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Population characteristics and movement of native and exotics turtles in urban area

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Abstract

The impacts from urban areas may result in alterations in environmental characteristics and wild populations dynamics. Therefore, we aimed at assessing population size, density, home range, maximum range of movement and habitat selection of native and aliens freshwater turtles in a Brazilian urban park (*Phrynops geoffroanus*-PG, *Trachemys dorbigni*-TD, *Trachemys scripta elegans*-TSE). We applied capture-mark-recapture procedures from July/2016 to August/2018. Home ranges were estimated from trap locations using a 100% minimum convex polygon (MCP) method, and habitat selections using eigenanalysis. We sampled 41 PG, 35 TD, and 20 TSE. Population size was estimated as 59 ± 7.6 (PG), 36 ± 1.4 (TD), and 20 ± 0.5 (TSE) individuals (± SE), with a density estimates of 1.36 (0.34), 1.72 (0.36), and 0.87 (0.25) individual/ha (± SE), respectively. Home ranges size ranged between 0.04 ha and 0.48 ha, the highest distance was reached by D'Orbigny's slider (525.8 m). Our results indicate that habitat preferred for all species is clearly influenced by human presence, and the turtle assemblage exhibit strategies as temporal segregation to coexist on this small, closed park. Both the presence of two established populations of invasive alien species and the changing movement of freshwater turtles reflect anthropic pressure on wild population dynamics and the lack of effectiveness of environmental policies and inspection in Brazil. The understanding that wild populations are being affected even in conservation units could be considered by the managers implement monitoring of target wild populations, control of exotic species, insertion of educational signs and actions, and control of visitors.

Introduction

Aquatic systems are one of the most productive ecosystems and also one of the most degraded environments in the world, as a result of human activities (e.g. urbanization, plantation, and pasture) (Bujes et al. 2011). The urbanization process, as other human activities, may change the natural environment quickly and diffusely; therefore, it represents a significant threat to aquatic ecosystems (Paul and Meyer 2001). Deforestation, degradation, and fragmentation of native and riparian vegetation are consequences of urbanization (Marchand and Litvaitis 2004; Bujes et al. 2011; Guzy et al. 2013). Habitat loss and fragmentation isolate wild populations in patches and leads to a reduced dispersion of individuals, may resulting in lower genetic variability and inducing population deleterious effects as local population extinction (Guzy et al. 2013). As well as affect the water temperature, and consequently, increasing the temperature fluctuation, decrease the biodiversity, and change the spatial distribution of the species (Paul and Meyer 2001; Marchand and Litvaitis 2004). The water bodies in urban environment also use to be altered by channeling, damming and associated silting (Spinks et al. 2003; Guzy et al. 2013). Additionally, biotic factors, as alien species, are potentials urban pressures faced by remaining native species in urban area (French et al. 2018). On the one hand, many species suffer the negative impacts of urbanization and may not survive in this type of environment. On the other hand, some species are able to remain, reproduce, and prosper in these urban areas (e.g. amphibians, reptiles, birds, mammals) (Ryan et al. 2008, 2014; Rees et al. 2009; Guzy et al. 2013; Pereira et al. 2018).

Even remaining, human disturbance influence how wild animals move, select and use the environment, and consequently, impacts its population parameters as size, density, biomass (Souza and Abe 2000; Slabbekoorn and Peet 2003; Ryan et al. 2008; Hill and Vodopich 2013; Howel and Seigel 2019). For freshwater turtles, are the local-scale measures of urbanization that affect their movement, varying according to riparian vegetation structure, availability of places to sunbath, refuge, and feeding behavior (Huey 1991; Standing et al. 1999; Souza and Abe 2000; Compton et al. 2002; Cosentino et al. 2010; Quesnelle et al. 2013; Hill and Vodopich 2013; Ghaffari et al. 2014). In addition to these features, the movement patterns of freshwater turtles may also vary according to the species, season, sex and coexistence with other species (Fachín-Terán et al. 2006; Segurado and Figueiredo 2007; Rees et al. 2009; Bower et al. 2012; Paterson et al. 2012; Famelli et al. 2016).

Brazil is the third richest country in the number of reptiles species, with 39 Testudines composed of 34 continental turtles (tortoise and freshwater turtle) (Costa et al. 2022). Even increasing the number of studies with Brazilians freshwater turtles in the last decades, which analyse different aspects of its biology (e.g. Brito et al. 2018, Fagundes et al. 2018, Pereira et al. 2018; Leão et al. 2019; Brito et al. 2020; Michalski et al. 2020), there is a lack of information regarding population parameters and movement of these species.

Considering the impact of urbanization on natural environments and on wild populations dynamics, our goal is identifying the environmental characteristics that influence movements and habitat preferences of one native and two alien freshwater turtle species in urban areas. We based our investigation on answering the following five key questions: (1) Do alien and native freshwater turtle have different annual activity pattern, population size, density? (2) Do native and alien species have different home range size, and, if so, do these features also differ between males and females? (3) What is the average of maximum range of movement for each species? (4) Is the distance ranged by animals related to body size? (5) Do freshwater turtles have preference for any of the urban park features, such as vegetation cover, basking sites, water, and walkways? We expect urban features to influence the population parameters and movement of turtles since wild animals may change their used of space and habitat preferences because of human disturbance (Ryan et al. 2008; Rees et al. 2009; Cosentino et al. 2010; Hill and Vodopich 2013).

Material And Methods

Study area and target species We sampled populations of freshwater turtles at a municipal urban park (47,3 ha) called Parque do Ingá (23°25'S, 51°55'O) in Maringá city, Paraná state, Southern Brazil (Fig. 1). This park is located in the Atlantic Forest ecosystem and it protects many river sources of Ivaí Basin, a tributary of the Paraná River (SEMA 2010). It is a Municipal Conservation Unit, and encompasses a transition zone of tropical and subtropical climate type, according to Köppen (1978). The predominant climate is subtropical, with rainy summer (December to March) and dry winter (June to September). The mean annual temperature varying between 16 and 20°C, and the mean annual rainfall varies between1500 mm and 1600 mm, being January the hottest and most humid month and July the coldest and driest (Deffune and Klosowski 1995; Marques 2004; SEMA 2011).

The turtle assemblage of this park is composed by four species. We targeted three of them: *Phrynops geoffroanus* (Schweigger 1812) (Geoffroy's side-necked turtle), *Trachemys dorbigni* (Duméril and Bibron 1835) (D'Orbigny's slider), and *T. scripta elegans* (Wied 1838) (Red-eared slider) (Fig. 2). The population of the fourth species (*Hydromedusa tectifera*, Cope, 1870) could not be accessed due to the low number of individuals captured over two years (n = 2).

Geoffroy's side-necked turtle is the only native species in the region among the turtles studied. D'Orbigny's slider even native from Brazil is considered an alien species in the region, since its distribution is restricted to Rio Grande do Sul and Santa Catarina states (Costa et al. 2022). Red-eared slider, also an alien species, occurs naturally in the north and center of United States of America and in northwest of Mexico, and has been introduced to all countries except Antarctica (Painter and Christman 2000; Rueda-Almonacid et al. 2007). Both congeneric species, D'Orbigny's slider and Red-eared slider, were introduced in the region probably from pet release and they are classified as invasive alien species according to the list of Environmental Institute of Paraná (IAP 2015). In addition, Red-eared slider is listed among the 100 worst invasive species of the world (Lowe et al. 2000).

Data collection We captured, marked and recaptured (CMR) the individuals at 11 different accessible locations to catch and sightings them (e.g. presence of tree trunks) (Fig. 1). We applied CMR procedures from July 2016 to August 2018 to estimate population size, density, home range, habitat selection, and maximum range of movement. On average, we sampled the area three times a month, every month, except between December 2016 and January 2017, in March 2017, and between June and July 2018. We used the following three different methods to capture the animals: i) Active search; ii) Hookless fishing (Rocha et al. in prep.), a new method similar to a traditional fishing, adapted from hookless trot line (Semeñiuk et al. 2017). Both methods (i and ii) were operated by two researchers during five hours, baited with gizzard; iii) Funnel trap (1 m long × 0.50 m external diameter × 0.25 m entrance diameter), baited with gizzard and activated during 24h – it was used occasionally as a complementary method due to the urban difficulties.

From each captured individual we measured curvilinear carapace length and width, plastron length, and width. They were sexed based on secondary sexual features (i.e. tail length, cloacal width; Rueda-Almonacid et al. 2007) and had their juvenile or adult status recorded according to the body size (Molina 1989; Close and Seigel 1997; Fagundes et al. 2010). We could not precisely determine the sex of the individuals < 10 cm (Geoffroy's side-necked turtle and Red-eared slider) and < 13 cm (D'Orbigny's slider) of CL; therefore, we classified them as juveniles.

All the individuals trapped at the first capture were marked with epoxy numbers glued on the carapace (Fig. 2D, 2E) and the plastrons photographed as a control mark. After these procedures, the individuals were released at the capture site. Since the number mark on the carapace enabled the individuals' identification through sighting, we considered the visualization of the turtles as a recapture. Instituto Nacional de Meteorologia (INMET) provided the climatic data (rainfall and temperature) (Fig. 3).

Data analysis We used linear regression to analyze the effect of accumulated rainfall on the number of individuals (abundance) of each species over the two years. We ran separate models for each species, where we used rainfall as independent variable and abundance as the dependent variable. We used the package “lme4” on the R statistical computing environment (RStudio Team 2020). We applied a closed population model to estimate population size and density for each species, considering the closed characteristic of the study area and the long period of life of the animals (Plummer 1977). We used a Maximum-likelihood approach on program DENSITY (version 5.0, Efford et al. 2004) to estimate population size, turtles’ density and average home-range parameters of each species from the trapping data according to the Spatial Explicit Capture-Recapture model (SECR). We modeled the capture probability based on the distance between the trap and the home-range center assuming that the spatial position of home-range centers followed a Poisson distribution. We applied the simplest spatial-detection function available in DENSITY (half-normal), a function with two parameters: the first (σ) corresponding to a measure of home range size (2.45σ = 95% home-range radius assuming a circular shape (Efford et al. 2005) and the second (g0) being the one-night probability of capture at the home-range center (Anderson et al. 2022). All computation procedures involved default settings. We used corrected Akaike’s information criterion (AICc) values to choose between a null model with g0 and σ constant – Model (.), and models in which both parameters varied according to: (1) Temporal variation (months) in detection parameters (g0 and σ) – Model (t); (2) behavioral response to capture, either permanent – Model (bp) (lasting the entire trapping session) – or temporary – Model (bt) (affecting only the next capture),and (3) considering sex differences in g0 and σ – Model (sex) (Borchers and Efford, 2008). We selected the best model based on the minimum values of the ΔAICc (< 2; Lebreton et al. 1992).

We calculated home range by using Minimum convex polygons (MPC), as recommended for amphibians and reptiles by Row and Blouin-Demers (2006), on the adehabitat HR package of R statistical computing environment (RStudio Team 2020). We estimated home range (MCP 100%) only for turtles trapped at least five times over the two years and also trapped at more than two different sites.

We analyzed the maximum range of movement per individual through a straight-line distance between the two farthest locations recorded (Ryan et al. 2014). We applied simple linear regression using ordinary least squares (Zar 1996) to assess the effect of the body size (carapace length - CL) on maximum distance ranged (MDR) according to the species. Since body size is closely related to sex (i.e. secondary sexual feature), we did not include the variable sex in this analysis. Finally, we used MDR as the dependent variable and CL as independent variable.

The analysis of habitat selection of the individuals was performed using the adehabitat HS package of R statistical computing environment, according to the Design II approach, which identifies the animals measures their habitat - habitat availability defined at the population level, i.e., the same for all animals (Calenge and Dufour 2006). To calculate the habitat available, we firstly characterized each trap location, created a concentric buffer of 5 m around each one, and calculated the percentage of cover vegetation, water, surface available to sunbath (basking sites), and walkways on software QGIS (Quantum Geographic Information System, version 3.26). We considered as habitat used the trap locations where a given individual was captured. We compared the habitat types used and available according to the Manly selection ratios (Manly et al. 2002). For each animal, we calculated a preference ratio according to the habitat type. Upon equal habitat preference for all individuals, preference ratios were averaged, while different preferences generated a factorial investigation using an eigenanalysis (Calenge and Dufour 2006). Eigenanalysis is an extension of principal component analysis including a graphic expression of habitat preference. This analysis produces plots that are explained by two factors or axes (factorial axis1 – the x-axis, and factorial axis 2 – the y-axis). The first factorial axis relates to the most selected habitat types and represents a useful tool to investigate the variability in habitat preference between individuals and identify groups of individuals choosing the same habitat (Calenge and Dufour 2006).

Results

We sampled 96 freshwater individual turtles out of 61 capture-recapture sessions over two years. Geoffroy's side-necked turtle was the most abundant species with 41 individuals, being 26 females, 9 males, 6 juveniles. The sex ratio of this turtle tended significantly to females − 2.8:1 ($\chi 2 = 8.25$, df = 1, p = 0.004). The second most abundant species was D'Orbigny's slider with 35 individuals, being 24 females, 9 males, and 2 juveniles, and presented the same sex ratio patter (2.6 females:1 male; $\chi 2 = 6.81$, df = 1, p = 0.009). The less abundant species was Red-eared slider with 20 individuals (11 females, 8 males, 1 juvenile), and for this slider the sex ratio did not differ from 1:1 ($\chi 2 = 0.47$, df = 1, p = 0.49).

The three species presented seasonal fluctuation in abundance along the seasons, being the abundance peak different for each species (Figs. 3 and 4). Geoffroy's turtle captures were more common in August 2017 (17 individuals), whereas D'Orbigny's slider occurred mainly in September 2017 (22 individuals), and Red-eared slider in January 2018 (12 individuals). Regarding the influence of climate variables on the turtles, our results showed that only Red-eared slider presented a significant relationship between abundance and rainfall ($P < 0.03$, $F = 5.32$, r2:0.21).

Population size (± SE) was estimated as 59 individuals (± 7.6) for Geoffroy's turtle, 36 individuals (± 1.4) for D'Orbigny's slider and 20 (± 0.5) for Red-eared slider. Regarding the density (Table 1), the population of D'Orbigny's slider showed the highest value: 1.72 individual/ha, followed by Geoffroy's side-necked turtle with 1.36 individual/ha, and Red-eared slider with lowest population density (0.87 individual/ha).

Table 1
Estimates of freshwater turtles's density per hectare (± Standard Error), and parameters of a half-normal detection function g0 and σ. ΔAICc is the difference between the corrected AIC of the model studied and the best model (with lowest AICc). See methods section for the explanation of models. Total number of captured species:41 *Phrynops geoffroanus*, 35 *Trachemys dorbigni*, and 20 *Trachemys scripta elegans* in an urban park, southern Brazil. The number of recaptures were 17, 23 and 14, respectively.

Model	**Density (± SE)**	**g0**	**σ**	**AICc**	**ΔAICc**
Phrynops geoffroanus					
[sex]	1.36 (0.34)	0.02	99.48	491.03	0
[.]	1.35 (0.34)	0.02	99.71	492.42	1.39
[t]	1.84 (0.40)	0.02	93.37	495.00	3.97
[bp]	1.59 (0.41)	0.01	169.68	496.04	5.01
[bt]	1.36 (0.34)	0.02	93.12	497.49	6.46
Trachemys dorbigni					
[bt]	1.72 (0.36)	0.03	86.56	1019.02	0
[sex]	1.67 (0.35)	0.03	97.66	1037.96	18.94
[t]	1.58 (0.34)	0.03	92.72	1038.19	19.17
[bp]	1.91 (0.45)	0.01	97.38	1038.35	19.33
[.]	1.66 (0.35)	0.03	97.97	1040.39	21.37
Trachemys scripta elegans					
[t]	0.87 (0.25)	0.07	64.18	691.15	0
[bt]	0.93 (0.26)	0.06	64.65	702.30	11.15
[sex]	0.91 (0.25)	0.12	57.52	709.68	18.53
[.]	0.91 (0.26)	0.10	59.62	711.18	20.03
[bp]	0.98 (0.27)	0.09	60.81	740.78	49.63

In overall, 44% of turtles were recaptured only once. Due to the low number of recaptures (most of them were recaptured less than five times) and/or low turtle mobility (individuals recaptured at the same point), we estimated the home range only for six individuals: five D'Orbigny's slider (four females and 1 male) and one female of Geoffroy's side-necked turtle. Home range size estimated as MCP 100% for these individuals ranged between 0.04 and 0.48 ha. Estimative of home range size for the single Geoffroy's side-necked turtle was 0.26 ha (2.600 m^2), whereas for D'Orbigny's slider the average was 0.31 ha (3.100 m^2).

D'Orbigny's slider presented the highest distance ranged, 525.8m, in addition to having been the only species with a positive relation between body size and maximum distance ranged ($P < 0.05$, $F = 8.70$, r2:0.30) (Fig. 5). The native species ranged 322.4m and Red-eared slider presented the lowest maximum distance, less than half the maximum distance covered by the congeneric species (227.3m).

Manly's selection ratios showed that individuals selected habitats in different ways ($\chi^2 = 289.6$, d.f. = 63, $P < 0.001$). Therefore, we expressed the graphic exploration of the habitats selected by individual turtles through eigenanalysis, which revealed a strong preference for walkway habitats by the three turtles (Fig. 6).

Discussion

Our study is pioneer at analyzing the population and movements of a native and two alien species of freshwater turtles coexisting in Brazil. The three populations accessed showed different activity pattern over the year, and presented similar population size and density. Both Geoffroy's side-necked turtle and D'Orbigny's slider presented changes in its annual peak of abundance. Geoffroy's side-necked turtle, for example, usually presents higher activity between September and November (Souza and Abe 2000, 2001), but in the present study showed the greater abundance slightly earlier, in July (2016) and August (2017). As well as D'Orbigny's slider presented higher relative abundance in September (2017) and January (2018), different from the previous records (February and March – Fagundes et al. 2010; November and December – Bager et al. 2007 and Bujes et al. 2011). In contrast, Red eared slider followed a pattern already recorded, closely related to rain events and warm temperatures (summer in North America) (Morreale et al. 1984; Mali et al. 2016). Regarding the population estimates, the native species and D'Orbigny's slider presented similar population size (n = 59 and n = 36, respectively) and density (1.36 and 1.72 individual/ha, respectively). Red-eared slider presented the lowest population size (20) and density (0.87 turtle/ha) compared to the other species.

Considering that these species is located at an urban park, with high supplementary food (offered by visitors) and absence or fewer presence of predator, the population size and density recorded can be considered low. However, since there is an assemblage with four freshwater turtles in a closed small area (total lakes area: 5,9 ha) is expected interspecific competition, habitat niche partitioning, regulation in population size and density, and changes in its movement (Vogt and Guzman 1988; Segurado and Figueiredo 2007; Alcalde et al. 2010; Gavina et al. 2018; Petrozzi et al. 2021). Second Classical Lotka-Volterra competition model, coexistence of two or more species becomes possible if intraspecific competition is stronger than interspecific competition (Grover 1997; MacArthur and Levins 1967). Otherwise, exclusive competition can happen; in case of native and alien species coexistence, with similar trophic requirements, the native species may be excluded by alien (Hardin 1960; Gotelli 2001; Pérez-Santigosa et al. 2011).

Activity pattern and movement in freshwater turtle assemblage is usually related to reproductive strategies (e.g. mates searching, breeding activity, nesting season), harvesting of food, sunbath, and in response to drought (Marreale et al. 1994; Bowne et al. 2006; Famelli et al. 2016. Mali et al. 2016; Clavijo-Blaquet and Magnone, 2017). Worldwide, micro-habitat is the most partitioned resource by this group, and basking sites is the main niche partitioned (Luiselli 2008). Among different strategies used to coexist, a spatial-temporal segregation was already recorded for freshwater turtles (Segurado and Figueiredo 2007), and in the present study, it seems to be one of the few strategies viable, since the features of the habitat and the behavior of all species (similar habitat use and selection).

Geoffroy's side-necked turtle and the alien D'Orbigny's slider seems to have similar home range size, in addition presents similarity between males and females. The home range estimated for a single Geoffroy's side-necked turtle presented higher value (0.26 ha) than that estimated by Souza et al. (2008) in a polluted urban river (0.04–0.12 ha). According to the authors, even living in a river which allows individuals move freely across the water body, the small home range recorded probably reflect the high supplementation of food provided by polluted habitat (Souza et al. 2008). Due to high food availability in polluted rivers, Geoffroy's side-necked turtle disperses less, decrease its habitat use and reach great population density (200 individuals/ha; Souza and Abe 2000: Souza et al. 2008). The inverse relationship between density and home range has been a noted pattern by some authors (Efford et al. 2015; Sanchez and Hudgens 2015), but also is rejected by others (i.e. Honora et al. 2019).

Home range size of the alien D'Orbigny's slider (0.04–0.48 ha) was similar to recorded for other Emydidae species in anthropized area; 0.003–3.12 ha for *Glyptemys muhlenbergii*, (Morrow et al. 2001), and 1.88 ha for *Terrapene carolina carolina* (Donaldson and Echternacht 2005). As habitat conservation increases, the home range of Emydidae species seems to increase, according to reported to *Clemmys guttata* (5ha – 16 ha; Litzgus and Mousseau 2006), *Clemmys insculpta* (28.3 ha; Arvisais et al. 2002), *Emydoidea blandingii* (61.2 ha; Edge et al. 2010). The pristine riparian vegetation and large wetlands areas may influence an increase in movement, since habitat is probably not a limiting resource and with greater availability of spatial resources their home ranges may increase (e.g. Edge et al. 2010; Pérez-Santigosa et al. 2013). However, this pattern can be different depending on the species, where the home range is little affected by landscape composition (e.g. *Emydoidea blandingii*; Fortin et al. 2012).

Regarding to habitat features, there are micro-scale characteristics that may be considered more important predictor of home range size, as site availability to basking, to egg deposition and to hibernate/aestivate (Ultsch 2006, Slavenko et al. 2016). In general, the exact effect of habitat features on home range size can be difficult to be interpret for aquatic species. However, there are some factors regarding to turtle morphology and needs, that is positively related to home movement and range size, as body mass, type of habitat used (aquatic, semiaquatic), and food gathering (Slavenko et al. 2016).

Although our data allowed to estimate home range only for a single individual of native species, and a male of one species, which implies an impossibility to support similarity between native and alien species and sex, we believe the information provided contribute to the knowledge on the ecology of these species. Mainly, because there are few studies about home range of Brazilian freshwater turtles (i.e. Magnusson et al. 1997; Fachín-Terán et al. 2006; Famelli et al. 2016; Leão et al. 2019; Muller et al. 2019; Hinderaker 2021) and these informations is essencial for planning turtle conservation.

All three species ranged more than 200m of distance into the water and the exotic species D'Orbigny's slider beyond presented the highest distance ranged (525.8m), was the only species with significant positive relation between this parameter and carapace length. Females represents the individuals with the highest carapace length, as well as with greatest body mass. The females also reach long distances upland (250m from water to nest; Bager and Rosado 2010), and these data point out the higher capacity to females and young D'Orbigny's slider to colonize new areas easily, favoring futures invasions.

The climate and human activities allows the establishment and invasion of D'Orbigny's slider in many Brazilian states, as Paraná, and across America (Fonseca et al. 2021). Considering this slider is legally sold in Brazil and recently introduced outside its natural range area (Ciccheto et al. 2018), there is a lack of knowledge about its population dynamics as an exotic species, as well as an absence of studies about competitive behavior between *T. dorbigni* and native species. Since we report changes in pattern activity of two species (D'Orbigny's slider and Geoffroy’s side-necked turtle) we recommend that futures studies investigate if the pressure of competition only or with other variables (e.g. different energetic needs) is affecting these variations.

Our results also showed at their home ranges, the turtles did not use the habitat randomly. All of them preferred areas with presence of walkways. Although we have not measured, we had previously observed people feeding wild animals inside the park studied. And this feature selected by turtles is closely related to the spots where residents and tourists feed them. Regardless of not being intentional, supplementary feeding of wildlife can generate severe problems, such as altered animal behavior and damages to natural ecological processes (Green and Giese 2004). As food gathering and type of diet are predictors of movement (Slavenko et al. 2016), we expected this clear influence of human presence on the habitat use and selection by turtles.

In conclusion, besides Geoffroy’s side-necked turtle presents great capacity to reproduce and survive in urban environment (Souza and Abe 2000; Martins et al. 2010; Müller et al. 2019), it also shows capacity to remain in a close environment coexisting with other two alien species. Even presenting these features and widely distribution in South America, some points needs attention. *Phrynops geoffroanus* complex comprises four geographically restricted species/lineages in Brazil, and the population of Parque do Ingá is in the lineage that includes populations from four Brazilian states and Argentina in the same group (Carvalho et al. 2017; Carvalho et al. 2022). This lineage is restricted to Paraná basin and biomes as Cerrado and Pantanal, the two Brazilian global biodiversity hotspots. In addition, its global conservation status was never accessed by IUCN, likely due to its broadly geographic distribution (Carvalho et al. 2022). Therefore, we strongly suggest a continuous monitoring of this species not only in our study area, but other urban areas in Brazil.

The same attention should be taken with the Red-eared slider populations, since it is also established at the park, is a threat to native chelonians living there (Martins et al. 2014), and trigger problems as it has been causing around the world (Lowe et al. 2000). Whereas human trade is ranked as the cause of Red-eared slider introduction (rather than the expansion of established populations) (Thomson et al., 2010), and this slider had only been recorded in public open areas in Maringá city (Grou 2015; Grou 2022), it is likely that this species was introduced into the study area by visitors. Even with the ban on the trade of Red-eared slider in Brazil, this species is still being sold illegally and a kept as pet in the country (Alves et al. 2019). Therefore, the monitoring of this population is priority considering its potential of invasion, the evidences of its reproduction (i.e., females nesting, males with courtship behavior and presence of juveniles), and also due to the occurrence of hybridization between congeneric species studied here (Red-eared slider and D'Orbigny's slider; Figueiredo 2014; Santos et al. 2020). Even not including individuals with morphological features of both species in our analysis, there are some individuals that can be morphologically classified as hybrid but genetically presents lineages of Red-eared slider (Figueiredo 2014). Hence, the population estimates of this species can be underestimated.

There are many evidences of changes in population dynamics and damages caused by Red-eared slider, including: avoidance of water bodies with chemical signs of Red-eared slider by native species (Polo-Cavia et al. 2009); aggressive and competitive behavior during feeding and basking activity, and performance advantage over native turtles by *T. scripta elegans* (Cadi and Joly 2003; Polo-Cavia et al. 2010, 2011; Taniguchi et al. 2017; Lambert et al. 2019); greater efficiency to use limited food resource by Red-eared slider, which favoring their growth and development (Pearson et al. 2015). Therefore, considering the invasion potential of both alien species coexisting with native species, as well as the likely displacement and population decline of native species coexisting with these alien species, is crucial to keep monitoring this assemblage. Additional research is need to understand whether interspecific competition occurs among these sympatric species, and if it may regulate the coexistence of competitors, as well as to develop experiments to compare the pattern of resource use by a target species in the presence/absence of a potential competitor.

Declarations

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Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Sabine Borges da Rocha, Carlos Eduardo Vargas Grou and Carlos Rouco. The first draft of the manuscript was written by Sabine Borges da Rocha and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability The data that support this study will be shared upon reasonable request to the corresponding author.

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Conflict of interest The authors declare no competing interests.

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Figures

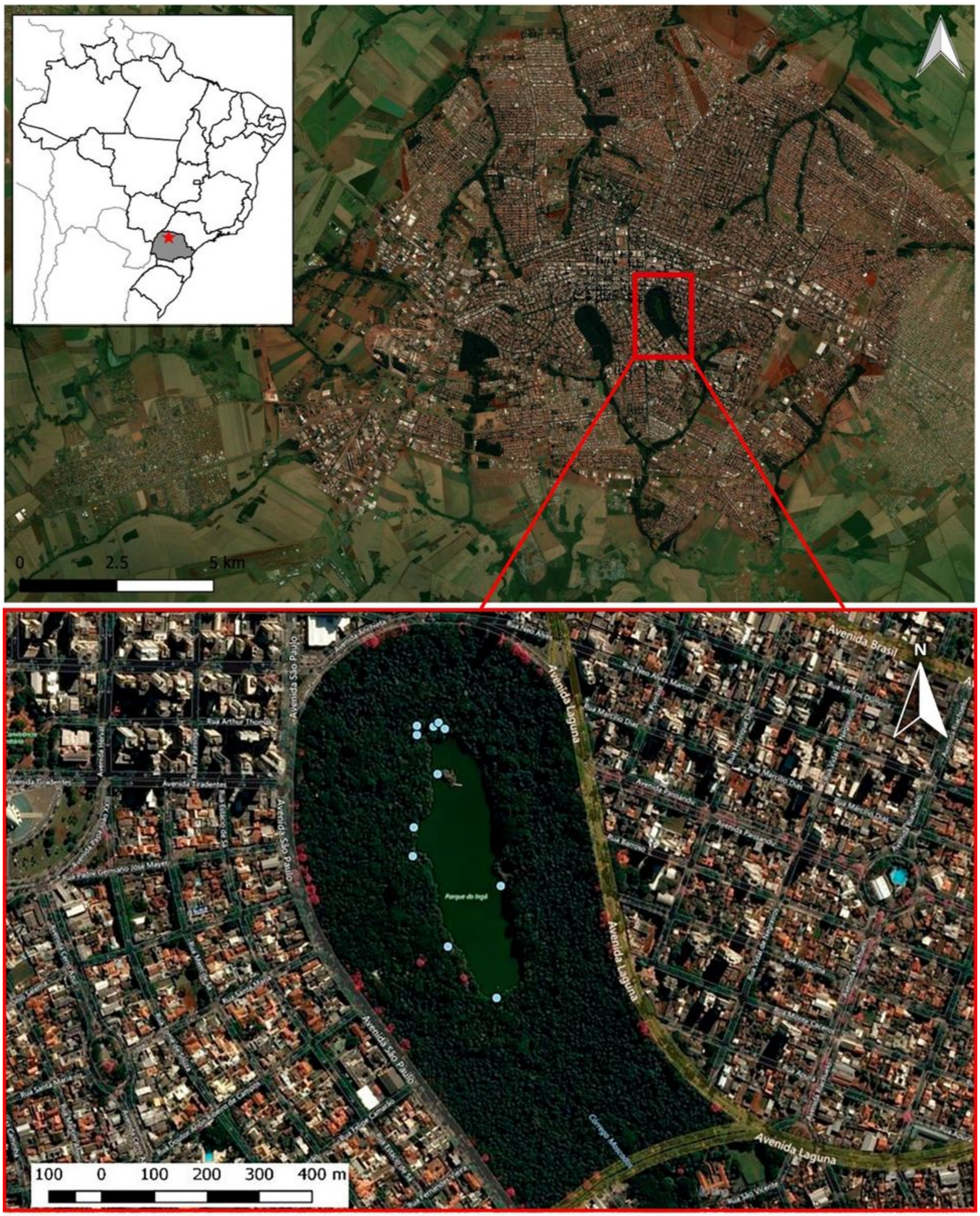

Figure 1

Location of the study area in Brazil. The red square represents the park studied (Parque do Ingá), located in the urban area of Maringá City. Blue spots represent the trap locations

Figure 2

Species of freshwater turtles studied in urban area in the southern of Brazil: (A) D'Orbigny's slider (*Trachemys dorbigni*); (B) Geoffroy’s side-necked turtle (*Phrynops geoffroanus*); (C) red-eared slider (*Trachemys scripta elegans)*; (D) D'Orbigny's slider, and (E) red-eared slider marked with epoxy number. Photos: Grou, C.E.V., Borges, T.F

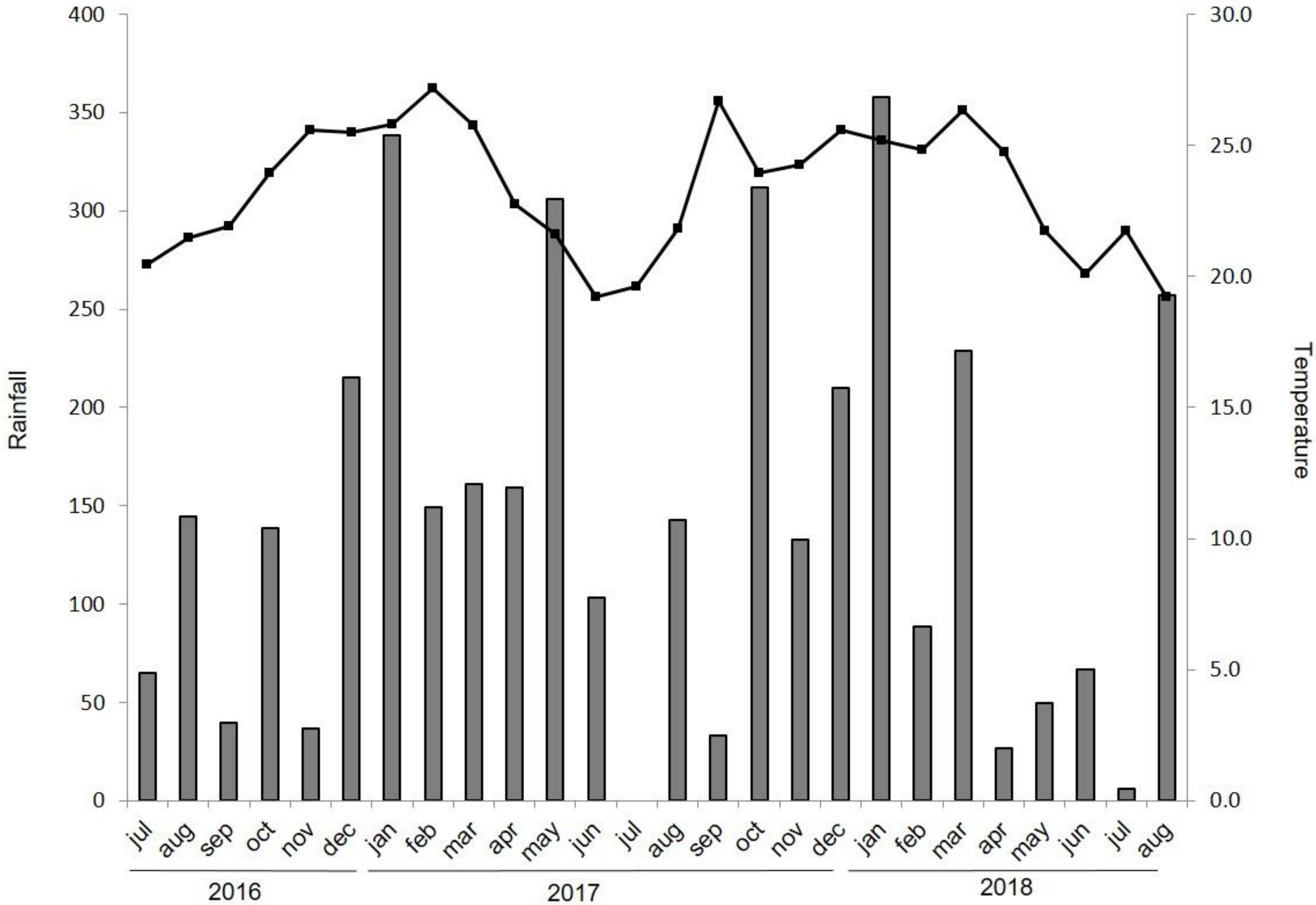

Figure 3

Rainfall and temperature registered between July 2016 and August 2018 in Maringá City, southern Brazil. Gray bars represent the rainfall (mm) and black line the temperature (C°)

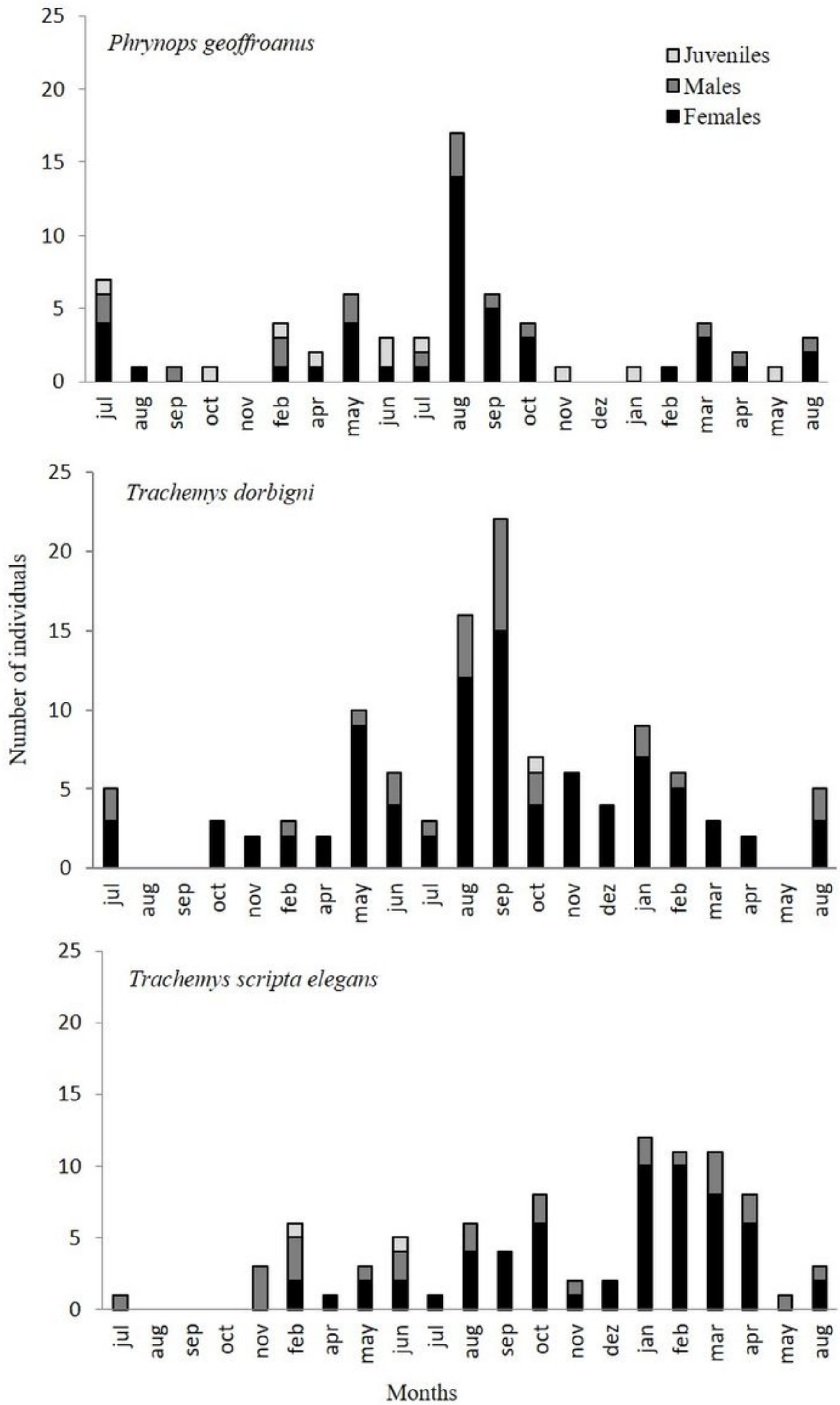

Figure 4

Total number of individuals of three freshwater turtles captured in 61 sampling sessions between July 2016 and August 2018, in an urban park, southern Brazil

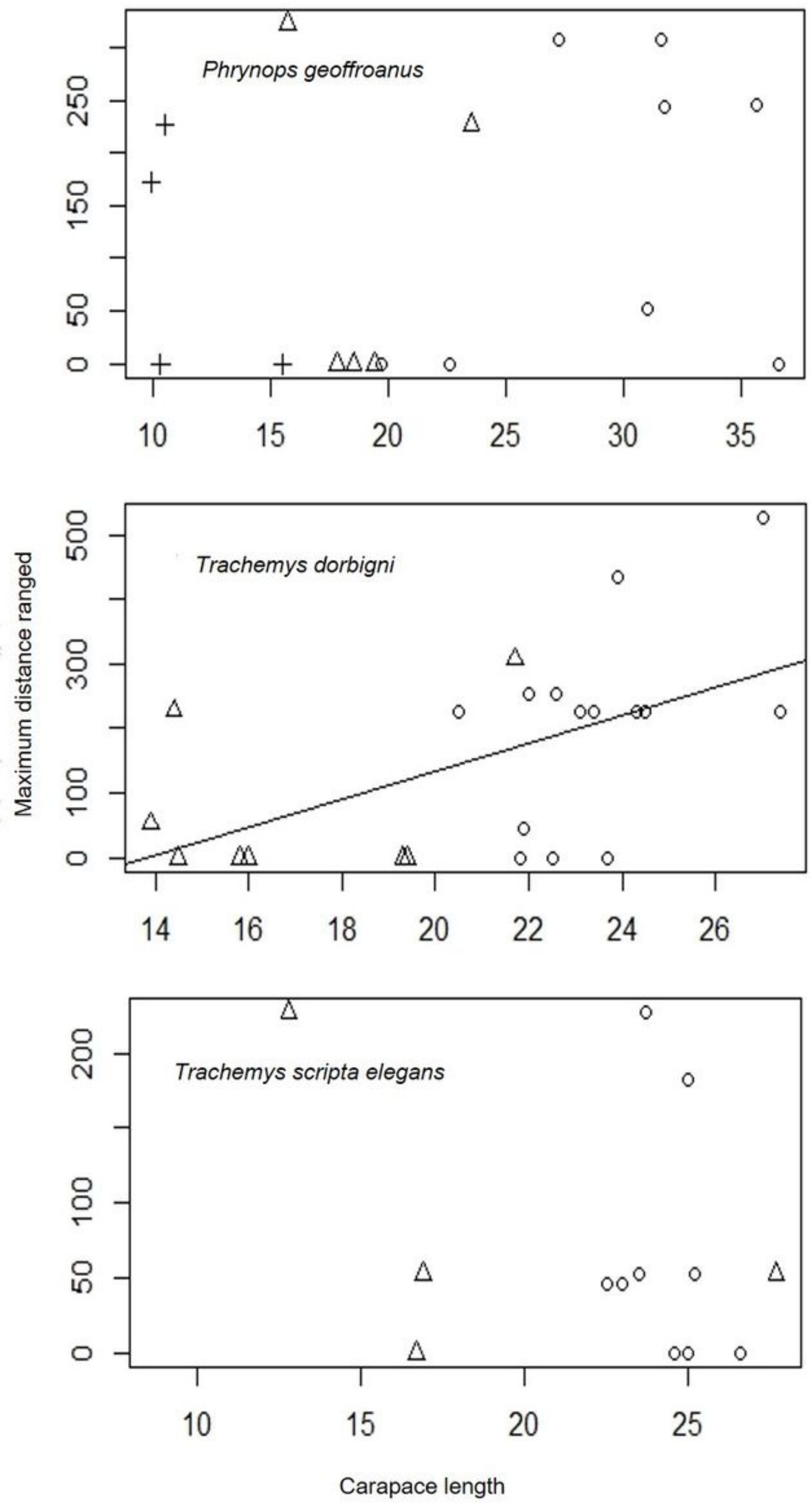

Figure 5

Linear regression between Maximum distance ranged (m) and curvilinear carapace length (cm) of freshwater turtles from southern Brazil; Cross = Juveniles; Triangle = Males; Circle = Females

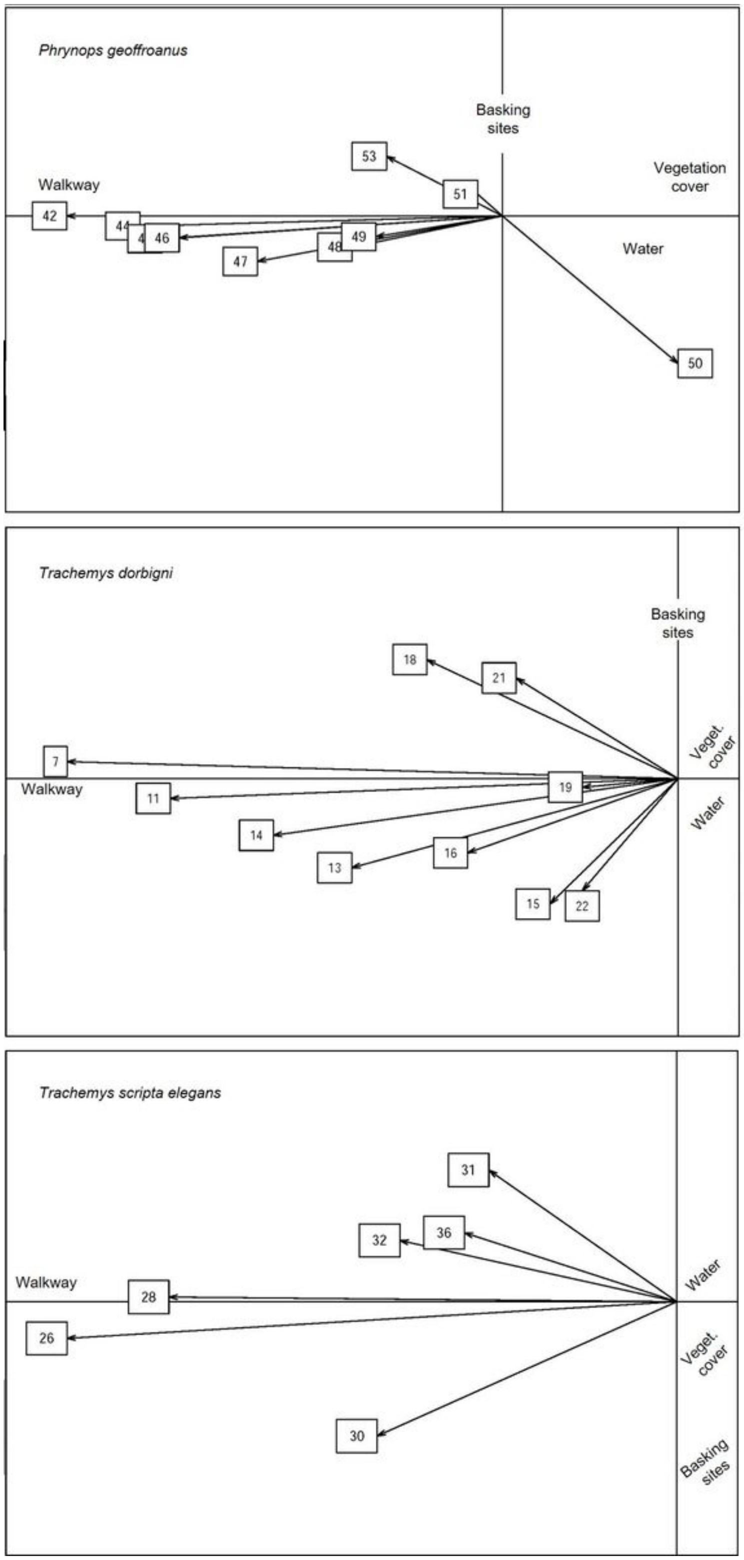

Figure 6

Results of eigenanalysis of selection rations showing habitat preference by capture-recaptured freshwater turtles in anurban park, southern Brazil. The longer the arrow the greater the preference by individuals for the type of habitat indicated. Each number is one individual