The Journal of Wildlife Management 77(5):1002–1009; 2013; DOI: 10.1002/jwmg.536

Population Ecology

Nesting Ecology of Florida Mottled Ducks Using Altered Habitats

DANA M. VARNER,[1] *School of Forestry and Wildlife Sciences, Auburn University, 602 Duncan Drive, Auburn, AL 36849, USA*
RONALD R. BIELEFELD, *Florida Fish and Wildlife Conservation Commission, Sebastian, FL 32958, USA*
GARY R. HEPP, *School of Forestry and Wildlife Sciences, Auburn University, 602 Duncan Drive, Auburn, AL 36849, USA*

ABSTRACT Habitat loss has negatively affected many species of upland-nesting waterfowl. Very few areas contain pristine nesting habitat in Florida because of conversion to agriculture and urban development. Although some species have acclimated to nesting in an altered landscape, little is known about the nesting ecology of Florida mottled ducks (*Anas fulvigula fulvigula*) that use altered habitats. We located and monitored 77 nests of radio-marked Florida mottled ducks in the Upper St. Johns River Basin (1999–2002) and in south Florida (2009–2011) and tested the effects of nest vegetation characteristics, human disturbance, and temporal variables on estimates of daily nest survival. We also calculated the percent of females that nested each year as a measure of breeding propensity. Nest age at discovery had a positive relationship with daily nest survival. Daily nest survival rates did not vary within or among years and were unaffected by density and height of vegetation at the nest and human disturbance parameters we measured. Breeding propensity ranged from 25% to 56%. Breeding propensities were less than those of other duck species, but our nest success estimate of 28% was greater than most estimates for ducks and is not likely to limit population growth of Florida mottled ducks. © 2013 The Wildlife Society.

KEY WORDS *Anas fulvigula fulvigula*, breeding propensity, disturbed habitat, Florida, mottled duck, nest success, urbanization.

Some research suggests that adult survival plays a greater role than reproductive parameters in determining population growth among the Anatidae, but other studies have found that reproductive parameters, such as nest success and breeding propensity, are more influential (Flint et al. 1998, Hoekman et al. 2002, Hoekman et al. 2006, Coluccy et al. 2008). Loss of unaltered nesting habitat is one of the greatest threats to many species of waterfowl because poor quality habitat may contribute to high nest failure rates. Additionally, a lack of natural wetland habitats during the breeding season may prevent females from accumulating the nutrient reserves needed for laying and incubation, resulting in low breeding propensity (Devries et al. 2008). Some species, however, have acclimated to nesting in altered habitat types (Baldassare and Bolen 1994). For example, mallards (*Anas platyrhynchos*) that nest in agricultural habitats often have recruitment and survival rates sufficient to maintain populations (Hoekman et al. 2006). Further, nest survival in pastures can be relatively high where adequate vegetative cover is available (Barker et al. 1990). However, nest success of mallards in urban areas can be negatively affected by lack of appropriate nesting cover and human disturbance (Greer 1982).

The mottled duck (*Anas fulvigula*), a close relative of the mallard, consists of 2 main populations and sub-species. The range of the western sub-species (*A. f. maculosa*) extends along the Gulf Coast between Alabama and Mexico and is defined as the Western Gulf Coast population (Bielefeld et al. 2010). The Florida sub-species (*A. f. fulvigula*), resides primarily in peninsular Florida (Bielefeld et al. 2010). Mottled ducks are 1 of only 6 non-migratory duck species in North America, and the 2 sub-species are genetically distinct with no gene flow between the populations (McCracken et al. 2001, Williams et al. 2005). In interior peninsular Florida, high densities are found on wetlands and agricultural lands near Lake Okeechobee and on upper St. Johns River Basin marshes (Johnson et al. 1991). Along both of Florida's coasts, high densities occur on ponds and ditches in urban and suburban areas (Bielefeld 2008). Survey data suggest greater than half of the Florida population may occur within urban and suburban areas (Bielefeld 2008). Florida mottled duck nesting ecology is poorly studied. Nesting occurs largely in habitats that have been modified for urban development and agriculture, but nest success rates in these areas have not been evaluated.

We located and monitored the nests of adult Florida mottled ducks that had been captured in urban and agricultural areas. We estimated daily nest survival and breeding propensity of these radio-marked ducks to determine how well they have acclimated to nesting in these altered habitats. Because duck nest survival has been found to vary over space and time (Klett et al. 1988), we tested for effects of study site and year. We also tested for effects of nest vegetation height

Received: 15 May 2012; Accepted: 7 January 2013
Published: 11 March 2013

[1]*E-mail: dmv0004@auburn.edu*

and density on nest survival and predicted that nest survival would decline with reduced vegetation height and density (Durham and Afton 2003). We used distance to nearest building as an index of human disturbance and predicted a positive relationship between nest survival and distance to the nearest building. Several studies have reported a positive linear or nonlinear relationship between nest age at discovery and nest survival (Garrettson and Rohwer 2001, Stephens et al. 2005, Hoekman et al. 2006, Grant and Shaffer 2012). Finally, we tested for linear (Garrettson and Rohwer 2001, Grant and Shaffer 2012) or curvilinear (Pieron and Rohwer 2010) effects of nest initiation date on nest survival.

STUDY AREA

We studied breeding mottled ducks at 2 study sites in Florida. From 1999 to 2002, we located and monitored nests in the Upper St. John's River Basin (USJRB) in east-central Florida. The USJRB extends north from northeastern Okeechobee County through parts of Indian River, Osceola, Brevard, Orange, and Seminole Counties, ending in southern Volusia County (Fig. 1). Much of this area has been converted from floodplain marsh to cattle pastures, citrus groves, and urban development. In 2009–2011, we studied nests in and near Palm Beach County in south Florida (Fig. 1). The western two-thirds of Palm Beach County mainly consists of the Everglades Agricultural Area (EAA) and Everglades-type sawgrass marsh impoundments managed for flood control, pollution mitigation, and water storage by the South Florida Water Management District and the United States Fish and Wildlife Service. The EAA is an artificially drained section of the northern Everglades that extends from the south shore of Lake

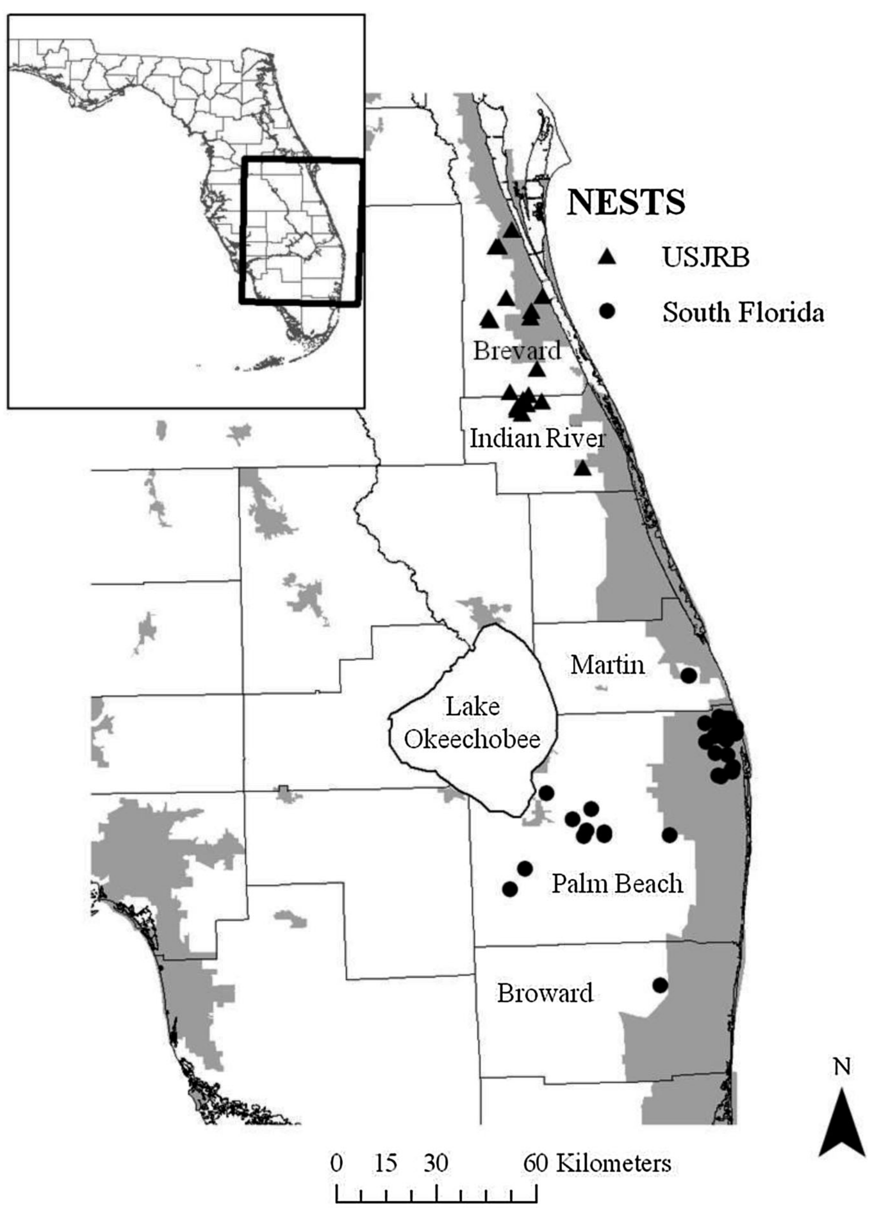

Figure 1. Map of Upper St. Johns River Basin (USJRB) and south Florida study sites (urban areas are gray).

Okeechobee to the Broward-Palm Beach county line. Approximately 280,000 ha (70%) of the EAA is used for farming and sugarcane is the primary crop (Rice et al. 2002). The eastern portion of Palm Beach County primarily consists of urban and suburban areas bordering the Atlantic Ocean between Jupiter and Boca Raton.

METHODS

We surgically implanted radio transmitters (18 g; AI-2M [12], Holohil System Ltd., Carp, Ontario, Canada) into the abdomens of female mottled ducks ($n = 357$) using methods described by Korschgen et al. (1996). In August and September, we captured molting female mottled ducks at night using spotlights and airboats in flooded agricultural fields and wetlands at both study sites. We implanted adult females captured in these areas with transmitters in 1998 ($n = 10$), 1999 ($n = 12$), 2000 ($n = 34$), 2001 ($n = 14$), 2008 ($n = 47$), 2009 ($n = 50$), and 2010 ($n = 50$). We also captured and radio-marked some females in the USJRB in January–April using decoy traps and rocket nets in 1999 ($n = 4$), 2000 ($n = 16$), 2001 ($n = 17$), and 2002 ($n = 4$). In south Florida, we used bait traps to capture and radio-mark female mottled ducks in urban areas of Palm Beach County in February–March 2009 ($n = 16$), December 2009 through March 2010 ($n = 45$), and December 2010 through March 2011 ($n = 38$). All urban trap sites in south Florida were located in the towns of Riviera Beach, Jupiter, and Palm Beach Gardens.

During the breeding season, March–July, we attempted to locate females between 0600 and 1200 hours, when egg laying usually occurs (Bielefeld et al. 2010). If we found a female in the same location for 2 consecutive days, we used a hand-held Yagi antenna to determine if she was in nesting cover. We then approached and flushed the female to locate the nest. We counted and candled the eggs to determine the nest age. We subtracted nest age in days from the date we discovered the nest to estimate nest initiation date. Each day we attempted to relocate the female from a distance via radio telemetry to confirm that the nest was still active. If a female was not found on the nest for 2 consecutive days, we checked the nest to determine nest fate. If the nest failed, we examined the condition of the nest and eggs to determine whether it had been abandoned, depredated, or destroyed by flooding or human activity. If the nest was successful, we estimated the number of hatched eggs based on the presence of intact eggs, shells, and membranes. Renesting is common in mottled ducks and we attempted to detect and monitor all renesting attempts (Stutzenbaker 1988). The incubation period for Florida mottled ducks lasts 25–26 days (Stieglitz and Wilson 1968). To reduce disturbance and the likelihood of abandonment, we avoided flushing the hen off the nest until the third week of incubation when we rechecked the nest to determine final clutch size and candled the eggs to get a more accurate estimate of hatch date. Immediately after the predicted hatch date, we visited nests to determine nest fate.

We entered nest coordinates into Google Earth v.6.1 (Google, Mountain View, CA) and measured distance to nearest building using satellite imagery from the same year the nest was active. After each nest hatched or failed, we recorded vegetation height and density at the nest and at an additional 5 points: 5 m from the nest in each of the 4 cardinal directions and at a randomly selected point within 5 m of the nest. We measured vegetation height (cm) as the tallest vegetation touching the measurement pole when held vertically at each point. To measure vegetation density, we placed a Robel pole at each point and recorded the smallest whole or half number visible between 0 and 16 from a distance of 4 m and a height of 1 m at each of the 4 cardinal directions (Robel et al. 1970). We used the mean of those 4 measurements as an index of vegetation density (i.e., visual obstruction) at each point. We used the Florida Natural Areas Inventory Cooperative Land Cover Map v.1.1 to classify the habitat type of each nest as either urban, agricultural, or other (Florida Natural Areas Inventory 2010).

Data Analysis

We used logistic regression in Program R to test for differences in vegetation height and density at the nest between study sites and between hatched and failed nests. We also compared height and density measurements at the nest to the mean of the 5 surrounding points using a paired t-test in Program R. Breeding propensity was the percentage of females that were alive on March 1 that made at least 1 nesting attempt each year. We excluded from the breeding propensity analysis those females that either left the study area or experienced transmitter failure. We used the nest survival model in Program MARK (<http://www.phidot.org/software/mark>, accessed 12 Nov 2012) as described by Dinsmore et al. (2002), to estimate daily nest survival. We built an a priori model set to evaluate the effects of year, nest initiation date, age at discovery, nest vegetation height and density, and distance to nearest building on daily survival. We also tested for differences between first nesting attempts and renesting attempts. We used Akaike's Information Criterion corrected for small sample size (AIC_c), for model comparison. We also used model averaging to estimate daily survival rates (DSR) based on all models.

RESULTS

We located 21 nests in the USJRB between 1999 and 2002, of which 3 were renests. About half (10 of 21) of the nests were successful and nest predation ($n = 5$), mowing ($n = 3$), and abandonment ($n = 3$) caused nests to fail. In south Florida, we found 56 nests during 3 breeding seasons, 12 nests in 2009 and 22 nests in both 2010 and 2011. Only 9 of these nests were renesting attempts. Most (33 of 56) nests failed, and causes of nest failure included nest predation ($n = 27$), abandonment ($n = 2$), mowing ($n = 2$), flooding ($n = 1$), and predation of hen ($n = 1$). Females initiated nests from March through July, but most nests (62%) were initiated in April and May on both study sites (Table 1). We discovered most nests (80%) during laying or the first week of incubation.

Most nests were located in human-dominated urban habitats ($n = 47$), which included residential neighborhoods,

Table 1. Characteristics of Florida mottled duck nests in the Upper St. Johns River Basin (USJRB; 1999–2002) and south Florida (2009–2011).

	USJRB				South Florida			
	n	Mean	SE	Range	*n*	Mean	SE	Range
Nest initiation date	21	24 Apr	7.77 days	1 Mar–2 Jul	56	5 May	4.07 days	1 Mar–8 Jul
Clutch size	21	8.48	0.34	6–11	44	7.48	0.33	1–11
Vegetation height (cm)	21	76.00	9.12	25–150	55	63.95	6.41	0–265
Vegetation density[a]	21	6.26	0.78	2–15	55	5.98	0.45	0.75–16
Distance to nearest building (km)	21	1.85	0.45	0.02–6.93	56	0.73	0.22	0–10.09
Nest age at discovery (days)	21	13.33	1.80	2–34	56	10.25	0.8	1–27

[a] Robel vegetation density measurements (0–16).

golf courses, parks, and commercial properties such as universities, hospitals, and shopping centers. Sixteen nests were located in agricultural habitats, mainly sugarcane, pasture, and citrus groves. We found 14 nests in other habitat types such as wet prairie, glades marsh, and rural open lands. Height and density of vegetation at the nest did not differ ($P > 0.05$) between the USJRB and south Florida sites (Table 1). Vegetation height and density also did not differ ($P > 0.05$) between nests that hatched and those that failed. Height ($t_{73} = 6.51$, $P < 0.001$) and density ($t_{73} = 5.28$, $P < 0.001$) of vegetation were greater at the nest than at points within 5 m of the nest (Table 2). Average breeding propensity in the USJRB was 40.7 ± 6.6% ($n = 4$ yrs, range: 25–55.6%) for radio-marked females ($n = 51$) alive on March 1. In south Florida, average breeding propensity was 28.6 ± 1.3% ($n = 3$ yrs, range: 26.3–30.8%) for radio-marked females ($n = 169$) alive on March 1. Overall, breeding propensity at both sites averaged 35.5 ± 4.3% ($n = 7$ yrs).

The most parsimonious model of daily nest survival had twice as much support as any other model. This model indicated that nest survival did not vary between the 2 study sites and that nest age at discovery was the only covariate correlated with daily nest survival (Table 3). We did not detect differences in nest survival among years. The second most parsimonious model indicated a curvilinear effect of nest age at time of discovery. Our models provided only weak support for differences in survival attributable to any covariates because all 95% confidence intervals for covariate beta parameters included zero. This also includes the beta parameter estimate for the age at discovery covariate in the top model, which was 0.0579 ± 0.0306 (95% CI = −0.0020 to 0.1178; Fig. 2). Assuming a laying period of 8 days and an incubation period of 25 days, the model averaged nest success estimate was 28.14% (DSR = 0.9623 ± 0.0085) for the USJRB and 28.27% (DSR = 0.9624 ± 0.0064) for south Florida.

DISCUSSION

We found that nest success of Florida mottled ducks did not vary in relation to nest vegetation characteristics, distance to nearest building, initiation date, year, or site. Our nest survival estimate of 28% is among the greatest reported for mottled ducks, with the notable exception of those that nested on small islands in Florida (Table 4). Our nest success estimate is nearly double the 15% estimate reportedly required to maintain stable mid-continent mallard populations (Cowardin et al. 1985). Greater nest success may be counter-balanced by reduced breeding propensity, however, as our propensity estimates were much less than those of prairie-nesting mallards (Devries et al. 2008). Ducks that use more stable habitats, such as diving and sea ducks, may have a *k*-selected life history strategy characterized by low breeding propensity and high adult survival (Johnson and Grier 1988). This is because nesting activities and nest defense behaviors cause female ducks to be more vulnerable to predation and may elevate mortality rates of nesters (Greenwood et al. 1995, Devries et al. 2003). We found that the years with the greatest breeding propensities also had the lowest breeding season survival and vice versa (D. Varner, Auburn University, unpublished data; Bielefeld and Cox 2006), a pattern which was also reported for mottled ducks in Texas

Table 2. Mean (±SE) density and height of vegetation at and near Florida mottled duck nests in the Upper St. Johns River Basin (USJRB; 1999–2002) and south Florida (2009–2011).

	Nest	5 m north	5 m east	5 m south	5 m west	Random
Vegetation density (0–16)[a]						
USJRB	6.3 ± 0.8	5.3 ± 1.0	7.3 ± 1.2	5.7 ± 1.1	5.6 ± 1.2	4.9 ± 1.0
South FL	6.0 ± 0.5	3.9 ± 0.5	4.3 ± 0.5	4.3 ± 0.5	4.1 ± 0.5	4.4 ± 0.4
Vegetation height (cm)						
USJRB	76.0 ± 9.1	51.7 ± 10.8	71.4 ± 12.9	50.0 ± 10.1	52.9 ± 12.2	45.5 ± 8.6
South FL	65.1 ± 6.6	32.1 ± 5.4	36.4 ± 4.8	41.9 ± 5.8	33.9 ± 5.6	33.7 ± 4.6

[a] Robel vegetation density measurements.

Table 3. Support for candidate models predicting Florida mottled duck daily nest survival (S) in the Upper St. Johns River Basin (USJRB; 1999–2002) and south Florida (2009–2011). Models are ranked from most to least supported based on Akaike's Information Criterion (AIC_c), ΔAIC_c, and Akaike weights (w_i). The top model had an $AIC_c = 266.28$.

Model[a]	ΔAIC_c	w_i	Model likelihood	Parameters	Deviance
S(AGE)	0	0.1772	1	2	262.27
S(AGE^2)	1.3812	0.0888	0.5013	2	263.65
S(.)	1.7944	0.0722	0.4077	1	266.07
S(AGE VEGD)	1.8540	0.0701	0.3958	3	262.11
S(AGE RENEST)	1.9323	0.0674	0.3806	3	262.19
S(AGE INIT)	1.9510	0.0668	0.3770	3	262.21
S(AGE $INIT^2$)	1.9819	0.0658	0.3712	3	262.24
S(AGE VEGH)	1.9825	0.0657	0.3711	3	262.24
S(AGE SITE)	1.9983	0.0652	0.3682	3	262.26
S(AGE BLDG)	2.0095	0.0649	0.3661	3	262.27
S(RENEST)	3.6140	0.0291	0.1642	2	265.88
S(VEGD)	3.7348	0.0274	0.1545	2	266.00
S(VEGH)	3.7434	0.0273	0.1539	2	266.01
S(BLDG)	3.7450	0.0272	0.1538	2	266.01
S(STUDY)	3.7626	0.0270	0.1524	2	266.03
S($INIT^2$)	3.7735	0.0269	0.1516	2	266.04
S(INIT)	3.7903	0.0266	0.1503	2	266.06
S(AGE YEAR)	7.9642	0.0033	0.0186	8	258.10
S(YEAR)	10.0140	0.0012	0.0067	7	262.18

[a] AGE, nest age at discovery; VEGD, vegetation density at nest; RENEST, >1 nesting attempt; INIT, initiation date; VEGH, vegetation height; SITE, study site (USJRB or south Florida); BLDG, distance to nearest building; STUDY, USJRB or South Florida; (.), null model.

(Rigby and Haukos 2012). Density estimates of Florida mottled ducks have been slowly increasing in recent years (Bielefeld et al. 2010), so these relatively low breeding propensities may be offset by greater adult survival and may not have a negative impact on population numbers.

Our estimates of breeding propensity (25–56%) are much less than those typically reported for temperate-nesting mallards (≥89%; Hoekman et al. 2002, Devries et al. 2008). Comparing mottled ducks with mallards may not be informative, however, because trapping methods probably sample different segments of the population. Female mallards were typically trapped and radio-tagged early in the breeding season using decoy traps in known nesting areas; therefore, estimates of breeding propensity may have been positively biased by targeting females that were more likely to nest

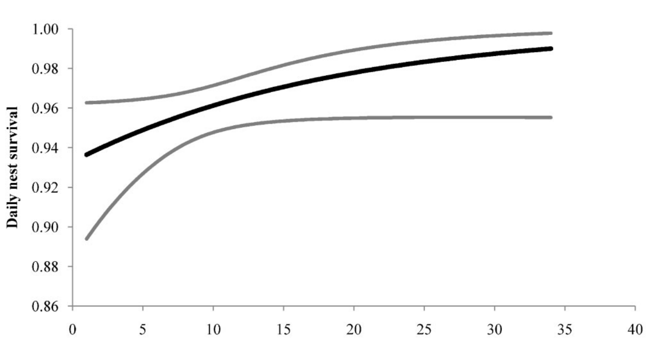

Figure 2. Daily nest survival estimates plotted against nest age at discovery for Florida mottled duck nests in the Upper St. Johns River Basin (1999–2002) and south Florida (2009–2011). Gray lines are upper and lower 95% confidence intervals.

(Lindstrom et al. 2006). Because we trapped most females during the winter (35%) and post-breeding (61%) seasons, the female mottled ducks we studied may have been more representative of the overall population than the temperate-nesting mallards studied by Hoekman et al. (2002) and Devries et al. (2008). Some radio-marking methods may directly interfere with breeding activities of female ducks (Rotella et al. 1993). We implanted transmitters intra-abdominally as did Hoekman et al. (2002) and Devries et al. (2008) for female mallards. Therefore, differences in breeding propensity were unlikely attributable to the radio attachment methods. Finally, low breeding propensities have also been reported for mottled ducks in interior Florida (27–56%) and the upper (15–63%) and mid-gulf coast of Texas (31–77%; Finger et al. 2003, Dugger et al. 2010, Rigby and Haukos 2012). Although these estimates may be artificially low because of an inability to detect nesting attempts that failed early, the consistency of these results likely indicate that breeding propensities of mottled ducks are less than those of mallards.

Several of our models of daily nest survival appeared to be competitive, but most of these models contained uninformative parameters, as described by Arnold (2010). For every additional parameter included in a model, a penalty of +2 AIC points is incurred. Because of this penalty, the AIC_c values of those models with 1 additional parameter are artificially inflated. Based on these results, none of the variables we selected had an impact on nest survival with the possible exception of age at discovery. Daily nest survival was greater for nests that were older when we discovered them. This occurs because nests that are more prone to depredation are often destroyed earlier in the nesting process (Klett and Johnson 1982, Dinsmore et al. 2002).

Table 4. Comparisons of estimated nest success for mottled ducks (adapted from Durham and Afton 2003).

Location	*n*	Nest success (%) Apparent	Nest success (%) Mayfield	Reference
Merritt Island, FL	90	76.7	57.0	Stieglitz and Wilson (1968)
Atchafalaya River delta, LA	265	47.5	30.6	Holbrook (1997)
Mississippi River delta, LA	279	40.0	20.0	Walters (2000)
TX	51	27.5	11.0	Engeling (1950)
Interior FL	25	16.0	9.5	Dugger et al. (2010)
TX and LA	146	24.7	9.0	Stutzenbaker (1988)
Cameron and Calcasieu Parishes, LA	66	21.0	6.0	Durham and Afton (2003)
Cameron Parish, LA	30	16.6	5.0	Baker (1983)
South and east-central FL	77	44.2	28.3	This study

Some studies have found that height and density of vegetation at duck nests are positively related with nest survival, but others have reported no relationship (Clark and Nudds 1991, Esler and Grand 1993, Stephens et al. 2005, Walker et al. 2008). Our models showed little effect of vegetation characteristics at the nest on daily survival rates. We also found no differences in nest vegetation height and density between nests that hatched and those that failed. Habitat features at broad landscape scales have been shown to influence nest survival in a variety of avian species (Stephens et al. 2003, 2005) and may impact nesting success of mottled ducks. In interior Florida, for example, most mottled ducks nest monitored by Dugger et al. (2010) were associated with dairy farms where vegetation characteristics at the nest were similar to our study, but nest success was much lower (9.5% vs. 28.3%). Dairy farming operations (e.g., grazing) may have affected the continuity of nesting habitat, thereby increasing the susceptibility of nests to predators (Dugger et al. 2010). Predator communities also may differ in urban habitats in Florida and impact both predation risk and nest survival (Stephens et al. 2005).

More than half of nests in this study were located in urban areas. Typically, nest success of mallards that nest in urban areas is low because of a lack of appropriate nesting habitat, human disturbance, and harassment by other ducks (Greer 1982). Frequency of nest predation also is high in urban areas (Jokimäki and Huhta 2000, Thorington and Bowman 2003). Some of the most common waterfowl nest predators selectively use building sites for denning or foraging (Fritzell 1978, Larivière et al. 1999). However, despite the fact that 32% of our nests were within 100 m of a building, distance to nearest building did not appear to be related to nest survival. Our results suggest that Florida mottled ducks nesting in urban areas have success rates similar to those in other habitats. Most Florida mottled ducks in this study nested in agricultural (21%) or urban (61%) habitats and yet nest success was greater than many species of prairie-nesting ducks. Our nest survival estimates suggest that mottled ducks in Florida have adapted well to loss of pristine nesting habitat.

MANAGEMENT IMPLICATIONS

As our understanding of the ecology of the Florida mottled duck has improved through research, the adaptability of this subspecies to large-scale habitat alterations is becoming apparent. Although our nest success estimates were greater than expected and population density estimates have shown a weakly increasing trend in recent years, a better understanding of other demographic attributes, especially duckling survival and adult survival, is necessary to put nesting success estimates in perspective, and to identify when and where in the annual cycle population growth may be constrained. Nesting habitat appears to be good quality, however, low breeding propensity estimates may suggest that wetland habitats used by pre-breeding females may be lacking, especially in dry years. Additionally, more intensive study is needed to determine whether the low breeding propensity estimates reported in this and other studies of mottled ducks are accurate or a result of missed nesting attempts. A minimum amount of nutrient reserves are needed by breeding females to meet the demands of egg laying and incubation (Moorman et al. 1992). Further research is needed to determine whether the nutritional requirements of female Florida mottled ducks are being met during the crucial late winter and early spring periods.

ACKNOWLEDGMENTS

This project was funded by the Florida Fish and Wildlife Conservation Commission (FWCC), in large part by the Aquatic Habitat and Restoration Section of the FWCC. Funding also was provided by Ducks Unlimited; Auburn University; St. Johns Water Management District; Archbold Biological Station; USFWS, Region IV; Safari Club International, Miami Chapter; and J. Rudolph. We gratefully acknowledge J. Albury, R. Brust, B. Dugger, D. Eggeman, and S. Rockwood for assistance with study design. J. Benedict, A. Fanning, J. Feddersen, and D. Blood with the FWCC; M. Milleson with USDA APHIS; and D. Heard, D.V.M. with the University of Florida Veterinary School provided equipment, data, and critical field assistance. South Florida Water Management District, A. Duda & Sons, and dozens of private landowners in the USJRB and south Florida provided access to study sites. C. August, F. Baziari, A. Brown, N. Bushue, N. Collier, J. Crait, L. Craver, D. Curtiss, J. Denton, J. Hamner, J. McMunigal, C. Metzgar, J. Millikin, A. Munters, R. O'Meara, T. O'Meara, J. Rodgers, K. Rogers, R. Rozar, T. Schrage, and J. Tapp assisted with field work. D. Heard, D.V.M. and J. Slade, D.V.M. assisted with implantation surgeries.

LITERATURE CITED

Arnold, T. 2010. Uninformative parameters and model selection using Akaike's Information Criterion. Journal of Wildlife Management 74:1175–1178.

Baker, O. E. 1983. Nesting and brood-rearing habits of the mottled duck in the coastal marsh of Cameron Parish, Louisiana. Thesis, Louisiana State University, Baton Rouge, USA.

Baldassare, G. A., and E. G. Bolen. 1994. Waterfowl ecology and management. Wiley, New York, New York, USA.

Barker, W. T., K. K. Sedivec, T. A. Messmer, K. F. Higgins, and D. R. Hertel. 1990. Effects of specialized grazing systems on waterfowl production in Southcentral North Dakota. Transactions of the North American Wildlife and Natural Resources Conference 55:462–474.

Bielefeld, R. R. 2008. Mottled duck survey report. Fish and Wildlife Research Institute. Florida Fish and Wildlife Conservation, Commission, St. Petersburg, USA.

Bielefeld, R. R., M. G. Brasher, T. E. Moorman, and P. N. Gray. 2010. Mottled duck (*Anas fulvigula*). Account 081 *in* A. Poole, editor. The birds of North America online. Cornell Lab of Ornithology, Ithaca, New York, USA.

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

Clark, R. G., and T. D. Nudds. 1991. Habitat patch size and duck nesting success: the crucial experiments have not been performed. Wildlife Society Bulletin 19:534–543.

Coluccy, J. M., T. Yerkes, R. Simpson, J. W. Simpson, L. Armstrong, and J. I. Davis. 2008. Population dynamics of breeding mallards in the Great Lakes states. Journal of Wildlife Management 72:1181–1187.

Cowardin, L. M., D. S. Gilmer, and C. W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildlife Monographs 92:1–37.

Devries, J. H., J. J. Citta, M. S. Lindberg, D. W. Howerter, and M. G. Anderson. 2003. Breeding-season survival of mallard females in the Prairie Pothole region of Canada. Journal of Wildlife Management 67:551–563.

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

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476–3488.

Dugger, B. D., R. Finger, and S. L. Melvin. 2010. Nesting ecology of mottled duck *Anas fulvigula* in interior Florida, USA. Wildfowl 60:95–105.

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

Engeling, G. A. 1950. The nesting habits of the mottled duck in Wharton, Ft. Bend, and Brazoria Counties, Texas, with notes on molting and movements. Thesis, Texas Agricultural and Mechanical University, College Station, USA.

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

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, USA.

Flint, P. L., J. B. Grand, and R. F. Rockwell. 1998. A model of northern pintail productivity and population growth rate. Journal of Wildlife Management 62:1110–1118.

Florida Natural Areas Inventory. 2010. Development of a cooperative land cover map: final report. Florida Natural Areas Inventory, Tallahassee, USA.

Fritzell, E. K. 1978. Habitat use by prairie raccoons during the waterfowl breeding season. Journal of Wildlife Management 42:118–127.

Garrettson, P. R., and F. C. Rohwer. 2001. Effects of mammalian predator removal on production of upland-nesting ducks in North Dakota. Journal of Wildlife Management 65:398–405.

Grant, T. A., and T. L. Shaffer. 2012. Time-specific patterns of nest survival for ducks and passerines breeding in North Dakota. Auk 129: 319–328.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Shaffer. 1995. Factors associated with duck nest success in the Prairie Pothole Region of Canada. Wildlife Monographs 128.

Greer, D. M. 1982. Urban waterfowl population: ecological evaluation of management and planning. Environmental Management 6:217–229.

Hoekman, S. T., L. S. Mills, D. W. Howerter, J. H. Devries, and I. J. Ball. 2002. Sensitivity analyses of the life cycle of midcontinent mallards. Journal of Wildlife Management 66:883–900.

Hoekman, S. T., T. S. Gabor, M. J. Petrie, R. Maher, H. R. Murkin, and M. S. Lindberg. 2006. Population dynamics of mallards breeding in agricultural environments in eastern Canada. Journal of Wildlife Management 70:121–128.

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

Johnson, D. H., and J. W. Grier. 1988. Determinants of breeding distributions of ducks. Wildlife Monographs 100:3–37.

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.

Jokimäki, J., and E. Huhta. 2000. Artificial nest predation and abundance of birds along an urban gradient. Condor 102:838–847.

Klett, A. T., and D. H. Johnson. 1982. Variability in nest survival rates and implications to nesting studies. Auk 99:77–87.

Klett, A. T., T. L. Shaffer, and D. H. Johnson. 1988. Duck nest success in the Prairie Pothole Region. Journal of Wildlife Management 52: 431–440.

Korschgen, C. E., K. P. Kenow, A. Gendron-Fitzpatrick, W. L. Green, and F. J. Dein. 1996. Implanting intra-abdominal radiotransmitters with external whip antennas in ducks. Journal of Wildlife Management 60:132–137.

Larivière, S., L. R. Walton, and F. Messier. 1999. Selection by striped skunks (*Mephitis mephitis*) of farmsteads and buildings as denning sites. American Midland Naturalist 142:96–101.

Lindstrom, E. B., M. W. Eichholz, and J. M. Eadie. 2006. Postovulatory follicles in mallards: implications for estimates of breeding propensity. Condor 108:925–935.

McCracken, K. G., W. P. Johnson, and F. H. Sheldon. 2001. Molecular population genetics, phylogeography, and conservation biology of the mottled ducks (*Anas fulvigula*). Conservation Genetics 2:87–102.

Moorman, T. E., G. A. Baldassarre, and D. M. Richard. 1992. Carcass mass, composition, and gut morphology dynamics of Mottled Ducks in fall and winter in Louisiana. Condor 84:407–417.

Pieron, M. R., and F. C. Rohwer. 2010. Effects of large-scale predator reduction on nest success of nesting ducks. Journal of Wildlife Management 74:124–132.

Rice, R. W., F. T. Izuno, and R. M. Garcia. 2002. Phosphorus load reductions under best management practices for sugarcane cropping systems in the Everglades Agricultural Area. Agricultural Water Management 56:17–39.

Rigby, E. A., and D. A. Haukos. 2012. Breeding season survival and breeding incidence of female mottled ducks on the Upper Texas Gulf Coast. Waterbirds 35:260–269.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weigh of grassland vegetation. Journal of Range Management 23:295–297.

Rotella, J. J., D. W. Howerter, T. P. Sankowski, and J. H. Devries. 1993. Nesting effort by wild mallards with 3 types of radio transmitters. Journal of Wildlife Management 57:690–695.

Stephens, S. E., D. N. Koons, J. J. Rotella, and D. W. Willey. 2003. Effects of habitat fragmentation on avian nesting success: a review of the evidence at multiple spatial scales. Biological Conservation 115:101–110.

Stephens, S. E., J. J. Rotella, M. S. Lindberg, M. L. Taper, and J. K. Ringelman. 2005. Duck nest survival in the Missouri Coteau region of North Dakota: the effects of landscape characteristics at multiple spatial scales. Ecological Applications 15:2137–2149.

Stieglitz, W. O., and C. T. Wilson. 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 Department, Austin, USA.

Thorington, K. K., and R. Bowman. 2003. Predation rate on artificial nests increases with human housing density in suburban habitats. Ecography 26:188–196.

Walker, J. A., Z. J. Cunningham, M. P. Vrtiska, S. E. Stephens, and L. A. Powell. 2008. Low reproductive success of mallards in a grassland-dominated landscape in the Sandhills of Nebraska. Prairie Naturalist 40:1–13.

Walters, N. F. 2000. Nesting activities of mottled ducks in the Mississippi River delta. Thesis, Louisiana State University, Baton Rouge, USA.

Williams, C. L., A. M. Fedynich, D. B. Pence, and O. E. Rhodes. Jr., 2005. Evaluation of allozyme and microsatellite variation in Texas and Florida mottled ducks. Condor 107:155–161.

Associate Editor: Joel Schmutz.