The Journal of Wildlife Management 78(5):840–847; 2014; DOI: 10.1002/jwmg.734

Research Article

Movements and Seasonal Use of Habitats by Rural and Urban Female Mottled Ducks in Southeast Florida

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ABSTRACT Florida will continue to undergo high rates of habitat loss, primarily the result of urbanization. In addition, invasive species are a major threat to Florida's biodiversity. The Florida mottled duck (*Anas fulvigula*), a bird unique to the state, is particularly vulnerable to loss of wetland habitats and hybridization with feral mallards. Because mottled ducks are more likely to encounter feral mallards in urban habitats, we trapped and radiomarked adult females in urban ($n = 99$) and rural ($n = 146$) habitats to estimate 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 Jul), post-breeding (1 Aug–18 Nov), and hunting (19 Nov–31 Jan) periods and estimated seasonal habitat selection of rural female mottled ducks. Urban females used mostly aquatic habitats in low and high intensity human development year-round. Rural ducks used freshwater marshes throughout the year, but selection of other habitat types varied seasonally. Use of glades marsh and agricultural habitats by rural ducks peaked during the breeding season. Rural ducks selected artificial impoundments and reservoirs during the post-breeding and hunting periods. Median home range size of rural females was more than 65 times greater than those of urban females. Our results suggest the spread of mallard genetic introgression caused by females leaving urban areas may be slow because as few as 6% of the adult females moved between urban and rural areas. Focusing wetland conservation efforts on freshwater marshes and artificial impoundments in south Florida would likely benefit mottled ducks.

KEY WORDS *Anas fulvigula fulvigula*, Florida, habitat selection, home range, hybridization, mottled duck, urbanization.

Habitat destruction and alien species are the 2 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 been lost (Dahl 2005). Between 1998 and 2004, estimated rates of wetland loss were greater in Florida than in any other state, primarily because of urban and rural development and conversion to citrus groves and pastures (Dahl 2006). Freshwater emergent wetlands, which provide habitat for native ducks, experienced greater declines than any other wetland type (Johnson et al. 1991, Dahl 2005). Although 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, Young and Rhymer 1998, Rhymer 2006, Williams and Basse 2006). Wild mallards only winter in Florida and are absent during the breeding season (Bellrose 1976). Feral mallards, however, are present year-round and will readily breed with closely-related mottled ducks (*Anas fulvigula*), producing fertile hybrid offspring. In 1 study, 11% of Florida mottled ducks were found to be hybrids with rates as high as 24% in some areas (Williams et al. 2005*a*). Genetic introgression currently is considered the greatest threat to the population 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 2 genetically distinct populations (McCracken et al. 2001, Williams et al. 2005*b*). The range of the western population 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 resides primarily in rural and urban areas of peninsular Florida south of Alachua County (Bielefeld et al. 2010). Existing data

Received: 16 August 2013; Accepted: 23 April 2014
Published: 17 June 2014

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suggest little to no gene flow or duck movement among any of the populations (McCracken et al. 2001).

Given the impact that habitat loss can have on populations, managers need to understand habitat use by species that are of conservation concern. Little data on habitat use exist for mottled ducks using the unique habitats of south Florida. 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. Whether mottled ducks that use urban areas regularly mix with ducks that do not, or vice versa, is unknown. 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). Our objective was to determine habitat use and movement patterns of females throughout their annual cycle, with an emphasis on comparing these behaviors between ducks in urban and non-urban areas. We used radio-telemetry to estimate home ranges and monitor movements of female mottled ducks in urban and non-urban areas. We also determined habitat use and selection patterns by females throughout the annual cycle.

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 included Lake Okeechobee, the Everglades Agricultural Area, Stormwater Treatment Areas, and parts of the Everglades Protection Area (Everglades). Lake Okeechobee consisted mainly of open water, although the western and southern littoral zones supported large areas of freshwater marsh and other non-forested wetland types (Havens and Gawlik 2005). The Everglades Agricultural Area was an artificially drained area north of the Everglades that extended from the south shore of Lake Okeechobee to the Broward-Palm Beach county line. Most of the Everglades Agricultural Area was devoted to farming. Sugarcane was the primary crop, but rice, vegetables, and sod also were produced. The Everglades Agricultural Area was dissected by hundreds of miles of ditches and canals used for drainage and irrigation of crop fields. It also contained the Stormwater Treatment Areas, which were freshwater artificial marsh impoundments designed to remove excess agricultural nutrients and other pollutants from Lake Okeechobee and Everglades Agricultural Area waters before being released to the Everglades. The Everglades Protection Area consisted primarily of wetlands, especially glades marshes and sawgrass (*Cladium jamaicense*) interspersed with small forested islands and included Water Conservation Areas, Wildlife Management Areas, and National Park and National Wildlife Refuge lands extending from the southern and eastern edges of the Everglades Agricultural Area 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 had a high density of man-made aquatic habitats as a series of borrow pit ponds and canals were 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 ($n = 50$). Because airboats could not be used in urban areas, 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. We transported captured birds to the University of Florida Everglades Research & Education Center in Belle Glade or the J.W. Corbett Wildlife Management Area in West Palm Beach. We determined age and sex of each individual using cloaca, bill, and plumage characteristics; we radio-marked only adult females. We implanted radio transmitters with percutaneous whip antennae in the abdomen of each female (18 g; AI-2M [12], Holohil System Ltd., Carp, Ontario, Canada; $n = 246$; Korschgen et al. 1996). We also marked females with United States Geological Survey metal leg bands. After surgery, we allowed birds a minimum recovery time of 60 minutes and released them at the same location where we captured them. We did not hold any birds for more than 24 hours and kept females held for more than 12 hours in a climate-controlled area with food and water. Auxiliary marking with radio transmitters was authorized under United States Federal Bird Banding and Marking Permit MB745817-0. Animal handling procedures were approved under Auburn University Animal Care and Use Committee protocols (PRNs 2007–1218 and 2010–1821).

Radiotracking of each bird began 7 days after capture to account for possible effects of handling. We located birds between sunrise and sunset. We used vehicles with roof-mounted null-peak antenna systems to collect at least 3 bearings per duck no more than once per day. We used bearings to estimate locations and 95% error ellipses using Program GTM 2.3.5 (Sartwell 2000). We obtained visual locations when possible. We also used fixed-wing aircraft up to 4 times a week to relocate birds we could not find during the most recent ground tracking attempt. We recorded locations collected during flights using a hand-held global positioning unit.

We determined habitat type of all marked duck locations using Florida Natural Areas Inventory Cooperative Land Cover Map v.1.1 in ArcGIS (Florida Natural Areas Inventory 2010) for 3 periods: breeding (Feb 1–Jul 31), post-breeding (Aug 1–Nov 18), and hunting (Nov 19–Jan 31). 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-

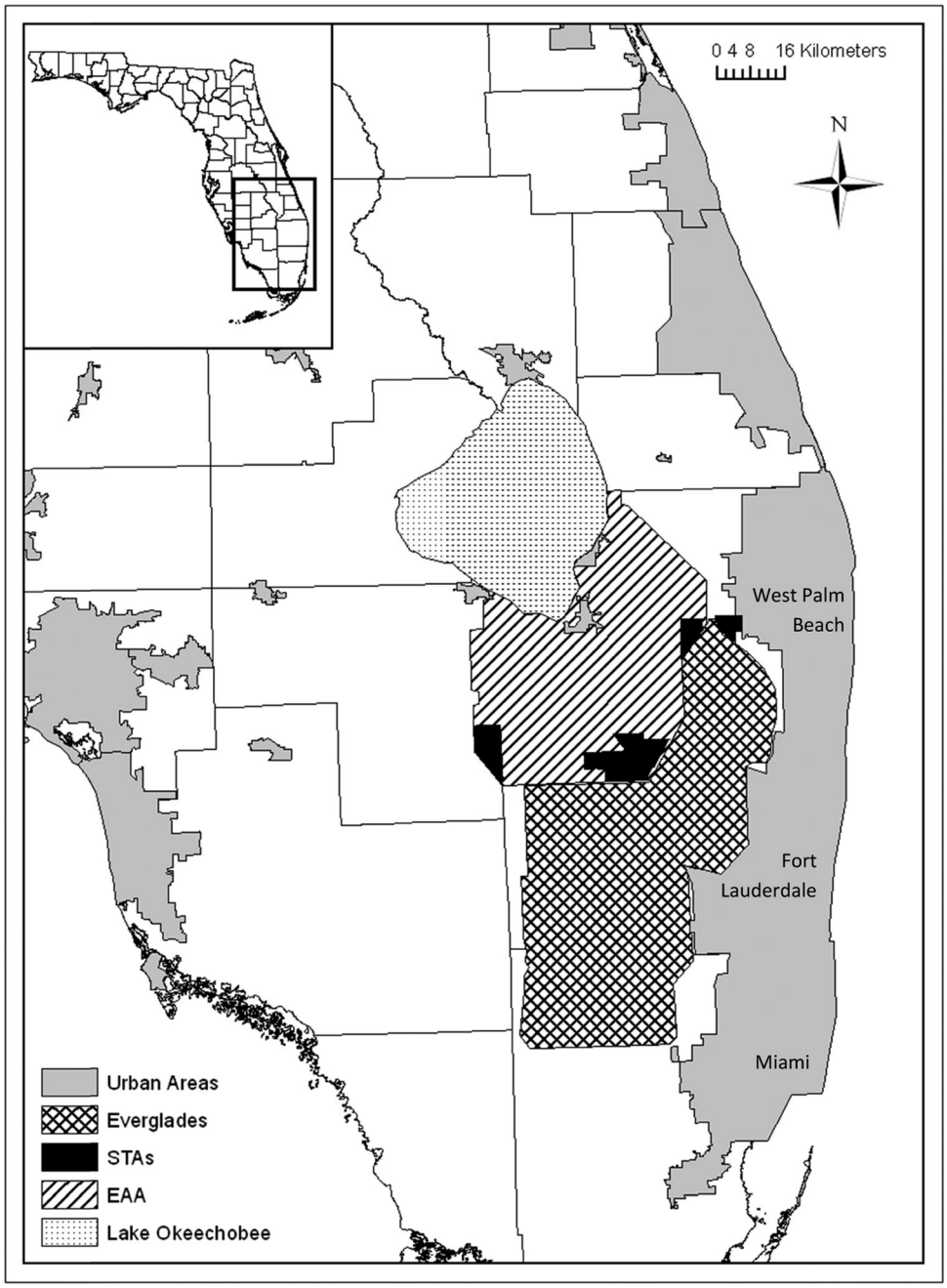

Figure 1. Map of study area in south Florida showing portions of urban and rural areas used by female mottled ducks in 2008–2011, including Stormwater Treatment Areas (STAs) and the Everglades Agricultural Area (EAA).

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. We calculated the proportional use of habitats by individual females for each season 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 females to obtain total mean use of each habitat type during each season.

We used the adaptive kernel density method to estimate the 95% utilization home ranges using the HRT tools extension in ArcGIS 9.3.1 (ESRI, Redlands, CA). We used a minimum of 30 locations per duck to estimate home range size (Seaman et al. 1999). We also conducted a third-order selection analysis to compare proportional habitat use to proportional availability of habitats within the home range scale (Johnson 1980). Management of urban habitats for the benefit of Florida mottled ducks does not appear to be

necessary at this time and would likely be cost-prohibitive; therefore, we did not conduct a selection analysis for urban-captured ducks. To determine habitat availability for each rural duck, we used ArcGIS to plot a number of random points equal to the number of locations for each duck within its home range. Because our method of analysis assumes females used all habitat types even if we did not detect them, Bingham and Brennan (2004) recommend replacing any zeros in the use data with 0.003 to reduce the likelihood of Type I errors. We used compositional analysis (Aebischer et al. 1993) to test for non-random habitat use in each of 3 seasons using the "compana" function in the "adehabitat" package in Program R 2.15.0 (R Development Core Team 2009). Compositional analysis considers each individual animal separately as a sampling unit, rather than pooling the locations of all animals together. This method is useful when the number of locations varies widely among individuals, as in this study.

RESULTS

We estimated diurnal habitat use using 12–212 ($\bar{x} = 111$) locations per individual for 98 female Florida mottled ducks captured in urban areas and 6–127 ($\bar{x} = 52$) locations for 141 females captured in the rural areas. Error ellipses of triangulated locations averaged 3.37 ± 0.21 ha for urban ducks and 17.09 ± 1.87 ha for rural-captured ducks. Only 5% of triangulated locations had an error ellipse larger than the habitat polygon in which it fell. Only 6 of the 98 (6.1%) urban-captured ducks were located outside of urban limits at least once. Similarly, only 9 females (6.4%) captured in rural areas used urban areas.

We estimated year-round home ranges for 104 rural-captured ducks and 89 urban-captured ducks that had ≥ 30 locations. Home range sizes varied widely from 0.17 km^2 to 5164.66 km^2. Median home range sizes for rural ducks were larger than those of urban ducks (Table 1). For ducks captured in rural areas, use of freshwater marshes was high during all seasons. Use of agricultural habitats in the Everglades Agricultural Area peaked during the breeding and post-breeding seasons (Table 2). Females located in agricultural areas were in sugarcane 95% of the time, most likely in 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 rural-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 2). 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 2).

For rural ducks, habitat use was non-random during the post-breeding ($\Lambda = 0.070$, $P = 0.002$), hunting ($\Lambda = 0.185$, $P = 0.002$), and breeding ($\Lambda = 0.349$, $P = 0.002$) seasons. Artificial impoundments and reservoirs were strongly selected during the post-breeding and hunting seasons but were avoided during the breeding season (Table 3). Freshwater marshes were selected during all seasons (Table 3). Glades marshes were avoided during post-breeding and hunting seasons (Table 3). Agricultural habitats were avoided during the hunting season (Table 3).

DISCUSSION

Rural females strongly selected freshwater marshes over most other habitat types during all seasons. Freshwater marshes also are preferred by wintering mallards in Louisiana and breeding mottled ducks in Texas (Haukos et al. 2010, Link et al. 2011). Johnson et al. (1991) found that mottled ducks avoided forested wetlands and uplands during the breeding season and our results agree. Use and availability of low and high intensity urban developments were low for rural mottled ducks and these habitat types were neither selected nor avoided. Urban ducks, conversely, mostly used low or high intensity human development year-round.

We found little seasonal variation in habitat use among urban ducks compared to rural ducks. Rural females selected artificial impoundments and reservoirs within Stormwater Treatment Areas during the post-breeding and hunting seasons, which included the dry winter period. Stormwater Treatment Areas are managed marsh impoundments designed to remove excess agricultural nutrients and other pollutants from water. Because of their important function, Stormwater Treatment Areas 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 waterbird densities when compared to reference wetlands (McAllister 1992, 1993). Ducks require large permanent wetlands with abundant food and cover during the post-breeding season wing molt, when they are flightless (Moorman et al. 1993, Fleskes et al. 2010), and artificial impoundments within Stormwater Treatment Areas meet these needs (Beck et al. 2013). Additionally, hunting in the

Table 1. Home range (HR) size estimates for female Florida mottled ducks captured in rural and urban areas of southeast Florida, 2008–2011.

	Study year	*n*	Mean no. of locations/bird	Median 95% HR (km^2)	Range (km^2)
Rural	2008–2009	37	57	881.01	1.6–5164.7
Rural	2009–2010	32	62	325.73	10.4–4494.5
Rural	2010–2011	35	72	408.24	11.4–4496.9
Urban	2008–2009	14	119	2.32	0.3–28.7
Urban	2009–2010	40	135	5.21	0.7–1000.9
Urban	2010–2011	35	103	5.98	0.2–2118.2

Table 2. Mean proportional use (and SE) of 10 habitats during the post-breeding (1 Aug–18 Nov), hunting (19 Nov–31 Jan), and breeding (1 Feb–31 Jul) seasons by adult female mottled ducks captured in rural and urban areas of southeast Florida, 2008–2011.

	Post-breeding		Hunting		Breeding	
	Mean	SE	Mean	SE	Mean	SE
Rural ($n = 141$)						
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
Urban ($n = 98$)						
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 3. Ranking matrix for third-order habitat selection for 96 adult female Florida mottled ducks trapped in the Everglades Agricultural Area (rural) during the post-breeding (1 Aug–18 Nov), hunting (19 Nov–31 Jan), and breeding (1 Feb–31 Jul) seasons, 2008–2011.

		Habitat type[a,b]									
Habitat type	Rank	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

[a] 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.

[b] (+) indicates row habitat type is selected over column habitat type; (−) indicates column habitat type is selected over row habitat type; (+ + +) or (− − −) indicates difference is statistically significant ($\alpha \leq 0.05$).

fall and winter is heavily restricted within the Stormwater Treatment Areas relative 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 these areas. Restrictions on hunting activity may have positively influenced mottled duck use of Stormwater Treatment Areas during the hunting season because other duck species also have 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).

Many rural females left Stormwater Treatment Areas and moved to agricultural habitats at the start of the breeding season. Rainfall levels typically peaked during the breeding season, which allowed ducks to use shallow irrigation ditches and flooded areas of fallow crop fields (Fig. 2). 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 quality breeding habitat in the form of tree islands, which are likely less accessible to nest predators (Frederick and Collopy 1989). As evidence of this, survival of adult females during the breeding season was higher for those that used the Everglades when compared to most other rural areas (Varner et al. 2014). Prior research also has found high nest success rates for mottled ducks and other ducks nesting on islands (Giroux 1981, Stieglitz and Wilson 1968, Holbrook et al. 2000).

We found distinct differences in the habitat use and movements 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 also have been found in harlequin ducks (*Histrionicus histrionicus*; Iverson and Esler 2006) and urban Canada geese (*Branta canadensis*; Groepper et al. 2008, Balkcom 2010). Bielefeld and Cox (2006), however, reported that 20–56% of female mottled ducks captured in rural areas of the Upper St. Johns River Basin 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 2011 of this study (Fig. 2), but we did not observe a shift in marked rural females into urban areas. This may be because of the greater availability of rural permanent wetlands in south Florida, when compared to the Upper St. Johns River Basin, or because drought conditions in south Florida during this study were not as extreme as those during the Upper St. Johns River Basin study (Fig. 2; Bielefeld and Cox 2006).

Figure 2. Monthly Palmer Hydrologic Drought Index (PHDI) measurements for mainland south Florida from August 2008 through December 2011. Negative values indicate moderate (−2) to extreme (−4) drought conditions, whereas positive values indicate moderate (+2) to extreme (+4) wet conditions.

Urban females had much smaller median home range sizes (2–6 km^2) than rural-captured ducks (326–881 km^2). Small home range sizes also have been reported for resident urban Canada geese in Nebraska ($\bar{x} = 25\ km^2$; Groepper et al. 2008). Urban individuals appear to be able meet their nutritional and habitat needs throughout the annual cycle without moving long distances. Some urban ducks had year-round access to supplemental foods, such as bird seed or cracked corn. Additionally, surface water conditions in urban areas are less variable, because urban aquatic habitats are managed for aesthetics and/or public use with a series of canals, retention ponds, and impoundments. In contrast, many rural wetlands are more sensitive to changes in rainfall forcing ducks to move longer distances to find suitable habitat during very dry or wet periods.

Varner et al. (2014) found higher survival rates among female mottled ducks that used predominantly urban versus rural habitats. Additionally, females that nest in urban areas have relatively high nest survival rates (Varner et al. 2013). Considering survival rates are higher and that urban and rural birds do not seem to intermix to any great degree, Florida mottled ducks may experience greater recruitment rates, and thus population growth, in urban areas 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

Our study indicates that mallard hybridization with Florida mottled ducks may be somewhat contained within urban areas in south Florida because of the small amount of female interchange between mottled ducks in urban and rural areas. We did not evaluate movements of juvenile or male ducks, however, so the interchange of genes among the 2 areas may still be high and requires additional research to address the potential genetic impacts of juvenile and male movements. In the Upper St. Johns River Basin, movement rates of mottled duck females 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, we recommend they focus their initial efforts in areas where duck movement between urban and rural areas is known to be high, such as

the Upper St. Johns River Basin. Because mottled duck females appear well-adapted to survive and thrive in the current urban environment, we recommend habitat management focus on rural areas. Mottled ducks likely would benefit from conservation and management of freshwater marshes and artificial impoundments.

ACKNOWLEDGMENTS

This project was funded by the Florida Fish and Wildlife Conservation Commission (FWCC); in large part by their Aquatic Habitat and Restoration Section. Additional funding and support was provided by Ducks Unlimited and the School of Forestry and Wildlife Sciences and the Alabama Agricultural Experiment Station at Auburn University. J. Benedict, A. Fanning, and J. Feddersen (FWCC); M. Milleson (United States Department of Agriculture Animal and Plant Health Inspection Service); and D. Heard (University of Florida Veterinary School) provided equipment, data, and critical field assistance. South Florida Water Management District, A. Duda & Sons, and more than 50 private landowners in south Florida provided access to study sites. C. August, F. Baziari, N. Bushue, L. Craver, D. Curtiss, J. Denton, J. Hamner, A. Munters, R. O'Meara, T. O'Meara, K. Rogers, T. Schrage, and J. Tapp assisted with field work. D. Heard and associates conducted radio implantation surgeries.

LITERATURE CITED

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radiotracking data. Ecology 74:1313–1325.

Anderson, M. G., J. M. Rhymer, and F. Rohwer. 1992. Philopatry, dispersal, and the genetic structure of waterfowl populations. Pages 365–395 *in* B. D. J. Batt, A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, editors. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis, USA.

Balkcom, G. D. 2010. Demographic parameters of rural and urban adult resident Canada geese in Georgia. Journal of Wildlife Management 74:120–123.

Beck, T. J., D. E. Gawlik, and E. V. Pearlstine. 2013. Community patterns in treatment wetlands, natural wetlands, and cropland in Florida. Wilson Journal of Ornithology 125:329–341.

Bellrose, F. C. 1976. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, Pennsylvania, USA.

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

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

Bingham, R. L., and L. A. Brennan. 2004. Comparison of Type I error rates for statistical analyses of resource selection. Journal of Wildlife Management 68:206–212.

Casazza, M. L., P. S. Coates, M. R. Miller, C. T. Overton, and D. R. Yparraguirre. 2012. Hunting influences the diel patterns in habitat selection by northern pintail. Wildlife Biology 18:1–13.

Cox, R. R., and A. D. Afton. 1997. Use of habitats by female northern pintails wintering in southwest Louisiana. Journal of Wildlife Management 61:435–443.

Czech, B., and P. R. Krausman. 1997. Distribution and causation of species endangerment in the United States. Science 277:1116–1117.

Dahl, T. E. 2005. Florida's wetlands: an update on status and trends 1985 to 1996. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Dahl, T. E. 2006. Status and trends of wetlands in the conterminous United States 1998 to 2004. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.

Derksen, D. V., and W. D. Eldridge. 1980. Drought-displacement of pintails to the Arctic Coastal Plain, Alaska. Journal of Wildlife Management 44:224–229.

Evans, D. M., and K. R. Day. 2002. Hunting disturbance on a large shallow lake: the effectiveness of waterfowl refuges. Ibis 144:2–8.

Fleskes, J. P., D. M. Mauser, J. L. Yee, D. S. Blehert, and G. S. Yarris. 2010. Flightless and post-molt survival and movements of female mallards molting in Klamath Basin. Waterbirds 33:208–220.

Florida Fish and Wildlife Conservation Commission. 2011. A conservation plan for the Florida mottled duck. Florida Fish and Wildlife Conservation Commission, Tallahassee, USA.

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

Frederick, P. C., and M. W. Collopy. 1989. Nesting success of five ciconiiform species in relation to water conditions in the Florida Everglades. Auk 106:625–634.

Giroux, J.-F. 1981. Ducks nesting on artificial islands during drought. Journal of Wildlife Management 45:783–786.

Groepper, S. R., P. J. Gabig, M. P. Vrtiska, J. M. Gilsdorf, S. E. Hygnstrom, and L. A. Powell. 2008. Population and spatial dynamics of resident Canada geese in southeastern Nebraska. Human–Wildlife Interactions 2:270–276.

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

Havens, K. E., and D. E. Gawlik. 2005. Lake Okeechobee conceptual ecological model. Wetlands 25:908–925.

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

Iverson, S. A., and D. Esler. 2006. Site fidelity and the demographic implications of winter movements by a migratory bird, the harlequin duck *Histrionicus histrionicus*. Journal of Avian Biology 37:219–228.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

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

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

Link, P. T., A. D. Afton, R. R. Cox, and B. E. Davis. 2011. Use of habitats by female mallards wintering in Southwestern Louisiana. Waterbirds 34:429–438.

McAllister, L. S. 1992. Habitat quality assessment of two wetland treatment systems in Mississippi: a pilot study. United States Environmental Protection Agency, Corvallis, Oregon, USA.

McAllister, L. S. 1993. Habitat quality assessment of two wetland treatment systems in the arid west: a pilot study. United States Environmental Protection Agency, Corvallis, Oregon, USA.

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

Moorman, T. E., G. A. Baldassarre, and T. J. Hess, Jr. 1993. Carcass mass and nutrient dynamics of mottled ducks during remigial molt. Journal of Wildlife Management 57:224–228.

R Development Core Team. 2009. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rhymer, J. M. 2006. Extinction by hybridization and introgression in anatine ducks. Acta Zoologica Sinica 52(Supplement):583–585.

Rhymer, J. M., and D. Simberloff. 1996. Extinction by hybridization and introgression. Annual Review of Ecology and Systematics 27: 83–109.

Sartwell, J. 2000. Geographic telemetry model (GTM) v.2.3.5. Missouri Department of Conservation, Columbia, Missouri, USA.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739–747.

Stieglitz, W. O., and C. T. Wilson. 1968. Breeding biology of the Florida duck. Journal of Wildlife Management 32:921–934.

Varner, D. M., R. R. Bielefeld, and G. R. Hepp. 2013. Nesting ecology of Florida mottled ducks using altered habitats. Journal of Wildlife Management 77:1002–1009.

Varner, D. M., G. R. Hepp, and R. R. Bielefeld. 2014. Annual and seasonal survival of adult female mottled ducks in southern Florida, USA. Condor 116:134–143.

Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. BioScience 48:607–615.

Williams, M., and B. Basse. 2006. Indigenous gray ducks, Anas superciliosa, and introduced mallards, *A. platyrhynchos*, in New Zealand: processes and outcome of a deliberate encounter. Acta Zoologica Sinica 52(Supplement):579–582.

Williams, C. L., R. C. Brust, T. T. Fendley, G. R. Tiller Jr., and O. E. Rhodes Jr. 2005*a*. A comparison of hybridization between mottled ducks (*Anas fulvigula*) and mallards (*A. platyrhynchos*) in Florida and South Carolina using microsatellite DNA analysis. Conservation Genetics 6:445–453.

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

Young, H. G., and J. M. Rhymer. 1998. Meller's duck: a threatened species receives recognition at last. Biodiversity and Conservation 7: 1313–1323.

Associate Editor: Pamela Garrettson.