Nesting ecology of Mottled Ducks *Anas fulvigula* in interior Florida, USA

BRUCE D. DUGGER[1], RICHARD FINGER[2,4] & STEFANI L. MELVIN[3,5]

[1]Department of Fisheries and Wildlife, Oregon State University, 104 Nash Hall, Corvallis, Oregon, USA.
E-mail: bruce.dugger@oregonstate.edu
[2]MacArthur Agro-Ecology Research Center, Lake Placid, Florida, USA.
[3]South Florida Water Management District, West Palm Beach, Florida, USA.
[4]Washington Department of Fish and Wildlife, 1550 Alder St., Ephrata, WA, USA.
[5]U. S. Forest Service, Salmon-Challis National Forest, 1206 S. Challis St. Salmon, Idaho, USA.

Abstract

Little is known about the breeding biology of Mottled Ducks *Anas fulvigula* that occupy the interior portions of Florida, USA. During 1997–1999, radio-transmitters were attached to 82 female Mottled Ducks to locate and characterise nest sites, and to estimate nesting propensity, clutch size, nest success and season-specific adult survival. Mean nest initiation date (n = 25) occurred relatively early in the wet year compared to the dry year. Vegetation height at nests averaged 68.8 ± 6 cm, modal canopy cover was 100% and mean distance of nests from water was 188 ± 41 m. Vegetation characteristics at nests were similar to those reported in other parts of the species range, but dominant plant species differed and nests were located farther from water than previously reported. Modal clutch size was 10 eggs (range = 7–14) and nest success for all years combined was 0.095 (95% C.I. = 0.032–0.268). Survival estimates for adult females during a 15-week interval (26 February to 10 June) were 0.902 ± 0.016 in 1998 and 0.879 ± 0.016 in 1999. Nesting propensity (22–50%) and nest success were the lowest reported for Mottled Ducks.

Key words: *Anas fulvigula*, breeding ecology, Florida, Mottled Duck, nesting ecology, nest success, survival.

The Mottled Duck *Anas fulvigula* is a year-round resident along coastal stretches of Texas, Louisiana, Alabama and Mississippi and on coastal and interior portions of peninsular Florida, USA (Moorman & Grey 1994). Although a hunted species, habitat loss and recent hybridization with feral Mallards *Anas platyrhynchos* threaten the status of the Mottled Duck, particularly in Florida, whose population is largely isolated from the larger population of birds that occupy the other Gulf Coast states. Conservation and harvest management plans in Florida would benefit from a better understanding of Mottled Duck biology and population demographics.

Little is known about the nesting ecology of the Mottled Duck in Florida compared to the population that occurs in Texas and Louisiana (Moorman & Gray 1994). The largest study in Florida reported data collected on coastal islands created by deposits of spoil material during dredging activities, a unique and uncommon habitat (Stieglitz & Wilson 1968). However, most Mottled Ducks in Florida breed in interior portions of the state (Johnson *et al.* 1991), an area dominated by cattle ranches, dairies and river drainages and remnant grasslands, so an estimate of nest success from protected islands on the coast is not applicable to the larger population. The only published data from interior Florida reported on a sample of only five nests (Beckwith & Hosford 1957). Studies of Mottled Duck in Texas indicate nests are most commonly found in cordgrass *Spartina* sp. prairie (Stutzenbaker 1988). Cordgrass is not common in many parts of central Florida, and native prairie habitat has been largely replaced by agricultural land. Furthermore, Florida has habitats not found in other range states (*e.g.* citrus groves). Thus, information about plant species composition and structure around nests from Texas and Louisiana may not be applicable to Mottled Duck in Florida.

Most information on nest placement throughout the species' range has come from studies that used nest dragging techniques (*i.e.* two or more people pulling a long piece of rope between them) to flush incubating females and locate nests. While an excellent tool for locating nests, efforts to characterise nesting habitat or estimate productivity using this technique may be biased by researchers selecting habitats to search based on their impression of what is suitable (Arnold *et al.* 1993). Radio-tagging females is an alternate technique for trying to describe nesting habitat and estimate productivity and it has the advantage of providing data for calculating season-specific adult survival. In this study, we used radio-telemetry to locate nests, describe nest site characteristics, and to estimate nest propensity, clutch size, nest success, and season-specific survival for female Mottled Ducks in interior Florida.

Methods

Study area and conditions

Research was conducted in Okeechobee and Highland County, Florida. Our study area was located north of the town of Okeechobee (27°15'N, 80°50'W) and roughly bordered by the Kissimmee River on the west, Highway 70 in the south, Highway 15 on the east and County Road 724 on the north. Flowing south from Lake Kissimmee into Lake Okeechobee, the once meandering Kissimmee River was channelised into a box-shaped canal and divided by a series of locks and dams into five reservoir-like pools (Koebel 1995). Because of channeling the river, the extensive floodplain marshes dried out, and except for remnant wetlands, land use was similar to areas outside the floodplain.

Historically, areas outside the floodplain were dominated by grassland/Saw Palmetto *Serenoa repens* prairies, Live Oak *Quercus virginiana*–Cabbage Palm *Sabal palmetto* hammocks and palustrine emergent wetlands. At the time of this study, the uplands on the study site were used primarily for cattle grazing, dairy farming and citrus production. Native prairie grasses have been replaced with forage grasses (*e.g.* Bahia Grass *Paspalum notatum*). Many natural wetlands that vary in size, permanence, and vegetation cover remain throughout the site. Human activities have added drainage ditches, water retention ponds associated with citrus and dairy operations, and dugout basins for watering cattle.

As an index of wetland conditions during each breeding season, deviation between 12-month total rainfall preceding April and the long-term (30-year) average for the same period was calculated each year. The deviation of mean monthly temperature (summed for February, March and April) from the long-term average was used to describe spring temperature patterns. Negative values indicated years that were cooler than average, whereas positive values indicated years that were warmer. Weather data were obtained from a South Florida Water Management District recording station located on the study area.

Capture and marking

Trapping occurred during 1 March–28 April in 1997, 20 February–16 March 1998 and 7 January–22 March in 1999, and birds were caught using decoy traps baited with game-farm female Mallard (Sharp & Lokemoen 1987). Paired females were targeted, but small groups of paired birds sometimes occurred together, particularly during January and February prior to most pairs being spatially isolated. Decoy trapping during the January–February period therefore was not necessarily focused on nesting pairs.

Radio-transmitters were implanted subcutaneously (in 1997–1999) or intra-abdominally (in 1999 only) in all captured females using the procedures described by Korshchgen *et al.* (1996) and Olson *et al.* (1992), respectively. Subcutaneous transmitters (Holohil model RI 2B) averaged 9.5 g and intra-abdominal transmitters (Holohil model RI 2CH) averaged 14 g. In 1999, we alternated implanting captured females with subcutaneous (n = 20) and intra-abdominal (n = 24) transmitters. All transmitters were equipped with a mortality switch that changed the transmitter's pulse frequency 24 h after a bird died allowing us to detect mortalities. Most birds were released 15–30 min after completion of surgery and usually within three hours of capture. Birds caught before dark were released the following morning. All birds were released from where they were captured. Any male caught with a female was released with the female. The first four days after release were considered an adjustment period (Cox & Afton 1998), and those data were not used in survival estimation.

Data collection

Birds were tracked using hand-held, truck- or plane-mounted four-element Yagi antennas. Attempts were made to locate each bird at least once per day and all birds were found at least once per week. Whenever possible, first nest visits were made during early incubation (indicated when telemetry triangulation located a female in the same upland area on several consecutive days and repeatedly during a day). During the first visit to each nest the following were recorded: the three most common plant species that occurred within 0.5 m of the nest (based on percent cover); maximum height (cm) of the dominant plant species (both live and dead); canopy cover above the nest bowl (estimated by looking down on the nest bowl from above as < 5%, 5–25%, 26–50%, 51–75%, 76–99%, 100%); distance from the nearest water (m); and incubation stage determined by candling (Weller 1956). If a nest was found during the laying period, it was visited again during early incubation to record final clutch size. Once final clutch size was determined, we used telemetry to confirm that a female was still incubating at least once every three days, but did not physically revisit the nest until after the female left with the brood or when telemetry suggested that the nest had failed. Nests were classified as successful (at least one egg hatched) or failed. Failed nests were classified as depredated, destroyed by agricultural practices, abandoned or unknown. Nests abandoned within one day after our first visit to the nest were attributed to researcher disturbance. Our nest visitation rate was below that found to affect nest success rates in other studies (Esler & Grand 1993).

Data analysis

Nesting propensity was defined as the proportion of radio-tagged females that attempted at least one nest within the study area during each breeding season. The population of Mottled Ducks on our study area fluctuated among and within years (B. Dugger pers. obs.) as wetland conditions fluctuated in response to precipitation patterns. Our estimate of breeding propensity included only those birds that remained on our study area during the breeding season (*i.e.* if a bird left prior to what we defined as the 'nesting season', see below, we omitted it from our study). Because some radio-tagged birds left the study area prior to or during the period of nest initiation (particularly in 1999 when trapping started in January), using all captured females to calculate nesting propensity would negatively bias estimates. Consequently, nesting propensity is reported as a range: the lower estimate uses females known to be on the study area one month prior to the first known nest initiated by a radio-tagged female, and the upper estimate uses only females that stayed on the study area during the entire period that nests were initiated.

Nest initiation date was calculated for each nest by back-dating from the number of eggs in the nest (if a nest was found whilst the female was still laying) and assuming that females laid one egg per day, or by back-dating from the incubation stage determined during the first nest visit by candling (Weller 1956) and the clutch size. Only first nests were used to calculate mean clutch size. The analysis of nest success included all nests (*i.e.* first nests and re-nests) and was based on the accumulation of exposure days from the first day a nest was found until it either failed or was successful

(Mayfield 1975; Johnson 1979). If a nest was abandoned immediately after our first visit, we attributed that to researcher activity and excluded it from nest success calculations. Although use of telemetry increased the probability of finding every nest, we used a Mayfield estimator because we felt the probability of detecting a nest was not 1.0. We estimated adult female survival for the interval 26 February–10 June. Analysis included birds that nested and those that did not. Kaplan–Meier known-fate estimation procedures that allowed for staggered entry of individuals into the study were used to estimate adult female survival (Pollock *et al.* 1989).

Results

Compared to the 30-year average (128 cm), the total 12-month rainfall preceding April was –30 cm in 1997, +27 cm in 1998 and –79 cm in 1999. The sum of temperature deviations for February, March and April differed to the 30-year average by + 4.1° C in 1997, –1.6° C in 1998 and –0.5° C in 1999.

In 1997, 13 female Mottled Duck were trapped and tagged, with 25 in 1998 and 44 in 1999. Mean body mass of our radio-tagged birds was 898 g (s.e. ± 20) in 1997, 893 g (s.e. ± 10) in 1998 and 867 g (s.e. ± 10) in 1999. No mortalities occurred the first week after radio-tagged birds were released. Three birds left the study area within one week of being released in 1997, zero in 1998 and four in 1999. For estimating nesting propensity, ten (77%) females remained on the study area until at least one month prior to the first nest initiation date in 1997, 25 (100%) remained in 1998 and 18 (41%) remained in 1999. Six (46%) females remained throughout the nest initiation period in 1997, 16 (64%) in 1998 and 15 (34%) in 1999. In 1999, 55% of females with subcutaneous transmitters remained compared to 42% of females with intra-abdominal transmitters. Only females with subcutaneous transmitters initiated nests on the study area in 1999. Nesting propensity was 0.30–0.50 in 1997, 0.36–0.56 in 1998 and 0.22–0.27 in 1999.

A total of 17 nests initiated by radio-tagged females and eight nests initiated by non-radio-tagged females were located during the three project years. Of these, 17 were first visited during incubation and eight during laying. Excluding known re-nesting attempts, the mean nest initiation date was 28 April (95% C.I. = 12 April–14 May) in 1997, 31 March (18 March–13 April) in 1998 and 20 May (9 May–31 May) in 1999 (Table 1). The range for all nests in all years combined was 31 January to 4 July. Based on the lack of overlap of 95% confidence intervals, nest initiation was significantly earlier in the wet year (1998) compared to the dry year (1999). Modal clutch size for first nests initiated by radio-tagged females was 10 eggs (range = 7–11, n = 10). Modal clutch size for first nests initiated by both radio-tagged and all nests of non-radio-tagged birds was also 10 eggs (range = 7–14, n = 16).

Mottled Ducks nested in hayfields (n = 14), cattle pastures (n = 9), native prairie (n = 1), and a fallow vegetable crop field (n = 1). Fifteen nests were located in ungrazed fields and ten in grazed. However, five of the nests located in grazed fields were in habitat patches protected from

Table 1. Nest site characteristics and select reproductive parameters for Mottled Ducks nesting in south-central Florida, 1997–99. Values reported as mean ± s.e. (*n*) or mean (95% C.I.).

	Year			
Parameter	**1997**	**1998**	**1999**	**Combined**
Nest initiation date[a]	118 ± 6 (5)	90 ± 9 (13)	140 ± 3 (4)	–
Clutch size	9.5 ± 0.5 (4)	10.0 ± 0.6 (9)	8.0 ± 0.6 (3)	9.5 ± 0.4 (16)
Daily nest survival	0.9178 ± 0.0321	0.9257 ± 0.0198	0.9491 ± 0.0286	0.9349 ± 0.0141
Nest success rate[b]	0.050 (0.004–0.531)	0.067 (0.015–0.291)	0.160 (0.018–1.25)	0.0946 (0.032–0.268)
Vegetation height	95.8 ± 13.4 (6)	55.5 ± 6.0 (14[c])	75.0 ± 7.4 (4)	68.8 ± 6.0 (24)
Distance to water	303 ± 128 (6)	113 ± 26 (15)	300 ± 24 (4)	188 ± 41 (25)

[a]Julian date (excludes known re-nests).
[b]For the 35-day nesting period (*i.e.* laying of a 10 egg clutch + 25 day incubation period).
[c]One nest was mowed before vegetation could be measured.

grazing (*e.g.* a small area around a culvert fenced to protect against cattle damage). Nests were generally well concealed from above: 10 (42%) nests had canopy coverage of 100%, six (25%) were 76–99% covered, four (16%) were 51–75% covered and four (16%) were 26–50% covered. Height of live vegetation at nests averaged 68.8 cm (range = 30–120, Table 1). Planted pasture grasses like Bahia Grass were the most common plants, occurring at 72% of nests, and were the dominant plants at 62%. However, birds did choose a diverse array of sites. One nest was located in a small (*c.* 6 m diameter) Sand Blackberry *Rubus cuneifolius* patch located in an intensively grazed pasture (grass < 3 cm tall). Additional plants recorded as dominants at nests included sedges *Carex* sp. (25%), Wire Grass *Aristida stricta* (25%), Saw Palmetto *Serenoa repens* (25%), Dog Fennel *Eupatorium capillifolium* (8%), oak *Quercus* sp. (8%), and Soda Apple *Solanum viarum* (4%). Dead vegetation occurred at only six nests; average height when present was 47.3 ± 10.3 cm. One nest was perched on dense, matted grass 20 cm above the ground. Mean distance of nests from water was 188 m (range = 10–860 m, Table 1).

Twenty-one of 25 nests failed. Depredation was the main factor (62%) followed by haying activities (24%), unknown (9%), and abandonment attributed to researcher activity (5%). Combining years, daily nest survival was 0.935 (s.e. ± 0.014), which translated to a nest success estimate for the 35-day nesting period (modal clutch size from this study plus a 25 day incubation period; Moorman & Gray 1994) of 0.095 (95% C.I. = 0.032–0.268). Two females re-nested. One bird laying when caught on 1 May abandoned her nest attempt and re-nested on 30 June. The second bird re-nested twice with 14 days between both re-nests.

Sample size was not sufficient to estimate adult female survival in 1997. Two birds died during 1998 and three birds during 1999. One bird in 1998 was killed during incubation and the condition of the carcass suggested an avian predator. The other deaths were non nesting females. Survival rates for the 15-week interval from 26 February to 10 June were 0.902 (s.e. ± 0.016) in 1998 and 0.879 (s.e. ± 0.016) in 1999.

Discussion

Structural characteristics of vegetation at nests were similar to those identified in coastal Florida (Steiglitz & Wilson 1968), Texas (Stutzenbaker 1988) and Louisiana (Durham and Afton 2003). Nests were placed predominantly in dense vegetation, usually with complete or near complete overhead cover. Dominant plant species differed from other studies, but grasses still predominated. Mottled Ducks placed nests in a variety of cover types indicating they will use a range of upland habitats including heavily grazed pasture if small areas of suitable cover are available (*e.g.* a blackberry patch). However, when nests were located in small remnant patches of habitat in an otherwise intensely grazed landscape; the nests were likely more vulnerable to predators. Mean distance of the nests from water (188 m) was similar to that reported for nests in Louisiana (185 m, range = 14–713 m; Durham & Afton 2003), but farther than nests in Texas (119 m, range = 15–219 m; Stutzenbaker 1988). More than 30% of our nests were located farther from water than nests in Texas.

Nests were commonly placed in hayfields associated with dairy farms. These fields were mowed periodically to provide forage for cows. The interval between mowing varied, but it was typically long enough to allow a female Mottled Duck to establish and successfully incubate a nest if birds began to nest as soon as cover characteristics became suitable. Nests established later, when grass height was close to the mean we report in our study, commonly were destroyed by mowing, suggesting dairies have some qualities that might make them ecological traps for Mottled Ducks.

Modal clutch size was 10 eggs, similar to that for females along the Florida coast (Steiglitz & Wilson 1968), in Texas (Stutzenbaker 1988) and in Louisiana (Baker 1983). Our estimate of nest success (9.5%) is considerably lower than the 77% (apparent nest success estimate) reported from spoil islands along the Florida coast (Steiglitz & Wilson 1968) and lower than recent, unpublished, estimates of 32% for interior habitats in east-central Florida and 41% in south Florida calculated using equations similar to this study (R. Bielefeld unpubl. data). Regional differences in nest success in Florida may be related to landscape features that influence predator abundance and nest searching efficiency. Nest success estimates from Texas and Louisiana have varied among studies, but our estimate was in the low end of that range (6–30%; Stutzenbaker 1988; Holbrook 1997; Durham & Afton 2003).

We do not believe that low nest success is an artifact of researcher activity. Research protocols like those we used are known to increase desertion rates in Mallard, but that same study indicated it did not expose nests to greater predation risk (Thorn *et al.* 2005). Although no special effort was made to identify nest predators, most evidence pointed toward mammals (*e.g.* nest canopy concealment not disturbed, egg shells scattered around the nest in cover, some eggs missing entirely) and on one occasion, a Raccoon *Procyon lotor* was observed destroying a nest. The point estimate of nest success (9.5%) was below the threshold reported as necessary (15%) to sustain temperate nesting Mallard populations (although the 95% C.I. included 15%, Cowardin *et al.* 1985). However, without estimates for other key population parameters, the implication of our nest success estimate on Mottled Duck population dynamics in Florida is unclear.

Rainfall varied considerably during the study, and like the Prairie Pothole region of the Northern Great Plains, USA, wetland abundance is directly correlated with precipitation in Florida (Johnson *et al.* 1991). Largely because of the El Nino event during the winter of 1997–98, all wetland basins were full and overflowing in spring 1998, and estimates from an aerial survey during March 1998 indicated 40% of "upland" habitats were inundated (B. Dugger unpubl. data). In contrast, a similar survey in March 1999 indicated all upland areas were dry and 44% of wetland basins were also dry (B. Dugger unpubl. data). Wetlands remained dry in 1999 until significant rainfall occurred in May. Our sample size was small, but nest initiation date was associated with the differences in habitat conditions, the mean date was 50 days later in the driest year (1999) than the wet year (1998). In contrast, no pattern was evident between nest initiation date and spring temperature, similar to temperate nesting Mallard (Cowardin *et al.* 1985). The results presented here agree with work in Texas where breeding chronology for Mottled Duck was more strongly influenced by rainfall (presumably a surrogate for wetland conditions) than temperature (Grand 1992).

Survival of females during late winter through early summer was 90% in 1998 and 87% in 1999, including both breeding and non-breeding females. Our estimates are similar to another breeding season estimate from east central Florida (Bielefeld & Cox 2006). Mean annual survival estimates calculated from band recovery analysis are 0.50 (Johnson *et al.* 1995). Our high interval estimate relative to the annual estimate suggests substantial within year variation in survival, which was confirmed by a more recent study that estimated relatively low survival during wing molt (Bielefeld & Cox 2006). The condition of one carcass in our study suggested an avian predator. Large avian predators on the study area included the Crested Caracara *Caracara plancus* and Peregrine Falcon *Falco peregrinus*, and at least Peregrine Falcons have been observed taking Mottled Ducks (R. Bielefeld pers. obs.).

The estimate of nesting propensity was low compared to similar studies conducted on temperate nesting Mallard (*e.g.* Coluccy *et al.* 2008; Devries *et al.* 2008). In part, this may reflect the difficulty of defining the population used to estimate the parameter. Compared to temperate nesting Mallard, the timing of Mottled Duck nesting varied considerably among years and nest initiation spanned a greater number of days. We do not attribute low nesting propensity solely to the influence of the radio transmitters. Subcutaneous transmitters are used less frequently in research on ducks, but the intra-abdominal transmitter and surgery procedure we used in 1999 followed well established protocols used for Mallard (Coluccy *et al.* 2008; Devries *et al.* 2008), and nesting propensity was higher for birds carrying subcutaneous compared to intra-abdominal transmitters in 1999. We suggest that low nesting indicates that habitats on our study area were of relatively low quality, particularly in years of low precipitation when many wetland basins were dry. Dry conditions may have influenced female body condition, which is known to influence nesting propensity in Mallard (Devries *et al.* 2008). Consistent with this explanation, female mass at capture was lowest in 1999, the dry year of our study. Moreover, during 1999, a greater percentage of marked females left the study area prior to the onset of breeding, and nesting propensity was lower for those that remained. Additionally, re-nesting rates during this study were generally low. Nesting propensity was also lower in our study than birds nesting in eastern Florida (Beilefeld pers. comm.), an area with a more stable wetland component. If this explanation is correct, then the ongoing restoration of wetland habitats associated with the Kissimmee River has the potential to increase Mottled Duck productivity in our study region of south-central Florida.

Acknowledgements

We thank K. M. Dugger, T. Greenall, M. Kearns, C. Mykut, R. Smith, and S. Wahaj for assistance with data collection. Project funding was provided by the South Florida Water Management District. Additional support was provided by Florida Game and Fresh Water Fish Commission. We thank P. Gray, R. Bielefeld, and R. Brust for sharing their personal experiences with Mottled Ducks in Florida. We thank the landowners of Dry Lake, MacArthur, and Bishop Dairies and the Flying G, Dixie, Grassy Island, and G-E cattle ranches for allowing us to work on their properties. K. M. Dugger, J. Gammonley, S. Gray, C. Hovey, L. A. Toth and three anonymous reviewers provided comments on earlier drafts of the manuscript. Research was initiated while B. Dugger was with MacArthur Agro-Ecology Research Center, Lake Placid Florida. This is contribution number 129 from the MacArthur Agro-Ecology Research Center.

References

Arnold, T.W., Sorenson, M.D. & Rotella, J.J. 1993. Relative success of overwater and upland mallard nests in southwestern Manitoba. *Journal of Wildlife Management* 57: 578–581.

Baker, O.E., III. 1983. Nesting and brood rearing habits of the Mottled Duck in the coastal marsh of Cameron Parish, Louisiana. M.Sc. Thesis, Louisiana State University, Baton Rouge, USA.

Beckwith, S.L. & Hosford, H.J. 1957. A report on seasonal food habits and life history notes of the Florida Duck in the vicinity of Lake Okeechobee, Glades County, Florida. *American Midland Naturalist* 57: 461–473.

Bielefeld, R.R. & Cox, R.R., Jr. 2006. Survival and cause-specific mortality of adult female mottled ducks in east-central Florida. *Wildlife Society Bulletin* 34: 388–394.

Coluccy, J.M., Yerkes, T., Simpson, R., Simpson, J.W., Armstrong, L. & J. Davis. 2008. Population dynamics of breeding Mallards in the Great Lakes States. *Journal of Wildlife Management* 72: 1181–1187.

Cowardin, L.M., Gilmer, D.S. & Shaiffer, C.W. 1985. Mallard recruitment in the agricultural environment of North Dakota. *Wildlife Monographs* 92. 37 pp.

Cox, R.R & Afton, A.D. 1998. Effects of capture and handling on survival of female Northern Pintails. *Journal Field Ornithology* 69: 276–287.

Devries J.H., Brook R.W., Howerter, D.W. & Anderson, M.G. 2008. Effects of spring body condition and age on reproduction in Mallards (*Anas platyrhynchos*). *Auk* 125: 618–628.

Durham, R.S. & Afton, A.D. 2003. Nest-site selection and success of mottled ducks on agricultural lands in southwest Louisiana. *Wildlife Society Bulletin* 31: 433–442.

Esler, D. & Grand, J.B. 1993. Factors influencing depredation of artificial duck nests. *Journal of Wildlife Management* 57: 244–248.

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

Holbrook, R.S. 1997. Ecology of nesting mottled ducks at the Atchafalaya River delta, Louisiana. M.Sc. Thesis, Louisiana State University, Baton Rouge, USA.

Johnson, D.H. 1979. Estimating nest success: the Mayfield method and an alternative. *Auk* 96: 651–661.

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

Johnson, F.A., Brakhage, D.H., Turnbull, R.E. & Montalbano, F., III. 1995. Variation in band-recovery and survival rates of Mottled Ducks in Florida. *Proceedings Annual Conference Southeast Fish & Wildlife Agencies* 49: 594–606.

Koebel, J.W., Jr. 1995. An historical perspective on the Kissimmee River restoration project. *Restoration Ecology* 3: 149–159.

Korschgen, C.E., Kenow, K.P., Green, W.L., Samuel, M.D. & Sileo, L. 1996. Technique for implanting radio transmitters subcutaneously in day-old ducklings. *Journal of Field Ornithology* 67: 392–397.

Mayfield, H. 1975. Suggestions for calculating nest success. *Wilson Bulletin* 73: 255–261.

Moorman, T.E. & Gray, P.N. 1994. Mottled Duck (*Anas fulvigula*) *In* A. Poole & F. Gill (eds.), *The Birds of North America*, No. 81. The Academy of Natural Sciences, Philadelphia, USA and The American Ornithologists' Union, Washington D.C., USA.

Olson, G.H., Dein, F.J., Haramis, M.G. & Jorde, D.G. 1992. Implanted radio transmitters in wintering Canvasbacks. *Journal of Wildlife Management* 56: 325–328.

Pollock, K.H., Winterstein, S.R., Bunck, C.M. & Curtis, P.D. 1989. Survival analysis in telemetry studies: the staggered entry design. *Journal of Wildlife Management* 53: 7–15.

Sharp, D.E. & Lokemoen, J.T. 1987. A decoy trap for breeding-season mallards in North

Dakota. *Journal of Wildlife Management* 51: 711–715.

Steiglitz, W.O. & Wilson, C.T. 1968. Breeding Biology of the Florida Duck. *Journal of Wildlife Management* 32: 921–934.

Stutzenbaker, C.D. 1988. *The Mottled Duck, its life history ecology and management*. Texas Parks and Wildlife Dept., Austin, Texas, USA.

Thorn, T.D., Emery, R.B., Howerter, D.W., Devries, J.H. & Joynt, B.L. 2005. Use of radio-telemetry to test for investigator effects on nesting Mallards, *Anas platyrhynchos*. *Canadian Field-Naturalist* 119: 541–545.

Toth, L.A., Arrington, D.A., Brady, M.A. & Muszick, D.A. 1995. Conceptual evaluation of factors potentially affecting restoration of habitat structure within the channelized Kissimmee River ecosystem. *Restoration Ecology* 3: 160–180.

Weller, M.W. 1956. A simple field candler for waterfowl eggs. *Journal of Wildlife Management* 20: 111–113.

