**Habitat use, survival, and reproductive success of female Florida mottled ducks
(*Anas fulvigula fulvigula*) using the Everglades Agricultural Area and urban
habitats of south-eastern Florida**

by

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Abstract

The most recent Conservation Plan for the Florida Mottled Duck identified

several areas where knowledge of the species is incomplete. This study was initiated to

provide critical information needed for the development of a more comprehensive

management plan for Florida mottled ducks (*Anas fulvigula fulvigula*). I radio-tagged

246 adult female mottled ducks in southeast Florida in order to collect survival, nesting,

and habitat use data. I found that median home range sizes of rural females were more

than 65 times greater than those of urban females. There was little movement (6%)

between urban and rural areas. Urban females mostly used low and high intensity urban

habitats. Rural ducks preferred freshwater marshes throughout the year, but selection of

other habitat types varied seasonally. Artificial impoundments and reservoirs were

particularly important during the post-breeding (1 Aug – 18 Nov) and hunting (19 Nov –

31 Jan) seasons. I found that annual survival was lower for ducks that did not use urban

areas (47%) compared to those that did (74%). Daily survival rates were lowest during

the breeding season (1 Mar–31 Jul). Females that used Everglades-type habitat during

the breeding season had higher seasonal survival rates (78 – 85%) than those that did not

(37 – 47%). Differences in hunting season survival for ducks that used non-hunted rural

areas (88%) when compared to those that used open (87%) or quota-hunting systems

(85%) were minimal. I located and monitored 56 nests in southeast Florida (2009-2011)

and also used data from 21 nests found in the Upper St. Johns River Basin (1999–2002)

during a prior study. 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. Breeding propensity ranged from 25–56%. 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. My results indicate that female Florida mottled ducks do well in urbanized areas but may benefit from conservation and management of rural habitats, especially during the breeding season.

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Chapter 1: Nesting Ecology of Florida Mottled Ducks Using Altered Habitats

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.

Introduction

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

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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 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 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

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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, 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 radiomarked 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 (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 (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).

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.

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Table 1. Characteristics of Florida mottled ducks nests in the Upper St. Johns River Basin (USJRB; 1999–2002) and south Florida (2009–11).

	USJRB				South Florida			
	n	mean	SE	range	n	mean	SE	range
Nest initiation date	21	Apr-24	7.77 days	Mar-1 – Jul-2	56	May-5	4.07 days	Mar-1 – Jul-8
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
Dist 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).

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	5m North	5m East	5m South	5m 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 (1999–2002) and south Florida (2009–11). 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	AIC_c weights	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.

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

| Location | n | Nest success (%) | | Reference |
		Apparent	Mayfield	
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

Figure 1. Map of Upper St. Johns River Basin (USJRB) and south Florida study sites (urban areas are gray).
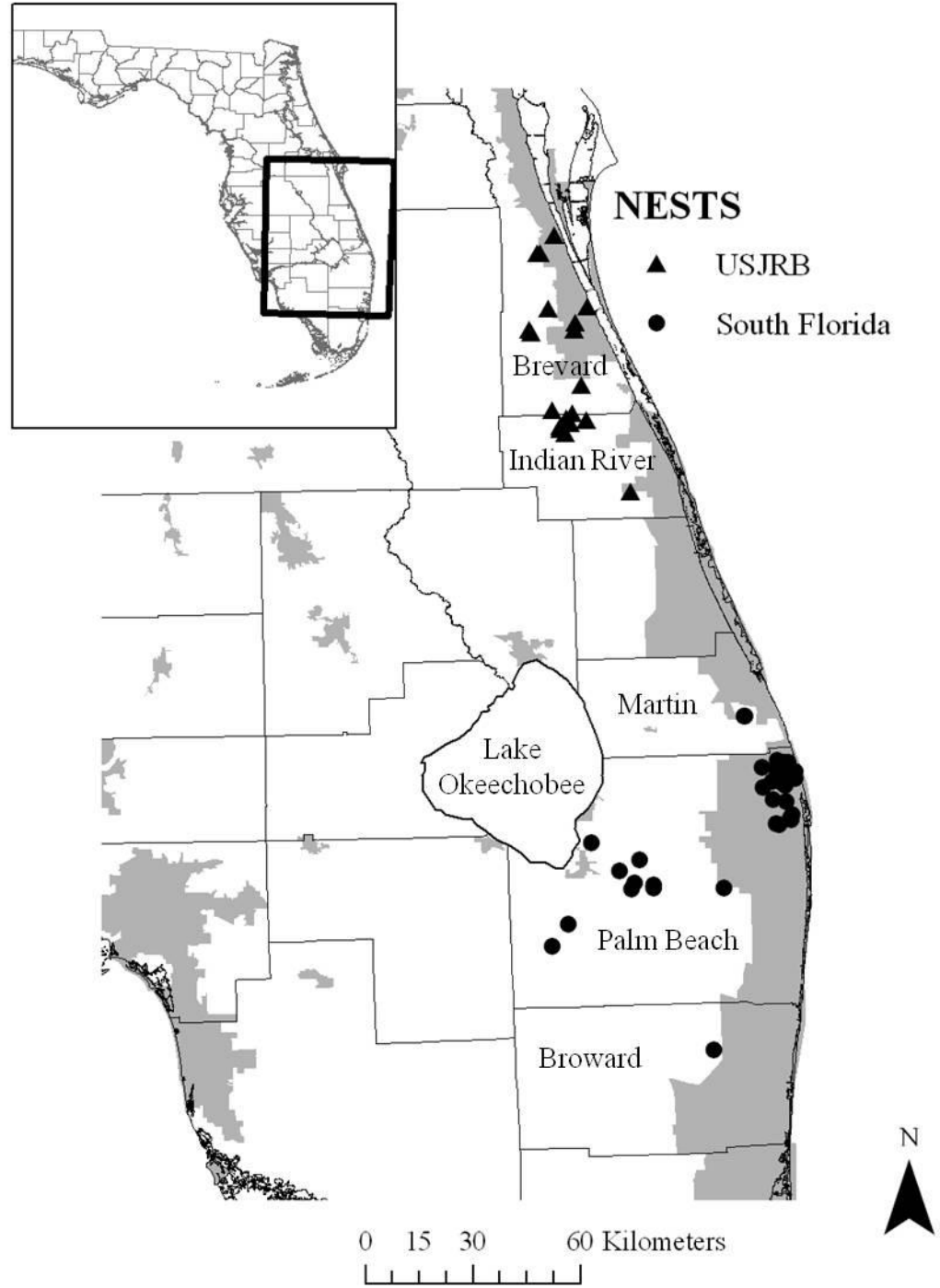
Figure 2. Daily nest survival estimates plotted against nest age at discovery for Florida mottled duck nests in the Upper St. Johns River Basin (1999–2002) and south Florida (2009–2011). Dashed lines are upper and lower 95% confidence intervals.
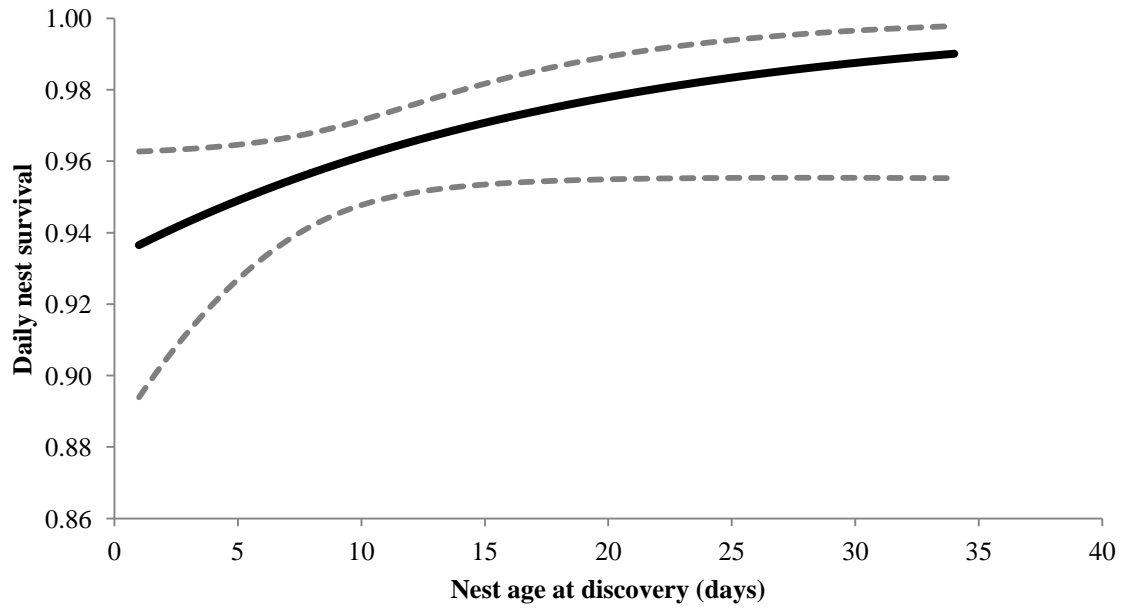
Chapter 2: Annual and Seasonal Survival of Adult Female Mottled Ducks in South Florida

Abstract

Florida's population is expected to double within the next 50 years leading to the urbanization of millions of acres. Nearly 500 bird species occur in Florida, including several endemics, such as Florida Mottled Ducks (*Anas fulvigula fulvigula*). Here we report information about how female Florida Mottled Duck survival varies over time which will help managers predict the effects of future habitat change. Additionally, we attempt to pinpoint geographic areas where most mortality occurs which may allow for more effective habitat and harvest management. Using data from 236 radio-marked Florida Mottled Ducks, we tested for temporal differences in survival of females that used urban areas compared to those that did not. We also tested for differences in survival among ducks using different geographic areas during the breeding season and different hunting regimes during the hunting season. Annual survival was lower for ducks that did not use urban areas (47%) compared to those that did (74%). Daily survival rates were lowest during the breeding season. Females that used Everglades-type habitat during the breeding season had higher seasonal survival rates (78 – 85%) than those that did not (37 – 47%). Differences in hunting season survival for ducks that used non-hunted rural areas (88%) when compared to those that used open (87%) or quota-hunting systems (85%) were minimal. Differences in survival among study years also were negligible. Our results indicate that Florida Mottled Ducks survive at high

rates in urbanized areas but may benefit from increases in the quantity and quality of breeding habitats.

Introduction

Survival of adult females is one of the most important vital rates affecting population growth rates of ducks (Flint et al. 1998, Hoekman et al. 2002, Flint et al. 2006). Certain periods of the annual cycle carry greater risks and challenges and are associated with increased mortality. The post-breeding season includes the remigial molt period, a time when flightless ducks are especially vulnerable to predation (Panek and Majewski 1990, Elsey et al. 2004). During the breeding season, nesting activities and nest defense behaviors also cause female ducks to be more vulnerable to predation and may elevate mortality rates (Greenwood et al. 1995, Devries et al. 2003, Arnold et al. 2012). Several studies have indicated that survival of female ducks is lowest during the time of greatest energetic demand, egg-laying and incubation (Devries et al. 2003, Koons and Rotella 2003, Brasher et al. 2006, Hoekman et al. 2006). Hunting also is an important cause of winter mortality for ducks and for some species is additive in nature (Fleskes et al. 2007, U.S. Fish & Wildlife Service 2012). Migration too may be a period of high mortality (Greenberg 1980, Newton 2006), but some duck species, such as the Mottled Duck (*Anas fulvigula*), are non-migratory.

The Mottled Duck is a close relative of the Mallard (*Anas platyrhynchos*) and consists of two genetically distinct sub-species (McCracken et al. 2001, Williams et al. 2005). 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 population (*A. f. fulvigula*) resides primarily in rural

and urban areas of peninsular Florida south of Alachua County (Bielefeld et al. 2010).

An introduced breeding population also persists in South Carolina. Existing data suggest

little to no gene flow or movement among any of the populations.

Habitat loss and degradation, especially by urbanization, is one of the greatest

threats to biodiversity in the United States (Czech and Krausman 1997, Wilcove et al.

1998) and Florida has not been exempt. By the year 2060, Florida's urban land area is

expected to more than double (Zwick and Carr 2006). Some studies have found that

urbanization negatively impacts waterfowl and contributes to hybridization between

species (Brodsky and Weatherhead 1984, McKinney et al. 2007), but the number of

Mottled Ducks using urban areas in Florida has increased in recent decades (Bielefeld et

al. 2010). These birds are exposed to urban feral Mallards and are hybridizing with them;

making Mallard genetic introgression a severe threat to this sub-species (Bielefeld et al.

2010). Ducks in urban areas reside there either full-time or seasonally in response to a

lack of surface water in more natural habitats (Bielefeld and Cox 2006). Up to half of the

Florida Mottled Duck population may occur within urban areas. Nest success of females

breeding in urban areas is high (Varner et al. 2013), but little is known about their

survival.

Because of their unique status as the state's only endemic duck species, Florida

Mottled Ducks must be maintained at sustainable population levels to provide hunting

and viewing opportunities for the general public (Florida Fish and Wildlife Conservation

Commission 2011). Knowing how survival of Mottled Ducks varies within and among

years would allow more effective management of habitats and hunting opportunities.

Previous research has indicated that annual survival of Mottled Ducks varied among

years and was likely influenced by habitat and surface water conditions (Johnson et al.
1995, Bielefeld and Cox 2006, Bielefeld et al. 2010). Seasonal variations in survival,
however, may be attributed largely to changes in predation risk (Elsey et al. 2004,
Bielefeld and Cox 2006).

In this study, we estimated annual and seasonal survival rates of adult female
Mottled Ducks. We compared survival of females using urban habitats to that of females
using less disturbed rural areas. We also explored the relationship between survival and
surface water conditions. Our analysis suggested the breeding season was the time of
greatest mortality risk for females, so we examined the relationship between use of major
habitat types in south Florida with breeding season survival. We also compared survival
rates among females exposed to three different hunting systems: quota hunting, open
hunting, and no hunting, to determine whether hunting regulations affected survival rates.
Results of this study provide critical information needed to help refine the comprehensive
management plan for Florida Mottled Ducks and provide insight into the possible long-
term impacts of urbanization.

Methods

Study Area

Our research area included all or parts of 15 counties in south Florida from
Osceola County in the north to Miami-Dade County in the south and from DeSoto
County in the west to Palm Beach County in the east (Fig. 1). This area contained Lake
Okeechobee, the Everglades Agricultural Area (EAA), Stormwater Treatment Areas
(STAs), and parts of the Everglades Protection Area. Lake Okeechobee consists mainly
of open water, although the western and southern littoral zones support large areas of

freshwater marsh (Havens and Gawlik 2005). The EAA is an artificially drained area

north of the Everglades that extends from the south shore of Lake Okeechobee to the

Broward-Palm Beach county line. Most of the EAA is devoted to farming. Sugarcane is

the primary crop, but rice, vegetables, and sod also are produced. The EAA also contains

the STAs, which are man-made, managed marsh impoundments designed to remove

excess agricultural nutrients and other pollutants from Lake Okeechobee and EAA waters

before being released to the Everglades. The Everglades Protection Area (Everglades)

consists primarily of freshwater wetlands, especially sawgrass (*Cladium jamaicense*) and

cattail marshes interspersed with small islands and includes Water Conservation Areas,

Wildlife Management Areas, National Park, and National Wildlife Refuge lands

extending from the southern and eastern edges of the EAA south to Florida Bay. Other

common habitat types in the study area include improved and unimproved pasture, citrus

groves and other row crops, dry prairies, and high impact urban areas (Florida Natural

Areas Inventory 2010).

Capture and Radio Telemetry

In STAs and flooded agricultural fields, we captured female Mottled Ducks from

airboats at night using spotlighting in September 2008 ($n = 47$) and August 2009 ($n = 50$)

and 2010 ($n = 50$). Agricultural properties were owned by A. Duda and Sons, Inc. and

were located in the EAA approximately 11 km south-east of Belle Glade. Duda fields

were used primarily for sugar cane production and attracted large numbers of molting

ducks in the late summer and early fall when they were temporarily flooded for weed and

pest control. STAs 1E and 1W were located just west of the town of Wellington and

directly adjacent to Loxahatchee National Wildlife Refuge. STAs 2 and 3/4 straddled

Highway 27 on the southern edge of Palm Beach County. Females using urban areas were captured in the cities of Jupiter, Palm Beach Gardens, and Riviera Beach in north-eastern Palm Beach County. Walk-in and swim-in bait traps and air-powered rocket nets were used in urban areas to capture Mottled Ducks in February-March 2009 ($n = 16$), December 2009-March 2010 ($n = 45$), and December 2010-March 2011 ($n = 38$).

Captured females ($n = 246$) were brought to the Corbett Wildlife Management Area for implantation with 18-gram radio transmitters (AI-2M [12], Holohil System Ltd., Carp, Ontario, Canada; Korschgen et al. 1996). Transmitters were programmed to have a 13-month lifespan. No birds were held for more than 24 hours and those females held for more than 12 hours were kept in a climate-controlled area and provided with food and water. Birds were allowed to recover from surgery for at least 60 minutes before being released at the location they were captured. Age and sex of each individual was determined using cloaca, bill, and plumage characteristics and only adult females were radio-marked. All animal handling methods were approved by the Auburn University Institutional Animal Care and Use Committee (PRNs 2007-1218 and 2010-1821).

We used truck-mounted 4-element null-peak antenna systems to triangulate the locations of each bird. Fixed-wing aircraft were used to locate birds in rural areas not accessible from the ground due to a lack of roads, such as Lake Okeechobee and the Everglades. We also used flights to relocate birds that were not found by ground trackers. Flights covered the entire 15-county study area. Females were monitored until the transmitter expired, the individual could not be located in the study area during flights, or the study ended on 30 December 2011. Transmitters were equipped with a mortality sensor that allowed us to determine the state (alive or dead) of each individual.

Birds that died within 7 days of release were excluded from analysis. Locations were plotted on a map using ArcMap v.9.3.1, allowing us to determine which areas were used by each bird.

We obtained monthly Palmer Hydrological Drought Index (PHDI) data from August 2008 to December 2011 from the National Oceanic and Atmospheric Administration's National Climatic Data Center in order to examine the relationship between surface water conditions and survival rates. The mean monthly PHDI of Florida Climate Divisions 5 (Everglades and Southwest) and 6 (Lower East Coast) was used as an index of surface water conditions on the study area. PHDI is measured on a scale ranging from +4.0 to -4.0 where +4.0 indicates extreme wet conditions and -4.0 indicates extreme drought conditions.

Survival Analysis

We used the nest survival model in Program MARK to estimate daily survival rates (DSRs) of females Mottled Ducks from radio telemetry data (Dinsmore et al. 2002). The nest survival model is frequently used to estimate survival rates when individuals are captured and monitored in uneven intervals (Hartke et al. 2006, Collier et al. 2009). Data of this type are referred to as "ragged telemetry data" (Dinsmore et al. 2002). We used model averaging, when appropriate, to manage model selection uncertainty (Burnham and Anderson 2002). We built an *a priori* model set to evaluate the effects of year, season, and use of urban areas on daily survival. Each duck location was assigned to one of two areas: urban or rural. All areas outside of the urban limits defined by Florida Department of Transportation's Transportation Statistics Office were considered to be rural regardless of land use classification (Fig. 1). An individual duck was then classified

as "urban" if >50% of her locations were within urban limits and vice versa. Seasons were defined as post-breeding (1 Aug – 18 Nov), hunting (19 Nov – 31 Jan), late winter (1 Feb – 28 Feb), and breeding (1 Mar–31 Jul). Akaike's Information Criterion, corrected for small sample size (AIC_c), was used for model comparison.

We also conducted *post hoc* analyses to further examine survival rates for the two seasons, breeding and hunting, with the highest mortality rates. Birds that only used urban areas during the breeding and hunting seasons were excluded from analysis, because initial results indicated high survival overall for those individuals. We examined differences in survival related to habitat use during the breeding season by assigning females to one of five categories based on number of locations collected during April and May (i.e. peak nesting season). Our five habitat categories were; EAA, Lake Okeechobee, Everglades, STAs, and other areas.

During the hunting season, we compared survival of females exposed to three different hunting regimes; quota-hunting (STAs 1W, 3/4, and 5 in all years and STA 2 in 2008-09), no hunting (Loxahatchee National Wildlife Refuge, STAs 1E and 6, and STA 2 in 2009-11), or open hunting (Lake Okeechobee, Everglades marsh, and all other private rural areas). The number of hunters and times when hunting was allowed were controlled for quota-hunted areas using permits issued via a lottery system. Harvest of all duck species on these areas was closely monitored and typically averaged 3-5 ducks per hunter-day, totaling >20,000 ducks each season (Florida Fish and Wildlife Conservation Commission, unpublished data). In open-hunted areas, there were no additional rules beyond state and federal regulations and harvest was not closely monitored. Non-hunted

areas were completely closed to all types of waterfowl hunting. Year was included as a covariate in breeding and hunting season model sets.

Results

Most females (98%) remained in the habitat area, urban ($n = 99$) or rural ($n = 137$), where they were captured. Ten ducks either died or experienced transmitter failure <1 week after release and were excluded from the analysis. We detected mortalities for 26% of urban females and 46% of rural females. Transmitter life spans of females for which we did not detect mortalities averaged 321.5 ± 12.1 days for urban ducks ($n = 73$; range 45-496) and 277.0 ± 10.2 days for rural ducks ($n = 74$; range 28-392). Overall, surface water conditions in south Florida were approximately average (PHDI = 0.066) during the first year (Aug 2008 – Jul 2009), slightly wetter than average (PHDI = 0.718) in the second year (Aug 2009 – Jul 2010), and drier than average (PHDI = -1.294) in the final year of the study (Aug 2010 – Dec 2011; Fig. 2).

Annual Survival

The top three candidate models of daily survival accounted for most of the overall model weight (0.98; Table 1). The top model had nearly half of the support and included additive effects of season and area and an interaction between season and area (Table 1). The second ranked model included additive effects of season, area, and year. Parameter likelihood values showed that season (0.9998) and area (0.9993) had greater relative importance than year (0.3380). We used model averaging of all models to generate DSR estimates. In all years, daily survival was lowest during the breeding season for both urban and rural ducks (Table 2). Rural ducks also experienced a drop in daily survival during the hunting season when compared to late winter, while urban ducks did not (Fig

3). Overall, survival was lower for ducks that used rural areas compared to those in urban areas (Fig. 3). Mean annual survival estimates calculated using DSRs for each season were 46.7% (range: 42.9 - 50.3%) for rural ducks and 73.6% (range: 71.1 – 76.3%) for urban ducks. Although differences in survival among years were small, DSRs were highest during 2008-09 and lowest during 2009-10 (Table 2).

Breeding Season Survival

DSRs were lowest during the breeding season for females using rural areas ($n =$ 97; Fig. 3), so we examined sources of variation in survival during this period. Rural females spent the breeding season in one of five locations: EAA ($n = 27$), Everglades ($n =$ 36), Lake Okeechobee ($n = 7$), STAs ($n = 16$), and other areas ($n = 11$). Model selection results indicated that DSR varied with the locations used by females (Table 3). The top model included only location. The next best model included location and year as interactive effects and was three times weaker than the top model (evidence ratio = 3.1; Table 3). Because models including location had a total weight of 0.99, we generated DSRs using only the top model. DSR estimates were highest for females using the Everglades and STAs and lowest for females using Lake Okeechobee, the EAA, and other areas (Fig. 4). Survival estimates for the 153-day breeding season were lowest (37%) in Lake Okeechobee and highest (85%) in the Everglades. PHDI data from March – July indicated drier than average conditions (-1.481) in 2009, moderately wet conditions (2.342) in 2010, and moderate drought conditions (-2.486) in 2011.

Hunting Season Survival

DSRs also were low during the hunting season for rural ducks ($n = 115$; Fig. 3). Based on model results, it appears that hunting season survival varied among years;

however, there is less support for an effect of hunting regime on DSR (Table 4). We used model averaging to generate DSR estimates based on all models. DSRs were highest during 2010-11 and lowest during 2009-10 (Fig. 5). Mean DSR of rural females for all years were higher in non-hunted areas (0.99830) than in open-hunted areas (0.99808) or quota-hunted areas (0.99784), but these differences were relatively minor. Surface water conditions were about average during the 2008-09 (PHDI = 0.165) and 2009-10 (PHDI = 0.220) hunting seasons and drier than average during the 2010-11 (PHDI = -1.220) hunting season.

Discussion

Previous studies have reported annual survival rates of approximately 50% for adult female Florida Mottled Ducks (Johnson et al. 1995, Bielefeld and Cox 2006, Bielefeld et al. 2010), which is similar to survival rates estimated for adult female Mallards and American Black Ducks (*Anas rubripes*), two closely related species (Anderson 1975, Krementz et al. 1987, Lake et al. 2006). Our estimates of annual survival for Mottled Ducks using rural areas were 43-50%, but survival of Mottled Ducks using urban areas was much higher (71-76%). Female Mottled Ducks using urban habitats experienced reduced mortality rates. Alligators can be one of the top sources of Mottled Duck mortality (Bielefeld and Cox 2006) and likely occur at lower densities in urban wetlands, because of Florida's nuisance alligator control policies (Dutton et al. 2002). Urban habitats also are unsuitable for some avian and mammalian predators (Berry et al. 1998, Crooks 2002, Riley 2006). In general, surface water levels in urban aquatic habitats are more stable because they are frequently managed for aesthetic, sanitation, or recreational purposes. Moreover, supplemental food, in the form of bird

seed, corn, and other non-natural foods is often available to ducks in these areas. Mottled Ducks that use urban areas experience higher levels of human disturbance, despite this survival appears to be higher when compared to more rural areas. This is most likely due to the overall more secure and stable nature of urban habitats.

In the Upper St. Johns River Basin (USJRB) region of Florida, survival of female Mottled Ducks was lowest during the post-breeding season (0.69), similar for the hunting (0.88) and reproductive seasons (0.86), and greatest during late winter (1.00; Bielefeld and Cox 2006). Our seasonal survival estimates for the late winter (0.97 - 1.00) and hunting (0.81 - 0.96) seasons were similar to the USJRB; however, unlike Bielefeld and Cox (2006), we found survival was higher during the post-breeding season (0.91 - 0.97) when compared to the breeding (0.58 - 0.84) season. Differences in seasonal survival patterns between the USJRB and south Florida may reflect differences in the availability and stability of suitable breeding and post-breeding habitats between regions. The late summer wing molt is a period of high energy demand and because ducks are unable to fly they are more vulnerable to predation and cannot move great distances to forage (Panek and Majewski 1990, Elsey et al. 2004, Fox et al. 2012). During their flightless period, ducks can require large permanent wetlands with abundant food resources and cover (Moorman et al. 1993, Fleskes et al. 2010). Higher post-breeding survival in south Florida likely reflects a greater availability and stability of these types of habitats as compared to the USJRB. For example, our south Florida study area was dominated by relatively stable aquatic systems including Lake Okeechobee, STAs, and urban ponds; whereas, the USJRB was dominated by more ephemeral wetlands including the St. Johns River marshes, wet prairie, and pasture ponds. The drought that persisted during the

USJRB study appeared to have concentrated post-breeding Mottled Ducks and alligators in the few remaining flooded wetlands, resulting in the high reported mortality (Bielefeld and Cox 2006).

Conversely, greater breeding season survival in the USJRB may be due to an increased availability of suitable upland nesting habitats when compared to south Florida. Previous research suggests that most breeding season mortality of female Mallards is directly related to nesting activities (Devries et al. 2003, Brasher et al. 2006, Arnold et al. 2012). Almost certainly, the amount of high quality, dense nesting cover available to female Mottled Ducks in the USJRB during that study, given the drought conditions that existed, exceeded that available in south Florida during our study. Female Mottled Ducks in south Florida may be more vulnerable to predation during the breeding season because of lower quality and amount of nesting habitats. Our results and those of Bielefeld and Cox (2006) also may indicate a difference in predator communities between the USJRB and south Florida. Because flightless females are more vulnerable to aquatic predation during the post-breeding wing molt and terrestrial predation while nesting, we may find that aquatic predators occur at higher densities in the USJRB where post-breeding survival is low and terrestrial predators occur at higher densities in south Florida where breeding season survival is low.

We also found that survival during the breeding season was related to habitat use. Ducks that used the Everglades or STAs had the highest survival, and females that used Lake Okeechobee and other areas, such as pasture and open grassland-type areas West and North of Lake Okeechobee, had the lowest survival. One explanation for these results is Mottled Ducks nesting in the Everglades and STAs consistently chose islands

for nesting. This is plausible given Mottled Ducks do not commonly nest over water (Bielefeld et al. 2010) and the Everglades and STAs do not contain large contiguous areas of upland grass or shrub habitat. Moreover, prior research has found that success of waterfowl nesting on islands is generally high (Stieglitz and Wilson 1968, Giroux 1981) and even shallow water greatly limits mammalian predator access to nesting islands in the Everglades (Frederick and Collopy 1989). Additionally, Dorcas et al. (2012) recently reported that populations of some mesopredators (e.g. raccoons, bobcats) were severely reduced in the Everglades by Burmese Pythons (*Python molurus bivittatus*; Dorcas et al. 2012). Consequently, high breeding season survival of females in these areas may have been partly caused by low predator densities. Another possible explanation for higher breeding season survival among birds that used the Everglades and STAs is that a high proportion did not attempt to nest or failed relatively early, thus reducing risk and overall mortality. Breeding propensities as low as 25% have been reported for Florida Mottled Ducks in some areas (Varner et al. 2013). Conversely, ducks that used Lake Okeechobee or other areas may have experienced higher mortality because they attempted to nest at a higher rate in habitats that supported higher predator populations.

We found evidence that hunting mortality may be weakly compensatory in nature for adult female Florida Mottled Ducks. We found little difference in DSRs of urban ducks between the hunting and late winter seasons. For urban ducks, mortality rates during the hunting season were the same as those during the late winter season indicating there was no difference in non-hunting mortality between the hunting and late winter seasons. For rural ducks, however, DSRs increased substantially when the hunting season ended, even exceeding those of urban ducks. If hunting mortality was additive,

we would have expected late winter DSRs of rural ducks to have been lower than those of urban ducks, as was the case during the other three seasons. Instead we found little to no mortality among rural ducks during the late winter, suggesting that hunting mortality was compensatory. Further, we found that females using non-hunted rural areas during the hunting season ($n = 28$) had season survival rates (88%) that were similar to those that used hunted areas (85 - 87%). Sources of non-hunting mortality should be similar, because non-hunted rural areas consisted of the same habitat types and were in close proximity to the hunted areas. This lack of appreciable differences in hunting season survival among the areas regardless of hunting pressure is also an indicator of compensatory hunting mortality because a similar proportion of ducks that were taken by hunters would have died from other causes in a non-hunted area.

Several studies have found strong relationships between wetland availability and duck population numbers and productivity (Krapu et al. 1983, Rotella and Ratti 1992, Austin 2002, Niemuth and Solberg 2003, Pietz et al. 2003). Survival of Mottled Ducks seems to be strongly influenced by habitat conditions, especially water levels (Bielefeld and Cox 2006). During dry years in Florida, water levels drop, availability of surface water decreases, and alligators and ducks become more concentrated, making ducks more vulnerable to alligator mortality (Bielefeld and Cox 2006). Indeed we found that both survival rates and water levels were higher in 2008-09 than in 2010-11. However, survival rates were lowest during 2009-10, when surface water and precipitation levels were greatest. It appears some other variable(s) besides surface water availability influenced mortality in 2009-10. First, south Florida experienced record cold weather during 2 - 11 January 2010 when temperatures dipped to near or below freezing on at

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least 3 nights; negatively impacting many native and non-native species of plants and animals (National Oceanic and Atmospheric Association 2010, Mazzotti et al. 2011). While it is unlikely that cold temperatures directly caused mortality in Mottled Ducks, they may have negatively impacted plant and invertebrate food resources to the extent that food became limiting during the remainder of winter 2009-2010, which indirectly lowered survival. Additionally, the first wetter than average spring following a prolonged drought may have spurred a sharp increase in plant and invertebrate foods for rodent and other terrestrial prey animal populations leading to an increase in mesomammal and raptor predator numbers in a type of bottom-up trophic cascade during the 2010 breeding season (Brook et al. 2008). An uptick in mammalian predator populations outside of the Everglades, could have caused the high adult female mortality in 2009-10, especially during the nesting season when females spend considerable time in terrestrial habitats while incubating (Arnold et al. 2012). Indeed, our estimates of breeding season survival were very low during the second year of the study.

Like Bielefeld and Cox (2006), we found some indications that Florida Mottled Ducks survive within a predator-driven system. Further research is needed to understand how future habitat change, including both improvement and degradation, will impact avian and mammalian predator populations. While urbanization has been generally regarded as having a negative impact on wildlife, in this case, it appears Mottled Ducks have the flexibility to survive in an urban landscape. Unfortunately, feral Mallards occur mostly in urban areas so high nest success (Varner et al. 2013) and survival of urban ducks may only serve to accelerate the spread of Mallard genetic introgression within the Florida Mottled Duck population. Further research examining how Mottled Ducks and

Mallards use urban areas can provide insight into how to best manage the hybridization issue.

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Table 1. Support for candidate models predicting daily survival rates of adult female Florida Mottled Ducks using two areas (urban and rural) in south Florida from 2008-11. 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$_c$ = 1023.40.

Model [1]	ΔAIC$_c$	ω_i	K	Deviance
Season*Area	0	0.4848	7	1009.40
Season+Area+Year	0.8691	0.3139	7	1010.27
Season+Area	2.0183	0.1767	5	1015.42
Season*Area*Year	6.0397	0.0237	17	995.43
Season	14.0156	0.0004	4	1029.42
Season*Year	15.8046	0.0002	11	1017.20
Season+Year	16.4282	0.0001	6	1027.83
Area	17.9814	0.0001	2	1037.38
Area+Year	18.2956	0.0001	4	1033.70
Area*Year	20.5746	0.0000	6	1031.98
Constant	26.5675	0	1	1047.97
Year	29.0980	0	3	1046.50

[1] Seasons: post-breeding (Aug 1 – Nov 18), hunting (Nov 19 – Jan 31), late winter (Feb 1 – Feb 28), and breeding (Mar 1 – Jul 31)

Table 2. Model averaged daily survival rates (DSR) and upper and lower 95% confidence intervals for adult female Florida Mottled Ducks during the post-breeding (Aug 1 – Nov 18), hunting (Nov 19 – Jan 31), late winter (Feb 1 – Feb 28) and breeding (Mar 1 – Jul 31) seasons in urban and rural areas of south Florida from Aug 2008 – Dec 2011.

		n	Post-Breeding			Hunting			Late Winter			Breeding		
		n	DSR	Lower c.i.	Upper c.i.	DSR	Lower c.i.	Upper c.i.	DSR	Lower c.i.	Upper c.i.	DSR	Lower c.i.	Upper c.i.
2008-09	Rural	45	0.999278	0.998801	0.999761	0.997769	0.996999	0.998546	0.999998	0.999093	1.000000	0.997113	0.996513	0.998522
2008-09	Urban	16	0.999687	0.998691	1.000000	0.999397	0.998990	0.999801	0.999491	0.998000	1.000000	0.998839	0.998059	0.999608
2009-10	Rural	46	0.999123	0.998586	0.999717	0.997233	0.996544	0.998565	0.999997	0.999091	1.000000	0.996442	0.995967	0.996985
2009-10	Urban	44	0.999620	0.998549	1.000000	0.999254	0.998774	0.999756	0.999072	0.998398	0.999678	0.998572	0.997687	0.999459
2010-11	Rural	46	0.999199	0.998680	0.999736	0.997598	0.996635	0.998561	0.999997	0.999092	1.000000	0.996817	0.996081	0.997652
2010-11	Urban	39	0.999648	0.998628	1.000000	0.999343	0.998903	0.999782	0.999186	0.998680	0.999736	0.998705	0.997833	0.999562

Table 3. Support for candidate models predicting adult female Florida Mottled Duck daily survival rates during the breeding season (Mar 1 – Jul 31) in five rural locations in south Florida from 2009-11. 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 $AIC_c = 314.60$.

Model[1]	ΔAIC_c	w_i	Model likelihood	K	Deviance
S(Loc)	0	0.6453	1	5	304.59
S(Loc*Year)	2.2569	0.2088	0.3235	13	290.82
S(Loc+Year)	3.2397	0.1277	0.1979	7	303.82
S(.)	7.6685	0.0140	0.0216	1	320.26
S(Year)	10.0667	0.0042	0.0065	3	318.66

[1] Loc: Everglades Agricultural Area, Everglades, Lake Okeechobee, Stormwater Treatment Areas, and other areas.

Table 4. Support for candidate models predicting daily survival rates of adult female Florida Mottled Ducks under three hunting regimes during the hunting season (Nov 19 – Jan 31) in rural areas of south Florida from 2008-11. 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 $AIC_c = 168.93$.

Model [1]	ΔAIC_c	w_i	Model likelihood	K	Deviance
S(Year)	0	0.4576	1	3	162.92
S(.)	0.8922	0.2929	0.6401	1	167.82
S(Hunt)	2.0769	0.1620	0.3540	3	165.00
S(Hunt+Year)	3.3073	0.0876	0.1914	5	162.23

[1] Hunt: quota-hunting, open hunting, and no hunting

Figure 1. Map of study area in south Florida showing portions of urban and rural areas used by female Mottle Ducks; including Stormwater Treatment Areas (STAs) and the Everglades Agricultural Area (EAA).
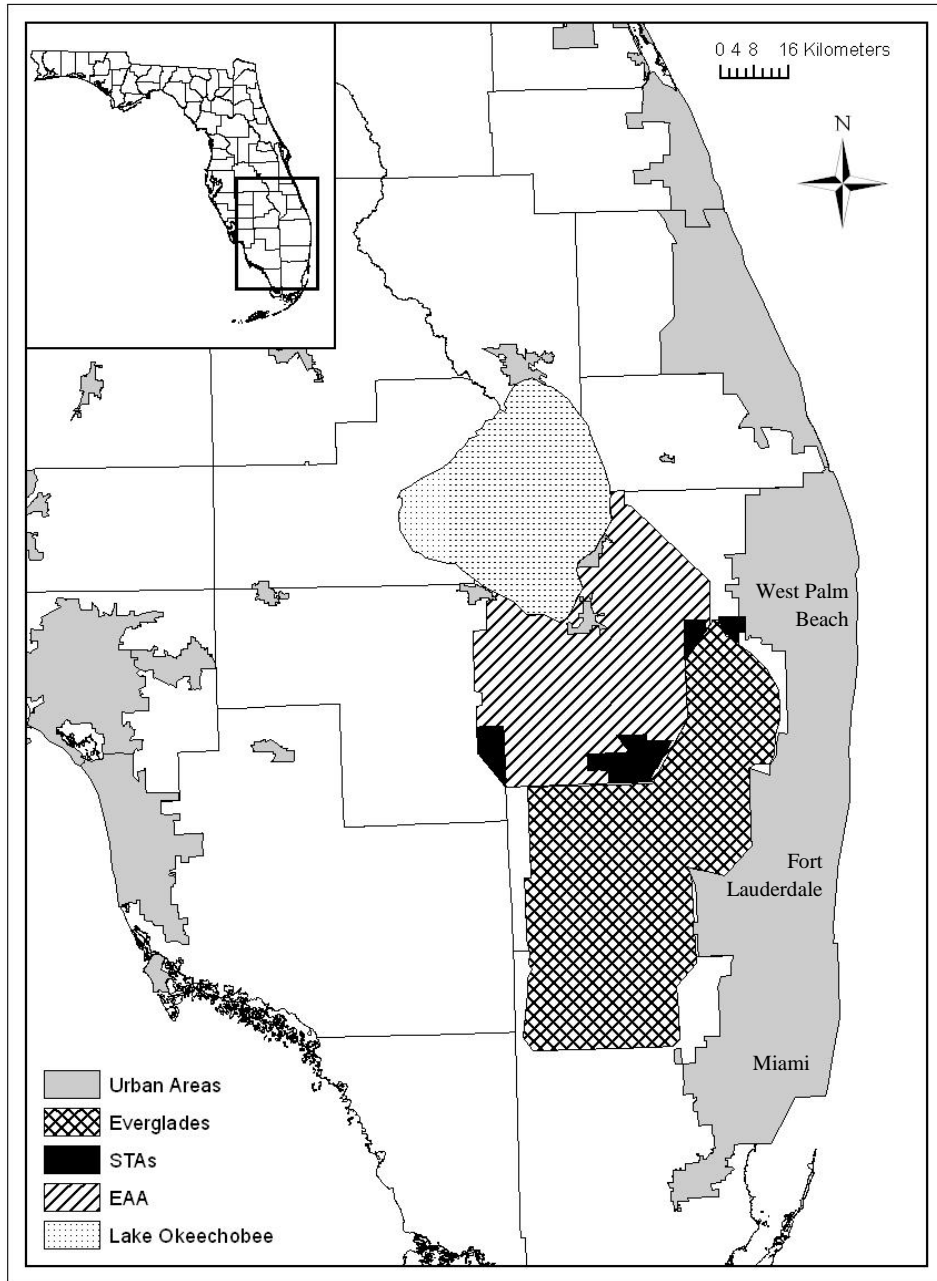
Figure 2. Monthly Palmer Hydrologic Drought Index (PHDI) and Palmer Drought Severity Index (PDSI) measurements for mainland south Florida from August 2008 through December 2011. Negative values indicate moderate (-2) to extreme (-4) drought conditions while positive values indicate moderate (+2) to extreme (+4) wet conditions.
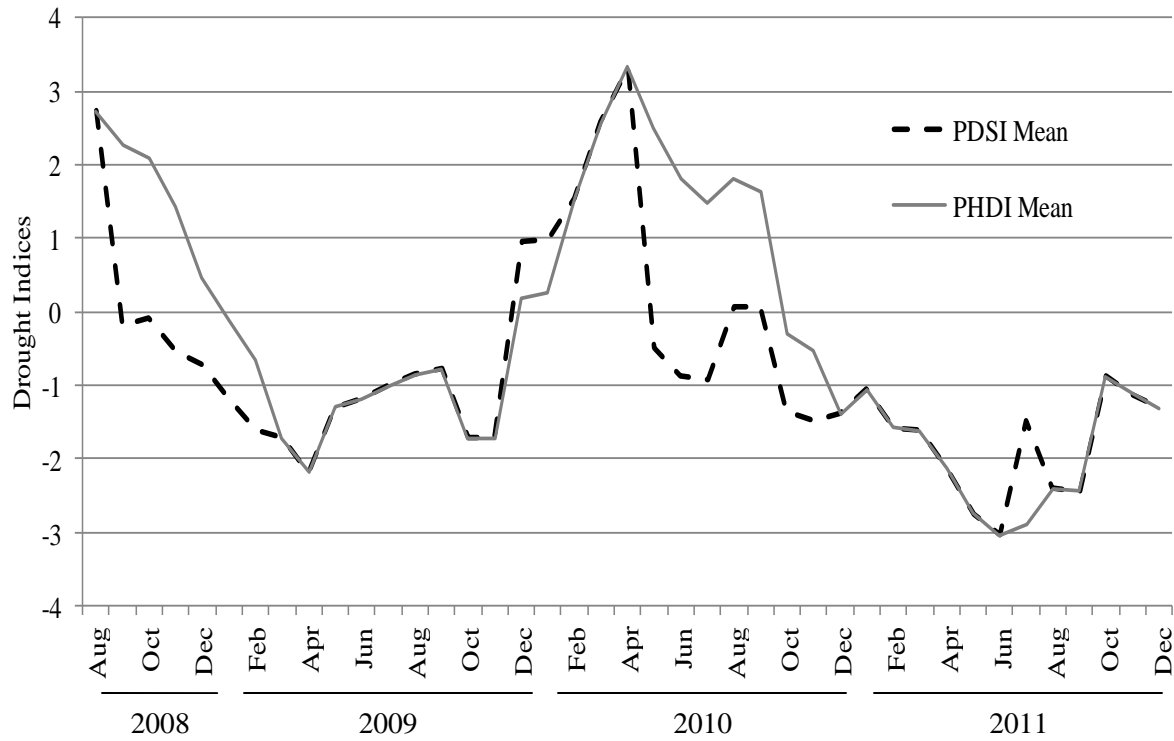
Figure 3. Daily survival rates (DSR) of adult female Florida mottled ducks using urban and rural areas of south-east Florida during the post-breeding (Aug 1 – Nov 18), hunting (Nov 19 – Jan 31), late winter (Feb 1 – Feb 28), and breeding (Mar 1 – Jul 31) seasons, 2008-2011. Error bars represent 95% confidence intervals.
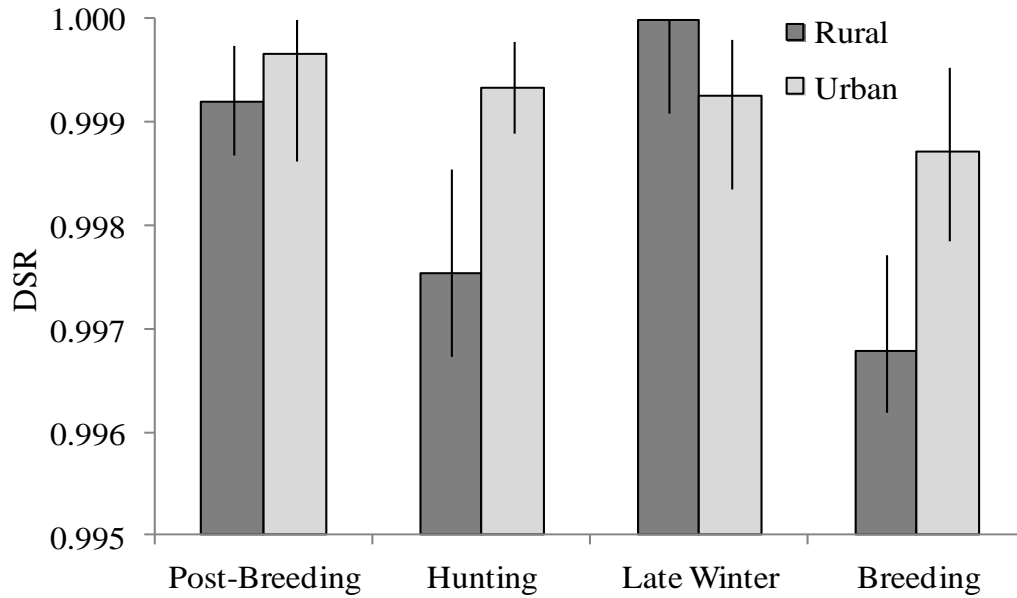
Figure 4. Daily survival rates of Florida Mottled Ducks using five locations during the breeding season (Mar 1- Jul 31) in south Florida from 2009-11. Error bars represent 95% confidence intervals.
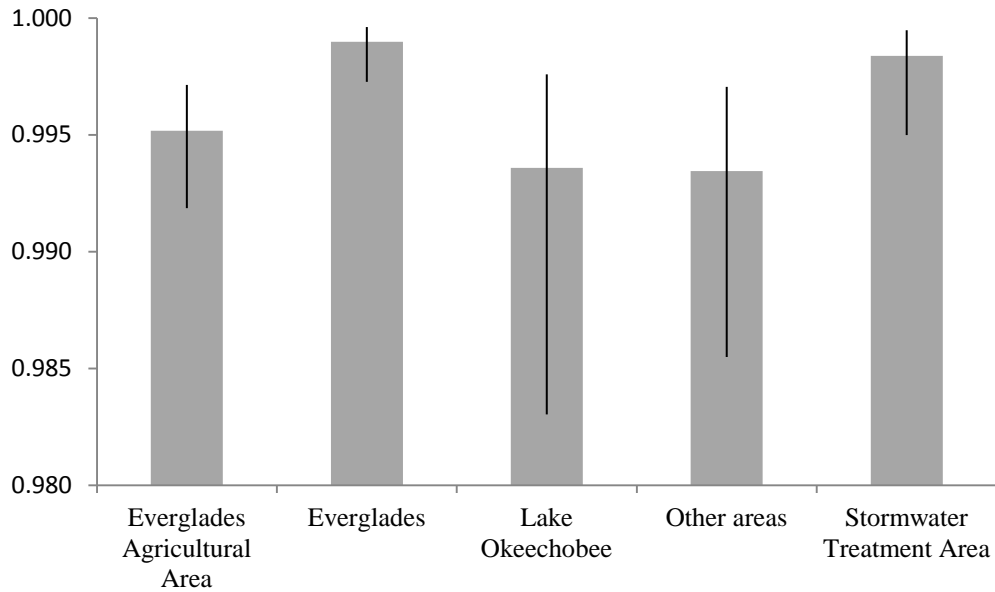
Figure 5. Daily survival rates (DSR) of Florida Mottled Ducks experiencing three different hunting regimes during the hunting season (Nov 19 – Jan 31) in south Florida from 2008-11. Hunting is closely monitored and restricted in quota hunt areas and unmonitored in open hunted areas.
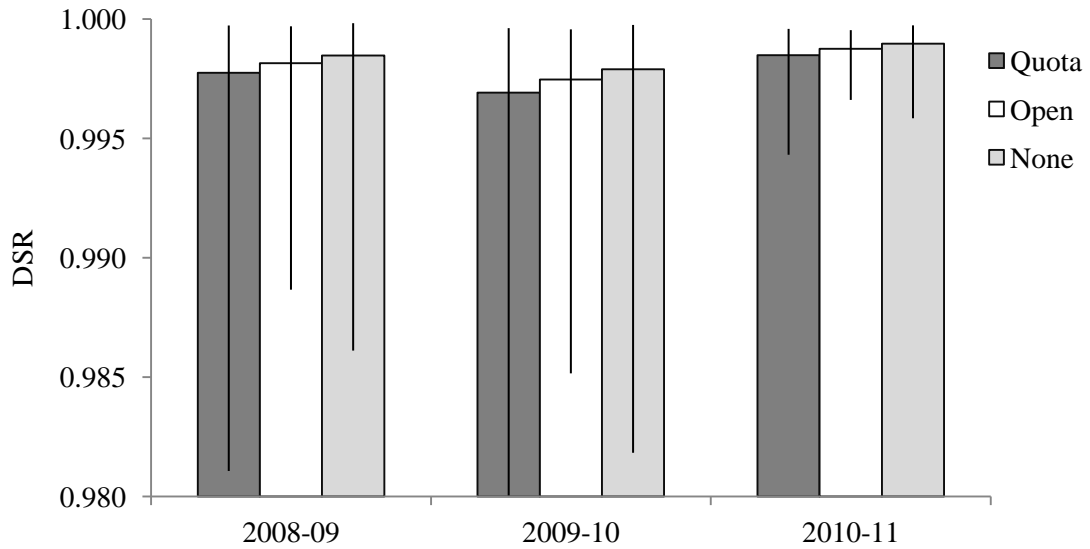
Chapter 3: Seasonal use and selection of habitats by female mottled ducks in southeast Florida

Abstract

Florida will continue to undergo high rates of habitat loss, mainly due to urbanization, and invasive species are a major threat to Florida's biodiversity. The Florida mottled duck, a species unique to the state, is particularly vulnerable to loss of wetland habitats and to hybridization with feral mallards. Because mottled ducks are more likely to encounter feral mallards in urban habitats, we trapped and radio-marked adult females in both urban ($n = 99$) and rural ($n = 146$) habitats to determine home ranges and rates of movement into and out of urban areas. We also determined habitat use in urban and rural areas during the breeding (1 Feb – 31 July), post-breeding (1 Aug – 18 Nov), and hunting (19 Nov – 31 Jan) seasons and estimated seasonal habitat preferences of rural female mottled ducks. We found that median home range sizes of rural females were more than 65 times greater than those of urban females. There was little movement (6%) between urban and rural areas. Urban females mostly used low and high intensity human development habitats year-round. Rural ducks preferred freshwater marshes throughout the year, but selection of other habitat types varied seasonally. Artificial impoundments and reservoirs were particularly important during the post-breeding and hunting seasons. Our results suggest the spread of mallard genetic introgression outside of urban areas may be slow due to the low amount of movement

into and out of those areas. Preservation, creation, and improvement of freshwater marshes and artificial impoundments would likely benefit Florida mottled ducks.

Introduction

Habitat destruction and alien species are the two greatest threats to biodiversity in the United States (Czech and Krausman 1997, Wilcove et al. 1998). Although Florida currently has the highest percentage of wetland cover (29%) of any state, 44% of Florida's original wetlands have now been lost (Dahl 2005). Between 1998 and 2004, estimated rates of wetland loss were higher in Florida than in any other state (Dahl 2006), primarily due to urban and rural development and conversion to citrus orchards and pastures. Freshwater emergent wetlands, which are preferred by native ducks, experienced greater declines than any other wetland type (Johnson et al. 1991, Dahl 2005). While annual rates of loss for all freshwater wetland types combined have decreased by more than 80% since the 1970s, rates of loss for freshwater emergent wetlands have more than doubled (Dahl 2005).

Hybridization with mallards (*Anas platyrhynchos*) is considered a cause of decline for several species of Anatidae world-wide (Rhymer and Simberloff 1996, Rhymer 2006, Williams and Basse 2006, Young and Rhymer 1998). Wild mallards only winter in Florida and are absent during the breeding season (Bellrose 1976). Feral domestic mallards, however, are present year-round and will readily breed with closely-related Florida mottled ducks, producing fertile hybrid offspring. In one study, 11% of mottled ducks were found to be hybrids with rates as high as 24% in some areas (Williams et al. 2005a). Genetic introgression is currently considered the greatest threat to the population

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and could ultimately cause the extinction of the Florida mottled duck if left unchecked (Bielefeld et al. 2010, Florida Fish and Wildlife Conservation Commission 2011).

The Mottled Duck is a close relative of the mallard and consists of two genetically distinct sub-species (McCracken et al. 2001, Williams et al. 2005b). 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). A small breeding population introduced from Louisiana also persists in coastal Georgia and South Carolina. The Florida population (*A. f. fulvigula*) resides primarily in rural and urban areas of peninsular Florida south of Alachua County (Bielefeld et al. 2010). Existing data suggest little to no gene flow or movement among any of the populations.

Given the impact that habitat change can have on populations, it is important to understand habitat use in species that are of conservation concern. Little data exist for mottled ducks using the unique habitats of south Florida. Additionally, Florida mottled ducks are more likely to encounter, and hybridize with, feral mallards in urban areas (Florida Fish and Wildlife Conservation Commission 2011), but information about mottled ducks using urban habitats is limited. It is unknown whether ducks that use urban areas regularly mix with ducks that do not, or vice versa. We used radio-telemetry data to examine home ranges and movements of female mottled ducks in urban and non-urban areas. We also examined habitat use and selection patterns of females throughout the annual cycle. The most recent Conservation Plan for the Florida Mottled Duck identified several areas where knowledge of the species' habitat requirements is incomplete (Florida Fish and Wildlife Conservation Commission 2011). This study will

provide critical information needed for the development of a more comprehensive management plan for Florida mottled ducks.

Study Area

Our research area included all or parts of 15 counties in south Florida from Osceola County in the north to Miami-Dade County in the south and from DeSoto County in the west to Palm Beach County in the east (Fig. 1). Major features of this area include Lake Okeechobee, the Everglades Agricultural Area (EAA), Stormwater Treatment Areas (STAs), and parts of the Everglades Protection Area (Everglades). Lake Okeechobee consists mainly of open water, although the western and southern littoral zones support large areas of freshwater marsh and other non-forested wetland types (Havens and Gawlik 2005). The EAA is an artificially drained area north of the Everglades that extends from the south shore of Lake Okeechobee to the Broward-Palm Beach county line. Most of the EAA is devoted to farming. Sugarcane is the primary crop, but rice, vegetables, and sod also are produced. The EAA is dissected by hundreds of miles of ditches and canals used for drainage and irrigation of crop fields. The EAA also contains the STAs, which are freshwater artificial marsh impoundments designed to remove excess agricultural nutrients and other pollutants from Lake Okeechobee and EAA waters before being released to the Everglades. The Everglades Protection Area consists primarily of wetlands, especially glades marshes and sawgrass (*Cladium jamaicense*) interspersed with small forested islands and includes Water Conservation Areas, Wildlife Management Areas, National Park, and National Wildlife Refuge lands extending from the southern and eastern edges of the EAA south to Florida Bay. The study area also included areas of high and low intensity urban development (Florida

Natural Areas Inventory 2010). Urban areas of southeast Florida often have a high density of man-made aquatic habitats as a series of borrow pit ponds and canals are used to contain and redirect stormwater run-off.

Methods

In August and September, we captured molting mottled ducks at night using spotlights and airboats in flooded agricultural fields and wetlands. We implanted transmitters in females captured in these areas in 2008 ($n = 47$), 2009 ($n = 50$), and 2010 ($n = 50$). We used bait traps to capture female mottled ducks in urban areas of Palm Beach County in February–March 2009 ($n = 16$), December 2009–March 2010 ($n = 45$), and December 2010–March 2011 ($n = 38$). All urban trap sites were located in the towns of Riviera Beach, Jupiter, and Palm Beach Gardens. Captured birds were transported to the University of Florida Everglades Research & Education Center in Belle Glade or J.W. Corbett Wildlife Management Area in West Palm Beach. Age and sex of each individual was determined using cloaca, bill, and plumage characteristics and only adult females were radio-marked. We used abdominal implantation methods to attach radio transmitters (18 g; AI-2M [12], Holohil System Ltd., Carp, Ontario, Canada) to adult female Florida mottled ducks ($n = 246$; Korschgen et al. 1996). We also marked females with U.S. Fish and Wildlife Service metal leg bands. After surgery birds were allowed a minimum recovery time of 60 min and released at the same location where they were captured. No birds were held for more than 24 hours and those females held for more than 12 hours were kept in a climate-controlled area and provided with corn and water. Animal procedures were approved under Federal Fish and Wildlife permit MB745817-0

and Auburn University Animal Care and Use Committee protocol (PRNs 2007-1218 and 2010-1821).

Radio-tracking of each bird began 7 days after capture. All locations were made between sunrise and sunset. We used vehicles with roof-mounted null-peak antenna systems to collect at least three bearings per duck no more than once per day. Bearings were used to estimate locations and 95% error ellipses using Program GTM 2.3.5 (Sartwell 2000). Visual locations were obtained when possible and entered manually. Fixed-wing aircraft also were used up to four times a week to relocate birds we could not find during the most recent ground tracking attempt. Locations collected during flights were recorded using a hand-held GPS unit.

We joined the duck location point layer to the Florida Natural Areas Inventory Cooperative Land Cover Map v.1.1 in ArcGIS to determine habitat type of all locations (Florida Natural Areas Inventory 2010). Each location was assigned a habitat type and use of each type was estimated for three seasons: breeding (Feb 1 – Jul 31), post-breeding (Aug 1 – Nov 18), and hunting (Nov 19 – Jan 31). Because locations fell within 70 different habitat types, we grouped habitats into 10 generalized categories including agriculture, artificial impoundment/reservoir, forested wetland, freshwater marsh, glades marsh, high intensity urban, low intensity urban, open water, other non-forested wetlands, and upland. Agricultural habitats included citrus, sugarcane, and other row crops. High intensity urban areas included commercial, residential, and institutional properties. Low intensity urban habitats included golf courses, parks, roadsides, and urban open lands. Open water habitats included canals, lakes, ponds, and rivers. Other non-forested wetlands included shrub bog, sawgrass, wet prairie, and floating or emergent aquatic

vegetation. Upland habitats included pastures, forests, mesic flatwoods, shrub, and rural

open lands. Individual female proportional use of habitats for each season was calculated

by dividing the number of locations in each habitat type by the total number of locations.

We then averaged the estimates of proportional use across all birds to obtain total mean

use of each habitat type during each season.

Home range analyses were conducted using the HRT tools extension in ArcGIS

9.3.1 (ESRI, Redlands, CA). We used the adaptive kernel density estimation method to

calculate 95% utilization home ranges. A minimum of 30 locations per duck were used

to estimate home range size (Seaman et al. 1999). We also conducted a third-order

selection analysis to compare proportional habitat use to availability of habitats at the

home range scale in order to better inform habitat management decisions (Johnson 1980).

Because urban habitat management would likely be cost-prohibitive in many instances,

we did not conduct a selection analysis for urban-captured ducks. To determine habitat

availability for each duck we used ArcGIS to randomly plot a number of points equal to

the number of locations for each duck within its home range. Because our method of

analysis assumes all females used all habitat types, we replaced any zeros in the use data

with 0.003 to reduce the likelihood of type I errors (Bingham and Brennan 2004). We

used compositional analysis to test for non-random habitat use in each of three seasons;

post-breeding, hunting, and breeding (Aebischer et al. 1993). We compared use to

availability data using the "compana" function in the "adehabitat" package in Program R

2.15.0 (R Development Core Team 2009). Compositional analysis considers each

individual separately as a sampling unit, rather than pooling locations. This method is

useful when the number of locations varies widely among individuals, as in this study.

Results

We estimated diurnal habitat use using 10846 locations of 98 female Florida mottled ducks captured in urban areas and 7269 locations of 141 females captured in the EAA. Error ellipses of triangulated locations averaged 3.37 ha for urban ducks and 17.09 ha for EAA-captured ducks. Only 5% of triangulated locations had an error ellipse larger than the habitat polygon in which it fell. There was little movement between urban and rural areas. Six of the 98 (6.1%) urban-captured ducks were located outside of urban limits at least once. Similarly, only nine females (6.4%) captured in the EAA used urban areas.

We estimated home ranges for 104 EAA-captured ducks and 89 urban-captured ducks that had $\geq$ 30 locations. Home range sizes varied widely from 0.168 km^2 to 5164.655 km^2. Median home range sizes for EAA ducks were much larger than those of urban ducks (Table 1). For ducks captured in the EAA, use of freshwater marshes was high during all seasons. Use of agricultural habitats in the EAA peaked during the breeding and post-breeding seasons (Table 2). Females in agricultural locations used sugarcane 95% of the time, most likely unmapped drainage ditches within the fields. Use of artificial impoundments was highest during the post-breeding and hunting seasons (Table 2). Most (98%) of the artificial impoundments used by EAA-captured ducks were within Stormwater Treatment Areas. Use of glades marsh habitats, 97% of which were within Water Conservation Areas, peaked during the pre-breeding and breeding seasons (Table 2). Conversely, seasonal changes in habitat use for urban ducks were small (Table 3). For urban ducks, use of high and low intensity human development, such as

residential areas, golf courses, institutional and commercial properties, and roadsides, was high during all 3 seasons (Table 3).

Habitat use was non-random during the post-breeding ($\Lambda = 0.06981$, *P* = 0.002), hunting ($\Lambda = 0.1851$, *P* = 0.002), and breeding ($\Lambda = 0.34909$, *P* = 0.002) seasons. Artificial impoundments and reservoirs were strongly selected during the post-breeding and hunting seasons, but were avoided during the breeding season (Table 4). Freshwater marshes were selected during all seasons (Table 4). Glades marshes were avoided during post-breeding and hunting seasons (Table 4). Agricultural habitats were avoided during the hunting season (Table 4).

Discussion

We found distinct differences in the habitat use of urban and rural female mottled ducks. Only 6% of females moved between urban and rural areas. Female waterfowl are often philopatric and tend to return to the area where they were hatched or previously nested (Anderson et al. 1992). High rates of site fidelity have also been found in harlequin ducks (Iverson and Esler 2006) and urban Canada geese (Groepper et al. 2008, Balkcom 2010). Our results differ from Bielefeld and Cox (2006), however, who reported that 20 – 56% of mottled ducks captured in rural areas of the Upper St. Johns River Basin (USJRB) in east-central Florida moved to urban habitats in response to reduced wetland habitat availability in rural areas during a prolonged drought. Use of atypical habitats by ducks is sometimes correlated with decreased availability of wetland habitats (Derksen and Eldridge 1980, Giroux 1981). Drought conditions also occurred during this study (Varner et al., in review), but we did not observe an increase in the number of rural females using urban areas. This may be due to the greater availability of

rural permanent wetlands in south Florida, when compared to the USJRB, or because

drought conditions in south Florida during this study were not as extreme as those during

the USJRB study (Bielefeld and Cox 2006, Varner et al. in review).

Because urban ducks typically remained within urban areas, which cover far less

land area, most had much smaller home range sizes ($2 - 6$ km^2) than rural-captured ducks

($326 - 881$ km^2). Small home range sizes have also been reported for resident urban

Canada geese in Nebraska ($\bar{x} = 25$ km^2; Groepper et al 2008). It appears that urban

individuals can meet their nutritional and habitat needs throughout the annual cycle

without moving long distances. Some urban ducks had year-round access to

supplemental foods. We found two sites where residents provided corn that attracted

dozens of mottled ducks and other waterbirds. We also found several locations where

ducks foraged for seeds that fell from feeders intended for songbirds. These reliable

sources of food helped urban females meet their nutritional needs without having to fly

long distances. Home range sizes of several bird, mammal, and reptile species have been

found to decrease in response to supplemental feeding (Boutin 1990, Staus 1998).

Additionally, the historically wet landscape of eastern Palm Beach County has been

controlled with a series of canals, retention ponds, and impoundments. In turn, surface

water conditions in these urban areas are less variable, because these aquatic habitats are

managed for aesthetics and/or public use. In contrast, many rural wetlands are more

ephemeral and sensitive to changes in rainfall forcing ducks to move longer distances to

find suitable habitat during very dry or wet periods.

Further, there was little seasonal variation in habitat use among urban ducks

compared to rural ducks. Rural females favored artificial impoundments and reservoirs

within Stormwater Treatment Areas (STAs) during the post-breeding and hunting seasons, which included the dry winter period. STAs are managed marsh impoundments designed to remove excess agricultural nutrients and other pollutants from water. Because of their important function, STAs are often maintained at high water levels and attract large numbers of waterbirds during the dry winter period (Beck et al. 2013). Studies of other treatment wetlands also have reported much higher bird densities when compared to reference wetlands (McAllister 1992, McAllister 1993). Urban mottled ducks, on the other hand, were not forced to seek out more permanent water sources during the winter. Many rural females left STAs and moved to agricultural habitats at the start of the breeding season. Rainfall levels typically peaked during the breeding season allowing ducks to use shallow irrigation ditches and flooded areas of fallow crop fields. Some females also attempted to nest in agricultural fields in south Florida, especially sugarcane (Varner et al. 2013). Use of glades marshes also increased during the breeding season. The Everglades may contain good quality breeding habitat in the form of tree islands that are less accessible to nest predators (Frederick and Collopy 1989). As evidence of this for ducks, survival of adult females during the breeding season was higher for those that used the Everglades when compared to most other areas (Varner et al. in review). Urban ducks were more flexible in regards to breeding habitat and did not have to travel far to find a suitable nest site. They often nested in small patches of native or ornamental vegetation in residential neighborhoods, golf courses, and parking lots (Varner et al. 2013).

Previous research indicated mottled ducks preferred non-tidal, low salinity wetlands (Grand 1988). We also found that mottled ducks did not use brackish or

saltwater. Johnson et al. (1991) reported that Florida mottled ducks preferred emergent

wetlands and ditches during March and April. In this study, emergent wetlands were

classified as other non-forested wetlands and ditches were classified as open water.

Similar to Johnson et al. (1991), we found that mottled ducks showed a weak preference

for other non-forested wetlands and open water during the breeding season. Johnson et

al. (1991) also found that mottled ducks avoided forested wetlands and uplands during

the breeding season and our results agree, although artificial impoundments were the

most strongly avoided during that time. Conversely, artificial impoundments were the

most strongly preferred during the post-breeding and hunting seasons. Ducks require

large permanent wetlands with abundant food and cover during the flightless wing molt,

which occurs during the post-breeding season (Moorman et al. 1993, Fleskes et al. 2010).

Artificial impoundments within STAs contain high quality habitat ideal for use during the

molting period (Beck et al. 2013). Additionally, hunting is heavily restricted within the

STAs when compared to other public lands. Special permits, issued via a lottery system,

are required and hunting is limited to a few impoundments during pre-scheduled times.

Otherwise, hunting is not permitted in many STA impoundments. Restricted hunting

activity in the STAs may attract mottled ducks to these areas during the hunting season.

Other duck species have also been found to increase their use of non-hunted sanctuaries

during the hunting season (Cox and Afton 1997, Evans and Day 2002, Casazza et al.

2012). Overall, rural ducks strongly preferred freshwater marshes over most habitat

types during all seasons. Freshwater marshes are also preferred by wintering mallards in

Louisiana and breeding mottled ducks in Texas (Haukos et al. 2010, Link et al. 2011).

Rural mottled ducks used low and high intensity human development very little and

showed neither preference nor avoidance for these habitat types. Urban ducks, conversely, mostly used low or high intensity human development year-round.

We found higher survival rates among female mottled ducks that used predominantly urban versus rural habitats (Varner et al. in review). Additionally, females that nest in urban areas have relatively high nest survival rates (Varner et al. 2013). Considering these high survival rates and that urban and rural birds seem not to intermix to any great degree, it appears Florida mottled ducks may experience greater recruitment rates, and thus population growth, in urban areas when compared to more rural areas. Unfortunately, feral and domestic mallards mostly occur in urban areas, which may lead to higher rates of hybridization in those areas (Florida Fish and Wildlife Conservation Commission 2011).

Management Implications

Given the small amount of female movement between urban and rural areas, it appears that mallard hybridization may be somewhat contained within urban areas in south Florida (R. Bielefeld, unpubl. data). In the USJRB, however, movement rates between urban and rural areas were much higher (Bielefeld and Cox 2006). Therefore, if Florida waterfowl managers wish to initiate programs to minimize the mallard genetic introgression threat, it may be most effective to focus their efforts in areas where movement between urban and rural areas is high, such as the USJRB, rather than south Florida. We did not, however, measure movements of males between urban and rural areas. Because male ducks have lower levels of breeding site fidelity (Anderson et al. 1992) and one male mallard or hybrid may mate with multiple female mottled ducks, further research is needed to determine the potential genetic impacts of male movements.

Habitat management in urban areas of south Florida appears to be unnecessary as mottled duck females appear well-adapted to survive and thrive in the current urban environment. However, mottled ducks likely would benefit from conservation and management of rural habitats, especially freshwater marshes and artificial impoundments.

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Figure 1. Map of study area in south Florida showing portions of urban and rural areas used by female Mottle Ducks; including Stormwater Treatment Areas (STAs) and the Everglades Agricultural Area (EAA).
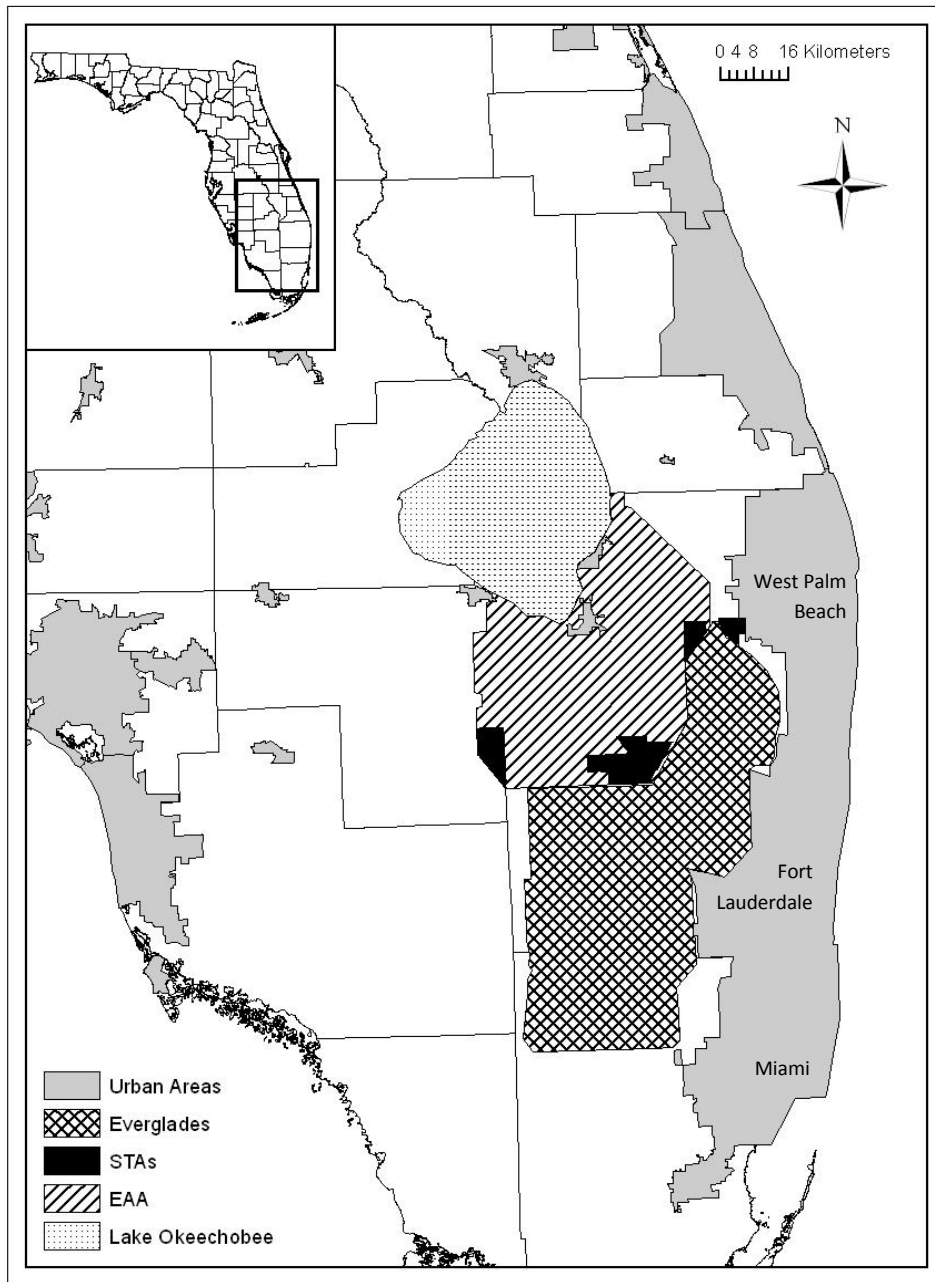
Table 1. Home range estimates for female Florida mottled ducks captured in the

Everglades Agricultural Area (EAA) and urban areas of south Florida, 2008-2011.

	study year [1]	n	mean # of locs/ bird	median 95% HR (km^2)	range (km^2)		
EAA	2008-09	37	57	881.01	1.6	-	5164.7
Urban	2008-09	14	119	2.32	0.3	-	28.7
EAA	2009-10	32	62	325.73	10.4	-	4494.5
Urban	2009-10	40	135	5.21	0.7	-	1000.9
EAA	2010-11	35	72	408.24	11.4	-	4496.9
Urban	2010-11	35	103	5.98	0.2	-	2118.2

[1] Study years begin in August for EAA ducks and December for urban ducks.

Table 2. Mean proportional use (and standard errors) of 10 habitats during the post-breeding (n = 88; 1 Aug – 18 Nov), hunting (n = 96; 19 Nov – 31 Jan), and breeding (n = 90; 1 Feb – 31 July) seasons by adult female Florida mottled ducks captured in the Everglades Agricultural Area, 2008-2011.

	Post-breeding		Hunting		Breeding	
	mean	se	mean	se	mean	se
Agriculture	0.2498	0.0328	0.0531	0.0154	0.3388	0.0314
Artificial impoundment / Reservoir	0.3377	0.0295	0.3138	0.0328	0.0385	0.0122
Forested wetland	0.0000	0.0000	0.0104	0.0035	0.0108	0.0031
Freshwater marsh	0.3096	0.0324	0.2608	0.0259	0.1975	0.0231
Glades marsh	0.0036	0.0013	0.0869	0.0233	0.1803	0.0302
High intensity human development	0.0026	0.0020	0.0136	0.0078	0.0131	0.0072
Low intensity human development	0.0015	0.0009	0.0132	0.0066	0.0101	0.0048
Open water	0.0353	0.0083	0.0669	0.0168	0.0527	0.0095
Other non-forested wetland	0.0299	0.0083	0.1231	0.0181	0.1036	0.0168
Upland	0.0298	0.0070	0.0581	0.0150	0.0544	0.0140

Table 3. Mean proportional use (and standard errors) of 10 habitats during the post-

breeding (n = 71; 1 Aug – 18 Nov), hunting (n = 71; 19 Nov – 31 Jan), and breeding (n =

99; 1 Feb – 31 July) seasons by adult female Florida mottled ducks captured in urban

areas of south-east Florida, 2009-2011.

	Post-breeding		Hunting		Breeding	
	mean	se	mean	se	mean	se
Agriculture	0.0008	0.0008	0.0020	0.0011	0.0167	0.0160
Artificial impoundment / Reservoir	0.1713	0.0277	0.1732	0.0182	0.1390	0.0186
Forested wetland	0.0004	0.0004	0.0023	0.0023	0.0083	0.0054
Freshwater marsh	0.0179	0.0111	0.0229	0.0031	0.0279	0.0073
Glades marsh	0.0008	0.0008	0.0000	0.0000	0.0047	0.0047
High intensity human development	0.4717	0.0403	0.4469	0.0082	0.3823	0.0274
Low intensity human development	0.2482	0.0271	0.2515	0.0198	0.2808	0.0113
Open water	0.0198	0.0118	0.0155	0.0037	0.0225	0.0074
Other non-forested wetland	0.0025	0.0013	0.0150	0.0103	0.0133	0.0058
Upland	0.0665	0.0220	0.0708	0.0112	0.1046	0.0118

Table 4. Ranking matrix for third-order habitat selection for adult female Florida mottled ducks trapped in the Everglades Agricultural Area during the post-breeding (1 Aug – 18 Nov), hunting (19 Nov – 31 Jan), and breeding (1 Feb – 31 Jul) seasons, 2008 – 2011.

| Habitat type | Rank | Habitat type [1,2] | | | | | | | | | |
		AGR	AIR	FOW	FRM	GLM	HIU	LIU	OPW	ONW	UPL
Post-Breeding											
AGR	5	0	---	+	---	+++	+	-	-	+++	+
AIR	1	+++	0	+++	+++	+++	+++	+++	+++	+++	+++
FOW	8	-	---	0	---	+++	-	-	-	+++	-
FRM	2	+++	---	+++	0	+++	+++	+++	+++	+++	+++
GLM	10	---	---	---	---	0	---	---	---	---	---
HIU	3	-	---	+	---	+++	0	+	+	+++	+
LIU	6	+	---	+	---	+++	-	0	-	+	+
OPW	4	+	---	+	---	+++	-	+	0	+++	+
ONW	9	---	---	---	---	+++	---	-	---	0	---
UPL	7	-	---	+	---	+++	-	-	-	+++	0
Hunting											
AGR	10	0	---	---	---	---	---	---	---	---	---
AIR	1	+++	0	+	+	+++	+++	+++	+++	+++	+++
FOW	4	+++	-	0	---	+++	+	+	+	-	+
FRM	2	+++	-	+++	0	+++	+++	+++	+++	+++	+++
GLM	9	+++	---	---	---	0	-	---	---	---	-
HIU	7	+++	---	-	---	+	0	-	-	-	+
LIU	6	+++	---	-	---	+++	+	0	-	-	+
OPW	5	+++	---	-	---	+++	+	+	0	-	+++
ONW	3	+++	---	+	---	+++	+	+	+	0	+++
UPL	8	+++	---	-	---	+	-	-	---	---	0
Breeding											
AGR	4	0	+++	+	---	-	+	+	-	-	+++
AIR	10	---	0	---	---	-	-	-	---	---	---
FOW	7	-	+++	0	-	-	+	-	-	-	+
FRM	1	+++	+++	+	0	+++	+++	+++	+++	+	+++
GLM	5	+	+	+	---	0	-	+	-	-	+
HIU	6	-	+	-	---	+	0	+	-	-	+
LIU	8	-	+	+	---	-	-	0	-	-	+
OPW	3	+	+++	+	---	+	+	+	0	-	+
ONW	2	+	+++	+	-	+	+	+	+	0	+++
UPL	9	---	+++	-	---	-	-	-	-	---	0

[1] AGR = agriculture, AIR = artificial impoundment/reservoir, FOW = forested wetland,

FRM = freshwater marshes, GLM = glades marsh, HIU = high intensity human development, LIU = low intensity human development, OPW = open water, ONW = other non-forested wetlands, UPL = upland

[2] (+) indicates row habitat type is selected over column habitat type; (-) indicates column habitat type is selected over row habitat type; the sign is tripled if the relationship is significant ($\alpha = 0.05$).