfinger et al. 2013, Anderson and Padding 2015). For example, 1.3 M waterfowl hunters in the United States contribute billions of dollars annually that benefit habitat conservation in North America (U.S. Fish and Wildlife Service 2006). Mallards (*Anas platyrhynchos*) are among the most coveted waterfowl by hunters and are a migratory species of ecological, economic, and social importance across North America and Europe (i.e., the Holarctic; Bellrose 1976, Baldassarre and Bolen 2006, Grado et al. 2011, U.S. Fish and Wildlife Service 2016).

The Mississippi Alluvial Valley (MAV) is an ancestral and continentally important wintering ground for mallards in North America, especially for birds using the Mississippi Flyway (Nichols et al. 1983, Reinecke et al. 1989). Despite significant wetland transformations in the MAV by human developments, it continues to provide critical habitat for mallards in North America (Nichols et al. 1983, Reinecke et al. 1988, Davis et al. 2011, Pearse et al. 2012, Baldassarre 2014). Forested and seasonal emergent wetlands are principal habitats used by non-breeding mallards (Heitmeyer 2006, Davis et al. 2009, Davis and Afton 2010), but these adaptive birds also exploit inundated

agricultural fields, using high-energy grains (e.g., corn, rice) to supplement their diets of natural seeds, tubers, and aquatic invertebrates (Wright 1959, Delnicki and Reinecke 1986, Combs and Fredrickson 1996, Dabbert and Martin 2000, Kaminski et al. 2003, Davis and Afton 2010, Callicutt et al. 2011).

Mallard harvest surpasses that of all other ducks in the Mississippi Flyway, accounting for 35% of total annual duck harvest between 1999 and 2015 (Fronczak 2016). In Mississippi, however, the proportion of mallards in overall duck harvest has declined approximately 1% per year since 2006, causing concern over quantity and quality of habitat in the state (Fronczak 2016). The scientific literature on estimating abundance and spatiotemporal variability of available forage and its energetic value among habitat types has increased in recent years, providing an important basis for evaluating foraging carrying capacity of habitats for waterfowl (Kaminski et al. 2003, Stafford et al. 2006, Kross et al. 2008, Foster et al. 2010*a*, Leach et al. 2012, Olmstead et al. 2013, Foth et al. 2014, Williams et al. 2014, Hagy et al. 2014, Straub et al. 2016, Marty 2017). Researchers also have incorporated reduced energetic capacity of habitats on private lands to compensate for the effects of hunting, and assume that waterfowl ideally and freely distribute among wetlands based on the adjusted energetic capacity (Fretwell 1972, Edwards et al. 2012). However, this scenario presupposes that waterfowl seek habitats with greatest energy availability in the presence of disturbance. This argument may be less tenable if waterfowl seek habitats with less food but increased security from predation and disturbance. For example, Davis et al. (2009) reported that forested wetlands were used most by mallards during winter in northeastern Louisiana,

despite these providing less energy than other habitats such as ricelands or emergent wetlands (Kaminski et al. 2003, Stafford et al. 2006).

Understanding relationships among hunting, associated anthropogenic impacts, and resource use by wildlife is essential for sustainable management of harvested species (Block and Brennan 1993, Sokos et al. 2013). Fox and Madsen (1997) hypothesized that recreational hunting may be a surrogate for predation through direct harvest and indirect effects of related disturbance. Thus, hunting may be a selective force that shapes behavior and other adaptations of harvested species (Lima and Dill 1990, Brøseth and Pedersen 2010, Madden and Whiteside 2014). Waterfowl may immediately change behavior in the presence of hunters, whereby individual birds become increasingly vigilant or temporarily alternate habitat use (Thornburg 1973, Hockin et al. 1992, Madsen 2001). However, prolonged or repeated disturbance can result in modified circadian habitat use wherein habitats with disturbance are used primarily nocturnally when risk of mortality from anthropogenic sources is absent (Girard 1941; Thornburg 1973; Madsen and Fox 1995; Cox and Afton 1997; Fox and Madsen 1997; Madsen 1998; Roy et al. 2013, 2014; Beatty et al. 2014; Lancaster et al. 2015). For example, mallards disturbed by an investigator or simulated harvest were less likely than uninterrupted mallards to return to the site of disturbance diurnally, yet both groups equally returned nocturnally (Dooley et al. 2010).

Apart from mature red oak (*Quercus* spp) bottomlands (Heitmeyer 2006, Straub et al. 2016), other forested and scrub-shrub wetlands comparatively contain little forage, but provide roosting and resting habitat (Davis et al. 2009). In contrast, emergent wetlands can provide an abundance of quality plant and animal foods, and flooded croplands also

can provide energy rich seeds (Kaminski et al. 2003, Reinecke and Kaminski 2006, Davis et al. 2009, Marty 2017). All three habitat types may be frequented by hunters, but waterfowl in open habitats, such as flooded croplands and emergent wetlands, may be more vulnerable to disturbance than those isolated in forested wetlands (Davis et al. 2009). Davis et al. (2009) surmised that forested habitats provide visual obstructions that allow mallards to be less impacted by anthropogenic disturbance. Therefore, I hypothesized that mallards in the Yazoo Basin of the Mississippi MAV would avoid flooded cropland and seasonal emergent wetlands diurnally during the hunting season, but exploit resources in croplands and seasonal emergent wetlands nocturnally, when risk of mortality and anthropogenic disturbance were diminished. If mallards avoid foraging habitats because of anthropogenic predation risk, I predicted females would: 1) make greater use of forested wetlands diurnally than nocturnally during hunting seasons, 2) make greater use of emergent wetlands and flooded croplands nocturnally than diurnally during hunting seasons, and 3) make greater diurnal use of emergent wetlands and flooded cropland post hunting seasons than during hunting seasons.

Study Area

The Yazoo Basin is nearly 20,000 km^2 and largest of six basins forming the MAV (Saucier 1994). The Yazoo Basin drains the entire MAV in Mississippi and a portion of west Tennessee through a series of rivers, which connect with the Yazoo River and flow into the Mississippi River at Vicksburg, Mississippi. I divided the Yazoo Basin into north and south regions by selecting east-west Mississippi Highway 82 from Greenwood, MS to Greenville, MS as a geographical demarcation (Figure 2.1). I evaluated female mallard habitat use in the south basin during winters 2010-2012 and in the north basin

during winters 2013-2015. I captured female mallards at the following three state wildlife management areas (WMAs) in the south basin and a national wildlife refuge (NWR) in the north basin (Figure 2.1): 1) Howard Miller WMA, a 971 ha seasonally flooded complex near Rolling Fork, Mississippi (32°49'48.93" N, 90°58'51.61" W), which was annually farmed for rice and soybean but also contained managed seasonal emergent wetlands; 2) Mahannah WMA, near Vicksburg, Mississippi (32°32'54.95" N, 90°52'14.08" W), was a 5,100 ha complex of agriculture, bottomland hardwoods, scrub-shrub, and seasonal emergent wetlands of which up to 80% was seasonally and naturally flooded; 3) Muscadine Farms WMA, near Avon, Mississippi (33°13'29.32" N, 90°59'01.51" W), was a 607 ha retired aquaculture facility managed for waterfowl in seasonal emergent wetlands augmented with Japanese millet; and 4) Coldwater River NWR, near Crowder, Mississippi (34°6'1.43" N, 90°7'58.52" W), was a 1,100 ha complex of seasonal emergent, scrub-shrub, and bottomland hardwood wetlands that were seasonally or semi-permanently flooded. The seasonal emergent wetlands were contained within a retired complex of catfish ponds and approximately 75% of Coldwater River NWR was seasonally or naturally flooded annually. Waterfowl hunting occurred at all WMAs and was temporally limited to four days per week until noon and hunter numbers were limited by daily quota (Lancaster 2013). All WMAs had designated spatial sanctuary composed of seasonal emergent wetlands or flooded cropland. Waterfowl hunting was prohibited at Coldwater River NWR in 2013-2014 but an adjacent 130-ha seasonal emergent wetland was opened to public hunting three days/wk until noon in 2014-2015. No other public access was permitted at Coldwater River NWR except for an observation tower located at the entrance to the NWR.

I did not randomly select capture sites within the Yazoo Basin but chose sites based on accessibility and legal ability to bait-trap waterfowl, but believe that mallards captured at each site were representative of those within the Yazoo Basin. I monitored radiomarked female mallards within 80 km of capture locations in Mississippi but also in portions of northeast Louisiana and eastern Arkansas outside the Yazoo Basin boundary (Figure 2.1; Cox and Afton 1997, Davis et al. 2009). Additional environmental details of the MAV are found elsewhere (e.g., Reinecke et al. 1989, Saucier 1994, Baldassarre and Bolen 2006, Lancaster 2013).

Methods

Mallard Capture and Tracking

I began capturing mallards the first week of November and continued until early February each winter. I captured mallards using swim in traps (Hunt and Dahlka 1953) and rocket nets fired from wetland edges (Dill and Thornberry 1950). I modified Hunt and Dahlka's (1953) swim-in trap design by using 2.5 x 5.1 cm welded wire and affixed the throat of the trap such that the opening was ~8-12 cm (Evrard and Bacon 1998). I baited capture sites with corn, rice, or soybean and located sites throughout WMAs and Coldwater River NWR prior to hunting season where I observed flocks of mallards. Ten to 12 days prior to hunting season, I relocated all traps and bait on WMAs to sanctuaries as distantly as possible from waterfowl hunting areas to eliminate effects of bait on duck distribution and hunting.

I leg banded and attached a dorsally mounted 23 g very high frequency (VHF) backpack transmitter (model A1820; Advanced Telemetry Systems, Isanti, MN) to captured female mallards (Dwyer 1972). Transmitters had a 55 pulse per minute rate, a

minimum life expectancy of 150 days, and an 8-hr mercury mortality switch. Transmitters increased weight of 265 marked females between 1.5 and 2.6% ($\bar{x}$ = 2.06%, SE = 0.01%; Cochran 1980). In winters 2010-2012, I released females 4 hr after instrumentation, except when holding an individual 4 hr would result in nocturnal release. I released these the following morning (Davis et al. 2009). Because females seemed to acclimate to transmitters quickly after being marked in previous winters, I released females immediately following instrumentation of all co-captured individuals in winters 2013-2015. Birds had access to corn and water ad libitum during confinement periods. All instrumented females were released with captured conspecific males to minimize possible disruption of any pair bonds (Cox and Afton 1998, Lercel et al. 1999). All capture, handling, and marking methods were approved by Mississippi State University Institutional Animal Care and Use Committee (protocols 10-070 and 13-073) and authorized under Federal Bird Banding Permit 06604.

I triangulated radiomarked females using trucks equipped with roof-mounted 4-element antennas in a null-peak array and an electronic compass (Cox et al. 2002, Gilsdorf et al. 2007). I calibrated electronic compasses to known locations of beacon transmitters ± 0.5° and trained technicians by triangulating beacon transmitters until they successfully maintained an azimuth standard deviation of ≤ 3º (Davis et al. 2009). I tracked radiomarked mallards diurnally (30 min before sunrise to 30 min after sunset) and nocturnally (30 min after sunset to 30 min before sunrise) throughout the study area (Figure 2.1; Cox and Afton 1997, Davis et al. 2009). To randomize daily locations of individuals temporally, I randomly selected a radiomarked female to begin tracking each day and corresponding night period. When few females were available for tracking, I

randomly chose without replacement a period of the day (i.e., morning, mid-day, afternoon) and corresponding nocturnal period to track females until all time periods had been selected. I pursued radiomarked mallards not detected from trucks after seven consecutive days without contact (Yetter et al. 2017), using a fixed wing aircraft equipped with left and right directional antennas. During aerial surveys, I advised the pilot to fly at an altitude of 2,100-2,800 m and descended to 300 m elevation to pinpoint an individual when detected (Gilmer et al. 1981). Upon locating a missing bird from the air, I recorded GPS coordinates and relayed information to technicians in telemetry trucks, so they could locate and triangulate birds' location from the ground (Davis et al. 2009, Yetter et al. 2017). I used aerially derived point locations for birds not triangulated from telemetry trucks on the flight day when necessary (Davis et al. 2009).

I estimated point locations for each bird with a maximum likelihood estimator (Lenth 1981), using a bearing standard deviation of 3° (Davis et al. 2009, Pearse et al. 2011, Newcomb et al. 2016). Triangulations were plotted in real-time in Location of a Signal (LOAS 4.0; Ecological Software Solutions LLC, Hegymagas, Hungary) on laptop/tablet computers. I examined azimuths and point locations in real-time and discarded apparently erroneous locations or azimuths and re-triangulated the individual. For location estimation, I endeavored to obtain 3 azimuths, but, if error ellipses contained multiple habitat types, I obtained additional azimuths until error ellipses fell within one habitat type or available vantage points were exhausted. If multiple triangulations occurred for an individual in a single daily diurnal or nocturnal period, I used the first obtained location, unless the first location was a biangulation and a subsequent location contained ≥ 3 azimuths.

Statistical Analysis

I excluded the first three days of habitat-use data following instrumentation of mallards to avoid possible biases from stress induced by capture and handling (Cox and Afton 1998). I exported all subsequent triangulated locations from LOAS into a geographic information system (GIS) in ARCMAP 10.3 (Environmental Systems Research Institute 2015). Within the GIS, I assigned a habitat type to each location determined by visual inspection, contact with landowners/managers, or by using a combination of National Agricultural Imagery Program and United States Department of Agriculture Service Agency records. I classified daily locations into one of four habitat types (Pearse et al. 2012, Homer et al. 2004): 1) flooded croplands (CR), including areas used for production of rice, soybean, corn, grain sorghum, or other agricultural seeds; 2) seasonal emergent wetlands (S-EM), including areas where natural herbaceous vegetation accounted for ≥ 80% of vegetative cover, managed moist-soil wetlands, and croplands left fallow the previous growing season; 3) forested wetlands (FO), including all areas where forest or scrub-shrub composed ≥ 20% of vegetative cover; and 4) permanent open water (P-W), including all wetlands containing < 25% vegetative cover or that held water annually including aquaculture ponds, rivers, and non-forested oxbow lakes (< 20% woody cover).

During the study, waterfowl hunting season contained multiple periods of hunting separated by short periods of closure. To account for differences in habitat use possibly related to hunting, I limited analyses to locations obtained during the main, uninterrupted portion of hunting season (≥53 continuous days after "split" season) following any closure periods and post-hunting season because sample sizes of radiomarked birds were

insufficient for statistical analysis before these time periods (Davis et al. 2009). Therefore, I classified mallard locations as occurring during the main hunting season (HUNT) or after hunting season until mallard departure or through the end of monitoring on 20 March annually (POST).

For each radiomarked female mallard, I calculated the proportional use of each habitat during HUNT and POST periods, thus treating individuals as the sampling unit (Kenward 1992, Aebischer et al. 1993). Because some individuals did not use every habitat type or they used only one habitat type within a period, I transformed proportional use values using the equation:

$$y^* = \frac{y(N-1)+1/C}{N} \tag{2.1}$$

where y is the value to be transformed, N is the number of observed individuals within HUNT and POST periods, and C is the number of available habitat categories (Smithson and Verkuilen 2006, Maier 2014). I then used package DirichletReg (Maier 2015) in Program R (R Core Team 2017) to perform a multivariate regression where the response variables (i.e., proportional use of CR, S-EM, FO, and PW) followed a Dirichlet distribution. I used common parameterization, where the Dirichlet distribution's α parameters were directly modeled by covariates for each habitat type using a log-link (Maier 2014). For each habitat type, I included an identical set of explanatory variables which included region (south or north basin), winter of study nested within region, within-winter period (HUNT or POST), time of day (diurnal or nocturnal), and two-way interactions of time of day and region and time of day and within-winter period. I calculated mean proportional use by first calculating the precision parameter (φ) using the equation:

$$\alpha_0 = \varphi = \sum_{c=1}^{C} \alpha_c \tag{2.2}$$

and subsequently calculating the mean proportional use of each habitat using the equation:

$$\mu_c = {}^{\alpha_c}/_{\varphi} \tag{2.3}$$

Because the DirichletReg package calculates confidence intervals on the alpha parameters, which are not [0,1] bound and subject to unit-summation, I calculated 95% confidence intervals of mean proportional habitat use by calculating the upper and lower 2.5% quantiles from 10,000 bootstrap samples from a multivariate normal distribution of the mean and covariance matrix of the full model. I report effect sizes and expected mean use (with associated 95% confidence intervals) of flooded cropland and emergent, forested, and permanent wetlands by radiomarked mallards.

Results

I captured 265 female mallards including 58 females in winter 2010-2011 (11 November 2010 to 24 January 2011), 68 in winter 2011-2012 (13 November 2011 to 23 January 2012), 74 in winter 2013-2014 (30 November 2013 to 25 January 2014), and 65 in winter 2014-2015 (15 December 2014 to 7 February 2015). I excluded 24 females from analysis, because they died within the 3-day acclimation period or were not located during hunting or post-hunting periods. Despite deletions, I retained 7,402 diurnal and 1,827 nocturnal locations (n = 9,229) from 241 radiomarked females (Table 2.1).

Results from the Dirichlet regression indicated that female mallards used forested wetlands 7.3% (-18.7 – 41.7%) more in the south than north basin. Forested wetland use by females was 98.5% (52.8 – 158.0%) greater in winter 2011-2012 than 2010-2011 in

the south basin and 65.0% (29.5 – 110.3%) greater in winter 2014-2015 than 2013-2014 in the north basin. Females used forested wetlands 40.4% (13.6 – 73.5%) more post-hunting than during the hunting season and 134.6% (77.0 – 211.1%) more diurnally than at night. Use of forested wetlands by females was 7.6% (-25.7 – 55.7%) greater at night in the north than the south basin, and 32.9% (-7.5 – 91.0%) greater at night during hunting than post-hunting seasons.

Mean use of forested wetlands ranged from 16–52%, and greatest use occurred diurnally (Table 2.2). Mean use of forested wetlands was 92–100% and 58–63% greater during diurnal than nocturnal periods in the south and north basins, respectively. This pattern persisted post-hunting season when mean use of forested wetlands was from 59–89% greater during the day than night among all winters of study.

Results from the full model indicated that female mallards used flooded cropland 38.6% (5.2 – 82.5%) more in the south than north basin. Within the south basin, female mallards used flooded cropland 81.6% (40.9 – 134.0%) more in winter 2010-2011 than 2011-2012, while they used flooded cropland 95.6% (53.1 – 149.9%) more in 2014-2015 than 2013-2014 in the north basin. Flooded cropland was used 39.7% (13.8 – 71.4%) more after than during the hunting season and 1.9% (-23.3 – 35.4%) more diurnally than at night. Nocturnal use of flooded cropland by females was 31.7% (-7.4 – 87.2%) greater in the north than south basin and 43.2% (0.70 – 103.6%) greater during hunting than post-hunting season.

Mean use of flooded croplands ranged from 12–41% during the study (Table 2.2). Female mallards showed disparate temporal patterns in use of cropland during hunting seasons in the south and north basins. In the south basin, females used flooded cropland

similarly diurnally and nocturnally, which persisted post-hunting season. In the north basin, use of flooded cropland was 43–44% greater nocturnally than diurnally within hunting seasons. Moreover, female mallards continued to use flooded cropland 32–35% more at night than during the day after the hunting season in the north basin.

Use of seasonal emergent wetlands by females was 40.2% (6.4 – 84.8%) greater in the north than south basin. Females in the south basin used emergent wetlands 84.8% (43.1 – 138.8%) more in winter 2011-2012 than 2010-2011, while they used these wetlands 62.2% (26.8 – 107.3%) more in winter 2014-2015 than 2013-2014 in the north basin. Emergent wetlands were used by mallards 7.8% (-12.9 – 33.3%) more during the hunting than post-hunting season and 52.8% (13.5 – 108.8%) more diurnally than nocturnally. At night, females were 91.8% (31.8 – 179.0%) more likely to use emergent wetlands in the south than north basin, and 22.8% (-15.6 – 78.7%) more likely to use these wetlands during the hunting that post-hunting season.

Mean use of emergent wetlands by females ranged from 17–52% with greatest use occurring at night in the south basin in winter 2011-2012 (Table 2.2). In the south basin, mean use of emergent wetlands was 63% greater during nocturnal than diurnal periods within hunting season. Mean use of emergent wetlands continued to be 83–88% greater at night post-hunting season in the south basin. In the north basin, use of emergent wetlands was similar between diurnal and nocturnal periods during and after the hunting season. My prediction that diurnal use of flooded cropland and emergent wetlands would be greater post-hunting season than during the season was not supported. In fact, emergent wetlands were used 33–41% and 31–36% more during hunting season than post-hunting season in the south and north basins, respectively.

Female mallards used permanent wetlands 0.16% (-23.5 – 31.2%) more in the north than south basin. Permanent wetlands were used 11.3% (-12.3 – 41.2%) more in winter 2011-2012 than 2010-2011 in the south basin, while they were used 12.0% (-12.6 – 43.5%) more in winter 2014-2015 than 2013-2014 in the north basin. Females used permanent wetlands 27.6% (4.4 – 55.9%) more after than during hunting seasons and 24.9% (-5.3 – 64.7%) more during the day than at night. Nocturnal use of permanent wetland was 15.3% (-18.9 – 63.8%) greater in the south basin, and 23.3% (-13.0 – 74.6%) greater during the hunting than post-hunting season.

Mean use of permanent wetlands by female mallards ranged from 9–17% (Table 2.2). There were few discernible trends in mallard use of permanent wetlands, but they used permanent wetlands 34-37% more at night than diurnally during post-hunting season in the south basin. Moreover, diurnal use of permanent wetlands was 47–49% greater during winter 2013-2014 than 2014-2015.

Discussion

Habitat use by radiomarked female mallards in the Mississippi Yazoo Basin varied with respective combinations of waterfowl-hunting and spatiotemporal covariates explored in my study. However, I detected some consistent patterns in habitat use that contrasted with my prediction that mallards would avoid flooded cropland and seasonal emergent wetlands diurnally during hunting season (McNeil et al. 1992), although use of these habitats was associated with public land sanctuaries. Among all habitats, mallards generally made greatest use of forested and seasonal emergent wetlands diurnally and emergent wetlands in the south and flooded cropland in the north basin at night. Below I offer possible explanations for these observations.

Greater diurnal than nocturnal use of forested wetlands during hunting season suggests some support for the prediction that mallards may avoid flooded cropland and emergent wetlands diurnally during hunting season (McNeil et al. 1992). Specifically, forested wetlands may provide increased isolation and security to mallards from hunters not found in open agricultural lands and emergent wetlands (Davis et al. 2009). However, this pattern in forested wetland use by mallards persisted post-hunting season after hunter-related disturbances had subsided. This trend may reflect that mallards either are unable to recognize the reduction in anthropogenic disturbance after the hunting season, there are lag effects or continued disturbance from alternate sources, predation risks from natural predators are less in forested wetlands, reduced availability of flooded croplands after the hunting season, forested wetlands meet physiological and social needs of mallards regardless of hunting activity, or a combination of these and other factors. Duck hunters impose a temporally explicit mortality risk during hunting seasons, but mallards are not omniscient to timing of hunting seasons, and other sources of disturbance may mimic duck hunting. For example, hunters participating in the light goose conservation order (LGCO) after duck hunting season may invoke disturbance caused by duck hunters. Dinges et al. (2005) reported greater waterfowl densities, including mallards, on wetlands closed to hunting during the LGCO in the Rainwater Basin of Nebraska. Auditory and visual cues used by mallards to detect presence or absence of duck hunters may persist during the LGCO or through other cues, leading to continued use forested and other safe habitats diurnally. Birds may abandon safe habitat when they recognize a reduction in predator risks (including from hunters) or when the quality and quantity of food resources is insufficient to meet dietary needs (Sih 1992).

However, mallards can fulfill nutrient demands nocturnally (Tamisier 1985, Guillemain et al. 2002) and may continue diel patterns post-hunting season because those strategies resulted in their winter and hunting season survival.

Aside from hunter avoidance, forested wetlands may provide habitat wherein female mallards avoid natural predators diurnally and fulfill socio-physiological needs such as courtship, pairing, and prebasic molt (Heitmeyer et al. 2005, Davis and Afton 2010). Pair formation in mallards is underway or complete by January and isolation from conspecific pairs or unpaired males reduces risk of pair dissolution and associated energy expenditures (Heitmeyer 1988, Paulus 1988, Johnson and Rohwer 1998). Additionally, if females lose a mate, forested wetlands may provide reclusive habitat to consort with males and form a subsequent pair bond (Heitmeyer 1995, Lercel et al. 1999). Seasonally renewable invertebrates contain proteins necessary for completion of pre-basic molt and lipid storage during mid-late winter (Heitmeyer and Fredrickson 1990, Wehrle et al. 1995, Heitmeyer 2006, Foth et al. 2014), and invertebrate abundances in forested wetlands are comparable with other wetland types (Duffy and LaBar 1994, Foth et al. 2014). Heitmeyer (2006) reported mallards considerably increased their consumption of animal matter in forested wetlands during late winter floods in Missouri. Moreover, as many as 71% of mallards collected in forested wetlands in southeastern Arkansas contained invertebrates, which comprised 35% of diet dry mass (Dabbert and Martin 2000). Thus, considering that forested wetlands, especially hardwood bottomlands, were ancestral wintering habitat for mallards in the MAV, diurnal use of forested wetlands may be a resilient behavioral trait coupled with the aforementioned functions.

Diel use of flooded cropland and emergent wetlands by mallards within hunting seasons did not consistently substantiate my prediction that mallards would use more open habitats nocturnally within hunting season. Female use of emergent wetlands and flooded cropland followed this trend in the south and north basins, respectively. However, mallards exhibited uniform diurnal and nocturnal use of flooded cropland and emergent wetlands in the south and north basins, respectively. These differences may relate to contrasting regional habitat availability, especially differences relating to management of hunted and sanctuary portions of public lands in each region (Stafford et al. 2010*a*, Yetter et al. 2017). Wetland availability has been the primary explanation for disparate habitat use patterns by wintering waterfowl among regions and winters of study (Migoya et al. 1994, Cox and Afton 1997, Fleskes et al. 2005, Davis et al. 2009, Link et al. 2011). Disparate habitat availability can result from myriad causes including annual weather conditions or regional management practices by state and federal managers on public lands such as those within the south and north basins. Specifically, most public land sanctuaries in the south basin contained flooded cropland, whereas those in the north basin were passively managed (Lancaster 2013). Consequently, approximately one-third of diel mallard locations in flooded cropland occurred on public lands in the south basin; whereas, in the north basin, only 2 (0.3%) nocturnal locations occurred in flooded cropland on public lands. Thus, mallard use of flooded cropland in the north basin primarily was restricted to private lands exposed to waterfowl hunting, and mallards may have responded by using flooded cropland more nocturnally than diurnally during hunting season. Cox and Afton (1997) found a similar increase in nocturnal use of

flooded cropland by northern pintails (*Anas acuta*) during the hunting season, following diurnal periods of birds' use of sanctuary habitats in southwestern Louisiana.

In the south basin, where flooded cropland was accessible in sanctuaries, mallards could exhibit two patterns that would lead to similar proportional use of flooded cropland throughout the day during hunting seasons. Firstly, they could use flooded cropland on sanctuaries diurnally and nocturnally; secondly, mallards could use flooded cropland on sanctuaries diurnally to avoid hunters and exploit these resources on private or hunted-public lands at night. These temporal strategies by mallards could also explain uniform diel use of seasonal emergent wetlands in the north basin, which were available extensively on public land sanctuaries. Guillemain et al. (2002) reported >85% of radiomarked mallard locations occurred in sanctuaries at night in western France, indicating that mallards may continue to use sanctuary habitats nocturnally. Whereas in Louisiana, 45% of female mallards using flooded rice diurnally continued to use rice nocturnally and 24% of females remained in seasonal emergent habitats (Davis and Afton 2010). Tamisier (1985) surmised that diurnal use of flooded cropland and emergent wetlands may arise from gregariousness; whereas, waterfowl relocate nocturnally based on energetic needs (Anderson and Smith 1999). Clearly, spatial and temporal availability of refuges influence mallard diel habitat use during hunting periods, but this relationship may be locally and regionally specific relative to area, proximity, food availability, and other characteristics of refuges and surrounding private lands. Future landscape-scale studies of radiomarked mallard and other species' use of refuges and associated habitats are needed to design public and private complexes of habitats of which attract

abundances of waterfowl (Pearse et al. 2012) and promote daily survival of individuals (Chapter 4).

Greater nocturnal use of emergent wetlands during hunting season in the south basin may have resulted from mallards exploiting these habitats on hunted public and private lands. Public lands in the south basin, including those where mallards were captured, contained managed emergent wetlands for wintering waterfowl and waterfowl hunting. Lancaster et al. (2015) found greatest mallard presence nocturnally during hunting season on a public hunting area with only managed emergent wetlands. Nocturnal resource use by mallards is not influenced by diurnal disturbance including hunting (Dooley et al. 2010, Beatty et al. 2014, Lancaster et al. 2015). Anderson and Smith (1999) witnessed greatest mallard abundance at night in emergent wetlands in Texas Playa Lakes, but suggested such nocturnal use was not related to hunting because disturbance intensity was low in the study area.

Mallard diurnal use of flooded cropland was unchanged from hunting to post-hunting seasons, hence providing no support for my prediction that mallards would increase diurnal use of flooded cropland post-hunting season. There are several explanations why mallards might not increase their use of flooded cropland post-hunting season. As described above for forested wetlands, females may have upheld diel patterns shaped during hunting season either because their strategy was energetically advantageous and led to survival or disturbance was ubiquitous through winter. The overall availability of flooded cropland on the landscape may have declined post-hunting season as farmers dried their fields and prepared for spring planting causing mallards to exploit other habitats. Moreover, Foster et al. (2010*b*) found agricultural seed abundance

declined 80% by January in Tennessee and Stafford et al. (2006) found a 71% decline in rice abundance by late autumn, which may cause mallards to seek other habitat types post-hunting season instead of increasing their use of flooded cropland. Furthermore, rates of seed loss may be greater in Mississippi which experiences increased temperature and relative humidity, earlier crop harvest, and do not promote and harvest a second rice crop (Foster et al. 2010*b*, Stafford et al. 2010*b*, Marty 2017).

Emergent wetlands were used less by mallards post-hunting season, counter to my prediction. This relationship is likely interrelated with mallard use of public lands which simultaneously declined post-hunting season (Chapter 3). During the hunting season, 75% and 63% of diurnal locations in emergent wetlands were on public lands in the north and south basins, respectively, while 25% and 46% were located there post-hunting season. Greater use of emergent wetlands during hunting season was likely related to mallards using public land sanctuaries.

Mallards appear to use complexes of habitats providing variable food resources and structural composition, such as forested wetlands that were used diurnally and emergent wetlands used at night. However, habitat use patterns of mallards observed in my study do not provide unconditional evidence that mallards are avoiding energy rich habitats diurnally during hunting season. Extensive use of sanctuary by mallards also complicated the interpretation of habitat use in relation to duck hunting season. McNeil et al. (1992) provided several alternative hypotheses to explain nocturnal habitat use including energetic advantages, increased prey abundance, or avoidance of diurnal predation or harassment from natural predators (i.e., Northern Harrier [*Circus cyaneus*]; Tamiseir 1985).

In the Yazoo Basin, state and federally operated public lands provide spatial and temporal sanctuary during hunting season (Edwards et al. 2012, Beatty et al. 2014). Sanctuary habitats are important resources during winter as evidenced by the displacement of many waterfowl species from hunted or otherwise disturbed environments to spatial and temporal sanctuaries (Cox and Afton 1997; Madsen 1998; Bregnballe et al. 2004; Link et al. 2011; Cassaza et al. 2012; Lancaster 2013; Roy et al. 2013, 2014; Beatty et al. 2014). Therefore, habitats commonly occurring on inviolate sanctuaries may seem particularly important to mallards diurnally, especially during hunting season. In any case, habitat use is not mutually exclusive of sanctuary use. Nevertheless, diel use of flooded cropland and emergent wetlands in the south and north basins, respectively, suggest that habitats provided on hunted and sanctuary portions of public land may provide the foundation for daily and seasonal habitat use by mallards. These findings deviate from claims of others, who suggest that the quality and type of habitat may be more important than sanctuary designation (Stafford et al. 2007, 2010*a*; Yetter et al. 2017).

I captured all females on public lands; therefore, radiomarked birds may have been accustomed to using public land as sanctuary, which may have further complicated the relationship between sanctuary and habitat (Guillemain et al. 2002). Moreover, studying the effects of waterfowl hunting with a during and post-hunting season design may bias habitat use conclusions, because the timing of hunting season and socio-physiological events of non-breeding mallards overlap. For example, the timing of pair formation and initiation of pre-basic molt may cause female mallards to use habitats that provide isolation and protein rich resources, respectively (Heitmeyer 1987, 1988;

Turnbull and Baldassarre 1987; Johnson and Rohwer 1998). Moreover, aside from periodic backwater and overbank flooding of Yazoo Basin lowlands, habitat availability is closely tied to waterfowl hunting season, as private landowners inundate impoundments or agricultural fields for hunting and typically drain them following the hunting season to prepare for spring planting. Thus, disentangling effects of hunting on habitat use patterns by mallards may require an experimental approach where large-scale treatments of similar habitat composition are hunted and non-hunted simultaneously. Brøseth and Pederson (2010) used this design to investigate the impact of hunting activity on willow ptarmigan (*Lagopus lagopus*) in Norway and were able to conclude that ptarmigan made shorter movements and shifted to dense forest/scrub habitats under intense hunting scenarios. A design similar for migratory ducks would be logistically complex, but similar attempts have been successfully implemented on several WMAs in Mississippi to address the impacts of hunting intensity on waterfowl density, hunter harvest, and diel patterns of WMA use by mallards (Lancaster 2013; St. James et al. 2013, 2015; Lancaster et al. 2015). Specifically, Lancaster et al. (2015) managed hunting intensity on a WMA by temporally restricting hunting to half or the undivided area. This design allowed them to observe reduced diurnal presence when the entire WMA was hunted, but uniform nocturnal use regardless of diurnal hunting intensity.

Management Implications

Forested wetlands are important diurnal habitats for mallards throughout the Mississippi Alluvial Valley. Continued efforts to restore farmlands to bottomland hardwoods with managed hydrology will provide long-term benefits to mallards in the region. The Wetland Reserve Easement (WRE; formerly the Wetlands Reserve Program)

is one of several similar programs that provide financial assistance to landowners to restore prior converted private lands to natural habitats (King et al. 2006). Afforestation tracts require several decades before achieving characteristics of mature forests (King et al. 2006) and because many of the current easements are less than two decades old, future research should quantify the benefits of these restoration and enhancement programs to wintering mallards prior to maturation (Chapter 3). Restoration of natural hydrological dynamics in existing large bottomland hardwood tracts could enhance the extent and periodicity of overbank flooding events which make important forested wetland habitats and resources available to mallards and other waterfowl (Heitmeyer 2006, Peterson 2014).

Researchers have hypothesized that waterfowl hunting prevents the landscape from reaching carrying capacity (Cassaza et al. 2012) or that landscape carrying capacity needs augmenting to compensate for impeded access to energetic resources (Edwards et al. 2012). However, mallards appear to adjust their diel habitat use to meet daily and seasonal needs by accessing forage resources at times or locales that are free from disturbance (McNeil et al. 1992). An important consideration is how local waterfowl hunting and habitat use by mallards impacts daily and non-breeding period survival. Thus, identifying regional complexes of habitat (*sensu* Pearse et al. 2012) that lead to increased seasonal survival and positively impact subsequent breeding (i.e., cross-seasonal effects; Sedinger and Alisauskas 2014) are important future topics to explore in maintaining or enhancing landscape conservation for mallards and other waterfowl in the Yazoo Basin of the MAV (Chapter 4).

Wetlands on public land are important to non-breeding mallards and the type and quality of habitat provided can impact habitat use patterns by birds in the vicinity (Stafford et al. 2007). Thus, changes in habitat management on NWRs following the USFWS decision to outlaw genetically modified glyphosate-tolerant crops and neonicotinoid insecticides has potential to alter mallard use surrounding refuges (James W. Kurth, U.S. Fish and Wildlife Service, unpublished data). Currently, most NWRs that planted crops prior to the ban have continued planting crops or employ cooperative farmers and use conventional seed varieties or alternative agricultural crops. Decreased yield with conventional seed varieties and the inability to control pest species may cause waterfowl to further supplement their diet off refuges either diurnally or nocturnally in accord with local anthropogenic disturbance. Decreased food availability on sanctuaries may lead to increased diurnal use of private lands, increased vulnerability to harvest, or otherwise decrease survival (Yetter et al. 2017).

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Table 2.1 Locational data for 241 radiomarked female mallards in Mississippi, 2010-2015.

Region	Winter	Period	Time of Day	Radiomarked Females	Total Locations	Mean Loc./Fem.	Min. Loc./Fem.	Max Loc./Fem.
South Basin	2010/ 2011	Hunt	Diurnal	47	838	17.8	1	50
			Nocturnal	1	1	1.0	1	1
		Post	Diurnal	36	727	20.2	1	46
			Nocturnal	17	104	6.1	2	8
	2011/ 2012	Hunt	Diurnal	59	879	14.9	1	51
			Nocturnal	55	349	6.3	1	17
		Post	Diurnal	57	1,835	32.2	1	43
			Nocturnal	51	708	13.9	1	23
North Basin	2013/ 2014	Hunt	Diurnal	57	947	16.6	1	45
			Nocturnal	47	290	6.2	1	16
		Post	Diurnal	51	463	9.1	1	29
			Nocturnal	24	209	8.7	1	20
	2014/ 2015	Hunt	Diurnal	33	441	13.4	2	24
			Nocturnal	30	164	5.5	1	9
		Post	Diurnal	51	1,272	24.9	1	41
			Nocturnal	2	2	1.0	1	1

For female mallards captured at three wildlife management areas and one national wildlife refuge in the Mississippi Alluvial Valley of Mississippi in winters 2010-2012 and 2013-2015.

Table 2.2 Mean proportional habitat use (CI_{95}) by radiomarked female mallards in Mississippi, 2010-2015.

Region	Winter	Period	Time of Day	Flooded Cropland	Seas-emerg. Wetland	Forested Wetland	Permanent Wetland
South Basin	2010/ 2011	Hunt	Diurnal	0.31 (0.26 – 0.36)	0.24 (0.20 – 0.29)	0.32 (0.27 – 0.38)	0.13 (0.10 – 0.16)
			Nocturnal	0.30 (0.23 – 0.38)	0.39 (0.30 – 0.47)	0.16 (0.12 – 0.22)	0.15 (0.11 – 0.20)
		Post	Diurnal	0.34 (0.29 – 0.40)	0.17 (0.14 – 0.21)	0.36 (0.30 – 0.41)	0.13 (0.10 – 0.16)
			Nocturnal	0.32 (0.25 – 0.39)	0.32 (0.25 – 0.39)	0.19 (0.15 – 0.24)	0.17 (0.13 – 0.22)
	2011/ 2012	Hunt	Diurnal	0.12 (0.10 – 0.15)	0.32 (0.27 – 0.36)	0.46 (0.41 – 0.51)	0.10 (0.08 – 0.12)
			Nocturnal	0.12 (0.09 – 0.15)	0.52 (0.45 – 0.58)	0.24 (0.19 – 0.29)	0.12 (0.09 – 0.15)
		Post	Diurnal	0.14 (0.11 – 0.17)	0.24 (0.20 – 0.28)	0.52 (0.47 – 0.57)	0.10 (0.08 – 0.13)
			Nocturnal	0.13 (0.10 – 0.16)	0.44 (0.38 – 0.51)	0.28 (0.23 – 0.34)	0.14 (0.11 – 0.18)
North Basin	2013/ 2014	Hunt	Diurnal	0.23 (0.19 – 0.27)	0.34 (0.29 – 0.39)	0.30 (0.26 – 0.35)	0.13 (0.10 – 0.16)
			Nocturnal	0.33 (0.27 – 0.39)	0.33 (0.27 – 0.39)	0.19 (0.15 – 0.23)	0.15 (0.12 – 0.19)
		Post	Diurnal	0.26 (0.22 – 0.30)	0.26 (0.22 – 0.30)	0.35 (0.30 – 0.40)	0.13 (0.11 – 0.16)
			Nocturnal	0.35 (0.28 – 0.42)	0.27 (0.21 – 0.34)	0.22 (0.17 – 0.28)	0.17 (0.13 – 0.22)
	2014/ 2015	Hunt	Diurnal	0.27 (0.23 – 0.32)	0.34 (0.28 – 0.39)	0.31 (0.26 – 0.36)	0.09 (0.07 – 0.11)
			Nocturnal	0.39 (0.32 – 0.45)	0.32 (0.26 – 0.38)	0.19 (0.15 – 0.24)	0.10 (0.08 – 0.13)
		Post	Diurnal	0.31 (0.26 – 0.36)	0.25 (0.21 – 0.30)	0.35 (0.30 – 0.40)	0.09 (0.07 – 0.11)
			Nocturnal	0.41 (0.32 – 0.50)	0.26 (0.19 – 0.34)	0.22 (0.16 – 0.29)	0.11 (0.08 – 0.16)

For female mallards captured at three wildlife management areas and one national wildlife refuge in the Mississippi Alluvial Valley of Mississippi in winters 2010-2012 and 2013-2015.

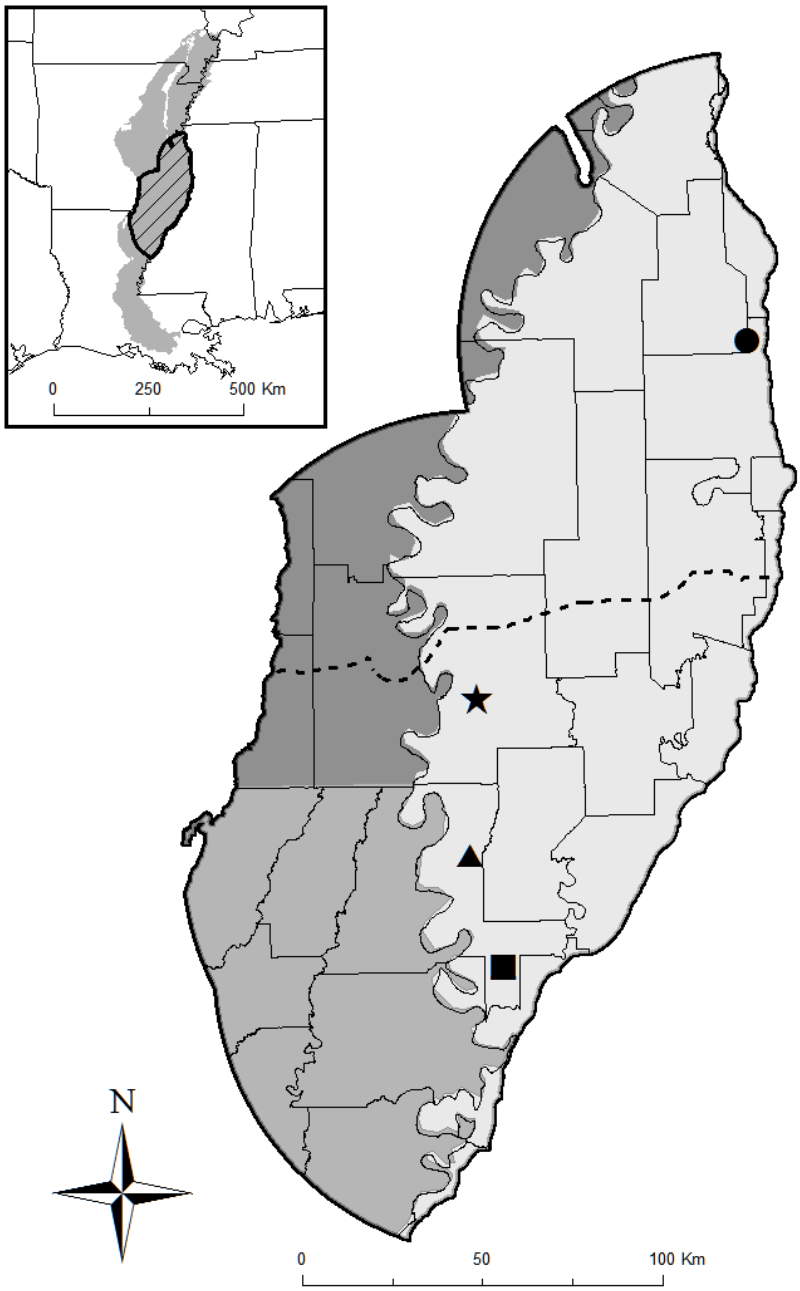

Figure 2.1 Female mallard capture locations and surrounding study area within the Mississippi Alluvial Valley.

Study area included the Mississippi Alluvial Valley within 80 km of capture locations: Coldwater River National Wildlife Refuge (circle), Muscadine Farms Wildlife Management Area (WMA; star), Howard Miller WMA (triangle), and Mahannah WMA (square). Highway 82 corridor shown (dashed) dividing the north and south study basins.

CHAPTER III

FEMALE MALLARD USE OF PUBLIC, PRIVATE, AND INCENTIVIZED CONSERVATION WETLANDS IN MISSISSIPPI'S ALLUVIAL VALLEY

Estimated breeding populations of mallard (*Anas platyrhynchos*) in North America in 2015, and again in 2016, were at an all-time high since traditional aerial surveys began in 1955 (U.S. Fish and Wildlife Service 2017). However, in the mid-1980s, populations of mallard and other North American ducks were among the lowest estimated levels in the 62-yr survey because of widespread drought and habitat loss (U.S. Fish and Wildlife Service 2017). In response, the North American Waterfowl Management Plan (NAWMP) was enacted with a goal of increasing waterfowl populations commensurate with levels of the 1970s through restoration and management of wetlands and associated uplands (NAWMP 1986). Concomitantly, and with a novel focus on conservation, the U. S. Congress passed the Food Security Act (hereafter, Farm Bill; Public Law 99-198) in 1985 establishing and funding the conservation reserve program (CRP) and compliance programs relating to wetlands and highly erodible lands (Cain and Lovejoy 2004, Reynolds et al. 2006). Although the CRP was originally administered to conserve soils by incentivizing private landowners to replace marginal croplands with native vegetation, wildlife became an explicit goal with the 1996 Farm Bill revision (Hohman et al. 2014). Directed management on private lands is important in the Mississippi Alluvial Valley (MAV), a continentally important region for wintering

waterfowl (Reinecke et al. 1989), because 90% of the MAV is privately owned and public lands are either managed at capacity or for alternative purposes, such as threatened and endangered species (Curtin 1993, Czech 2005).

Among accomplishments of NAWMP are unified regional partnerships of governmental and private interests known as Joint Ventures (JVs; NAWMP 1986, Anderson and Padding 2015). The original NAWMP established eight regional JVs, including the Lower Mississippi Valley Joint Venture (LMVJV), which guides waterfowl and other avian habitat management in the 10 M ha MAV. As with other non-breeding JV's, waterfowl management in the MAV embraces a central tenant that food resources may limit the number of non-breeding waterfowl the region can support during winter (Edwards et al. 2012, Williams et al. 2014). Accordingly, the LMVJV uses energetic carrying capacity (ECC) models to establish regional habitat objectives to sustain 4.3 million non-breeding waterfowl (Reinecke and Loesch 1996). The LMVJV recognizes provision of waterfowl habitat from three primary sources: public lands, managed private lands, and natural flooding (Edwards et al. 2012). Exclusive of natural flooded lands, 75% of energy resources available to ducks in Mississippi are presumed available on managed public lands including federal national wildlife refuges (NWRs) and state wildlife management areas (WMAs; Lower Mississippi Valley Joint Venture 2015).

The LMVJV further subdivides private lands as 1) managed in a landowner incentivized program (MIP) or 2) managed outside of incentive programs (MOP), which account for 19% and 6% of duck energy days (DEDs; Williams et al. 2014) exclusive of that provided by natural flooding, respectively. Private landowners enrolling land in an incentivized program implement practices on their land that conserve soil, water, wildlife,

and related natural resources in exchange for financial and technical assistance. Most notable to waterfowl conservation in the MAV is the wetlands reserve program (WRP) which was launched with the 1990 Farm Bill update. Like the CRP, the WRP is an easement for retiring marginal farmland but focuses on restoring wetland and associated vegetative communities (King et al. 2006). As of 2013, Mississippi ranked fourth nationally for total WRP area with 71,200 ha within more than 570 easements, most of which are located within the Yazoo Basin, a prominent floodplain in the MAV within Mississippi wherein I conducted this study (Reinecke et al. 1989, Rooks-Barber et al. 2007).

Whether through targeted objectives or ancillary effects of soil and water conservation initiatives, other financial assistance programs expand waterfowl habitat in the Yazoo Basin including: 1) the environmental quality incentives program (EQIP), 2) the wildlife habitat incentives program (WHIP), 3) the conservation stewardship program (CSP), 4) winter water for wildlife (WWW), and 5) the partners for fish and wildlife program (hereafter, Partners; Table 3.1). Recent studies have contributed descriptions of waterbird communities, waterbird abundance, and food availability estimates on WRP wetlands (Rewa 2005, Feaga 2013, Olmstead et al. 2013, Fleming et al. 2015, Tapp and Webb 2015, Tapp et al. 2017). Few other efforts have evaluated fish and wildlife benefits, let alone waterfowl specific benefits of federal, state, and private-sector incentivized conservation programs on private lands (Heard et al. 2000, Berkland and Rewa 2005, Gray et al. 2005).

Overall, forage availability for waterfowl of palatable seeds and tubers and aquatic invertebrates on WRP easements seems quite variable and is sometimes greater

(Tapp and Webb 2015), lesser (Feaga 2013, Olmstead et al. 2013), or similar (Tapp et al. 2017) to forage availability on non-enrolled private lands in the surrounding landscape. Moreover, Fleming et al. (2015) reported an inverse relation between duck density and woody vegetation, but a positive relation between duck densities and potential vegetative forage quality on WRP easements in Mississippi (Fleming et al. 2012). Feaga et al. (2015) reported similar densities of waterbirds on production aquaculture ponds and previously idled but restored aquaculture impoundments enrolled in Natural Resources Conservation Service's Migratory Bird Habitat Initiative (MBHI, discussed below) after the 2010 Deepwater Horizon oil spill in the Gulf of Mexico, as well as increased waterbird species richness in restored impoundments. Lastly, Beatty et al. (2014) evaluated the influence of WRP easements on wetland selection by mallards and found birds selected wetlands with more WRP in the surrounding landscape throughout winter, wetlands closer to WRP lands at night during hunting season, and proximate WRP lands throughout the day post-hunting season. Therefore, WRP may provide enhanced ecological benefits not otherwise provided on private lands managed outside of a conservation program.

Although Farm Bill programs generally are viewed favorably for providing some benefits to wildlife (Burger 2006), very little information exists on how non-WRP Farm Bill programs and alternate incentive programs (e.g., WWW and Partners) are used by waterfowl relative to private and public lands. Understanding how various wetland dependent birds, such as mallards, use the available suite of conservation program lands helps conservation program planners adapt decision making for future program conception and delivery. One prominent example of adaptive conservation management

followed the 2010 Deepwater Horizon oil spill in the Gulf of Mexico, where NRCS rapidly implemented the MBHI to incentivize private landowners to flood and otherwise manage wetland and agricultural lands for migrating and wintering waterbirds inland away from oil-impacted Gulf coastal wetlands (Davis et al. 2014). Specifically, additional incentive payments were made to landowners on nearly 190,000 ha enrolled in the WRP, EQIP, and WHIP to inundate easements to preferred foraging depths of shorebird and waterfowl during fall and winter, respectively (Buler et al. 2013). The MBHI rationalized that Farm Bill easements could enhance shallowly flooded (0 - 10 cm, Fall, 15-25 cm, Winter; USDA NRCS 2010, Buler et al. 2013) habitats away from oil impacted coastal waters, thus reducing waterbirds' contact with these environments (Henkel et al. 2012). My purpose herein is not to evaluate the efficacy of the MBHI wetlands in preventing mallards from reaching oil-impacted wetlands along the Gulf Coast. However, I evaluated female mallard use of incentivized private lands that were either enrolled in the MBHI or otherwise provided shallowly flooded habitat compared to other private and public wetlands on the landscape.

Incentivized private lands provide an estimated four times greater carrying capacity than non-incentivized private lands and about three times less than public lands in Mississippi (LMVJV 2015). Thus, I predicted that mallard use of incentivized private conservation lands in the Yazoo Basin of Mississippi would be greater than non-incentivized private lands but less than public lands during winter. My study was unique among previous research in the MAV and elsewhere that addressed use of habitats by radiomarked mallards (Jorde et al. 1984, Fleskes et al. 2005, Davis et al. 2009, Link et al. 2011, Chapter 2), because I have estimated female mallard use of these variously

incentivized conservation programs on private lands. An understanding of how mallards and other waterfowl use private and public lands in the Yazoo Basin will advance future conservation planning efforts.

Study Area

The Yazoo Basin is nearly 20,000 km^2 and largest of six basins forming the MAV (Saucier 1994). The Yazoo Basin drains the entire MAV in Mississippi and a portion of west Tennessee through a series of rivers, which connect with the Yazoo River and flow into the Mississippi River at Vicksburg, Mississippi. I divided the Yazoo Basin into north and south regions by selecting east-west Mississippi Highway 82 from Greenwood, MS to Greenville, MS as a geographical demarcation (Figure 3.1). I evaluated female mallard habitat use in the south basin during winters 2010-2012 and in the north basin during winters 2013-2015. I captured female mallards at the following three state wildlife management areas (WMAs) in the south basin and a national wildlife refuge (NWR) in the north basin (Figure 3.1): 1) Howard Miller WMA, a 971 ha seasonally flooded complex near Rolling Fork, Mississippi (32°49’48.93” N, 90°58’51.61” W), which was annually farmed for rice and soybean but also contained managed seasonal emergent wetlands; 2) Mahannah WMA, near Vicksburg, Mississippi (32°32’54.95” N, 90°52’14.08” W), was a 5,100 ha complex of agriculture, bottomland hardwoods, scrub-shrub, and seasonal emergent wetlands of which up to 80% was seasonally and naturally flooded; 3) Muscadine Farms WMA, near Avon, Mississippi (33°13’29.32” N, 90°59’01.51” W), was a 607 ha retired aquaculture facility managed for waterfowl in seasonal emergent wetlands augmented with Japanese millet; and 4) Coldwater River NWR, near Crowder, Mississippi (34°6’1.43” N, 90°7’58.52” W), was a 1,100 ha

complex of seasonal emergent, scrub-shrub, and bottomland hardwood wetlands that were seasonally or semi-permanently flooded. The seasonal emergent wetlands were contained within a retired complex of catfish ponds and approximately 75% of Coldwater River NWR was seasonally or naturally flooded annually. Waterfowl hunting occurred at all WMAs and was temporally limited to four days per week until noon and hunter numbers were limited by daily quota (Lancaster 2013). All WMAs had designated spatial sanctuary composed of seasonal emergent wetlands or flooded cropland. Waterfowl hunting was prohibited at Coldwater River NWR in 2013-2014 but an adjacent 130-ha seasonal emergent wetland was opened to public hunting three days/wk until noon in 2014-2015. No other public access was permitted at Coldwater River NWR except for an observation tower located at the entrance to the NWR.

I did not randomly select capture sites within the Yazoo Basin but chose sites based on accessibility and legal ability to bait-trap waterfowl, but believe that mallards captured at each site were representative of those within the Yazoo Basin. I monitored radiomarked female mallards within 80 km of capture locations in Mississippi but also in portions of northeast Louisiana and eastern Arkansas outside the Yazoo Basin boundary (Figure 3.1; Cox and Afton 1997, Davis et al. 2009). Additional environmental details of the MAV are found elsewhere (e.g., Reinecke et al. 1989, Saucier 1994, Baldassarre and Bolen 2006, Lancaster 2013).

Methods

Mallard Capture and Tracking

I began capturing mallards the first week of November and continued until early February each winter. I captured mallards using swim in traps (Hunt and Dahlka 1953)

and rocket nets fired from wetland edges (Dill and Thornberry 1950). I modified Hunt and Dahlka's (1953) swim-in trap design by using 2.5 x 5.1 cm welded wire and affixed the throat of the trap such that the opening was ~8-12 cm (Evrard and Bacon 1998). I baited capture sites with corn, rice, or soybean and located sites throughout WMAs and Coldwater River NWR prior to hunting season where I observed flocks of mallards. Ten to 12 days prior to hunting season, I relocated all traps and bait on WMAs to sanctuaries as distantly as possible from waterfowl hunting areas to eliminate effects of bait on duck distribution and hunting.

I leg banded and attached a dorsally mounted 23 g very high frequency (VHF) backpack transmitter (model A1820; Advanced Telemetry Systems, Isanti, MN) to captured female mallards (Dwyer 1972). Transmitters had a 55 pulse per minute rate, a minimum life expectancy of 150 days, and an 8-hr mercury mortality switch. Transmitters increased weight of 265 marked females between 1.5 and 2.6% ($\bar{x}$ = 2.06%, SE = 0.01%; Cochran 1980). In winters 2010-2012, I released females 4 hr after instrumentation, except when holding an individual 4 hr would result in nocturnal release; I released those birds the following morning (Davis et al. 2009). Because females seemed to acclimate to transmitters quickly after being marked in previous winters, I released females immediately following instrumentation of all co-captured individuals in winters 2013-2015. Birds had access to corn and water ad libitum during confinement periods. All instrumented females were released with captured conspecific males to minimize possible disruption of any pair bonds (Cox and Afton 1998, Lercel et al. 1999). All capture, handling, and marking methods were approved by Mississippi

State University Institutional Animal Care and Use Committee (protocols 10-070 and 13-073) and authorized under Federal Bird Banding Permit 06604.

I triangulated radiomarked females using trucks equipped with roof-mounted 4-element antennas in a null-peak array and an electronic compass (Cox et al. 2002, Gilsdorf et al. 2007). I calibrated electronic compasses to known locations of beacon transmitters ± 0.5° and trained technicians by triangulating beacon transmitters until they successfully maintained an azimuth standard deviation of ≤ 3º (Davis et al. 2009). I tracked radiomarked mallards diurnally (30 min before sunrise to 30 min after sunset) and nocturnally (30 min after sunset to 30 min before sunrise) throughout the study area (Figure 3.1; Cox and Afton 1997, Davis et al. 2009). To randomize daily locations of individuals temporally, I randomly selected a radiomarked female to begin tracking each day and corresponding night period. When few females were available for tracking, I randomly chose without replacement a period of the day (i.e., morning, mid-day, afternoon) and corresponding nocturnal period to track females until all time periods had been selected. I pursued radiomarked mallards not detected from trucks after seven consecutive days without contact (Yetter et al. 2017), using a fixed wing aircraft equipped with left and right directional antennas. During aerial surveys, I advised the pilot to fly at an altitude of 2,100-2,800 m and descended to 300 m elevation to pinpoint an individual when detected (Gilmer et al. 1981). Upon locating a missing bird from the air, I recorded GPS coordinates and relayed information to technicians in telemetry trucks, so they could locate and triangulate birds' location from the ground (Davis et al. 2009, Yetter et al. 2017). I used aerially derived point locations for birds not triangulated from telemetry trucks on the flight day when necessary (Davis et al. 2009).

I estimated point locations for each bird with a maximum likelihood estimator (Lenth 1981), using a bearing standard deviation of 3° (Davis et al. 2009, Pearse et al. 2011, Newcomb et al. 2016). Triangulations were plotted in real-time in Location of a Signal (LOAS 4.0; Ecological Software Solutions LLC, Hegymagas, Hungary) on laptop/tablet computers. I examined azimuths and point locations in real-time and discarded apparently erroneous locations or azimuths and re-triangulated the individual. For location estimation, I endeavored to obtain 3 azimuths, but, if error ellipses contained multiple habitat types, I obtained additional azimuths until error ellipses fell within one habitat type or available vantage points were exhausted. If multiple triangulations occurred for an individual in a single daily diurnal or nocturnal period, I used the first obtained location, unless the first location was a biangulation and a subsequent location contained ≥ 3 azimuths.

Statistical Analysis

I excluded the first three days of exposure of radiomarked mallards following their instrumentation to avoid any possible biases from possible stress from capture myopathy (Cox and Afton 1998). Thereafter, I exported all triangulated locations from LOAS into a geographic information system (GIS) in ARCMAP 10.3 (Environmental Systems Research Institute 2015). In GIS, I assigned daily locations into one of three habitat sources (LMVJV 2015): 1) PUB - public wetlands managed by the USFWS, MDWFP, Arkansas Game and Fish Commission (AGFC), or the Louisiana Department of Wildlife and Fisheries (LDWF); 2) MIP - wetlands privately owned and enrolled in an incentivized conservation program including WRP, CRP, CSP, WHIP, EQIP, Partners, or WWW ; and 3) MOP - wetlands privately owned and are either actively, passively, or

unmanaged outside of a conservation program. I identified locations on PUB using cadastral boundaries of USFWS NWRs and MDWFP, AGFC, and LDWF WMAs. I consulted with NRCS, USFWS, and MDWFP biologists to identify points that were located on aforementioned incentivized program lands. I also classified any points that did not fall within PUB or MIP as private lands managed outside of a conservation program. Each wetland source (PUB, MIP, MOP) contained all four habitat types discussed in chapter 2, however, some wetland sources may be biased towards providing some habitat types more than others. For example, although several incentivized programs improve wetland conditions on active cropland, a majority of restoration retires cropland from production and restores ancestral habitats such as forested and emergent wetland. Investigating resource use using pairwise combinations of habitat type and wetland source would result in 16 categorizations and increase the frequency of unused habitats types which can introduce severe bias into proportional use studies (Aebischer et al 1993, Maier 2014).

The WRP was repealed with the 2014 Farm Bill update, and replaced with the Wetland Reserve Easement (WRE) under the Agricultural Conservation Easement Program (ACEP; Public Law 113-79). Despite the changed definition, acreages established by the WRP remained on the landscape, and no WRE projects were yet implemented under WRE during my study; therefore, I continued to refer to these easements as WRP.

During the study, waterfowl hunting season contained multiple periods of hunting separated by short periods of closure. To account for differences in habitat use possibly related to hunting, I limited analyses to locations obtained during the main, uninterrupted

portion of hunting season (≥53 continuous days after "split" season) following any closure periods and post-hunting season because sample sizes of radiomarked birds were insufficient for statistical analysis before these time periods (Davis et al. 2009). Therefore, I classified mallard locations as occurring during the main hunting season (HUNT) or after hunting season until mallard departure or through the end of monitoring on 20 March annually (POST).

For each radiomarked female mallard, I calculated the proportional use of each wetland source during HUNT and POST periods, thus treating the individual as the sampling unit (Kenward 1992, Aebischer et al. 1993). Because some individuals did not use every wetland source or they used only one wetland source within a period, I transformed proportional use values using the equation:

$$y^* = \frac{y(N-1)+1/C}{N} \tag{3.1}$$

where y is the value to be transformed, N is the number of observed individuals within HUNT and POST periods, and C is the number of available habitat categories (Smithson and Verkuilen 2006, Maier 2014). I then used package DirichletReg (Maier 2014) in Program R (R Core Team 2017) to perform a multivariate regression where the response variables (proportional use of MIP, MOP, and PUB) followed a Dirichlet distribution. I used common parameterization where the Dirichlet distribution's α parameters were directly modeled by covariates for each wetland source using a log-link (Maier 2014). For each wetland source, I included an identical set of explanatory variables which included region (south or north Basin), winter of study nested within region, within-winter period (HUNT or POST), time of day (diurnal or nocturnal), and two-way interactions of time of day and region and time of day and within-winter period. I

calculated mean proportional use by first calculating the precision parameter (φ) using the equation:

$$\alpha_0 = \varphi = \sum_{c=1}^{C} \alpha_c \tag{3.2}$$

and subsequently calculating the mean proportional use of each habitat using the equation:

$$\mu_c = {}^{\alpha_c}/_{\varphi} \tag{3.3}$$

Because the DirichletReg package calculates confidence intervals on the alpha parameters, which are not [0,1] bound and subject to unit-summation, I calculated 95% confidence intervals of mean proportional wetland source use by calculating the upper and lower 2.5% quantiles from 10,000 bootstrap samples from a multivariate normal distribution of the mean and covariance matrix of the full model. I report effect sizes of the Dirichlet Regression alpha parameters and mean proportional use (with associated 95% confidence intervals) of public, incentivized private, and non-incentivized private wetlands by radiomarked mallards.

Results

I captured 265 female mallards including 58 birds in winter 2010-2011 (11 November 2010 to 24 January 2011), 68 in winter 2011-2012 (13 November 2011 to 23 January 2012), 74 in winter 2013-2014 (30 November 2013 to 25 January 2014), and 65 in winter 2014-2015 (15 December 2014 to 7 February 2015). I excluded 24 females from data analysis because they died within the 3-day acclimation period or were not located during the hunting or post-hunting periods. Despite deletions, I retained 7,402 diurnal and 1,827 nocturnal locations (*n* = 9,229) from 241 radiomarked females (Table

3.2). Females were located on incentivized program wetlands 1,801 times (19.5%), private managed wetlands 3,433 times (37.2%), and public wetlands 3,995 times (43.3%) throughout the study (Table 3.3).

Female mallard use of incentivized program wetlands was 31.6% (CI_{95} = -0.2 – 73.5%) greater in the north than south Yazoo Basin (Table 3.4). Use of incentivized wetlands was 33.2% (8.0 – 64.3%) greater post-hunting season and 10.6% (-16.3 – 46.2%) greater diurnally than at night. Females in the south Basin used incentivized wetlands 14.3% (-10.6 – 46.3%) more in winter 2011-2012 than 2010-2011, while females in the north Basin used incentivized wetlands 54.9% (20.0 – 100.1%) more in winter 2014-2015 than 2013-2014. Incentivized wetlands in the north Basin were used 8.1% (-26.0 – 57.8%) more at night than those in the south Basin, and incentivized wetlands were used 19.0% (-18.6 – 73.9%) more at night within hunting season than post-hunting season.

Mean use of incentivized program wetlands ranged from 16 – 35% with predominate use occurring post-hunting season (Table 3.5). Diurnal use of incentivized wetlands by mallards ranged from 26.6 – 60.6% and was greater post-hunting season than within hunting season in winters 2010-2012 and 2013-2014, but use was similar between these periods in 2014-2015. In the south Basin, mallards used incentivized wetlands 39.1% and 58.1% more in winter 2011-2012 than winter 2010-2011 diurnally during and post-hunting season, respectively. At night, mallards used incentivized wetlands 42.5 and 42.8% more in winter 2011-2012 than 2010-2011 during hunting and post-hunting season, respectively. In the north Basin post-hunting season, mallards used incentivized

wetlands 32.3 and 24.9% more in winter 2013-2014 than 2014-2015 during diurnal and nocturnal periods, respectively.

Mallard use of wetlands managed outside of a conservation program on private lands was 14.1% (-15.6 – 54.3%) greater in the north than south Basin. Privately managed wetlands were used 88.6% (50.1 – 137.0%) more post-hunting season and 3.9% (-23.0 – 40.2%) more diurnally than at night. In the south Basin, females used privately managed wetlands 82.4% (38.3 – 140.7%) more in winter 2011-2012 than 2010-2011, while, they used privately managed wetlands 58.0% (20.8 – 106.6%) more in winter 2013-2014 than 2014-2015 in the north Basin. Females in the north Basin used privately managed wetlands 13.3% (-23.1 – 66.9%) more at night than those in the south Basin. Lastly, privately managed wetlands were used 88.0% (28.5 – 175.2%) more at night within hunting season than at night post-hunting season.

Mean use of private lands managed outside of a conservation program by mallards was 15 – 66% with greatest use occurring during the day post-hunting season within each winter (Table 3.5). Mallards used MOP wetlands 59 – 127% more post-hunting season than within hunting season diurnally, but use was similar between hunting and post-hunting seasons at night. Moreover, mean use of privately managed wetlands by mallards was 55 – 76% greater in winter 2010-2011 than winter 2011-2012 in the south Basin, and 21 – 36% greater in winter 2014-2015 than winter 2013-2014 in the north Basin. In the south Basin, mallard use of MOP was similar between diurnal and nocturnal periods during hunting seasons, but mallards used MOP wetlands 49 – 64% more diurnally than nocturnally post-hunting season. In the north Basin, mean use was

27 – 35% greater at night during the hunting season, while it was 21 – 28% greater during the day post-hunting season.

Use of public wetlands by radiomarked females was 20.9% (-11.1 – 64.2%) greater in the south than north Basin. Female mallards used public wetlands 148.3% (96.9 – 213.1%) more within hunting season and 110.0% (52.0 – 190.1%) more diurnally than nocturnally. Public wetlands were used 11.5% (-14.0 – 44.5%) more in winter 2011-2012 than 2010-2011 in the south basin, and 21.7% (-8.9 – 62.5%) more in winter 2014-2015 than 2013-2014 in the north Basin. Females in the south Basin used public wetlands 18.7% (19.5 – 74.8%) more at night than those in the north Basin. Public wetlands were used 97.4 (34.4 – 189.8%) more at night post-hunting season than during hunting season.

Mean use of public wetlands by female mallards ranged from 14 – 63% and greatest use occurred diurnally during hunting season (Table 3.5). Mean use of public wetlands was 18 – 21% and 50 – 59% greater diurnally than nocturnally during hunting season in the south and north Basins, respectively. In contrast, use was 50 – 66% and 43 – 52% greater nocturnally than diurnally post-hunting season in the south and north Basins, respectively. Diurnal use of public wetlands by females was 1.06 – 1.34 times greater during hunting season that post-hunting season in the south Basin and 1.61 – 1.95 times greater in the north Basin.

Discussion

Female mallard use of public and private wetlands varied spatiotemporally; whereas, use of incentivized wetlands was relatively uniform with variation between hunting and post-hunting seasons throughout the study and winters in the south Basin.

Females used incentivized wetlands 58% more than privately managed wetlands, despite the LMVJV assuming as much as four times greater food availability in incentivized versus privately managed wetlands. Use of public wetlands was nearly three times greater than incentivized wetlands during the 2010-2011 hunting season. However, use of incentivized wetlands ranged from 1.16 times less to 1.90 times greater among hunting and post-hunting periods in other winters, suggesting food was likely not the primary driver of wetland source use. Mallard use of incentivized wetlands generally was low (16 – 35%), but at times was commensurate with use of private or public managed wetlands during the post-hunting season. I interpret these trends below, particularly regarding how females may have been attracted to non-hunted sanctuaries on public wetlands, and how former telemetry studies found patterns in food depletion by birds and how that resulted in decreased use of public land in late winter. Lastly, I discuss mallard use of incentivized wetlands focusing on easements enhanced through the MBHI, and consider how incentivized wetlands may be a source for future mitigation from natural and anthropogenic disasters.

Private landowners retain recreational privileges on their conservation easements, and hunting is a predominate activity on CRP easements (Farm Services Agency 2007, Ferris and Siikamaki 2009). Hunting intensity on WRP and other incentivized programs has not been evaluated, but USDS-NRCS (2009) recognizes the WRP as a program that expands hunting opportunity. During hunting season, mallards predominately used public wetlands diurnally, wherein sanctuaries existed, and avoided private and incentivized wetlands because of disturbance and risk of mortality. Widespread research has linked prolonged or repeated anthropogenic disturbance to altered circadian habitat

use by waterfowl and tendency to use diurnally disturbed habitats nocturnally (Girard 1941, Thornburg 1973, Madsen and Fox 1995, Cox and Afton 1997, Fox and Madsen 1997, Madsen 1998, Roy et al. 2013, 2014; Beatty et al. 2014, Lancaster et al. 2015). Beatty et al. (2014) reported mallards selected wetlands near WRP easements nocturnally during hunting season and all day post-hunting season. Likewise, mallards in my study used incentivized wetlands more diurnally post-hunting season and at night during hunting seasons. Therefore, hunting on WRP and other incentivized wetlands may cause avoidance or displacement of mallards during hunting season. St. James et al. (2013) found no differences in mallard use of public hunting areas when hunting occurred 2 or 4-days per wk. However, others have suggested the duration between disturbance events should be measured in weeks, not days (Fox and Madsen 1997). Moreover, the density of hunters on public areas likely greatly surpasses that of private wetlands, therefore waterfowl may tolerate more frequent disturbance.

Sanctuary habitats in proximity to hunted wetlands can ameliorate displacement or avoidance of disturbed areas by waterfowl and help maintain local abundances of birds during hunting seasons (Fox and Madsen 1997, Stafford et al. 2007, Lancaster 2013). Proximity of sanctuary habitats to hunted wetlands is debated, but, a minimum separation distance is required such that hunting disturbance does not impact individuals in the sanctuary (Fox and Madsen 1997), and a maximum distance such that it is available within a typical daily flight distance (Cox and Afton 1997, 1998; Stafford et al. 2007). Therefore, displacement or avoidance related to hunting should result in a decrease in sanctuary use at times when hunting is diminished, such as at night during hunting season or post-hunting season (Cox and Afton 1997; Evans and Day 2002, Link et al. 2011; Roy

et al, 2013, 2014). Beatty et al. (2014) reported mallards selected wetlands with more surrounding public land sanctuary and wetlands closer to sanctuary throughout the day during hunting season. I did not classify public lands as sanctuary or hunted, but female mallards in my study decreased their use of public wetlands at night during hunting season and decreased diurnal use during hunting and post-hunting seasons, suggesting public land use was associated with disturbance avoidance. Pearse et al. (2012) found no support that sanctuary influenced presence or size of mallard groups during diurnal aerial surveys in Mississippi, attributing the relationship to the exclusion of private land temporal or spatial sanctuaries that could not be ascertained. Existence, expanse, and location of sanctuary on private lands in a landscape are rarely known beyond the scale of an individual property, yet numerous studies have found effects of waterfowl hunting when considering only public land sanctuary (Cox and Afton 1997; Stafford et al. 2007, 2010, Link et al. 2011; Roy et al. 2013, 2014, Beatty et al. 2014). However, use of sanctuary by birds on private lands may reduce use of public lands and lead to increased uniformly distributed use during and after hunting season (Davis et al. 2009). A recent survey suggested that 60% of WRP easements in the MAV provide temporal or spatial sanctuary on approximately 11% of easement acres (Dale James, Ducks Unlimited, personal communication). Therefore, in some regions with expansive WRP acreage, sanctuary on private lands may influence the distribution and wetland source use of mallards.

Public wetlands may also function as information centers within a "functional unit system" (Tamisier 1985) leading to prodigious daytime use by mallards. A functional unit system consists of: 1) a central resting place wherein waterfowl concentrate diurnally

and engage in comfort activities, courtship, and opportunistic feeding, and 2) several feeding areas scattered within a nominal flight distance (2-20 km, Tamisier 1985). This pattern could explain greatest use of public wetlands diurnally and the nocturnal shift to private and incentivized wetlands where food resources may have been predictable and abundant. However, the presumption of the functional unit system is that nocturnal feeding results from diurnal gregariousness and not avoidance of anthropogenic disturbance in foraging patches (Tamisier 1985, Cox and Afton 1997). This hypothesis was not supported in my study as mallards shifted away from public wetlands diurnally after hunting season and had greater nocturnal than diurnal use by mallards post-hunting season. Cox and Afton (1997) witnessed a similar breakdown of the functional unit system hypothesis when northern pintails (*Anas acuta*) they tracked abandoned their diurnal retreats on public sanctuaries after hunting season.

McNeil et al. (1992) hypothesized that nocturnal feeding was a necessary endeavor when birds failed to meet dietary needs diurnally. As winter progressed, resources on public wetlands may have become depleted causing mallards to shift to private lands in search of more reliable food sources (Hamilton and Watt 1970, Hagy and Kaminski 2012, Beatty et al. 2014). Mean use of private wetlands (MIP and MOP) were greater or at least equal to public land use at night during hunting season. Therefore, mallards may have used private lands at night to supplement daily energy requirements during hunting season, but shifted to private wetlands diurnally after hunting season, because diurnal feeding on public wetlands diminished to a point that it was insufficiently supplemented by nocturnal feeding (McNeil et al. 1992). Davis and Afton (2010)

reported increased movement distance as winter progressed for females located diurnally in rice fields citing resource depletion as probable cause.

There is inconclusive evidence that either sanctuary or forage levels may have led to increased use of public lands diurnally during hunting season and some un-reconcilable combination of these factors may provide the best explanation. Hagy and Kaminski (2012) found consistent seed and tuber densities from December to late February on public land sanctuary sites despite continued use by dabbling ducks and reported that birds continued to use and sample the sites for forage or used them as refugia. Future research should concurrently sample food availability and hunting disturbance levels on public and private wetlands through winter to determine how waterfowl foraging, sanctuary use, and hunting are related.

Mallard use of incentivized wetlands was inconsistent relative to other wetland sources among winters in the south Basin. I attribute this pattern to the availability of incentivized wetlands near capture sites between winters. Specifically, I captured most (92%) mallards at Mahannah WMA in 2011-2012 which contained an order of magnitude (19,626 vs 1,396 ha) more WRP within 30 km than Muscadine WMA where I captured most (63%) females in 2010-2011. Moreover, greater nocturnal use of public wetlands in 2010-2012 may have resulted from mallards accessing resources on hunted portions of WMAs at night (Lancaster 2013, Lancaster et al. 2015). Patterns of WMA attendance by mallards at Muscadine WMA support this view, and nocturnal use was not diminished by diurnal hunting intensity (Lancaster et al. 2015). Moreover, Dooley et al. (2010) showed that interrupted mallards were equally likely as uninterrupted mallards to return to

disturbed sites nocturnally, further suggesting that diurnal activities may not impact the use of sites nocturnally.

The WRP (65%) and CRP (24%) comprised most use of incentivized wetlands by mallards; whereas, other conservation programs contained less than 4% of mallard locations. Trivial use of certain incentivized programs is not surprising given limited enrollment or recent program establishment in Mississippi. For example, the Winter Water for Wildlife pilot program was not used by mallards during my study, but it commenced in 2014 with less than 650 ha. Moreover, the USFWS Partners program had between 2,092 and 3,330 ha enrolled during my study, which may have contributed to reduced use by mallards. Comparatively, the WRP and CRP had 71,000 and 300,000 ha of existing contracts in Mississippi during my study. However, not all WRP and CRP acreage is restored wetland or even inundated seasonally. For instance, available figures suggested that 8.7-16.8% of WRP was inundated during my study (J. D. Lancaster, unpublished data). Using an alternate study design that incorporates availability and juxtaposition of incentivized wetlands may provide a more accurate representation of mallard response to incentivized wetlands (Beatty et al. 2014).

I located 17 mallards on 42 occasions on EQIP (n = 4), WHIP (n = 25), and WRP (n = 13) easements enhanced through the MBHI in response to the Deepwater Horizon Oil Spill (Davis et al. 2014). The MBHI funded EQIP for 1 year, WHIP for 2 years, and WRP for 3 years beginning in fall 2010 after the April 2010 oil spill, thus enhancements were not available for the duration of my study (Buler et al. 2013). As mentioned previously, availability of MBHI wetlands near capture sites was variable and some counties within the study area did not contain MBHI enhancements enrolled in one or

more eligible programs (EQIP, WHIP, WRP) leading to disparate availability and use among sub-programs (K. Nelms, NRCS, personal communication). Sieges et al. (2014) found increased diurnal densities of waterbirds in response to MBHI enhancements using weather radar and Tapp et al. (2017) found greater abundances of waterfowl and other waterbirds using MBHI enhanced wetlands and croplands in her study. Although I found limited use of MBHI easements by mallards, I recorded additional use of EQIP, WHIP, and CSP outside of MBHI which when flooded emulate the incentivized enhancement of MBHI. The EQIP and WHIP enhancements were centered toward shorebirds (Charadriiformes) that migrate through the MAV and were considered more susceptible to oil-impacted coastal wetlands than mallards (Foth 2016). Moreover, mallards made significant use of forested wetlands (Davis et al. 2009, Chapter 2) which were a component of WRP, but not EQIP or WHIP through the MBHI.

Management Implications

Public wetlands were used extensively by mallards in the MAV and should continue to be managed actively to provide foraging and other habitats for non-breeding waterfowl (Kross et al. 2008, Fleming et al. 2015, Hagy and Kaminski 2015). Moreover, public land sanctuary is an integral part of landscape design for wintering waterfowl and should be incorporated when feasible. Where spatial sanctuary is unrealistic, managers should consider temporal sanctuary which may allow mallards to access resources during the hunting season. Private lands are fundamental to birds post-hunting season as birds can acquire critical resources when not disturbed compared to hunting seasons. Specifically, I advocate that land managers maintain shallowly flooded conditions (e.g., ≤ 16 cm [Hagy and Kaminski 2012]) in wetlands post-hunting season where possible so

that birds can forage on aquatic invertebrates and seeds as females' complete pre-basic molt and prepare for spring migration.

The WRP was used extensively among incentivized wetlands by mallards in my study, but active management of these sites could further benefit non-breeding waterfowl (Burger 2006, Kross et al. 2008, Fleming et al. 2015). The lack of appropriate soil disturbance regimes to maintain early successional plant species potentially reduces resource quality and availability to mallards and other waterfowl (Kross et al. 2008, Fleming et al. 2012). Additionally, many counties have attained or are rapidly approaching their maximum allowable enrollment relative to active cropland. Future Farm Bill amendments should relax these restrictions to promote additional conservation easements on the landscape. Moreover, current demand for enrollment in many conservation easements surpasses the budget allocation and has created a backlog of eligible contracts. However, extensive use of the WRP by mallards is encouraging because many WRP easements are protected in perpetuity and can continue to provide wintering waterfowl habitat in the future (Beatty et al. 2014).

Compared to private wetlands managed outside of a conservation program and public wetlands, mallards made modest use of incentivized wetlands. Naturally, those conservation programs that have widespread enrollment such as the WRP and CRP were most used by radiomarked mallards. Incentivized programs provide an inroad to rapid enrichment for mitigation purposes following an unforeseen catastrophe. Given the circumstances of the mitigation effort, important consideration must be given as to the impact of hunting disturbance on the target species. Specifically, if hunting negatively impacts body condition or survival rates of the target species, incorporation of hunting

restrictions may be necessary. However, for many migratory waterfowl species, such as the mallard, hunting on current incentivized wetlands likely does not negatively impact these demographics because they are unrestricted nocturnally (McNeil et al. 1992, Guillemain et al. 2002). Moreover, landowners may be reluctant to participate if they must limit hunting activities, therefore, program managers must weigh benefits and shortfalls of potential hunting regimes. Future research should quantify and further understand landowner views on the subject.

The NRCS implemented the Regional Conservation Partnership Program (RCPP) program with the 2014 Farm Bill and has since invested $2.4 billion in partner-driven initiatives such as Ducks Unlimited's Rice Stewardship Partnership to address natural resource management concerns. The goal of the RCPP is to leverage additional funds to increase effectiveness of federal conservation investment and allows partners to implement additional conservation using existing program authorities (ACEP, EQIP, and CSP). The Rice Stewardship Partnership has impacted more than 29,000 ha of rice fields in the MAV, Gulf Coastal Prairie, and California through the EQIP program since project inception. In addition to the Rice Stewardship Partnership, there are additional RCPP projects through Wildlife Mississippi and Delta Wildlife that are benefitting waterfowl habitat in the MAV. These and existing conservation easements may allow researchers to evaluate the contribution of incentivized wetlands to non-breeding survival of waterfowl in the MAV and fully understand the contribution of these wetlands to waterfowl populations. The use of incentivized wetlands by mallards displays how financial and technical assistance programs enhance resources for mallards and other waterfowl that may otherwise not be available. Moreover, additional assistance programs, such as the

successful MBHI program, aimed at active seasonal management using existing infrastructure may engage landowners to take an active role in managing conservation easements for waterfowl (Tapp et al. 2017).

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Table 3.1 Incentivized private land conservation programs and their potential benefit to Mallards.

Acronym	Program	Agency[1]	Enrollment Period	Extent (yrs.)	Program Purpose[2]	Potential Benefit to Mallards[3]
WRP	Wetland Reserve Program	NRCS	1990 – 2014[4]	30, Perpetual	Improve water quality, reduce soil erosion, and provide wildlife habitat through retirement of marginal farmland	Increased habitat and food in restored seasonal emergent and forested wetlands
CRP	Conservation Reserve Program	FSA	1985 – Current	10 – 15		
EQIP	Environmental Quality Incentives Program	NRCS	1996 – Current	≤ 10	Improve soil, water, plant, animal, air, and related natural resources on agricultural land	Increased habitat and food availability in agricultural fields, and created or restored wetlands
CSP	Conservation Stewardship Program	NRCS	2002[5] – Current	5		Increased habitat and food (including unharvested grain) availability in agricultural fields
WHIP	Wildlife Habitat Incentives Program	NRCS	1996 – 2014[6]	5 – 10	Develop and improve wildlife habitat on agricultural land	Increased habitat and food availability in agricultural fields

Table 3.1 (continued)

Partners	Partners for Fish and Wildlife	USFWS/ MDWFP	1987 – Current	10 – 15	Develop and improve wildlife habitat	Increased habitat and food availability in agricultural fields and seasonal emergent wetlands
WWW	Winter Water for Wildlife	MDWFP/ Wildlife Mississippi	2014 – 2016	3	Improve waterbird habitat in selected Mississippi regions	
MBHI	Migratory Bird Habitat Initiative	NRCS	2010 – 2010[7]	1 – 3[8]	Enhance wetlands for waterbirds on EQIP, WHIP, WRP easements	Increased habitat and food availability on EQIP, WHIP, and WRP easements

[1] FSA- Farm Services Agency; MDWFP - Mississippi Department of Wildlife, Fisheries, and Parks; NRCS - Natural Resources Conservation Service; USFWS- United States Fish and Wildlife Service.
[2] The original intent of the conservation program.
[3] Alternate benefits to mallards and other waterfowl of practices implemented by the program.
[4] WRP was repealed in the 2014 Farm Bill and replaced with the Wetlands Reserve Easement under the Agricultural Conservation Easement Program.
[5] The CSP began as a pilot program in 2002 titled the Conservation Security Program but became fully operational as the Conservation Stewardship Program in 2010.
[6] The WHIP was repealed in the 2014 Farm Bill but some practices were rolled into the EQIP.
[4,6] Repeal of these programs stopped new enrollment, but existing contracts remained enrolled for the duration of their agreement.
[7] Enrollment in the MBHI was limited to fall 2010 following the Deepwater Horizon Oil Spill.
[8] Duration of MBHI enhancement was 1-yr for EQIP, 2-yrs. for WHIP, and 3-yrs. for WRP.

Table 3.2 Locational data for 241 radiomarked female mallards in Mississippi, 2010-2015.

Region	Winter	Period	Time of Day	Radiomarked Females	Total Locations	Mean Loc./Fem.	Min. Loc./Fem.	Max Loc./Fem.
South Basin	2010/ 2011	Hunt	Diurnal	47	838	17.8	1	50
			Nocturnal	1	1	1.0	1	1
		Post	Diurnal	36	727	20.2	1	46
			Nocturnal	17	104	6.1	2	8
	2011/ 2012	Hunt	Diurnal	59	879	14.9	1	51
			Nocturnal	55	349	6.3	1	17
		Post	Diurnal	57	1,835	32.2	1	43
			Nocturnal	51	708	13.9	1	23
North Basin	2013/ 2014	Hunt	Diurnal	57	947	16.6	1	45
			Nocturnal	47	290	6.2	1	16
		Post	Diurnal	51	463	9.1	1	29
			Nocturnal	24	209	8.7	1	20
	2014/ 2015	Hunt	Diurnal	33	441	13.4	2	24
			Nocturnal	30	164	5.5	1	9
		Post	Diurnal	51	1,272	24.9	1	41
			Nocturnal	2	2	1.0	1	1

For female mallards captured at three wildlife management areas and one national wildlife refuge in the Mississippi Alluvial Valley of Mississippi in winters 2010-2012 and 2013-2015.

Table 3.3 Summary of mallard locations within each wetland source and individual incentivized program during winters 2010-2015.

Habitat Source	2010-2011	2011-2012	2013-2014	2014-2015
Conservation Program	150	1,000	360	291
CRP	47	58	146	180
WRP[1,2]	71 (10)	941 (3)	110(–[5])	40(–)
CSP	0	0	32	35
EQIP[1,3]	7 (4)	0 (–)	31 (–)	4 (–)
WHIP[1,4]	25 (25)	0 (–)	13 (–)	3 (–)
PFW	0	1	28	29
WWW	–	–	–	0
Public Land	767	2,086	720	422
WMA	322	1,261	2	0
NWR	445	825	718	422
Private Land	753	685	829	1,166

[1] Parentheses indicate number of locations on the conservation program enhanced through the Migratory Bird Habitat Initiative (MBHI).
[2] WRP enrolled in MBHI had a 3-year term limit that began in 2010.
[3] EQIP enrolled in MBHI had a 1-year term limit that began in 2010.
[4] WHIP enrolled in MBHI had a 2-year term limit that began in 2010.
CRP - Conservation Reserve Program, WRP - Wetland Reserve Program, CSP - Conservation Stewardship Program, EQIP - Environmental Quality Incentives Program, WHIP - Wildlife Habitat Incentives Program, PFW - Partners for Fish and Wildlife, WWW - Winter Water for Wildlife, WMA - Wildlife Management Area, NWR - National Wildlife Refuge.
[5] A dash indicates that the program did not overlap with the winter of study.

Table 3.4 Model predicted alpha parameters and 95% confidence intervals for female mallard wetland use.

Region	Winter	Period	Time of Day	Private MIP	Private MOP	Public
South Basin	2010/ 2011	Hunt	Diurnal	0.16 (0.12 – 0.20)	0.26 (0.21 – 0.34)	0.57 (0.45 – 0.73)
			Nocturnal	0.13 (0.09 – 0.18)	0.22 (0.16 – 0.32)	0.32 (0.22 – 0.47)
		Post	Diurnal	0.21 (0.16 – 0.26)	0.50 (0.39 – 0.64)	0.23 (0.18 – 0.30)
			Nocturnal	0.15 (0.11 – 0.20)	0.22 (0.16 – 0.31)	0.26 (0.18 – 0.36)
	2011/ 2012	Hunt	Diurnal	0.24 (0.20 – 0.30)	0.17 (0.13 – 0.21)	0.70 (0.55 – 0.88)
			Nocturnal	0.20 (0.15 – 0.26)	0.14 (0.11 – 0.18)	0.39 (0.31 – 0.51)
		Post	Diurnal	0.32 (0.26 – 0.40)	0.31 (0.26 – 0.39)	0.28 (0.22 – 0.36)
			Nocturnal	0.23 (0.18 – 0.29)	0.14 (0.11 – 0.18)	0.31 (0.24 – 0.41)
North Basin	2013/ 2014	Hunt	Diurnal	0.20 (0.17 – 0.25)	0.30 (0.24 – 0.37)	0.47 (0.37 – 0.61)
			Nocturnal	0.18 (0.15 – 0.23)	0.29 (0.23 – 0.37)	0.23 (0.18 – 0.29)
		Post	Diurnal	0.27 (0.22 – 0.34)	0.57 (0.44 – 0.73)	0.19 (0.15 – 0.24)
			Nocturnal	0.21 (0.15 – 0.29)	0.29 (0.21 – 0.40)	0.18 (0.14 – 0.24)
	2014/ 2015	Hunt	Diurnal	0.23 (0.19 – 0.30)	0.55 (0.43 – 0.70)	0.53 (0.41 – 0.69)
			Nocturnal	0.21 (0.16 – 0.27)	0.53 (0.39 – 0.72)	0.25 (0.19 – 0.34)
		Post	Diurnal	0.31 (0.25 – 0.39)	1.04 (0.78 – 1.37)	0.21 (0.17 – 0.26)
			Nocturnal	0.24 (0.16 – 0.34)	0.53 (0.36 – 0.77)	0.20 (0.14 – 0.28)

For female mallards captured at three wildlife management areas and one national wildlife refuge in the Mississippi Alluvial Valley of Mississippi in winters 2010-2012 and 2013-2015.

Table 3.5 Mean proportional use (95% CI) by radiomarked female mallards in Mississippi, 2010-2015.

Region	Winter	Period	Time of Day	Private MIP	Private MOP	Public
South Basin	2010/ 2011	Hunt	Diurnal	0.16 (0.12 – 0.20)	0.27 (0.22 – 0.32)	0.58 (0.51 – 0.64)
			Nocturnal	0.19 (0.14 – 0.26)	0.33 (0.25 – 0.42)	0.48 (0.38 – 0.57)
		Post	Diurnal	0.22 (0.18 – 0.27)	0.53 (0.46 – 0.60)	0.25 (0.20 – 0.30)
			Nocturnal	0.23 (0.18 – 0.30)	0.36 (0.28 – 0.44)	0.41 (0.32 – 0.50)
	2011/ 2012	Hunt	Diurnal	0.22 (0.18 – 0.26)	0.15 (0.12 – 0.19)	0.63 (0.57 – 0.68)
			Nocturnal	0.27 (0.22 – 0.33)	0.19 (0.15 – 0.24)	0.53 (0.47 – 0.60)
		Post	Diurnal	0.35 (0.30 – 0.40)	0.34 (0.29 – 0.40)	0.31 (0.26 – 0.36)
			Nocturnal	0.33 (0.27 – 0.39)	0.21 (0.17 – 0.26)	0.46 (0.39 – 0.53)
North Basin	2013/ 2014	Hunt	Diurnal	0.21 (0.17 – 0.25)	0.31 (0.26 – 0.36)	0.48 (0.42 – 0.54)
			Nocturnal	0.26 (0.22 – 0.32)	0.41 (0.35 – 0.48)	0.32 (0.27 – 0.38)
		Post	Diurnal	0.26 (0.22 – 0.31)	0.55 (0.49 – 0.61)	0.19 (0.15 – 0.23)
			Nocturnal	0.31 (0.23 – 0.39)	0.43 (0.34 – 0.51)	0.27 (0.20 – 0.33)
	2014/ 2015	Hunt	Diurnal	0.18 (0.14 – 0.22)	0.42 (0.36 – 0.48)	0.40 (0.34 – 0.47)
			Nocturnal	0.21 (0.17 – 0.27)	0.53 (0.45 – 0.61)	0.25 (0.20 – 0.32)
		Post	Diurnal	0.20 (0.16 – 0.25)	0.66 (0.60 – 0.72)	0.14 (0.11 – 0.17)
			Nocturnal	0.24 (0.17 – 0.33)	0.55 (0.45 – 0.64)	0.21 (0.15 – 0.28)

For female mallards captured at three wildlife management areas and one national wildlife refuge in the Mississippi Alluvial Valley of Mississippi in winters 2010-2012 and 2013-2015.

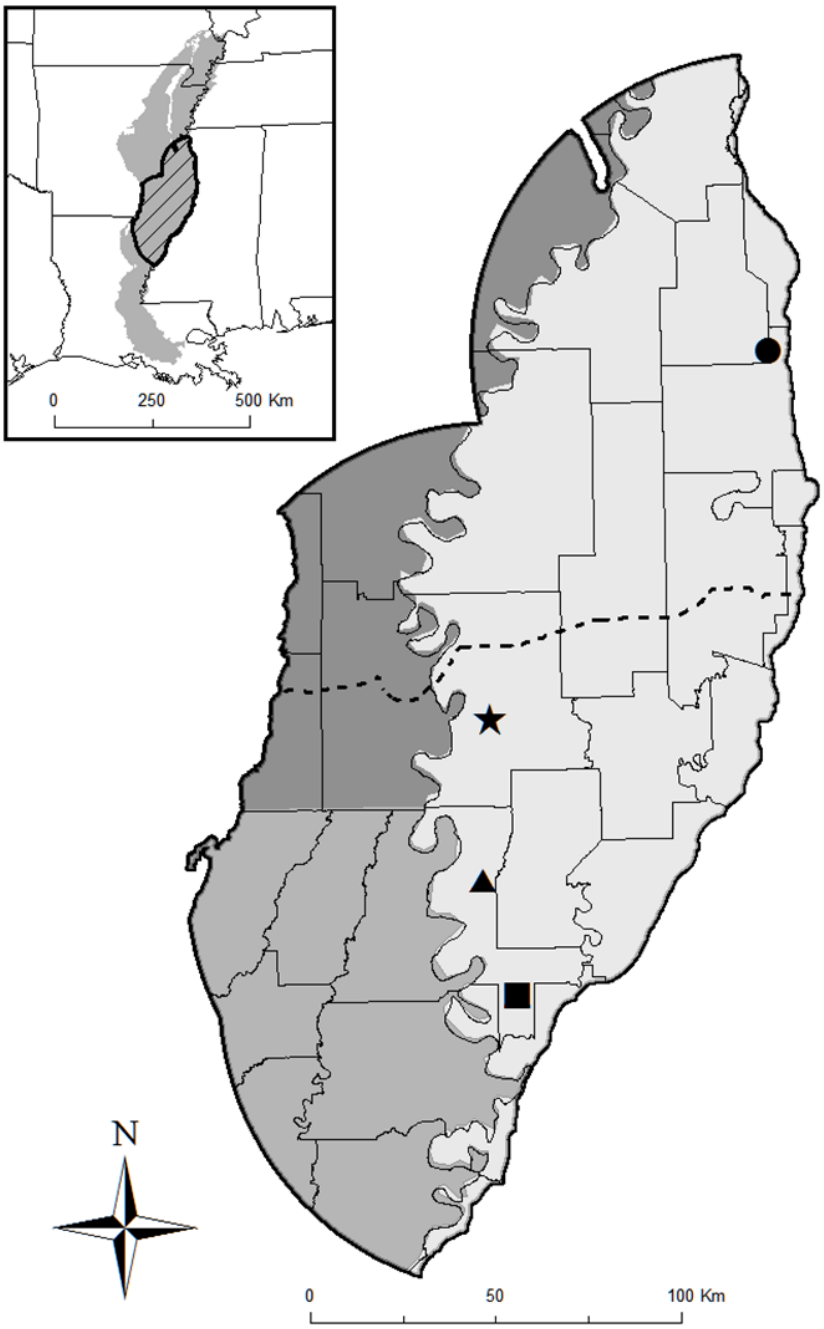

Figure 3.1 Female mallard capture locations and surrounding study area within the Mississippi Alluvial Valley.

Study area included the Mississippi Alluvial Valley within 80 km of capture locations: Coldwater River National Wildlife Refuge (circle), Muscadine Farms Wildlife Management Area (WMA; star), Howard Miller WMA (triangle), and Mahannah WMA (square). Highway 82 corridor shown (dashed) dividing the north and south study basins.

CHAPTER IV

APPARENT DAILY SURVIVAL OF FEMALE MALLARDS IN MISSISSIPPI'S ALLUVIAL VALLEY

Recognizing and enhancing resources that positively impact important biological events, such as survival and reproduction, are necessary for effective population management of a species (Leopold 1933, Ayers et al. 2013). The need to meet annual species needs at local and landscape scales is fundamental for conservation planning and management of wildlife populations (Hoekman et al. 2002, Sibly and Hone 2002). Minimally, wildlife must survive and reproduce to persist as individuals and as a population, respectively. In addition, wildlife managers may seek to maintain hunted species at population levels commensurate with public entreaty (Cooch et al. 2014). For decades ornithologists have studied bird-habitat relationships accounting for birds' presence, abundances, or demographic consequences (Stoddard 1931, MacArthur 1958, Hilden 1965, Cody 1981, Van Horne 1983, Hutto 1985, Wiens 1989, Dugger et al. 2005, Gaillard et al. 2010) but few have linked demography to individual variation in habitat use (cf. Holmes et al 1996, Whitaker et al. 2009, Breininger et al. 2009).

Migratory species impose additional challenges in relating resource use or selection to demographic consequences of individuals, because biological outcomes are compounded by sequential 'decisions' made by birds cross-spatially and seasonally (i.e., carry-over effects; Harrison et al. 2011, Sedinger and Alisauskas 2014, Osnas et al.

2016). Complexity lies with linking cumulative habitat use during non-breeding periods to subsequent fitness that culminates in a separate geography (e.g., northern breeding grounds) and time in the individual's life (Norris 2005, Harrison et al. 2011, Sedinger et al. 2011). Nevertheless, researchers have inferred some level of habitat quality within and among heterogeneous environments by assuming that individuals select resources therein that enhance individual survival and subsequently maximize long-term fitness (Arlt et al. 2008, Sedinger and Alisauskas 2014).

The mallard (*Anas platyrhynchos*) is an ecologically and economically important migratory bird abundant throughout the northern hemisphere (Baldassarre and Bolen 2006, Grado et al. 2011, Baldassarre 2014, U.S. Fish and Wildlife Service 2016). Mallard population dynamics are strongly influenced by events that occur during the breeding season including female, clutch, and duckling survival (Hoekman et al. 2002, Amundson and Arnold 2011). However, winter flooding in the Lower Mississippi Alluvial Valley (MAV) positively influences age ratios of harvested mallards the following year, suggesting winter habitat conditions influence recruitment (Heitmeyer and Fredrickson 1981, Kaminski and Gluesing 1987, Osnas et al. 2016). The Mississippi Flyway forms the primary migratory corridor for mid-continent Nearctic mallards, where ≥ 40 percent of mallards within the flyway winter in the MAV (Bellrose 1968, 1976; Nichols et al. 1983; Davis et al. 2011; Pearse et al. 2012). Mallards are enticed by the MAV's extant and restored bottomland hardwood forests, seasonally flooded wetlands, and flooded croplands that satisfy their physiological and behavioral needs during migrations and winter (Reinecke et al. 1989, Heitmeyer 2006, Davis et al. 2009, Pearse et al. 2012).

Pearse et al. (2012) identified complexes of wetland and cropland habitats in the Mississippi MAV that attracted greatest abundances of mallards. However, population density does not necessarily proxy habitat quality (Van Horne 1983), and biological outcomes may not be accurately predicted by typical habitat correlations or energy availability (Kaminski and Prince 1984, Ayers et al. 2013, Kaminski and Elmberg 2014). Regardless, Pearse et al. (2012) rigorously quantified associations of mallard abundances and habitats in Mississippi's MAV and established a novel foundation for testing hypotheses about mallard habitat use and subsequent survival of individuals (Kaminski and Elmberg 2014). These logical research progressions remain steeped in classical ecological models of animal space use and fitness (Fretwell 1972, Southwood 1977, Van Horne 1983). Obtaining demographic outcomes, such as daily and seasonal survival of individuals resulting their use of specific resources or habitats (e.g., 3rd order selection [Johnson 1980]), advances our understanding of consequences of resource exploitation by birds (Holmes et al 1996, Dugger et al. 2005, Aldridge and Boyce 2008, Whitaker et al. 2008, Breininger et al. 2009).

My study builds on previous work in the MAV that studied mallard movements, habitat use, and survival during winter (Reinecke et al. 1987; Dugger et al. 1994; Davis et al. 2009, 2011; Davis and Afton 2010; Lancaster 2013, Lancaster et al. 2015). Davis et al. (2009, 2011) hypothesized that forested wetlands provide energetic and other survival advantages to female mallards in the MAV. That is, female mallards that occupied forested habitats were less likely to switch habitats, and consequently moved shorter distances than those occupying non-forested habitats, such as flooded agricultural fields (Davis and Afton 2010). In synthesizing these recent studies and their potential

ecological constructs (Davis and Afton 2010, Pearse et al. 2012), I hypothesized that winter survival of female mallards would be limited by the availability of and access to forested wetlands in the Mississippi MAV. If less than adequate access to forested wetlands diminishes non-breeding survival of mallards, or alternatively, if forested wetlands promote survival of birds relative to other resource types in the MAV, I then predict that females using forested wetlands will experience greatest daily survival rates among all habitat types. Understanding mallard survival in relation to resource use, or exploitation of habitat complexes, will improve our understanding of quality habitats needed for continued enhancement and future restoration of resources in the Mississippi MAV.

Study Area

The Yazoo Basin is nearly 20,000 km^2 and largest of six basins forming the MAV (Saucier 1994). The Yazoo Basin drains the entire MAV in Mississippi and a portion of west Tennessee through a series of rivers, which connect with the Yazoo River and flow into the Mississippi River at Vicksburg, Mississippi. I divided the Yazoo Basin into north and south regions by selecting east-west Mississippi Highway 82 from Greenwood, MS to Greenville, MS as a geographical demarcation (Figure 4.1). I evaluated female mallard habitat use in the south basin during winters 2010-2012 and in the north basin during winters 2013-2015. I captured female mallards at the following three state wildlife management areas (WMAs) in the south basin and a national wildlife refuge (NWR) in the north basin (Figure 4.1): 1) Howard Miller WMA, a 971 ha seasonally flooded complex near Rolling Fork, Mississippi (32°49’48.93” N, 90°58’51.61” W), which was annually farmed for rice and soybean but also contained managed seasonal

emergent wetlands; 2) Mahannah WMA, near Vicksburg, Mississippi (32°32'54.95" N, 90°52'14.08" W), was a 5,100 ha complex of agriculture, bottomland hardwoods, scrub-shrub, and seasonal emergent wetlands of which up to 80% was seasonally and naturally flooded; 3) Muscadine Farms WMA, near Avon, Mississippi (33°13'29.32" N, 90°59'01.51" W), was a 607 ha retired aquaculture facility managed for waterfowl in seasonal emergent wetlands augmented with Japanese millet; and 4) Coldwater River NWR, near Crowder, Mississippi (34°6'1.43" N, 90°7'58.52" W), was a 1,100 ha complex of seasonal emergent, scrub-shrub, and bottomland hardwood wetlands that were seasonally or semi-permanently flooded. The seasonal emergent wetlands were contained within a retired complex of catfish ponds and approximately 75% of Coldwater River NWR was seasonally or naturally flooded annually. Waterfowl hunting occurred at all WMAs and was temporally limited to four days per week until noon and hunter numbers were limited by daily quota (Lancaster 2013). All WMAs had designated spatial sanctuary composed of seasonal emergent wetlands or flooded cropland. Waterfowl hunting was prohibited at Coldwater River NWR in 2013-2014 but an adjacent 130-ha seasonal emergent wetland was opened to public hunting three days/wk until noon in 2014-2015. No other public access was permitted at Coldwater River NWR except for an observation tower located at the entrance to the NWR.

I did not randomly select capture sites within the Yazoo Basin but chose sites based on accessibility and legal ability to bait-trap waterfowl, but believe that mallards captured at each site were representative of those within the Yazoo Basin. I monitored radiomarked female mallards within 80 km of capture locations in Mississippi but also in portions of northeast Louisiana and eastern Arkansas outside the Yazoo Basin boundary

(Figure 4.1; Cox and Afton 1997, Davis et al. 2009). Additional environmental details of the MAV are found elsewhere (e.g., Reinecke et al. 1989, Saucier 1994, Baldassarre and Bolen 2006, Lancaster 2013).

Methods

Mallard Capture and Tracking

I captured mallards 3 November 2010 through 7 February 2015. I captured mallards using swim-in traps (Hunt and Dahlka 1953) and rocket nets fired from wetland edges (Dill and Thornberry 1950). I modified Hunt and Dahlka's (1953) swim-in trap design by using 2.5 x 5.1 cm welded wire and affixed the throat of the trap such that the opening was ~8-12 cm (Evrard and Bacon 1998). I baited capture sites with corn, rice, or soybean and located sites throughout WMAs and Coldwater River NWR prior to hunting season, at sites where I observed flocks of mallards. Ten to 12 days prior to hunting season, I relocated all traps and bait on WMAs that allowed waterfowl hunting to sanctuaries as distantly as possible from hunting areas to alleviate effects of bait on duck habitat use and hunting.

I classified captured females as juvenile (< 1 yr. since hatch) or adult using wing feather characteristics (> 1 year since hatch; Carney 1992). I weighed (± 10 g), measured (wing chord, ± 1 mm; bill width and tarsus length, ± 0.05 mm), leg banded, and attached a dorsally mounted 23 g very high frequency (VHF) backpack transmitter (model A1820; Advanced Telemetry Systems, Isanti, MN; Dwyer 1972) to captured female mallards. Transmitters had a 55-pulse per minute rate, a minimum life expectancy of 150 days, and an 8-hr mercury mortality switch. Transmitters increased weight of 265 marked females from 1.5-2.6% ($\bar{x}$ = 2.06%, SE = 0.01%; Cochran 1980). In winters 2010-2012, I

released females 4 hr after instrumentation, except when holding an individual 4 hr would result in nocturnal release. I released these the following morning (Davis et al. 2009). Because females seemed to acclimate to transmitters quickly after being marked in previous winters, I released females immediately following instrumentation of all co-captured individuals in winters 2013-2015. Birds had access to corn and water ad libitum during confinement periods. All instrumented females were released with captured conspecific males to minimize possible disruption of any pair bonds (Cox and Afton 1998, Lercel et al. 1999). All capture, handling, and marking methods were approved by Mississippi State University Institutional Animal Care and Use Committee (protocols 10-070 and 13-073) and authorized under Federal Bird Banding Permit 06604.

I triangulated radiomarked females using roof-mounted 4-element antennas in a null-peak array and an electronic compass from a truck (Cox et al. 2002, Gilsdorf et al. 2007). I calibrated electronic compasses to known locations of beacon transmitters ± 0.5° and trained technicians by triangulating beacon transmitters until they successfully maintained an azimuth standard deviation of ≤ 3º (Davis et al. 2009). I tracked radiomarked mallards diurnally (30 min before sunrise to 30 min after sunset) and nocturnally (30 min after sunset to 30 min before sunrise) throughout the study area (Figure 4.1; Cox and Afton 1997, Davis et al. 2009). To randomize daily locations of individuals temporally, I randomly selected a radiomarked female to begin tracking each day and corresponding night period. When few females were available for tracking, I randomly chose, without replacement, a period of the day (i.e., morning, mid-day, afternoon) and corresponding nocturnal period to track females until all time periods had been selected. I pursued radiomarked mallards not detected from trucks after seven

consecutive days without contact (Yetter et al. 2017), using a fixed wing aircraft equipped with left and right directional antennas. During aerial surveys, I advised the pilot to fly at an altitude of 2,100-2,800 m and descended to 300 m elevation to pinpoint an individual when detected (Gilmer et al. 1981). Upon locating a missing bird from the air, I recorded GPS coordinates and relayed information to technicians in telemetry trucks, so they could locate and triangulate birds' location from the ground (Davis et al. 2009, Yetter et al. 2017). I used aerially derived point locations for birds not triangulated from telemetry trucks on the flight day when necessary (Davis et al. 2009).

I estimated point locations for each bird with a maximum likelihood estimator (Lenth 1981), using a bearing standard deviation of 3° (Davis et al. 2009, Pearse et al. 2011, Newcomb et al. 2016). I plotted triangulations in real-time in Location of a Signal (LOAS 4.0; Ecological Software Solutions LLC, Hegymagas, Hungary) on laptop/tablet computers. I examined azimuths and point locations in real-time and discarded apparently erroneous locations or azimuths and re-triangulated the individual. For location estimation, I endeavored to obtain 3 azimuths, but, if error ellipses contained multiple habitat types, I obtained additional azimuths until error ellipses fell within one habitat type or available vantage points were exhausted. If multiple triangulations occurred for an individual in a single daily diurnal or nocturnal period, I used the first obtained location, unless the first location was a biangulation and a subsequent location contained ≥ 3 azimuths.

Statistical Analysis

I excluded the first three days of data following instrumentation of mallards to avoid possible biases from stress induced by capture and handling (Cox and Afton 1998).

I exported all subsequent triangulated locations from LOAS into a geographic information system (GIS) in ARCMAP 10.3 (Environmental Systems Research Institute 2015). Within the GIS, I assigned a habitat type to each location determined by visual inspection, contact with landowners/managers, or by using a combination of National Agricultural Imagery Program and United States Department of Agriculture Service Agency records. I classified daily locations into one of the following four habitat types commensurate with designations established by the national land cover dataset (Homer et al. 2004, Pearse et al. 2012): 1) flooded croplands (CR), including areas used for production of rice, soybean, corn, grain sorghum, or other agricultural seeds; 2) seasonal emergent wetlands (S-EM), including areas where natural herbaceous vegetation accounted for ≥ 80% of vegetative cover, managed moist-soil wetlands, and croplands left fallow the previous growing season; 3) forested wetlands (FO), including all areas where forest or scrub-shrub composed ≥ 20% of vegetative cover; and 4) permanent open water (P-W) including all wetlands containing < 25% vegetative cover or that held water annually including aquaculture ponds, rivers, and non-forested oxbow lakes (< 20% woody cover).

Waterfowl hunting seasons in Mississippi typify both brief (weekends) and extended or uninterrupted periods of hunting separated by short periods of closure. To account for differences in habitat use possibly related to hunting, I limited analyses to bird locations obtained during the primary, uninterrupted portion of hunting season (≥53 continuous days after "split" season) following any closure periods and post-hunting season because sample sizes of radiomarked birds were insufficient for statistical analysis before these time periods (Davis et al. 2009). Therefore, my habitat-related mallard

locations are classified as occurring during the main hunting season (HUNT) or after hunting season until mallard departure or through the end of monitoring on 20 March annually (POST).

Body condition is an important correlate of non-breeding season survival for mallards (Hepp et al. 1986, Bergan and Smith 1993, Dufour et al. 1993, Link 2007, Davis et al. 2011). Thus, I calculated a body condition index to account for individual differences in lipid stores, body mass, and structural size (Whyte and Bolen 1984). I assumed an allometric relationship between body mass and size (Devries et al. 2008, Arsnoe et al. 2011, Yetter et al. 2017); thus, I estimated a females' condition (COND) as the residual from an ordinary least-squares (OLS) regression of female body mass on an index of size. The size index was calculated as the first principal component (PC1; PROC PRINCOMP; SAS Institute Inc. 2011) of wing chord, bill width, and tarsus measurements (Ankney and Afton 1988). Lastly, I conducted a 2-way Analysis of Variance (ANOVA; PROC GLM; SAS Inst. Inc. 2011) to explore influences of age, winter, and date of capture on COND (Link 2007, Lancaster 2013) and used each females' residual from the ANOVA as a body condition index (BCI) value for use in subsequent survival analysis. Therefore, females with positive BCI values were assumed to have greater lipid stores than the average female of their age at the time of capture within each winter.

Survival Calculation

The multistate capture-recapture with dead recovery model is a merger of the Seber (1970) band recovery model and the multistate model of Brownie et al. (1993; Barker et al. 2005, White et al. 2006). I used this model in program MARK (White and

Burnham 1999, White et al. 2006) to analyze a set of *a priori* conceived models in which daily encounters were classified into four strata based on diurnal habitat use. I chose only diurnal locations to allow comparison of habitat specific survival rates with previously acquired data from aerial surveys that were only available diurnally (Pearse et al. 2012). In addition, I incorporated several other variables potentially important to mallard survival including winter of capture (winter), female age (juv or adult), BCI, capture date, and within-winter periods (HUNT, POST), as previous research has reported these important sources of variation in female mallard winter survival rates (Reinecke et al. 1987, Bergan and Smith 1993, Jeske et al. 1994, Fleskes et al. 2007, Link 2007, Davis et al. 2011, Lancaster 2013). My interval length for analysis was 98 days, which included 54 encounter occasions during HUNT (i.e., the duration of the uninterrupted hunting season following brief hunted and non-hunted splits) and 44 encounter occasions during the POST period.

The multistate capture-recapture with dead recovery model estimates four parameters: 1) survival (s^s), or the probability an individual alive at time i in state s is alive at time $i + 1$; 2) detection probability (p^s_i), or the probability that a marked individual alive in state s at time i is resighted at that sampling occasion, 3) transition probability (psi, ψ^{rs}), or the probability of being in state s at time i +1 for an individual in state r at time i conditional on surviving state r, and 4) conditional reporting rate (r), or the probability that a dead individual is reported (White et al. 2006). State transition is a Markovian process (i.e., the transition depends only on the current state and is an instantaneous event occurring at an interval separating two encounter occasions, conditional on surviving the former). However, only one 'event' (released, resighted, or

recovered) can occur per encounter occasion which is problematic when two events (e.g., an individual is resighted and recovered) occurred within a single encounter occasion. For example, if an individual is observed in state *r* and recovered the following occasion in state *s*, death has understandably occurred after migration to the new state, but occupancy of the new state and recovery cannot occur in a single occasion. I therefore postponed all dead recoveries by one occasion to separate movement and death, thus, survival depended on the site of arrival, rather than the site of departure (Breininger et al. 2009).

When movement of an individual from observable strata is inherently permanent, then this movement is confounded with survival leading to estimation of apparent survival (Burnham 1993, White et al. 2006). The multistate model incorporating dead recovery can be used to calculate true survival by incorporating emigration to unobserved states so long as marked individuals cannot escape recovery (White et al. 2006). However, the mechanism responsible for recovery (hunter harvest) in my study could not occur post-hunting season, thus recovery outside of my strata was not possible through the entire interval (White et al. 2006). Therefore, my survival estimate is calculated as apparent survival and not true survival, because mortality is confounded with emigration (Burnham 1993, White et al. 2006).

Because the survival parameter was of primary interest, I evaluated p, ψ, and r in sequence using *a priori* model sets for each parameter (Breininger et al. 2009). Specifically, I evaluated model sets which included *a priori* combinations of explanatory variables for r while incorporating a fully parameterized variable set for s, p, and ψ. I identified the best approximating model for r and used this in subsequent models and

repeated this process for p, ψ, and s to determine the best approximating variable combinations (Breininger et al. 2009). I used simulated annealing optimization in all models because of its increased flexibility in finding the global maximum during likelihood estimation in multi-state survival models (Goffe et al. 1994).

I attempted to evaluate models in which survival varied by two and three-way interactions of habitat type, winter of study, and within-winter periods; however, several parameter estimates were poorly estimated in these models. Therefore, I re-ran these models with data-cloning in program Mark which duplicated each encounter history 100 times to determine whether poor parameter estimation was due to extrinsic non-identifiability. Extrinsic non-identifiability can arise from inadequate data or when the true estimate is near the (0,1) boundaries. If the estimate was truly being estimated near the lower or upper boundary, the standard error and associated confidence interval of the data-cloned parameters would be reduced in accordance with the number of data clones (Lele et al. 2010). Because data-cloning did not reduce all parameter intervals, I re-ran the model using profile likelihood and compared profile confidence intervals to data-cloned profile confidence intervals to determine whether non-identifiability was related to insufficient data or poor performance of the link-function. Again, the profile intervals were not substantially reduced, suggesting that I had insufficient data to support complex interactions among covariates. I therefore excluded all interactive combinations of covariates from consideration and limited my inference to additive models.

I ranked the remaining survival models based on second order Akaike's Information Criterion (AIC_c) and model averaged real estimates of daily survival among all models with $w_i > 0$ (Burnham and Anderson 2002). I report all models with $w_i > 0$

and a reference model incorporating constant survival (i.e., null), model averaged daily survival and associated 95% confidence intervals calculated from unconditional standard errors, and percent differences among pairwise combinations of temporal and habitat specific covariates with associated 95% confidence intervals.

Results

I captured 265 female mallards including 58 females in winter 2010-2011 (11 November 2010 to 24 January 2011), 68 in winter 2011-2012 (13 November 2011 to 23 January 2012), 74 in winter 2013-2014 (30 November 2013 to 25 January 2014), and 65 in winter 2014-2015 (15 December 2014 to 7 February 2015). I excluded 24 females from analysis, because they died within the 3-day acclimation period or were not located during hunting or post-hunting periods. Despite deletions, I retained 7,250 diurnal locations from 241 radiomarked females (Table 4.1). Thirty-five females (15%) died during the study period, and I attributed 13 (37%) mortalities to hunting while the remaining 22 deaths (63%) were from avian, mammalian, or unknown causes. Nine non-hunting mortalities occurred during hunting season, while 13 occurred post-hunting season. The mean (± SE), median, minimum, and maximum number of days in which mortality occurred after radio-marking a mallard was 32 (± 3.6), 26, 5, and 93 days following the adjustment period, respectively. Of 113 female mallards that I confirmed departed the study area, because I no longer located them via truck or aircraft, 24 (21%) departed during the hunting season, whereas 89 (79%) departed post-hunting season.

The SIZE (PCA1) variable accounted for 51% of overall variation in wing chord, bill width, and tarsus measurements among females. Female body mass was positively related to SIZE ($F_{1,263} = 58.02$, $P < 0.001$, $R^2 = 0.18$) and results of the 2-way ANOVA

indicated COND varied among winters ($F_{3,259} = 4.07$, $P = 0.008$), positively with female age ($F_{1,259} = 6.23$, $P = 0.01$), and negatively with capture date. ($F_{1,259} = 32.56$, $P < 0.001$). The resulting residual value (BCI) used in analysis provided a condition estimate relative to the time of capture: A positive value indicated a female was in better than expected condition at the time of her capture, and vice versa, relative to others in the sample population.

The most parsimonious model for conditional reporting rate (r) contained an additive combination of winter of study, occupied habitat, and body condition. Detection probability (p) was best approximated by an additive model containing winter, habitat type, and within-winter periods. The best supported model for transition probability (ψ) between habitats contained an additive combination of habitat type, winter, and female body condition. Three survival models contained model weight (Table 4.2), and the most parsimonious model ($w_i = 0.76$) indicated that daily survival of female mallards varied among winters of study, within-winter periods, with body condition, and capture date. The second-best model ($w_i = 0.21$) contained additive effects of winter of study, habitat type, within-winter periods, and female age. The least supported model ($w_i = 0.03$) contained an additive combination of winter of study, habitat type, and capture date. I model averaged real parameter estimates among these top three models and present pairwise comparisons of apparent daily survival (± 95% CI) among all covariates combinations (Table 4.3). Models that estimated daily survival as a function of winter contained 100% of model weight indicating a strong influence of winters on survival.

Females experienced greatest daily apparent survival in winter 2011-2012 (99.66-99.82%; Table 4.4). The odds of apparent survival in winter 2011-2012 was 1.67 times

greater than winter 2014-2015, 4.14 times greater than in winter 2010-2011, and 6.64 times greater than in winter 2013-2014. Apparent daily survival was second highest in winter 2014-2015 (99.10-99.52%). The odds of apparent survival in 2014-2015 were 92.3% greater than winter 2010-2011, and 186.1% greater than winter 2013-2014. Females in winter 2010-2011 experienced the third greatest apparent daily survival rate (98.27-99.09%; Table 4.4), and the odds of apparent survival was 48.7% greater than during winter 2013-2014 (97.45-98.65%; Table 4.4).

I model averaged female apparent daily survival among habitats. Females that used flooded cropland experienced greatest apparent daily survival (97.71-99.82%: Table 4.4), and the odds of apparent survival there was 8.8% greater than emergent wetlands, 10.5% greater than forested wetlands, and 13.8% greater than permanent wetlands. Apparent daily survival for females was second greatest for individuals that used emergent wetlands (97.54-99.82%; Table 4.4), and the odds of apparent survival there were 1.5% and 4.6% greater than forested and permanent wetlands, respectively. The third-greatest apparent daily survival rate among wetland habitats occurred in forested wetland (97.51-99.80%; Table 4.4), and the odds of apparent survival in there was 3.06% greater than permanent wetlands (97.01-99.73%; Table 4.4). Because apparent daily survival rates differed among habitat types, female mallard winter survival is related to the complex of habitats used by female mallards during winter. Specifically, winter survival is positively related to the number of locations in flooded agriculture and negatively affected with increasing time spent in alternate habitat types. However, apparent winter survival of females in my study varied less than 1.2% depending on the complex of habitats used during winter.

Apparent daily survival odds were 71.3% greater during hunting season than post-hunting season. Juvenile females experienced greater apparent survival than adults and the odds of apparent survival for a juvenile female was 3.7% greater than for adult females. Apparent daily survival odds increased 0.76% for every 10% increase in BCI (Figure 4.2) and 2.4% for every one-week delay in capture (Figure 4.3).

Discussion

Forested wetlands historically dominated the MAV and an ancestral wintering habitat for mallards in this region, providing important resources and seasonal residency to millions of birds during winter (Nichols et al. 1983, Fredrickson and Heitmeyer 1988; Reinecke et al. 1988, 1989). Forested wetlands continue to be regarded as vital habitats for female mallards in the MAV (Heitmeyer 2006, Davis et al. 2009, Davis and Afton 2010, Lancaster 2013, Chapter 2). Commensurate with these observations, I predicted daily survival of female mallards in forested wetlands would exceed that for other habitat types used by mallards in the Mississippi MAV. Although model averaged apparent survival varied among habitat types, it was greatest for females that used flooded agriculture, followed by emergent, forested, and permanent wetlands. However, 95% confidence intervals of effect sizes overlapped zero among pairwise combinations of apparent survival, indicating weak support for survival differences among habitat types. Thus, apparent survival of female mallards in the MAV of Mississippi appears to be independent of diurnal habitat use.

There was no evidence that daily survival was greater for females diurnally that used forested wetlands, contrasting with my prediction that forested wetlands inferred greatest winter survival for mallards. However, given similarities in apparent daily

survival among all habitat types, my evidence suggests that forested and other wetlands form an integral habitat complex for wintering mallards in the Mississippi MAV. Fretwell and Lucas's (1970) ideal free distribution theorizes that individuals in a population distribute themselves among habitats such that conspecifics experience minor variation in realized fitness (Nichols and Kendall 1995). Realized suitability is a measure of the fitness prospect of individuals occupying a habitat and is conditional on conspecific density. Under the ideal free distribution, individuals select sites in a manner where all conspecifics experience similar fitness, but basal habitat suitability invokes a positive relationship with conspecific density at equilibrium (Fretwell and Lucas 1970, Van Horne 1983, Wiens 1989, Johnson 2007). Mallards used forested wetlands as much as 2.8, 1.2, and 4.0 times more than flooded agriculture, emergent wetlands, and permanent wetlands, respectively (Chapter 2). I did not measure habitat availability, so I cannot reconcile if female mallards used forested wetlands at greater densities than other habitat types. However, forested wetlands in the MAV of Mississippi may infer high habitat suitability because survival was independent of habitat type yet mallards exhibited high proportional use of forested wetlands diurnally. Future research should resolve this uncertainty by identifying habitat availability while simultaneously measuring conspecific densities of mallards among habitat types to determine which resources provide the greatest suitability.

Pearse et al. (2012) found that greatest mallard abundances were associated with landscapes containing about 1.5 times more flooded agriculture than forested wetlands. If mallards ideally and freely distribute among habitat types in the MAV, less area of forested wetlands would be needed, compared with flooded agriculture, to support similar

mallard abundances. Aside from post-hunting season in the south basin, mallards used forested and emergent wetlands similarly during the day suggesting these habitat types may support similar mallard densities and may be equally suitable (Chapter 2). Moreover, similar suitability of forested and emergent wetlands may validate similar proportions of these habitats in landscapes occupied by large groups of mallards, as detected by Pearse et al. (2012). Permanent wetlands may be a habitat of less importance, primarily getting used when conspecific density becomes great in other more suitable habitats, or during inclement ice conditions that temporarily eliminate shallow wetlands. This could explain why mallards seldom used permanent wetlands (Chapter 2), and why only 10% of landscapes occupied by large groups of mallards were comprised of permanent wetlands (Pearse et al. 2012).

Habitat selection occurs in a hierarchical fashion in which first order selection is innate and learned but increasing orders become more specific as birds select habitats from macro- to micro-scales (Hutto 1985). Mallards may select landscapes (i.e., 2nd order; Johnson 1980) that contain a complex of habitats that support similar conspecific abundance although at variable or changing densities (Fredrickson and Reid 1988). Specifically, if habitat *A* was more suitable than habitat *B*, more of habitat *B* would be required to support an equal number of conspecifics than *A*; however, habitat *A* would contain greater a density at equilibrium. Using this example, mallards may be adept at selecting a landscape complex having more flooded agriculture than forested wetlands, because the latter is more suitable and can support greater mallard densities. This arrangement would allow mallards to switch habitats to acquire needed resources while realizing similar suitability. Within the landscape, mallards may diurnally use habitats

based on their realized suitability leading to an ideal free distribution within the third-order (Fretwell and Lucas 1970, Johnson 1980). Alternatively, mallards may select landscapes based on nocturnal feeding opportunities and ideally and freely distribute themselves among habitats diurnally to thermoregulate, forage, loaf, and engage in comfort movements, courtship, or other important social functions (Tamisier 1985, McNeil et al. 1992, Davis et al. 2009, Chapter 2).

Because I measured apparent survival, which is the product of true survival and site fidelity (Burnham 1993), the relationship between measured covariates and apparent survival may reflect differences in the probability of true survival, emigration, or both. For example, greater apparent survival of mallards during hunting seasons may have been an artifact of lower probability and occurrence of emigration from the study area during this period. Study area fidelity was nearly 3 times greater during hunting than post-hunting seasons, which may have led to greater apparent survival during the former. For example, if true daily survival was 99.72% as reported for non-breeding mallards by others (Reinecke et al. 1987, Davis 2007, Lancaster 2013), a 1% difference in site fidelity between hunting and post-hunting season could lead to apparent survival differences during my study.

Numerous studies have reported greater survival during the post-hunting period (Fleskes et al. 2007, Link 2007, Dooley et al. 2010, Davis et al. 2011), and all female mallards marked post-hunting season in a former study in Arkansas survived and emigrated (Dugger et al. 1994). In my study, except for winter 2011-2012 when 3 mortalities occurred, more females died during than after the hunting season in the remainder of the study. These patterns suggest that emigration is masking true effects of

within-winter period on survival. Post-hunting season coincides with pre-basic molt in female mallards, and increased invertebrate consumption for protein for feather replacement (Heitmeyer 1985,1988 *a,b*) may increase foraging needs and result in reduced survival through reduced vigilance. Moreover, many natural and agricultural seeds become depleted as winter progresses (Stafford et al. 2006, Havens et al. 2009, Foster et al. 2010, Hagy and Kaminski 2012, Marty 2017), and mallards may risk mortality from predators to access remaining nutrient resources (Lima and Dill 1990, Ackerman et al. 2006). Mallards are displaced from some habitats and wetland sources by hunters during hunting season and redistribute post-hunting season (Chapter 2, 3). Moreover, habitat conditions are dynamic post-hunting season. Although agricultural producers begin draining fields immediately or soon after the hunting season to prepare for spring planting, other areas may become inundated with rainfall or flooding. Arguably, these newly flooded habitats could create "novel" environments if mallards were not free to choose these during the hunting season. Perhaps mallards using these habitats post-hunting season may be less familiar with natural predators or situations experienced therein, which could increase risk of predation.

Disparate apparent survival between adult and juvenile females is likely not related to timing of emigration, because mallards initiate spring migration independent of age (Dugger 1997). Mean last-detected dates of mallards in my study were identical between adult and juvenile females, suggesting that differences in apparent survival were independent of emigration probability. Increased juvenile mallard survival occurs during the breeding season because juveniles nest at lesser rates than adults and therefore are less vulnerable to predation during egg laying and incubation (Reynolds et al. 1995,

Dufour and Clark 2002, Devries et al. 2003). In contrast, adult female mallard survival is typically is greater (Reinecke et al. 1987, Fleskes et al. 2007) or independent of female age during the non-breeding season (Bergan and Smith 1993, Link 2007, Davis et al. 2011). In previous studies of mallard survival during the non-breeding season, survival of adults typically exceeded that for juveniles when hunter harvest was the primary mortality agent, whereas survival was independent of age when non-hunting mortality exceeded hunting mortality (Reinecke et al. 1987, Bergan and Smith 1993, Fleskes et al. 2007, Davis et al. 2011). Although I did not present cause-specific mortality agents, non-hunting mortality accounted for approximately two-thirds of all female mortality during my study. Therefore, non-hunting mortality may be biased toward adult females which may avoid hunted habitats and use habitats with more natural predators, whereas, juvenile females may be more susceptible to hunting mortality (McDougall and Amundson 2017). Overall, mallard harvest in Mississippi is variable and does not always support the hypothesis that juveniles are more susceptible to harvest. Juveniles composed 38-57% of mallard harvest in Mississippi during my study, indicating that adults were harvested more than or nearly equivalently to juveniles during several winters of study (Raftovich et al. 2017).

Apparent survival of females among winters had a similar relationship to mean emigration date suggesting differences in survival, should they exist, may have been masked by emigration probability. Apparent survival was greatest in winter 2011-2012, when females remained in the study area the longest and most females were present in the study area on the last day of monitoring on 7 March 2012. In decreasing order of apparent survival among winters, females on average left the study area 5, 9, and 22 days

earlier than those in winter 2011-2012 and fewer (44, 20, and 19%) females were present in the study area on the last day of tracking. Reinecke et al. (1987) attributed greater winter survival to above-average rainfall and mild temperatures. Rainfall and daily minimum temperature can impact wetland and food availability, increase thermoregulatory costs, and impact feeding activity which may influence daily survival and emigration probability (McKinney and McWilliams 2005). Cumulative rainfall from December to March was greatest in winters 2011-2012 and 2014-2015 when females experienced greatest apparent survival. Winter rainfall promotes backwater flooding and ponding in agricultural fields when soils are saturated and can increase habitat and forage availability for mallards and lead to greater survival or a greater probability of remaining in the study area (Heitmeyer and Fredrickson 1981, Kaminski and Gluesing 1987, Heitmeyer 2006, Davis et al. 2011). Daily minimum temperatures were warmer in winter 2011-2012 than 2014-2015, which may have resulted in greater apparent survival in the former winter. Relative to these two wet winters, the study area received half the rainfall in winters 2010-2011 and 2013-2014, which may have led to decreased survival or an increased probability of emigrating from the study area to search for more abundant resources. Among dry winters, 2013-2014 was the coldest winter of the study and mean minimum daily temperatures from December thru March were near freezing. Prolonged freeze events that result in ice formation on shallow wetlands reduce wetland availability and increase energetic requirements, which may lower apparent survival if females become more susceptible to harvest or fail to meet greater nutritional demands (Reinecke et al. 1987). Previous research has demonstrated a positive relationship between winter precipitation in the MAV and subsequent juvenile to adult age ratios of harvested

mallards, suggesting that winter survival and duck production is greater during and following, respectively wet winters in the MAV (Heitmeyer and Fredrickson 1981, Kaminski and Gluesing 1987, Osnas et al. 2016). Subsequent production may be a consequence of increased food availability in the MAV resulting in improved body condition, which produces greater survival during winter and results in earlier nest initiation (Bergan and Smith 1993, Devries et al. 2008, Davis et al. 2011, Sedinger and Alisauskas 2014). Increased apparent survival also may be attributed to later capture of females if transmitter attachment delayed spring migration and thus increased site fidelity. However, mean nor median capture dates correspond to apparent survival rate differences among winters.

Apparent survival was positively related to body condition at capture, which has been reported previously for non-breeding mallards (Bergan and Smith 1993, Link 2007, Davis et al. 2011). Because I captured birds through winter, I accounted for declining endogenous reserves that occur through mid-winter (Loesch et al. 1992, Newcomb et al. 2016); therefore, body condition was independent of capture date. Females in poorer condition may take increased risks to acquire resources and become more vulnerable to harvest and natural predation. Davis et al. (2011) found no relationship between body condition and mortality from hunting sources in their study of female mallards in northeastern Louisiana and southeastern Arkansas. However, numerous studies have reported evidence that mallards in poor condition are at greater risk of hunter harvest (Hepp et al. 1986, Dufour et al. 1993, Heitmeyer et al. 1993, Link 2007). Zimmer et al. (2010, 2011) found that mallards alter their body mass in response to repeated disturbance, perhaps as a mechanism to improve flight performance and decrease wing

loading. Therefore, birds in poorer condition when captured may have previously encountered repeated disturbance or harassment from predators. Maintaining lower body condition can increase risk aversiveness, but birds undoubtedly must meet some threshold condition to avoid starvation (Lima 1986, Zimmer 2011), which may be problematic if sudden prolonged freeze events limit forage accessibility (Bergan and Smith 1993). Newcomb et al. (2016) found that survival was positively related with body condition in American black ducks (*Anas rubripes*) during a cold winter, but survival was independent of body condition during a mild winter in Tennessee. Therefore, the influence of body condition on survival may be linked with weather and/or the probability or frequency of predator encounters.

Apparent survival was positively related to capture date in my study; however, the influence of capture date may have been biased by 24 females captured post-hunting season that survived winter. Dugger et al. (1994) experienced similar survival of their entire marked sample of 92 female mallards following hunting season in Arkansas. Therefore, late captured females may be better fit to survive the remaining winter period than those captured early in winter.

Finally, although I was unable to differentiate between mortality and emigration, apparent survival is a valuable metric because the probability of emigration should depend on energetic costs associated with movement, and females should make decisions that maximize immediate and long-term fitness (Fretwell and Lucas 1970, Fretwell 1972). The prospect of increased fitness through emigration is typically realized through decreased mortality (i.e., predation) or increased nutrition (Legagneux et al. 2009, Alves et al. 2013). Female mallards often move throughout the MAV as heterogeneity in

habitat quality shifts due to spatio-temporally dynamic rainfall and resources (Nichols et al. 1983, Dugger et al. 1994). Differences in apparent survival thus may indicate how well resources available in the study area support wintering populations of mallards. Dugger (1997) found that late-molting females initiated spring migration later than early molting females, and Heitmeyer (2006) reported that females initiated molt earlier in wet winters in the MAV. However, I exercise caution in this relationship, because mallards are a migratory species and emigration from the study area is eminent. In some winters, mallards appear to have left the study area earlier, but this may be unrelated to quality or availability of resources remaining in the study area and suggest earlier initiation of spring migration as dictated by weather and other proximate cues (Miller et al. 2005, Krementz et al. 2011).

Management Implications

Female mallards exhibited similar apparent survival among habitat types suggesting mallards survived winter by using a complex of habitats (Pearse et al. 2012), which although varied temporally among winters, endorses mallards plastic use of resources (Mulhern et al. 1985). Despite similarities in survival among habitats, forested wetlands which were used extensively by mallards diurnally, may provide greater habitat suitability than other habitat types in the region. Therefore, restoration and management of forested wetlands may continue to provide important habitat to wintering mallards in Mississippi, assuming these wetlands are inundated during winter. Conservation easement programs and management of green-tree reservoirs provide an inroad to restoration of forested wetland on private lands (King et al. 2006, Davis et al. 2009, Foth et al. 2014, Chapter 3).

Additionally, mature bottomland hardwoods, afforested tracts of varying ages, forested oxbow lakes, and scrub-shrub wetlands comprised forested wetlands in my study. Therefore, afforestation of bottomland hardwoods should not be the sole focus of restoration, but should be accompanied by planting tupelo gum (*Nyssa aquatica*) and bald cypress (*Taxodium distichum*) timber in semi-permanent wetlands and scrub-shrub wetland edges, where applicable. Moreover, tree plantings should include diverse species to mimic a more natural regeneration process and provide resources for a broad range of wetland species (Schoenholtz et al. 2001, Faulkner et al. 2011, Craft 2016).

Body condition of female mallards was positively correlated with apparent survival and may be increased through a reduction in disturbance or increased forage availability. Mississippi met its habitat goal of providing 72 M duck energy days in 2 of 3 winters between 2011-2014, suggesting that body condition may not be energy limiting. Body mass dynamics of mallards may be a tradeoff between starvation and predator avoidance, and poor body condition may indicate elevated levels of natural and hunting-related predation (Dufour et al. 1993). Habitats that provide overhead cover such as forested and emergent wetlands may conceal birds from predators.

Aside from seasonal survival, reproductive success is a vital component of fitness and future research should address whether habitat use during winter relates cross-seasonally to reproductive success (i.e., carry-over effects; Sedinger and Alisauskas 2014, Osnas et al. 2016). If forested wetlands infer greatest habitat suitability during winter, female mallards using these habitats may also realize benefits such as enhanced body mass during winter perhaps contributing ultimately to successful reproduction.

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Table 4.1 Distribution of encounters used to calculate apparent daily survival.

Winter	Females	Period	Deaths	AG[1]	S-EM[1]	FO[1]	P-W[1]
2010/ 2011	49	Hunt	9	228 (2)	173 (1)	420 (5)	38 (1)
		Post	7	240 (2)	139 (1)	259 (4)	51
2011/ 2012	61	Hunt	1	144	220 (1)	513	28
		Post	2	115 (1)	629 (1)	1,020	85
2013/ 2014	70	Hunt	5	157 (2)	356 (2)	404 (1)	29
		Post	5	135 (1)	74 (3)	165 (1)	37
2014/ 2015	61	Hunt	5	90 (3)	209	151 (2)	13
		Post	1	371	273 (1)	433	51

[1] AG – flooded agriculture, S-EM = seasonal-emergent wetlands, FO = forested/scrub-shrub wetlands, and P-W = permanent/open wetlands. Numbers in parentheses indicate the number of mortalities occurring in the habitat type.

Table 4.2 Apparent daily survival model selection results.

Model[1,2]	**ΔAIC_c**[3]	w_i	**Deviance**	***K***
Wint. + Per. + BCI + CD	–	0.76	28817.37	39
Wint. + Hab. + Per. + Age	2.56	0.21	28815.88	41
Wint. + Hab. + CD	6.32	0.03	28821.66	40
…	…	…	…	…
Null	654.49	0.00	29483.97	33

[1] Model structure is for survival parameter only. All models contained *p*(Wint. + Hab. + Per.), ψ(Wint. + Hab. + BCI), and *r*(Wint. + Hab. + BCI). Plus sign (+) indicates an additive relationship among covariates.
[2] Wint. = winter of study (2010-2011, 2011-2012, 2013-2014, 2014-2015), Per. = within winter periods (HUNT, POST), BCI =body condition index, CD = capture date, Hab. = habitat (flooded agriculture, seasonal emergent, forested, permanent wetland), Age = female age (juvenile, adult).
[3] AICc of the best supported model was 28895.80

Table 4.3 Percent difference (95% confidence interval) of pairwise comparisons of female mallard apparent daily survival.

	W1 AG Hunt	W1 AG Post	W1 SE Hunt	W1 SE Post	W1 FO Hunt
W1 AG Post	-0.64 (-1.3 – -0.0044)	–	–	–	–
W1 SE Hunt	-0.079 (-0.57 – 0.41)	0.56 (-0.37 – 1.5)	–	–	–
W1 SE Post	-0.76 (-1.6 – 0.066)	-0.12 (-0.87 – 0.63)	-0.68 (-1.3 – -0.034)	–	–
W1 FO Hunt	-0.094 (-0.58 – 0.39)	0.54 (-0.4 – 1.5)	-0.015 (-0.4 – 0.37)	0.67 (-0.16 – 1.5)	–
W1 FO Post	-0.78 (-1.6 – 0.00018)	-0.14 (-0.88 – 0.6)	-0.7 (-1.5 – 0.05)	-0.022 (-0.59 – 0.55)	-0.69 (-1.3 – -0.05)
W1 PW Hunt	-0.12 (-0.71 – 0.46)	0.51 (-0.54 – 1.6)	-0.045 (-0.48 – 0.39)	0.63 (-0.28 – 1.5)	-0.03 (-0.39 – 0.33)
W1 PW Post	-0.82 (-1.6 – -0.02)	-0.18 (-1 – 0.66)	-0.74 (-1.5 – -0.023)	-0.064 (-0.69 – 0.56)	-0.73 (-1.4 – -0.03)
W2 AG Hunt	0.73 (0.24 – 1.2)	1.4 (0.53 – 2.2)	0.81 (0.26 – 1.4)	1.5 (0.65 – 2.3)	0.83 (0.29 – 1.4)
W2 AG Post	0.6 (0.061 – 1.1)	1.2 (0.45 – 2)	0.68 (0.044 – 1.3)	1.4 (0.53 – 2.2)	0.7 (0.064 – 1.3)
W2 SE Hunt	0.72 (0.18 – 1.2)	1.4 (0.46 – 2.2)	0.8 (0.28 – 1.3)	1.5 (0.66 – 2.3)	0.81 (0.29 – 1.3)
W2 SE Post	0.58 (-0.025 – 1.2)	1.2 (0.35 – 2.1)	0.66 (0.074 – 1.2)	1.3 (0.56 – 2.1)	0.68 (0.057 – 1.3)
W2 FO Hunt	0.71 (0.18 – 1.3)	1.4 (0.45 – 2.3)	0.79 (0.25 – 1.3)	1.5 (0.62 – 2.3)	0.81 (0.31 – 1.3)
W2 FO Post	0.58 (-0.033 – 1.2)	1.2 (0.34 – 2.1)	0.66 (0.029 – 1.3)	1.3 (0.5 – 2.2)	0.67 (0.084 – 1.3)
W2 PW Hunt	0.71 (0.16 – 1.3)	1.3 (0.43 – 2.3)	0.79 (0.24 – 1.3)	1.5 (0.6 – 2.3)	0.8 (0.28 – 1.3)
W2 PW Post	0.57 (-0.053 – 1.2)	1.2 (0.3 – 2.1)	0.65 (0.02 – 1.3)	1.3 (0.48 – 2.2)	0.66 (0.053 – 1.3)
W3 AG Hunt	-0.44 (-0.96 – 0.086)	0.2 (-0.71 – 1.1)	-0.36 (-1.2 – 0.46)	0.32 (-0.84 – 1.5)	-0.34 (-1.2 – 0.48)
W3 AG Post	-1.4 (-2.5 – -0.24)	-0.74 (-1.6 – 0.15)	-1.3 (-2.7 – 0.12)	-0.62 (-1.9 – 0.7)	-1.3 (-2.7 – 0.16)
W3 SE Hunt	-0.55 (-1.3 – 0.22)	0.087 (-1.1 – 1.3)	-0.47 (-1 – 0.076)	0.21 (-0.77 – 1.2)	-0.46 (-1.2 – 0.27)
W3 SE Post	-1.6 (-2.8 – -0.31)	-0.91 (-2.1 – 0.3)	-1.5 (-2.6 – -0.35)	-0.79 (-1.7 – 0.12)	-1.5 (-2.7 – -0.17)
W3 FO Hunt	-0.57 (-1.3 – 0.19)	0.065 (-1.2 – 1.3)	-0.49 (-1.2 – 0.22)	0.19 (-0.97 – 1.3)	-0.48 (-1 – 0.074)
W3 FO Post	-1.6 (-2.8 – -0.41)	-0.94 (-2.1 – 0.23)	-1.5 (-2.7 – -0.31)	-0.82 (-1.9 – 0.3)	-1.5 (-2.6 – -0.39)
W3 PW Hunt	-0.62 (-1.5 – 0.24)	0.022 (-1.3 – 1.4)	-0.54 (-1.3 – 0.23)	0.14 (-1.1 – 1.4)	-0.52 (-1.2 – 0.19)
W3 PW Post	-1.6 (-2.8 – -0.48)	-1 (-2.2 – 0.24)	-1.6 (-2.7 – -0.44)	-0.88 (-2 – 0.24)	-1.5 (-2.7 – -0.44)
W4 AG Hunt	0.43 (-0.013 – 0.88)	1.1 (0.24 – 1.9)	0.51 (-0.084 – 1.1)	1.2 (0.28 – 2.1)	0.53 (-0.059 – 1.1)
W4 AG Post	0.098 (-0.56 – 0.76)	0.74 (-0.012 – 1.5)	0.18 (-0.67 – 1)	0.86 (-0.08 – 1.8)	0.19 (-0.66 – 1)
W4 SE Hunt	0.4 (-0.16 – 0.96)	1 (0.075 – 2)	0.48 (-0.013 – 0.96)	1.2 (0.3 – 2)	0.49 (-0.056 – 1)
W4 SE Post	0.039 (-0.72 – 0.8)	0.68 (-0.24 – 1.6)	0.12 (-0.6 – 0.83)	0.8 (0.0065 – 1.6)	0.13 (-0.66 – 0.93)

Table 4.3 (continued)

W4 FO Hunt	1.2 (0.35 – 2)	0.51 (-0.072 – 1.1)	1.2 (0.36 – 2.1)	-0.34 (-0.68 – -0.0096)	-0.22 (-0.65 – 0.22)
W4 FO Post	0.81 (0.029 – 1.6)	0.15 (-0.69 – 0.99)	0.85 (-0.014 – 1.7)	-0.7 (-1.2 – -0.2)	-0.58 (-1.1 – -0.059)
W4 PW Hunt	1.2 (0.26 – 2)	0.5 (-0.018 – 1)	1.2 (0.38 – 2)	-0.36 (-0.73 – 0.0082)	-0.23 (-0.7 – 0.24)
W4 PW Post	0.79 (-0.081 – 1.7)	0.13 (-0.63 – 0.89)	0.83 (0.036 – 1.6)	-0.73 (-1.2 – -0.22)	-0.6 (-1.1 – -0.068)
	W1 FO Post	**W1 PW Hunt**	**W1 PW Post**	**W2 AG Hunt**	**W2 AG Post**
W1 PW Hunt	0.66 (-0.17 – 1.5)	–	–	–	–
W1 PW Post	-0.042 (-0.56 – 0.47)	-0.7 (-1.3 – -0.068)	–	–	–
W2 AG Hunt	1.5 (0.73 – 2.3)	0.86 (0.25 – 1.5)	1.6 (0.78 – 2.3)	–	–
W2 AG Post	1.4 (0.61 – 2.2)	0.73 (0.022 – 1.4)	1.4 (0.64 – 2.2)	-0.13 (-0.27 – 0.019)	–
W2 SE Hunt	1.5 (0.72 – 2.3)	0.84 (0.26 – 1.4)	1.5 (0.77 – 2.3)	-0.016 (-0.11 – 0.081)	0.11 (-0.086 – 0.31)
W2 SE Post	1.4 (0.59 – 2.1)	0.71 (0.025 – 1.4)	1.4 (0.64 – 2.2)	-0.15 (-0.33 – 0.029)	-0.024 (-0.17 – 0.12)
W2 FO Hunt	1.5 (0.73 – 2.3)	0.84 (0.26 – 1.4)	1.5 (0.77 – 2.3)	-0.019 (-0.12 – 0.078)	0.11 (-0.093 – 0.31)
W2 FO Post	1.4 (0.62 – 2.1)	0.7 (0.029 – 1.4)	1.4 (0.64 – 2.2)	-0.15 (-0.33 – 0.018)	-0.028 (-0.17 – 0.12)
W2 PW Hunt	1.5 (0.69 – 2.3)	0.83 (0.29 – 1.4)	1.5 (0.78 – 2.3)	-0.025 (-0.14 – 0.095)	0.1 (-0.12 – 0.32)
W2 PW Post	1.3 (0.57 – 2.1)	0.69 (0.057 – 1.3)	1.4 (0.66 – 2.1)	-0.16 (-0.35 – 0.021)	-0.037 (-0.21 – 0.14)
W3 AG Hunt	0.34 (-0.79 – 1.5)	-0.31 (-1.2 – 0.59)	0.39 (-0.79 – 1.6)	-1.2 (-1.8 – -0.52)	-1 (-1.7 – -0.34)
W3 AG Post	-0.6 (-1.9 – 0.74)	-1.3 (-2.8 – 0.3)	-0.56 (-2 – 0.89)	-2.1 (-3.3 – -0.96)	-2 (-3.1 – -0.9)
W3 SE Hunt	0.23 (-0.87 – 1.3)	-0.43 (-1.2 – 0.34)	0.27 (-0.83 – 1.4)	-1.3 (-2 – -0.59)	-1.2 (-1.9 – -0.38)
W3 SE Post	-0.77 (-1.9 – 0.39)	-1.4 (-2.8 – -0.055)	-0.73 (-2 – 0.51)	-2.3 (-3.4 – -1.2)	-2.2 (-3.2 – -1.1)
W3 FO Hunt	0.21 (-0.78 – 1.2)	-0.45 (-1.2 – 0.26)	0.25 (-0.83 – 1.3)	-1.3 (-2 – -0.64)	-1.2 (-1.9 – -0.42)
W3 FO Post	-0.8 (-1.7 – 0.11)	-1.5 (-2.7 – -0.19)	-0.76 (-1.9 – 0.38)	-2.3 (-3.3 – -1.3)	-2.2 (-3.1 – -1.2)
W3 PW Hunt	0.16 (-1 – 1.3)	-0.49 (-1.1 – 0.081)	0.21 (-0.82 – 1.2)	-1.3 (-2.1 – -0.61)	-1.2 (-2.1 – -0.37)
W3 PW Post	-0.86 (-1.9 – 0.21)	-1.5 (-2.6 – -0.45)	-0.82 (-1.7 – 0.1)	-2.4 (-3.3 – -1.5)	-2.2 (-3.2 – -1.3)
W4 AG Hunt	1.2 (0.35 – 2.1)	0.56 (-0.1 – 1.2)	1.3 (0.38 – 2.1)	-0.3 (-0.6 – 0.0018)	-0.17 (-0.54 – 0.2)
W4 AG Post	0.88 (-0.027 – 1.8)	0.22 (-0.72 – 1.2)	0.92 (-0.034 – 1.9)	-0.63 (-1.2 – -0.11)	-0.51 (-1 – -0.0041)

Table 4.3 (continued)

W4 SE Hunt	1.2 (0.32 – 2)	0.52 (-0.082 – 1.1)	1.2 (0.37 – 2.1)	-0.34 (-0.67 – -0.0024)	-0.21 (-0.64 – 0.22)
W4 SE Post	0.82 (-0.036 – 1.7)	0.16 (-0.7 – 1)	0.86 (-0.018 – 1.7)	-0.69 (-1.2 – -0.17)	-0.57 (-1.1 – -0.038)
W4 FO Hunt	1.2 (0.35 – 2)	0.51 (-0.072 – 1.1)	1.2 (0.36 – 2.1)	-0.34 (-0.68 – -0.0096)	-0.22 (-0.65 – 0.22)
W4 FO Post	0.81 (0.029 – 1.6)	0.15 (-0.69 – 0.99)	0.85 (-0.014 – 1.7)	-0.7 (-1.2 – -0.2)	-0.58 (-1.1 – -0.059)
W4 PW Hunt	1.2 (0.26 – 2)	0.5 (-0.018 – 1)	1.2 (0.38 – 2)	-0.36 (-0.73 – 0.0082)	-0.23 (-0.7 – 0.24)
W4 PW Post	0.79 (-0.081 – 1.7)	0.13 (-0.63 – 0.89)	0.83 (0.036 – 1.6)	-0.73 (-1.2 – -0.22)	-0.6 (-1.1 – -0.068)

	W2 SE Hunt	**W2 SE Post**	**W2 FO Hunt**	**W2 FO Post**	**W2 PW Hunt**
W2 SE Post	-0.14 (-0.28 – 0.012)	–	–	–	–
W2 FO Hunt	-0.003 (-0.079 – 0.073)	0.13 (-0.047 – 0.31)	–	–	–
W2 FO Post	-0.14 (-0.31 – 0.028)	-0.0043 (-0.12 – 0.11)	-0.14 (-0.28 – 0.0098)	–	–
W2 PW Hunt	-0.009 (-0.098 – 0.08)	0.13 (-0.068 – 0.32)	-0.0061 (-0.079 – 0.067)	0.13 (-0.048 – 0.31)	–
W2 PW Post	-0.15 (-0.32 – 0.02)	-0.013 (-0.14 – 0.12)	-0.14 (-0.31 – 0.018)	-0.0084 (-0.11 – 0.097)	-0.14 (-0.29 – 0.0084)
W3 AG Hunt	-1.2 (-1.9 – -0.45)	-1 (-1.8 – -0.25)	-1.2 (-1.9 – -0.44)	-1 (-1.8 – -0.24)	-1.1 (-1.9 – -0.42)
W3 AG Post	-2.1 (-3.3 – -0.89)	-2 (-3.1 – -0.79)	-2.1 (-3.3 – -0.87)	-2 (-3.1 – -0.77)	-2.1 (-3.3 – -0.85)
W3 SE Hunt	-1.3 (-1.9 – -0.62)	-1.1 (-1.9 – -0.41)	-1.3 (-1.9 – -0.58)	-1.1 (-1.9 – -0.36)	-1.3 (-1.9 – -0.57)
W3 SE Post	-2.3 (-3.3 – -1.2)	-2.1 (-3.1 – -1.1)	-2.3 (-3.3 – -1.2)	-2.1 (-3.2 – -1.1)	-2.3 (-3.4 – -1.2)
W3 FO Hunt	-1.3 (-1.9 – -0.64)	-1.2 (-1.9 – -0.41)	-1.3 (-1.9 – -0.66)	-1.2 (-1.9 – -0.44)	-1.3 (-1.9 – -0.63)
W3 FO Post	-2.3 (-3.3 – -1.3)	-2.2 (-3.1 – -1.2)	-2.3 (-3.3 – -1.3)	-2.2 (-3.1 – -1.2)	-2.3 (-3.3 – -1.3)
W3 PW Hunt	-1.3 (-2.1 – -0.61)	-1.2 (-2 – -0.38)	-1.3 (-2 – -0.62)	-1.2 (-2 – -0.38)	-1.3 (-2 – -0.64)
W3 PW Post	-2.4 (-3.3 – -1.5)	-2.2 (-3.1 – -1.3)	-2.4 (-3.3 – -1.5)	-2.2 (-3.1 – -1.3)	-2.3 (-3.2 – -1.5)
W4 AG Hunt	-0.28 (-0.62 – 0.062)	-0.15 (-0.57 – 0.28)	-0.28 (-0.62 – 0.067)	-0.14 (-0.56 – 0.28)	-0.27 (-0.63 – 0.086)
W4 AG Post	-0.62 (-1.2 – -0.041)	-0.48 (-1.1 – 0.091)	-0.62 (-1.2 – -0.033)	-0.48 (-1.1 – 0.1)	-0.61 (-1.2 – -0.0094)
W4 SE Hunt	-0.32 (-0.63 – -0.012)	-0.19 (-0.58 – 0.21)	-0.32 (-0.65 – 0.016)	-0.18 (-0.6 – 0.24)	-0.31 (-0.65 – 0.028)
W4 SE Post	-0.68 (-1.2 – -0.17)	-0.54 (-1 – -0.04)	-0.67 (-1.2 – -0.14)	-0.54 (-1.1 – 0.0018)	-0.67 (-1.2 – -0.12)
W4 FO Hunt	-0.33 (-0.66 – 0.0042)	-0.19 (-0.62 – 0.24)	-0.32 (-0.64 – -0.013)	-0.19 (-0.59 – 0.22)	-0.32 (-0.65 – 0.012)
W4 FO Post	-0.69 (-1.2 – -0.17)	-0.55 (-1.1 – -0.029)	-0.69 (-1.2 – -0.18)	-0.55 (-1 – -0.049)	-0.68 (-1.2 – -0.15)
W4 PW Hunt	-0.34 (-0.7 – 0.013)	-0.21 (-0.67 – 0.25)	-0.34 (-0.69 – 0.0092)	-0.2 (-0.65 – 0.25)	-0.33 (-0.66 – -0.0058)
W4 PW Post	-0.71 (-1.2 – -0.2)	-0.57 (-1.1 – -0.048)	-0.71 (-1.2 – -0.2)	-0.57 (-1.1 – -0.05)	-0.7 (-1.2 – -0.2)

Table 4.3 (continued)

	W2 PW Post	W3 AG Hunt	W3 AG Post	W3 SE Hunt	W3 SE Post
W3 AG Hunt	-1 (-1.8 – -0.21)	–	–	–	–
W3 AG Post	-1.9 (-3.2 – -0.74)	-0.94 (-1.9 – -0.015)	–	–	–
W3 SE Hunt	-1.1 (-1.9 – -0.35)	-0.11 (-0.81 – 0.59)	0.83 (-0.52 – 2.2)	–	–
W3 SE Post	-2.1 (-3.2 – -1)	-1.1 (-2.3 – 0.059)	-0.17 (-1.2 – 0.89)	-1 (-1.9 – -0.067)	–
W3 FO Hunt	-1.1 (-1.9 – -0.4)	-0.14 (-0.83 – 0.56)	0.8 (-0.58 – 2.2)	-0.021 (-0.57 – 0.53)	0.98 (-0.22 – 2.2)
W3 FO Post	-2.2 (-3.1 – -1.2)	-1.1 (-2.3 – -0.035)	-0.2 (-1.3 – 0.85)	-1 (-2.1 – 0.054)	-0.031 (-0.85 – 0.79)
W3 PW Hunt	-1.2 (-2 – -0.41)	-0.18 (-1 – 0.64)	0.76 (-0.77 – 2.3)	-0.065 (-0.69 – 0.56)	0.93 (-0.38 – 2.3)
W3 PW Post	-2.2 (-3.1 – -1.4)	-1.2 (-2.3 – -0.088)	-0.26 (-1.5 – 0.93)	-1.1 (-2.1 – -0.068)	-0.091 (-0.98 – 0.8)
W4 AG Hunt	-0.13 (-0.57 – 0.3)	0.87 (0.29 – 1.5)	1.8 (0.68 – 2.9)	0.99 (0.27 – 1.7)	2 (0.84 – 3.1)
W4 AG Post	-0.47 (-1.1 – 0.13)	0.54 (-0.22 – 1.3)	1.5 (0.5 – 2.5)	0.65 (-0.31 – 1.6)	1.6 (0.54 – 2.8)
W4 SE Hunt	-0.17 (-0.6 – 0.25)	0.83 (0.12 – 1.6)	1.8 (0.5 – 3)	0.95 (0.35 – 1.5)	1.9 (0.87 – 3)
W4 SE Post	-0.53 (-1.1 – 0.025)	0.48 (-0.42 – 1.4)	1.4 (0.23 – 2.6)	0.59 (-0.23 – 1.4)	1.6 (0.63 – 2.6)
W4 FO Hunt	-0.18 (-0.6 – 0.24)	0.83 (0.099 – 1.6)	1.8 (0.47 – 3.1)	0.94 (0.25 – 1.6)	1.9 (0.77 – 3.1)
W4 FO Post	-0.54 (-1.1 – -0.006)	0.47 (-0.44 – 1.4)	1.4 (0.2 – 2.6)	0.58 (-0.33 – 1.5)	1.6 (0.48 – 2.7)
W4 PW Hunt	-0.2 (-0.62 – 0.23)	0.81 (0.048 – 1.6)	1.8 (0.41 – 3.1)	0.93 (0.22 – 1.6)	1.9 (0.71 – 3.1)
W4 PW Post	-0.56 (-1.1 – -0.059)	0.44 (-0.49 – 1.4)	1.4 (0.11 – 2.7)	0.56 (-0.36 – 1.5)	1.6 (0.41 – 2.7)

	W3 FO Hunt	W3 FO Post	W3 PW Hunt	W3 PW Post	W4 AG Hunt
W3 FO Post	-1 (-1.9 – -0.09)	–	–	–	–
W3 PW Hunt	-0.043 (-0.56 – 0.47)	0.97 (-0.23 – 2.2)	–	–	–
W3 PW Post	-1.1 (-2.1 – -0.079)	-0.06 (-0.8 – 0.68)	-1 (-1.9 – -0.12)	–	–
W4 AG Hunt	1 (0.31 – 1.7)	2 (0.96 – 3.1)	1.1 (0.26 – 1.8)	2.1 (1.1 – 3.1)	–
W4 AG Post	0.67 (-0.3 – 1.6)	1.7 (0.64 – 2.7)	0.72 (-0.36 – 1.8)	1.7 (0.69 – 2.8)	-0.34 (-0.69 – 0.02)
W4 SE Hunt	0.97 (0.31 – 1.6)	2 (0.92 – 3)	1 (0.28 – 1.7)	2 (1 – 3)	-0.039 (-0.28 – 0.2)
W4 SE Post	0.61 (-0.3 – 1.5)	1.6 (0.61 – 2.6)	0.66 (-0.35 – 1.7)	1.7 (0.7 – 2.7)	-0.4 (-0.82 – 0.029)
W4 FO Hunt	0.96 (0.37 – 1.5)	2 (0.96 – 3)	1 (0.3 – 1.7)	2 (1 – 3)	-0.047 (-0.29 – 0.2)
W4 FO Post	0.6 (-0.23 – 1.4)	1.6 (0.69 – 2.5)	0.64 (-0.33 – 1.6)	1.7 (0.7 – 2.6)	-0.41 (-0.81 – 0.00043)
W4 PW Hunt	0.95 (0.3 – 1.6)	2 (0.85 – 3.1)	0.99 (0.36 – 1.6)	2 (1.1 – 3)	-0.062 (-0.36 – 0.23)
W4 PW Post	0.58 (-0.3 – 1.5)	1.6 (0.55 – 2.6)	0.62 (-0.26 – 1.5)	1.6 (0.75 – 2.5)	-0.43 (-0.85 – -0.0092)

Table 4.3 (continued)

	W4 AG Post	W4 SE Hunt	W4 SE Post	W4 FO Hunt	W4 FO Post	W4 PW Hunt
W4 SE Hunt	0.3 (-0.2 – 0.79)	–	–	–	–	–
W4 SE Post	-0.059 (-0.42 – 0.31)	-0.36 (-0.71 – -0.0022)	–	–	–	–
W4 FO Hunt	0.29 (-0.22 – 0.8)	-0.0075 (-0.2 – 0.18)	0.35 (-0.089 – 0.79)	–	–	–
W4 FO Post	-0.07 (-0.44 – 0.29)	-0.37 (-0.77 – 0.036)	-0.011 (-0.29 – 0.27)	-0.36 (-0.71 – -0.0092)	–	–
W4 PW Hunt	0.28 (-0.29 – 0.84)	-0.023 (-0.24 – 0.2)	0.33 (-0.15 – 0.82)	-0.015 (-0.2 – 0.17)	0.35 (-0.095 – 0.79)	–
W4 PW Post	-0.091 (-0.51 – 0.33)	-0.39 (-0.78 – 0.00078)	-0.032 (-0.35 – 0.28)	-0.38 (-0.76 – -0.0039)	-0.021 (-0.28 – 0.24)	-0.37 (-0.71 – -0.018)

Pairwise comparisons follow from row to column. For example, apparent survival of female mallards in flooded agriculture was -0.64 % (-1.3 – -0.0044%) less during post-hunting than hunting season in 2010-2011. W1 = 2010-2011, W2 = 2011-2012, W3 = 2013-2014, W4 = 2014-2015, AG = flooded agriculture, SE = seasonal emergent wetlands, FO = forested wetlands, PW = permanent/open wetlands, Hunt = open waterfowl hunting season, and Post = period following hunting season to 20 March.

Table 4.4 Model averaged apparent daily survival and 95% confidence interval of female mallards.

Winter	Period	AG	S-EM	FO	P-W
2010/ 2011	Hunt	0.991 (0.984-0.995)	0.990 (0.982-0.994)	0.990 (0.983-0.994)	0.990 (0.983-0.994)
	Post	0.985 (0.973-0.991)	0.983 (0.974-0.989)	0.983 (0.973-0.990)	0.983 (0.974-0.989)
2011/ 2012	Hunt	0.998 (0.996-0.999)	0.998 (0.995-0.999)	0.998 (0.996-0.999)	0.998 (0.996-0.999)
	Post	0.997 (0.993-0.999)	0.997 (0.993-0.998)	0.997 (0.993-0.998)	0.997 (0.993-0.998)
2013/ 2014	Hunt	0.987 (0.977-0.992)	0.985 (0.975-0.991)	0.985 (0.976-0.991)	0.985 (0.977-0.991)
	Post	0.977 (0.962-0.986)	0.974 (0.964-0.982)	0.975 (0.963-0.984)	0.975 (0.964-0.983)
2014/ 2015	Hunt	0.995 (0.991-0.998)	0.995 (0.990-0.997)	0.995 (0.990-0.997)	0.995 (0.990-0.997)
	Post	0.992 (0.984-0.996)	0.991 (0.985-0.995)	0.991 (0.985-0.995)	0.991 (0.985-0.995)

For female mallards captured at three wildlife management areas and one national wildlife refuge in the Mississippi Alluvial Valley of Mississippi in winters 2010-2012 and 2013-2015.

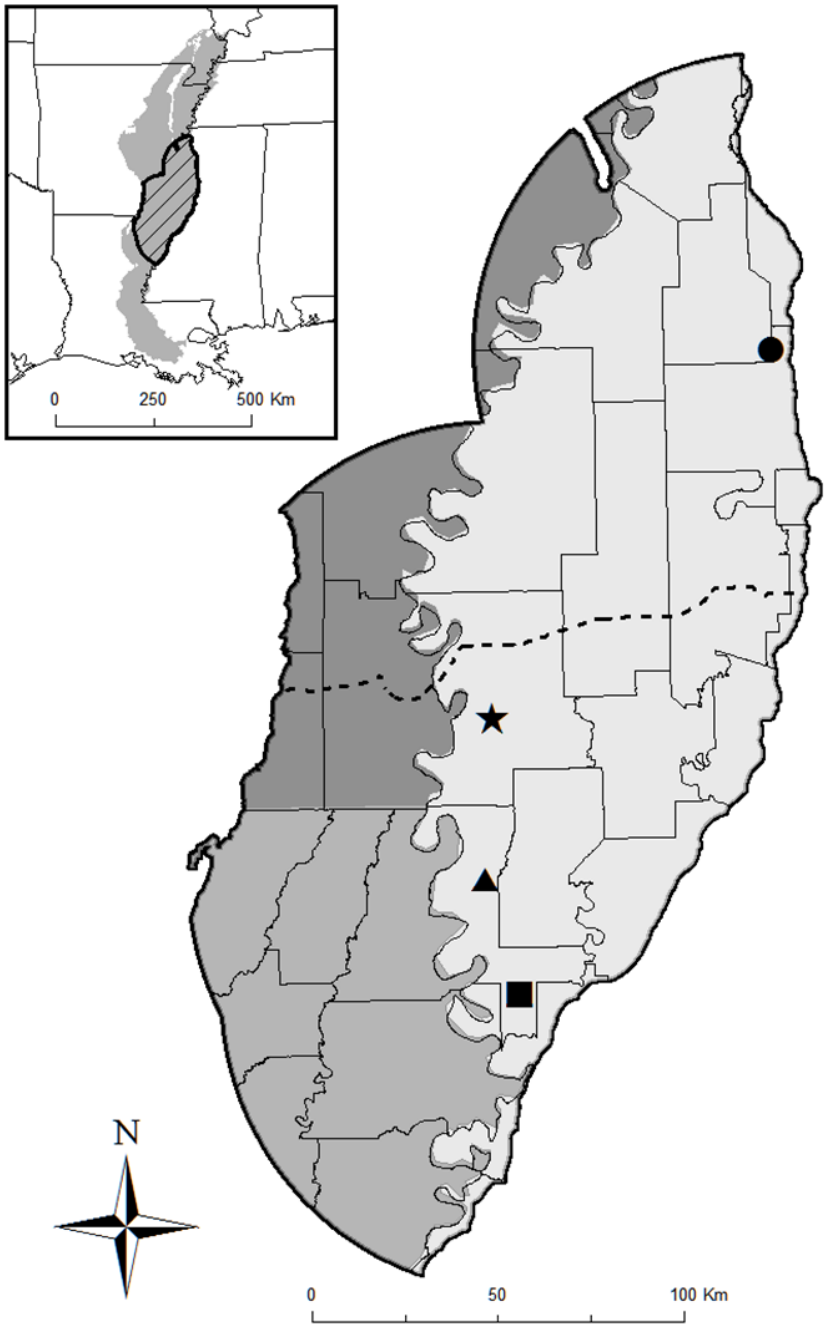

Figure 4.1 Female mallard capture locations and surrounding study area within the Mississippi Alluvial Valley.

Study area included the Mississippi Alluvial Valley within 80 km of capture locations: Coldwater River National Wildlife Refuge (circle), Muscadine Farms Wildlife Management Area (WMA; star), Howard Miller WMA (triangle), and Mahannah WMA (square). Highway 82 corridor shown (dashed) dividing the north and south study basins.

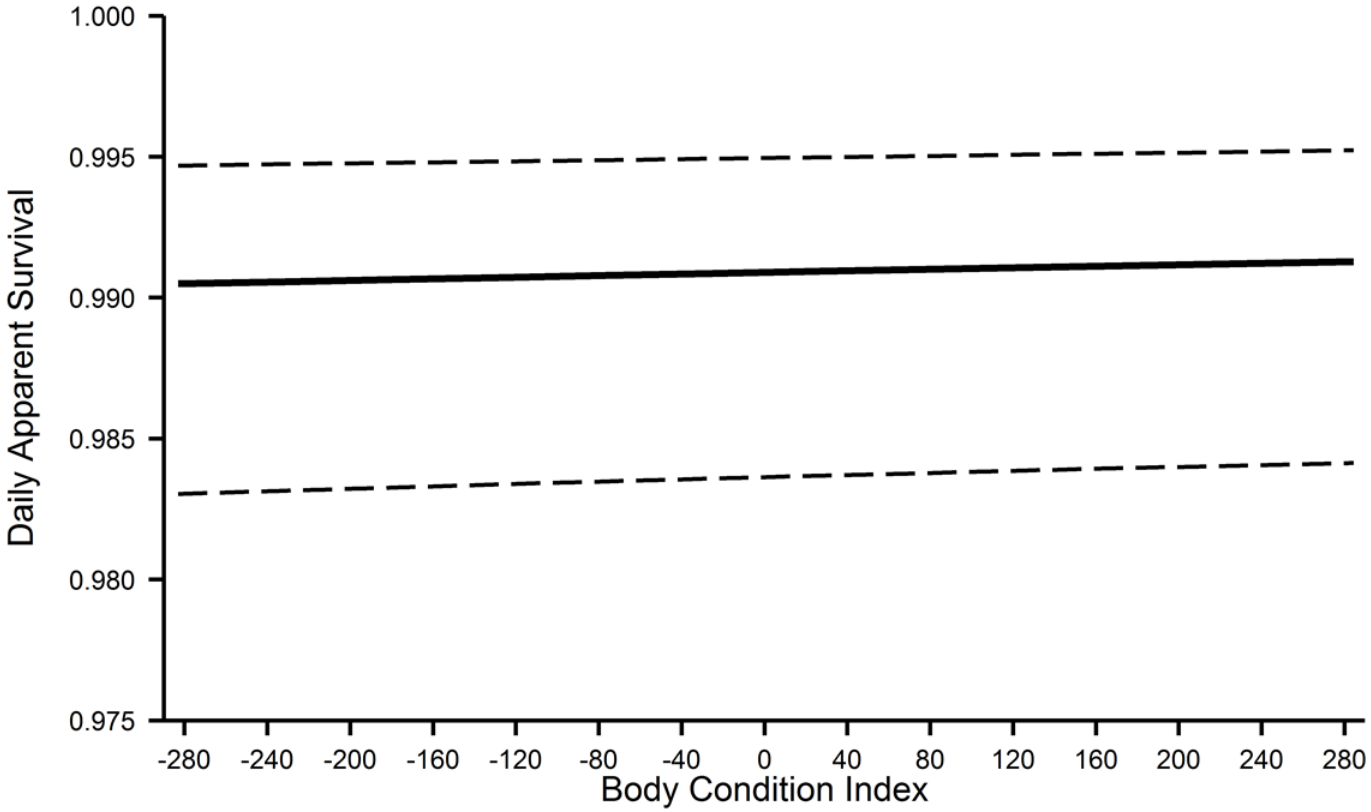

Figure 4.2 Influence of body condition at capture on apparent daily survival of female mallards.

For female mallards during hunting season in the Mississippi Alluvial Valley of Mississippi during winter 2010-2011.

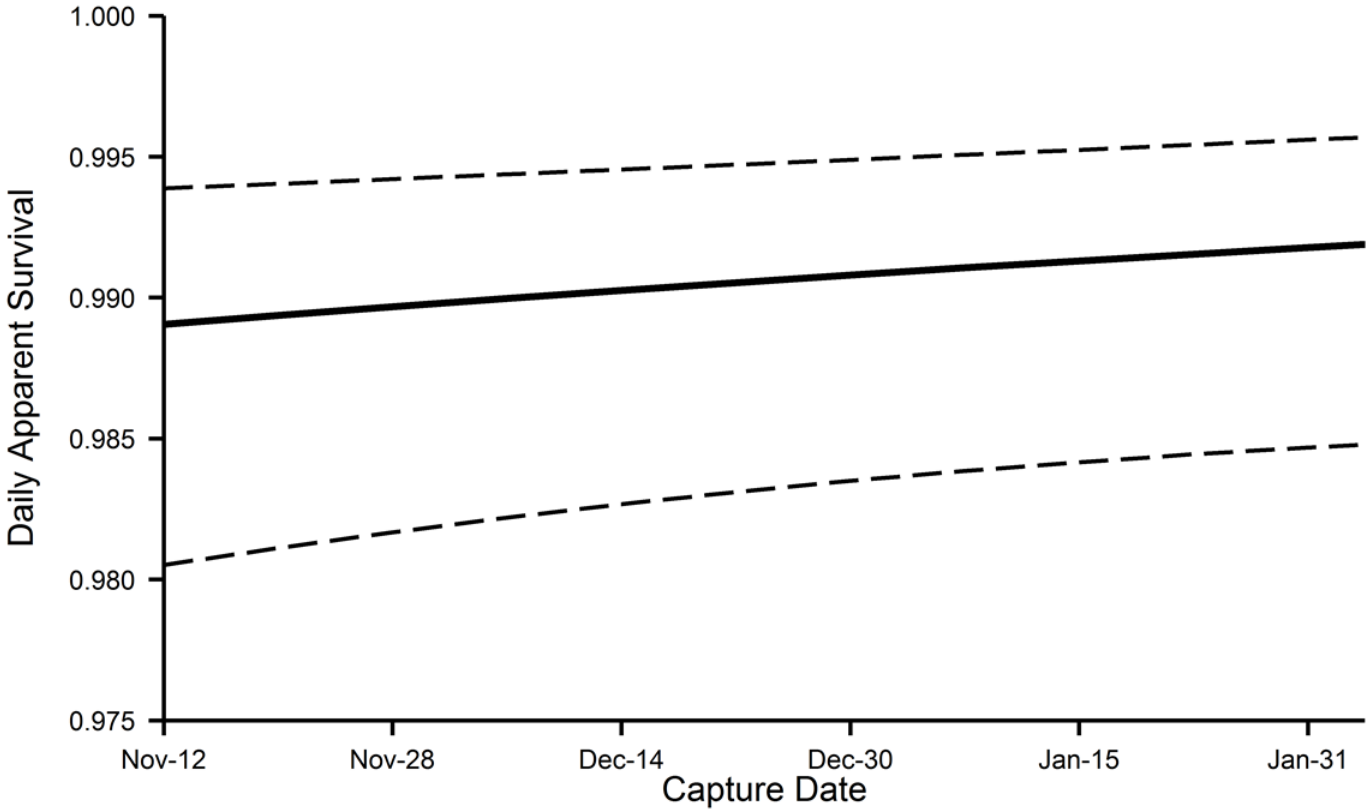

Figure 4.3 Influence of capture date on apparent daily survival of female mallards.

For female mallards in the Mississippi Alluvial Valley of Mississippi during winter 2010-2011.