Home Range and Habitat Selection of an Inland Alligator (*Alligator mississippiensis*) Population at the Northwestern Edge of the Distribution Range

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Abstract - Although well studied in coastal ecosystems, comparatively little information exists on the ecology of inland *Alligator mississippiensis* (American Alligator) populations, particularly at the periphery of their range. Our specific objectives were to estimate home-range area and assess diel (i.e., day vs. night) habitat-selection patterns of an urban, inland American Alligator population at the northwestern edge of the species' range. During 2010–2011, we captured 14 (6 female, 5 male, 3 unknown sex) American Alligators, 9 (5 female and 4 male) of which were fitted with VHF transmitters. Mean home range (95% kernel) was 68.9 ha (SD = 31.6) and 40.9 ha (SD = 20.7) and the mean core area (50% kernel) was 20.6 ha (SD = 18.5) and 10.1 ha (SD = 6.6) for males and females, respectively. American Alligators primarily selected river channels and open-canopy shorelines during both day and night. The amount of emergent or floating vegetation and canopy cover in a particular habitat influenced the probability of selection by American Alligators but this probability was dependent on the diel time period. During the day, the probability of selection was higher in areas with emergent or floating vegetation and more canopy cover, whereas at night the probability of selection decreased with increasing canopy cover. American Alligators did not select open water at either the study-area level or within the home range, which may have been due at least in part to the presence of recreational boaters or differences in food availability between open-water areas and other areas occupied by American Alligators on the Fort Worth Nature Center and Refuge. Overall, the results of our study are largely incongruent with patterns of home-range size and habitat selection reported for the species elsewhere, suggesting that further study of other American Alligator populations at the periphery of the distribution range is warranted.

Introduction

Research on behavior (Brisbin et al. 1982, Lang 1976), population ecology (Goodwin and Marion 1979, Rootes and Chabreck 1993, Taylor 1984), growth rates (Rootes et al. 1991, Wilkinson and Rhodes 1997), sex ratios (Rootes and Chabreck 1992), habitat use (Goodwin and Marion 1979; Joanen and McNease 1970, 1972), and physiological ecology (Brandt and Mazzotti 1990, Spotila et al. 1972) has been

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conducted on *Alligator mississippiensis* Daudin (American Alligator; hereafter, Alligator). However, the vast majority of these studies have been carried out on Alligator populations in coastal regions, with little research on inland populations (but see Saalfeld et al. 2008, 2011; Webb et al. 2009). Although they are important to the ecology of wetlands (Craighead 1968, Rosenblatt and Heithaus 2011), comparatively little is known about Alligator populations that inhabit inland wetlands, habitats which are generally more heterogeneous than coastal wetlands (Ryberg et al. 2002, Webb 2005). For example, water levels fluctuate to a greater degree in inland wetlands than in coastal wetlands, which can lead to fragmentation of inland Alligator populations (Ouboter and Nanhoe 1988). Resource availability, Alligator density, growing-season length, and salinity differ between coastal and inland wetlands (Saalfeld et al. 2011, Webb 2005). Alligator growth rates and body condition may also differ between inland and coastal populations; for example, sub-adult Alligators from an inland population grew faster and had lower estimated body conditions than those reported for sub-adult Alligators from a coastal population (Saalfeld et al. 2008).

Although there has been limited research on inland American Alligator populations, information from populations at the edge of their known range is virtually nonexistent. However, the abundance and distribution of a species are limited by the combination of physical and biotic environmental characteristics (Brown 1984); individuals at the edge of the species' range tolerate environmental conditions different from those experienced by most of the population. Differences in biotic and abiotic parameters near range limits can make ecological processes more variable than in the interior of the range. The magnitude of seasonal variability in climatic conditions is often higher at the edge of a species' range and is more likely to approach physiological tolerance limits than in the center of the range (Sexton et al. 2009). Climatic variability can influence food availability, growth, survival, and reproductive rates. For many species, population density tends to be greatest in the center of the range and declines gradually toward the range boundaries (Brown 1984, but see Sexton et al. 2009).

With a few exceptions (e.g., Saalfeld et al. 2008, Webb 2005), the vast majority of research on Alligators has been conducted in coastal systems; this bias potentially limits our understanding of the species' ecology across its range. More information is needed on inland Alligator populations, particularly those that occur at the edges of their geographic range. The goal of this study was to determine habitat use by Alligators within an urban, inland population at the edge of the species' geographic range. Our specific objectives were to estimate Alligator home-range area and assess diel patterns of habitat selection.

Methods

Study area

We conducted this study on the Fort Worth Nature Center and Refuge (FWNCR), located in Tarrant County, TX (Fig. 1). The FWNCR is located just inside the Fort Worth city limits on the north end of Lake Worth and encompasses 1465 ha of mixed forests, short-grass prairies, and wetlands (Fort Worth Nature Center and Refuge 2008). The average annual precipitation for Fort Worth is 864 mm (National Climatic Data Center 2000).

The north end of the FWNCR includes the West Fork of the Trinity River, which flows into Lake Worth. Submerged vegetation is sparse throughout the FWNCR. Aquatic vegetation communities include shallow marshes covered with *Typha domingensis* Pers. (Southern Cattail) and other emergent species. The low, flat terrain surrounding the river and lake is seasonally flooded due to heavy precipitation during the winter and spring (Fort Worth Nature Center and Refuge 2008).

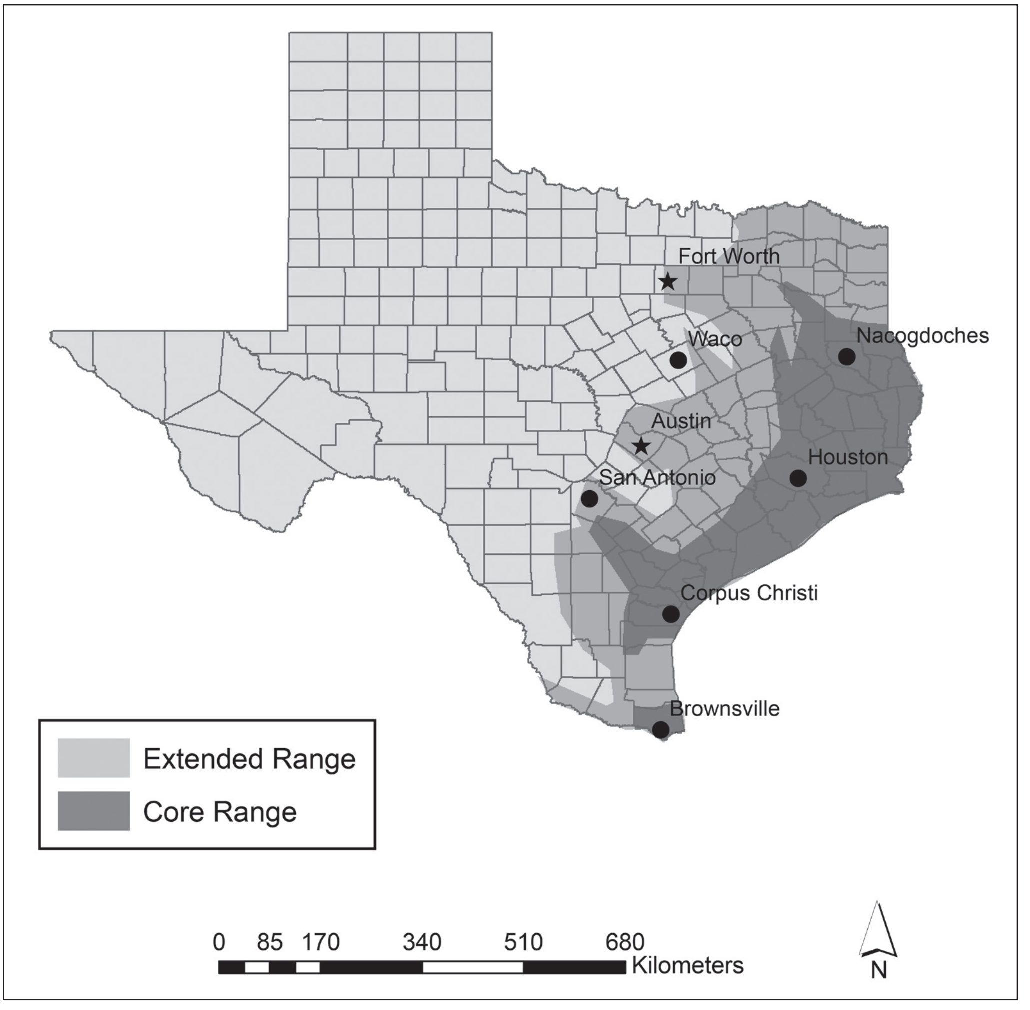

Figure 1. Known distribution range of the American Alligator (*Alligator mississippiensis*) in Texas (Adapted from Distribution of American Alligators in Texas; TPWD 2003). Core range = areas with optimal habitat conditions and higher quality of food sources resulting in a higher density of Alligators; extended range = areas with less than optimal habitat conditions, a lower quality and quantity of food sources, and a lower density of Alligators. Study area is located on the northwest side of Fort Worth, TX.

Capture and handling

We captured Alligators <1.2 m in length either by hand or using a pole snare from a flat-bottomed jon boat. We captured Alligators >1.2 m using swim-in live traps (Ryberg and Cathey 2004, Webb 2005) baited with decaying chicken carcasses and small perforated tins of sardines wired to the edge of the traps. For each individual captured, we measured total length (ventral tip of snout to tail), snout–vent length (ventral tip of snout to proximal tip of vent), eye to naris length, total head length (dorsal tip of snout to distal part of head scute), tail girth (circumference of tail directly behind rear legs), and mass (Saalfeld et al. 2008). We determined sex by cloacal examination (Chabreck 1963, Joanen and McNease 1978) for individuals >50 cm (individuals <50 cm cannot be accurately identified to sex; Joanen and McNease 1978). We uniquely marked all captured Alligators by removing a dorsal tail-scute (Chabreck 1963, Saalfeld et al. 2008) and we inserted a passive integrated transponder (PIT) tag into either of the hind legs or in the tail depending on the size of the Alligator (Saalfeld et al. 2008, Webb 2005). For Alligators >1.5 m in length, we attached a VHF radio transmitter (Telonics Inc., MOD-400; 205, Mesa, AZ) to the dorsal scutes located behind the head (Kay 2004). We fastened transmitters by steel cable woven through holes drilled into the keratinized portion of the dorsal scutes and used crimps to secure cable ends. Marine epoxy was used to make the transmitters more hydrodynamic and to decrease the chance of debris being caught underneath, increasing transmitter retention time. We released all Alligators at the site of capture as quickly as possible (i.e., ≤ 60 min.). For those Alligators that were either captured by hand or with a pole snare, we used a handheld GPS to record the location where the Alligator was initially observed and placed a numbered, weighted buoy for habitat-data collection (see below). All capture and handling procedures were approved by the Texas A&M University-Commerce Institutional Animal Care and Use Committee (IACUC protocol #P10-01-01) and Texas Parks and Wildlife Department (Scientific research permit # SPR-0310-028).

Home range and habitat selection

We relocated all radio-marked Alligators by homing using the VHF transmitter until we obtained a visual observation of the Alligator. We attempted to relocate each Alligator at least 6 times per week, at 3 day and 3 night locations at least 12 hours apart; however, we were unable to relocate each Alligator on every attempt. Because each Alligator retained its transmitter for varying lengths of time, the total duration of radio tracking for each animal also varied. We used Hawth's Tools (Beyer 2004) in ArcGIS 9.3 (Environmental Systems Research Institute, Redlands, CA) to delineate 95% fixed-kernel home-range and 50% core areas (Worton 1989) using least-squares-cross validation to select the smoothing parameter (Seaman and Powell 1996, Seaman et al. 1999).

Each time we relocated an Alligator, we marked the location using a handheld GPS and buoy, which served as the center for a 20-m-radius circular plot. We then recorded the habitat type (as described below for second- and third-order habitat selection), water depth, water temperature, distance from the center of the plot to nearest woody or aquatic vegetation, and visually estimated percent canopy-cover (Webb et al. 2009). In addition, for each Alligator location, we collected the same habitat data in 2 additional plots that we established 40 m from the relocation plot along randomly selected compass bearings. These additional plots represented available habitat. We recorded water temperature at the time the Alligators were observed; however, to minimize disturbance to study animals, we collected all other data the following day.

We assessed second-order (i.e., home range compared to study area) and third-order (i.e., within home range) habitat-selection patterns (Johnson 1980). We mapped the entire study area using a combination of existing geospatial data (i.e., park boundaries and roads; City of Fort Worth 2010) and satellite imagery (Tarrant County 2005 NAIP 2M NC; TNRIS 2009) in ArcGIS 9.3. We mapped the study area according to the following categories: open water (i.e., no vegetation above the surface of the water), emergent vegetation (i.e., rooted vegetation breaking the surface of the water), floating vegetation (i.e., vegetation floating on the surface of the water), river channel, or open-canopy shoreline (Fig. 2). To incorporate periods when seasonal flood conditions inundated portions of the shrubland and forest areas near the lake and river, we assumed that terrestrial habitat ≤100 m from the water's edge was available to Alligators and we classified it as either shrubland or forested area; we selected 100 m because it represented the maximum area we observed to be influenced during spring floods.

Because our delineation of the habitat map was largely based on satellite imagery, we were unable to incorporate changes in the water level throughout each study season. Therefore, our demarcation between aquatic and terrestrial habitat classes was based on the water level we observed during the majority of the study period. To assess the accuracy of our habitat map, we overlaid the Alligator locations recorded in the field and compared field-based classification of habitat types with those derived from our map; 95.3% of our field-based locations corresponded with the map-based classification. We defined the area available at the study-area level by pooling the relocations of all study animals and calculating 95% fixed-kernel home-range as described above. Using ArcGIS 9.3, we clipped the amalgamated home-range to remove those areas >100 m from the water's edge, then calculated the total area (i.e., availability) of each habitat class within the study area (i.e., amalgamated 95% kernel home-range) in ArcGIS 9.3, overlaid the relocations of all radio-tagged Alligators, and recorded the habitat type for each location. To assess third-order selection, we calculated the total area (i.e., availability) of each habitat class within the home range of each Alligator in ArcGIS 9.3.

Statistical analysis

Second-order habitat selection consisted of comparing the proportion of relocations in each habitat type (i.e., used habitat) to the proportion of each habitat type within the study area (i.e., available habitat). For each radio-marked Alligator, we calculated selection ratios and associated 95% Bonferroni-adjusted confidence intervals (Johnson 1980, Manly et al. 2002, McDonald et al. 2005). For third-order habitat selection, we calculated selection ratios (and 95% Bonferroni-adjusted confidence intervals) using the proportion of the relocations in each habitat type and the proportion of each habitat type available within the home range of each animal (i.e., availability differed for each animal). We used selection ratios and confidence intervals to determine if the proportion of use differed from availability at the study-area and home-range scales. Selection ratios >1 with confidence intervals that did not include 1 indicated habitat types that were used in a higher proportion than

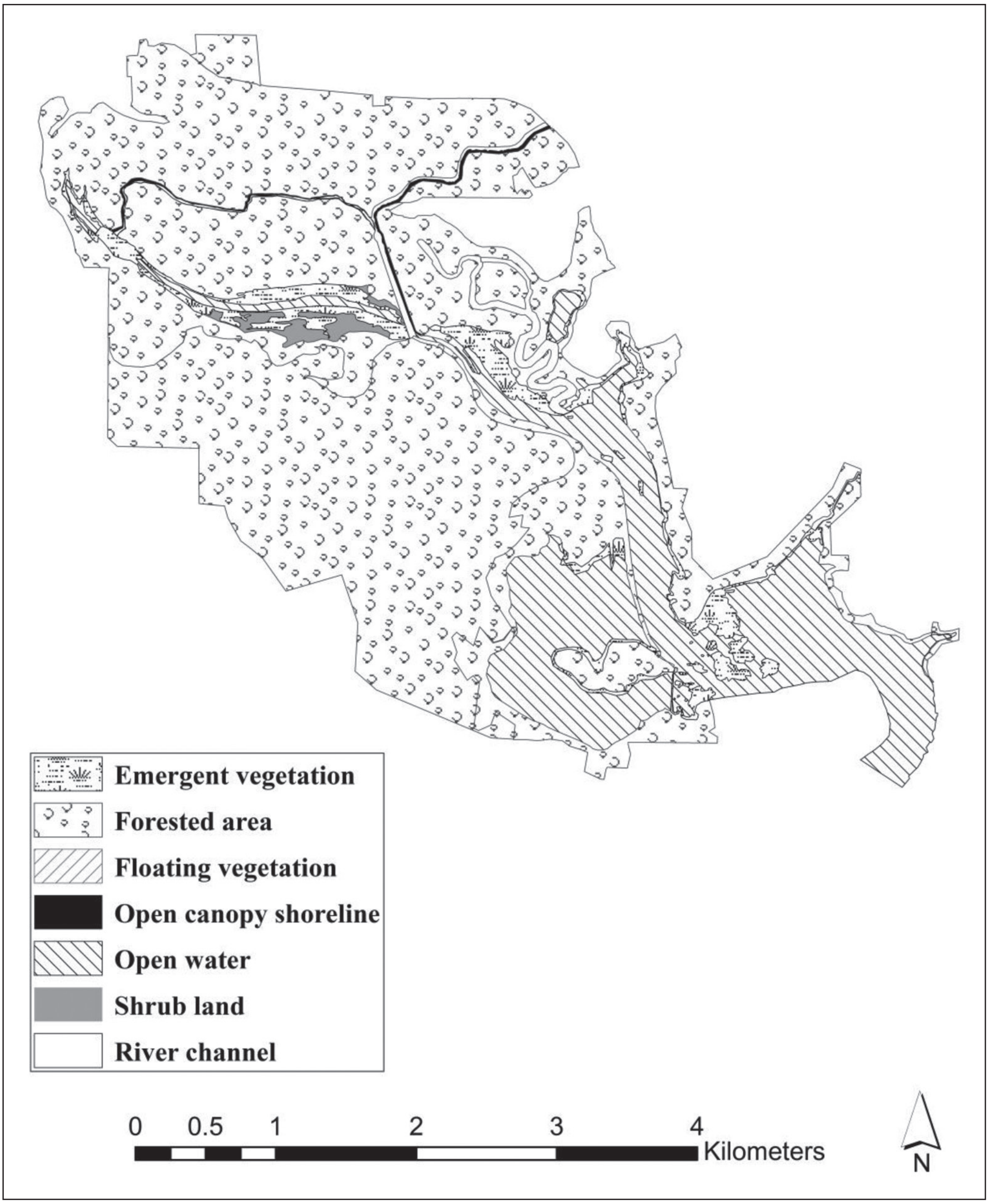

Figure 2. Map of habitat types used to assess habitat selection of American Alligators (*Alligator mississippiensis*) on the Fort Worth Nature Center and Refuge, TX, 2010–2011.

available (i.e., selected for), whereas selection ratios <1 with confidence intervals that did not include 1 indicated habitat types that were used in a lower proportion than available (i.e., avoided) (Manly et al. 2002).

We also modeled habitat selection using logistic regression so that we could incorporate both continuous and categorical predictor variables. We used mixed-effects logistic regression including a random intercept for each Alligator to determine the factors that influenced habitat selection (Breslow and Clayton 1993, Gillies et al. 2006) with library lme4 (Bates et al. 2013) in program R version 2.12.2 (R Development Core Team 2013). Continuous explanatory variables were those collected at the Alligator-use locations and the associated random locations described above, and included water depth, distance to vegetation, percent canopy-cover, and water temperature. We coded all habitat types into one categorical variable and set open water as the reference category. We combined the terrestrial habitat types into one category (other) due to low sample size. The binary response-variable was the location type coded as used or available.

We developed a set of a priori models to assess combinations of habitat variables believed to potentially influence habitat selection by this Alligator population (Table 1). We used an information-theoretic approach to select the most parsimonious model using Akaike's information criterion (AIC_c) corrected for small sample size (Burnham and Anderson 2002). The number of parameters (k) was the sum of the total number of parameters estimated for fixed effects plus 1 for each random intercept (Skrondal and Rabe-Hesketh 2004). We accounted for model uncertainty by calculating model-averaged parameter estimates (±SE) (Burnham and Anderson 2002). Odds ratios and 95% confidence intervals were then derived by exponentiation of the model-averaged parameter estimates. The odds ratio indicated how much more or less likely it was for the outcome of interest (i.e., selection) to occur with a 1-unit change in the explanatory variable. Changes in explanatory variables with odds-ratio confidence intervals not including 1 were deemed to result in a change in the likelihood of selection.

Table 1. Model number and structure of the 11 a priori models relating the probability of habitat selection by American Alligators (*Alligator mississippiensis*) to environmental characteristics at the Fort Worth Nature Center and Refuge, TX, 2010–2011.

Model #	Model structure
1	Habitat type
2	Canopy cover
3	Water depth
4	Water temperature
5	Distance to vegetation
6	Water temperature + water depth
7	Habitat type + canopy cover
8	Habitat type + water depth
9	Habitat type +water temperature
10	Habitat type + distance to vegetation
11	Habitat type + water temperature + water depth + distance to vegetation + canopy cover

Habitat-selection patterns observed at a given point in time are often associated with the behavioral state of the animal. For example, environmental characteristics related to habitat selection often differ between animals that are actively foraging compared with those that are resting (Smith 1975, Watanabe et al. 2013). Previous research has demonstrated that Alligator activity patterns and movement rates differ between daytime and nighttime periods (Rosenblatt et al. 2013, Smith 1975, Watanabe et al. 2013). Thus, we expected that habitat-selection patterns would also differ between day and night and we conducted separate analyses for data from diurnal and nocturnal periods to assess differences in diel patterns of habitat selection.

Results

During the 2010 season (May–August), we captured 7 Alligators (3 males, 3 females, 1 unknown sex; Table 2) during 203 trap nights and fitted 5 (2 male and 3 female) with VHF transmitters; 2 Alligators were too small to be fitted with transmitters. We were unable to locate 1 female 3 days after capture, likely due to transmitter failure; therefore, we only collected relocation data on 2 males and 2 females in 2010.

In 2011 (April–September), we captured 7 Alligators (2 males, 3 females, 2 unknown sex; Table 2) during 213 trap nights; 4 (2 males, 2 females) were fitted with VHF transmitters. One of the males was a recapture from the previous year and had a home range that was spatially distinct from the home range used during the first

Table 2. Sex, body-size characteristics, duration of radio monitoring, number of relocations, and home-range (95% kernel) and core (50% kernel area) size (ha) for each radio-transmitted Alligator captured at the Fort Worth Nature Center and Refuge, TX, 2010–2011. A = transmitter failed 3 days after capture; B = female remained on nest after capture. U = unknown sex.

Alligator	Sex	Eye to nare length (cm)	Total length (cm)	Duration of radio monitoring	Number of relocations	95% home range (ha)	50% core area (ha)
2010							
43	M	29	295	4 Jun–4 Aug	30 (16 night, 14 day)	64.9	15.5
53	F	15	160	11 Jun–4 Jul	21 (13 night, 8 day)	64.8	17.6
51	F	18	197	30 Jun–28 Jul	20 (10 night, 10 day)	27.9	7.4
46	F	26	232	A		-	-
-	M	28	282			-	-
38	M	24	275	19 Jun–10 Sep	17 (9 night, 8 day)	110.6	47.3
-	U	2	24			-	-
2011							
38	M	23	281	8 Jul–10 Sep	22 (12 night, 10 day)	33.9	4.7
11	F	19	229	16 Jun–8 Oct	78 (37 night, 41 day)	30.1	5.3
39	M	27	335	26 Jun–8 Oct	66 (32 night, 34 day)	66.1	14.8
48	F	17	236	B		-	-
-	F	13	142			-	-
-	U	1	23			-	-
-	U	2	23			-	-

season; therefore, we treated them as 2 unique samples. The second female was tagged towards the end of the season while on a nest. Because she did not leave the nest over the course of our study, she was excluded from further analyses.

Home range

Mean home range (95% kernel) for all Alligators combined for both years was 56.9 ha (range = 27.9–110.6 ha) and mean core area (50% kernel) was 16.1 ha (range = 4.7–47.3 ha; Table 2). Overall mean home-range size was 67 ha in 2010 and 43.4 ha in 2011. Average female home-range (95% kernel; $n = 3$) was 40.9 ha (range = 27.9–64.7 ha), and mean home range for males ($n = 4$) was 68.9 ha (range = 33.9–110.6 ha). Mean core area (50% kernel) for female Alligators ($n = 3$) was 10.1 ha (range = 5.3–17.6 ha), whereas average core area for males ($n = 4$) was 20.6 ha (range = 4.7–47.3 ha).

Habitat selection

Habitat selection within the study area (second order). For 4 Alligators, the highest selection ratio was for open-canopy shoreline (selection ratio range = 28.7–58.4; Table 3); 3 Alligators selected against open-canopy shoreline (selection ratio = 0.36 for all 3 Alligators). Five Alligators selected for river channel (selection ratio range = 4.2–8.9). Two Alligators selected for and 5 Alligators selected against floating vegetation (selection ratio range = 1.7–8.8 and 0.01–0.30, respectively). Three Alligators selected for emergent vegetation (selection ratio range = 5.0–8.7), and 2 selected against that variable (selection ratio = 0.03 for both Alligators), and 2 had no selection for or against emergent vegetation (selection ratio range = 0.82–1.14; Table 3). One of the Alligators that did not select for or against emergent vegetation was the only Alligator to select for shrubland. All Alligators selected against open water (selection ratio range = 0.01–0.53), and all but 1 selected against forested areas (selection ratio range = 0.01–0.99; Table 3).

Habitat selection within home range (third order). Four Alligators selected for open-canopy shoreline (selection ratio range = 3.5–10.7; Table 4), and 1 Alligator selected against open-canopy shoreline. Four Alligators selected for river channel (selection ratio range = 1.5–5.8), 3 Alligators had high selection ratios for emergent vegetation (selection ratio range = 3.5–18.5), 2 Alligators selected against emergent vegetation (selection ratio range = 0.14–0.30), and 2 neither selected for nor against emergent vegetation (selection ratio range = 1.1–1.3; Table 4). Two Alligators selected for floating vegetation (selection ratio range = 1.9–29.4), 1 selected against floating vegetation, and 4 Alligators did not have floating vegetation within their home range. Similar to second-order habitat selection, all animals with open water within their home range selected against it (selection ratio range = 0.04–0.38); all individuals also selected against forested areas (selection ratio range = 0.01–0.59; Table 4).

Diel habitat selection

The highest-ranking model in both the day and night habitat-selection analysis was the model with all covariates (Table 5). There were no competing models in the

Table 3. Second-order selection ratios (i.e., within the study area) and 95% confidence limits for American Alligators (*Alligator mississippiensis*) on the Fort Worth Nature Center and Refuge, TX, 2010–2011. $^{+}$ indicates habitat types that were selected for (i.e., ratios >1) and $^{-}$ indicates habitat types that were selected against (i.e., ratios < 1). Shrublands and forests were seasonally flooded. Negative lower confidence limits set to zero.

Alligator ID	Open-canopy shoreline	River channel	Floating vegetation	Emergent vegetation	Open water	Shrubland	Forested area
11	57.01^{+}	8.99^{+}	0.01^{-}	0.03^{-}	0.01^{-}	0.41^{-}	0.01^{-}
	(55.79–58.23)	(8.53–9.46)	(0.00–0.03)	(0.00–0.07)	(0.00–0.03)	(0.27–0.50)	(0.00–0.03)
43	58.38^{+}	7.04^{+}	1.69^{+}	0.822	0.01^{-}	0.40^{-}	0.01^{-}
	(56.44–60.32)	(6.31–7.76)	(1.23–2.16)	(0.513–1.13)	(0.00–0.04)	(0.18–0.63)	(0.00–0.04)
53	0.36^{-}	7.13^{+}	0.30^{-}	1.14	0.01^{-}	7.99^{+}	0.99
	(0.00– .75)	(5.77–8.49)	(0.00– .66)	(0.47–1.81)	(0.00–0.07)	(6.17–9.81)	(0.49–1.51)
38 (2010)	0.36^{-}	0.05^{-}	0.30^{-}	7.76^{+}	0.53	0.41^{-}	0.01^{-}
	(0.00–0.87)	(0.00–0.25)	(0.00–0.77)	(6.68–8.84)	(0.00 – 1.09)	(0.00–0.96)	(0.00–0.96)
38 (2011)	28.67^{+}	4.18^{+}	0.30^{-}	5.02^{+}	0.01^{-}	0.41^{-}	0.01^{-}
	(26.27–31.04)	(3.27–5.08)	(0.22–0.58)	(4.23–5.81)	(0.00–0.05)	(0.08–0.73)	(0.00–0.05)
39	41.92^{+}	7.13^{+}	8.82^{+}	0.03^{-}	0.23^{-}	0.41^{-}	0.01^{-}
	(40.51–43.34)	(6.57–7.68)	(8.05–9.59)	(0.00–0.08)	(0.11–0.36)	(0.23–0.58)	(0.00–0.03)
51	0.36^{-}	0.05^{-}	0.30^{-}	8.73^{+}	0.27^{-}	0.40^{-}	0.01^{-}
	(0.00–0.87)	(0.00–0.25)	(0.00–0.77)	(7.92–9.53)	(0.00–0.69)	(0.00–0.96)	(0.00–0.08)

Table 4. Third-order (i.e., within the home range) selection ratios (and 95% confidence limits) for American Alligators (*Alligator mississippiensis*) on the Fort Worth Nature Center and Refuge, TX, 2010–2011. $^+$ indicates habitat types that were selected for (i.e., ratios >1) and $^-$ indicates habitat types that were selected against (i.e., ratios < 1). Shrublands and forests were seasonally flooded. Negative lower confidence limits set to zero.

Alligator ID	Open-canopy shoreline	River channel	Floating vegetation	Emergent vegetation	Open water	Shrubland	Forested area
11	8.00^+ (7.56–8.44)	3.31^+ (3.04–3.58)		0.30^- (0.18–0.42)	0.06^- (0.01–0.13)		0.01^- (0.00–0.02)
43	7.45^+ (6.63–8.26)	0.90 (0.61–0.19)	1.93^+ (1.45–2.40)	1.25 (0.87–1.62)	0.14^- (0.01–0.26)		0.01^- (0.00–0.03)
53	0.15^- (0.00–0.39)	5.80^+ (4.62– 0.98)		1.08 (0.45–1.70)	0.04^- (0.00–0.17)	0.94 (0.34–1.55)	0.59^- (0.22–0.97)
38 (2010)		0.30^- (0.00–0.74)		4.68^+ (3.89–5.47)	0.38^- (0.00–0.83)		0.01^- (0.00–0.09)
38 (2011)	3.45^+ (2.66–4.24)	1.55^+ (1.02–2.08)	0.02^- (0.00–0.09)	18.47^+ (17.01–19.94)			0.01^- (0.00–0.04)
39	10.70^+ (9.99–11.40)	3.85^+ (3.45–4.25)	29.41^+ (28.03–30.79)	0.14^- (0.038–0.23)	0.34^- (0.19–0.49)		0.01^- (0.00–0.03)
51				3.49^+ (3.04–3.94)	0.18^- (0.00–0.48)		0.02^- (0.00–0.12)

model sets for either day or night habitat-selection (all $\Delta AIC_c > 8.0$). In each case, the model with all covariates was the most highly supported model based on model weights (day $W_i = 0.97$, night $W_i = 0.99$).

Nocturnal habitat selection. Based on model-averaged parameter estimates, the probability of use was 1.5 times greater for emergent vegetation, 128 times greater for river channel, and 33.7 times greater for open-canopy shoreline than for open water. Terrestrial habitats combined were 87% less likely to be selected than open water. After accounting for the influence of habitat type, the probability of use decreased by approximately 21% for every 1% increase in canopy cover and decreased by 77% for every 1 m increase in water depth (Table 6).

Diurnal habitat selection. The probability of use during the day was 3.7 times greater for emergent vegetation, 11.6 times greater for river channel, 5.8 times greater for floating vegetation, and 31 times greater for open-canopy shoreline than open

Table 5. A priori models for the probability of habitat use during day and night for American Alligators (*Alligator mississippiensis*) relative to environmental characteristics on the Fort Worth Nature Center and Refuge, TX, 2010–2011. Maximized log likelihoods, number of parameters (k), Akaike's information criterion adjusted for small sample size (AIC_c), ΔAIC_c, and Akaike weights. Models ranked from best- to worst-approximating model.

Model	Log likelihood	k	AICc	ΔAICc	AICc weight
Day					
Habitat type + water temperature + water depth + distance to vegetation + canopy cover	-186.1	16	338.9	0.00	0.9751
Habitat type + canopy cover	-187.4	13	347.9	9.07	0.0104
Habitat type + water depth	-183.2	9	348.0	9.14	0.0101
Habitat type +water temperature	-188.5	13	350.1	11.27	0.0035
Habitat type + distance to vegetation	-190.6	13	354.3	15.47	0.0004
Habitat type	-190.7	13	354.5	15.67	0.0004
Water temperature + water depth	-191.0	12	357.3	18.41	0.0001
Canopy cover	-268.2	8	520.1	181.23	0.0000
Water depth	-284.6	8	552.9	214.03	0.0000
Water temperature	-299.2	8	582.1	243.23	0.0000
Distance to vegetation	-305.9	8	595.5	256.63	0.0000
Night					
Habitat type + water temperature + water depth + distance to vegetation + canopy cover	-120.2	16	207.1	0.00	0.9997
Habitat type + canopy cover	-125.2	13	223.6	16.46	0.0003
Habitat type + water depth	-126.9	13	227.0	19.86	0.0000
Habitat type +water temperature	-130.5	13	234.2	27.06	0.0000
Habitat type + distance to vegetation	-130.5	13	234.2	27.06	0.0000
Habitat type	-130.6	12	236.5	29.39	0.0000
Water temperature + water depth	-183.2	9	348.0	140.91	0.0000
Canopy cover	-181.2	8	346.1	139.00	0.0000
Water depth	-183.5	8	350.7	143.60	0.0000
Water temperature	-198.5	8	380.7	173.60	0.0000
Distance to vegetation	-199.0	8	381.7	174.60	0.0000

water (Table 7). Combined terrestrial habitat types were 99% less likely to be used than open water. After accounting for habitat type, the probability of use during the daytime increased by 12% for every 1% increase in canopy cover.

Discussion

The habitat-selection and home-range patterns we observed in this study differed from those reported previously for inland and coastal Alligator populations. During our study, Alligators consistently selected for river channels and open-canopy shoreline, which is consistent with the findings of Joanen and McNease (1989) where the majority of locations were in deep-water canals; however, this finding differed from a study in north-central Florida where the highest proportions of male and female Alligators were located in lake or open-water habitat, and lower proportions of Alligators were observed in swamp habitat (Goodwin and Marion 1979). Open water was not selected at the study-area or home-range levels in this

Table 6. Model-averaged coefficients, standard errors, odds ratios, and 95% confidence limits for odds ratios included in the best-approximating models for the probability of nighttime habitat use by American Alligators (*Alligator mississippiensis*) on the Fort Worth Nature Center and Refuge, TX, 2010–2011. Other = combined terrestrial habitats.

				95% Confidence limits	
Variable	β	SE	Odds ratio	Lower	Upper
Emergent vegetation	0.41	0.65	1.51	0.42	5.39
River channel	4.85	0.73	128.47	30.56	540.15
Floating vegetation	0.46	1.02	1.58	0.22	11.60
Open-canopy shoreline	3.52	0.93	33.68	5.50	206.45
Other	-2.018	1.01	0.13	0.02	0.96
Distance to vegetation	0.01	0.01	1.01	0.98	1.03
Water temperature	-0.08	0.07	0.93	0.81	1.06
Water depth	-1.49	0.49	0.23	0.09	0.59
Canopy cover	-0.22	0.06	0.79	0.71	0.91

Table 7. Model-averaged coefficients, standard errors, odds ratios, and 95% confidence limits for odds ratios included in the best-approximating models for the probability of daytime habitat use by American Alligators (*Alligator mississippiensis*) on the Fort Worth Nature Center and Refuge, TX, 2010–2011. Other = combined terrestrial habitats.

				95% Confidence limits	
Variable	β	SE	Odds ratio	Lower	Upper
Emergent vegetation	1.30	0.62	3.67	1.08	12.42
River channel	2.45	0.51	11.59	4.19	32.06
Floating vegetation	1.76	0.87	5.82	1.05	32.27
Open-canopy shoreline	3.44	0.79	31.23	6.52	149.57
Other	-4.22	1.11	0.01	0.002	0.13
Distance to vegetation	-0.03	0.02	0.97	0.92	1.02
Water temperature	-0.03	0.07	0.97	0.85	1.10
Water depth	-0.16	0.31	0.85	0.46	1.58
Canopy cover	0.11	0.05	1.12	1.01	1.25

study, which was contrary to the results reported from a study of an inland population in East Texas, where adults occupied deeper, less-vegetated open-water areas (Webb et al. 2009). In our study, habitat-selection patterns also differed somewhat between day and night periods. Compared to habitat selection at night, during the day Alligators were more likely to use areas near aquatic (floating and emergent) vegetation and selected for areas with more canopy cover. At night, Alligators had higher selection for river channel than during the day. During both time periods, Alligators were more likely to select for any of the other aquatic habitat types rather than open water.

Some of the differences between the habitat-selection patterns we observed and those reported for other populations may be due to differences in both the configuration and relative availabilities of each of the habitat types. For example, similar to a study in East Texas (Webb et al. 2009), our study area had higher (e.g., 70% of aquatic habitat) levels of open water than the 20–40% reported as optimal for coastal populations in Louisiana and Texas (Newsom et al. 1987). However, in our study, areas of open water were not interspersed with vegetated wetlands as Newsome et al. (1987) reported was optimal, but rather vegetated areas were largely concentrated at one end of the refuge and along the periphery of some of the open-water areas. Emergent vegetation was also more abundant in our study area than in others and represented approximately 19% of the aquatic habitat types, a proportion 2–3 times as high as reported for inland populations in East Texas (Webb et al. 2009).

It is unclear why Alligators did not select for open water at either spatial scale. The avoidance of open water by our radio-marked Alligators could have been due to the presence of larger, unmarked Alligators relegating our radio-marked Alligators to other habitat types. However, even our radio-marked Alligators that exceeded 2.5–3.5 m in length did not select open-water areas. We also did not observe any large, unmarked Alligators during our study, and we believe that it is unlikely that Alligators larger than our radio-marked animals would have gone undetected during the entire course of our study. Another possible reason for the avoidance of open water is the high level of recreation (i.e., boating) on the FWNCR throughout the day. Boats, both motorized and non-motorized, were commonly observed approaching Alligators (J.D. Lewis, pers. observ.) which may have resulted in Alligators avoiding the open water where detection by boaters would have been more likely. A study on *Caiman crocodilus* L. (Spectacled Caiman) in the Tortuguero region of Costa Rica found that increasing boat traffic associated with ecotourism, recreation, and local human population-growth increased the likelihood of boat-collision–related injuries; Spectacled Caiman were also frequently observed avoiding boats (Grant and Lewis 2010).

Changes in the biotic and abiotic parameters at range edges make ecological processes more variable than at the core of the distribution range (Sexton et al. 2009), which may explain some of the home-range and habitat-selection patterns we observed. For example, sex, reproductive status, habitat characteristics, and temperature can all influence home-range area and movements of adult Alligators (Morea et al. 2000). The home ranges of females from our study were 2–4 times (mean = 40.9 ha, range = 27.9–64.7 ha) higher than those reported in Florida (22–35.9 ha; Morea et al. 2000, Phillips et al. 2002) and coastal Louisiana (8.4 ha; Joanen and McNease 1970), whereas average home–range size for males in our study (mean = 68.9 ha, range = 33.9–110.6 ha) were substantially smaller than documented in Florida (144 ha; Phillips et al. 2002), with the exception of those reported by Morea et al. (2000), and coastal Louisiana (e.g., 328 ha; Joanen and McNease 1972) .

Home-range sizes we observed during our study may be related to the habitat types within the home ranges and low Alligator density (0.014–0.065 Alligators/ha; Lewis 2012). The Alligator densities estimated at our study area are lower than the estimated densities (0.12–0.31 Alligators/ha) reported for other inland Alligator populations in East Texas (Lutterschmidt and Wasko 2006, Webb 2005), and substantially lower than densities reported in coastal Louisiana (1.29 Alligators/ha; Taylor et al. 1991), or in Florida (0.22–0.7 Alligators/ha; Woodward et al. 1996). The location of our study population at the northwestern edge of the range experienced colder winter temperatures, shorter growing season, and likely lower food abundance in comparison with coastal Alligator populations (Rootes et al. 1991), which probably contributed to both the lower Alligator density and larger home ranges we observed in females. However, it is unclear why males had smaller home ranges than in coastal populations. One possibility is that the overall area with suitable environmental conditions for Alligators is relatively small in our study area compared to coastal populations, and this may limit the upper home-range size for male Alligators.

During our study, we were unable to fit a large number of Alligators with VHF transmitters and some Alligators that were fitted with transmitters failed to retain the transmitter for an entire season. However, a separate study estimated that there were only 7–31 Alligators in the study area (Lewis 2012). Therefore, although our absolute sample size could be considered low, our sample size relative to the total population size was between 19% (6 unique Alligators captured out of a population of 31) and 86% (6 out of 7). Given that our inferences are strictly limited to this population, we believe that our sample provided representative estimates of home range and habitat-selection patterns for the Alligator size-classes we studied. Unfortunately, we were unable to assess sex or age-specific patterns of habitat selection.

Alligator populations at the edge of their distributional range may display habitat-use patterns that differ not only from those of coastal populations, but also from other inland populations. During our study, Alligators selected for areas that included the river channel, floating and emergent vegetation, and open-canopy shorelines, but they avoided open water. With the exception of open-canopy shorelines, these environmental conditions also tended to occur in the areas of the wetlands that are most susceptible to changes in water levels associated with flood control during high rainfall periods and declining water tables during drought periods. Hence, the management of water levels in this lake has the potential to profoundly influence the conditions in areas most frequently selected by this population of Alligators.

Furthermore, the management of water levels in urban reservoirs is likely to be more intensively controlled given that the costs associated with flooding in terms of both property damage and human safety are higher than near reservoirs in more-rural and less-densely populated areas. Reservoirs located closer to urban areas are also more likely to experience higher levels of water withdrawal during dry periods, which can influence the availability of habitat for Alligator populations.

The avoidance of open water in our study is perhaps the most notable difference between the habitat-selection patterns we observed and those reported for other inland populations (e.g., Webb et al. 2009). We believe that avoidance of open water may be related to either reduced food availability in the open-water areas or to high levels of human recreation on the refuge, particularly people in motorized boats and canoes. To our knowledge, this is the first published study based on data collected at the edge of the distribution range for the American Alligator; therefore, further work is warranted to determine if the patterns we observed are characteristic of other Alligator populations at the edge of the range (Lutterschmidt and Wasko 2006).

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