Annual Habitat Selection by Mottled Ducks in Coastal South Carolina

James C. Shipes, *Department of Wildlife, Fisheries, and Aquaculture, Box 9690, Mississippi State, MS 39762*

J. Brian Davis, *Department of Wildlife, Fisheries, and Aquaculture, Box 9690, Mississippi State, MS 39762*

Ernie P. Wiggers, *Nemours Wildlife Foundation, 161 Nemours Plantation Road, Yemassee, SC 29945*

William E. Mills, *Nemours Wildlife Foundation, 161 Nemours Plantation Road, Yemassee, SC 29945*

Richard M. Kaminski, *Department of Wildlife, Fisheries, and Aquaculture, Box 9690, Mississippi State, MS 39762*

Molly R. Kneece, *Department of Wildlife, Fisheries, and Aquaculture, Box 9690, Mississippi State, MS 39762*

Abstract: Mottled ducks (*Anas fulvigula*) are endemic to Gulf Coastal United States, Florida, and Mexico. Birds from Florida, Louisiana, and Texas were released in coastal South Carolina from 1975–1983, and subsequent banding data suggest a dispersing and increasing population in the state. Because autecology of mottled ducks is little known in South Carolina, we radio-marked 116 females in August 2010–2011 in the Ashepoo, Combahee, and Edisto Rivers Basin to assess habitat use throughout the annual cycle. We monitored habitat use by aircraft during fall-winter and via ground reconnaissance during spring-summer. Because of small sample size due to radio-transmitter failure and logistics, we pooled data across years to obtain 1,241 locations from 67 females. Selection ratios (w_i) showed that females selected managed tidal impoundments but avoided unmanaged wetlands during fall-winter and spring-summer. In fall-winter, females selected wetlands containing planted corn ($w_i = 1.96$ [1.25, 2.57]) over wetlands with natural vegetation ($w_i = 0.92$ [0.86, 0.98]). Mottled ducks also selected brackish wetlands ($w_i = 1.87$ [1.68, 2.07]) over wetlands that were fresher ($w_i = 0.18$ [0.08, 0.29]) or more saline ($w_i = 0.65$ [0.37, 0.92]). Our study highlights the importance of managed brackish impoundments to mottled ducks in South Carolina and underscores differences between birds' habitat use compared to elsewhere in their range.

Key words: mottled ducks, habitat selection

Journal of the Southeastern Association of Fish and Wildlife Agencies 2:268–273

The annual cycle of waterfowl consists of several physiologically- and behaviorally-distinct periods, including breeding, summer molting, fall and spring migration, and winter (Bellrose 1980, Smith et al. 1989, Batt et al. 1992, Baldassarre and Bolen 2006). Most Nearctic species of dabbling ducks nest at northern latitudes and winter in central to southern United States or farther south (Bellrose 1980, Baldassarre and Bolen 2006). However, some species of dabbling ducks are relatively non-migratory. For example, western (e.g., California) breeding mallards (*Anas platyrhynchos*; Yarris et al. 1994, McLandress et al. 1996), southern populations of wood ducks (*Aix sponsa*; Bellrose and Holm 1994) and hooded mergansers (*Lophodytes cucullatus*; Baldassarre 2014), and Gulf coastal and Florida mottled ducks (*Anas fulvigula*) live year-round in local to regional areas (Stutzenbaker 1988, Bielefeld et al. 2010). Indeed, knowledge of annual autecology is critical to meet annual-cycle needs of non-migratory species given that they typically reside in a smaller geographic region (Wilson 2007, Bielefeld et al. 2010).

Mottled ducks are endemic to peninsular Florida and coastal regions of Alabama, Mississippi, Louisiana, and Texas (Bielefeld et al. 2010). Mottled duck habitat use has been studied throughout their endemic range (Stutzenbaker 1988, Zwank et al. 1989, Johnson et al. 1991, Davis 2012, Moon 2012, Varner 2013). Mottled ducks in the Gulf coast region use flooded ricelands considerably during the breeding season, but a complex of agricultural and other habitats and resources, including coastal marsh, pastures, and prairies, are also important for non-breeding birds (Stutzenbaker 1988, Holbrook et al. 2000, Durham and Afton 2006, Bielefeld et al. 2010). Moreover, Gulf coastal mottled ducks also appeared to select brackish and fresh marshes over other coastal habitats during both the breeding and non-breeding period (Davis 2012, Moon 2012). Historically, mottled ducks inhabited fresh emergent and brackish wetlands inland and along both coastlines of Florida, but today these birds use a variety of habitats because of wetland loss and degradation (Bielefeld et al. 2010). It is estimated that >50% of mottled ducks in Florida use urban/suburban wetlands such as retention ponds and drainage ditches during both the breeding and non-breeding periods (Bielefeld 2002, Bielefeld et al. 2010). In more rural regions of Florida, such as the Everglades Agricultural Area, mottled ducks use seasonally flooded ponds and marshes associated with major rivers and lakes, storm-water treatment areas, and the Everglades (Johnson et al. 1991, Bielefeld 2002, Bielefeld et al. 2010).

Wetland habitats of South Carolina differ from resources encountered by mottled ducks in Gulf coastal and Florida regions. Natural marshes of coastal South Carolina exhibit a semi-diurnal tidal cycle where water depths fluctuate by as much as 2.29 m (Ricketts 2011). In contrast, Gulf coastal tidal marshes have an amplitude of <1 m (Dardeu et al 1992). Unlike elsewhere in the mottled duck's range, flooded pastures, associated seasonal wetlands, flooded croplands, and retention ponds associated with agriculture and storm water treatment have typically been absent from coastal South Carolina. Rice production that was initiated in the early 1700s in the Lowcountry was an important precursor to current-day managed tidal impoundments in South Carolina. Intensive management of these impoundments for migrating and wintering waterfowl may have begun as early as the early 1900s, and today the impoundments mimic seasonally flooded wet prairie habitats. Prior to the mid 1970s mottled ducks apparently did not exist in South Carolina, despite suitable habitats apparently being available. Wildlife managers and private conservationists from South Carolina and elsewhere translocated 1,285 mottled ducks from Louisiana, Texas, and Florida to two coastal regions of South Carolina from 1975–1983. By 2010, the South Carolina population of mottled ducks was estimated to be between 15,000 and 20,000 individuals (South Carolina DNR, unpublished data).

To our knowledge, only one study of breeding mottled ducks has been conducted in coastal South Carolina (Weng 2006). Mottled ducks preferred water depths of 3–45 cm in managed tidal impoundments, but Weng (2006) did not study other potentially important habitat covariates such as salinities, vegetation dynamics, hunting regime, or wetland management practices. To better understand the annual autecology of mottled ducks in South Carolina, we assessed habitat use of these birds throughout much of their annual cycle (Shipes 2014). Wetland managers also desire information on specific habitat needs of mottled ducks during the birds annual cycle to guide habitat conservation planning for mottled ducks (Shipes 2014).

Study Area

We conducted our study in the 182,115-ha estuarine complex of the ACE Basin located in the southern half of South Carolina's coastline in Beaufort, Charleston, and Colleton counties. The ACE Basin is one of 27 national research reserves monitored by the National Estuarine Research Reserve System and contains 128,000 ha of land protected by state, federal, private, and nonprofit organizations (NOAA 2012). The ACE Basin contains pine and hardwood uplands, forested wetlands, fresh, brackish and salt water tidal marshes, barrier islands, and beaches (SCDNR 2013). Our study included wetlands and associated habitats on private, state, and federal lands including Ernest F. Hollings ACE Basin National Wildlife Refuge (NWR), Bear Island Wildlife Management Area (WMA), Nemours Plantation Wildlife Foundation, and Cheeha Combahee Plantation.

Methods

Mottled Duck Capture

We captured mottled ducks on our study area using night-lighting techniques during August–September 2010–2011 when most birds were wing-molting (Merendino et al. 2005, Mills et al. 2011). We transported all captured females to the laboratory at Nemours Plantation and prepared them for radio-marking. We outfitted 115 hatch-year and after-hatch-year females either with a harness style transmitter (21 g; Advanced Telemetry Systems model A2300, Isanti Minnessota) or an intra-abdominal transmitter (18 g; Holohil Systems Model RI-2D, Carp, Ontario, Canada) in 2011, but only used intra-abdominal transmitters in 2012, as these devices have been successfully used on mottled ducks in other studies (Davis 2012). We followed Dwyer's (1972) method for attaching harness transmitters and Korschgen et al. (1984) for intra-abdominal transmitters, using a team of skilled veterinarians to implant transmitters in a laboratory at Nemours (Korschgen 1984). Both transmitters were ≤3% of the bird's body mass at capture (mean body mass: 752.7 ± 6.3 g) and had an estimated 30-month lifespan. Each transmitter was equipped with a mortality sensor that doubled the pulse rate when the transmitter was motionless ≥8 hours. We also banded each mottled duck with a standard USGS aluminum leg band.

Radio Tracking

We began monitoring radio-marked females five days post release. In August–December 2010 and 2011, we located radio-marked females weekly using an aircraft equipped with strut-mounted 4-element Yagi antennas (Gilmer et al. 1981). Beginning in January 2011 and 2012, we located radio-marked birds ≥3 times per week from a truck using an ATS receiver (Model R4000, Advanced Telemetry Systems, Inc. Isanti, Minnesota) and a handheld 3-element Yagi antenna. For both aerial reconnaissance and ground tracking we recorded positions using a handheld GPS unit (Garmin Corporation, Olathe, Kansas) where error was <5 m for each fix and triangulated each birds' location during daylight hours (White and Garrott 1990). We used Locate 3.33 (Pacer Computing, Nova Scotia, Canada) to convert the raw coordinates to actual bird locations. Upon detecting a mortality signal, we attempted to retrieve the transmitter and determine cause of bird's death.

Habitat Categorization

We used ArcMap 10 and overlaid bird locations onto 2011 National Agricultural Imagery digital orthophoto images of the study area. We used a 95% kernel density estimator to determine area used by radio-marked mottled ducks (Legagneux et al. 2008). We created polygons within the 95% KDE to differentiate the following habitat and management categories: 1) management regime; i.e., whether or not wetland impoundments received active hydrological management by managers, 2) salinity regime; i.e., intermediate (1–5 ppt.), brackish (5–15 ppt.), and brackish/salt (15–25 ppt.), 3) hunting regime; whether or not waterfowl hunting occurred within a wetland, and 4) vegetation coverage; whether wetlands contained natural wetland vegetation only or natural vegetation and agricultural crops, such as corn and Japanese millet. In GIS, we assigned each of these four categorical variables to individual polygons and used the join function in ArcMap 10 to assign or link categories and individual female locations. Lastly, we calculated the total area of each category within the 95% KDE so proportions of each category could be differentiated for subsequent analyses of habitat selection.

Statistical Analysis

We assessed habitat selection by female mottled ducks using the Manly et al. (2002) selection ratio approach, where: $wj = uj / aj$ and uj was the proportion of use of the habitat class j and aj is the proportion of this habitat available to individual mottled ducks within their KDE. Habitat selection ratios are a simplified case of resource selection functions where each resource unit is classified into distinct categories (Manly et al. 2002). We used chi–square analysis to determine whether female mottled ducks used resource units similar to one another and whether habitat use occurred in proportion to availability (Manly et al. 2002, Rogers and White 2007). We then calculated selection ratios and accompanying 95% Bonferroni confidence intervals to determine if specific resource units were used disproportionally to their availability, implying units were selected or alternatively avoided by mottled ducks (Thomas and Taylor 1990, Manly et al. 2002, Rogers and White 2007). Selection ratio values greater than one imply selection for a category while ratio values less than one suggest avoidance. We used program Fishtel (v 1.4) to calculate chi-square statistics and selection ratios (Rogers and White 2007). This analysis does consider individual variation associated with resource selection, but it allows pooled observations among all individuals in a sample population. Therefore, our resulting selection ratios are provided at a population and not individual level (Manly et al. 2002).

As described, our distinct resource units included hydrological management, salinity category, vegetation types within wetlands, and presence or absence of hunting. We examined selection of hydrological management and salinity category for two time periods: 1) 15 August – 31 January, which encompassed post-breeding through mid-winter, and 2) 1 February–1 June, or post-waterfowl hunting through the breeding season. We evaluated habitat selection relative to presence or absence of hunting only during the regular South Carolina waterfowl hunting season (i.e., 20 November – 30 January). We evaluated habitat selection for vegetation types (natural vs. agricultural vegetation) in wetlands for the period 15 November–15 February, when we were certain agricultural crops were available to mottled ducks. Crops in wetlands generally were toppled, decomposed, or eliminated by managers soon after the waterfowl hunting season, thus only leaving wetlands with native vegetation and non-cropped wetlands for comparison of duck use.

Results

Radio Instrumentation and Tracking

We radio-marked 80 and 36 female mottled ducks from August–September 2010 and 2011, respectively. Because of failed transmitters (primarily backpacks), non-detection of radio-marked females in (or outside) the study area after their release, or birds' deaths, we obtained 1,241 locations from 67 females (58%) from fall-spring 2010–2012 and used these data in analyses for habitat selection. All results reported here are from females with implanted transmitters. Despite unexplained lack of detection of backpack transmitted mottled ducks, we have no reason to believe that this cohort of birds would have used regions or habitats differently (i.e., biasing habitat use/selection results) than birds marked with implants, as we captured birds at similar times and molting wetlands in both years. Thus, although non-detection of backpack transmitters limited our sample size, we regarded results from mottled ducks with implanted transmitters being representative of the greater population.

Habitat Use and Selection

Fall-winter. We obtained data from 67 females (n = 693 locations) to investigate habitat selection during fall-winter relative to hydrologic management and salinity category. Females used hydrologically managed wetlands >8 times more than unmanaged wetlands ($\chi^2_{66} = 92.15$, $P = 0.01$; Table 1). Additionally, females' use of managed wetlands exceeded availability of these wetlands ($\chi^2_{67} = 606.40$, $P < 0.001$), implying females selected managed habitats ($w_i = 1.86$ [1.79–1.93] [CI]) but avoided unmanaged wetlands ($w_i = 0.89$ [0.80, 0.98]); Table 1).

Females also differentially used wetlands relative to salinity designation ($\chi^2_{132} = 321.90$, $P < 0.001$), and use was disproportional to availability of the wetlands ($\chi^2_{133} = 612.97$, $P < 0.001$). Females were 10 times more likely to select brackish over intermediate wetlands,

Table 1. Habitat categories, selection ratios, and corresponding 95% Bonferroni confidence intervals for radio-marked mottled ducks (n) in the Ashepoo, Combahee, and Edisto Rivers Basin, South Carolina, fall-summer 2010-2012.

Wetland characteristic	Fall-Winter n	Fall-Winter Selection ratio w_i (CI)[a]	Spring-Summer n	Spring-Summer Selection ratio w_i (CI)[a]
Managed	67	1.86 (1.79, 1.93)	36	2.02 (1.89, 2.15)
Unmanaged		0.89 (0.80, 0.98)		0.10 (0.05, 0.15)
Agricultural Vegetation	55	1.96 (1.25, 2.67)		
Natural Vegetation		0.92 (0.86, 0.98)		
Hunted areas	55	1.02 (0.95, 1.09)		
Non-hunted areas		0.79 (0.31, 1.27)		
Intermediate	67	0.21 (0.06, 0.36)	36	0.21 (0.09, 0.33)
Brackish		2.00 (1.73, 2.27)		2.01 (1.74, 2.28)
Brackish/Salt		0.45 (0.09, 0.81)		0.47 (0.12, 0.82)

a. Selection ratios and corresponding 95% Bonferroni confidence intervals for habitats encountered by radio-marked mottled ducks.
b. All variables were significant at $P<0.03$.
c. Blanks denote that wetland characteristic was not applicable.

and 4 times more likely to select brackish over brackish/saline wetlands (Table 1).

Winter-Waterfowl Hunting Season. We obtained data from 55 females (n = 354 locations) to investigate habitat selection in relation to presence or absence of waterfowl hunting in wetlands used by females during South Carolina's waterfowl hunting season. Females differentially used hunted over non-hunted wetlands ($\chi^2_{54} = 110.0$, $P < 0.001$), and use was disproportional to availability ($\chi^2_{55} = 112.2$, df = 55, $P < 0.001$). However, because Bonferroni 95% confidence intervals included 1 we could not demonstrate selection of one habitat type over another by females (Table 1).

We evaluated selection by 55 radio-marked females (n = 364 locations) for wetlands with natural vegetation versus those with a combination of crops and native vegetation. Female use between types differed ($\chi^2_{54} = 78.9$, $P = 0.015$) and these habitats were used disproportionally to their availability ($\chi^2_{55} = 93.5$, $P < 0.001$). Selection ratios indicated that females were two times more likely to select wetlands containing crops than only natural vegetation (Table 1).

Spring-summer. We used data from 36 radio-marked females (n = 548 locations) to investigate selection of habitats during spring-summer relative to hydrological management and salinity. Crops in wetlands generally were toppled, decomposed, or eliminated by managers soon after the waterfowl hunting season, thus only leaving wetlands with native vegetation but no other wetland types for comparison. Females differentially used managed and unmanaged wetlands ($\chi^2_{35} = 755.3$, $P < 0.001$), and use was disproportional to availability of these wetlands ($\chi^2_{36} = 773.7$, $P < 0.001$). Female mottled ducks were >27 times more likely to select managed wetlands ($w_i = 2.02$ [1.89, 2.15]) over unmanaged wetlands ($w_i = 0.10$ [0.05, 0.15]; Table 1).

Female mottled ducks differentially used wetlands of varying salinities ($\chi^2_{68} = 277.1$, $P < 0.001$) throughout spring and summer. Females use of brackish wetlands exceeded availability of these wetlands ($\chi^2_{69} = 722.5$, $P < 0.001$), implying females selected brackish wetlands ($w_i = 2.01$ [1.74, 2.28]) but avoided intermediate ($w_i = 0.21$ [0.09, 0.33]) and brackish/salt wetlands ($w_i = 0.47$ [0.12, 0.82]; Table 1).

Discussion

Resource Selection

Our study was one of the first to demonstrate empirically habitat selection by radio-marked female mottled ducks in South Carolina. Gordon et al. (1998) reported more migrating and wintering dabbling ducks in managed tidal impoundments than unmanaged tidal wetlands, but did not report individually on mottled ducks. Patterns of selection of managed brackish wetlands by radio-marked mottled ducks in our study seemed consistent across fall-winter and spring-summer seasons and commensurate with previous observations of waterfowl in general (Gordon et al. 1998). For decades, managed brackish wetlands have been acknowledged as critical for waterfowl migrating through and wintering in the ACE Basin (Gordon et al. 1998). Our findings also corroborate habitat associations of mottled ducks during the breeding season that were observed during aerial surveys in the Santee River Basin.

Managed tidal impoundments differ considerably from unmanaged tidal wetlands in South Carolina, especially in vegetation communities and surface-water area (Gordon et al. 1989). Managed tidal impoundments are typically shallowly flooded (<1 m). Water levels are managed in summer to promote growth of wetland emergent and submerged aquatic plants, such as dwarf spikerush (*Eleocharis parvula*) and wigeongrass (*Ruppia maritima*; Gordon et al. 1989). Foliage and seeds of these species provide quality food for nonbreeding dabbling ducks in this region (Prevost et al. 1978, Gordon et al. 1989). Moreover, vegetation in managed tidal impoundments is often actively manipulated to create interspersed herbaceous vegetation and open water (i.e., hemi-marsh) that enhances access and other activities by nonbreeding waterfowl (Gordon et al. 1989, Gordon et al. 1998, Smith et al. 2004). In contrast, unmanaged tidal areas in our study area were dominated by smooth cordgrass (*Spartina alterniflora*), with black needlerush (*Juncus roemarianus*) forming largely homogenous patches in higher elevations. Also, saltmarsh bulrush (*Schoenoplectus robustus*), giant cordgrass (*Spartina cynosuroides*), and soft-stemmed bulrush (*Schoenoplectus tabernaemontani*) are interspersed with *Spartina alterniflora* (Ricketts 2011). Unmanaged tidal wetlands undergo a semidiurnal tide cycle (NOAA 2012) where daily frequency, duration, and depth of water vary spatially and temporally. These natural dynamics often promote tall, dense wetland vegetation with limited open water that is difficult to access by waterfowl (Kaminski and Prince 1981, Gordon et al. 1998). Consequently, most open water in these tidal systems is associated with river and creek channels, which are relatively deeply flooded (>1 m; Gordon et al 1998). We suspect that relatively stable water conditions in managed brackish and saline wetlands unlike that of natural tidal marshes contributed to great use of brackish-saline wetlands by mottled ducks.

Mottled ducks in Louisiana and Texas may shift habitat use from marsh and wet prairie habitats during winter and pre-breeding periods to agricultural lands (e.g., rice) during the breeding seasons (Stutzenbaker 1988, Zwank et al. 1989, Davis 2012). Wetlands with planted crops (e.g., corn) were most important to mottled ducks during winter, and these resources were unavailable during breeding because wetlands are drained post-hunting season in preparation for subsequent management. Female mottled ducks in our study selected wetlands with planted crops, primarily corn, over those with only natural vegetation during fall-winter (15 November–15 February). Davis (2012) observed female mottled ducks shifting from natural wetlands to ricelands from winter to the breeding period. We likely did not observe this trend because wetlands containing crops generally were available during winter for waterfowl hunting, then drained shortly after the season. We cannot fully explain use of agricultural wetlands by mottled ducks but corn contains high energy and is among the most metabolizable of waterfowl foods (Kaminski et al. 2003). One hypothesis is that, like congeneric mallards, mottled ducks may consume corn when it is flooded and available. However, we did not study food habits of mottled ducks so we can only speculate at this time.

Across much of their range, mottled ducks select fresh and intermediate wetlands over brackish and brackish/salt wetlands during winter and breeding seasons (Johnson et al. 1991, Davis 2012, Wehland 2012). However, an affinity by mottled ducks in the ACE Basin for brackish wetlands may be related to vegetation composition and water management. Brackish wetlands share vegetation characteristics with tidal freshwater and salt marsh (Gordon et al. 1989). Brackish managed wetlands contain seeds of annual grasses, widgeon grass, spikerushes, and other important plants (Gordon et al. 1989). Invertebrates are likely a vital component of mottled duck diets in these wetlands, but virtually nothing is known about this aspect. We found that intermediate wetlands were essentially avoided during both winter and spring by radio-marked mottled ducks. Intermediate wetlands of the ACE Basin are dominated by early successional and herbaceous emergent plants such as rice cutgrass (*Leersia oryzoides*) and panic grasses (*Panicum* spp.). Management strategies in intermediate wetlands prioritize quality moist-soil plant communities, providing quality food and other resources for wintering waterfowl (Kross et al. 2008, Schummer et al. 2012). Thus, we cannot fully explain why mottled ducks didn't select these wetlands in winter. Intermediate wetlands in spring and summer contain dense and uniform vegetation and water levels <0.3 m, which may have been unfavorable to breeding mottled ducks or females with broods because of limited access into the wetlands.

Hunted and Non-Hunted Wetlands

State and private managed lands and part of ACE Basin NWR (4,781 ha) comprised much of our study area, and these areas vary in hunting frequency. For example, Bear Island WMA is a 4,864-ha wetland complex that allows approximately 20 hunting parties once per week (D. Harrigal, personal communication). This level of hunting disturbance may not be enough to discourage use by mottled ducks on non-hunted days, and may explain why hunted areas did not seem to be avoided by birds. We had no information on the frequency and intensity of hunting on private lands and it likely varied considerably per individual landowner prerogatives. The ACE Basin NWR was the only property in our study area prohibiting waterfowl hunting. Radio-marked mottled ducks did use wetlands there but not in proportion to their availability, perhaps because of most of the wetland types there classified as intermediate. The early pairing chronology, less gregarious sociobility, and year-round residency of mottled ducks may benefit them in safely exploiting habitats amid hunting activity (Stutzenbaker 1988, Paulus and Weller 1988, Grand 1992, Zwank et al. 1989). In conclusion, managed brackish wetlands seem vital to mottled ducks in the ACE Basin, but more information is needed on the annual ecology and habitat use by the species, especially with respect to seasonal needs (e.g., diet) and how they relate to current wetland management practices in the ACE Basin.

Literature Cited

Baldassarre, G. A. 2014. Ducks, Geese, and Swans of North America. Fourth edition. Johns Hopkins University Press. Baltimore, Maryland.

_____ and E. G. Bolen. 2006. Waterfowl Ecology and Management. Second edition. John Wiley & Sons, Inc. New York.

Batt, B. D. J., A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu. 1992. Ecology and Management of Breeding Waterfowl. University of Minnesota Press, Minneapolis.

Bellrose, F. C. 1980. Ducks, geese, and swans of North America. Third Edition. Stackpole Books, Harrisburg, Pennsylvania.

_____ and D. J. Holm. 1994. Ecology and Management of the Wood Duck. Stackpole Books, Harrisburg, Pennsylvania.

Bielefeld, R. R. 2002. Habitat use, survival, and movements of Florida mottled duck (*Anas fulvigula fulvigula*) females using the Upper St. Johns River Basin in Florida. Final Report. Florida Fish and Wildlife Conservation Commission, Fellsmere.

______, M. G. Brasher, T. E. Moorman and P. N. Gray. 2010. Mottled duck (Anas fulvigula). *In* A. Poole, editor. The Birds of North America. Cornell Lab of Ornithology, Ithica, New York.

Dardeu, M. R., R. F. Modlin, W. W. Schroeder, and J. P. Stout. 1992. Estuaries. Pages 614–744 *in* C. T. Hackney, S. M. Adams, and W. M. Martin, editors. Biodiversity of the southeastern United States: Aquatic Communities. Wiley, New York.

Davis, B. E. 2012. Habitat use, movements, and ecology of female mottled ducks on the Gulf Coast of Louisiana and Texas. Dissertation. Louisiana State University, Baton Rouge.

Durham, R. S. and A. D. Afton. 2006. Breeding biology of mottled ducks on agricultural lands in southwestern Louisiana. Southeastern Naturalist 5:311–316.

Dwyer, T. J. 1972. An adjustable radio-package for ducks. Bird Banding 43:282–284.

Gilmer, D. S., L. M. Cowardin, R. L. Duval, L. M. Mechlin, C. W. Shaiffer, and V. B. Kuechle. 1981. Procedures for the use of aircraft in wildlife biotelemetry studies. U.S. Fish and Wildlife Service, Resource Publication 140. Washington, D.C.

Gordon, D. H., B. T. Gray, and R. M. Kaminski. 1998. Dabbling duck habitat associations during winter in coastal South Carolina. Journal of Wildlife Management 62:569–580.

______, ______, R. D. Perry, M. B. Prevost, T. H. Strange, and R. K. Williams. 1989. South Atlantic Coastal Wetlands. Pages 57–92 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock.

Grand, J. B. 1992. Breeding chronology of mottled ducks in a Texas coastal marsh. Journal of Field Ornithology 63:195–202.

Holbrook, R. S., F. C. Rohwer, and W. P. Johnson. 2000. Habitat use and productivity of mottled ducks on the Atchafalaya River Delta, Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 54:292–303.

Johnson, F. A., F. Montalbano III, J. D. Truitt, and D. R. Eggeman. 1991. Distribution, abundance, and habitat use by mottled ducks in Florida. Journal of Wildlife Management 55:476–482.

Kaminski, R. M., and H. H. Prince. 1981. Dabbling duck and aquatic macroinvertebrate responses to manipulated wetland habitat. Journal of Wildlife Management 45:1–15.

______, J. B. Davis, H. W. Essig, P. D. Gerard, and K. J. Reinecke. 2003. True metabolizable energy for wood ducks from acorns compared to other waterfowl foods. Journal of Wildlife Management 67:542–550

Korschgen, C. E., S. J. Maxson, V. B. Kuechle. 1984. Evaluation of implanted radio transmitters in ducks. Journal of Wildlife Management 48:982–987.

Kross, J., R. M. Kaminski, K. J. Reinecke, E. J. Penny, and A. T. Pearse. 2008. Moist-soil seed abundance in managed wetlands in the Mississippi Alluvial Valley. Journal of Wildlife Management 72:707–714.

Legagneux, P., C. Blaize, F. Latraube, J. Gautier, and V. Bretagnolle. 2008. Variation in home-range size and movements of wintering dabbling ducks. Journal of Ornithology 150:183–193.

Manly, B. F. J., L. L. McDonald, and D. L. Thomas. 2002. Resource Selection by Animals: Statistical Design and Analysis for Field Studies. 2nd edition. Kluwer Academic Publishers.

McLandress, M. R., G. S. Yarris, A. E. H. Perkins, D. P. Connelly, and D. G. Raveling. 1996. Nesting biology of mallards in California. Journal of Wildlife Management 60:94–107.

Merendino M. T., D. S. Lobpries, J. E. Neaville, J. D. Ortego, W. P. Johnson. 2005. Regional differences and longterm trends in lead exposure in mottled ducks. Wildlife Society Bulletin 33:1002–1008.

Mills, W. E., D. E. Harrigal, S. F. Owen, W. F. Dukes, D. A. Barrineau, and E. P. Wiggers. 2011. Capturing clapper rails using thermal imaging technology. The Journal of Wildlife Management 75(5):1218–1221.

Moon, J. A. 2012. Movements, Habitat Use, Survival, and Potential Implications of Climate Change on Mottled Ducks (*Anas fulvigula*) in the Texas Chenier Plain Region. Dissertation, Stephen F. Austin State University, Nacogdoches, Texas.

National Oceanic and Atmospheric Administration (NOAA). 2012. Tide tables 2012, east coast of North America, Charleston, SC. <http://tidesandcurrents.noaa.gov/map/>. Accessed 14 April 2014.

Paulus, S. L. and M. W. Weller. 1988. Social behavior and pairing chronology of mottled ducks during autumn and winter in Louisiana USA. Waterfowl in Winter. Symposium. University of Minnesota Press, Minneapolis.

Prevost, M. B., A. S. Johnson and J. L. Landers. 1978. Production and utilization of waterfowl foods in brackish impoundments in South Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 32:60–70.

Ricketts, C. E. 2011. Multi-scale analyses of habitat selection and demographic consequences for South Carolina clapper rails (*Rallus longirostris*), Georgia. Master's thesis, University of Georgia, Athens.

Rogers, K. B. and G. C. White. 2007. Analysis of movement and habitat use from telemetry data. Pages 625–676 *in* C. S. Guy and M. L. Brown, editors. Analysis and Interpretation of Freshwater Fisheries Data. American Fisheries Society, Bethesda, Maryland.

Schummer, M. L., H. M. Hagy, K. S. Fleming, J. C. Cheshier, and J. T. Callicutt. 2012. A guide to moist-soil wetland plants of the Mississippi Alluvial Valley. University Press of Mississippi, Jackson.

Shipes, J. C. 2014. Aspects of the ecology and management of mottled ducks in the Ashepoo, Combahee, and Edisto Rivers Basin South Carolina. Thesis. Mississippi State University, Starkville.

Smith, L. M., D. A. Haukos and R. M. Prather. 2004. Avian response to vegetative pattern in playa wetlands during winter. Wildlife Society Bulletin 32:474–480.

______, R. L. Pederson, and R. M. Kaminski. 1989. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock.

South Carolina Department of Natural Resources, (SCDNR) South Carolina Code of Laws. 2013. Marine Resources Act, Section 50-5-80.

Stutzenbaker, C. D. 1988. The Mottled Duck: Its Life History, Ecology, and Management. Texas Parks and Wildlife Department. Austin, Texas.

Thomas, D. L. and E. J. Taylor. 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54:322–330.

Varner, D. M. 2013. Habitat use, survival, and reproductive success of female Florida mottled ducks (*Anas fulvigula fulvigula*) using the Everglades Agricultural Area and urban habitats of south-eastern Florida, Auburn. Master's thesis. Auburn University, Auburn, Alabama.

Wehland, E. M. 2012. Survival and post-breeding habitat use of mottled ducks in the western gulf coast. Dissertation. Texas A&M University, Kingsville.

Weng, G. J. 2006. Ecology and population genetics of mottled ducks within the south atlantic coastal zone. Master's dissertation. University of Georgia, Athens.

Wilson, B. C. 2007. North American Waterfowl Management Plan, Gulf Coast Joint Venture: Mottled duck conservation plan. North American Waterfowl Management Plan, Albuquerque, New Mexico.

White, G. C. and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press. San Diego, California.

Yarris, G. S., M. R. McLandress, and A. E. H. Perkins. 1994. Molt migration of postbreeding female mallards from Suisun Marsh, California. Condor 96:36–45.

Zwank, P. J., P. M. McKenzie, and E. B. Moser. 1989. Mottled duck habitat use and density indices in agricultural lands. Journal of Wildlife Management 53:110–114.