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RESEARCH ARTICLE

Annual and seasonal survival of adult female Mottled Ducks in southern Florida, USA

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ABSTRACT

Continuing human population growth and urbanization in Florida may impact the survival of native birds, including the Florida Mottled Duck (*Anas fulvigula fulvigula*). Survival of adult females is an important vital rate that affects population growth rates, thus estimates of female survival as well as sources of variation affecting survival rates are needed for the development of a more informed conservation plan for Florida Mottled Ducks. In this study, we estimated annual and seasonal survival rates of radio-tagged adult female Mottled Ducks ($n = 236$) using urban and rural areas in southern Florida from 2008 to 2011. Additionally, we tested for differences in survival among ducks using different geographic areas during the breeding season and that were exposed to different hunting regimes during the hunting season. Identifying the geographic areas where higher rates of mortality occur may allow for more effective habitat and harvest management of the Florida subspecies of Mottled Duck. Annual survival was higher for ducks that used urban areas (74%) than for ducks that did not (47%). 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%). We found evidence of density-dependent mortality during and after the hunting season. Differences in hunting season survival for ducks that used unhunted rural areas (88%) when compared with survival of ducks that used areas with open (87%) or quota hunting systems (85%) were not significant. Differences in survival among study years 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.

Keywords: Anas fulvigula fulvigula, annual survival, Florida Mottled Duck, seasonal survival, urbanization

Supervivencia anual y temporal de hembras adultas de *Anas fulvigula* en el sur de Florida

La continua urbanización y crecimiento de la población humana en Florida puede impactar la supervivencia de aves nativas, incluyendo los *Anas fulvigula fulvigula* de Florida. La supervivencia de hembras adultas nativas es una importante tasa vital que afecta las tasas de crecimiento poblacional y estimaciones de supervivencia de hembras, que junto a otras fuentes de variación son necesarias para el desarrollo de un plan de conservación mejor comprendido para los *Anas fulvigula*. En este estudio, estimamos las tasas de supervivencia anual y estacional de hembras adultas de *Anas fulvigula*, marcadas con radios ($n = 236$) en zonas urbanas y rurales en el sur de Florida entre 2008 and 2011. Además, estudiamos las diferencias en supervivencia de patos en diferentes áreas geográficas durante la época reproductiva, y bajo diferentes regímenes durante la temporada de caza. La identificación de las áreas geográficas donde ocurren las mayores tasas de mortalidad permitirían una gestión mas eficaz del hábitat y la caza de esta subespecie. La supervivencia anual de los patos que utilizan las zonas urbanas (74%) fue mayor que para los patos que no lo hicieron (47%). Las tasas diarias de supervivencia fueron más bajas durante la época reproductiva. Las hembras cuyos hábitats fueron similares a los de los Everglades durante la temporada de cría, tuvieron mayores tasas de supervivencia por temporada (78–85%) que las que no lo hicieron (37–47%). Encontramos evidencias que mortalidad es dependiente de la densidad durante y después de la temporada de caza. La diferencia en la supervivencia de patos que habitan áreas rurales sin caza (88%) no fueron significativas cuando se compararon con aquellas que usaron sistemas de cuota (85%) o abiertos (87%). La diferencia en la supervivencia fue insignificante, durante los años del estudio. Nuestros resultados indican que los *Anas fulvigula* en la Florida sobreviven en altas tasas en las zonas urbanas, pero pueden beneficiarse con un aumento en la cantidad y calidad de los hábitats reproductivos.

Palabras clave: Anas fulvigula fulvigula, supervivencia anual, supervivencia estacional, urbanización

INTRODUCTION

Survival of adults is one of the most important vital rates affecting population growth rates of birds (Flint et al. 1998, Sæther and Bakke 2000, Flint et al. 2006). Certain periods of the annual cycle carry greater risks and challenges and are associated with increased mortality. The postbreeding season includes the remigial molt period, a time when flightless ducks are especially vulnerable to predation (Panek and Majewski 1990, Elsey et al. 2004). Several studies have indicated that survival of female ducks is lowest during the breeding season (Devries et al. 2003, Koons and Rotella 2003, Brasher et al. 2006). This might be caused by the energetic demands of egg-laying and incubation, but is more likely due to the fact that nesting activities, nest defense behaviors, and brood rearing cause female ducks to be more vulnerable to predation by terrestrial or avian predators (Greenwood et al. 1995, Hartke et al. 2006, Arnold et al. 2012). In addition, hunting is an important cause of winter mortality for ducks, and it is unknown whether density-dependent changes in survival may occur within the hunting season or afterward (Fleskes et al. 2007, U.S. Fish and Wildlife Service 2012).

The Mottled Duck (*Anas fulvigula*) is a close relative of the Mallard (*Anas platyrhynchos*) and consists of two genetically distinct subspecies (McCracken et al. 2001, Williams et al. 2005). The range of the western subspecies (*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 subspecies (*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 (R. R. Bielefeld personal observation).

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 from these effects. 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 affects 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). Mallard genetic introgression is a severe threat to Florida Mottled Ducks because a portion of the population is exposed to feral Mallards and is hybridizing with them (Bielefeld et al. 2010). Ducks in urban areas reside there either year-round 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.

Current management goals for the Florida Mottled Duck include maintenance of a stable population that can provide both 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 varies among years and is 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 with that of females using less disturbed rural areas. We also explored the relationship between survival and surface water conditions. Our analysis suggested that the breeding season was the time of greatest mortality risk for females, so we examined the relationship between use of major habitat types in southern Florida and breeding season survival. We also compared survival rates among females exposed to 3 different hunting systems—quota hunting, open hunting, and no hunting—to assess whether hunting system affected survival rates. Results of this study provide critical information needed to 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 southern 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 (Figure 1). This area contained Lake Okeechobee, the Everglades Agricultural Area, various Stormwater Treatment Areas, 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 Everglades Agricultural Area is an artificially drained area north of the Everglades that extends from the southern shore of Lake Okeechobee to the Broward–Palm Beach county line. Most of the Everglades Agricultural Area is devoted to farming. Sugarcane is the primary crop, but rice, vegetables, and sod also are produced. The Everglades

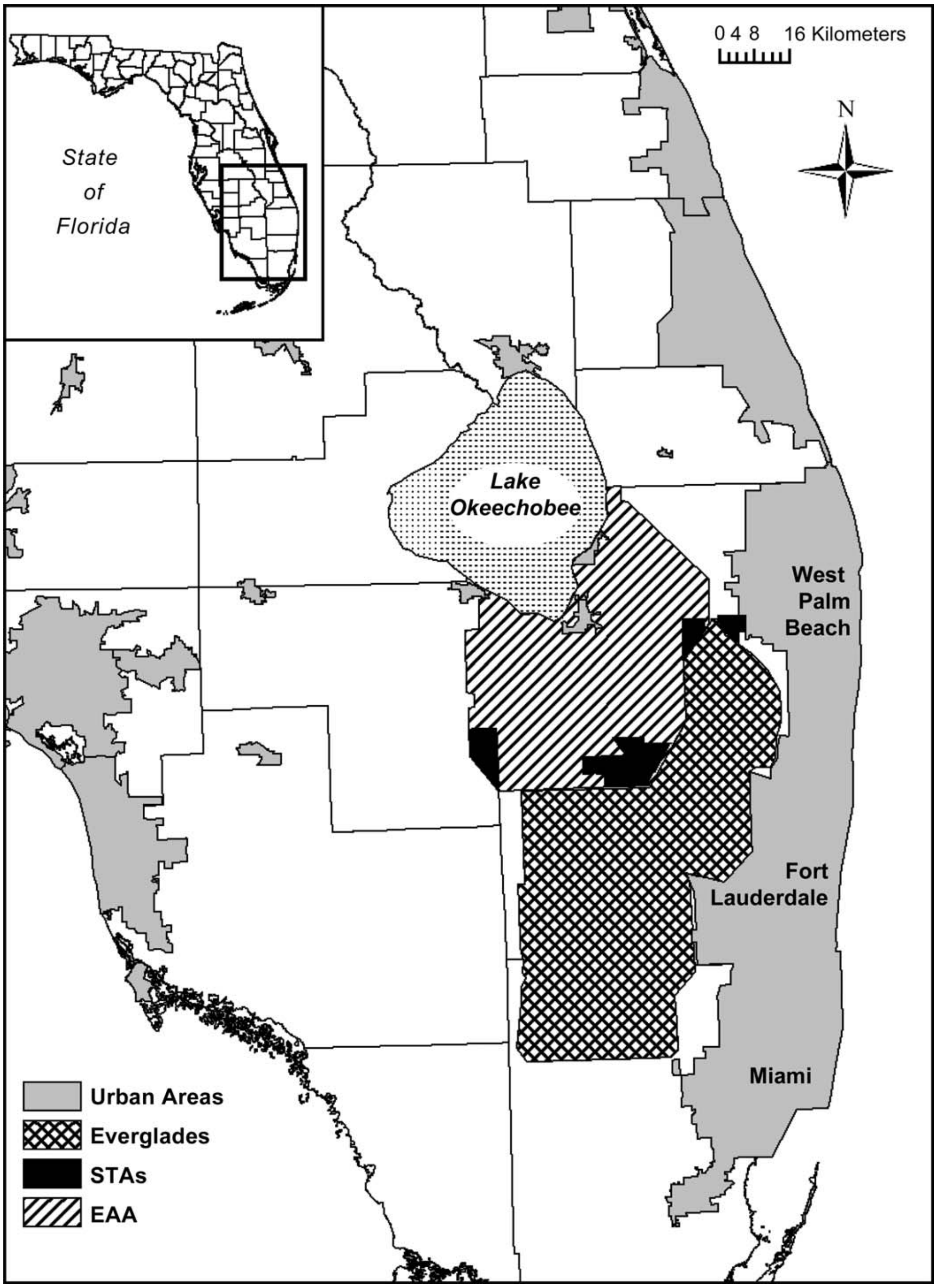

FIGURE 1. Study area in southern Florida showing portions of urban and rural areas used by female Mottled Ducks, including Stormwater Treatment Areas (STAs) and the Everglades Agricultural Area (EAA).

Agricultural Area also contains Stormwater Treatment Areas, which are man-made, managed marsh impoundments designed to remove excess agricultural nutrients and other pollutants from Lake Okeechobee and Everglades Agricultural Area waters before being released into the Everglades. The Everglades Protection Area (hereafter, Everglades) consists primarily of freshwater wetlands, especially sawgrass (*Cladium jamaicense*) and cattail (*Typha* spp.) 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 Everglades Agricultural Area south to Florida Bay. Other common rural habitat types in the study area included improved and unimproved pasture, citrus groves and other row crops, and dry prairies (Florida Natural Areas Inventory 2010). We defined urban limits as per the Florida Department of Transportation's Transportation Statistics Office, which uses data from the United States Census Bureau. Urban habitats used by Mottled Ducks included natural or man-made lakes, ponds, canals, and ditches located at golf courses, parks, commercial, residential, and institutional properties, and along roadsides (Varner 2013).

Capture and Radio-Telemetry

In Stormwater Treatment Areas and flooded agricultural fields, we captured female Mottled Ducks from airboats at night using spotlighting in September 2008 ($n = 47$), August 2009 ($n = 50$), and August 2010 ($n = 50$). Agricultural properties were owned by A. Duda and Sons and were located in the Everglades Agricultural Area approximately 11 km southeast 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 autumn when they were temporarily flooded for weed and pest control. Stormwater Treatment Areas 1E and 1W were located just west of the town of Wellington and directly adjacent to Loxahatchee National Wildlife Refuge. Stormwater Treatment Areas 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 northeastern Palm Beach County. Walk-in and swim-in baited traps and air-powered rocket nets were used to capture Mottled Ducks in urban areas 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-g radio-transmitters (AI-2M, Holohil Systems, Carp, Ontario, Canada; Korschgen et al. 1996). Transmitters were programmed to have a 13-month lifespan. No birds were held for more than 24 hr, and any females that were kept for more than 12 hr were housed in a climate-controlled area and provided with food and water. Birds were allowed to recover from surgery for at least 60 min before being released at the location from which they were captured. Age and sex of each individual was determined using cloacal, bill, and plumage characteristics, and only adult females were radio-marked.

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 December 30, 2011. Transmitters were equipped with a mortality sensor that allowed us to determine the status of each individual as alive or dead. Birds that died within 7 days of release ($n = 6$) were excluded from analysis because preliminary results indicated higher mortality in the first week, likely caused by the effects of capture and marking. Locations were plotted on a map using ArcGIS version 9.3.1 (Environmental Systems Research Institute, Redlands, California, USA), allowing us to determine which areas were used by each bird.

Survival Analysis

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 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 in 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.

We used the nest survival model in Program MARK (White and Burnham 1999) to estimate daily survival rates of female 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 at uneven intervals (Hartke et al. 2006, Collier et al. 2009). We used model averaging, when appropriate, to manage model selection uncertainty (Burnham and Anderson 2002). We created 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 the urban limits defined by the Florida Department of Transportation were considered to be rural regardless of land use classification (Figure 1). An individual duck was then classified as "urban" if >50% of her locations were within urban limits or "rural" otherwise, although most ducks remained in the area where they were initially captured. Seasons were defined as postbreeding (Aug 1–Nov 18), hunting (Nov 19–Jan 31), late winter (Feb 1–Feb 28), and breeding (Mar 1–Jul 31). We used Akaike's Information Criterion corrected for small sample sizes (AIC_c) to compare models.

We also conducted post-hoc analyses to further examine survival rates for the two seasons with the highest mortality rates, breeding and hunting. Birds that used

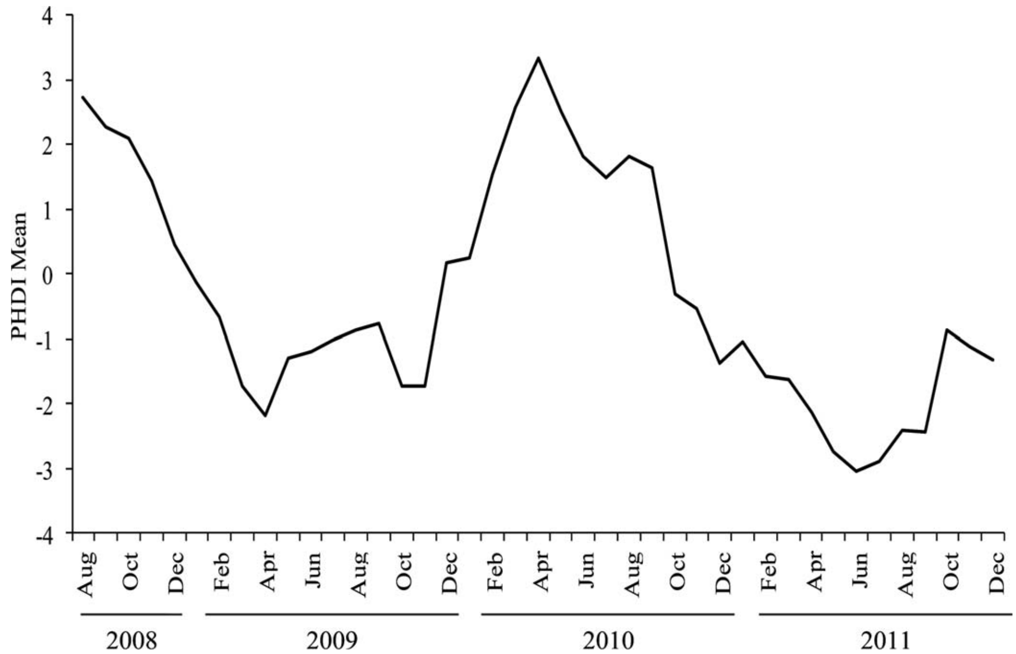

FIGURE 2. Monthly Palmer Hydrologic Drought Index (PHDI) measurements for mainland southern Florida from August 2008 through December 2011. Negative values indicate moderate (–2) to extreme (–4) drought conditions, while positive values indicate moderate (+2) to extreme (+4) wet conditions.

only urban areas during the breeding and hunting seasons were excluded from analysis because initial results indicated high survival overall for these individuals. We examined differences in survival related to habitat use during the breeding season by assigning females to 1 of 5 categories based on the amount of time spent in each area during April and May (i.e. peak nesting season). Our 5 habitat categories were: Everglades Agricultural Area, Lake Okeechobee, Everglades, Stormwater Treatment Areas, and other areas.

During the hunting season, we compared survival of females exposed to 3 different hunting regimes: quota hunting (Stormwater Treatment Areas 1W, 3/4, and 5 in all years and Stormwater Treatment Area 2 in 2008–2009), no hunting (Loxahatchee National Wildlife Refuge, Stormwater Treatment Areas 1E and 6, and Stormwater Treatment Area 2 in 2009–2011), and 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 in quota-controlled areas was closely monitored and typically averaged 3–5 ducks per hunter-day, totaling >20,000 ducks each season (A. Fanning personal communication). In open-hunted areas, there were no additional rules beyond state and federal regulations and harvest was not closely monitored. Areas with no hunting 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, 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 analyses. We detected mortalities for 26% of urban 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 southern Florida were average (PHDI = 0.07) during the first year (August 2008–July 2009), slightly wetter than average (PHDI = 0.72) in the second year (August 2009–July 2010), and drier than average (PHDI = –1.29) in the final year of the study (August 2010–December 2011; Figure 2).

Survival Rates

The top 3 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 the effects of season, area, and their interaction (Table 1). The second-ranked model included additive effects of season, area, and year. Summed parameter likelihood values (w_i) showed that season (1.00) and area (1.00) had greater

TABLE 1. Support for all candidate models predicting daily survival rates of adult female Florida Mottled Ducks using 2 areas (urban and rural) in southern Florida from 2008 to 2011. Models are ranked from most to least supported based on Akaike's Information Criterion adjusted for small sample sizes (AIC_c), differences in AIC_c (ΔAIC_c), and Akaike weights (w_i).

Model [a]	ΔAIC_c	w_i	K [b]	Deviance
Season * Area [c]	0.00	0.48	7	1009.40
Season + Area + Year	0.87	0.31	7	1010.27
Season + Area	2.02	0.18	5	1015.42
Season * Area * Year	6.04	0.02	17	995.43
Season	14.02	0.00	4	1029.42
Season * Year	15.80	0.00	11	1017.20
Season + Year	16.43	0.00	6	1027.83
Area	17.98	0.00	2	1037.38
Area + Year	18.30	0.00	4	1033.70
Area * Year	20.57	0.00	6	1031.98
Constant	26.57	0.00	1	1047.97
Year	29.10	0.00	3	1046.50

[a] Seasons are defined as postbreeding (August 1–November 18), hunting (November 19–January 31), late winter (February 1–February 28), and breeding (March 1–July 31).
[b] K = number of model parameters.
[c] The top model had an AIC_c value of 1023.40.

relative importance than year (0.34; Table 1). We averaged across all models to generate daily survival rate estimates. For both urban and rural ducks, the lowest survival rates occurred during the breeding season (Figure 3). Rural ducks also experienced a drop in daily survival during the hunting season, while urban ducks did not (Figure 3). Although differences in survival among years were small, annual survival rates for both rural and urban ducks were highest during 2008–2009 (50.3% and 76.3%, respectively)

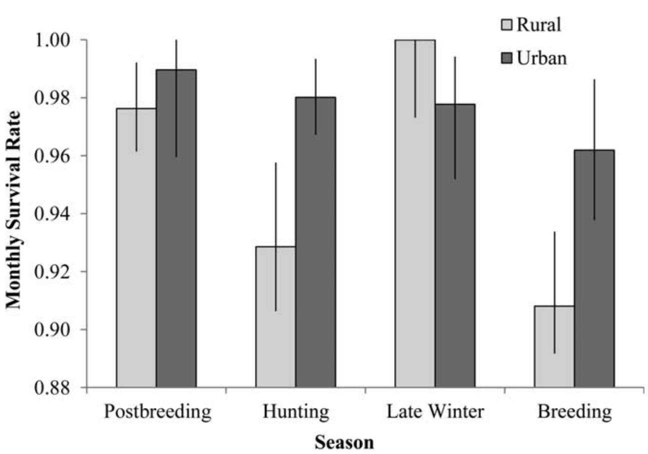

FIGURE 3. Monthly (30 days) survival rates of adult female Florida Mottled Ducks using urban and rural areas of southeastern Florida during the postbreeding (August 1–November 18), hunting (November 19–January 31), late winter (February 1–February 28), and breeding (March 1–July 31) seasons, 2008–2011. Error bars represent 95% confidence intervals.

TABLE 2. Support for all candidate models predicting adult female Florida Mottled Duck daily survival rates during the breeding season (March 1–July 31) in 5 rural locations in southern Florida from 2009 to 2011. Models are ranked from most to least supported based on Akaike's Information Criterion adjusted for small sample sizes (AIC_c), differences in AIC_c (ΔAIC_c), and Akaike weights (w_i).

Model [a]	ΔAIC_c	w_i	K [b]	Deviance
Location [c]	0.00	0.65	5	304.59
Location * Year	2.26	0.21	13	290.82
Location + Year	3.24	0.13	7	303.82
Constant	7.67	0.01	1	320.26
Year	10.07	0.00	3	318.66

[a] Locations were: Everglades Agricultural Area, Everglades, Lake Okeechobee, Stormwater Treatment Areas, and other rural areas such as pastures and dry prairies.
[b] K = number of model parameters.
[c] The top model had an AIC_c value of 314.60.

and lowest during 2009–2010 (42.9% and 71.1%, respectively). Overall, survival was lower for ducks that used rural areas than for those that used urban areas (Figure 3). Mean annual survival estimates calculated using daily survival rates for each season were 46.7% for rural and 73.6% for urban ducks.

Breeding Season Survival

The lowest survival rates were for females using rural areas during the breeding season (n = 97; Figure 3), so we examined sources of variation in survival during this period. In comparison, survival of urban females during the breeding season was high, so we did not include them in this analysis. Rural females spent the breeding season in 1 of 5 locations: Everglades Agricultural Area (n = 27), Everglades (n = 36), Lake Okeechobee (n = 7), Stormwater Treatment Areas (n = 16), and other rural areas (e.g., pastures, dry prairies; n = 11). Model selection results indicated that survival varied with the locations used by females (Table 2). The top model included only location. The next best model included location and year as interactive effects and had 3 times less support than the top model (evidence ratio = 3.1; Table 2). Because models including location had a total weight of 0.99, we generated survival estimates using only the top model. Breeding season survival estimates were highest for females using the Everglades and Stormwater Treatment Areas and lowest for females using Lake Okeechobee, the Everglades Agricultural Area, and other rural areas (Figure 4).

Hunting Season Survival

Survival rates also were low during the hunting season for rural ducks (n = 115; Figure 3). Based on model results, hunting season survival varied among years, but there was weak support for an effect of hunting regime (Table 3). We

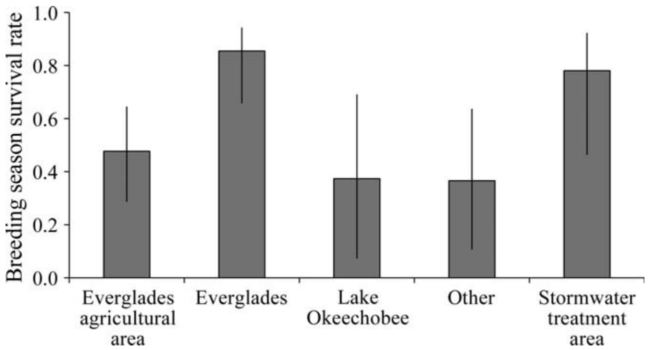

FIGURE 4. Breeding season (March 1–July 31) survival rates of Florida Mottled Ducks using five rural locations in southern Florida from 2009 to 2011. Error bars represent 95% confidence intervals. "Everglades" is the Everglades Protection Area, and "Other" locations include pastures, citrus groves and other row crops, and dry prairies.

used model averaging to generate survival estimates based on all models. Survival rates for the 74-day hunting season were highest during 2010–2011 (0.91; 95% CI = 0.68–0.98) and lowest during 2009–2010 (0.82; 95% CI = 0.16–0.98). Mean hunting season survival estimates for rural females for all years were slightly higher in unhunted areas (0.88; 95% CI = 0.48–0.98) than in open-hunted areas (0.87; 95% CI = 0.32–0.98) or quota-hunted areas (0.85; 95% CI = 0.29–0.98), but these differences were not statistically significant.

DISCUSSION

Previous studies have reported annual survival rates of approximately 50% for adult female Florida Mottled Ducks (Bielefeld et al. 2010), which is similar to survival rates estimated for adult female Mallards and American Black Ducks (*Anas rubripes*), 2 closely related species (Anderson 1975, Krementz et al. 1987, Lake et al. 2006). Our estimate of annual survival for Mottled Ducks using rural areas was 43%–50%, but survival of Mottled Ducks using urban areas was much higher (71%–76%). There are a few possible explanations for why female Mottled Ducks using urban habitats experienced reduced mortality rates. First, alligators (*Alligator mississippiensis*) 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 than in rural areas because they are frequently managed for aesthetic, sanitation, or recreational purposes. Moreover, supplemental foods, in the form of bird seed, corn, and other nonnatural foods, are often available to ducks in urban areas. Mottled Ducks that use urban areas experience higher levels of human disturbance, but survival was higher when compared with more rural areas. We suggest that differences in survival were due to more stable habitat conditions, greater food availability, and reduced movements and predator densities (Varner 2013).

TABLE 3. Support for all candidate models predicting daily survival rates of adult female Florida Mottled Ducks under three hunting regimes (Hunt) during the hunting season (November 19–January 31) in rural areas of southern Florida from 2008 to 2011. Models are ranked from most to least supported based on Akaike's Information Criterion adjusted for small sample sizes (AIC_c), differences in AIC_c (ΔAIC_c), and Akaike weights (w_i).

Model [a]	ΔAIC_c	w_i	K [b]	Deviance
Year [c]	0.00	0.46	3	162.92
Constant	0.89	0.29	1	167.82
Hunt	2.08	0.16	3	165.00
Hunt + Year	3.31	0.09	5	162.23

[a] Hunt (hunting regime) was either quota hunting, open hunting, or no hunting.
[b] K = number of model parameters.
[c] The top model had an AIC_c value of 168.93.

In the Upper St. Johns River Basin (USJRB) region of Florida, survival of female Mottled Ducks was lowest during the postbreeding season (0.69), greatest in late winter (1.00), and similar for the hunting (0.88) and reproductive seasons (0.86; Bielefeld and Cox 2006). Our seasonal survival estimates for the late winter (0.97–1.00) and hunting (0.82–0.96) seasons were similar to the USJRB; however, unlike Bielefeld and Cox (2006), we found survival was higher in the postbreeding season (0.91–0.97) than in the breeding season (0.58–0.84). Differences in seasonal survival patterns between the USJRB and southern Florida may reflect temporal differences, as the 2 studies did not take place during the same years; however, differences may also have resulted from dissimilar predator communities or disparities in availability and stability of suitable breeding and postbreeding habitats.

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). Our study area in southern Florida was dominated by relatively stable aquatic systems including Lake Okeechobee, Stormwater Treatment Areas, Everglades Agricultural Area canals, and urban ponds, whereas the USJRB was dominated by ephemeral wetlands including the St. Johns River marshes, wet prairies, and pasture ponds. In the USJRB, alligator mortalities were recorded only during years of moderate to extreme drought (Bielefeld and Cox 2006). The dry conditions that persisted during much of the USJRB study appeared to have concentrated alligators and molting Mottled Ducks in the few remaining wetlands, resulting in high postbreeding mortality (Bielefeld and Cox 2006). Higher postbreeding survival in southern Florida is consistent with there being greater availability and stability of postbreeding habitats compared with the USJRB.

We also found that breeding season survival was related to habitat use. Survival was greatest for females using the Everglades or Stormwater Treatment Areas and was lowest for females using Lake Okeechobee and other areas, such as pasture and open grassland-type areas west and north of Lake Okeechobee. Because nesting is generally associated with low survival, it is possible that a high proportion of females that used the Everglades and Stormwater Treatment Areas 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 (Varner et al. 2013). Further, Mottled Ducks that did attempt to nest in the Everglades and Stormwater Treatment Areas during the breeding season may have used relatively safe islands for nesting. Mottled Ducks do not commonly nest over water (Bielefeld et al. 2010) and the only upland grass or shrub habitats available in the Everglades are on small islands. Moreover, previous research has found that Mottled Ducks will readily nest on islands (Stieglitz and Wilson 1968), and success of waterfowl nesting on islands is generally high (Giroux 1981); 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*). Consequently, high breeding season survival of females in these areas may have been partly caused by low predator densities.

We found evidence that hunting mortality may cause a weakly density-dependent increase in survival rates for adult female Florida Mottled Ducks. For ducks in urban areas, mortality rates during the hunting season were the same as those during the late winter season, indicating that there were similar rates of nonhunting mortality between the hunting and late winter seasons. For rural ducks, however, survival increased substantially when the hunting season ended, even exceeding survival of urban ducks. If hunting mortality was additive to natural mortality, we would have expected late winter survival rates of rural ducks to have been the same or lower than those of urban ducks, as was the case during the other 3 seasons. Instead we found little to no mortality among rural ducks in late winter, which is consistent with a density-dependent increase in survival caused by hunting. Further, we found that females using unhunted rural areas during the hunting season ($n = 28$) had seasonal survival rates (88%) that were similar to those that used hunted areas (85%–87%). Sources of nonhunting mortality should be similar, because unhunted rural areas consisted of the same habitat types and were in close proximity to the hunted areas. Lack of appreciable differences in hunting season survival among the areas regardless of presence or absence of hunting also is an indicator of within-season density-dependent effects, because a similar proportion of ducks that were taken by hunters would have died from other causes in an unhunted area.

Several studies report strong relationships between wetland availability and duck populations 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). In our study, there was no consistent relationship between survival and water levels. Survival rates and water levels were higher in 2008–2009 than in 2010–2011, but survival rates were lowest in 2009–2010, when surface water and precipitation levels were greatest. In some years, factors other than surface water availability may have affected mortality of Mottled Ducks in southern Florida. For example, this area experienced record cold weather during January 2–11, 2010, when temperatures dipped to near or below freezing on at least 3 nights, negatively affecting many native and nonnative species of plants and animals (National Oceanic and Atmospheric Association 2010, Mazzotti et al. 2011). While it is unlikely that cold temperatures directly caused Mottled Duck mortality, low temperatures may have indirectly influenced their survival by negatively affecting plant or invertebrate food resources.

Similar to Bielefeld and Cox (2006), we found some indications that Florida Mottled Ducks can survive within a predator-rich 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 generally been regarded as having a negative impact on wildlife, in this case it appears that Mottled Ducks have the flexibility to survive in an urban landscape. Unfortunately, feral Mallards mostly occur 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 in the Florida Mottled Duck population. Further research examining how Mottled

Ducks and Mallards use urban areas will provide insight into how best to manage the hybridization issue.

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