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The home range of adult *Phrynops geoffroanus* (Testudines, Chelidae) in relation to sex and body mass

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Abstract

Studying how different variables influence the size and shape of animals' home ranges helps our understanding of the ecology of individuals and populations. This study aims to assess the effects of sex and body mass on home range size and the sexual differences in the use of terrestrial habitats of a population of aquatic turtles *Phrynops geoffroanus* from an urban area in Mato Grosso do Sul, Brazil. Turtles were captured along a river by active search, occasional encounter and hoop traps. Using individual VHF radio transmitters, 13 individuals (7 females and 6 males) were radio-tracked by homing in on the signal strength of the transmitter. Home ranges were estimated by 95% and 50% core one-dimensional fixed kernel and linear distance method. Home ranges were similar for both sexes (t = -0.50, DF = 12, $p = 0.62$) and independent of body mass (t = -0.53, DF = 12, $p = 0.60$). However, females seemed to use terrestrial habitats more than males (females = six recorded locations out of 767 points; males = none), probably to nest. To gain insight on how males and females use their space, it would be useful to focus future studies on the influence of sex in microhabitat selection of *Phrynops geoffroanus*. Finally, as sex did not influence home range, studying the contribution of other variables – both intrinsic, as age or personality, and extrinsic, as habitat composition or distribution of trophic resources – shaping the home ranges of the species is proposed.

Key Words

one-dimensional fixed kernel, radio-tracking, turtle, VHF transmitters

Introduction

Understanding how home ranges are arranged in the landscape helps us to identify the most important habitat traits influencing the ecology of a given species (Powell 2000). For example, we can study which habitat traits lead individuals to select or avoid a certain place (Sung et al. 2015; De la Quintana et al. 2017). Besides, assessing the degree of overlap between home ranges could reveal mating systems and contribute to understanding population dynamics (Wone and Beauchamp 2003; Smith and Cherry 2016).

Many species of turtles have overlapping home ranges (e.g. *Mesoclemmys dahli*, Forero-Medina et al. 2011; *Rafetus euphraticus*, Ghaffari et al. 2014). The degree of overlap and home range size could be mediated by sex, with females generally using smaller areas and sharing

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them with multiple males (Harless et al. 2009; Bower et al. 2012). This is probably due to the different reproductive strategies of the two sexes, where males usually move extensively in search of females while females remain near nesting areas (Morreale et al. 1984; Souza 2004).

Body size could also influence the extension of the home range. Reptiles demonstrate positive relationships between body mass and home range size (Tamburello et al. 2015). Heavier lizards (Turner et al. 1969; Christian and Waldschmidt 1984) usually have larger home ranges, probably due to energetic requirements and sexual size dimorphism (Perry and Garland 2002). Body size in turtles positively influences home range in many species (Pérez-Santigosa et al. 2013; Slavenko et al. 2016). Furthermore, the length of linear home range is also influenced by body size (Roe and Georges 2008). Information about the home range of South American chelids is limited (Forero-Medina et al. 2011).

Phrynops geoffroanus (Schweigger, 1812) is a widely distributed species complex in Brazil (Rueda-Almonacid et al. 2007; van Dijk et al. 2014), including urban areas (Souza and Abe 2001). Individuals of this species are mainly carnivores and extremely aquatic. Besides, females can reach 35 cm of carapace length and body mass 2.5 kg, being larger than males (Rueda-Almonacid et al. 2007). However, there is still a lack of knowledge about the home range of this common freshwater turtle in its many different habitats.

Our objective was to study the home range of *P. geoffroanus*. Specifically, we aimed to test if sex and body mass influenced home range and if there was a differential use of terrestrial habitat between sexes. Based on previous studies of other species, we hypothesized that heavier animals and males would have larger home ranges. Males would increase their movement areas to increase their chances of finding females, and females would move less, concentrating on smaller areas near nesting sites. For similar reasons, females would be more frequently found on land than males.

Methods

Study area

We conducted the study at a Private Natural Heritage Reserve (RPPN–"Reserva Particular do Patrimônio Natural") of the Universidade Federal de Mato Grosso do Sul (UFMS; Campo Grande, Mato Grosso do Sul, Brazil; 20.4990S, 54.6134W; WGS84). The RPPN has an area of 50.11 ha (Imasul 2014), composed of a mosaic of savannah *sensu stricto* gallery forest and dense savannah forest (Bueno et al. 2013). The RPPN is enclosed by a continuous wire fence, separating it from the surrounding urban area (Fig. 1).

Within the RPPN, two streams (Cabaça and Bandeira) flow into the Amor Lake (Fig. 1). In the Cabaça Stream, industrial and residential waste is released into the water upstream from the study area. The stream is usually narrow (~ 0.5–4 m wide) and shallow (< 1 m deep) with stones and riverbanks along it, where *P. geoffroanus* can bask or access the forest. The current of the stream is normally slow, but increases both in speed, width and depth depending on the voracity of the rains, varying from 0.5–12 m wide and 0.1–4.5 m deep dependent on rainfall. No aquatic vegetation is present in the stream, the stream bed and banks being composed of sand and clay soils, with a scattering of human garbage. The stream banks have exposed tree roots and holes, below the water level, that turtles can use as shelter. Upstream, there is a waterfall about 2.5 m high, that has a small reservoir of about 12 m at its widest point and 2 m deep at its deepest point. There are two basking sites on each side of the reservoir where *P. geoffroanus* are frequently observed. All individuals were captured at the Cabaça Stream, and locations were obtained at both the Cabaça and Bandeira Streams and the Amor Lake. We did not capture turtles in the Bandeira Stream because its entire access is limited due to dense vegetation that prevents spotting the individuals; it was difficult to find accessible parts of the stream that were not continuously too shallow, and freshwater turtles were rarely sighted compared to the Cabaça Stream.

Sampling methods

We captured *P. geoffroanus* individuals along a 200 m stretch of the Cabaça Stream (Fig. 1). Turtles were captured and recaptured from March 2015 to July 2016 by active search, occasional encounter and hoop traps (Fig. 1). Each (re)captured individual was weighed using digital scales (Marine Sports 25 kg) to the nearest gram. In order to avoid a confounding effect of age, we only estimated the home range of adults. We considered adults those individuals showing a straight carapace length above 21 cm (Souza and Abe 2001) and weighing more than 1 kg. Body mass was defined as the mean weight of each turtle, from all its (re)captures (ranging from just one capture to five recaptures). Individuals were sexed by comparing the tail length and cloaca position in relation to carapace (Rueda-Almonacid et al. 2007). Turtles were individually marked by notching the marginal scutes (Cagle 1939) and adding a corresponding number using epoxy paste (Durepoxi, Loctite) on the anterior or posterior margin of the carapace. As our study is part of a long-term project, digital photographs of the carapace and plastron were taken to help to identify individuals by their unique fingerprint colour pattern for future recognition. A total of 13 adult turtles (7 females and 6 males) were equipped with VHF (Very High Frequency) radio transmitters TXF–314G model (Telenax; Playa del Carmen, La Toscana, Mexico). Each transmitter was fixed to the carapace with epoxy paste (Durepoxi, Loctite). The equipment's weight was less than 7% of each turtle's weight (Schubauer 1981). All individuals were released at their respective points of capture on the same day.

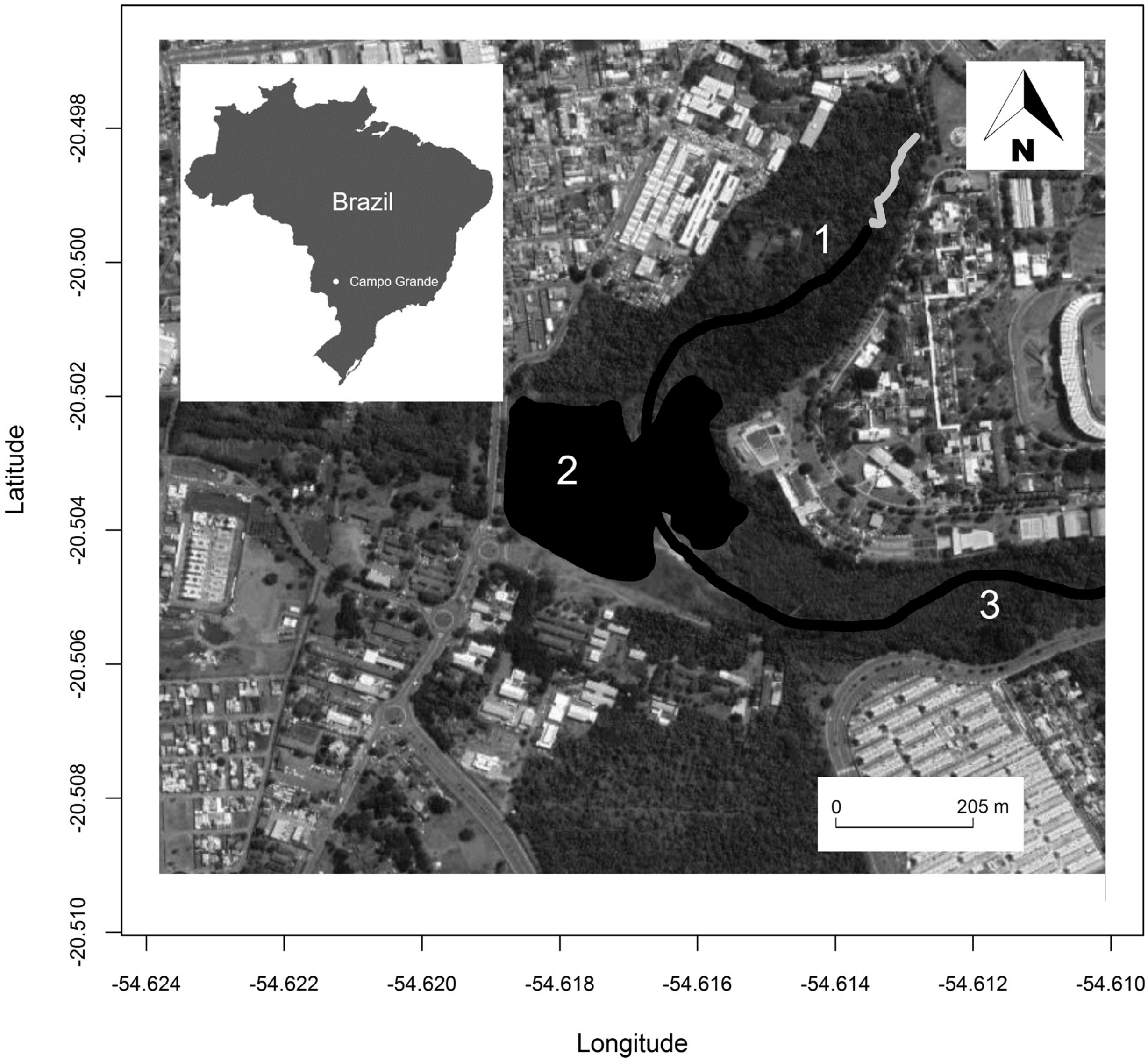

Figure 1. Study area at RPPN-UFMS (Campo Grande, MS, Brazil). **1.** Cabaça Stream; **2.** Amor Lake; **3.** Bandeira Stream; **Black area** – the three water bodies used by *Phrynops geoffroanus*; **White area** – the 200 m stretch of Cabaça Stream where individuals were initially captured; **Vertical axis** – Latitude; **Horizontal axis** – Longitude.

Radio-tracking

Radio-tracking was conducted by a handheld receiver Icom (IC–R20) and antenna Telonics (Model RA–14). Turtle locations were obtained between April 2015 and October 2016, from two to seven days per week, with a maximum of one location per day and individual, in order to guarantee data independence. We took all locations during the day, between 7:00 h and 18:00 h, according to the activity period of this species (Rueda-Almonacid et al. 2007). One VHF radio-tracked female (ID F2, Table 1) was also monitored by a Modified–GPS (model i-gotUGPS logger 120; Mobile Action Technology; New Taipei, Taiwan), for testing purposes. Its GPS monitoring occurred simultaneously to the VHF monitoring, but the first lasted a shorter time than the second. We included all data of the female F2 (GPS and VHF) for analysis together with the data from the other individuals. During the study, we started monitoring each individual at a different date, when we captured it. Thus, the number of locations varied according to the amount of time the VHF of each individual was functioning (Tables 1, 2). The individual's locations were obtained by homing in on the signal strength of the transmitter. Locations were determined: (1) by directly observing the individual, (2) when the handheld receiver detected the VHF signal at the minimal possible distance (~ 1 m), or (3) by triangulation, when there were interferences. Minimal possible distance occurred when we were likely very near to the radio-tracked individual, but it was not possible to see it, for example because of turbid water or because it was inside a refuge. In these cases, we recorded the point where the strongest radio-signal was detected. Interferences were not strong enough to incapacitate estimating the location of the radio-tracked individual. The signal in the shallow Cabaça Stream was not static interfered and the water depth did not affect the signal reception. Locations were recorded using a handheld GPS unit (model Oregon 450; Garmin; Miami, Florida, USA; accuracy of 5–12 m).

Data analyses

The home ranges of *P. geoffroanus* were estimated using a 95% fixed kernel, with 50% as the core area (Worton 1989) and applying *h* of reference (see Silverman 1986) as a smoothing parameter. Specifically, a one-dimensional fixed kernel was applied, which only considers the density of points distributed along the stream. Home ranges were estimated using *kde*() function available at *ks* package (Chacón and Duong 2018). We also estimated the minimum linear home range (Ldist), by connecting the two most extreme points among the individual's locations (Kornilev et al. 2010). Because locations of VHF transmitters were obtained in UTM coordinates (two-dimensional locations), we needed to rescale them to transform them in one-dimensional locations. We did this by simply obtaining the linear distance from an arbitrary starting point located at the source of the river. The R code to rescale relocations, estimations of one-dimensional kernel, cut isopleths of probability and plots of home range on maps are available as Suppl. material 1. We tested the effects of sex, body mass and the interaction of sex-body mass on the home range (for the 95% fixed kernel) using an Analyses of Covariance (ANCOVA). Maps for the figures were downloaded from GoogleAPP using the *RgoogleMaps* package of R (Loecher 2012), where forest polygons were drawn by eye over Google Earth images. All analyses were run in R software version 3.5.0 (R Core Team 2018).

Results

Body mass varied between 2.03–3.61 kg for females (Table 1) and 1.45–1.98 kg for males (Table 2). We recorded a total of 767 locations from the 13 radio-tracked adult individuals (mean overall individuals' locations = 59, mean overall Ldist = 560 m, Table 2). The main concentration of individuals' points was established in the stretch of the Cabaça Stream, extending to the Amor Lake and the Bandeira Stream for some individuals (Fig. 2). The female F2's GPS functioned for two months, providing overall 67 locations from 23 days from one to eight locations/day (Table 1). The mean home range of females was 330 m (1D Kernel 95%), 80 m for the core area (1D Kernel 50%) and 595 m for the minimum linear home range (Table 1). For males, the mean home range was 180 m (1D Kernel 95%), 44 m for core area (1D Kernel 50%), and 519 m for the minimum linear home range (Table 2). The home range was not influenced by sex (t = -0.50, DF = 12, p = 0.62) or body mass (t = -0.53, DF = 12, p = 0.60). Finally, the interaction between sex and body mass was also not significant (t = 0.23, DF = 12, p = 0.81). We recorded three females (a total of 6 recorded locations) and no males in terrestrial habitats (Tables 1, 2).

Table 1. Distance travelled by radio-tracked *Phrynops geoffroanus* females at the studied area (Campo Grande, MS, Brazil). **ID** – individual; **Bm** – body mass; **LT** – locations recorded in terrestrial habitat; **N** – number of recorded locations; **Time** – number of days elapsed from first to last recorded location; **Ldist** – minimum linear home range; **K1d95** – 1D Kernel 95%; **K1d50** – 1D Kernel 50%; **kg** – kilograms; **m** – meters.

ID	Bm (kg)	LT	Period of monitoring	N (locations)	Time (days)	Ldist (m)	K1d95 (m)	K1d50 (m)
F1	2.30	–	September/16–October/16	15	43	192	212	64
F2	2.03	1	May/15–August/15	135	96	508	281	78
F3	3.19	3	April/15–October/16	180	574	255	270	78
F4	3.06	2	April/15–July/15	59	98	1019	638	146
F5	2.28	–	June/15–August/15	62	87	1360	666	144
F6	3.61	–	June/15–August/15	29	51	14	79	24
F7	2.83	–	July/16–October/16	24	95	818	164	29
Mean for females	2.75	–	–	72	149	595	330	80

Table 2. Distance travelled by radio-tracked *Phrynops geoffroanus* males at the studied area (Campo Grande, MS, Brazil). **ID** – individual; **Bm** – body mass; **LT** – locations recorded in terrestrial habitat; **N** – number of recorded locations; **Time** – number of days elapsed from first to last recorded location; **Ldist** – minimum linear home range; **K1d95** – 1D Kernel 95%; **K1d50** – 1D Kernel 50%; **kg** – kilograms; **m** – meters; **Mean overall** – average for females and males.

ID	Bm (kg)	LT	Period of monitoring	N (locations)	Time (days)	Ldist (m)	K1d95 (m)	K1d50 (m)
M1	1.53	–	April/15–August/15	94	143	104	114	29
M2	1.79	–	July/15–December/15	80	161	14	79	29
M3	1.98	–	September/16–October/16	14	43	763	144	29
M4	1.45	–	June/15–June/15	18	18	803	213	54
M5	1.91	–	July/15–August/15	22	30	123	109	29
M6	1.87	–	April/16–September/16	35	159	1311	421	94
Mean for males	1.75	–	–	43	92	519	180	44
Mean overall	2.29	–	–	59	122	560	260	63

Discussion

Home ranges were similar between males and females of *P. geoffroanus* living in an urban area of the Brazilian central-west region. Similar results were found for *Clemmys insculpta* in Canada (Arvisais et al. 2002), *Kinosternon integrum* in México (Pérez-Pérez et al. 2017) and *Pseudemys concinna suwanniensis* in the United States (Kornilev et al. 2010). A meta-analysis on the home range of 64 species of turtles found that body mass explains little variation in home range size (Slavenko et al. 2016). Therefore, our results about the influence of body mass on home range size reinforce these previous findings.

As expected, the studied turtles used aquatic habitats almost exclusively, with only six points (of 767) detected in terrestrial habitats. Kernel estimators barely represent the importance of a habitat that is used in a disproportionately small frequency (Powell 2000). One female (individual F3, see Fig. 2) showed some isolated points in terrestrial habitat surrounding the Cabaça stretch, which suggests nesting activity. The same female was found nesting near the Cabaça stretch at another time as well. Another female (individual F4, see Fig. 2) was also found in a terrestrial habitat, although nesting was not observed.

Handling the turtles would potentially impact their movement ecology estimations because of a propensity to escape after being released. Souza et al. (2008) demonstrated that *P. geoffroanus* initially increased their moved distance after release, and then it was gradually reduced again after 48 hours. The individuals of our study have been monitored

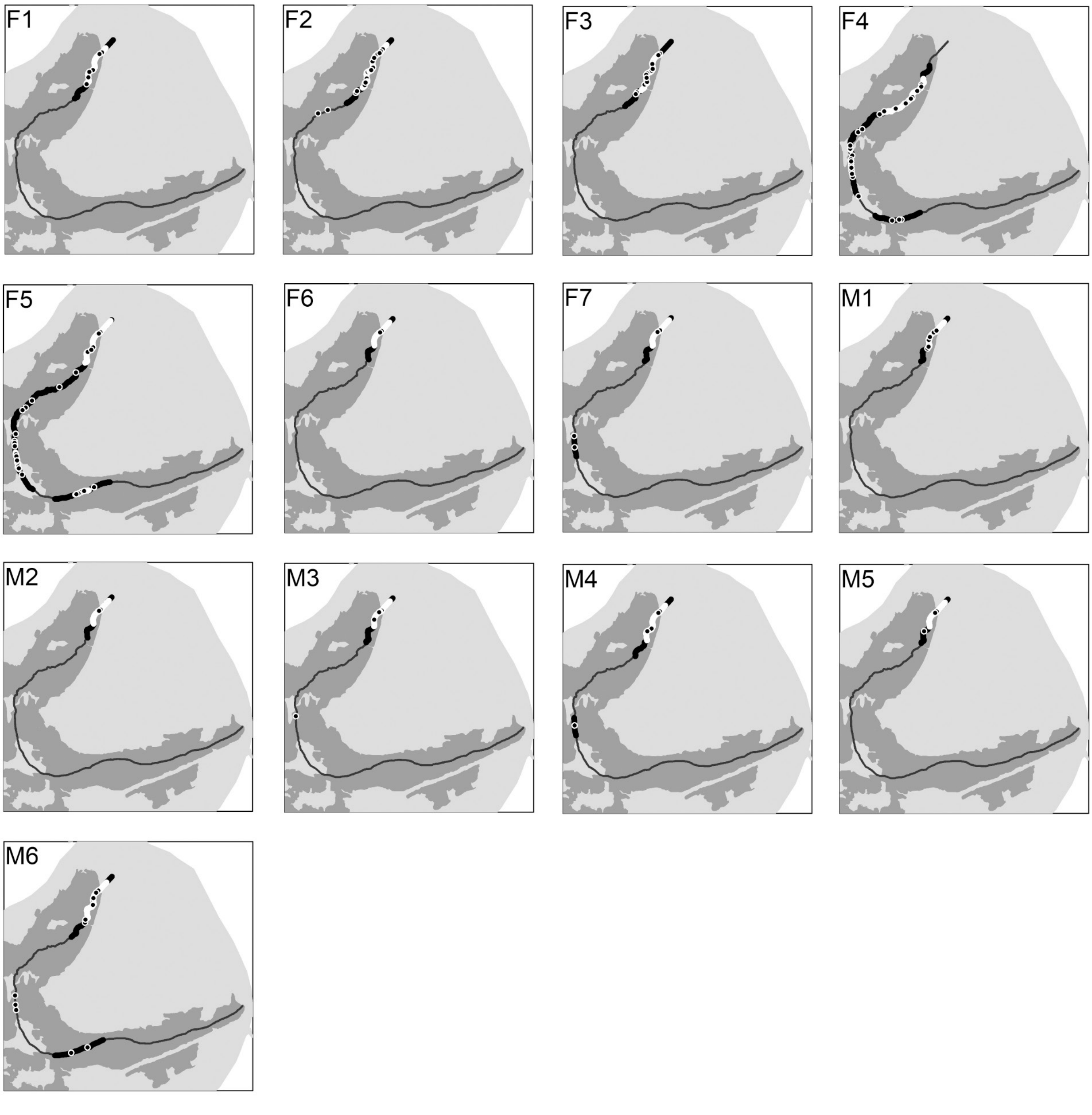

Figure 2. Home range of seven females (F1–F7) and six males (M1–M6) of *Phrynops geoffroanus*. **White area** – 1D Kernel 50%; **Black area** – 1D Kernel 95%; **Dark grey** – water bodies; **Medium grey** – forested area; **Light grey** – not forested area; **Black circles** – individual observations of *P. geoffroanus*.

for 18–574 days, which substantially exceeds this period of 48 h on which they could have moved longer distances as a response to manipulation. In addition, our experience —as a part of the long-term research project where we conduct continuous observations at the study area— is that most individuals continued to be directly observed at the study site after capture. Besides, while VHF was operating, no radio-tracked individual left the study area.

In urban areas, *P. geoffroanus* are known to forage within the water, and their diet is mainly composed of larvae of *Chironomus* sp. (Martins et al. 2010). Since incursions in terrestrial habitats are rare, it is difficult to gather a high number of terrestrial locations in a study about home range as the present one. However, the fact that females need terrestrial habitats to nest is vital for the long-term management of these populations. In urban areas, many turtles could suffer car collisions when trying to get across the streets searching for nesting places and females could not find suitable places to nest near streams. Therefore, greater effort should be devoted to assessing the locations of terrestrial habitat used by this species throughout the year and their characteristics regarding habitat structure. This is required to inform urban planners and conservationists on how to design and manage urban natural reserves taking the viability of freshwater turtle populations into account.

Conclusions

Our study showed no differences in home range between sexes. Terrestrial habitats were only used by females for nesting. Further studies should expand our understanding on which factors modulate *P. geoffroanus* home range size and shape in urban and natural populations. In addition, it is important to get more insight into the characteristics of aquatic habitats that are used, selected and/or avoided by males and females of *P. geoffroanus* throughout their daily and annual activity. Finally, assessing which terrestrial areas are used for nesting throughout the year is also essential to inform urban planners on the management of urban natural reserves and ensure the preservation of freshwater turtles in cities.

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Supplementary material 1

Code used to estimate the home range of *Phrynops geoffroanus*

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Data type: ZIP file

Explanation note: Code to rescale relocations, estimations of one-dimensional kernel, cut isopleths of probability and plots of home range on maps.

Link: https://doi.org/10.3897/herpetozoa.32.e38237.suppl1