Mottled Duck (*Anas fulvigula*) Movements in the Texas Chenier Plain Region

Jena A. Moon, *U.S. Fish and Wildlife Service, 1035 Buccaneer Drive, Winnie, TX 77665*

David A. Haukos, *U.S. Geological Survey, Kansas Cooperative Fish and Wildlife Research Unit, Kansas State University, 205 Leasure Hall, Manhattan, KS 66506*

Warren C. Conway,[1] *Stephen F. Austin State University, Box 6109, Nacogdoches, TX 75962*

Abstract: As a surrogate species for Strategic Habitat Conservation, the mottled duck (*Anas fulgivula*) is an indicator species to coastal marsh health and function. Currently, biologists have a relatively poor understanding of regional mottled duck movements. We outfitted adult female mottled ducks with solar satellite transmitters during summer 2009–2011. Movement patterns were measured among years and phenology, in relation to available habitat at the landscape level, and in association to potential disturbance. Movement distances were measured in ArcGIS and then evaluated using analysis of variance for independent variables of year, month, biological time period, and season. Average weekly distances traveled by mottled ducks were relatively short (<5,000 m) compared to other waterfowl. Movement occurrence and distance were linked to biological season with longest distances documented during the molt period. Movements also differed among years, with drought conditions associated with longer movement distances. Magnitude of movements may be an indicator of habitat quality for mottled ducks in the Texas Chenier Plain Region. By focusing on providing large freshwater pools and fresh/intermediate marsh during the molt period, managers could positively impact mottled ducks.

Key words: coastal marsh, life cycle, mottled duck, movement, Texas Chenier Plain, waterfowl

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Many studies have demonstrated that factors associated with waterfowl movements in the Gulf Coast Region include foraging needs, weather and rainfall patterns, and disturbance (Cox and Afton 1996, 2000; Lincoln et al. 1998; Link 2007; Gray 2010). Generally, movements by waterfowl occur as feeding events (Sugden 1973, Baldassare and Bolen 1984, Miller 1985, Cox and Afton 1996). However, factors other than foraging can influence movements of waterfowl, such as changing weather patterns (Jorde et al. 1984, Lovvorn 1994) and human disturbance near wetlands (Kahl 1991, Havera et al. 1992, Korschgen and Dahlgren 1992, Kenow et al. 2003). Unfortunately, little is known about the cumulative effect of resource availability and human disturbance on waterfowl within Gulf Coast habitats, particularly in temporal periods other than winter. Wetland management schemes, resource availability, and environmental factors vary among geographical areas of the Gulf Coast (Stutzenbaker 1988, USGS 1997, Davis 2012, Moon 2014); where disturbance (e.g., hunting, boating, agricultural practices, oil and gas exploration, etc.) may increase energy expenditure, decrease body condition, and alter movement patterns. Disturbance may be defined as any deviation from normal activity that may or may not have ecological and conservation relevance (Paulus 1988). These factors, in turn, may negatively affect survival and reproductive capacity of waterfowl (Kahl 1991, Havera et al. 1992, Korschgen and Dahlgren 1992, Mori et al. 2001, Fleskes et al. 2002, Kenow et al. 2003, Michot et al. 2006).

Information is needed to assist in strategic habitat conservation planning and improve conservation efforts for mottled ducks (*Anas fulvigula*) (USFWS 2012). Mottled ducks are year-long residents of Gulf Coast marshes, and timing of their movements among regional and local habitats is needed for conservation planning, habitat management, and development of effective monitoring programs (USFWS 2012). Data on movements will be particularly helpful if linked with habitat selection and survival models. Few data are currently available on mottled duck movements throughout their life cycle. Because mottled ducks are non-migratory, movement patterns inferred from other waterfowl species (particularly during winter) may not be reflective of mottled duck patterns and would be expected to be different from this typically sedentary species (Bielefeld et al. 2010).

Records of residence time in habitats and distances traveled among coastal and agricultural habitats by mottled ducks within the Chenier Plain Region of Texas are of interest to conservation planners and managers. Tracking species in coastal marsh systems can be exceedingly difficult due to access being restricted mainly to airboats, or aircraft, as few roads exist in Gulf coastal marsh systems, and travel on levees, pipelines, and other man-made struc-

1. Current address: Natural Resources Management, Texas Tech University, Box 42125, Lubbock, TX 79409

tures do not always provide dependable or reliable access for researchers to accurately locate animals using traditional telemetry methods (Carethers 2011). Platform Transverse Terminal (PTT) radio transmitters have many advantages over traditional Very High Frequency (VHF) radio telemetry technology, but the primary advantage is that satellite radios enable researchers to track animals over long distances and in remote or inaccessible areas (e.g., Miller et al. 2005, Haukos et al. 2006). These transmitters provide greater temporal coverage compared to VHF transmitters as they can be programmed to record locations during specific time periods (Microwave Telemetry, Inc., Columbia, Maryland). Due to the overall secretive nature of mottled ducks and limited access for tracking in their habitats, use of satellite PTT transmitters was an appropriate tool for measuring movements of this species.

Movement patterns may be more clearly examined as they relate to phenology, hunting and non-hunting periods, and habitat availability throughout the annual cycle. In general, mottled duck movements, distances traveled, and patterns are hypothesized to be dissimilar to congeners. Movement among years is suspected to vary due to variations in water availability on the landscape and climatic perturbations. Additionally, movements are suspected to vary based on phenology, with shorter distances being traveled during typical periods of nesting and brood rearing. High disturbance periods, such as those during the hunting season, were also suspected to increase movement distances traveled by mottled ducks. Dispersal events in the Chenier Plain of Lousiana have been recorded (Davis 2012); however, routes of travel, distances dispersed, and time spent in alternative habitats are currently unknown. Thus, our objective was to measure and compare mottled duck movement and dispersal patterns among years, biological time periods (i.e., pairing, breeding, brooding, molt), and periods of high disturbance using PTT transmitters on the upper Texas Gulf Coast.

Study Area

Our study area was comprised of the Chenier Plain Region of Texas (Texas Gulf Coast; east of Houston, Texas, to the Sabine River). This region lies within the Gulf Prairie and Marsh ecological region of Texas (Gould et al. 1960, Gossenlink et al. 1979). The area has a humid, subtropical climate, with a strong maritime influence. The area has an annual average precipitation of 137 cm, with a mean air temperature of 20 C, ranging from 0 to 39 C (NOAA, NCDS, Texas 1971–2000). The average growing season is 250 days, with infrequent freezes within the region (USFWS 2008). Wetland types across the Texas Chenier Plain include coastal marshes, forested wetlands, natural and man-made reservoirs, livestock ponds, open water bays, rivers, bayous, and other drainages (Moulton et al. 1997, Haukos et al. 2010).

Coastal marsh type is generally characterized by vegetation and salinity characteristics. These wetlands include saline (≥18 ppt), brackish (5–18 ppt), intermediate (0.5–5 ppt), and fresh (0–0.5 ppt) conditions (USFWS 2008). The majority of marshes within the study area were classified as intermediate or brackish (Haukos et al. 2010). Common vegetation in intermediate marsh included Olney bulrush (*Schoenoplectus americanus*), California bulrush (*S. californicus*), banana waterlily (*Nymphaea mexicana*), and seashore paspalum (*Paspalum vaginatum*) (Stutzenbaker 1999, USFWS 2008). Common vegetation in brackish marsh included saltmarsh bulrush (*Bolboschoenus rosbustus*), widgeon grass (*Ruppia maritima*), dwarf spikerush (*Eleocharis parvula*), and marshhay cordgrass (*Spartina patens*) (Stutzenbaker 1999, USFWS 2008).

Our research was conducted during 2009–2011, where annual rainfall for the study period and study area was derived by averaging rainfall from two remote automated weather stations; one on McFaddin NWR (FADT2) and one on Anahuac NWR (TR474). During 2009, annual rainfall averaged 124.3 cm and was considered representative of the long-term average. In 2010, moderate drought conditions followed the semi-wet fall and winter of 2009. Average annual rainfall for the region was 122.4 cm, slightly below the long-term average for the region (Texas Remote Automated Weather Station 2012). During 2011, severe drought conditions characterized the region, and Texas experienced its most significant recorded one-year drought event (Neilson-Gammon 2012). Average rainfall for the year was 76.2 cm, 44% below the 137 cm long-term average (Texas Remote Automated Weather Station 2012).

Methods

The Texas Chenier Plain National Wildlife Refuge Complex banding crew captured mottled ducks via night lighting from airboats during summer 2009, 2010, and 2011 under Bird Banding Laboratory permit #09072 and U.S. Fish and Wildlife Service Animal Care and Use guidelines. Capture dates ranged from early May to mid-August. To ensure that a representative population of mottled ducks inhabiting the Texas Chenier Plain Region was sampled, birds were captured during brooding and molt periods relative to their distribution among management units within Anahuac, McFaddin, and Texas Point NWRs. Sampling in this manner was necessary to incorporate the variability among birds within our sample frame. All birds were handled in accordance with the North American Bird Banding Manual (Gustafson et al. 1997).

Upon capture, mottled ducks were sexed, aged, and body mass (±5 g using a spring scale) (Carney 1992, Stutzenbaker 1988) was recorded. A U.S. Geological Survey numbered aluminum leg band was attached to each mottled duck. Each adult candidate female (those weighing >740 g) was fitted with a Model 100 solar/satellite PTT (Microwave Telemetry, Inc., Columbia, Maryland) backpack mounted dorsally between the wings. Each unit weighed 18 g and was attached with a 0.476 cm Teflon ribbon harness (Bally Ribbon Mills, Bally, Pennsylvania) that was custom fashioned to each female following Miller et al. (2005). All PTTs were attached immediately upon capture in the field, and all mottled ducks were held for less than one hour. If the candidate female had a brood, the brood was placed in a separate mesh bag for holding while the PTT was attached to the hen. Broods were released with hens following PTT placement, in an effort to reduce brood displacement or abandonment. During 2009 and 2010, PTTs were deployed with a duty cycle of 10 hours active and 72 inactive on a rotating window. The duty cycle for 2011 was changed to 10 hours active and 24 hours inactive. Each PTT was equipped with sensors to transmit information on unit temperature, battery voltage, and bird motion that were used to determine mortality events of marked mottled ducks. The Argos system was used to collect data on date, time, latitude, longitude, and location class (quality; LC) of each tagged female (http://www.argos-system.org/?nocache=0.26685971112391293). Multi-satellite service with standard and auxiliary location processing was used to monitor mottled duck locations. Because of potential impacts of capture myopathy (Dabbert and Powell 1993), data collection began 72 hours after radio-tagged birds were released. Thereafter, adult female mottled duck locations were recorded for ≥2 times each week for each radio-tagged bird until confirmed mortality, radio malfunction, transmitter failure, or the study ended.

To assess mottled duck movements, all LC 3 points (≤250 m error) were plotted in ArcGIS 9.3 (ESRI 2000) and weekly distances traveled were measured using Hawth's Tools (Beyer 2004). Minimum weekly distance traveled was estimated by measuring the distance between subsequent locations and averaging multiple measurement distances per week. Movement distances were only measured when locations were recorded for sequential transmission periods. For example, if a LC 3 location was not recorded for a 10-hr transmission period three days prior to the most current 10-hr transmission period, a movement distance was not estimated. Average weekly distances traveled were then compared using a factorial analysis of variance (ANOVA) among years, months, biological time period, and between hunting and non-hunting seasons ($\alpha = 0.05$; SAS Institute 1997). Biological time periods consisted of breeding/incubation (1 January–15 May), brooding (16 May–31 July), molt (1 August–15 September), and pairing (16 September–31 December) (Stutzenaker 1988, Rigby 2008, Bielefeld et al. 2010). Movements estimated for various biological time periods corresponded with traditional activities during those time periods for mottled ducks (Stutzenaker 1988, Rigby 2008, Bielefeld et al. 2010), where it was assumed that movements during specific biological windows reflected "normal" relative movement patterns. However, whether movements by marked mottled ducks were specifically related to breeding/nesting, brood rearing, molting, or searching for a mate was not verified. The mottled duck hunting season was closed for the first five days of the general waterfowl hunting season for all three years of the study. Specific hunting seasons for mottled ducks were 31 October–29 November 2009, 12 December 2009–24 January 2010, 30 October–28 November 2010, 11 December 2010–23 January 2011, 5 November–27 November 2011, and 10 December 2011–29 January 2012. Mottled duck hunt season closures occurred 5–9 November 2009, 30 October–4 November 2010, and 31 October–5 November 2011. Specific dates for the special early teal season were 12–27 September 2009, 11–26 September 2010, and 10–25 September 2011. When statistical differences ($P \leq 0.05$) were found in our evaluation of movement distances based on the analysis of variance main effects, we performed a least significant difference test on the main effect levels to identify which time periods had the greatest evidence of biological meaningful differences (SAS Institute 1997).

Results

A total of 2,287 individual one-way weekly movements were measured for 92 individuals 2009–2012. Movements were generally among coastal marsh and associated pasture habitats, with occasional inland movements (<50 km) to fresh water ponds and agricultural habitats (primarily rice). Minimum mean weekly distance traveled across all biological periods was 2.72 km (SE = 0.41), where the shortest one-way distance measured was 0.54 km and the longest was 35.25 km. The longest distance traveled within the study area was from western Anahuac NWR to rice production areas in northern Jefferson County. There were 10.6% and 1.3% of locations documented outside of the study area in Louisiana and Texas (Texas Mid-Coast between the cities of Houston and Corpus Christi), respectively. Dispersal for the study period was defined as a long-distance movement, from which a female did not return to the study area within one week. Common dispersal locations in Louisiana for marked females were Sabine NWR and wetlands/marshes in the Lake Charles, Louisiana, vicinity. Timing of movements from the study area varied, but movement primarily occurred during molt and pairing periods. Of the females that moved outside of the study area (11%), 30% returned within a three-month period. The longest dispersal distance overall was 93.76 km for 2009, 119.15 km in 2010, and 197.44 km in 2011.

Minimum weekly movement distance varied among years ($F_{3, 2287} = 3.24$, $P = 0.02$) and biological period ($F_{3, 2287} = 8.82$,

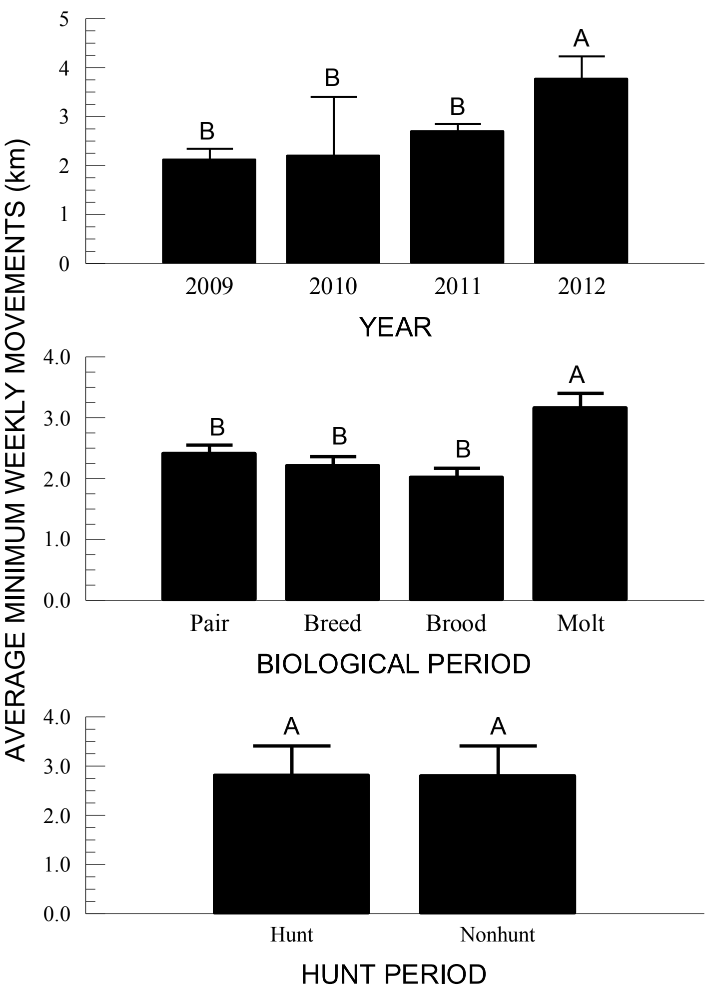

Figure 1. Comparisons of average mean weekly movements (km) among years (2009–2012), biological periods (breeding 1 January–15 May, brooding 16 May–31 July, molt 1 August–15 September, and pairing 16 September–31 December), and hunting vs. nonhunting periods for female mottled ducks with satellite PTT transmitters on the Chenier Plain of the upper Texas Gulf Coast. Means with the same uppercase letter do not differ ($P < 0.05$).

$P \leq 0.001$), although there was not a year * biological period interaction ($F_{6,2287} = 1.32$, $P = 0.25$). The average minimum weekly movement was 61% greater in 2012 than 2009–2011 (Figure 1). Movement distances were 43% greater during the molting period than the breeding, brooding, and pairing periods (Figure 1). Weekly movement distances were similar between hunting in the general waterfowl season and non-hunted periods ($F_{1,2287} = 0.00$, $P = 0.99$; Figure 1).

Discussion

Unsurprisingly, female mottled ducks moved comparatively less during nesting and brood-rearing periods than other periods, but greater distances traveled during the post-breeding molt period were noteworthy. Data from this study provide further support that movements during the breeding season are shorter both in length and duration than during other biological periods (Engeling 1950, Singleton 1953, Stutzenbaker 1988, Finger et al. 2003, Rigby 2008). Incubating females generally do not move great distances during incubation (Rigby 2008) and typically place nest sites in relatively close proximity to suitable brood rearing habitat (Stutzenbaker 1988, Finger et al. 2003). Both of these factors negate the need to exert energy through movements by incubating or care-giving female mottled ducks.

Movement estimates during the molt period indicate that mottled ducks potentially undergo a previously unreported short molt migration to wetland habitats suitable for molting (e.g., permanent, fresh water systems) when habitat conditions were not favorable within their established breeding range. Molt migration is commonly observed in latitudinal migrant waterfowl (Oring 1964, Salomonsen 1968, Davis et al. 1985, Abraham et al. 1999). Molt migration behavior would not be expected for breeding non-migratory waterfowl to move from areas that would theoretically have been potentially high quality brood habitat (i.e., high invertebrate production) to complete the similarly protein-intensive remigial molt (Bailey and Titman 1984, Dubowy 1985, Ringelman 1990). However, in addition to relocating to molting habitat, movements during this time period also correspond to the end of brooding and dispersal events (Rigby 2008, Davis 2012). Movements during this temporal window may have also been linked to searching for potentially available habitats during this biological period, as coastal marsh decreases in availability and mottled ducks used habitats with the greatest salinities during this period (Moon 2014). Therefore, the molt biological period is the period of greatest movements, but measured movements may not all be related to molting activities.

Maximum one-way distances traveled by adult female mottled ducks in the Texas Chenier Plain NWR Complex were markedly shorter (average 46%) than maximum distances documented in Louisiana (Davis 2012). The maximum mean weekly distance traveled during this study was 35.3 km, whereas maximum mean distances traveled by female mottled ducks in Louisiana varied among years and were 44.0 km in 2007, 105.5 km in 2008, and 81.2 km in 2009 (Davis 2012). Differences in mottled duck movements between states is likely related to the relatively smaller amount of available habitat in coastal marshes in the Chenier Plain of Texas as compared to Louisiana (Moon 2014). Coastal marsh in Texas is characterized by greater fragmentation and considerably less breadth on the landscape compared to Louisiana (Gosselink et al. 1979, USGS 1997); thus, mottled ducks are much more restricted in terms of area of available habitat in Texas, limiting their movements to much smaller habitat patches than available in Louisiana.

Previous research has indicated a high rate of movement by mottled ducks from Texas to Louisiana between banding and harvest (USFWS 2012), as band recovery data indicate more Texas-marked mottled ducks are harvested in Louisiana than vice versa. In fact, approximately 30% of recovered birds marked in Texas are harvested in Louisiana (mostly male recoveries), whereas only 1.6% of Louisiana marked individuals are recovered in Texas (USFWS 2012). Davis (2012), who tracked movements of female mottled ducks in both Texas and Louisiana, indicated that the overall tendency to move between states was low, only ranging from 2.3%–4.4%. In contrast, our results indicates a greater rate of movement of female mottled ducks from Texas to Louisiana with >10% of all locations occurring in Louisiana. Both banding results and the movement data herein suggest there is disproportionate late summer–fall movement of mottled ducks from Texas to eastern portions of the Chenier Plain Region in Louisiana. These movements typically occur during the defined molting period. We hypothesize that these movements are driven by mottled ducks attempting to avoid habitats of reduced quality (i.e., increasing salinity) in Texas during this period (Moon 2014). Coastal Louisiana, on average receives 16 cm more annual rainfall than coastal Texas (Stutzenbaker 1988, National Weather Service 2013) and supports approximately double the area of coastal marsh than Texas (USGS 1997). Thus, it is certainly plausible that as habitat conditions degrade during late summer in Texas, mottled ducks possess the ability to engage in movements to remove them from potentially deleterious habitat conditions when strategically necessary.

Other forms of disturbance such as hunting have been considered to be factors in elevating frequency of movements and distance(s) traveled, particularly during winter (Lima 1986, Afton and Anderson 2001, Fleskes et al 2002, Peron et al. 2012). Coupled with finding and acquiring food, distribution of food resources and other forms of disturbance have been frequently cited as influencing movements and habitat use for some waterfowl species (Jorde et al. 1984, Madsen 1998). However, the mottled duck hunt season overlaps not only with the general duck and goose hunting seasons, but mottled ducks are also present on the landscape during the early teal season and alligator (*Alligator mississippiensis*) season. Disturbance associated with human activity may affect mottled duck movements and subsequent survival by increasing frequency and duration of movements and availability for hunter harvest or even predation (Lima 1986, Afton and Anderson 2001, Anteau and Afton 2004, St. James 2011, Peron et al. 2012). We did not document weekly movements that differed between hunt and nonhunt periods of the general waterfowl season. This was likely due to limited hunting opportunity and availability of refugia contiguous to hunt areas on NWRs, which enabled mottled ducks to escape disturbance related to hunting without extensive movements.

In addition to movements of mottled ducks in fragmented and highly disturbed areas of Texas (e.g., Anahuac NWR) being reduced, as habitat quality decreases, mottled ducks will likely exhibit a decrease in body mass compared to birds of less fragmented habitats (e.g., McFaddin NWR; Haukos et al. 2001). Reduction in body condition in relation to habitat quality has been demonstrated in other waterfowl (e.g., northern pintail [*Anas acuta*]; Moon and Haukos 2006), Thus, habitat fragmentation of coastal marsh in the Texas Chenier Plain restricts the ability of mottled ducks to exploit quality habitat, reducing body condition, which may be a factor negatively influencing individual fitness (USFWS 2012).

The effect of climatic events and other large scale climatic perturbations on mottled duck populations to date has been largely unmeasured. While this study failed to document any differences in movement patterns due to tropical storms, one year was categorized by severe drought. Our findings were similar to Davis (2012) and adult females were documented to travel longer distances in dry years when compared with average or wet years. This was likely due to the general lack of wetland availability in the Texas Chenier Plain Region during dry periods. Almost 60% fewer hectares of wetlands were available in late 2011–early 2012 to mottled ducks compared to the driest period in 2009 or 2010 (Moon 2014).

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Literature Cited

Abraham, K. F., J. O. Leafloor, and D. H. Rusch. 1999. Molt migrant Canada geese in northern Ontario and western James Bay. Journal of Wildlife Management 63:649–655.

Afton, A. D. and M. G. Anderson. 2001. Declining scaup populations: a retrospective analysis of long-term population and harvest survey data. Journal of Wildlife Management 65:781–796.

Anteau, M. J. and A. D. Afton. 2004. Nutrient reserves of lesser scaup during spring migration in the Mississippi Flyway: a test of the spring condition hypothesis. Auk 121:917–929.

Bailey, R. O. and R. D. Titman. 1984. Habitat use and feeding ecology of postbreeding redheads. Journal of Wildlife Management 48:1144–1155.

Baldassarre, G. A. and E. G. Bolen. 1984. Field feeding ecology of waterfowl wintering on the Southern High Plains of Texas. Journal of Wildlife Management 48:63–71.

Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. http://www.spatialecology.com/htools.

Bielefeld, R., M. G. Brasher, T. E. Moorman and P. N. Gray. 2010. *In* A Poole, editor: Mottled duck (*Anas fulvigula*), The Birds of North America Online. Cornell Lab of Ornithology. Ithica, New York. Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/081doi:10.2173/bna.81.

Carethers, B. 2011. The use of corridors by meso-predators on the upper Texas Gulf Coast. Master's thesis. Texas State University, San Marcos.

Carney, S. M. 1992. Species, age, and sex identification of ducks using wing plumage. U.S. Department of the Interior, Washington, D.C.

Cox, R. R. and A. D. Afton. 1996. Evening flights of female northern pintails from a major roost site. Condor 98:810–819.

_____ and _____. 2000. Predictable interregional movements by female northern pintails during winter. Waterbirds 23:258–-269.

Dabbert, C. and K. Powell. 1993. Serum enzymes as indicators of capture myopathy in mallards (*Anas platyrhynchos*). Journal of Wildlife Diseases 29:304–309.

Davis, B. E. 2012. Habitat use, *movement*s, and ecology of female mottled ducks on the Gulf Coast of Louisiana and Texas. Ph.D. dissertation, Louisiana State University, Baton Rouge.

Davis, R. A., R. N. Jones, C. D. MacInnes, and A. J. Pakulak. 1985. Molt migration of large Canada geese on the west coast of Hudson Bay. Wilson Bulletin 97:296–305.

Dubowy, P. J. 1985. Feeding ecology and behavior of postbreeding male blue-winged teal and northern shovelers. Canada Journal of Zoology 63:1292–1297.

Dugger, B. D. 1997. Factors influencing the onset of spring migration in mallards. Journal of Field Ornithology 68:331–337.

Engeling, G. A. 1950. Nesting habits of the mottled duck in Colorado, Fort Bend and Brazoria Counties, Texas. M.S. thesis. Texas A&M University, College Station.

ESRI. 2000. ArcGIS 9.2. ESRI Press. Redlands, California.

Finger, R. S., B. M. Ballard, M. T. Merendino, J. P. Hurst, D. S. Lobpries, and A. M. Fedynich. 2003. Habitat use, movements and survival of female mottled ducks and ducklings during brood rearing. Texas Parks and Wildlife Department, Austin.

Fleskes, J. P., R. L. Jarvis, and D. S. Gilmer. 2002. Distribution and movements of female northern pintails radiotagged in San Joaquin Valley, California. Journal of Wildlife Management 66:138–152.

Gossenlink, J. G., C. L. Cordes, and J. W. Parsons. 1979. An ecological characterization study of the Chenier plain coastal ecosystem of Louisiana and Texas. 3rd Volume. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Office of Biological Services. Slidell, Louisiana. USFWS/OBS-78/9 through 78/11.

Gould, F. W., G. O. Hoffman, and C. A. Rechenthin. 1960. Vegetational Areas of Texas. Texas A&M University, Texas Agricultural Experiment Station Leaflet 492. College Station.

Gray, J. M. 2010. Habitat use, movements, and migration chronology and corridors of female gadwalls that winter along the Louisiana Gulf Coast. M.S. thesis. Louisiana State University, Baton Rouge.

Gustafson, M. E., J. Hildenbrand and L. Metras. 1997. The North American Bird Banding Manual (Electronic Version). Version 1.0.

Havera, S. P., L. R. Boens, M. M. Georgi, and R. T. Shealy. 1992. Human disturbance of waterfowl on Keokuk Pool, Mississippi River. Wildlife Society Bulletin 20:290–298.

Haukos, D. A., S. Martinez, and J. Heltzel J. 2010. Characteristics of ponds used by breeding mottled ducks on the Chenier Plain of the Texas Gulf Coast. Journal of Fish and Wildlife Management 1:93–101.

_____, M. R. Miller, D. L. Orthmeyer, J. Y. Takekawa, J. P. Fleskes, M. L. Casazza, W. M. Perry, and J. A. Moon. 2006. Spring migration of northern pintails from Texas and New Mexico, USA. Waterbirds 29:127–136.

Jorde, D. G., G. L. Krapu, R. D. Crawford, and M. A. Hay. 1984. Effects of weather on habitat selection and behavior of mallards wintering in Nebraska. Condor 86:258–265.

Kahl, R. 1991. Boating disturbance of Canvasbacks during migration at Lake Poygan, Wisconsin. Wildlife Society Bulletin 19:242–248.

Kenow, K. P., C. E. Korschgen, J. M. Nissen, A. Elfessi, and R. Steinbach. 2003. A voluntary program to curtail boat disturbance to waterfowl during migration. Waterbirds 26:77–87.

Korschgen, C. E., L. S. George, and W. L. Green. 1985. Disturbance of diving ducks by boaters on a migrational staging area. Wildlife Society Bulletin 13:290–296.

Lima, S. L. 1986. Predation risks and unpredictable feeding conditions: determinants of body mass in birds. Ecology 67:77–385.

Lincoln, F. C., S. R. Peterson, and J. L. Zimmerman. 1998. Migration of birds. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Washington, D.C. Circular 16. Jamestown, North Dakota: Northern Prairie Wildlife Research Center Online. www.npwrc.usgs.gov/resou rce/birds/migratio/migratio.htm(Version 02APR2002).

Link, P. T. 2007. Survival, habitat use, and movements of female mallards wintering in southwestern Louisiana. M.S. thesis, Louisiana State University, Baton Rouge.

Lovvorn, J. R. 1994. Nutrient reserves, probability of cold spells, and the question of reserve regulation in wintering canvasbacks. Journal of Animal Ecology 63:11–23.

Michot, T. C., M. C. Woodin, S. E. Adair, and E. B. Moser. 2006. Diurnal time-activity budgets of redheads (*Aythya americana*) wintering in seagrass beds and coastal ponds in Louisiana and Texas. Hydrobiologia 567:113–128.

Miller, M. R. 1985. Time budgets of northern pintails wintering in the Sacramento Valley, California. Wildfowl 36:5–-64.

_____, J. Y. Takekawa, J. P. Fleskes, D. L. Orthmeyer, M. C. Casazza, W. M. Perry. 2005. Spring migration of northern pintails with satellite telemetry from California's Central Valley wintering area tracked with satellite telemetry: routes, timing, and destinations. Canadian Journal of Zoology 83:1314–1332.

Moon, J. A. 2014. Mottled duck (*Anas fulvigula*) ecology in the Texas Chenier Plain Region. Ph.D. dissertation. Stephen F. Austin State University, Nacogdoches, Texas.

Mori, Y., N. S. Sodhi, S. Kawanishi, and S. Yamagishi. 2001. The effects of human disturbance and flock composition on the flight distances of waterfowl species. Journal of Ethology 19:115–119.

Moulton, D. W., T. E. Dahl, and D. M. Dall. 1997. Texas coastal wetlands: status and trends, mid-1950s to early 1990s. U.S. Department of the Interior, Fish and Wildlife Service, Albuquerque, New Mexico.

National Oceanic and Atmospheric Administration, NCDS, Texas.http://cdo.ncdc.noaa. gov/climatenormals/state-pdf/tx.pdf.

National Weather Service. 2013. accessed online: http://www.weather.gov/.

Oring, L. W. 1964. Behavior and ecology of certain ducks during the postbreeding period. Journal of Wildlife Management 28:223–233.

Paulus, S. L. 1988. Time-activity budgets of nonbreeding Anatidae: a review. Pages 135–152 *in* M. W. Weller, editor: Waterfowl in Winter. University of Minnesota Press, Minneapolis.

Peron, G., C. A. Nicolai, and D. N. Koons. 2012. Demographic response to perturbations: the role of compensatory density dependence in a North American duck under variable harvest regulations and changing habitat. Journal of Animal Ecology 81:960–969.

Randall, L. A., R. H. Diehl, B. C. Wilson, W. C. Barrow, Jr., and C. W. Jeske. 2011. Potential use of weather radar to study movements of wintering waterfowl. Journal of Wildlife Management 75:1324–1329.

Rigby, E. A. 2008. Recruitment of mottled ducks (*Anas fulvigula*) on the upper Texas Gulf Coast. M.S. thesis. Texas Tech University. Lubbock.

Salomonsen, F. 1968. The moult migration. Wildfowl 19:5–24.

SAS Institute. 1997. SAS/STAT software: changes and enhancements. Release 6.12. SAS Institute, Cary, North Carolina.

Singleton, J. R. 1953. Mottled duck studies. Texas Coastal Waterfowl Survey. Federal Representative Service, Number 11. Texas Game and Fish Commission.

St. James, E. 2011. Effect of hunting frequency on duck abundance, harvest, and hunt quality in Mississippi. M.S. thesis. Mississippi State University, Starkville.

Stutzenbaker, C. D. 1988. The mottled duck, its life history, ecology and management. Texas Parks and Wildlife Department. Austin.

_____. 1999. Aquatic and wetland plants of the Western Gulf Coast. Texas Parks and Wildlife Press. Austin.

Sugden, L. G. 1973. Feeding ecology of pintail, gadwall, American widgeon, and lesser scaup ducklings in southern Alberta. Canada Wildlife Service Report No. 24. Ottawa, Canada.

Texas Remote Automated Weather Station. 2012. http://raws.wrh.no aa.gov/cgibin/roman/ meso_base.cgi?stn =FADT2.

U.S. Fish and Wildlife Service (USFWS). 2008. Texas Chenier Plain Refuge Complex: Final Environmental Impact Statement, Comprehensive Conservation Plan, and Land Protection Plan. Department of the Interior, Fish and Wildlife Service, Albuquerque, New Mexico.

U.S. Fish and Wildlife Service (USFWS). Mottled Duck Focal Species Plan. U.S. Fish and Wildlife Service, Regional Migratory Bird Office, Albuquerque, New Mexico.

U.S. Geological Survey. 1997. Coastal wetlands and global climate change: Overview. USGS Fact Sheet FS-089-97. Lafayette, Louisiana.