JNAH
THE JOURNAL OF NORTH AMERICAN HERPETOLOGY
ISSN 2333-0694
Volume 2025, Number 1 December 2025 journals.ku.edu/jnah

HOME RANGE, HABITAT USE, AND BEHAVIORS OF FLORIDA BOX TURTLES, *TERRAPENE CAROLINA BAURI* AT AN ENCLOSED SITE IN SOUTHWESTERN FLORIDA

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Abstract.— Until recently, little was documented on the movement patterns and habitat preference of Florida Box Turtles (*Terrapene carolina bauri*). We investigated the home range (HR), and habitat preference, and general behaviors of ten Florida Box Turtles (five of each sex) within an enclosed preserve site in Southwestern Florida across a calendar year. HR estimates using 100% Minimum Convex Polygons (MCPs) and 95% Kernel Density Estimates (KDEs) averaged 1.76 ± 0.48 ha and 2.80 ± 0.87 ha, respectively. HRs were larger in the wet season for KDEs, while MCPs showed no seasonal difference. Males and females exhibited no significant differences in HR. Landscape-level selection differed significantly from habitat availability, with Oak-Rosemary Scrub (ORS) having ranked highest in use relative to availability, followed by Pine Flatwoods (PFW), Grassy Meadow (GM), and Former Wetland (FW). Only ORS and FW usage differed significantly. Activity-level selection also differed significantly from availability, with FW ranked highest, followed by PFW, ORS, and GM, with all habitats differing significantly in selection. Turtles were observed hiding under cover on most relocations. Florida Box Turtles were also documented using Gopher Tortoise burrows on eight separate occasions. These data provide new insights into home range dynamics, seasonal movement patterns, and habitat selection in Florida Box Turtles. These findings will become more relevant as habitat fragmentation and additional anthropogenic barriers continue to encroach on the limited remaining wild spaces in peninsular Florida.

Keywords.— Home Range, Box Turtles, Habitat Selection, Burrow

INTRODUCTION

Home range (HR) studies are a common and informative tool used to better understand the ecology of reptiles, providing important information for life history knowledge, along with conservation and management decisions (Bowen et al. 2004; Dodd and Griffey, 2005; Averill-Murray 2020). Specifically, in turtles, HR studies have been used to indicate space use (Refsnider et al. 2012), distance traveled (Rittenhouse et al., 2007), and habitat preference (Rasmussen and Litzgus 2010). One of the most represented turtles in HR studies are North American box turtles (Terrapene sp.) with HR studies having been conducted throughout the known geographic range of the genus (Dodd 2001).

Home ranges of North American box turtles vary between taxonomic groups (species/subspecies) and even between conspecific populations within similar geographic regions (Dodd, 2001; Habeck et al. 2019). This variation is likely due to the multitude of different habitats and environmental conditions that box turtles are exposed to throughout their distributions, which extends north to Maine up the eastern seaboard and into the midwestern United States westward to Arizona, with several species ranging south into Mexico (Dodd, 2001).

Environmental variables that may influence home ranges include but are not limited to proportion and availability of habitat that provide natural shelter, food resources, reproductive opportunities, thermoregulation, and weather patterns (Stickel, 1950). For instance, the arrival of summer and increased precipitation in the rainy season saw the expansion of HRs and activity in several populations (Stickel, 1950, Reagan, 1974; Dodd et al. 1994, Nieuwolt 1996).

Sex also likely influences HR in Terrapene species, as several other turtle species show variation in HR based on sex (McRae et al. 1981; Doody et al. 2002; Mauro et al. 2002; Riedle et al. 2006), though Dodd (2001) summarized conflicting observations, with some studies showing larger female ranges, others showing larger male ranges, and still others that report no difference in HR between sexes.

Habitat selection is also associated with HR studies in box turtles when multiple habitats/microenvironments may be present (Dodd et al. 1997, Kapfer et al., 2013, Henriquez et al. 2017, Demetrio et al. 2022). Habitat availability is likely a driver in the HR of animals and may vary between seasons if neighboring habitats offer different resources (e.g., nesting sites, food, water) (Marchand et al. 2004; Donaldson & Echternacht, 2005).

The Florida Box Turtle (Terrapene carolina bauri) can be found in numerous ecosystems throughout peninsular Florida and its barrier islands, south to the Florida Keys (Dodd et al. 1994; Verdon & Donnelly, 2005, Farrell et al. 2006, Platt et al. 2009; Jones et al., 2016). While some group T. c.bauri within the Woodlands Box Turtle clade (Terrapene carolina), recent assessments indicate that Florida Box Turtles are potentially a unique lineage (T. bauri) (Butler et al. 2011, Rhodin et al., 2021), thus indicating need for additional studies.

Compared to its more northern congeners, the HR and habitat preference of T. c. bauri has been poorly studied, particularly in the southern reaches of its range. Limited movement or HR studies have been performed on T. c. bauri, with the only published studies to investigate these subjects coming from Egmont Key off the coast of central Florida (Jennings 2007), inland central Florida (Pilgrim, 1997, Farrell et al. 2006) and some coastal and island populations in southwestern Florida (Demetrio et al. 2022; Donini et al 2024), with an additional thesis by Verdon (2004) that assessed HRs in the Florida Keys. Only three of these studies provide quantitative information on the HR of Florida Box Turtles (Verdon, 2004, Demetrio et al. 2022, Donini et al. 2024) indicating the need for additional assessments in the species throughout the state.

Habitat use is similarly underrepresented in the literature for T. c. bauri. Observations on Egmont Key indicate differences in habitat preferences between size classes with juveniles preferring canopy cover provided from palm pepper forest habitats (Jennings 2007), while adults used the same canopy covered habitat but were more widely distributed throughout open habitats as well (Dodd et al. 1994). In the Ten Thousand Islands, Demetrio et al. (2022) indicated heavy preference for hardwood hammock based on the number of detections within the habitat, while Donini et al. (2024) indicated use of a mosaic of habitats with heavy use of coastal grasslands and canopy covered regions.

In addition to lack of data in the southern portion of their range, T. c. bauri faces extreme pressure from habitat fragmentation, including threats to major corridors of unprotected land (Main et al. 1999;.Hoctor et al., 2015). Thus, there is a need for further understanding how these animals may function in the face of restricted ranges, or even instances of relocation could be pertinent for making conservation decisions. The HR of reintroduced or translocated individuals has been studied in other box turtle species (Cook 2004, Rittenhouse et al.2007, Orr et al. 2020), but few have directly looked at individuals within regions with known artificial boundaries in place, a potential new reality for some species that may be unable to disperse over fencing installations and other urban structures. Better understanding of box turtle HR in such enclosed systems could help inform relocation/reintroduction programs and increase survivorship of relocated populations, allowing for better recognition of spatial and habitat needs.

In this study our objectives were to use radiotelemetry to (1): Quantify the HR of male and female Florida Box Turtles within a closed system during the wet and dry season in southwestern Florida (2): To assess the habitat preference and behaviors of turtles throughout a full year of study.

METHODS

Study area

The study took place at a small 3.8 hectare (ha) preserve area in Collier County, Florida. The region is divided into four primary habitat types based on predominant vegetation composition; Pine Flatwoods (PFW) (~1.2 ha) composed of Slash Pine (*Pinus elliottii*) and Saw Palmetto (*Serenoa repens*), Oak-Rosemary Scrub (ORS) (~1.8 ha) composed of several Oak types (Quercus sp.), Florida Rosemary (*Ceratiola ericoides*), and West-Indian Mahogany (*Swietenia mahogany*), Grassy Meadow (GM) (~0.75 ha) composed of Bluestem grasses (Andropogon sp.), Mexican Clover (*Richardia brasiliensis*), and Prickly Pear (*Opuntia sp.*), and an area that was formerly wetland (FW) (~0.07 ha) prior to development composed of Cabbage Palm (*Sabal palmetto*), Cocoplum (*Chrysobalanus icaco*), Pennywort (*Hydrocotyle umbellate*) and assorted other unidentified grasses. The property formerly served as a recipient site for relocated Gopher Tortoises (*Gopherus polyphemus*) and is enclosed by a buried fence line that reaches ~0.3–1.0 m in height to prevent dispersal of the tortoises into adjacent areas. The site boasts a high density of tortoises, with 275–300 burrows including those that are inactive or occupied by juveniles (Speer, Unpublished Data).

Surveys

Turtles were collected opportunistically via meandering surveys (Currylow et al., 2011; Jones et al. 2021) from 11 November 2019 to 14 December 2019 until ten individuals (five of each sex) were found. Upon capture animals were weighed (g), measured (mm), externally notched on the marginal scutes (Cagel 1939) and injected with a Passive Integrated Transponder (PIT) tag (Buhlman et al. 2001). Once weighed, animals were placed into temporary holding containers prior to application of radio-transmitters.

Each individual was fitted with a SOPR-2380 VHF Radio-transmitter (Wildlife Materials Inc.) on the costal scutes on the anterior portion of the carapace on so as to not inhibit mating activity. Each transmitter was fixed by Devcon© 5-Minute Epoxy Gel (14265). Epoxy was molded around the transmitter and allowed to set for 6 hours before release. Each tag with epoxy accounted for no more than 5% of the animal's mass. Turtles were then released at their original site of capture. Individuals were tracked bi-weekly with 3–4 days between tracking sessions for 12–13 months (November 2019–December

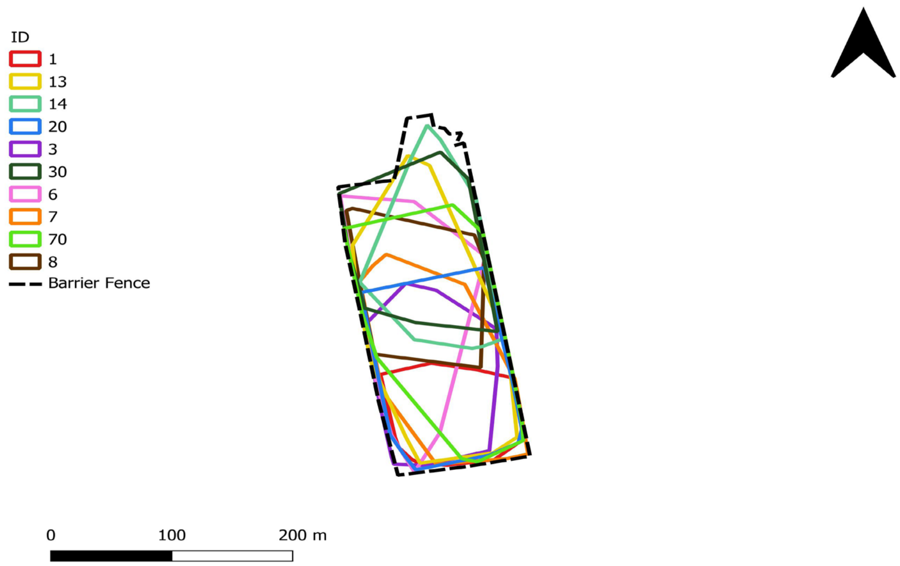

Figure 1. 100% Minimum Convex Polygons depicting home range of male and female Florida Box Turtles for the entire year. Arrow indicates north, ID key corresponds to individual ID for each turtle.

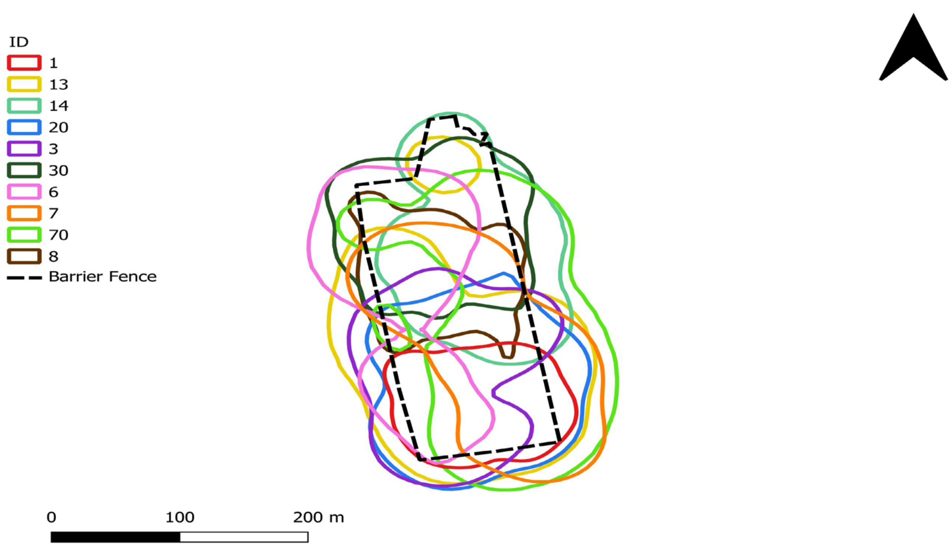

Figure 2. 95% Kernel Density estimates depicting home range of male and female Florida Box Turtles for the entire year. Arrow indicates north, ID key corresponds to individual ID for each turtle.

2020) with survey periods separated into wet and dry season based on the sub-tropical climate of the region. An exception occurred to normal tracking schedules from March–May 2020 where individuals were only tracked once weekly due to restrictions from the early days of the COVID-19 Pandemic. Tracking sessions were conducted randomly between 0600–1900 hours. The turtles were tracked until the frequency and clarity of the signal indicated a distance of < 1 m. Animals were then visualized if possible, however subjects were left undisturbed in most instances to not bias future sampling by altering behaviors. Limited periodic inspections of epoxy and transmitters were performed to confirm optimum functionality. A non-visual designation was given when the subject was not able to be physically observed. Upon location GPS coordinates were recorded in the GPS Tracks IOS App (Morneault 2011), with an accuracy of ~2–3 m. In addition to coordinates, habitat type, and observed behavior of the subject were also recorded. Behaviors included hiding (H) in which an animal was buried or tucked into a form or other vegetation, resting (R) in which an animal was found out in the open uncovered, walking (W) where turtles were observed directly moving, eating/foraging (E), breeding/courting (B), and other (O) if the behavior didn't match any others listed.

Home range and habitat selection analysis

All HR and statistical analyses were performed using R version 4.4.2 (R Core Team 2024). In this study, we utilized 100% Minimum Convex Polygon (MCP) and 95% Kernel Density Estimation (KDE) to assess HR areas of turtles within the fenced preserve. 95% KDE is a widely used method for estimating space use based on recorded locations; however, it operates under the assumption of continuous movement across space, without accounting for physical barriers. As a result, our KDE estimations may extend beyond the actual accessible area. We chose to retain 95% KDEs for comparability with previous studies and standard HR estimation practices. We calculated 100% MCP for each individual during the wet and dry seasons independently. MCPs encompass the area contained by the smallest polygon around the observed locations. Each individual was relocated between 95 and 107 (101.7 ± 3.8) times over the course of a full year. We report the 100% MCP to encompass the entire area of observed use by each individual and because plots of the HR size continued to increase smoothly for some individuals, while increasing the percentage of points used in the calculation. Presentation of 100% MCP is also comparable to other studies of terrestrial turtles (e.g. Kapfer et al. 2013,Bernstein and Richtsmeier 2007, Diemer, 1992). Both HR estimators were calculated using adehabitatHR with the reference bandwidth method (h = "href") to determine spatial use (Calenge 2006), with polygons extracted using getverticeshr and HR areas calculated using st_area (Pebesma 2018).

Resulting KDE and MCP polygons were exported as ESRI shapefiles using st_write for visualization in GIS software (Pebesma 2018). A separate analysis was conducted to construct a barrier fence line, converting GPS points into a LineString before exporting as a shapefile for spatial reference. KDE outputs were interpreted with the understanding that the method does not recognize physical barriers, which may lead to overestimation beyond the fenced boundary, a common limitation of KDE in constrained environments, whereas MCPs inherently define a hard outer limit but may include areas not actively utilized by individuals. We mapped the locations overlayed with the MCPs and KDEs for each individual using shape files imported into QGIS 3.34.3. A two-way analysis of variance (ANOVA) was performed using the stats package (R Core Team, 2024) to assess the effects of sex and season on home range size, measured via 95% KDEs and 100% MCPs. Residual diagnostics, including Shapiro-Wilk tests for normality and Bartlett's test for homogeneity of variances, were performed within the stats package. Kruskal-Wallis tests were subsequently performed for any non-conforming data.

We used the adehabitatHS package (Calenge 2006) in R 3.6.3 (R Core Team 2020) to conduct compositional analysis using 10,000 randomization simulations to rank and make pairwise comparisons between habitat use and availability within habitat types. Both 2nd order landscape level analysis and 3rd order activity range analysis were performed (Johnson 1980). All estimates are reported as mean ± standard deviation.

RESULTS

Home range

Data for both 100% MCPs and 95% KDEs met all assumptions for ANOVA. Average HR estimate for all turtles was 1.76 ± 0.48 ha for 100% MCPs and 2.80 ± 0.87 for 95% KDE. No significant interactions (MCP: $F_{1,6}$ = 3.853; p = 0.097, and KDE: $F_{1,6}$ = 0.295; p = 0.606) were detected between variables. Average HR during the dry season for 100% MCP estimates was 1.22 ± 0.36 ha (Figure 1.) and 2.43 ± 0.94 ha for 95% KDE estimates (Figure 2.). Average HR during the wet season for MCP estimates were 1.45 ± 0.59 ha (Figure 3.) and 3.18 ± 1.67 for KDE estimates (Figure 4.). A significant difference existed between the 95% KDEs of box turtles in the wet season compared to the dry season ($F_{1,6}$ = 20.440; p = 0.004) with larger HR during the wet season, while MCP HRs showed no significant difference ($F_{1,6}$ = 0.719; p = 0.429)

No significant differences existed between the HR of males or females for both MCP and KDE estimates (MCP: $F_{1,6}$ = 0.177; p = 0.744, and KDE: $F_{1,6}$ = 0.054; p = 0.823). Average MCP estimated HR for male turtles was 1.81 ± 0.49 and 2.76 ± 0.89 for KDE estimates. Average MCP estimated HR for female turtles was 1.71 ± 0.53, and 2.83 ± 0.95 for KDE estimates. Extensive overlap of HRs between males and females and individuals was observed based on both MCP and KDE estimates (Figure 1. and 2.).

Habitat selection

The majority of the 1018 detections were within PFW habitat (n = 487 or 47%), followed by ORS at n = 396 (or 38.9%), with GM and FW making up the remaining 13.3% (n = 67 and n = 68 detections respectively).

Landscape level (2nd order) compositional analysis indicated a significant difference in use of habitats compared to availability (λ-0.366; p = 0.029). Habitat use ranked from most to least used in relation to availability is listed as follows 1) ORS, 2) PFW, 3) GM, and 4) FW. However, the only statistically significant difference in habitat use was between ORS and FW. Use of all other habitats did not vary significantly from one another according to availability (Figure 5.).

Activity level (3rd order) compositional analysis indicated a significant difference in the selection of habitats compared to availability (λ-0.024; p = 0.008). Habitat selection ranked from most to least used in relation to availability is listed as follows, 1) FW, 2) PFW, 3) ORS, 4) GM. Use of all habitats varied significantly from one another according to availability (Figure 6.).

Observed behaviors

1018 individual locations were made during the course of the study. The majority of behaviors observed independent of location time were designated as hiding (H) (n = 734, or 72.1%), resting (R) (n = 127 or 12.48%), or walking (W) (n = 124, or 12.18%) behaviors. Other activities were observed much less frequently, usually having occurred in earlier periods of the day. Eating, foraging, or consumption of water was observed a total of 11 times throughout the study (1.08% of total observations), with breeding and courting behaviors observed 19 times but accounting only for 1.87% of the total observations made. An additional three observations were made that did not fit into any of these categories (O). In this instance two observations of turtles completely submerged and swimming in a flooded portion of the site post tropical storm Sally, and a single instance of male-male combat or a misplaced breeding attempt. Additionally, on eight separate occasions in this study, six different individual turtles were directly observed within or on the aprons of Gopher Tortoise burrows (Figure 7.).

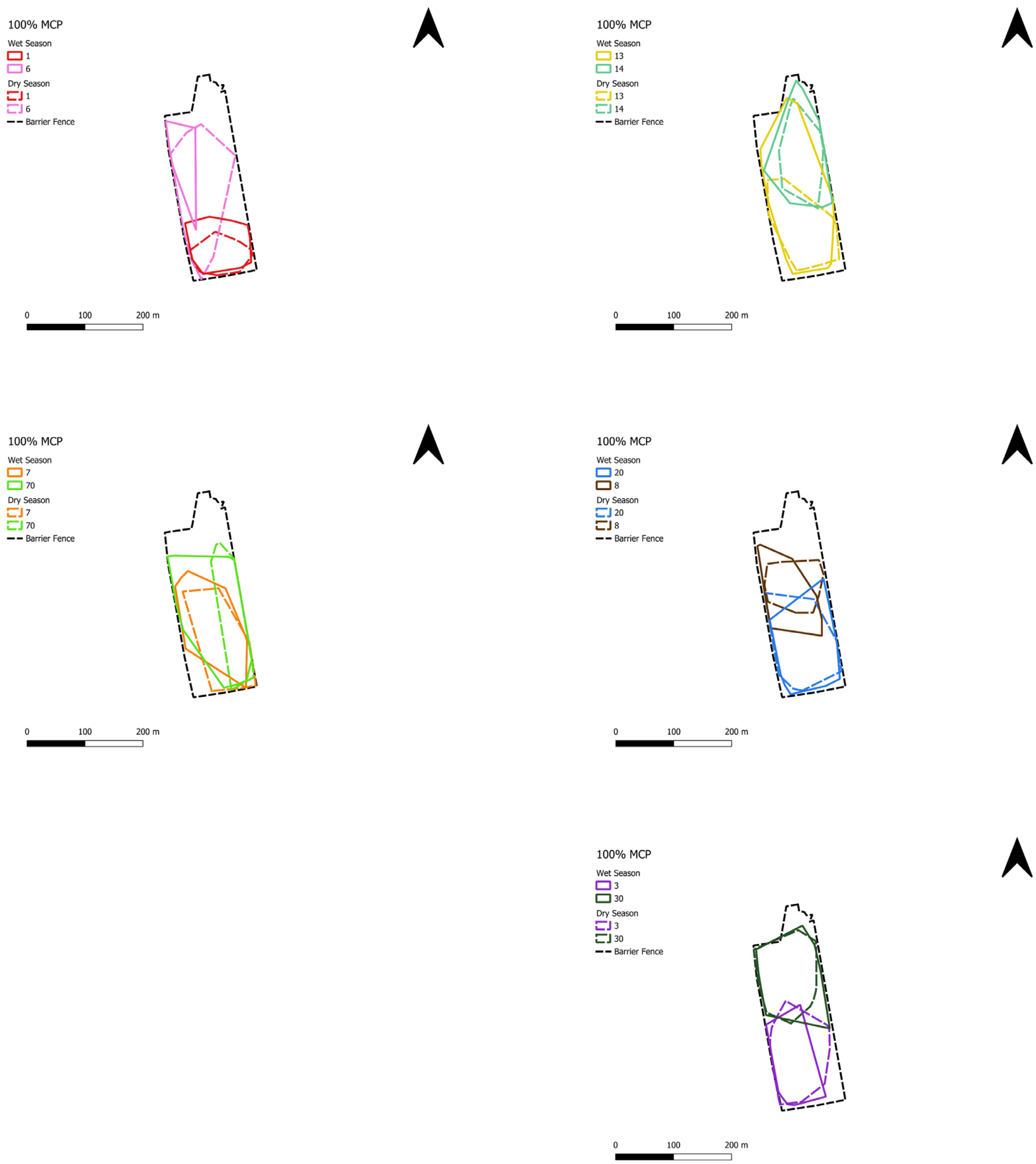

Figure 3. 100% Minimum Convex polygons depicting home range of Florida Box Turtles (*Terrapene carolina bauri*) in Wet and Dry seasons. Arrow indicates north, ID key corresponds to individual ID for each turtle.

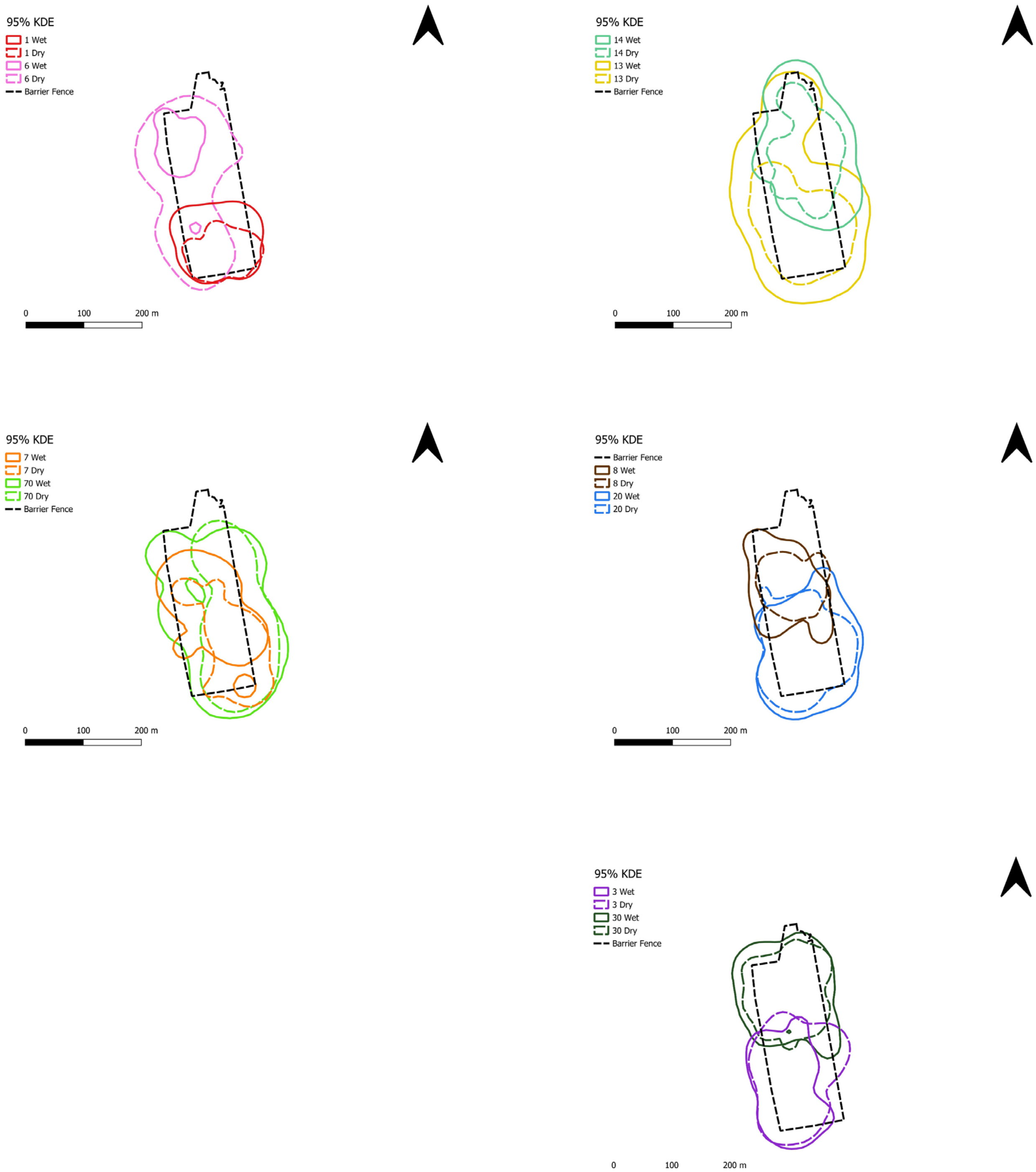

Figure 4. 95% Kernel Density Estimates depicting home range of Florida Box Turtles (*Terrapene carolina bauri*) in Wet and Dry seasons. Arrow indicates north, ID key corresponds to individual ID for each turtle.

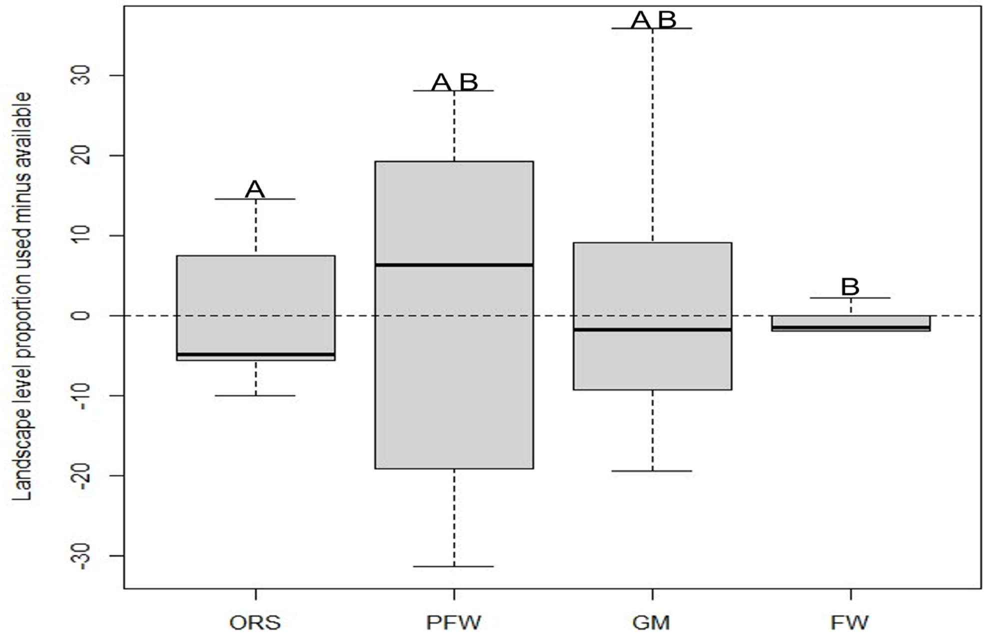

Figure 5. Landscape Level (2nd order) Compositional Analysis for each major habitat type assessed. Use ranked in the following order 1) Oak Rosemary Scrub (ORS), 2 Pine Flatwoods (PFW), 3 Grassy Meadow (GM), and 4 Former Wetland (FW). ORS only significantly differed from FW with no significant differences existing between other comparisons. Bold lines are medians, ends of boxes are interquartile range (25th and 75th percentile), and whiskers are the minimum and maximum. Different letters indicate statistically significant difference between habitats.

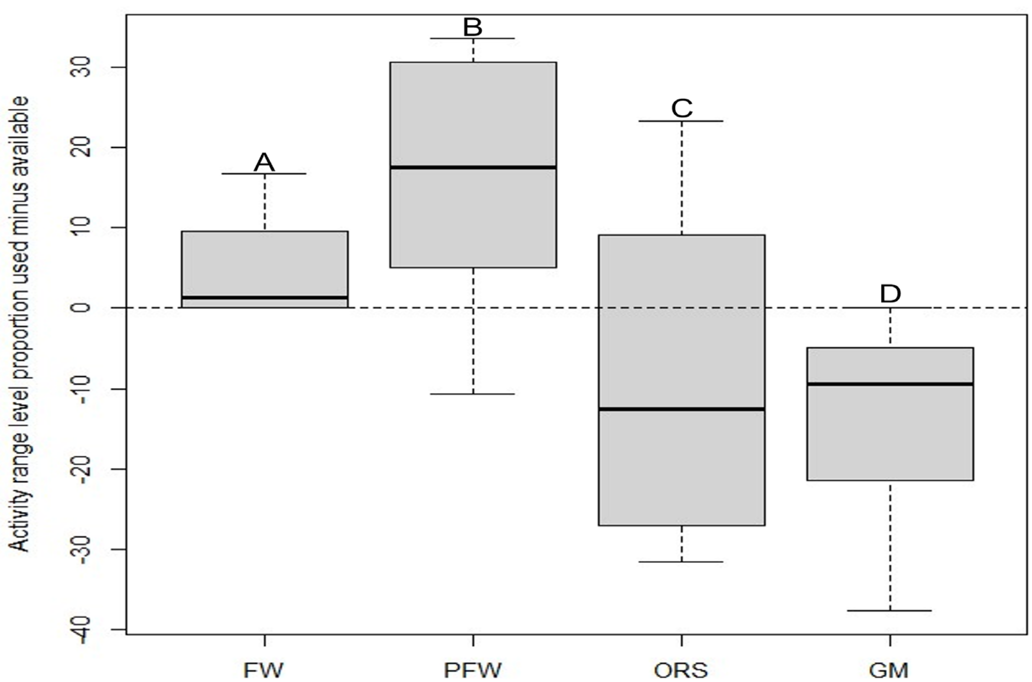

Figure 6. Activity Range Level (3rd order) Compositional Analysis for each habitat used. Use ranked in the following order 1) Former Wetland (FW), 2) Pine Flatwoods (PFW), 3) Oak Rosemary Scrub (ORS), and 4) Grassy Meadow (GM). All four habitat types showed significant differences in use. Bold lines are medians, ends of boxes are interquartile range (25th and 75th percentile), and whiskers are the minimum and maximum. Different letters indicate statistically significant difference between habitats.

Figure 7. Examples of Florida Box Turtles (*Terrapene carolina bauri*) using Gopher Tortoise (*Gopherus polyphemus*) burrows during the study.

DISCUSSION

Overall, no differences in the HR were observed between sexes, which is consistent with several studies that also indicated HR between sexes in other box turtle species may not be statistically different (Stickel, 1989; Nieuwolt, 1996, Aall, 2011,Harris et al. 2020). Demetrio et al. (2022) also documented no difference in HR between sexes in Florida Box Turtles at similar latitudes to the current study. Contrarily, Donini et al. (2024) observed some significant differences between sexes in both 100% MCP and 95% KDE, especially in interactions with seasonality. Further, a review of metadata by Habeck et al. (2019), showed that female box turtles in the T. carolina clade had a 27% larger HR compared to males across their distribution. One of the reasons why significant differences were not observed in the present study could be related to the overall size of the site, as the field site with its borders is slightly less than 4 ha. This site was much smaller than those studied by Demetrio et al. (2022) and Donini et al. (2024), which ranged between 30–60 ha with effectively continuous habitat for turtles to use. Thus, the contracted space available for the turtles at this site could be a driver of the lack of differences observed, as many of the individual home ranges overlapped within the site.

Despite the lack of significance in MCP estimates, we did see significant differences in HR between seasons when using 95% KDEs, with wet season HR expanding larger than that of the dry season. Few comparable studies have investigated the HR of box turtles in similar geographic areas as our study, with most box turtle studies occurring in temperate regions that experience four full seasons with winter inactivity (Currylow et al. 2013). Only the previously mentioned studies by Verdon (2004), Demetrio et al. (2022), and Donini et al. (2024) were conducted at southern subtropical latitudes similar to the current study. Neither Demetrio et al. (2022) nor Donini et al. (2024) observed significant differences in HR between seasons in this species. Verdon (2004) however, indicated a greater average daily movement estimate in the wet season, but did not include descriptions of HR variation between seasons, which corresponds similarly to increased HR size in the wet season observed in the current study. At our site during the wet season, some sections may become temporarily flooded which may influence turtles to move to or away from the flooded zones pending other environmental conditions.

Many of the results observed in this study are likely influenced by the restrictions imposed by the barrier fence line. These fences prevent dispersal from outside of the field site and likely lead to more overlap in individual HRs than seen in populations with more contiguous habitat where overlap between tagged male and female Florida Box Turtles was limited (Demetrio et al. 2022). This overlap in HR may be advantageous as it may increase the frequency of breeding opportunities (Dodd 2001), and some studies (Belzer and Seibert 2009) indicate the visual cues may be important for male box turtles to detect females. Contrarily this overlap may also bring with it increased opportunity for stress, competition, and pathogen transmission as seen in translocated populations, along with the possibility of increased inbreeding (Rittenhouse et al., 2007; Allender et al., 2011; Cozad et al. 2020). However, despite this extensive overlap, we observed direct interactions between turtles (radio-tagged or otherwise) on less than 2% of relocations.

Most sightings occurred in PFW habitat, which is logical as PFW makes up an estimated 1.2 ha of the field site (31.4 % of available habitat). While being the largest continuous habitat proportionally (second only to ORS, but only when including fragmented "islands" in the meadow), it also offers some degree of canopy cover, along with adequate sunlight and microhabitats for security and thermoregulation. PFW also likely boasts a high degree of productivity, with a number of plant, fungal, and animal-based food sources found throughout (Speer & Donini, personal observation). However, neither level of compositional analysis indicated PFW as the most selected habitat despite the higher number of detections. Landscape level (2nd order) compositional analysis ranked ORS as the most selected habitat type but detected no significant differences in usage of habitat types, with the exception of ORS showing a higher degree of selection than smallest habitat section (FW). As

2nd level analysis factor in the HR of the entire observed population, this makes sense given that ORS (both continuous habitat, and the aforementioned "island" patches within the meadow) makes up a larger total proportion of habitat than any other described habitat (47.2%). ORS habitat also offers similar microhabitats and resource opportunities to the PFW. Both PFW and ORS habitats likely provide far more security than the open meadow (19.5%) and former wetland habitats (1.8%). Landscape level compositions performed by Donini et al. (2024) examined habitat selection with a great variety of habitat types and saw selection of more open grassland habitats in a coastal ecosystems, however selection of dense Mangrove forests were also detected as the second most selected habitat, with these forests possibly offering a similar resources (e.g. coverage, thermoregulation). Dodd et al. (1994) and Demetrio et al. (2022) described similar preference for habitats with some degree of canopy coverage in T .c. bauri, while other box turtle populations also show an affinity for covered habitat (Budischak et al. 2006, Harris et al. 2020). However, this comparison also indicates there was no significant selection preference between ORS and PFW or GM, which suggests that Florida Box Turtles are seemingly adaptable to a variety of habitat types, and use a number of differing habitat types regardless of availability. Activity level (3rd order) compositional analysis indicated significant differences in habitat usage between all four habitat types, with FW showing the highest usage of the four. This may be indicative of FW habitat being sought out in relation to its availability, meaning some turtles may have actively avoided other habitats and selected to instead use the FW. It is not apparently clear why such a small habitat like FW would be selected for initially, however it is possible that resources play a role. A single large (~2.5 m wide and ~ 1.5 m tall) Cocoplum existed on the perimeter of the FW providing both coverage and high energy fruit known to be consumed by T. c. bauri (Loredo et al. 2022). High energy fruits have been observed to disproportionately attract box turtles with Dodd et al. (1994) documenting greater than 40 individual turtles using a single Sea Grape (Coccoloba uvifera) plant while in fruit. Thus it is very possible that the Cocoplum observed is acting as a major driver of habitat selection in the case of FW similar to the Seagrape observed by Dodd et al. (1994).

The majority of behaviors documented in our study were resting or hiding (83.6 % of relocations). Although our definitions of resting versus hiding may be slightly different, our findings are comparable to reports from Dodd et al. (1994) who found the bulk of a sample of Florida Box Turtles resting on the ground surface not fully buried. The majority of our relocations were animals either partially buried or tucked into forms and other vegetation. Given that tracking sessions often occurred in the early morning before animals had been adequately able to respond to increasing temperatures, it's not surprising that the majority of our observations were these resting or hiding behaviors. Though our sample size was biased towards 10 individuals compared to the greater number of individual turtles documented by Dodd (et al. 1994), we saw much lower proportions of feeding/foraging, breeding/courting and other behaviors (~3.25%).

Eight observations of direct use of Gopher Tortoise burrows were documented in this study, however given the density of tortoises in the region, one might expect a higher frequency of burrow usage. Several observations of box turtles using Gopher Tortoise burrows throughout their range have been identified in the literature (Jackson and Milstrey, 1989; Hipps, 2019), though these events appear to be relatively rare. Dodd (2005) described Florida Box Turtles only using inactive burrows as refuge, which was the same case for three of our observations, with one turtle making use of the same burrow for almost a week during 27 February–5 March 2020. However, this same individual also made use of an active burrow only four days later on 9 March 2020. All other observations were documented in active burrows, although we do not know if Gopher Tortoises were using the burrows at the same time. Interestingly, all of the radio-tagged turtles observed using Gopher Tortoise burrows were male except for a single female. We anticipated possible use of burrows and burrow aprons as box turtle nesting sites as seen in Donini et al. (2021); however, no direct observations of nesting in aprons or burrows were documented during this study. The lack of use of tortoise burrows is somewhat surprising given the density of tortoises and the amount of available burrow microhabitats present throughout the field site. Although it is likely that some instances of burrow use were missed due to the tracking regimen, it is also quite possible that the abundance of tortoises directly impacted the lack of burrow usage of box turtles. Multiple Gopher Tortoises may share a burrow, and Gopher Tortoises may be territorial with conspecifics (Ashton and Ashton 2008). Perhaps box turtles were treated as a nuisance or even as rival tortoises in some instances, leading to tortoises warding off attempts of burrow use by box turtles, however this hypothesis has yet to be tested.

Overall, this study provides new insights into a relatively under-researched aspect of the ecology of Florida Box Turtles. The condensed and confined setting of the site appear to have led to extensive overlap in the HR of individuals, and overall smaller estimated HR compared to other conspecifics in the literatures. The barriers of movement likely heavily influenced the overall HR estimates in light of the limited ability to disperse from the site. Habitat selection itself appeared to have been driven by both canopy cover and resources. These data may also indicate that even small relative amounts of resources in specific habitats could influence the movement patterns of this species. Furthermore, this study adds valuable data on the Florida Box Turtle in a unique framework in an understudied portion of its range. The insights gained here may provide information for future management techniques as the development of Florida's natural area continues.

ACKNOWLEDGEMENTS

We thank Katharine Ebaugh, Isabella Danaher, Prenn Nguyen, Julianna Loredo, Cristal Navarrete, Kristina Kitun, Cody Weber, and Victoria Mann for their assistance in tracking and data collection. We thank the Florida SouthWestern State College Office of Sponsored Programs and Research for providing funding for this project via Academic Research Council (ARC) Grants for 2019. Animals were sampled under FWC Permit LSCC-17-0022A. Animals were handled in a manner consistent with the Herpetological Animal Care and Use Committee of the American Society of Ichthyologists and Herpetologists.

LITERATURE CITED

Aall, N. C. 2011. Influence of season and sex on Terrapene c. carolina (Eastern Box Turtle) movements: an observation of a population in West Virginia. Unpublished Masters Thesis, Marshall University, West Virginia, United States.

Allender, M.C., Abd-Eldaim, M., Schumacher, J., McRuer, D., Christian, L.S., and Kennedy, M. 2011. PCR prevalence of ranavirus in free-ranging eastern box turtles (Terrapene carolina carolina) at rehabilitation centers in three southeastern US states. Journal of Wildlife Diseases 47: 759–764. https://doi.org/10.7589/0090-3558-47.3.759

Averill-Murray, R.C., Fleming, C.H., and Riedle, J. 2020. Reptile home ranges revisited: a case study of space use of Sonoran Desert tortoises (Gopherus morafkai). Herpetological Conservation and Biology 15: 253–271

Ashton, R.E., and P.S. Ashton. 2008. The Natural History and Management. of the Gopher Tortoise, Gopherus polyphemus. Florida, USA, Krieger Publishing. 35–37.

Belzer, W.R. and S. Seibert. 2009. How do male box turtles find mates? Turtle and Tortoise Newsletter 13:11–21. https://doi.org/10.2744/1526-3096-13.1.2

Bernstein, N.P., and Richtsmeier, R.J. 2007. Home range and philopatry in the Ornate Box Turtle, Terrapene ornata ornata, in Iowa. The American Midland Naturalist, 157: 162–174. https://doi.org/10.1674/0003-0031(2007)157[162:HRAPIT]2.0.CO;2

Bowen, K. D., Colbert, P. L., and Janzen, F. J. 2004. Survival and recruitment in a human-impacted population of ornate box turtles, Terrapene ornata, with recommendations for conservation and management. The Journal of Herpetology 38: 562–568. https://doi.org/10.1670/78-04A

Buhlmann, K., and Tuberville, T.D. 1998. Use of passive integrated transponder (PIT) tags for marking small freshwater turtles. Chelonian Conservation and Biology 3: 102–104.

Butler, J.M., Dodd Jr, C.K., Aresco, M., and Austin, J.D. 2011. Morphological and molecular evidence indicates that the Gulf Coast box turtle (Terrapene carolina major) is not a distinct evolutionary lineage in the Florida Panhandle. Biological Journal of the Linnean Society 102: 889–901. https://doi.org/10.1111/j.1095-8312.2011.01625.x

Budischak, S.A., Hester, J.M., Price, S.J., and Dorcas, M.E. 2006. Natural history of Terrapene carolina (box turtles) in an urbanized landscape. Southeastern Naturalist 5:191–204. https://doi.org/10.1656/1528-7092(2006)5[191:NHOTCB]2.0.CO;2

Cagle, F. R. 1939. A System of Marking Turtles for Future Identification. Copeia 1939: 170–173. https://doi.org/10.2307/1436818

Calenge, C. 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modelling 197: 516–519. https://doi.org/10.1016/j.ecolmodel.2006.03.017

Compton, B. W., J. M. Rhymer, and M. McCollough. 2002). Habitat selection by wood turtles (Clemmys insculpta): an application of paired logistic regression. Ecology 83: 833–843. https://doi.org/10.1890/0012-9658(2002)083[0833:HSBWTC]2.0.CO;2

Cook, R. 2004. Dispersal, home range establishment, survival, and reproduction of translocated eastern box turtles, Terrapene c. carolina. Applied Herpetology 1:197-228.

Cozad, R.A., Hernandez, S.M., Norton, T.M., Tuberville, T.D., Stacy, N.I., Stedman, N.L., and Aresco, M.J. 2020. Epidemiological investigation of a mortality event in a translocated gopher tortoise (Gopherus polyphemus) population in northwest Florida. Frontiers in Veterinary Science 7: 120. https://doi.org/10.3389/fvets.2020.00120

Currylow, A.F., Zollner, P.A., MacGowan, B.J., and Williams, R.N. 2011. A survival estimate of Midwestern adult Eastern Box Turtles using radiotelemetry. The American Midland Naturalist 165: 143–149. https://doi.org/10.1674/0003-0031-165.1.143

Currylow, A.F., Macgowan, B.J., and Williams, R.N. 2013. Hibernal thermal ecology of eastern box turtles within a managed forest landscape. The Journal of Wildlife Management 77: 326–335. https://doi.org/10.1002/jwmg.463

Demetrio, C.M., Willey, L.L., Jones, M.T., Danaher, M. and Franklin, J. 2022. Home Range and Habitat Use of Florida Box Turtles (Terrapene bauri) in the Ten Thousand Islands, Florida. Journal of Herpetology 56: 376–385. https://doi.org/10.1670/20-071

Diemer, J.E. 1992. Home range and movements of the tortoise Gopherus polyphemus in northern Florida. Journal of Herpetology 26: 158–165. https://doi.org/10.2307/1564857

Dodd Jr, C.K., Franz, R., and Smith, L.L. 1994. Activity patterns and habitat use of box turtles (Terrapene carolina bauri) on a Florida island, with recommendations for management. Chelonian Conservation and Biology 1: 97–106.

Dodd Jr, C.K. 2005. Dilemma of the common species: Florida Box Turtles. Iguana 12:153–159.

Dodd Jr., C.K. 2001. North American Box Turtles: A Natural History Vol. 6. University of Oklahoma Press.

Dodd Jr, C. Kenneth, and Marian L. Griffey 2005. The conservation of box turtles on public lands in Florida. In: Amphibians and Reptiles, Status and Conservation in Florida. Malabar, FL: Krieger Publishing, 2005: 103–110.

Donaldson, B.M., and Echternacht, A.C. 2005. Aquatic habitat use relative to home range and seasonal movement of eastern box turtles (Terrapene carolina carolina: Emydidae) in eastern Tennessee. Journal of Herpetology 39: 278–284. https://doi.org/10.1670/0022-1511(2005)039[0278:AHURTH]2.0.CO;2

Donini, J, J.S. Doody, M. Craft, R, Speer, and G.L. Heinrich. 2021. Terrapene bauri (Florida Box Turtle) and Gopherus polyphemus (Gopher Tortoise). Burrow Associate and Reproduction. Herpetological Review 52(3):635–636.

Donini, J., Coury, M., Talley, B.L., Rodriguez, A., Drew, J., Mann, T. and Weber, C. 2024. Home Range and Habitat Selection of Florida Box Turtles (Terrapene carolina bauri) in Coastal Southwest Florida. Northeastern Naturalist, 31(sp12), pp.T12–T36.

Doody, J. S., Young, J. E., and Georges, A. 2002. Sex differences in activity and movements in the pig-nosed turtle, Carettochelys insculpta, in the wet-dry tropics of Australia. Copeia 2002: 93–103. https://doi.org/10.1643/0045-8511(2002)002[0093:SDIAAM]2.0.CO;2

Doroff, A.M., and Keith, L.B. 1990. Demography and ecology of an ornate box turtle Terrapene ornata population in south-central Wisconsin. Copeia 1990: 387–399. https://doi.org/10.2307/1446344
van Dijk, P.P. 2011. Terrapene carolina (errata version published in 2016). The IUCN Red List of Threatened Species 2011:e.T21641A97428179.
Farrell, T., Dodd Jr, C.K., and May, P. 2006. Terrapene carolina – Eastern Box Turtle. Chelonian Research Monographs 3: 235–248.
Fasola, M., Mazzotti, S., and Pisapia, A. 2002. Activity and home range of Testudo hermanni in Northern Italy. Amphibia-Reptilia 23: 305–312.
Feldman, S. H., Wimsatt, J., Marchang, R. E., Johnson, A. J., Brown, W., Mitchell, J. C., and Sleeman, J. M. 2006. A novel mycoplasma detected in association with upper respiratory disease syndrome in free-ranging eastern box turtles (Terrapene carolina carolina) in Virginia. Journal of Wildlife Diseases 42: 279–289. https://doi.org/10.7589/0090-3558-42.2.279
Garber, S.D., and Burger, J. 1995. A 20-yr study documenting the relationship between turtle decline and human recreation. Ecological Applications 5:1151–1162. https://doi.org/10.2307/2269362
Habeck, C.W., Figueras, M.P., Deo, J.E., and Burke, R.L. 2019. A Surfeit of Studies: What have we learned from all the Box Turtle (Terrapene carolina and T. ornata) Home Range Studies? Diversity 11:68. https://doi.org/10.3390/d11050068
Henriquez, M.C., Macey, S.K., Baker, E.E., Kelly, L.B., Betts, R.L., Rubbo, M.J., and Clark, J.A. 2017. Translocated and resident eastern box turtles (Terrapene c. carolina) in New York: movement patterns and habitat use. Northeastern Naturalist 24: 249–266. https://doi.org/10.1656/045.024.0303
Harris, K.A., Clark, J.D., Elmore, R.D., and Harper, C.A. 2020. Spatial ecology and resource selection of eastern box turtles. The Journal of Wildlife Management 84(8): 1590–1600. https://doi.org/10.1002/jwmg.21945
Hipps, A.C. 2019. Vertebrate and Invertebrate Commensals in Gopher Tortoise Burrows of Southeast Florida. Unpublished Masters Thesis, Florida Atlantic University.
Hoctor, T., R. Noss, R. Hilsenbeck, J. Guthrie, and C. Ward. 2015. The history of Florida wildlife corridor science and planning efforts. http://floridawildlifecorridor.org/about/history/
Jennings, A.H. 2007. Use of habitats and microenvironments by juvenile Florida box turtles, Terrapene carolina bauri, on Egmont Key. Herpetologica 63:1–10. https://doi.org/10.1655/0018-0831(2007)63[1:UOHAMB]2.0.CO;2
Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61: 65–71. https://doi.org/10.2307/1937156
Johnson, A.J., Pessier, A.P., Wellehan, J.F., Childress, A., Norton, T.M., Stedman, N.L., and Jacobson, E.R. 2008. Ranavirus infection of free-ranging and captive box turtles and tortoises in the United States. Journal of Wildlife Diseases 44: 851–863. 10.7589/0090-3558-44.4.851.
Jones, M.T., Willey, L.L., and Charney, N.D. 2016. Box Turtles (Terrapene carolina bauri) on ancient, anthropogenic shell work islands in the Ten Thousand Islands Mangrove Estuary, Florida, USA. Journal of Herpetology 50: 94–101. https://doi.org/10.1670/13-149
Kahle, D., and Wickham, H. 2013. ggmap: Spatial Visualization with ggplot2. The R Journal 5: 144–161. URL: http://journal.r-project.org/archive/2013-1/kahle-wickham.pdf
Kapfer, J.M., Muñoz, D.J., Groves, J.D., and Kirk, R.W. 2013. Home range and habitat preferences of eastern box turtles (Terrapene carolina Linnaeus, 1758) in the Piedmont Ecological Province of North Carolina (USA). Herpetology Notes 6: 251–260.
Loredo, J., Navarrete, C., and Donini, J. 2022. The diet of Florida Box Turtles (Terrapene bauri) in a coastal ecosystem in southwestern Florida. Reptiles & Amphibians 29: 175–181. https://doi.org/10.17161/randa.v29i1.16401
Main, M.B., Roka, F.M., and Noss, R.F. 1999. Evaluating costs of conservation. Conservation Biology 13: 1262–1272. 0.1046/j.1523-1739.1999.98006.x
Marchand, M., Quinlan, M., and Swarth, C.W. 2004. Movement patterns and habitat use of eastern box turtles at the Jug Bay Wetlands Sanctuary, Maryland. In Conservation and ecology of turtles of the Mid-Atlantic region, pp. 55–62
McRae, W.A., Landers, J.L., and Garner, J.A. 1981. Movement patterns and home range of the gopher tortoise. American Midland Naturalist 106: 165–179. https://doi.org/10.2307/2425146
Meck, J.R., Jones, M.T., Willey, L.L., and Mays, J.D. 2020. Autecological study of Gulf Coast box turtles (Terrapene carolina major) in the Florida Panhandle, USA, reveals unique spatial and behavioral characteristics. Herpetological Conservation and Biology 15:293–305
Morneault, D. 2011. GPS Tracks Pro Version 4.0 Mobile App. Available online at https://
apps.apple.com/us/app/gps-tracks/id425589565.

Nieuwolt, P.M. 1996. Movement, activity, and microhabitat selection in the western box turtle, Terrapene ornata luteola, in New Mexico. Herpetologica 52: 487–495.
Nijman, V., and Shepherd, C.R. 2007. Trade in non-native, CITES-listed, wildlife in Asia, as exemplified by the trade in freshwater turtles and tortoises (Chelonidae) in Thailand. Contributions to Zoology 76: 207–211.
Orr, J.M., Ernst, C.H., and Boucher, T.P. 2020. Long-term comparison of relocated and resident box turtles, Terrapene carolina carolina. Herpetological Bulletin 151: 6–9. 10.33256/hb151.69
Pebesma, E. 2018. Simple features for R: standardized support for spatial vector data. The R Journal 10(1):439–446.
Pilgrim, M.A., Farrell, T.M., and May, P.G. 1997. Population structure, activity, and sexual dimorphism in a central Florida population of box turtles, Terrapene carolina bauri. Chelonian Conservation and Biology 2: 483–488.
Platt, S. G., Hall, C., Liu, H., and Borg, C. K. 2009. Wet-season food habits and intersexual dietary overlap of Florida box turtles (Terrapene carolina bauri) on National Key Deer Wildlife Refuge, Florida. Southeastern Naturalist 8: 335–346. https://doi.org/10.1656/058.008.0212
R Core Team 2021. R: A language and environment for statistical computing. R Foundation for Statistical

Computing, Vienna, Austria. URL https://www.R-project.org/.
Rasmussen, M.L., and Litzgus, J.D. 2010. Habitat selection and movement patterns of spotted turtles (Clemmys guttata): effects of spatial and temporal scales of analyses. Copeia 2010: 86–96.
Reagan, D.P. 1974. Habitat selection in the three-toed box turtle, Terrapene carolina triunguis. Copeia 1974: 512–527. https://doi.org/10.2307/1442543
Refsnider, J.M., Strickland, J., and Janzen, F.J. 2012. Home range and site fidelity of imperiled ornate box turtles (Terrapene ornata) in northwestern Illinois. Chelonian Conservation and Biology 11:78–83. https://doi.org/10.2744/CCB-0919.1
Rhodin, A.G.K., Iverson, J.B., Bour, R., Fritz, U., Georges, A., and Shaffer, H.B. 2021. Turtles of the world annotated checklist and atlas of taxonomy, synonymy, distribution, and conservation status. Ninth edition. Chelonian Research Monographs 8:401.
Riedle, J.D., et al. 2006. Microhabitat use, home range, and movements of the alligator snapping turtle, Macrochelys temminckii, in Oklahoma. The Southwestern Naturalist 51: 35–40. https://doi.org/10.1894/0038-4909(2006)51[35:MUHRAM]2.0.CO;2
U.S. Census Bureau 2021. Population, percent change 2010-2021. Retrieved from https://www.census.gov/quickfacts/fact/table/colliercountyflorida,leecountyflorida/PST120219
Rittenhouse, C.D., Millspaugh, J.J., Hubbard, M.W., and Sheriff, S.L. 2007. Movements of translocated and resident three-toed box turtles. Journal of Herpetology 41:115–121. https://doi.org/10.1670/0022-1511(2007)41[115:MOTART]2.0.CO;2
Stickel, L.F. 1950. Populations and home range relationships of the box turtle, Terrapene c. carolina (Linnaeus). Ecological Monographs 20:351–378. https://doi.org/10.2307/1943570
Stickel, L.F. 1989. Home range behavior among box turtles (Terrapene c. carolina) of a bottomland forest in Maryland. Journal of Herpetology 23: 40–44. https://doi.org/10.2307/1564314
Verdon, E. 2004. Activity patterns, habitat use, and movements of the Florida Box Turtle (Terrapene carolina bauri) in the Florida Keys. Unpublished Masters Thesis, Florida International University, USA.
Verdon, E., and Donnelly, M.A. 2005. Population structure of Florida box turtles (Terrapene carolina bauri) at the southernmost limit of their range. Journal of Herpetology 39:572–577. https://doi.org/10.1670/131-04A.1
Wickham, H. 2016. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.
Worton, B.J. 1995. Using Monte Carlo simulation to evaluate kernel-based home range estimators. The Journal of Wildlife Management 59: 794–800. https://doi.org/10.2307/3801959