Universidad de Córdoba

Universidade Federal de Mato Grosso do Sul

Ecología poblacional de tortugas de agua dulce en áreas urbanas del sur de Brasil

Population ecology of freshwater turtles in urban area of Southern Brazil

Sabine Borges da Rocha

Tesis Doctoral

TITULO: *Population ecology of freshwater turtles in urban area of Southern Brazil*

AUTOR: *Sabine Borges Da Rocha*

© Edita: UCOPress. 2020
Campus de Rabanales
Ctra. Nacional IV, Km. 396 A
14071 Córdoba

https://www.uco.es/ucopress/index.php/es/
ucopress@uco.es

Ecología poblacional de tortugas de agua dulce en áreas urbanas del sur de Brasil

Population ecology of freshwater turtles in urban area of Southern Brazil

Autora: Sabine Borges da Rocha

Programa de Pós Graduação em Ecologia e Conservação
Centro de Ciências Biológicas e da Saúde
Universidade Federal de Mato Grosso Do Sul (Brazil)

Programa de Doctorado Recursos Naturales y Gestión Sostenible
Facultad de Ciencias
Universidad de Córdoba (España)

Memoria presentada para la obtención del título de Doctor por el por el Programa de Doctorado Recursos Naturales y Gestión Sostenible, Universidad de Córdoba (España) en COTUTELA con el Programa de Postgrado en Ecología y Conservación, Universidad Federal de Mato Grosso do Sul (Brasil).

Director: Dr. Carlos Rouco Zufiaurre
Codirectora: Dra. Vanda Lúcia Ferreira

DEPARTAMENTO DE ZOOLOGÍA
Universidad de Córdoba

Córdoba,Enero 2020

TÍTULO DE LA TESIS: Ecología poblacional de tortugas de agua dulce en áreas urbanas del sur de Brasil - *Population ecology of freshwater turtles in urban area of Southern Brazil*

DOCTORANDO/A: Sabine Borges da Rocha

INFORME RAZONADO DEL/DE LOS DIRECTOR/ES DE LA TESIS

(se hará mención a la evolución y desarrollo de la tesis, así como a trabajos y publicaciones derivados de la misma).

Sabine Borges da Rocha en su tesis a estudiado por primera vez la ecología de tortugas de agua dulce en zonas urbanas en Brasil. Dentro de un contexto general, la tesis se encuadra dentro del campo de la biología y de la gestión de las poblaciones de tortugas de agua dulce en ambientes urbanos. El presente trabajo aborda temas en directa relación con el estudio de los parámetros poblacionales de tres especies de tortugas en un parque urbano del sur de Brasil. Aporta hallazgos muy interesantes sobre los diferentes factores que afectan a día de hoy a la abundancia, áreas de campeo y distribución de estas especies así como los hábitats preferidos por las tres especies estudiadas, con un especial énfasis en dos especies invasoras. Lo que supone una información muy importante para poder gestionar las poblaciones de estas especies de forma adecuada y eficiente. La candidata de doctorado emplea y combina con habilidad métodos de captura marca y recaptura y radiotelemetría para estimar densidades, áreas de campeo y habita preferido de estas tres especies a lo largo de 2 años. Considero que este trabajo presenta el resultado de varios años de trabajo que han dado lugar a un modelo a seguir por futuros doctorandos que se encuadren dentro de la biología de tortugas, en particular, la tesis se presentan resultados muy novedosos y apoyados experimentalmente.

Como fruto del trabajo realizado a lo largo de su tesis doctoral ha publicado 5 artículos en revistas indexadas, dos de ellos directamente relacionada con su tesis. Además de presentar su trabajo en 24 comunicaciones a congresos nacionales e internacionales.

Por todo ello, se autoriza la presentación de la tesis doctoral.

Córdoba, 10 de enero de 2020

Firma del/de los director/es

Fdo.:Carlos Rouco Zufiaurre

Banca avaliadora

Dr. Elizângela Silva de Brito
[Instituto Nacional de Pesquisas do Pantanal]

Dr. Camila Kurzmann Fagundes
[Wildlife Conservation Society]

Dr. Franco Leandro de Souza
[Universidade Federal de Mato Grosso do Sul]

Dr. Luis Arias de Reyna Martínez
[Universidad de Córdoba]

Dr. Carlos Rouco Zufiaurre
[Universidad de Córdoba]

To all the women who have dared to study science

Acknowledgments

This thesis was only possible to be developed with the help, support and cooperation of many people whom I had opportunity to know. Many of them are Brazilian and Spanish people. Therefore, this part I will write and Portuguese/Spanish.

Sou grata a minha orientadora Dra. Vanda L. Ferreira por aceitar me orientar em um momento conturbado do meu doutorado, e mesmo distante sempre fez o que pode para me ajudar, sempre muito atenciosa. Um agradecimento especial vai para toda a equipe do Laboratório de Ictioparasitologia do Nupelia/UEM, e ao prof. Ricardo Takemoto, que me recebeu de braços abertos e me deu todo suporte necessário para desenvolver minha tese. Sem você e sua equipe a minha tese não sairia do papel. Agradeço a toda a equipe do Parque do Ingá, que me deram suporte logístico, disponibilizaram recursos quando possível e incentivaram os trabalhos de Educação Ambiental no Parque. Agradeço também aos donos das propriedades urbanas pela autorização de coleta. A empresa IACO Agrícola pelos equipamentos para rastreamento dos animais e ao PPGEC/UFMS pelo empréstimo dos equipamentos. A Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) que financiou esse trabalho. Ao Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) e ao Comitê de Ética na Utilização de Animais da UFMS pela licença de coleta cedida (55637-3 e 811/2016, respectivamente).

Agradeço imensamente minhxs companheirxs do Sapabonde, e a Pri e Amandita, que me ajudaram psicologicamente ao longo de todo o meu doutorado, dando suporte nos momentos difíceis, sempre compartilhando ensinamentos que me fizeram crescer muito. Ao Matheus Neves, que me ajudou e me ajuda muito até hoje, pelo incentivo, artigos em parceria, mapas, visita na Espanha, risadas. Aos meus amigos de Maringá, que sem eles não haveria Projeto TAMARI. Agradeço aos meus auxiliares

Patrícia, Tatiane (minha super co-orientada), Juliana, Gabriel, Luquinhas, e aos amigos e colegas que me ajudaram de alguma forma (coletas, suporte logístico, correção do manuscrito, insights) Lucas Stag, Altoe, Carlos, Thiago Borella, Rufus, Mateus Reck, Fernando, Gabriel Deprá, Caio Felix, Igor Paiva. Ao meu amigo/sócio Eduardo Grou (Du), serei eternamente grata pelo conhecimento compartilhado, saídas de campo, disponibilidade de tempo e alegria, lanchinhos e paieros na coleta. Não tenho palavras para agradecer o seu nobre gesto. Aos meus *house mates* Pirata, Reck, Giacomini, que além de amigos são também parte da minha família Maringaense. Obrigada pelos momentos de descontração, insights biológicos, e especialmente por cuidarem da minha filha Paçoca. Também agradeço imensamente a Nayara (Nay), minha anja, que sempre me ajudou muito tanto no quesito profissional quanto pessoal, sempre disponibilizando seu tempo para me ajudar nas coletas, mudança, viagens. A Suelen, Mariane, Rebecca que me dão suporte emocional e sempre estiveram presentes, mesmo com a distância. A minha família que sempre esteve ao meu lado, me dando todo o suporte necessário, me incentivando e dando todo o amor que necessitei. Graças a vocês eu consegui chegar até aqui. Não tenho palavras para agradecer.

Deseo consignar mi gratitud a mi orientador Carlos Rouco por haber confiado en mi trabajo, por su constante estímulo, por su apoyo, *insights* y por acogerme en su casa y en su laboratorio en la Universidad de Córdoba (UCO). Mi especial reconocimiento a todo el equipo del Departamento de Zoología de UCO (Patrícia, Juan, Pilar y Luis). A mi amiga Chaima por todo el cariño y amistad. Y a mis amigos brasileños/argentinos con los que vivi en Córdoba André, Clara, Saul, Sofi, Flor y Vane.

Table of contents

General abstract

Urbanization process represents a significant threat, especially to aquatic ecosystems. Changes in riparian vegetation and water body structure, as well as the introduction of exotic species and the contact of wild animals and humans, are some of the impacts faced in urban areas. Because of these changes in the environment, wild species may be affected. Therefore, the main goals of this study are: i) to evaluate the population parameters of three urban freshwater turtles, one native (*Phrynops geoffroanus*) and two exotic species (*Trachemys dorbigni dorbigni*, *Trachemys scripta elegans*); ii) analyze its home range, habitat selection and maximum distance ranged by each species; iii) identify which urban features may influence its movements patterns. Turtles were monitored between July 2016 and August 2018 in an urban park in the state of Paraná, Brazil, and a capture-recapture method and radio telemetry was used to monitor populations during this period. Both native and alien species presented similar population parameters, the home range varied according to the data collection method and estimator used (MCP100 and KDE95), and turtles selected habitats with urban characteristics (mainly those associated with human presence). Our study is the first in Brazil to analyze the population ecology of native and alien species of freshwater turtles that are coexisting. Long-term monitoring of the three species should be considered by the Brazilian authorities in order to avoid local extinction of native species and to control the alien species invasion. In addition, environmental education activities will help people to concern them about the damage that introduction of exotic species (by releasing pets) may cause to ecosystems, even in urban areas.

Resumo geral

O processo de urbanização representa uma ameaça significativa aos ecossistemas, especialmente para os aquáticos. Mudanças na vegetação ripária e na estrutura do corpo d'água, bem como a introdução de espécies exóticas e o contato de animais silvestres e seres humanos, são alguns dos impactos enfrentados nas áreas urbanas. Como conseqüência das mudanças no ambiente, as espécies selvagens podem ser afetadas. Dessa forma, os principais objetivos deste estudo são: i) avaliar os parâmetros populacionais de de três espécies de quelônios de água doce urbanas, uma nativa (*Phrynops geoffroanus*) e duas espécies exóticas (*Trachemys dorbigni dorbigni*, *Trachemys scripta elegans*); ii) analisar sua área de vida, seleção de habitat e distância máxima percorrida por cada espécie; iii) identificar quais características urbanas podem influenciar seu padrão de movimento. Coletamos quelônios entre Julho de 2016 e Agosto de 2018 em um parque urbano no estado do Paraná, Brasil, e usamos o método de captura-recaptura e radiotelemetria para monitorar populações durante esse período. Tanto as espécies nativas quanto as exóticas apresentaram parâmetros populacionais semelhantes, a área de vida variou de acordo com o método de coleta dos dados e estimador utilizado (MCP100 e KDE95), e elas selecionam habitats com características urbanas (principalmente com a presença humana). Nosso estudo é o primeiro no Brasil a analisar a ecologia populacional de espécies nativas e exóticas de quelônios de água doce que coexistem. O monitoramento a longo prazo das três espécies deve ser considerado pelas autoridades brasileiras para evitar a extinção local das espécies nativas e controlar as espécies exóticas. Além disso, as atividades de educação ambiental ajudarão a população a se preocupar com os danos que a introdução de novos indivíduos (liberando animais de estimação) pode causar aos ecossistemas, mesmo nas áreas urbanas.

Resumen general

El proceso de urbanización plantea una amenaza significativa para los ecosistemas, especialmente para los acuáticos. Los cambios en la vegetación ribereña y la estructura del cuerpo de agua, así como la introducción de especies exóticas y el contacto de la vida silvestre y humanos, son algunos de los impactos que se enfrentan en las zonas urbanas. Como resultado de los cambios en el ambiente, las especies silvestres pueden verse afectadas. Por lo tanto, los objetivos principales de este estudio son: i) evaluar los parámetros de población de tres tortugas de agua dulce urbana, una nativa (*Phrynops geoffroanus*) y dos especies exóticas (*Trachemys dorbigni dorbigni*, *Trachemys scripta elegans*); ii) analizar su área de campeo, selección de hábitat y distancia máxima recorrida por cada especie; iii) identificar qué características urbanas pueden influir en su patrón de movimiento. Recolectamos tortugas entre Julio de 2016 y Agosto de 2018 en un parque urbano en el estado de Paraná, Brasil, y utilizamos el método de captura-recaptura y radio telemetría para monitorear las poblaciones durante este período. Tanto las especies nativas como las exóticas tenían parámetros de población similares, el área de campeo variaba según el método de recolección de datos y el estimador utilizado (MCP100 y KDE95), y las tortugas seleccionan hábitats con características urbanas (principalmente con presencia humana). Nuestro estudio es el primero en Brasil en analizar la ecología poblacional de especies nativas y exóticas de tortugas de agua dulce coexistentes. Las autoridades brasileñas deberían considerar el monitoreo a largo plazo de las tres especies para prevenir la extinción local de especies nativas y controlar las especies exóticas. Además, las actividades de educación ambiental ayudarán a las personas a preocuparse por el daño que la introducción de nuevas personas (liberar mascotas) puede causar en los ecosistemas, incluso en áreas urbanas.

General Introduction

The urban areas still lodging wild species through forest remnants, such as parks, riparian vegetation, and squares (e.g. Slabbekoorn & Peet 2003; Ryan et al. 2014; Viana et al. 2017). Birds, mammals, amphibians and reptiles are some of the animals that can persist at these areas (Hunt et al. 2013; Villaseñor et al. 2017; Beaugeard et al. 2019; Santini et al. 2019). Even lodging biodiversity, urban environments suffer with some impacts related to fragmentation and degradation of riparian vegetation, channeling of water bodies, and as a consequence, the silting of rivers. Other regular disturbance are regarding to urban noise, recreational activities (e.g. fishing), wild-feeding, and introduction of alien species (Slabbekoorn & Peet 2003; Green & Giese 2004; Hunt et al. 2013; Ciccheto et al.. 2018; Rocha et al. 2018). Since these changes may affect the biodiversity and their ecology, such as survival, movement pattern, distribution (Ryan et al. 2008; Rees et al. 2009; Cosentino et al. 2010; Hill & Vodopich 2013) is important to evaluate how environmental pressures is affecting wild populations.

Recreational fishing, for example, is a common activity in the Brazilian culture and it is often recorded in urban places, even in protected areas. However, this activity may damage the aquatic native fauna (Nemoz et al. 2004; Steen et al. 2014), such as turtles which remain in these areas. This type of incidents occurs because the freshwater turtles are usually opportunistic scavengers and feed on living prey, therefore they are attracted by baited traps and hooks (Borkowski 1997). There are many records about incidents with freshwater turtles regarding to ingestion of fishing sinkers, hooks, as well as monofilament lines, and it can lead to problems in the digestive tract in general and ultimately to death (Larocque et al. 2012; Steen et al. 2014). In the urban area studied (Maringá City) a case of mortality of the native freshwater turtle *Phrynops geoffroanus* (Schweigger 1812) was recorded due to fishing activity, and this reflects the human impact on the environment (Rocha et al. 2018). Even our record being the first causality for Brazilian freshwater turtles, this type of accident is well known among fishermen, and reflects the lack of knowledge regarding the turtle populations. *Phrynops geoffroanus* is not a threatened species, however this type of urban impact can cause a population decrease and eventual local extinction of the specie (Steen et al., 2014; Rocha et al. 2018). Therefore, the monitoring of wild native species should be considered in urban environments management plans.

The introduction of alien species is other problem faced by urban areas. According to the Convention on Biological Diversity - CBD (2006), the designation of alien species is related to a particular species, subspecies or inferior taxon introduced in the past or in the present, outside of its natural area of distribution. It includes any structure of this organism (e.g. gamete, seeds, eggs or propagule) that can survive and posteriorly reproduce. Since one species is introduced it should exceed the environmental barrier to survive, such as predators, diseases, and climatic conditions. Whether this species can overcome these barriers and start to reproduce, and maintain a self-regenerating population, then it is consider an established species (Ziller & Zalba 2007). The next barrier to be crossed is the geographic one, which is closely related to the capacity of dispersion of this species. Exceeding the point where it was introduced, and therefore reaching large areas, through physical ways (e.g. wind, dispersers, by human indirect help) or by them own means. The species then is considered an invasive one. Finally, if this species is introduced in many different and separated areas, the invasions increase (Ziller & Zalba 2007).

There are different reasons which can contribute to the flow of alien species, such as the trade of pets, which move millions of individuals annually worldwide (Kraus 2003). In particular, the introduction of amphibian and reptiles started to rise on the 1960s (Kraus 2003). The United States and European Union were the pioneers to trade reptiles and amphibian pets (Tapley et al. 2011; Romagosa 2015). The problem with this activity starts with the fact that many pet's owners receive erroneous or no information regarding to the biology of the animal (e.g. body size that they can reach, longevity, etc.). This lack of information lead owners to introduce intentionally unwanted animals into the wild (Romagosa 2016). In Brazil, exists an additional source of introductions of pets: the release done by authorities after seizure of illegal animals, usually birds and reptiles (Destro et al. 2012). This occurs due to the savage condition of the animals, as well as the lack of places to keep them in captivity (*pers. obs*). On the other hand, some pets can be introduced accidentally, because of their capacity to escape easily (Pysek et al. 2010). As a consequence, the alien invasion can threaten the local biodiversity, its ecosystem and local economy, being this the second cause of biodiversity loss around the world (Lowe et al. 2000; Ziller & Zalba 2007). It may affect the biodiversity by changing communities organization and functionality, modifying the process of animals foraging, spreading pathogens and inducing the exclusion by competition (Lowe et al. 2000; Ziller & Zalba 2007; Ferronato et al. 2009).

Considering the pressures of urban environment on wild species, the overall goal of the present study was to investigate the influence of urban habitat on population parameters and movement pattern of freshwater turtles. Specifically in Chapter I, we presented the populations parameters (i.e. population size, density, sex ratio and recapture rates) of three species of freshwater turtles in an urban area, being one native (Geoffroy’s slide-necked turtle - *Phrynops geoffroanus*) and two alien species: D'Orbigny's slider - *Trachemys dorbigni dorbigni* (Duméril & Bibron, 1835), and Red-eared slider - *Trachemys scripta elegans* (Thunberg in Schoepff, 1792); as well as information regarding to the home range, distance ranged and the influence of urban features in the habitat selection of species. In Chapter II, we described the spatial ecology of the alien species D'orbigni's slider, presenting for the first time data related to this species outside of its natural distribution range. Since data for both chapters was collected at the same study area, and with the same species, both topics are detailed in this current section.

The study area is located in Maringá City, in the northwest of Paraná state, South of Brazil. Maringá is divided by two hydrographic basins: Pirapó in the North, and Ivaí in the South, being both hydrographic basins tributary of the Paraná River (SEMA 2010). Freshwater turtles were recorded before in both basins, in the streams and lakes (Grou 2015). The Municipality of Maringá presents nearby 12 km^2 of Atlantic Forest remained distributed in patches (Marques 2004). In the urban perimeter, most of the patches are classified as area of permanent protection, which protect the river sources and the streams of the city. The forest remnants are connected by riparian vegetation and by streams, providing connections for the freshwater community. The riparian vegetation is continuous over the city, however, some parts of the water bodies presents a narrow strip of riparian vegetation and others presents wider ones (SEMA 2011).

The data was collected at a Municipal Park “Parque do Ingá”, located in the urban area of Maringá City (23°25'S, 51°55'W). This area is located in the Atlantic forest ecosystem and it protects many river sources of Ivaí Basin. Parque do Ingá is the second largest forest remnant of the city (473.300m^2), lodging high biodiversity of plants and animals (SEMA, 2011). The water bodies sampled in this area are perennial ponds and lake, all connected by small streams or channels. The riparian vegetation is composed by shrubs and arboreal species of semidecidual seasonal forest.

Since worked was carried out in an urban park, there were many limitations to collect the turtles. The main constrain was finding an appropriate method to capture the specimens. The use traps was limited, because there were high risk of been stolen. The use of dragging net was almost unviable due to the presence of many submerged branches and trash, and due to the depth of water bodies that would entangle the net. Hence, to solve these problems, our researcher group adopted the technique of *Hookless trot line* proposed by Semeñiuk et al. (2017), creating the called Fishing clip (see description in Appendix A). This technique was very effective to capture turtles in the study area.

The target species of freshwater turtles studied here was: two introduced species: the D'Orbigni's slider and the Red-eared turtle (Emydidae), and one native turtles Geoffroy’s slide-necked turtle (Chelidae). Geoffroy’s slide-necked is widely distributed in South America, with the broadest distribution of all Chelidae (Rueda-Almonacid et al., 2007). However, a recent study described it as four geographically restricted lineages in Brazil (Carvalho et al. 2017). The conservation status of this species is considered as less concern (LC), because there is no evidence of the threats for this species (IUCN 2019). D'Orbigny's slider presents a restricted distribution in Brazil, with presence only in the extreme south (state of Rio Grande do Sul). It also occurs in the northeast of Argentina and Uruguay (Fritz & Havas 2006).The commercial trade followed by the release of these individuals into the wild lead the animals to reach new areas (Romagosa 2015). In Brazil for example, this slider was recorded in ten more states (northern locations), and in Argentina was registered in the most southern localities (Alcalde et al. 2012; Ciccheto et al. 2018). The conservation status of this species in their natural distribution area is near threatened (NT), due to agricultural activity and its impact on nesting areas, commercial trade of juveniles as pet, and road mortality of females (IUCN 20190). Red-eared slider occurs naturally in the north and center of United States of America and in the extreme northwest of Mexico (Painter 2000; Rueda-Almonacid et al. 2007). It was introduced in the Andean countries in the earlier 1970s and currently it is a popular pet around the world. Due to pet release, it has established invasive population on every continent (except Antarctica) and it is one of the 100 worst invasive species of the world (Lowe et al. 2000; Kikillus et al. 2012). The conservation status of the species is less concern (LC) (IUCN 2019).

The lack of knowledge about population ecology of Brazilian freshwater turtles,, jointly with the potential damage that alien species can cause, highlights the importance to analyze the population dynamic and the spatial ecology of freshwater turtles in this urban area.

1. Freshwater turtles in urban environment: population parameters, home range and habitat selection

Quelônios-de-água-doce em ambiente urbano: parâmetros populacionais, área de vida e seleção de habitat

Tortugas de agua dulce en un entorno urbano: parámetros de población, área de vida y selección de hábitat

Abstract

Even though urbanization causes degradation in aquatic systems, some wild species can remain in these areas, such as freshwater turtles. The impacts from urban areas may result in alterations in environmental characteristics and wild populations dynamics. Therefore, we aimed mainly at assessing population parameters and movement patterns of three freshwater turtles (one native and two alien species) in an urban area and identifying the environmental characteristics that influence their movements. After 61 capture-recapture sessions of turtles between July 2016 and August 2018 at a park in Paraná state (Brazil), we sampled 41 *Phrynops geoffroanus* (PG), 35 *Trachemys dorbigni dorbigni* (TDD), and 20 *Trachemys scripta elegans* (TSE). We obainted a high recapture rate: 42%, 65%, and 70%, respectively. Population size (±SE) was estimated as 59 ± 7.6 (PG), 36 ± 1.4 (TDD), and 20 ± 0.5(TSE) individuals, and density (±SE) was 1.36 (0.34), 1.72 (0.36), and 0.87 (0.25) turtle/ha, respectively. Sex ratio was female-biased for the two sliders. Urban features, mainly walkways, were highly preferred by the three species, probably due to wild animals feeding by the park users. In addition, the body size influenced the total movement ranged by alien species. Our study is the first to analyze the population ecology of native and alien species of

freshwater turtles coexisting in Brazil. Our results represent an alert regarding the issues involving alien species and their potential of invasion.

Resumo

A urbanização causa degradação no ambiente aquático. Contudo, algumas espécies silvestres podem permanecer nessas áreas, como os quelônios-de-água-doce. Os impactos gerados pelas áreas urbanas podem mudar as características do ambiente, e conseqüentemente a dinâmica das populações silvestres. Dessa forma, nossos principais objetivos foram avaliar os parâmetros populacionais e padrões de movimento de três espécies de quelônios de água doce (uma nativa e duas espécies exóticas) em uma área urbana, e identificar quais características do ambiente pode influenciar seu movimento. Após 61 sessões de captura-recaptura entre julho de 2016 a Agosto de 2018 em um parque urbano no estado do Paraná (Brasil), nós capturamos 41 *Phrynops geoffroanus* (PG), 35 *Trachemys dorbigni dorbigni* (TDD) e 20 *Trachemys scripta elegans* (TSE). A taxa de recaptura foi elevada para as três espécies: 42%, 65% e 70%, respectivamente. O tamanho populacional (±SE) estimado foi de 59 ± 7.6 (PG), 36 ± 1.4 (TDD), e 20 ± 0.5 (TSE) indivíduos, e a densidade (±SE) foi 1.36 (0.34), 1.72 (0.36), and 0.87 (0.25) indivíduo/ha, respectivamente. A razão sexual foi desviada para fêmeas, para duas espécies. Dentre as características urbanas, em especial, a presença de passarelas foi altamente selecionada pelas três espécies de quelônios, provavelmente devido a alimentação dos animais silvestres pelos visitantes do parque. Adicionalmente, o tamanho do corpo da espécie exótica influenciou em sua distância total percorrida. Nosso estudo é o primeiro no Brasil o qual avaliou a ecologia populacional de espécie nativa e exóticas de quelônios de água-doce coexistindo. Os resultados apresentados deveriam alertar a população a respeito dos problemas envolvendo espécies exóticas e seu potencial de invasão.

Resumen

La urbanización provoca degradación en el ambiente acuático. Sin embargo, algunas especies silvestres pueden permanecer en estas áreas, como las tortugas acuáticas. Los impactos generados por las áreas urbanas pueden cambiar las características del medio y la dinámica de las poblaciones silvestres. Por lo tanto, nuestros objetivos principales fueron evaluar los parámetros de la población y el movimiento de tres tortugas de agua dulce (una nativa y dos especies exóticas) en un área urbana, e identificar qué características ambientales pueden influir en su movimiento. Después de 61 sesiones de captura-recaptura de Julio de 2016 a Agosto de 2018 en un parque urbano en el estado de Paraná (Brasil), capturamos 41 *Phrynops geoffroanus* (PG), 35 *Trachemys dorbigni dorbigni* (TDD) y 20 *Trachemys scripta elegans* (TSE). La tasa de recaptura ha sido alta para las tres especies: 42%, 65% y 70%, respectivamente. El tamaño de población estimado (± SE) es de 59 ± 7.6 (PG), 36 ± 1.4 (TDD) y 20 ± 0.5 (TSE), y la densidad (± SE) 1.36 (0.34), 1.72 (0.36) y 0.87 (0.25) tortugas/ha, respectivamente. La proporción de sexos se cambió a hembras para dos especies. Las características urbanas, especialmente la presencia de senderos, fueron altamente seleccionadas por las tres especies de tortugas, probablemente debido a la alimentación de animales salvajes por parte de los visitantes del parque. Además, el tamaño del cuerpo de las especies exóticas influyó en su distancia total recorrida. Nuestro estudio es el primero en Brasil en evaluar la ecología de la población de tortugas de agua dulce nativas y exóticas que coexisten. Los resultados presentados deben alertar a la población sobre los problemas que involucran especies exóticas y su potencial de invasión.

Introduction

Aquatic systems are one of the most productive ecosystems and also 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 & Meyer 2001). Urbanization can cause alterations in the native and riparian vegetation through deforestation, degradation, and fragmentation of forests (Marchand & Litvaitis 2004; Bujes et al. 2011; Guzy et al. 2013). Habitat loss and fragmentation isolate wild populations and leads to a reduced dispersion of individuals and consequently lower genetic variability of populations, causing deleterious effects (Guzy et al. 2013). Furthermore, the degradation of riparian vegetation affects water temperature and consequently increases temperature fluctuation, decreases biodiversity, and change the spatial distribution of the species (Paul & Meyer 2001; Marchand & Litvaitis 2004). Another constant issue in urban areas is related to the channeling of water bodies and associated silting (Spinks et al. 2003). Many species suffer the negative impacts of urbanization and may not survive in this type of environment, whereas others are able to remain, reproduce, and prosper in these urban areas (e.g. some species of reptiles, birds, mammals) (Ryan et al. 2008, 2014; Rees et al. 2009; Guzy et al. 2013).

Human disturbance influences how wild animals move, select and use the environment (Slabbekoorn & Peet 2003; Ryan et al. 2008; Hill & Vodopich 2013). Freshwater turtles, for example, are affected by local-scale measures of urbanization (Hill & Vodopich 2013); additionally, some specific features may influence their movement, such as the riparian vegetation structure, availability of places to sunbath, refuge, and feeding behavior (Huey 1991; Standing et al. 1999; Souza & Abe 2000;

Compton et al. 2002; Cosentino et al. 2010; Paterson et al. 2012; Ghaffari et al. 2014). In addition to these features, the movement patterns of freshwater turtles may also vary according to the species, current seasons, and gender involved (Ostfeld 1990; Rees et al. 2009; Bower et al. 2012; Paterson et al. 2012).

Brazil is the third richest country in the number of reptiles species, with 36 Testudines composedof31 continental turtle (tortoise and freshwater turtle) (Costa & Bérnils 2018). Nineteen percent of the continental turtleshave faced some degree of threat, mainly due to habitat degradation, introduction of invasive species, and pollution (Gibbons et al. 2000; ICMBio 2018). However, little has been investigated on Brazilian freshwater turtles (Souza 2004), even during the past decade, which may hamper the species management and conservation programs in Brazil. Similarly to studies on other reptiles, the literature presents only a few investigations on turtles, which is associated with their low detectability and density (Ernst et al. 1994). However, for urban environments this scenario is different. Polluted water bodies with high organic matter (resultingfromhuman sewage), provide turtles with food supplementation (Souza et al. 2008). Consequently, turtle populations present higher biomass and density, as recorded for *Phrynops geoffroanus* (Souza & Abe 2000). In addition, urban areas imply issues of species introduction, usually related to pet release (Romagosa 2015; Ciccheto et al. 2018), leading these areas to have higher turtle richness as a result from the sliders assemblage composed of both native and alien species (Grou 2015; Molina et al. 2016). The following two common alien species of freshwater turtle occur in Brazilian urban areas: *Trachemys dorbigni* and *T. scripta* (eg. Santos et al. 2009; Molina et al. 2016; Ciccheto et al. 2018). The assessment of their establishment degree and invasion potential in Brazil represents a major issue because of their fast pace when reaching new areas (Molina et al. 2016). Unfortunately, little information is available regarding these alien species in Brazil (Ziller & Zalba 2007).

Considering that urbanization can affect environmental characteristics and the dynamics of wild populations, we aimed improving our knowledge on the population parameters (e.g. population structure, density, movement, habitat preferences etc.) of three freshwater turtles, as well as identifying the environmental characteristics that influence their movement in urban areas. We based our investigation on the following five leading questions: (1) Do alien and native species have different population size, density and sex ratio and recapture rates? (2) Do native and alien species have different home range size, and, if so, do these feature also differ between males and females? (3) Do freshwater turtles have preference for any of the urban park features, such as vegetation cover, basking sites, water, and walkways? (4)What is the average of maximum range of movement for each species? (5) Is the distance ranged by animals related to body size? We expect urban features to influence the population parameters and movement of turtles since wild animals change their habitat use because of human disturbance (Ryan et al. 2008; Rees et al. 2009; Cosentino et al. 2010; Hill & Vodopich 2013).

Material and Methods

Study area and target species

We sampled populations of three freshwater turtles at *Parque do Ingá* (23°25'S, 51°55'O), a municipal park in Maringá city, Paraná sate (Figure 1). Its location encompasses a transition zone of tropical and subtropical climate type, according to

Köppen (1948). The predominant climate is subtropical, with mean annual temperature varying between 20 and 21°C –the coldest month from 16 to17°C, and the hottest between 27°C and 28°C. The mean annual rainfall varies between1500 and 1600 mm, with wet summers and autumns (Deffune & Klosowski 1995; Marques 2004; SEMA 2011). We targeted the four species registered in the park: Geoffroy's slide-necked turtle (*P. geoffroanus*, Chelidae), D'Orbigny's slider (*T. dorbigni dorbigni*, Emydidae), Red-eared slider (*T. scripta elegans*, Emydidae), and *Hydromedusa tectifera* (Chelidae). However, based on the number of individuals captured over two years, and considering that we captured only one individual of *H. tectifera*, we focused on the three remaining species (Figure 2). Geoffroy's slide-necked is the only native species in the region among the turtles studied (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, since both are popular in the context of commercial pet trade. Red-eared slider is listed among the 100 worst invasive species of the world (Lowe et al. 2000). Detailed description of the study area and target species are available above, in "General introduction section".

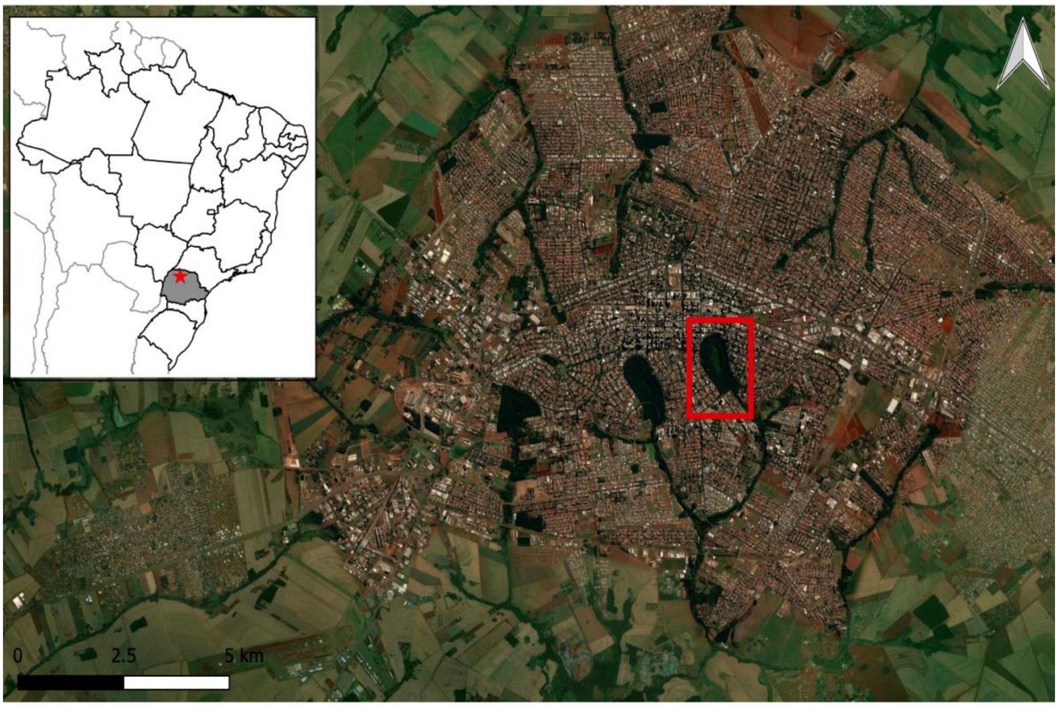


Figure 1. Location of the area studied in Southern Brazil. The red square represents the park studied (Parque do Ingá), located in the urban area of Maringá City.

Figure 2. Species of freshwater turtles studied in urban area in the southern of Brazil: (A) D'Orbigny's slider (*Trachemys dorbigni dorbigni*); (B) Geoffroy's slide-necked turtle (*Phrynops geoffroanus*); (C) Red-eared slider (*Trachemys scripta elegans)*; (D) Red-eared slider, and (E) D'Orbigny's slider marked with epoxy number. Photos: Grou, C.E.V., Borges, T.F.

Data collection

We captured the animals at 11 different locations along the park (Figure 3) and recorded all trap locations in the field as Universal Transverse Mercator (UTM) coordinates by using a Global Positioning System (GPS) portable receiver. We applied capture-mark-recapture procedures from July 2016 to August 2018to estimate population size, density, home range, habitat selection, and maximum range of movement. We used the following three different methods to capture the animals: i) Active search; ii) Fishing clip - adopted by Semeñiuk et al. (2017) (see detailed description in Appendix A). Both methods (i and ii) were executed by two people during five hours; iii) Funnel trap 1.2m baited with meat activated during 24h – used occasionally as a complementary method due to the above-mentioned difficulties.

Figure 3. Map with trap locations(blue dots) to capture three species of freshwater turtles at an urban park, Paraná state, Brazil.

From each captured individual we measured curvilinear carapace length (CL) and width (CW), plastron length (PL), and width (PW). They were sexed based on secondary sexual features (e.g. body size) and had their juvenile or adult status recorded according to the body size (Molina 1989; Close & Seigel 1997; Fagundes et al. 2010). We could not precisely determine the sex of the individuals <10 cm (Geoffroy's slide-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 (Figure 1D, 1E) andthe plastrons photographed as a control mark. After these procedures, the turtles were released at the capture site. The number mark on the carapace of the individuals enabled the identification of the sliders through active search.We considered the visualization of the individuals as a recapture. In total, we have 61 capture-recapture sessions, our of which24 represented capture events. On average, we sampled the area three times amonth, every month of the study period, except between November 2016 and February 2017, February and April 2017, and May, and August 2018. Instituto Nacional de Metereologia (INMET) provided the climatic data (rainfall and temperature) related the period between July 2016 and August 2018.

Data analysis

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. All computation procedures involved default settings. We used chi-square test for each species to verify whether sex ratio differed from 1:1.

We applied a closed population model to estimate density and population size considering the closed characteristic of the study area and the long period of life of the animals, in addition to the lack of expectations for large fluctuations in the population parameters during the study period (Plummer 1977). 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 in detection parameters (g0 and σ) over the time – 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 & 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 & Blouin-Demers (2006), on the adehabitat HR package of R statistical computing environment (RStudio Team 2016). We estimated home range (MCP 100%) only for turtles occuring in at least five locations (trapped at least five times over the two years) and also trapped at more than two different sites. The analysis of habitat selection of the individuals was perfomed 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. 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 Quantum GIS (QGIS Development Team 2016, version 2.16).We considered as habitat used the trap locations where a given individual was trapped. 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 & 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 & Dufour 2006).

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, in which CL is the independent variable and MDR is the dependent one. In addition, we used linear regression to analyze the effect of accumulated rainfall on the abundance of each species. We ran separate models for each species, in which the rainfall the independent variable and abundance as the dependent variable. We used the package “lme4” on the R statistical computing environment (RStudio Team 2016).

Results

We sampled 96 freshwater individual turtles out of 61 capture-recapture sessions over two years, distributed in 41 Geoffroy's side-necked turtles (26 females, 9 males, 6 juveniles), 35 D'Orbigny's sliders (24 females, 9 males, and 2 juvenile), and 20 Red-eared turtles (11 females, 8 males, 1 juvenile).The three species presented fluctuation in abundance along the seasons (Figure 4 and 5), however, only the Red-eared turtle had a significant relationship between abundance and rainfall ($P < 0.03$, $F=5.32$, $r2:0.21$). 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 turtle in January 2018 (12 individuals). For two species, the sex ratio tended significantly to females: 2.8:1 for Geoffroy's side-necked turtle ($x2 = 8.25$, $df = 1$, $p = 0.004$), and 2.6:1for D'Orbigny's slider ($x2 = 6.81$, $df = 1$, $p = 0.009$). The sex ratio did not differ from 1:1 for Red-eared turtle ($x2 = 0.47$, $df = 1$, $p = 0.49$).

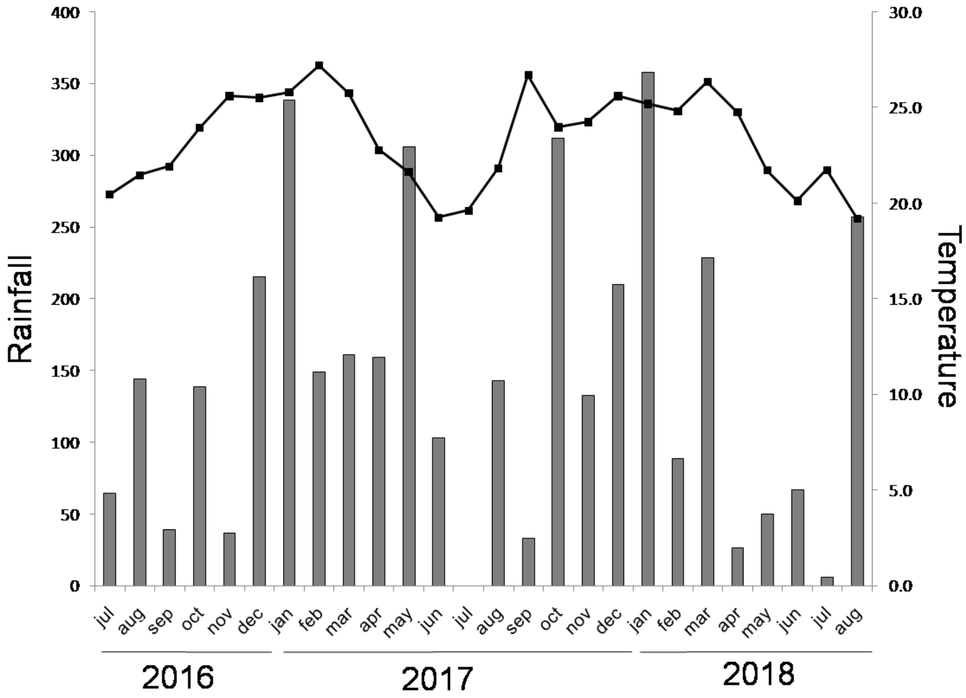


Figure 4. Rainfall and temperature registered between July 2016 and August 2018 in Maringá City, southern Brazil. Gray bars represent the rainfall (mm) and black line the temperature (C°).

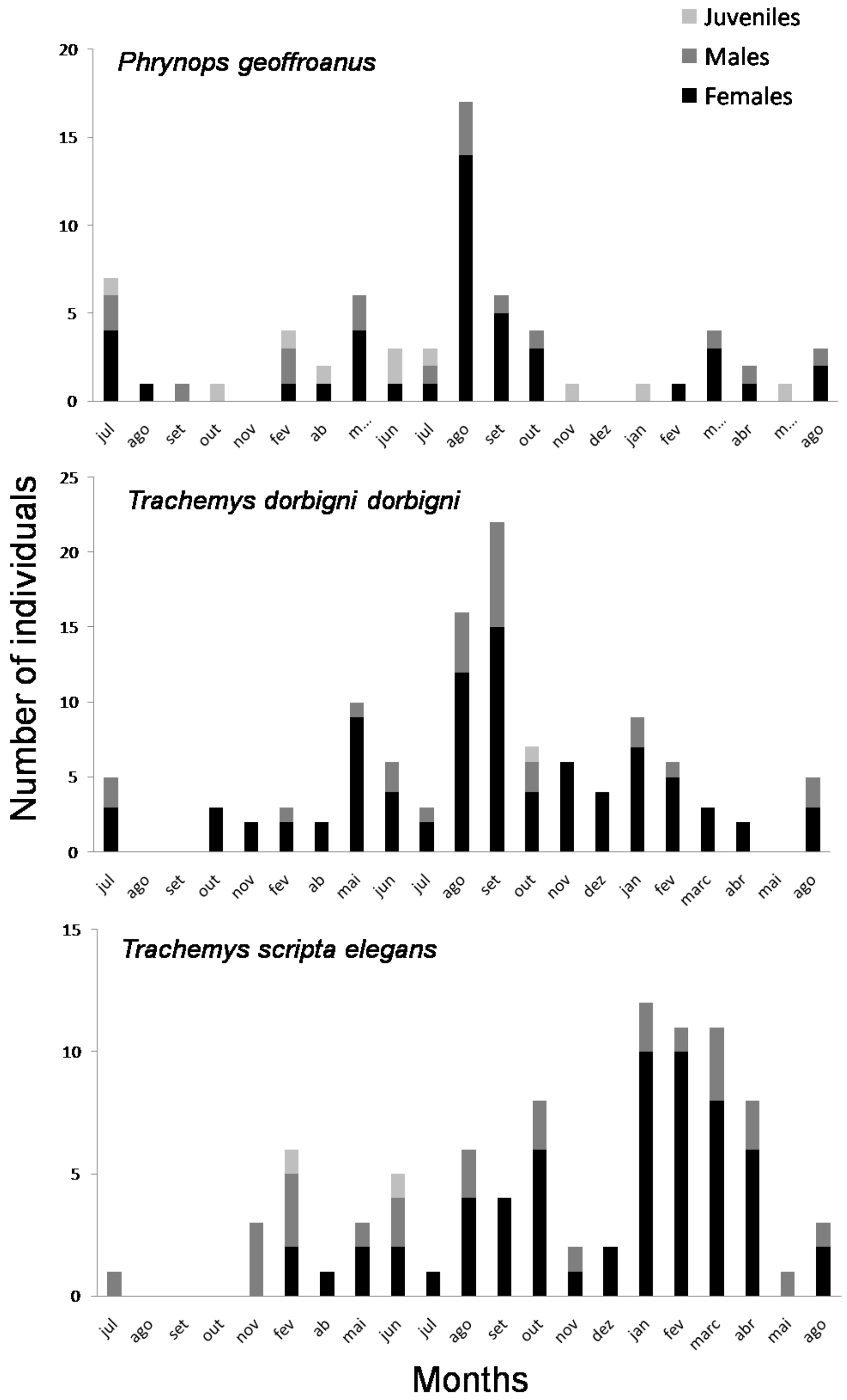


Figure 5. Total number of individuals of three freshwater turtles captured in 61 sampling sessions between July 2016 and August 2018, in an urban park, southern Brazil.

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 turtle. Each species presented one different variable influencing the probability of capture (Table 1). The top models for all turtles were strongly supported (Table 1). The model including the variable sex[sex] supported the capturability of Geoffroy's side-necked turtle. The non-native species D'Orbigny's slider presented a temporary response behavior to capture [bt], and the variable of time influenced the Red-eared turtle catchability [t]. Turtle density for all species ranged between 0.8 and 1.7 individuals per hectare (Table 1). Red-eared turtle presented the lowest population density: 0.87 individual/ha, followed by Geoffroy's side-necked turtle with 1.36 individual/ha. The population of D'Orbigny's slider showed the highest density: 1.72 individual/ha. The proportion of recaptures was higher for the alien species (70% and 65% for Red-eared turtle and D'Orbigny's slider, respectively), whereas the native species presented a recapture rate of 42%. Overall, 44% of turtles were recaptured only once. More than half (58%) of Geoffroy's side-necked turtles were captured once, although this percentage was lower for both alien species, 37% for D'Orbigny's slider and 30% for Red-eared turtle. Additionally, aliens species were recaptured more frequently (over 10 times) than the native ones (maximum of 6 times).

Table 1. Estimates of freshwater turtles 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 in question and the best model (with lowest AICc). See methods section for explanation of models. Total number of *Phrynops geoffroanus* was 41, *Trachemys dorbigni dorbigni* was 35, and *Trachemys scripta elegans* captured was 20 at 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 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

Many of the individuals captured presented less than five recaptures and/or were recaptured at the same point. Therefore, 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 m2), whereas for D'Orbigny's slider the average was 0.31 ha (3.100 m2).

Manly's selection ratios showed that individuals selected habitats in different ways (X2 = 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 (Figure 6). 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) (Figure 7C). The native species ranged 322.4m and Red-eared turtle presented the lowest maximum distance ranged,227.3m.

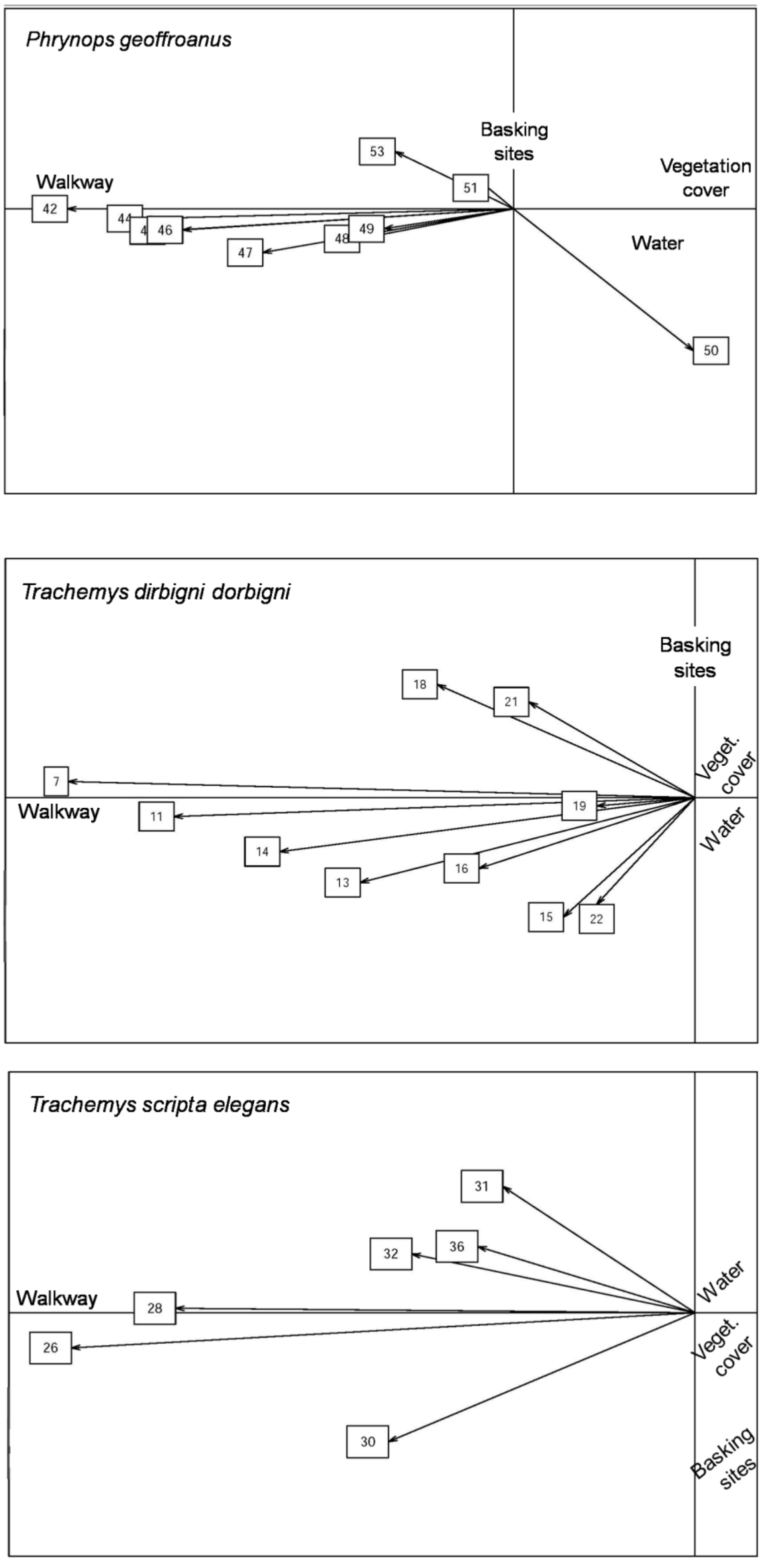


Figure 6. Results of eigenanalysis of selection rations, showing habitat preference by capture-recaptured freshwater turtles at urban park, southern Brazil. The longer is the arrow, the greater is the preference by individuals for the habitat type indicated.

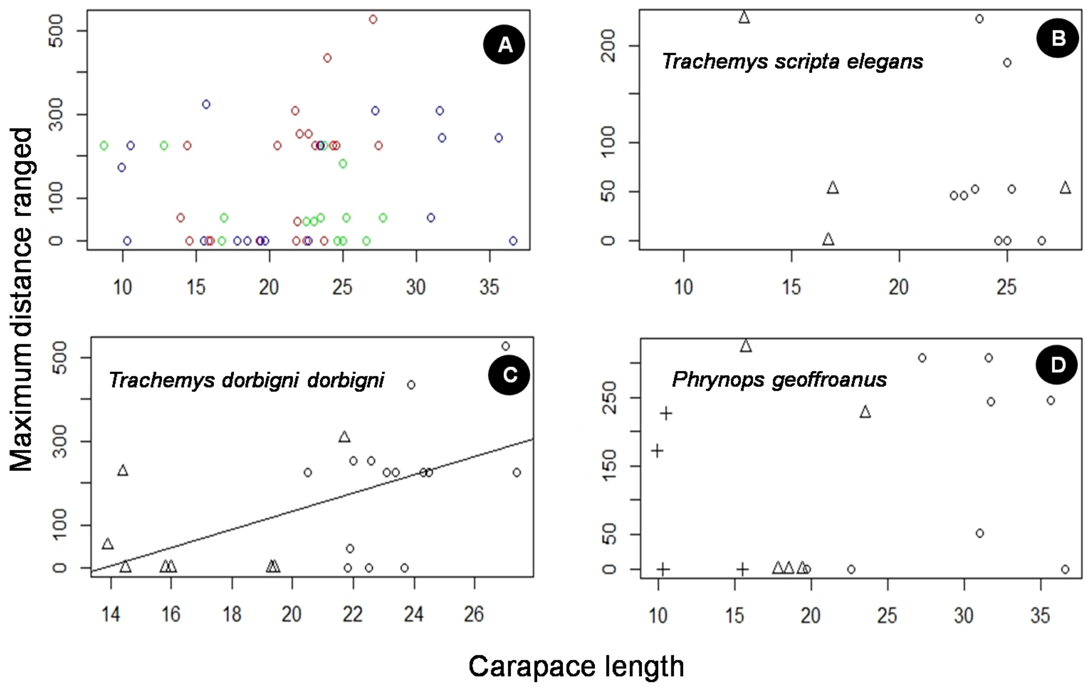


Figure 7. Linear regression between Maximum distance ranged (m) and curvilinear carapace length (cm) of freshwater turtle from southern Brazil. A) Linear regression with the three species: Red = *Trachemys dorbigni dorbigni*; Gren = *Trachemys scripta elegans*; Blue = *Phrynops geoffroanus*. B), C) and D) represents the linear regression for each species: Cross = Juveniles; Triangle = Males; Circle = Females.

Discussion

Our study is pioneer at analyzing the population ecology of native and alien species of freshwater turtles coexisting in Brazil. The three freshwater turtles studied presented similar population parameters in the context of the urban park studied. Our results showed that a particular urban feature (i.e. presence of walkway) strongly influenced the turtles' preference of habitat. Furthermore, our study detected a change in behavior to avoid trapping by the alien species D'Orbigny's slider. Moreover, other characteristics recorded here for D'Orbigny's slider (eg. longest distance ranged and its relation with body size), suggest its potential as an invasive alien species.

The species of turtles inhabiting the study area may present different strategies to coexist, such as spatial-temporal segregation, different use and selection of habitat, in addition to dietary shifts (Segurado & Figueiredo 2007; Alcalde et al. 2010). In fact, our study revealed a variation in an annual activity pattern including a monthly fluctuation for each species. The native species was more abundant in August, slightly earlier than expected (Souza &Abe 2001). D'Orbigny's slider presented higher relative abundance in September, different from the related previous records (February and March – Fagundes et al. 2010; November and December – Bujes et al. 2011). Red eared turtle presented activity pattern during the summer, between January and March, when this species occurs at the highest abundance in its natural distribution range (Morreale et al. 1984; Bluett & Cosentino 2013). The months of the highest abundance of males and females did not overlapp as expected. A possible explanation is that males become active earlier in time to increase their chances of mating with females (Morreale et al. 1984). We recorded this activity in 2016, however, in 2017 the highest abundance of males occurred just after the highest activity period of females. This pattern differs from the other two species studied, in which both genders presented an activity peak within the same month. The activity pattern of Testudines closely relates to weather conditions, such as temperature and rainfall (Souza 2004). In the city of Maringá, the hottest and rainiest months occur in the summer, and the coldest and drought period are in the winter. Both Geoffroy's slide-necked turtle and D'Orbigny's slider presented high activity during the dry season. Warm temperatures were recorded during such period (>25 C°), which is important for turtles activity (Kepenis & McManus 1974). Additionally, the drought period offers a higher availability of basking sites due to a lower water level, thus enhancing sunbath activity (Souza & Abe 1999; Souza 2004). Meanwhile, red-eared turtles had more occurrences in the summer, period with higher temperatures and rainfall. As a result, food availability increases, which seems to be an important factor influencing their activity (Morreale et al. 1984).

We recorded more females than males for all three sliders, which has many possible explanations, such as the capture method used, season studied, or even the incubation temperature of the embryo (Dobie 1971; Bull & Vogt 1979; Souza & Abe 2001).Some authors found the same pattern at other locations (Fagundes et al. 2010; Bujes et al. 2011; Silva 2016), however, the opposite pattern also appeared in records for the three species (Morreale et al. 1984; Parker 1996; Bager 2003; Souza & Abe 2000; Souza & Abe 2001; Silveira 2013). It is possible that our study underestimated the abundance of young turtles as a result of lower detectability and/or due to the capture method applied. Neither the trap or fishing clip captured these animals, which occurred only through active search. Therefore, we did not assess the recruitment of juveniles turtles.

Regardless, our results showed a high recapture ratio for all the three species studied, despite the low values for population size and density. The study area is relatively closed, which can provide the permanence of the animals. The park studied hasmany connected lakes, but the connection between the lakes and the stream, which flows out to the park, occurs through a channel. The stream is very shallow and presents consequences of human interference. When the channel reaches the stream, a large drop emerges. These characteristics probably lead the turtles to avoid passing through this path, therefore, the structure of the park, the features of the stream and the mobility across these water bodies may explain the relation between size/density of the population as well as there capture rate (Souza & Abe 2001; Fagundes et al. 2010; Bujes et al. 2011).

In our study site, the native turtle presented low population size (59) and density (1.36 turtle/ha). Estimates of Chelidae population size can reach much higher values according to the habitat conditions, ranging from 16 (*Mesoclemmys vanderhaegei*) to 318 turtles (*Hydromedusa maximiliani*).Protected areas (e.g. Conservation Units) have a higher population size than thosesurrounded by pastures or under some human disturbance (Martins & Souza 2009; Forero-Medina et al. 2011; Marques et al. 2013; Brito et al. 2018). Geoffroy’s slide-necked turtle presented a low density estimate, similarly to the Chelidae *M. vanderhaegei* in a silvicultural system (0.65; Marques et al. 2013). In contrast, the density of *M. dahli* an environment under human impact (livestock around) varies between 16 to 170 turtles/ha, according to the season (Forero-Medina et al. 2011). For the Geoffroy’s slide-necked turtle inhabiting an other urban area, including food supplement from polluted river, the density reached a much higher value in relation to the findings in our study (200 turtle/ha; Souza & Abe 2000). However, since these estimates derive from distinct sample methods and environmental conditions, caution should be considered when establishing a comparison (Forero-Medina et al. 2011).

Despite its small population size, the native Geoffroy's slide-necked turtle had higher population size than the two alien species. Sex ratio (female-biased) representing another parameter with a higher value , supporting the highest parsimony model for this species, in which sex influenced the capturability (Table 1). In contrast, our percentage of recapture recorded for Geoffroy's slide-necked turtle (42%) is much higher than the previous recordsfor this species in other habitat types (2.4%, Souza & Abe 2001; 0.99%, Santana 2016).

The study area presents many anthropic disturbances, such as modification of marginal vegetation, changes in the water bodies structures, recreational fishing (Rocha et al. 2018), and especially the introduction of alien species along with all the associated impacts (e.g. disease transmission, resource competition, and possible extinction of local species; Ziller & Zalba 2007; Bujes 2011; Romagosa 2015). The Geoffroy's slide-necked turtle remain living in these areas despite all the factors of human impacts mentioned. This slider is well known for its resilient capacity to inhabit and prosper in altered areas (e.g. Martins et al. 2010). However, our study was pioneer at analyzing the population dynamics of Geoffroy's slide-necked turtle coexisting , which should receive a continuous monitoring considering all the potential impacts involved. D'Orbigny's slider presented the highest density (1.72 individual/ha) among the species assessed, but in its natural distribution area, it presents a much higher density (7 - 19 individual/ha, Bujes 2008; Bujes et al. 2011), probably because of the park environmental characteristics, as previously mentioned. In contrast, our results evidenced an invasive potential of D'Orbigny's slider. As an alien species, it has features of an established population, reproducing locally and capable to reach new areas (Ziller & Zalba 2007; Ciccheto et al. 2018).Our results also demonstrated changes in the D'Orbigny's slider's behavior in response to capture (i.e. marked turtles shifted their temporary behavior to avoid recapture). Other studies had recorded the wariness behavior during the capture-recapture process for some Emydidae species (Tinkle 1958). In addition, D'Orbigny's slider presented high spatial orientation (i.e. ability to return to nesting areas and to distinguish movement direction; Bager et al. 2012).All these features indicate a complex cognitive ability, which implies further, improved assessments.

Our study points out to the red-eared turtle with the lowest density (0.87 turtle/ha) and population size (20). The literature introduces studies encompassing other locations in which the high population size and density estimated relate to the size of the area sampled, much larger than ours(Parker 1996; Gibbons 1970; Abigayle 2009). Additionally, we applied a different method to our investigation and some of the sampled areas were undergoing the introduction of the animal. It is important to emphasize that these factors can influence the estimates (Abigayle 2009). Our study area is a public park, and Red-eared turtle had been recorded for this type of environment on nearby the city (Grou 2015); therefore, it is rather likely that this species had been introduced by local people (Romagosa 2016). Some authors suggest human traffic as the fundamental triggering factor for the introduction of Red-eared turtle distribution, and not the expansion of established populations(Thomson et al. 2010). Currently, it is illegal to trade this slider species in Brazil, which is probably the reason for the recent lower incidence of introduction of new individuals. In addition, we found evidence of their reproduction and settling in the area studied (i.e. females nesting, males displaying court behavior, and presence of juveniles).

Currently, only a few studies propose to analyze the population ecology of Brazilian freshwater turtles, and even fewer investigate their movement pattern, home range or habitat selection (Fachín-Terán et al. 2006; Famelli et al. 2016; Leão et al. 2019). The alien D'Orbigny's slider and the native Geoffroy’s slide-necked turtle seem to have similar size according to the home range estimated in this study; in addition to the same similarity between males and females. However, our data allowed to estimate such parameter only for a single individual of native species, and one male, which implies an impossibility to support this similarity. Moreover, we also acknowledge that the home ranges size estimated in this study may dependent on the scale of the trapping grid used, but we believe the information provided from our investigation to contribute to the knowledge on the ecology of these species.

Nevertheless, the home range and movement pattern of freshwater turtles estimated in other types of habitat types are similar to our findings. Even though the home range size of alien D'Orbigny's slider (0.04 - 0.48 ha) is low, it is within in the range estimated for Emydidae species, which varies between 0.003 ha (*Glyptemys muhlenbergii*) and 61.2 ha (*Emydoidea blandingii*) (Morrow et al.2001; Arvisais et al. 2002; Donaldson & Echternacht 2005; Litzgus & Mousseau 2006; Edge et al. 2010; Fortin et al. 2012).The home range estimated for a single Geoffroy's slide-necked also presented a low value (0.26 ha), but higher than that estimated by Souza et al. (2008) for the same species in an urban river (0.04-0.12 ha). According to the authors, the small areas recorded probably reflect the high supplementation of food by the polluted river. For Brazilian Chelidae species, the home range size varies from 0.2 ha (*Hydromedusa maximiliani*) to 16 ha (*Mesoclemmys dahli*) (Magnusson et al. 1997; Forero-Medina et al. 2011; Famelli 2013).

Regarding habitat preferences, the species did not use overall habitat randomly at their home ranges, but preferred areas with presence of walkways. This behavior is expected since the study site is located in a public park inside an urban area frequently visited by residents and tourists. We had previously observed people feeding wild animals, including sliders (pers. obs.), inside the park studied. Regardless of being intentional, supplementary feeding of wildlife can generate severe problems, such as altered animal behavior and damages to natural ecological processes (Green & Giese 2004).

Furthermore, we found the maximum range of movement for the D'Orbigny's slider, which was the only only species to show a significant positive relation between the maximum distance ranged and carapace length. Similar results had been registered for populations of turtles in Brazil (*P. geffroanus*– Souza et al. 2008; *T.dorbigni*– Bager et al. 2012). Some variables are able to influence the home range and dispersal of freshwater turtles, such as environmental structure, presence of predators, availability of reproduction area, and food availability (Souza & Abe 2000; Compton et al. 2002; Cosentino et al. 2010; Paterson et al. 2012; Ghaffari et al. 2014).

Our results revealed similar population parameters, home range and habitat selection between native and alien species of freshwater turtles coexisting in urban environment. The urban features influence the movement of these sliders, especially the presence of walkway (presence of feeders). We also recorded that both of the alien species are established (currently reproducing), especially according to the results found for D'Orbigny's slider, highlighting its potential as an invasive alien species. Therefore, it is fundamental to maintain the monitoring of freshwater turtles inhabiting in *Parque do Ingá* in order to assess the dynamics of both native and alien populations over the following years. It is important that Brazilian environmental authorities are attentive to our results to support and provide legal and political infrastructure to projects involving urban fauna, especially those including alien species. It is essential to apply such strategy at national and regional levels with elements to prevent and control the distribution of alien species by training technicians, creating public policies, investing in education and research, and fostering an integrated management between society and government (Ziller & Zalba 2007). The information in this study can support management plans for the context of urban parks in the city of Maringá.

2. Home range and habitat selection of an alien turtle species in the Southern Brazil: the D'Orbigny's slider (Emydidae:Testudinae)

Área de vida e seleção de habitat de uma espécie exótica de quelônio no Sul do Brasil: o Tigre d'água (Emydidae:Testudinae)

Áreas de campeo y selección de habitat de una especie de tortuga exótica en el Sur de Brasil: la Tortuga pintada (Emydidae:Testudinae)

Abstract

Different alien species have been invaded freshwater ecosystems, such as freshwater turtle. Increasing knowledge about homing patterns and individual movement is crucial to understand the activity of potential damaging species to the environment. Therefore, our main goal in the present study was to provide information from radio tracking data regarding to home range, habitat selection and maximum distance range by D'Orbigny's slider (*Trachemys dorbigni dorbigni*) as an alien species. We captured ten D'Orbigny's slider (nine females and one male)in an urban park in southern Brazil, and we tracked then between September 2017 and May 2018 by radio transmitter. Our results revealed a mean home range of 1.90 ha (KDE 95%) and 3.39 ha (MPC 100%), and this was dependent to body size. Studied turtles selected habitats with urban features, in particular with presence of feeders. Our results showed that D'Orbigny's slider as an alien species present an established population, with high availability of food, and with potential to reach new areas. Long term monitoring should be considered by authorities to assess its expansion in urban areas to control this alien species.

Resumo

Diferentes espécies exóticas têm invadido os ecossistemas de água doce, como as quelônios-de-água-doce. O aumento do conhecimento sobre os padrões de área de vida e movimento individual é crucial para entender a atividade de possíveis espécies que podem causar danos ao ambiente. Dessa forma, o principal objetivo do presente estudo é trazer informações através de rádio telemetria a respeito da área de vida, seleção de habitat e máxima distância alcançada pela espécie introduzida Tigre d'água (*Trachemys dorbigni dorbigni*). Nós capturamos dez Tigre d'água (nove fêmeas e um macho) em um parque urbano no sul do Brasil, e os rastreamos entre setembro de 2017 e maio de 2018 por meio de rádio transmissor. Nossos resultados apontam para uma área de vida média 1.90 ha (KDE 95%) e 3.39 ha (MPC 100%), e este parâmetro foi dependente do tamanho do corpo. Os animais selecionaram ambientes com características urbanas, principalmente com a presença de pessoas que os alimentam. Nossos resultados mostraram que o Tigre d'água, como espécie exótica, apresenta população estabelecida, com alta disponibilidade de alimento e apresenta potencial para alcançar novas áreas. O monitoramento a longo prazo do Tigre d'água deve ser considerados por autoridades ambientais de modo a avaliar sua expansão em áreas urbanas e prever ações para controlar essa espécie exótica.

Resumen

Diferentes especies exóticas han invadido los ecosistemas de agua dulce, como las tortugas de agua dulce. Incrementarar el conocimento sobre los patrones de area de campeo y el movimiento individual es crucial para comprender la actividad de especies potencialmente daniñas para el medio ambiente. Por lo tanto, el objetivo principal del presente estudio es proporcionar información de radio telemetría sobre la área de vida, la selección del hábitat y la distancia máxima alcanzada por la especies introducida Tortuga pintada (*Trachemys dorbigni dorbigni*). Capturamos diez Tortuga pintadas(nueve hembras y un macho) en un parque urbano en el sur de Brasil, y los rastreamos entre Septiembre de 2017 y Mayo de 2018 por un transmisor de radio. Nuestros resultados apuntan a un área de vida promedio de 1.90 ha (95% KDE) y 3.39 ha (100% MPC), y este parámetro dependía del tamaño corporal. Los animales seleccionaron ambientes con características urbanas, principalmente con la presencia de personas que los alimentan. Nuestros resultados mostraron que la Tortuga pintada como especie exótica tiene una población establecida con alta disponibilidad de alimentos y potencial para alcanzar nuevas áreas. El monitoreo a largo plazo debe ser considerado por las autoridades ambientales para evaluar su expansión en áreas urbanas y controlar esta especie exótica.

Introduction

Freshwater ecosystems have been heavily invaded by many different alien species (Strayer 2010).Turtles are one of these alien species which are introduced in the freshwater system directly by human, principally through trade of pets (Lowe et al. 2000; Kraus 2003).There is an overall lack of knowledge regarding the introduction of alien species in Brazil. Hence, applied research should be developed to build a framework to prevent, manage and, if necessary, to control the invasive alien species (Ziller & Zalba 2007).Increasing our knowledge about homing patterns and individual movement is crucial to understand the activity of potential damaging species to the environment. These type of study may be even more essential when involve problems associated with habitat fragmentation, climate change, spread of diseases/pests, and biological invasions (Nathan 2008;Türkozan et al. 2019).Therefore, information about spatial-temporal distribution and movement patterns of alien species are key to facilitate its management (Ziller & Zalba 2007; Hawkes et al. 2011).

The D'Orbigny's slider (*Trachemys dorbigni dorbigni)* (Duméril&Bibron 1853), was one of the most abundant freshwater turtle in Rio Grande do Sul, the only state in Brazil where it is considered a native species (Bujes & Verrastro 2008; Bujes 2010). Currently, this slider is near threatened as result of the intense human impact over its population (e.g. commercial trade of hatchling) (IUCN 2019). Due to trading as pet, it is reaching new areas in South America as an alien species, mainly in urban areas (Santos et al. 2009; Alcalde et al. 2012; Santanaet al. 2014; Ciccheto et al. 2018). Information about the ecology of D'Orbigny's slider within its natural distribution range has been published in several studies (eg. Bager et al. 2007; Fagundes et al. 2010; Hahn et al. 2014). However, these information is neglected from those areas where this slider has been introduced and even less in urban areas. Increasing our knowledge regarding the spatial ecology and habitat preferences of an alien slider is key to understand its potential invasions capacity. Therefore, our main aim in this study was to provide novel knowledge regarding the ecology of the species in an urban area where it has been introduced. In particular we monitored sliders through radio-tagged animals to determine their home range size, habitat preferences and maximum distance ranged by individuals. This would facilitate the efficiency and effectiveness for future slider management in urban areas.

Material and Methods

Data collection

This study was carried out at a Municipal park called Parque do Ingá, in Maringá City (23°25'S, 51°55'O), state of Paraná, Brazil (see detailed description in General Introduction session). We captured the animals with two methods: active search and a Fishing clip (Appendix A), during monitoring between September 2017 to May 2018. After capture, we recorded the body measures of each individual (e.g. carapace length and body mass), we sexed them based on secondary sexual characteristics (Fagundes et al. 2010), and marked with epoxy numbers glued on the slider carapace. A total of 10 adult D'Orbigny's sliders (nine females and one male; Figure 1A) were tagged with very high frequency (VHF) radio telemetry (Transmitter VHF TIGRINUS, version 1.2, Tigrinus Equipamentos para Pesquisa, Timbó, Brazil). We attached the VHF component to the upper middle of the carapace, with epoxy glue (Figure 1B). The entire package attached to the turtles not exceeded 7% of the individual's body mass, conform recommended by Schubauer 1981. We tracked the individuals on a weekly basis during the entire study period.

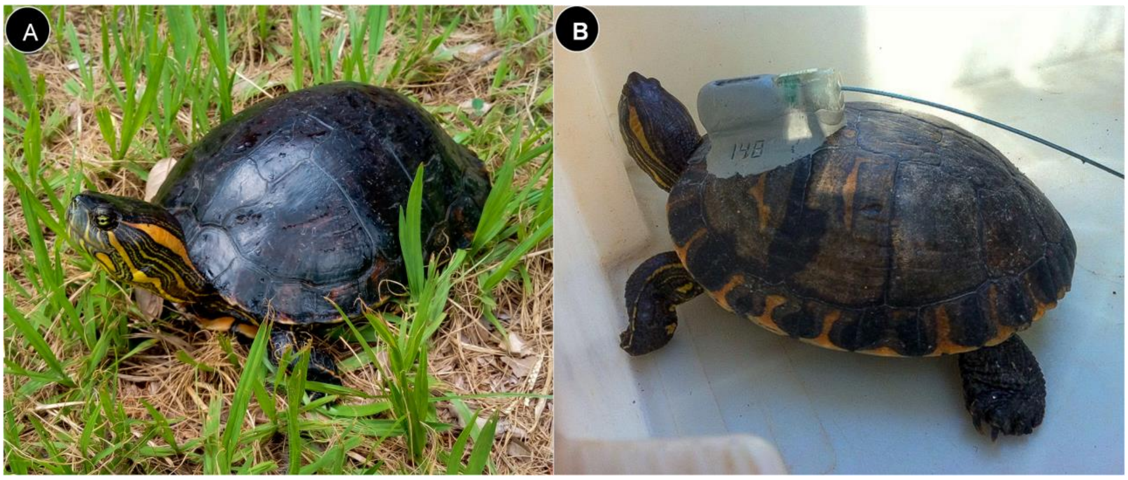


Figure 1. D'Orbigny's slider (*Trachemys dorbigni dorbigni*) after capture (A) and with radio transmitter VHF attached in the carapace (B). Photo: Grou, C. E. V., Rocha, S. B.

Data analysis

Slider home ranges were calculated with two estimators: 95% and 50% kernel density contour range estimates (KDE95 and KDE50, respectively) (Worton 1987), and 100% minimum convex polygons (MCP100) using 'adehabitatHR' package (Calenge 2006) in the R statistical computing environment (RStudio Team 2016).The KDE95 estimate corresponds to the smallest area over which the probability of locating an animal is 0.95 (Calenge 2006). This estimator generally provides more accurate estimates of range use than the MCP100 (Seaman et al. 1999; Borger et al., 2006), as the MCP100 includes longer-distance forays away from the core home range (Laver & Kelly 2008).Similarly for the KDE50 estimate, the probability of locating an animal is 0.5,and generally represent the core area of the home range (Matthews & Green 2012). The KDE estimates were calculated using the least-squares cross-validation (LSCV) smoothing parameter (Seaman et al. 1999), and the MCP estimates were calculated using the harmonic mean peel center (Blackie et al. 2011).Despite MCP provide a simple and crude outline of a home range, for amphibians and reptiles this is the recommended estimator to calculate home range size (Row & Blouin-Demers 2006). However, we decided to calculate both estimates in order to allow comparisons with other studies. Additionally, we used linear regression to evaluate if there were a lineal relationship between body size (carapace length) and home range size. We ran separate models for each estimator (i.e. MCP100 and KDE95) using package "lme4"in the R statistical computing environment (RStudio Team 2016).

Habitat preference analyses were based on the approach that assumes that all habitat types are equally available to all monitored turtles, but habitat used is measured for each individual (Thomas & Taylor 1990). Habitats were identified by digitizing habitat types from Google Earth aerial photographs using Quantum GIS (QGIS

Development Team 2016, version 2.16). To calculate proportion of habitat availability, we created 700 random points throughout the park area, considering that this species can move both in water and land habitat (Bager & Rosado 2010).To access the habitat selected, we overlaid sliders locations on the map of the area. Each available and selected location were classified as one of the seven types of habitat: I) Vegetation cover; II) Water; III) Walkway - track which people and vehicle can transit; IV) Channel - system which drain water from rainwater/unknown origin to the lake of the park; the point where the channel reach the lake is submerged in water, becoming a concrete burrow; V) Feeders - specific places where local people use to give food to turtles; VI) Basking area - surface available to sunbath; VII) Rest area - small swamp on the edge of the lake, covered by twigs, and far from walkways; at this place turtles dig natural burrows and retreating back at dusk to rest/sleep. Finally, we calculated the proportion of available locations in each habitat types. To evaluate habitat used, we calculated the proportion of fixes in each habitat type for each individual.

To analyze habitat preferences by the individuals we used the adehabitatHS package in the software R. We compared the habitat types used and available through Manly selection ratios. For each animal, a preference ratio was calculated for each habitat type. If habitat preference was the same for all individuals, preference ratios were averaged. If preferences differed between individuals, a factorial analysis was carried out using an eigenanalysis (Calenge & Dufour 2006). This is a useful tool for investigating variability in habitat preference between individuals, and for identifying groups of individuals that choose the same habitat. The analysis assigns scores that maximize the squared deviation between individuals. It also assigns scores to the habitat types that maximize the squared distance between the habitats that are used in proportion to their availability (Calenge & Dufour 2006). The 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 is for habitat types that are selected the most.

Finally, for each individual, we analyzed the maximum range of movement through straight line distance between two farthest locations recorded (Ryan et al. 2014). The climatic data (rainfall) between September 2016 and May 2018 were taken from Instituto Nacional de Metereologia (INMET). To evaluate the effect of rainfall on the mean distance ranged (MDR) per month we used linear regression, being the rainfall as the independent variable and MDR as the dependent variable. We used the package "lme4"in the R statistical computing environment (RStudio Team 2016).

Results

In overall, we recorded 190 slider locations, approximately 19 for each individual. There was a variation in the number of days that the animals were tracked (Figure 2): half of them were tracked for 252 consecutive days (ID 20, 37, 38, 56 57), one slider for 247 days (ID 27), another for 114 days (ID 69), and the others three sliders were monitored for 86 days (ID 8, 43, 78). No terrestrial movement was recorded for animals tracked, being all fixes registered in water (Figure 3). D'Obrigny's slider showed high fidelity to burrows submerged in water (rest area and rain drain channel). All individuals monitored used the rest area at least once, with other turtles; and the drain channel presented the same pattern, however was used only for 7 individuals.

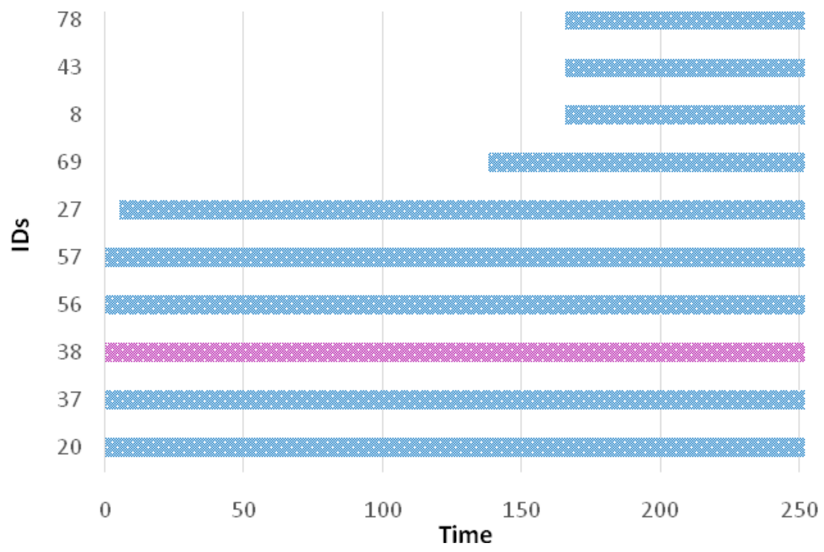
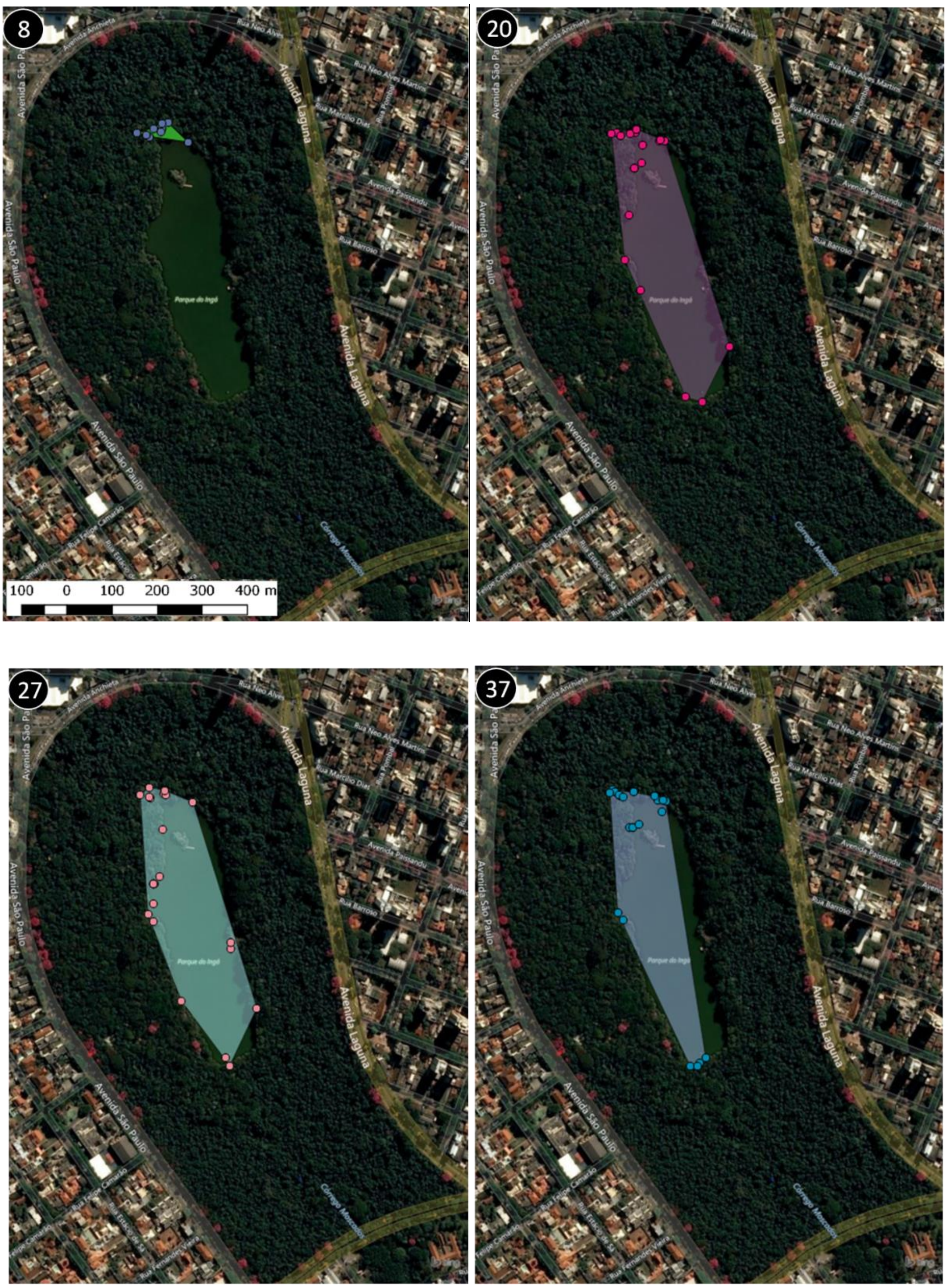
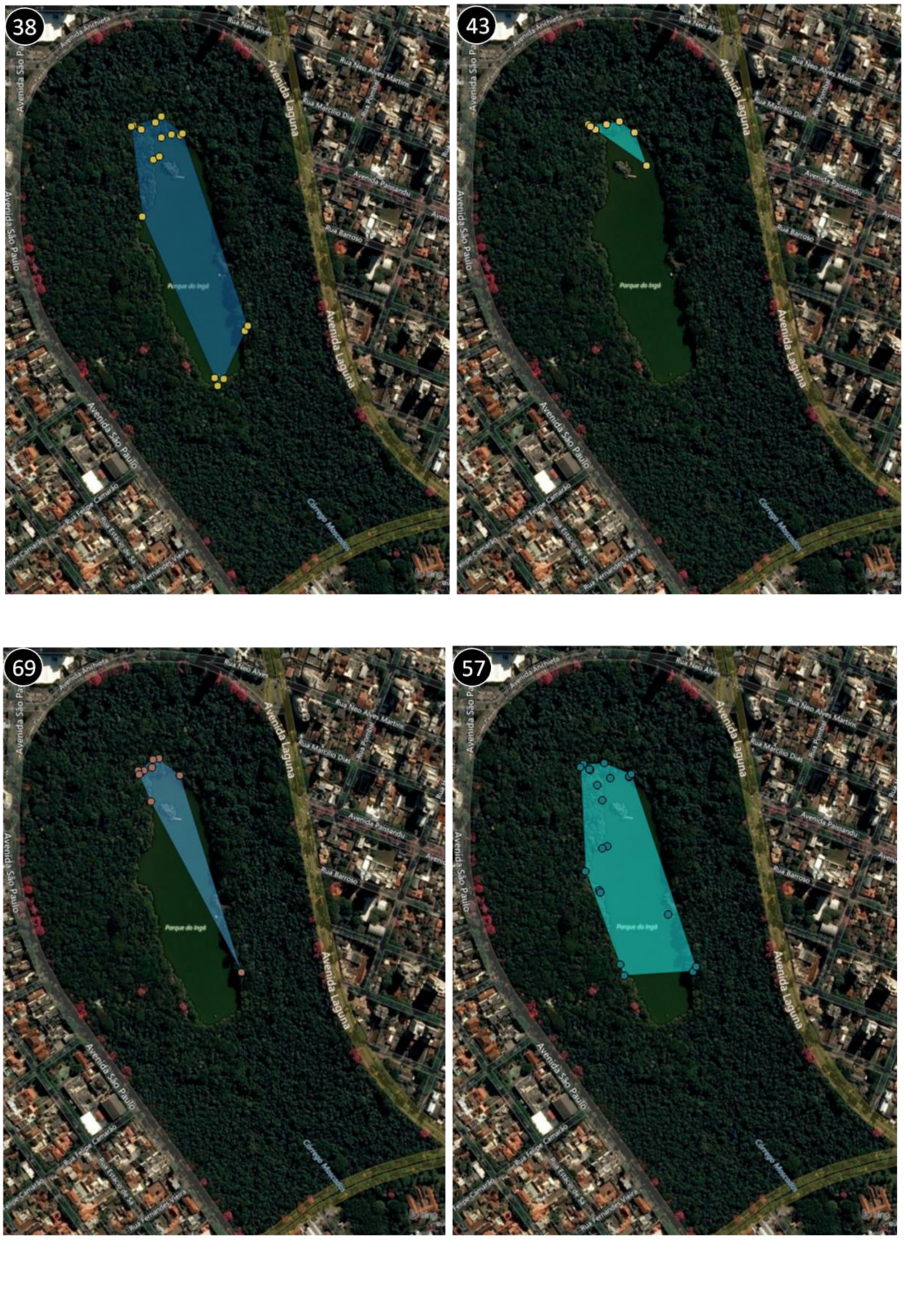


Figure 2. Number of days (Time) which each individual of D'Orbigny's slider (IDs) was radio tracked, from September 2017 to May 2018. Blue bars represents the females (N = 9) and pink male (N = 1).


8
20
27
37
100 0 100 200 300 400 m
Avenida Laguna
Avenida São Paulo


38
43
69
57
Avenida São Paulo
Avenida Laguna
Parque do Ingá

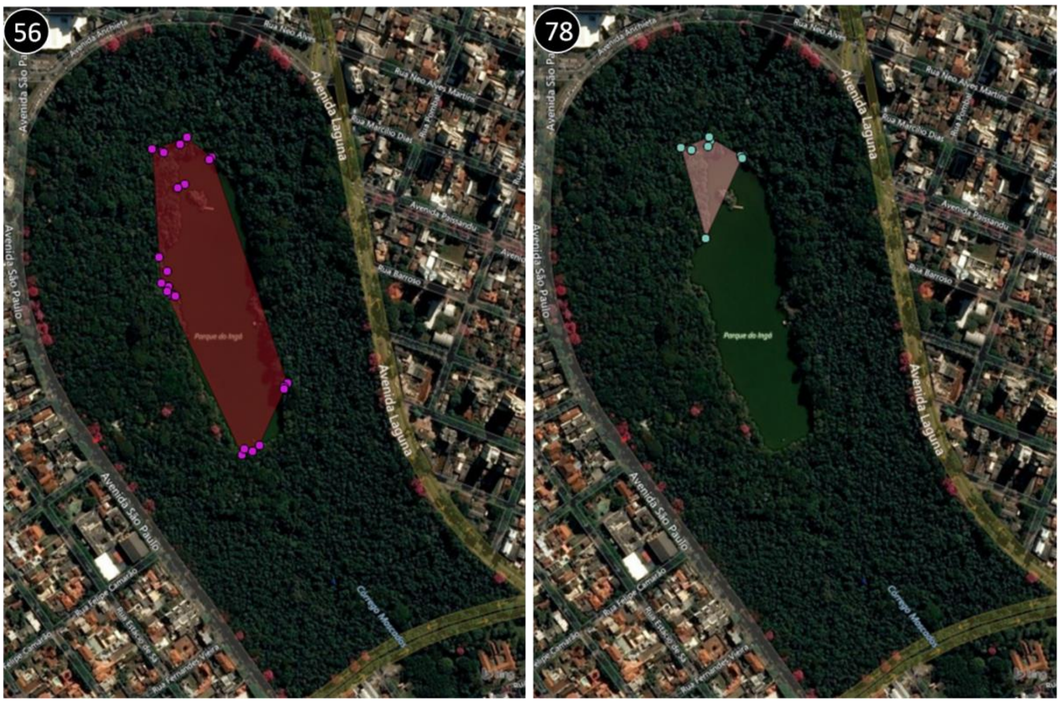


Figure 3. Home range of each D'Orbigny's slider tracked in Parque do Ingá, Paraná state, Southern Brazil. The number on the corner of the image is the individual identification. All individuals are females, except individual 38. Home range estimated by 100% of minimum convex polygon.

The estimative of home range size was different for each estimator used (Table 1). For MCP100 the size estimated varied between0.16 and 6.01 ha (3.39±2.48), whereas for KDE95 the values ranged from 0.78 to 3.09 ha (1.90±0.84),with a mean core area (KDE50) of 0.40 (±0.17).The only male tracked presented home range size included in the range estimated for other individuals (MCP100 = 5.19 ha; KDE95 = 2.13 ha).In average, home range size estimated by MCP100 was nearly twice larger than KDE95. Only for two individuals the home range calculated by MCP100 was smallest than KDE95.

There was a significant relation between carapace length and home range size estimated by MCP100 ($F_{1,8}$ = 7.54, R^2 = 0.48,P = 0.02, Figure 4), however this relationship was not significant for KDE95 ($F_{1,8}$ = 2.89, R^2 = 0.26,P = 0.12).In our study site, most of the available habitat was covered by vegetation (81.4%), whereas the availability of other habitat types was much lower (Water 8.1%; Walkway 6%;Basking sites 1.86%; Rest area 1.29%; Feeders 0.71%; Channel 0.57%). Regarding habitat preferences, our results showed that individuals sliders selected habitats in different ways (Manly´s selection rations chi-square test; X2= 4124.8, d.f.= 6, P <0.001 ,Figure 5). So, we graphically explored the habitats selected by individual sliders using the eigenanalysis (Calenge & Dufour, 2006).This showed a strong preference by two slider for places with feeders, three preferred rest area, followed by basking areas, rain drain channel and one individual selected water. In contrast, places covered by vegetation and walkways were avoided by all tagged sliders (Figure 6).

Table 1. Home range size of 10 D'Orbigny's slider (nine females and one male) radio tracked at urban park, Paraná state, southern Brazil. Area (hectare) estimated by 100% of minimum convex polygon (MCP100), and by kernel density 50% (KDE50) and 95% (KDE95). Gray row represents the only male tracked.

ID	**KDE50**	**KDE95**	**MCP100**
8	0.17	0.78	0.16
20	0.52	2.46	5.65
27	0.60	3.09	5.85
37	0.39	1.90	4.52
43	0.24	1.05	0.34
56	0.56	2.57	6.01
57	0.64	2.92	5.38
69	0.26	1.25	1.75
78	0.25	1.11	0.84
38	0.48	2.13	5.19

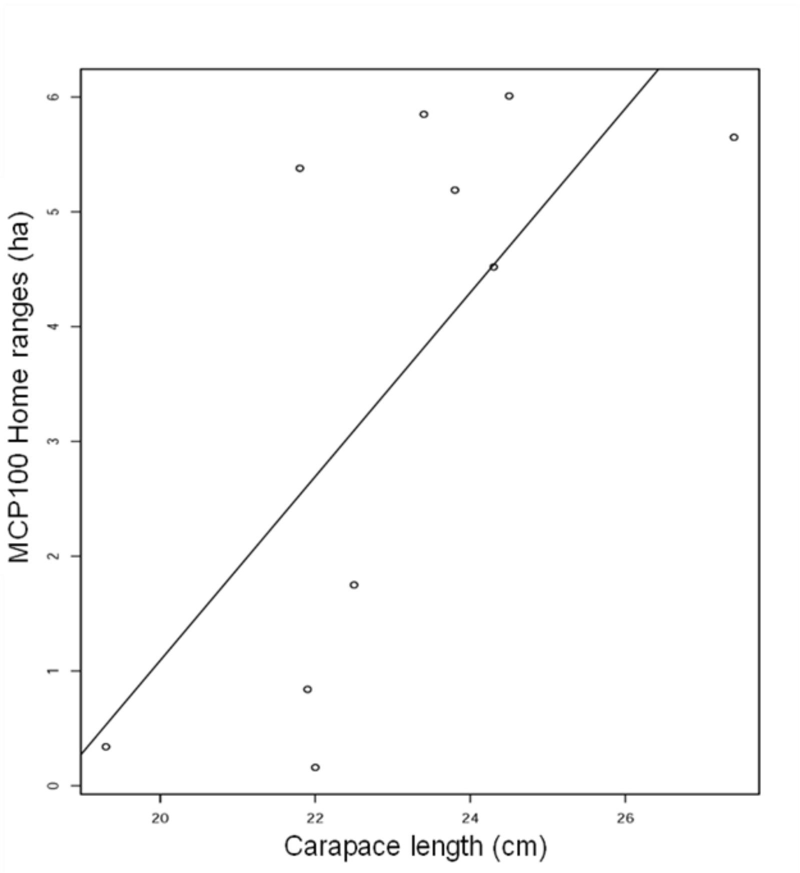


Figure 4. Relation between home range size estimated by 100% minimum convex polygon (MCP100), and carapace length of ten D'Orbigny's slider tracked in an urban park, Paraná state, southern Brazil.

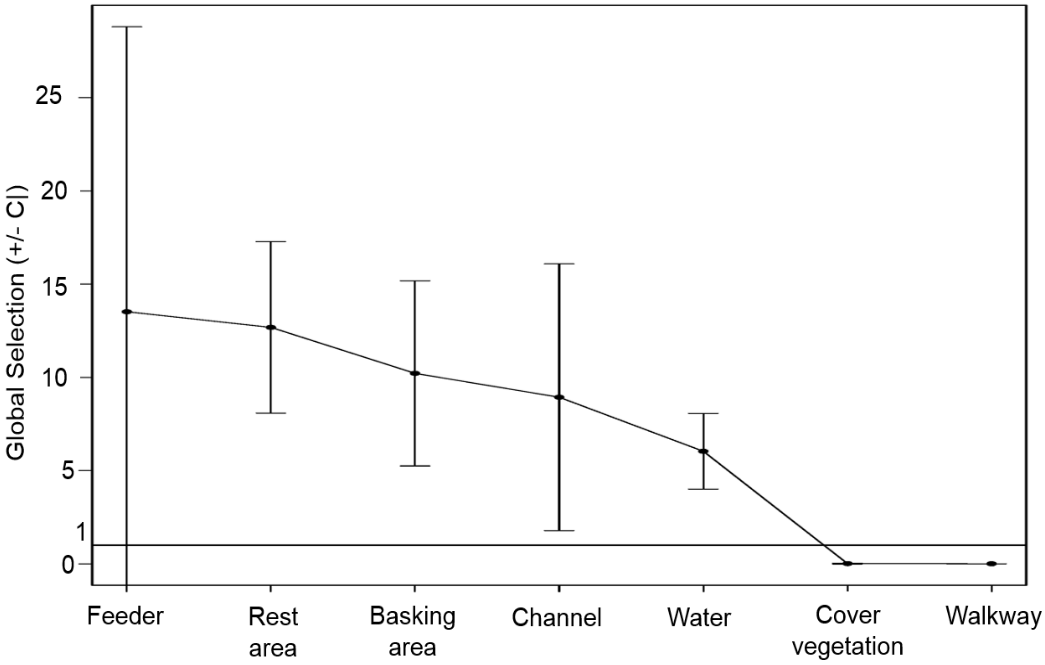


Figure 5. Manly’s selection ratios of habitat use based on radio tracking data of ten D'Orbigny's slider. Values above 1 indicate habitat selection relative to availability; values below 1 indicate avoidance. Channel = Rain drain channel; Feeder = places where local people give food to turtles.

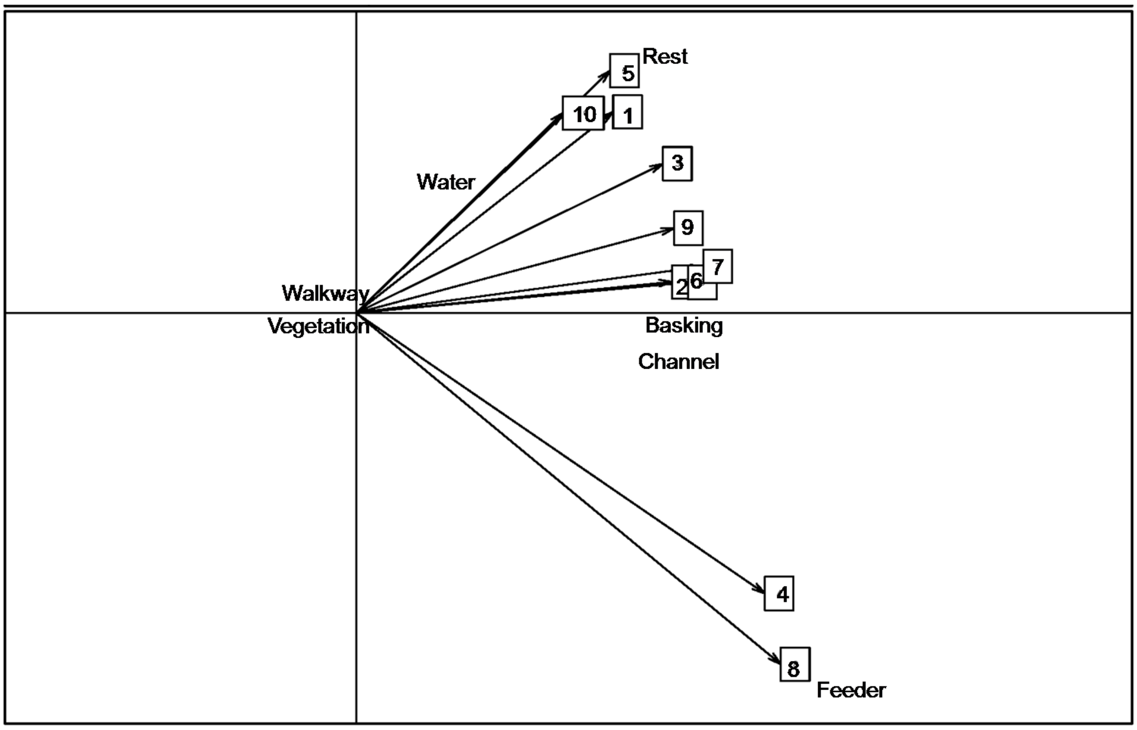


Figure 6. Results of eigenanalysis of selection rations, showing habitat preference by individual radio tracking data of ten D'Orbygny's slider, using design II. The arrow length represents the selection by individual for the habitat type indicated (the longer is the arrow, the greater is the preference).

The maximum distance ranged by sliders spanned from 33.60m to 410.40 m, and we recorded a changing in the distance ranged by turtles over the months (Figure 7). The mean distance moved for all individuals reached maximum value in October 2017 (312.7m), same period which the rainfall increased (311.9mm), and after a drought period in the region. In January 2018, month with highest value of total rainfall (357.7 mm), movement of the sliders had risen again, however, they moved less than in October (mean of 92.62m). Between March and May 2018 the animals decrease them movement and remain for many days in the small lakes. Although, the relationship between rainfall and mean movement ranged per month was not significant ($F_{1,7} = 3.10$, $R^2 = 0.30$, $P = 0.12$).

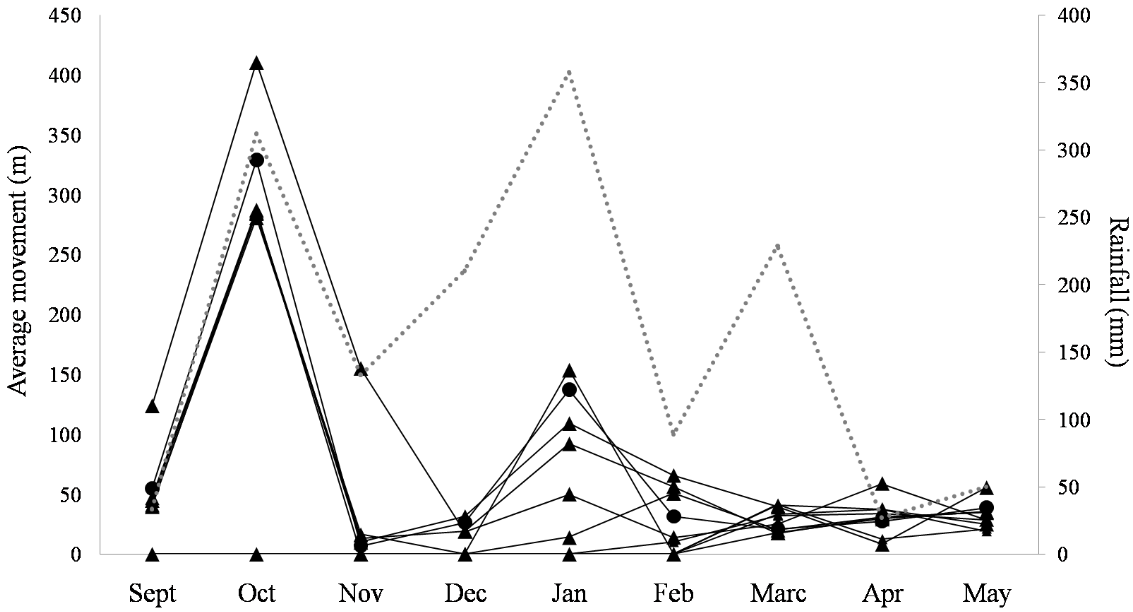


Figure 7. Mean range of movement per month for 10 D'Orbigny's slider monitored by telemetry, and mean rainfall from September 2017 to May 2018, in urban park in southern Brazil. Triangle means females (N = 9), and circle male (N = 1). Dashed line represents rainfall.

Discussion

Our study presents for the first time data regarding to spatial ecology of D'Orbigny's slider as an alien species in Brazil. Nine months tracking D'Orbigny's slider at urban setting revealed that its movement is restrict to the park area, and it is influenced by urban features, especially by presence of park users who feed these animals. Sliders were tracked only inside water, and the home range of the male and females presented similar size.

Previous studies on Emydidae species have shown that home range size varies depending of the mating season, gender, and structure of the environment (e.g. Morrow et al., 2001; Litzgus & Mousseau 2006). The small home range estimated for D'Orbigny's slider in the current study is similar to other turtles inhabiting similar antrophic systems (Morrow et al. 2001; Donaldson and Echternacht 2005). Donaldson and Echternacht (2005) for example, studied the Eastern Box Turtles (*Terrapene carolina carolina*) in an environment under human impacts (e.g. presence of road, pipelines), and in this study the authors calculated the home range size as 1.88 ha (by MPC100%), and 2.26 ha (by KDE95%). Similarly, Morrow et al. (2001) found a very small home range size for Bog turtle (*Clemmys muhlenbergii*) monitored in an area under human disturbance (pasture, agriculture); in this study the home range varied between 0.03 and 3.12 ha (KDE95%).On other hand, in a pristine area Edge et al. (2010) found larger home ranges for Blanding’s turtles (*Emydoidea blandingii*); 57.1 ha for males and 61.2 ha for females (by Kernel 95%). For the Wood turtle (*Clemmy sinsculpta*) inhabiting a protected area, the mean estimate of home range size was 28.3 ha (by MPC95%; Arvisais et al. 2002).In other preserved area, Litzgus & Mousseau (2006) calculated the home range size for Spotted Turtle (*Clemmys guttata*)varying between 19,06 ha (by MPC100%) and 10.36 ha (by KDE95%). Taking into account these studies, the home range estimated here for D'Orbigny's slider suggest the environment features, and also the own species characteristics, may determine its sizes.

The park studied is inside the city, surrounded by buildings and roads; In addition, the water body structure changes when flows out to the park. Inside the park there are many lakes connected among them, and the connection with the polluted stream outside of the park is made by a channel. These characteristics are probably influencing the turtle permanence within the park, as the result the home range is restricting to this area. Other reason which is likely related to the permanence in the park and the small home range size is the feeding activity, since the habitat preferences analysis results pointed out the animal resource requirements (Perry & Garland Jr. 2002). D'Orbigny's slider in this park mostly feed on vegetal matter (seeds, fruits, leaves; Borges 2018), and the riparian forest is an important source of food for the animals. Moreover, there are people who use to give food to these sliders (e.g. bread, snacks), and it may supplement its diet. Therefore, there is plenty of available food to D'Orbigny's slider in this area.

Other variables which can influence the home range estimate is the method used to record the individual locations and the type of estimator employed (Ryan et al. 2008).In the first chapter, we calculated the home range size of five D'Orbigny's slider based on capture-recapture data. The estimative was smaller (0.31±0.21), however is similar to the core habitat calculated by Kernel 50% (0.40 ha ± 0.17).This is expected seem home range size based on capture, mark and recapture is directly dependent on the size of trapping grid (Efford et al. 2004). Our results shows that through radio telemetry data we can generate more accurate values of home range size, since we monitored individuals (N=10) more frequently and with more accurately recorded locations.

Regarding to the home range estimators (i.e. MCP100 or KDE), we should consider the group studied, the sample size, and the structure of the water body to choose the best estimator to use (Plummer et al. 1997; Row & Blouin-Demers 2006). Kernel estimator for example, provide an estimate of home range based on a nonparametric probability density approach, including the amount of time which each individual has spent in its home range (Worton 1989). This estimator is widely accepted, however, for amphibians and reptiles it is not recommended due to low mobility of individuals and habitat fidelity presented by many species (Row & Blouin-Demers 2006). As many amphibian and reptiles, D'Orbigny's slider often used the same area multiple times during long time of the periods, and they do not move frequently. Based on Row & Blouin-Demers (2006) and considering the low sample size presented in our study, we suggest that MCP would be more realistic estimator to calculate home range size for the species.

The home range as dependent of body size is expected, since larger individuals which require more nutrients, may foray larger areas in order to satisfy its nutricional requirements (Mysterud et al. 2001; Harestad & Bunnel 2006). Across lizards for example, this pattern is strongly positive, and reflect the type of lizard diet(Perry & Garland Jr. 2002). Such relationship has been recorded for turtles in urban area before, as well as the influence of availability of basking sites, and breeding season (Cagle 1944; Litzgus & Mousseau 2006; Souza et al. 2008).

Considering the size of the park (44.33 ha) the sliders used a very small area (1.90 - 3.39 ha) compared to what is available which is highlighted by amount of habitat not used by sliders. All locations recorded were inside the water, however this species present the capacity to move in both aquatic and terrestrial habitats (Bager et al. 2010). Considering that we monitored the sliders during egg laying season, is very likely that females moved to the land. At this period, this slider can extend its movement in land up to 250 m from water, whereas the most frequent distances found ranged is between 20 m and 50 m (Fagundes 2007; Bager & Rosado 2010). Based on the records of nesting areas very close to the main lake of the park (about 5 - 10m; *pers. obs*) and on our radio tracking data, we suggest that females do not move far from the main water body in this park, avoiding spending lots of time in land. The land disturbance caused by people and vehicles can provide movement avoidance by sliders which has been recorded for turtles living in urban areas before (Ryan et al. 2008; Ryan et al. 2014).

Habitat selection analysis showed that walkways is being avoided by D'Orbigny's slider (different than Chapter 1). In this chapter, due to the higher number of fixes recorded, was possible to separate the walkways locations to the places with walkways plus feeders, classified here only as presence of Feeders. In addition, our results revealed that the most preferred habitat is with presence of Feeders, showing that the sliders prefer places with people who supplement its diet, instead of places where only is a track of people and vehicles. These results highlight the learning capacity of this species. D'Orbigny's slider presented changes on its behavior after capture sessions to avoid recapture (see Chapter 1), and showed great spatial orientation - being females able to discern the direction of its movement and returning to nest sites (Bager et al., 2012). Therefore, this species seems to have high cognitive capacity that should be studied.

The rest area was the other habitat category selected by D'Orbigny's slider, which presented a high fidelity to this sites. Different than the concrete burrow (channel), this site did not present human interference, and the sliders used them to dig they own burrow. Since they were recorded retreating back at dusk, and they were found in immobility state inside the water (visual observation and mortality sensor activated), that place seems to be used as sleep area (Libourel & Herrel 2015). There is little knowledge about the use of these areas for overnighting among turtles, however it has been recorded for other Emydidae species, such as *Terrapene carolina triunguis T. carolina. carolina*, and *Trachemys scripta elegans* (Stickel 1950; Abigayle 2009; Riedle et al. 2017).

Rain drain channel was other habitat type selected by turtles which present human features. This site receives water mainly from rain/unknown origin, and may carry lead leaves, organic matter, and also garbage with water. These channels retain part of these matters, and can be used by turtles as a shelter or burrow and also as place with food. Burrow fidelity was already recorded for freshwater turtles, such as the sedentary Chelidae *Hydromedusa maximiliani* (Famelli et al. 2016) and for the Emydidae *Clemmys guttata* (Litzgus et al. 1999). The spotted turtles (*C.guttata*) presented similar behavior as D'Orbigny's slider, since they presented fidelity to its burrows in winter season, which presented very alike features of rest area (swamp place). In addition, spotted turtle as D'Orbigny's slider, use this hibernacula together with other turtles (up to nine individuals). However, there is no pattern regarding to the use in group or alone of these hibernacula areas in both studies. In the urban park studied, the use of the same area by many individuals to rest is likely related to the selection of the features, instead of be a group behavior. Since the rest area is undisturbed (considering the other places in the park), and a protected place (water covered by branches), these features seems to make this area a safe place to spend the night.

The fluctuation of distance ranged over the months, even without significant relation , tends to be closely associated to climate conditions (rainfall and temperature) (Souza 2004), and also attributed to egg laying season, since most of tracked individuals are females (N=9). The highest movement occurred in October 2017 and January 2018, period of nesting activity (Bager et al. 2007; Fagundes et al. 2010;Tortato et al. 2014).This wet season with warm weather, increase the body temperature of females, as well as prevent eggs desiccation (Moll & Legler 1971).The movement of D'Orbigny's slider was already studied in its natural distribution area, and showed mean distance ranged for females of 545m and 523m (Bager et al. 2012). Our estimates of movement were lower, and as mentioned before, can reflect the structure of the park which limit the distance moved by the sliders.

The results of this study showed that D'Orbigny's slider as an alien species is established (reproducing), with high availability of food, and present potential to reach new areas. In addition, recent study showed that the alien species may be a best competitor for resource against the native *P. geoffroanus* (Rocha et al. in prep.). In this study, D'Orbigni's slider species remained for longer periods at the sunbath areas and also, showed faster capture of food, highlighting the damage potential of the alien species to the native.

Long term monitoring of D'Orbigni's slider and the other turtles which coexist in the areas should be considered, to continue analyzing the populations at the park. In addition, considering that the water body inside and outside are connected, this area structurally is like a matrix of biological invaders. Since the park protects river sources which flow into larger rivers, the water bodies can lead the associated fauna (i.e. D'Orbigny's slider). Finally, an environment education is needed in this park to inform the local people about the problems associated with the alien species (i.e. disease, resource competition with native species) and avoid future pet releases. In Brazil we do not have information about the problems that this species is bringing around the ten states where it has been introduced. Nevertheless, based on the huge impact caused by the congeneric Red-eared turtle (*T. scripta*) around the world (Lowe et al. 2000), it is necessary to carried out actions to avoid similar problems with this slider in Brazil. Failure to act may facilitate future invasions, and therefore, losing the opportunity to solve this problem before hand. Thus it is essential that the Management Plan of Parque do Ingá consider and use the information presented here considering the potential invasion of D'Orbigny's slider.

General Conclusion

At urban areas, our results revealed that anthropic features is influencing the movement of *Phrynops geoffroanus* (Geoffroy's slide-necked turtle) , *Trachemys dorbigni dorbigni* (D'Orbigny's slider) and *Trachemys scripta elegans* (Red eared turtle). The data recorded by radio telemetry demonstrated more accuracy and supported more detailed monitoring of turtles. Our results proved that the sliders may live long period in the park, at least two years. Even with similar demographic parameters, the presence of two alien species (Red eared turtle and D'Orbigny's slider) seems to be able to bring future problems regarding to its potential of invasion. Special attention should be given to the alien D'Orbigny's slider, which showed characteristics that support its high cognitive capacity.

We strongly suggest long term monitoring of the three species to continue analyzing the dynamic of the population, mainly with the alien species *T. d. dorbigni*. In addition, social programs should be developed to avoid future introductions of alien species (pet release). Our data should be used as a framework for management of wild urban species.

Literature cited

Abigayle NPK. 2009. Ecology of non native red eared sliders in Singapore and their potential impact on the native fauna of Singapore. Ph.D. Thesis, National University of Singapore, Singapore.

Alcalde L, Derocco NN & Rosset SD. 2010. Feeding in Syntopy: Diet of *Hydromedusa tectifera* and *Phrynops hilarii* (Chelidae). Chelonian Conservation and Biology 9: 33-44.

Alcalde L, Derocco NN, Rosset SD & Williams JD. 2012. Southernmost localities of *Trachemys dorbigni* and first record of *Trachemys scripta elegans* for Argentina (Cryptodira: Emydidae). Chelonian Conservation and Biology 11: 128-133.

Arvisais M, Bourgeois J-C, Lévesque E., Daigle C, Masse D & Jutras J. 2002. Home range and movements of a wood turtle (*Clemmys insculpta*) population at the northern limit of its range. Canadian Journal of Zoology 80: 402-408.

Bager A. 2003. Aspectos da biologia e ecologia da Tartaruga Tigre D'Água, *Trachemys dorbigni*, (Testudines, Emydidae) no extremo Sul do Estado do Rio Grande do Sul - Brasil. Ph.D. Thesis, Universidade Federal do Rio Grande do Sul, Brasil.

Bager A, Freitas TRO & Krause L. 2007. Nesting ecology of a population of *Trachemys dorbigni* (Emydidae) in southern Brazil. Herpetologica 63: 56-65.

Bager A, Freitas TRO & Krause L. 2010. Morphological characterization of adults of Orbigny's slider *Trachemys dorbignyi* (Duméril & Bibron 1835) (Testudines Emydidae) in southern Brazil. Tropical Zoology 23: 0-000.

Bager A, Krause L & De Freitas TRO. 2012. Fidelity to nesting sites and orientation of *Trachemys dorbigni* (Duméril & Bibron, 1835) (Testudines: Emydidae) female in southern Brazil. Tropical Zoology 25: 31–38.

Bager A & Rosado JLO. 2010. Estimation of core terrestrial habitats for freshwater turtles in southern Brazil based on nesting areas. Journal of Herpetology 44(4): 658-662.

Beaugeard E, Brischoux F, Henry P Y, Parenteau C, Trouvé C & Angelier F. 2019. Does urbanization cause stress in wild birds during development? Insights from feather corticosterone levels in juvenile house sparrows (*Passer domesticus*). Ecology and Evolution 9(1): 640-652.

Blackie HM, Russell JC & Clout MN. 2011. Maternal influence on philopatry and space use by juvenile brushtail possums (*Trichosurus vulpecula*). Journal of Animal Ecology 80: 477-483.

Bluett R & Cosentino B. 2013. Estimating occupancy of *Trachemys scripta* and *Chrysemys picta* with time-lapse cameras and basking rafts: a pilot study in Illinois, USA. Transactions of the Illinois State Academy of Science 106: 15-21.

Borkowski RDVM. 1997. Lead Poisoning and Intestinal Perforations in a Snapping Turtle (*Chelydra serpentina*) due to fishing gear ingestion. Journal of Zoo and Wildlife Medicine 28(1): 109-113.

Borges TF. 2018. Dieta de duas espécies congenéricas de quelônios em um parque urbano. Trabalho de Conclusão de Curso, Universidade Estadual de Maringá, Brasil.

Bower DS, Hutchinson M & Georges A. 2012. Movement and habitat use of Australia's largest snake-necked turtle: Implications for water management. Journal of Zoology 287: 76-80.

Bower DS, Hutchinson M & Georges A. 2012. Movement and habitat use of Australia's largest snake-necked turtle: Implications for water management. Journal of Zoology 287: 76-80

Borchers DL & Efford MG. 2008. Spatially explicit maximum likelihood methods for capture–recapture studies. Biometrics 64: 377-385.

Borger L, Franconi N, Ferretti F, Meschi F, De Michele G, Gantz A & Coulson T. 2006. An integrated approach to identify spatiotemporal and Individual-level determinants of animal home range size. The American Naturalist 168(4): 471-485.

Brito ES, Vogt RC, Valadão RM, França LF, Penha J & Strüssmann C. 2018. Population ecology of the freshwater turtle *Mesoclemmys vanderhaegei* (Testudines: Chelidae). Herpetological Conservation and Biology 13: 355-365.

Bujes CS. 2008. Biologia e conservação de quelônios no Delta do Rio Jacuí – Rs : Aspectos da história natural de espécies em ambientes alterados pelo homem. Ph.D Thesis, Universidade Federal do Rio Grande do Sul, Brasil.

Bujes CS. 2010. Os Testudines continentais do Rio Grande do Sul, Brasil: taxonomia, história natural e conservação. Iheringia Série Zoologia 100: 413-424.

Bujes CS. 2011. Chelonia Project—Study Group for Freshwater Turtle Conservation and Biology in Southern Brazil: Introduction of *Trachemys scripta elegans* in the Jacuí Delta Turtle and Tortoise Newsletter 15: 2-42.

Bujes CS & Verrastro L. 2008. Chelonians from the Delta of Jacuí River, RS, Brazil: habitats use and conservation. Natureza & Conservação 6(2): 157-170.

Bujes CS, Molina FB & Verrastro L. 2011. Population characteristics of *Trachemys dorbigni* (Testudines, Emydidae) from Delta Do Jacuí State Park, Rio Grande do Sul, Southern Brazil. South American Journal of Herpetology 6(1): 27-34.

Bull JJ & Vogt RC. 1979. Temperature-dependent sex determination in turtles. Science 206: 1186-1188.

Calenge C & Dufour AB. 2006. Eigenanalysis of selection ratios from animal radio-tracking data. Ecology 87(9): 2349-55.

Cagle FR. 1944. Home range, homing behavior and migration in turtles. University of Michigan Press (n 61), Michigan, 44pp.

Calenge C. 2006. The package "adehabitat " for the R software: A tool for the Cl. Ecological Modelling 197: 516-519.

Carvalho VT, Martínez JG, Hernández-Rangel SM, Astolfi-Filho S, Vogt RC, Farias IP & Hrbek T. 2017. Giving IDs to turtles: SNP markers for assignment of individuals to lineages of the geographically structured *Phrynops geoffroanus* (Chelidae: Testudines). Conservation Genetics Resources 9(1): 157-163.

Ciccheto JRM, Grou CEV & Rocha SB. 2018. Novos registros de ocorrência de *Trachemys dorbigni* no Brasil. In: Estudo Da Herpetofauna Brasileira (Ed. DP Oldiges), pp. 42-50. Atena Editora, Ponta Grossa.

Close LM & Seigel RA. 1997. Differences in body size among populations of Red-Eared sliders (*Trachemys scripta elegans*) subjected to different levels of harvesting. Chelonian Conservation Biology 2(4): 563-566.

Compton BW, Rhymer JM & Mccollough M. 2002. Habitat selection by Wood Turtles (*Clemmys Insculpta*): An application of paired logistic. Ecology 83(3): 833–843.

Cosentino BJ, Schooley RL & Phillips CA. 2010. Wetland hydrology, area, and isolation influence occupancy and spatial turnover of the painted turtle, *Chrysemys picta*. Landscape Ecology 25(10): 1589-1600.

Costa HC & Bérnils RS. 2018. Répteis do Brasil e suas Unidades Federativas: Lista de espécies. Revista Herpetologia Brasleira 8(1): 11-57.

Deffune G & Klosowski ES. 1995. Variabilidade mensal e interanual das precipitações pluviométricas de Maringá, 1976-1994. Revista Unicesumar 17(3): 501-510.

Destro GFG, Pimentel TL, Sabaine RM, Borges RC & Barreto R. 2012. Efforts to combat wild animals trafficking in Brazil. In: Biodiversity enrichment in a diverse world according (Ed. GA Lameed), pp. 421–436. Intech Open, London.

Dobie JL. 1971. Reproduction and growth in the Alligator Snapping turtle, *Macroclemys temmincki* (Troost). Copeia 1971(4): 645-658.

Donaldson BM & Echternacht AC. 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(2): 278-284.

Edge CB, Steinberg BD, Brooks RJ & Litzgus JD. 2010. Habitat selection by Blanding's turtles (*Emydoidea blandingii*) in a relatively pristine landscape. Ecoscience 17(1): 90-99.

Efford MG, Dawson DK & Robbins CS. 2004. DENSITY: Software for analysing capture-recapture data from passive detector arrays. Animal Biodiversity and Conservation 27(1): 217-28.

Efford MG, Warburton B, Coleman MC & Barker RJ. 2005. A field test of two methods for density estimation. Wildlife Society Bulletin 33: 731-738.

Ernst CH, Lovich JE & Barbour RW. 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington DC, 578 pp.

Fachín-Terán A, Vogt RC & Thorbjarnarson JB. 2006. Seasonal movements of *Podocnemis sextuberculata* (Testudines: Podocnemididae) in the Mamirauá sustainable development reserve, Amazonas, Brazil. Chelonian Conservation and Biology 5(1): 18-24.

Fagundes CK. 2007. Dinâmica populacional de *Trachemys dorbigni* , (Testudines : Emydidae) em ambiente antrópico em Pelotas, Rs. Ph.D. Thesis, Universidade Federal de Santa Maria, Brasil.

Fagundes C, Bager A & Cechin SZ. 2010. *Trachemys dorbigni* in an anthropic environment in southern Brazil: I) Sexual size dimorphism and population estimates. Herpetological Journal 20: 185-193.

Famelli S. 2013. Área de vida, movimentação e seleção de habitat do cágado *Hydromedusa maximiliani* (Testudines: Chelidae) no Parque Estadual Carlos Botelho. Ph.D. Thesis, Universidade de São Paulo, Brasil.

Famelli S, Souza FL, Georges A & Bertoluci J. 2016. Movement patterns and activity of the Brazilian snake-necked turtle *Hydromedusa maximiliani* (Testudines: Chelidae) in southeastern Brazil. Amphibia-Reptilia 37(2): 1-14.

Ferronato BO, Marques TS, Souza FL, Verdade LM & Matushima ER. 2009. Oral bacterial microbiota and traumatic injuries of free-ranging *Phrynops geoffroanus* (Testudines, Chelidae) in southeastern Brazil. Phyllomedusa 8(1): 19-25.

Forero-Medina G, Cárdenas-Arevalo G & Castaño-Mora OV. 2011. Abundance, home range, and movement patterns of the endemic species Dahl's Toad-Headed Turtle (*Mesoclemmys dahli*) in Cesar, Colombia. Chelonian Conservation and Biology 10(2): 228-236.

Fortin G, Blouin-Demers G & Dubois Y. 2012. Landscape composition weakly affects home range size in Blanding's turtles (*Emydoidea blandingii*). Écoscience 19(3): 191-197.

Fritz U & Havas P. 2007. Checklist of chelonians of the world (Eds. Fritz U & Havas P). Museum für Tierkunde Dresden, Dresden 292 pp.

Ghaffari H, Ihlow F, Plummer MV, Karami M, Khorasani N, Safaei-Mahroo B & Rödder D. 2014. Home range and habitat selection of the endangered Euphrates Softshell Turtle *Rafetus euphraticus* in a fragmented habitat in Southwestern Iran. Chelonian Conservation and Biology 13(2): 202-215.

Gibbons JW. 1970. Terrestrial activity and the population dynamics of aquatic Turtles. American Midland Naturalist 83(2): 404-414.

Gibbons JW, Scott DE, Travis R, Kurt A, Mills T, Leiden Y, Poppy S & Winne C. 2000. The global decline of reptiles, déjà vu amphibians. Bioscience 50(8): 653-66.

Green R & Giese M. 2004. Negative Effects of Wildlife Tourism on Wildlife. In: Wildlife Tourism: Impacts, Management and Planning (Ed K Higginbottom), pp. 81-93. Common Ground Publishing Pty Ltd, Melborne.

Grou CEV. 2015. Levantamento da fauna de quelônios em cinco pontos amostrais na região de Maringá, Paraná, Brasil. Trabalho de Conclusão de Curso, Unicesumar, Brasil.

Guzy JC, Price SJ & Dorcas ME. 2013. The spatial configuration of greenspace affects semi-aquatic turtle occupancy and species richness in a suburban landscape. Landscape and Urban Planning 117: 46-56.

Hahn AT, Rosa CA, Bager A & Krause L. 2014. Dietary variation and overlap in D'Orbigny's slider turtles *Trachemys dorbigni* (Duméril and Bibron 1835) (Testudines: Emydidae). Journal of Natural History 48: 1-10.

Harestad AS & Bunnel FL. 2006. Home range and body weight - A reevaluation. Ecology 60: 389–402.

Hawkes LA, Witt MJ, Broderick AC, Coker JW, Coyne MS, Dodd M, Frick MG, Godfrey MH, Griffin DB, Murphy SR, Murphy TM, Williams KL & Godley BJ. 2011. Home on the range: Spatial ecology of loggerhead turtles in Atlantic waters of the USA. Diversity and Distributions 17: 624-640.

Hill SK & Vodopich DS. 2013. Habitat use and basking behavior of a freshwater turtle community along an urban gradient. Chelonian Conservation and Biology 12(2): 275-282.

Huey RB. 1991. Physiological consequences of habitat selection. American Naturalist 137(1): S91-S115.

Hunt SD, Guzy JC, Price SJ, Halstead BJ, Eskew EA & Dorcas ME. 2013. Responses of riparian reptile communities to damming and urbanization. Biological Conservation 157: 277–284.

ICMBio -Instituto Chico Mendes de Conservação da Biodiversidade. 2018. Livro Vermelho da Fauna Brasileira Ameaçada de Extinção: Volume IV - Répteis. In: : Instituto Chico Mendes de Conservação da Biodiversidade. (Org). Livro Vermelho da Fauna Brasileira Ameaçada de Extinção. Brasília: ICMBio. 252p.ICMBio, Brasília.

IUCN. 2019. The IUCN Red List of Threatened Species. Version 2019-2. Available at http://www.iucnredlist.org.

Kepenis V & McManus JJ. 1994. Bioenergetics of young painted turtles *Chrysemys picta.* Comparative Biochemistry and Physiology 48: 309-317.

Kikillus KH, Hare KM & Hartley S. 2012. Online trading tools as a method of estimating propagule pressure via the pet-release pathway. Biological Invasions 14: 2657-2664.

Köppen W. 1948. Climatologia: con un estudio de los climas de la tierra. Fundo de Cultura Econômica, México, 479pp.

Kraus F. 2003. Invasion pathways for terrestrial vertebrates. In Invasive species: vectors and management strategies (Eds. RMJ Carlton & G Ruiz), pp. 68–92. Island Press, Washington DC.

Larocque SM, Colotelo AH, Cooke SJ, Blouin-Demers G, Haxton T & Smokorowski KE. 2012. Seasonal patterns in bycatch composition and mortality associated with a freshwater hoop net fishery. Animal Conservation 15(1): 53-60.

Laver P & Kelly MJ. 2008. A Critical Review of Home Range Studies. The Journal of Wildlife Management 72: 290-298.

Leão SP, Famelli S & Vogt RC. 2019. Home Range of Yellow-Spotted Amazon River Turtles (*Podocnemis unifilis*) (Testudines: Podocnemididae) in the Trombetas River Biological Reserve, Pará, Brazil. Chelonian Conservation and Biology 18(1): 10-18.

Lebreton JD, Burnham KP, Clobert J & Anderson DR. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62: 67–118.

Libourel P & Herrel A. 2015. Sleep in amphibians and reptiles: a review and a preliminary analysis of evolutionary patterns. Biological Reviews 000–000.

Litzgus JD, Costanzo JP, Brooks RJ & Lee RE. 1999. Phenology and ecology of hibernation in spotted turtles (*Clemmys guttata*) near the northern limit of their range. Canadian Journal of Zoology 77(9): 1348-1357.

Litzgus JD & Mousseau TA. 2006. Home range and seasonal activity of Southern Spotted Turtles (*Clemmys guttata*): implications for management. Copeia 2004(4): 804-817.

Lowe S, Browne M, Boudjelas S & De Poorter M. 2000. 100 of the World's Worst Invasive Alien Species: A Selection from the Global Invasive Species Database. The Invasive Species Specialist Group (ISSG), Auckland, 12 pp.

Matthews A & Green K. 2012. Seasonal and altitudinal influences on the home range and movements of common wombats in the Australian Snowy Mountains. Journal of Zoology 287: 24–33.

Magnusson WE, Lima AC, Costa VL & Vogt RC. 1997. Home range of the turtle, *Phrynops rufipes*, in an isolated reserve in central Amazônia, Brazil. Chelonian Conservation and Biology 2(4): 494-499.

Manly BFJ, Mcdonald LL, Thomas DL, Mcdonald TL & Erickson WP. 2002. Resource Selection by Animals - Statistical Design and Analysis for Field Studies. Kluwer Academic Publishers, Boston 240 pp.

Marchand MN & Litvaitis JA. 2004. Effects of habitat features and landscape composition on the population structure of a common aquatic turtle in a region undergoing rapid development. Conservation Biology 18(3): 758-767.

Marques AJ. 2004. Mapeamento de fragmentos de mata no Município de Maringá, PR: uma abordagem da ecologia da paisagem. Dissertação de Mestrado,Universidade Estadual Paulista, Brasil.

Marques TS, Lara NRF, Bassetti LAB, Ferronato BO, Malvásio A & Verdade LM. 2013. Population structure of *Mesoclemmys vanderhaegei* (Testudines, Chelidae) in a silvicultural system in southeastern Brazil. Herpetology Notes 6(1): 179-182.

Martins FI & Souza FL. 2009. Demographic parameters of the Neotropical freshwater Turtle *Hydromedusa maximiliani* (Chelidae). Herpetologica 65(1): 82-91.

Martins FI, Souza FL & Costa HTM. 2010. Feeding habits of *Phrynops geoffroanus* (Chelidae) in an urban river in central Brazil. Chelonian Conservation and Biology 9(2): 294-297.

Molina FB. 1989. Observações sobre a biologia e o comportamento de *Phrynops geoffroanus* (Schweigger, 1812) em cativeiro (Reptilia, Testudines, Chelidae). Ph.D Thesis, Universidade de São Paulo, Brasil.

Molina FB, Ferronato BO & Souza FL. 2016. Freshwater Turtles in Natural, Rural and Urban Ecosystems in São Paulo State, Southeastern Brazil. In: Biodiversity in Agricultural Landscapes of Southeastern Brazil (Eds. C Gheler-Costa, M Lyra-Jorge, LM Verdade), pp. 151-162. De Gruyter Open, São Paulo.

Moll EO & Legler JM. 1971. The life history of a Neotropical slider turtle, *Pseudemys scripta* (Schoepff), in Panamá. Bulletin of the Los Angeles County Museum of Natural History - Science 11: 1-102.

Morreale SJ, Gibbons JW & Congdon JD. 1984. Significance of activity and movement in the yellow-bellied slider turtle (*Pseudemys scripta*). Canadian Journal of Zoology 62: 1038-1042.

Morrow JL, Howard JH, Smith SA & Poppel DK. 2001. Home range and movements of the Bog Turtle (*Clemmys muhlenbergii*) in Maryland. Journal of Herpetology 35(1): 68-73.

Mysterud A, Pérez-barbería FJ & Gordon IJ. 2001. The effect of season , sex and feeding style on home range area versus body mass scaling in temperate ruminants. Oecologia 127(1): 30–39.

Nathan R. 2008. An emerging movement ecology paradigm. Proceedings of the National Academy of Sciences 105(49): 19050-19051.

Nemoz M, Cadi A & Thienpont S. 2004. Effects of recreational fishing on survival in an *Emys orbicularis* population. Biologia 59(Suppl. 14): 185-189.

Ostfeld RS. 1990. The ecology of territoriality in small mammals. Trends in Ecology and Evolution 5(12): 411-415.

Painter CW & Christman BL. 2000. Geographic distribution. *Trachemys scripta*. Herpetological Review 31: 253.

Parker WS. 1996. Age and survivorship of the Slider (*Trachemys scripta*) and the Mud Turtle (*Kinosternon subrubrum*) in a Mississippi Farm Pond. Journal of Herpetology 30(2): 226-268.

Paterson JE, Steinberg BD & Litzgus JD. 2012. Generally specialized or especially general? Habitat selection by Snapping Turtles (*Chelydra serpentina*) in central Ontario. Canadian Journal of Zoology 90: 139-149.

Paul MJ & Meyer JL. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32: 333-365.

Perry G & Garland Jr T. 2002. Lizard home ranges revisited: Effects of sex , body size , diet, habitat, and phylogeny. Ecology 83(7): 1870–1885.

Plummer MV. 1977. Activity, habitat and population structure in the Turtle, *Trionyx muticus*. Copeia 1977(3): 431-440.

Pysek P, Jarosik V, Hulme PE et al. 2010. Disentangling the role of environmental and human pressures on biological invasions across Europe. Proceedings of the National Academy of Sciences 107(27): 12157–12162.

QGIS Development. QGIS Geographic information system. 2016. http://qgis.osgeo.org.

Rees M, Roe JH & Georges A. 2009. Life in the suburbs: Behavior and survival of a freshwater turtle in response to drought and urbanization. Biological Conservation 142: 3172-3181.

Riedle JD, Weiberg T, King-Cooley F, Johson S, Riedle TDH & Asahl D. 2017. Observations of the population ecology of three- toed Box Turtles in small, urban forest fragments. Collinsorum 6(2-3): 10–14.

Rocha SB, Grou CEV., Takemoto RM & Ferreira VL. 2018. *Phrynops geoffroanus* (Geoffroy's Side-necked Turtle). Mortality from fishing hook. Herpetological Review 49(2): 321-322.

Romagosa CM. 2015. Contribution of the live animal trade to biological invasions. In: Biological Invasions in Changing Ecosystems - Vectors, Ecological Impacts, Management and Predictions (Ed. J Canning-Clode), pp. 116-134. De Gruyter Open, Berlim.

Row JR & Blouin-Demers G. 2006. Kernels are not accurate estimators of home-range size for Herpetofauna. Copeia 4: 797-802.

RStudio Team. 2016. RStudio: Integrated Development for R. http://www.rstudio.com/.

Rueda-Almonacid JV, Carr JL, Mittermeier RA, Rodriguez-Mahecha JV, Mast RB, Vogt RC, Rhodin AGJ, de la Ossa-Velásquez J, Rueda JN & Mittermeier CG. 2007. Las Tortugas y los Cocodrilianos de los países andinos del trópico. Conservación Internacional, Bogotá, Colômbia, 537pp.

Ryan TJ, Conner CA, Douthitt BA, Sterrett SC & Salsbury CM. 2008. Movement and habitat use of two aquatic turtles (*Graptemys geographica* and *Trachemys scripta*) in an urban landscape. Urban Ecosystems 11: 213-225.

Ryan TJ, Peterman WE, Stephens JD & Sterrett SC. 2014. Movement and habitat use of the snapping turtle in an urban landscape. Urban Ecosystems 17: 613-623.

Santana DO. 2016. Autoecologia comparativa de duas espécies de quelônios (*Phrynops geoffroanus* e *Mesoclemmys tuberculata*) em áreas de caatinga e mata Atlântica no nordeste do Brasil. Ph.D. Thesis, Universidade Federal da Paraíba, Brasil.

Santana DO, De-Carvalho CB, Rocha SM, Freitas EB & Faria RG. 2014. *Trachemys dorbigni* (Duméril & Bibron, 1835) (Testudines: Emydidae) recorded in an artificial pond in northeastern Brazil. Herpetology Notes 7: 211–213.

Santini L, González-Suárez M, Russo D, Gonzalez-Voyer A., Von Hardenberg A & Ancillotto L. 2019. One strategy does not fit all: determinants of urban adaptation in mammals. Ecology Letters 22(2): 365–376.

Santos TG, Vasconcelos TS, Molina FB & Zaher H. 2009. First record of *Trachemys dorbigni* (Duméril & Bibron, 1835) (Testudines, Emydidae) in a remnant of Mesophytic Semideciduous Forest of São Paulo State, southeastern Brazil. Herpetological Bulletin 108:27–30.

Schubauer JP. 1981. A reliable radio-telemetry tracking system suitable for studies of chelonians. Journal of Herpetology 15(1): 117–120.

Seaman DE, Millspaugh JJ, Kernohan BJ, Brundige GC, Raedeke KJ & Gitzen RA. 1999. Size on Kernel home range estimates effects. The Journal of Wildlife Management 63(2): 739–747.

Segurado P & Figueiredo D. 2007. Coexistence of two freshwater turtle species along a Mediterranean stream : The role of spatial and temporal heterogeneity. Acta Oecologica. 32: 134-144.

SEMA - Secretaria do Meio Ambiente. 2010. Bacias Hidrográficas do Paraná. Prefeitura do Município de Maringá, Maringá, 138 pp.

SEMA - Secretaria do Meio Ambiente. 2011. Plano Municipal de Conservação e Recuperação Da Mata Atlântica, Maringá - Paraná. Prefeitura do Município de Maringá, Maringá, 113 pp.

Semeñiuk MB, Alcalde L, Sánchez RM & Cassano MJ. 2017. An Easy, Cheap, and Versatile Method to Trap Turtles, with Calibrated Sampling Effort. South American Journal of Herpetology 12(2): 107-116.

Silveira ML. 2013. Variação morfológica e populacional de *Trachemys dorbigni* (Testudines, Emydidae) no extremo sul do Brasil. Ph.D. Thesis, Universidade Federal de Lavras, Brasil.

Slabbekoorn H & Peet M. 2003. Birds sing at a higher pitch in urban noise. Nature 424-267.

Souza FL & Abe AS. 1999. Fauna urbana: o cágado e a poluição dos rios. Ciência Hoje 25: 59-61.

Souza FL. 2004. Uma revisão sobre padrões de atividade, reprodução e alimentação de cágados brasileiros (Testudines, Chelidae). Phyllomedusa 3(1): 15-27.

Souza FL & Abe AS. 2000. Feeding ecology, density and biomass of the freshwater turtle, *Phrynops geoffroanus*, inhabiting a polluted urban river in south-eastern Brazil. Journal of Zoology 252: 437-446.

Souza FL & Abe AS. 2001. Population structure and reprodutive aspects of the freshwater turtle, *Phrynops geoffroanus*, inhabiting an urban river in Southeastern Brazil. Neotropical Fauna and Environment 36(1): 57-62.

Souza FL, Raizer J, Costa HYM & Martins FI. 2008. Dispersal of *Phrynops geoffroanus* (Chelidae) in an urban river in central Brazil. Chelonian Conservation Biology 7(2): 257-261.

Spinks PQ, Pauly GB, Crayon JJ & Shaffer HB. 2003. Survival of the western pond turtle (*Emys marmorata*) in an urban California environment. Biological Conservation 113: 257-267.

Standing KL, Herman TB & Morrison IP. 1999. Nesting ecology of Blanding’s turtle (*Emydoidea blandingii*) in Nova Scotia, the northeastern limit of the species’ range. Journal of Zoology 77: 1609-1614.

Steen DA, Hopkins BC, Dyke JUV & Hopkins WA. 2014. Prevalence of ingested fish hooks in freshwater turtles from five rivers in the southeastern United States. Plos one 9(3): 1–6.

Stickel LF. 1950. Populations and home range relationships of the Box Turtle, *Terrapene c . carolina* (Linnaeus). Ecological Monographs 20(4): 351-378.

Strayer DL. 2010. Alien species in fresh waters: Ecological effects, interactions with other stressors, and prospects for the future. Freshwater Biology 55(1): 152-174.

Tapley B, Griffiths RA & Bride I. 2011. Dynamics of the trade in reptiles and amphibians within the United Kingdom over a ten-year period. Herpetological Journal 21: 27-34.

Thomas D & Taylor E. 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54: 322-30.

Thomson RC, Spinks PQ & Shaffer HB. 2010. Distribution and Abundance of Invasive Red-Eared Sliders (*Trachemys scripta elegans*) in California's Sacramento River Basin and Possible Impacts on Native Western Pond Turtles (*Emys marmorata*). Chelonian Conservation and Biology 9(2): 297-302.

Tinkle DW. 1958. Experiments with censusing of southern turtle populations. Herpetologica 14(3): 172-175.

Tortato MA, Bressan RF & Kunz TS. 2014. Reproduction of two exotic species of *Trachemys* Agassiz, 1857 (Testudines, Emydidae) at Parque Estadual da Serra do Tabuleiro, state of Santa Catarina, southern Brazil. Herpetology notes 7: 11-15.

Türkozan O, Karaman S, Yılmaz C & Ülger C. 2018. Daily movements and home range of Eastern Hermann's Tortoise, *Testudo hermanni boettgeri* (Reptilia: Testudines). Zoology in the Middle East 65(1): 28–34.

Viana IR, Prevedello JA & Zocche JJ. 2017. Effects of landscape composition on the occurrence of a widespread invasive bird species in the Brazilian Atlantic Forest. Perspectives in Ecology and Conservation 15(1): 36–41.

Villaseñor NR, Driscoll DA, Gibbons P, Calhoun AJK & Lindenmayer DB. 2017. The relative importance of aquatic and terrestrial variables for frogs in an urbanizing landscape: Key insights for sustainable urban development. Landscape and Urban Planning 157: 26-35.

Worton BJ. 1987. A Review of Models of Home Range for Animal. Ecological Modelling 38: 277-298.

Worton BJ 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164-168.

Zar JH. 1996. Biostatistical Analysis. Prentice Hall: Upper Saddle River, New Jersey, 620 pp.

Ziller SR & Zalba S. Propostas de ação para prevenção e controle de espécies exóticas invasoras. Natureza e Conservação 5(2): 8-15.

Appendix A

Adapted method to collect freshwater turtles: Fishing clip.

Description: This technique is similar to a traditional fishing, with similar devices (Figure S1). At one extremity of the trap is located a specific clip (Figure S1.A, B), which was previously analyzed to not harm the mouth of the animals. This clip is used to attach the bait (meat) and it is tied to a fishing line around three and five meters long. Optionally a float may be attached (Figure S1 C), and the distance between the clip and the float depend on the target species. For example, the effectiveness to capture both *Trachemys* species (*T. scripta elegans* and *T. dorbigni dorbigni*) increase if the float is setted closer to the clip, whereas for Chelidae (*Prynops geoffroanus* and *Hydromedusa tectifera*) we sugest to set it more distant. The opposite end of the line is tied in a marginal branch to the water, and the researcher remain around the line waiting for some movement in that trap. Since the bait attracts the turtles, the researcher bring the clip closer and catch the turtles using a dip net (Figure S1 D, E).

Advantages: Staying close to that trap increase the effectiveness of capture since is possible to capture many animals at the same day using one equipment. Additionally, if fishes consume the bait is possible to replace it and keep collecting data. *Cautions:* Is important to keep silent to use this technique, without noise and sudden movement by the operator,in order to not disturb the turtles. In addition, we recommend using light clothes and staying crouched in the capture moment to avoid to be viewed by the turtles. Taking these cares, this method is very simple and only require one operator to work.

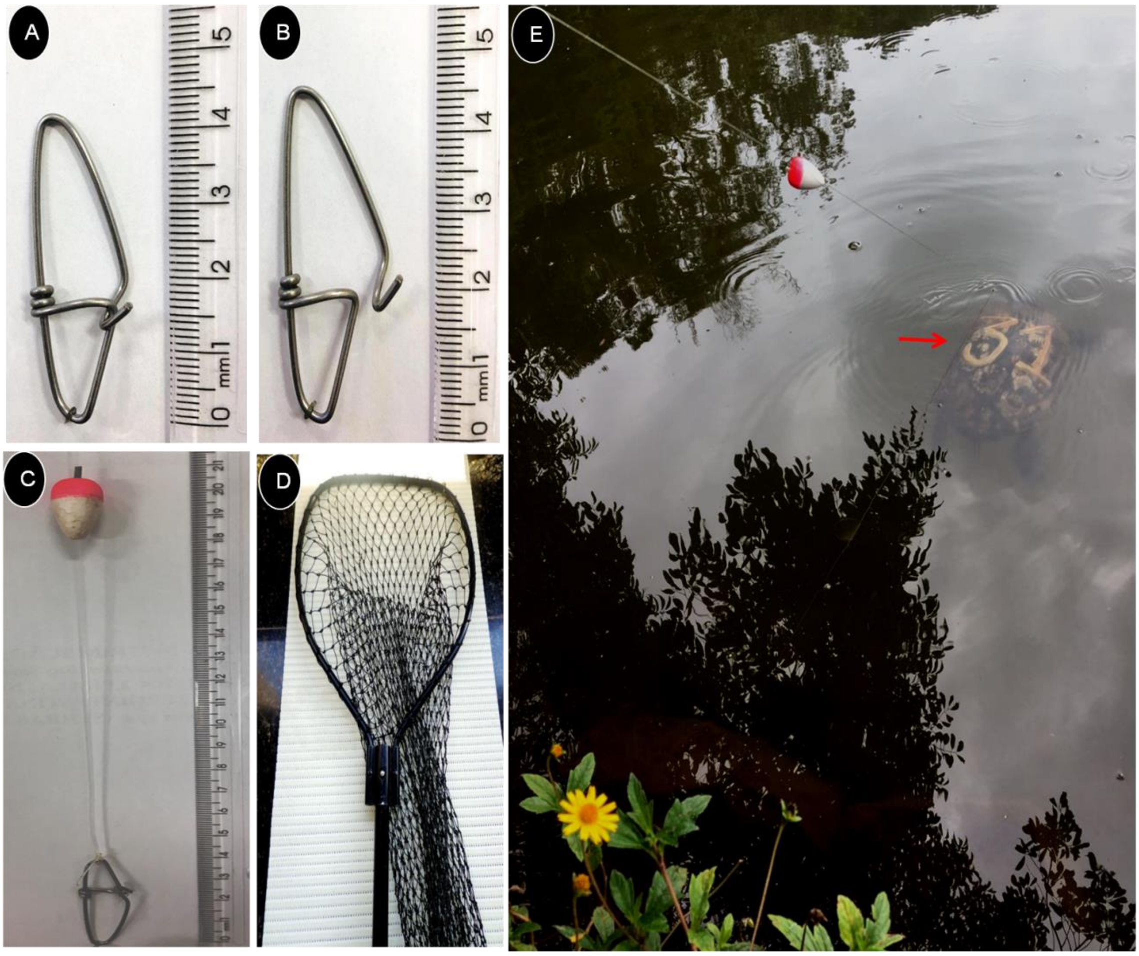


Figure S1. Equipment needed to use Fishing clip method. A) and B) Clip; C) Float attached in the line; D) Dip net; E) Turtle attracted by bait (red arrow).

UNIVERSIDAD DE CÓRDOBA

UFMS

UNIVERSIDADE FEDERAL DE MATO GROSSO DO SUL

idep

Instituto de Estudios de Posgrado

Programa de Doctorado Recursos Naturales y Gestión Sostenible

Programa de Pós Graduação em Ecologia e Conservação

UEM

Universidade Estadual de Maringá

CAPES

PROJETO TAMARI

IACO

AGRÍCOLA S.A