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GABRIEL SCHETTINI ARMILIATO

PARÂMETROS DE VIDA DE *ACANTHOCHELYS SPIXII* (CHELIDAE: TESTUDINES) NO EXTREMO SUL DA MATA ATLÂNTICA

PORTO ALEGRE
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Dissertação apresentada ao Programa de Pós-Graduação em Biologia Animal, Instituto de Biociências da Universidade Federal do Rio Grande do Sul, como requisito parcial à obtenção do título de Mestre em Biologia Animal.

Área de concentração: Biodiversidade e Comportamento Animal

Orientador(a): Profa. Dra. Laura Verrastro

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Aprovada em ____ de ____________ de _____.

BANCA EXAMINADORA

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Dr Márcio Borges-Martins

____

Dra Maria Joao Pereira

____

Dr Guarino Rinaldi Colli

Biology is the Science.
Evolution is the concept that
makes biology unique.

(Jared Diamond)

Aos,

que se inspiram na natureza e na sua mais bela e sublime simplicidade,

que acreditam no valor intrínseco da vida,

eu devoto a minha mais sincera admiração.

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SUMÁRIO

RESUMO

Mais da metade das espécies da ordem Testudines encontram-se ameaçadas de extinção na lista vermelha de espécies da IUCN. Caracterizados como indivíduos de vida longa, os quelônios possuem uma baixa sobrevivência de jovens e maturação tardia de adultos, tendo assim uma alta vulnerabilidade frente à impactos no seu habitat e necessitando longos trabalhos de monitoramento para que os parâmetros de vida e o real status das populações sejam compreendidos ao longo de sua distribuição. Foram efetuados dois anos de marcação e recaptura ao longo de dez anos em uma população de *Acanthochelys spixii* no Parque Estadual de Itapeva, um dos últimos remanescentes de Mata Atlântica preservados no sul do Brasil, a fim de preencher lacunas de conhecimento ao longo da distribuição da espécie. Os resultados foram analisados com o modelo Robusto no programa MARK. A população demonstrou um decréscimo na sobrevivência anual dos indivíduos após uma década do primeiro período de amostragem, assim como uma menor sobrevivência anual de machos ao longo de todo o estudo. Parâmetros como emigração, probabilidade de captura e recaptura e abundância foram importantes para demonstrar a relação dos indivíduos com o regime dos banhados permanentes e temporários e o uso das áreas terrestres pelos indivíduos. Assim como a maioria dos quelônios, a população de *Acanthochelys spixii* apresentou uma forte relação com o regime de seca e cheia do mosaico de banhados no qual foi amostrada, aspectos que necessitam ser entendidos para manejar as populações.

Palavras-chave: cágado-preto, chelidae, quelônio, pluviosidade, dunas, região costeira

ABSTRACT

More than a half of Testudines are under some threat of extinction into the Red List of Threatened Species of IUCN. Characterized as long-lived species, freshwater turtle has low hatchling survivorship and late adult maturity, thus been more vulnerable to recover from anthropogenic impacts and consequently needing long-term studies to prevent a false impression about its real conservation status. We applied two years of mark-recapture trough ten years interval in an *Acanthochelys spixii* population into the "Parque Estadual de Itapeva", a remnant of Atlantic Forest in southern coast of Brazil, in order to fill the gaps of knowledge about the specie all over its distribution. We analyzed data with robust design model into program MARK. Both sexes decrease the survivorship after a decade and males showed lower survivorship than females all over the study. Parameters as emigration, probability of capture and recapture and abundance showed a strait relationship between individuals, wetlands and land. As the pattern of most chelonian species, the present *Acanthochelys spixii* population showed a strong relationship with drought and flood of the mosaic wetlands in which is an important aspect to draw up strategies of management.

Keywords: Black Spiny-necked Swamp Turtle, chelidae, chelonian, pluviosity, dunes, coastline

INTRODUÇÃO GERAL

Dentre as 356 espécies de quelônios (denominação vulgar dada à ordem Testudines) descritas até o momento (tartarugas marinhas, cágados e jabutis), 186 estão ameaçadas ou extintas (52.2%) segundo os critérios da IUCN (Rhodin et al, 2017; IUCN, 2017). Quando acrescentados nessa análise os táxons com dados deficientes ou não avaliados, a porcentagem de espécies em algum nível de ameaça sobe para 59%, estes dados tornam os Testudines o táxon mais ameaçado dentre os maiores grupos de vertebrados (Rhodin et al, 2017). No Brasil, os Testudines são compostos de 36 espécies, destas, cinco espécies são tartarugas marinhas, duas são jabutis terrestres e 29 espécies são cágados de água doce (Costa e Bérnils, 2015). Dentre as espécies com distribuição dentro dos limites do país, cinco tartarugas marinhas e um cágado de água doce estão em algum grau de ameaça (MMA, 2014). Segundo Mittermeier et al (2015), o Brasil está entre os países com maior riqueza de Testudines, tendo a Amazônia denominada como uma Área natural com alta biodiversidade e a Mata Atlântica como um *Hotspot* da biodiversidade, com nove e três espécies de quelônios endêmicas respectivamente.

A longevidade dos indivíduos da ordem Testudines e a sua alta taxa de ameaça requer monitoramentos longos, pois estudos de curto prazo podem passar uma falsa impressão sobre seu real status de conservação (Magurran et al, 2010). Algumas características compartilhadas entre os quelônios como a baixa sobrevivência de ninhos e jovens e maturação sexual tardia os torna um dos grupos mais ameaçados do mundo e dificulta a recomposição das populações frente aos impactos antrópicos (Iverson, 1991; Congdon et al, 1993).

Dentre os cinco critérios para categorizar a ameaça das espécies pela IUCN, dois deles dependem de conhecimentos prévios sobre os parâmetros populacionais (IUCN, 2017) reforçando assim a necessidade de monitoramento das populações de táxons mais suscetíveis como os quelônios.

Monitoramentos implantados *in situ* são importantes para gerar conhecimento sobre populações, auxiliando em projetos de conservação e manejo (Schmeller et al, 2015). Estudos longos com espécies longevas geram informações mais precisas sobre os parâmetros de vidas das populações (Congdon and Dunham 1997).

Caracterizados como integrantes do grupo de vertebrados de vida longa, os quelônios são amplamente estudados em todos os continentes. Apesar de não se ter informações detalhadas do tempo de vida das espécies em vida livre, há indícios de indivíduos que atingiram os 70 anos em cativeiro (Gibbons, 1987). Tais atributos destas espécies as fazem difíceis de serem monitoradas, pois machos e fêmeas podem viver até mais do que os pesquisadores que as estudam (Gibbons, 1987; Iverson, 1991).

Estudos longos e mais detalhados, principalmente utilizando as técnicas de marcação e recaptura descritas por Cagle (1939), foram efetuados ao longo de boa parte do território dos Estados Unidos no qual é um dos países com maior riqueza e endemismo de quelônios em todo mundo (53 espécies sendo 33 endêmicas) (Congdon et al, 1993; Mittermeier et al, 2015; Folt et al 2016).

No Brasil, os estudos com quelônios são concentrados na região amazônica onde possui a maior biodiversidade de cágados de água doce do país. Dentre os quelônios não amazônicos, o estudo mais amplo e longo foi efetuado com uma população da espécie *Hydromedusa maximiliani,* endêmica da Mata Atlântica durante uma década de amostragens (Martins and Souza, 2009).

O cágado *Acantochelys spixii* (Duméril & Bibron, 1835) é pertencente à família Chelidae e é uma das quatro espécies descritas para o gênero *Acanthochelys* sp. A ocorrência deste quelônio no Brasil vai do Rio Grande do Sul a São Paulo (desde áreas abertas do Sul à Mata Atlântica), além dos estados de Minas Gerais e Bahia (Rhodin *et al*., 1984; Ribas &

Monteiro Filho, 2002), e uma população no Bioma Cerrado do Distrito Federal (Brandão *et al*., 2002). A ocorrência do táxon é comprovada também no Uruguai e Argentina (Fritz & Havaz, 2007). O cágado-preto foi descrito por Duméril & Bibron em 1835. Segundo os autores o táxon possui como diagnose uma depressão ao longo dos escudos vertebrais e protuberâncias em forma de espinhos na região do pescoço, dimorfismo sexual identificado através de características secundárias como alargamento da base da cauda e afundamento do plastrão em machos e ausência destas características e tamanho avantajado em fêmeas (Molina e Rocha, 1990). Os espécimes costumam habitar corpos d'água lênticos permanentes e temporários (Lema e Ferreira, 1990). Desde sua descrição, apenas conhecimentos pontuais foram adquiridos pela comunidade científica sobre seus padrões de atividade, uso de habitat e conservação no estado do Rio Grande do Sul (Miorando, 2006; Bujes, 2008; Bujes, 2010; Bager et al, 2016). Já em outras regiões, estudos mais aprofundados focando demografia, dieta e área de vida da espécie foram efetuados somente em uma população restrita do Bioma Cerrado (Horta, 2008; Brasil et al, 2011; Neto et al, 2011). A espécie consta na Lista Vermelha de Espécies Ameaçadas da IUCN na categoria "Quase Ameaçada" (*Near Threatened* - NT) e devido ao pouco conhecimento sobre sua biologia e aspectos populacionais seu status pode ainda ser agravado (IUCN, 2017).

Técnicas para analisar dados de monitoramentos longos tem sido aprimoradas nas últimas duas décadas, além de estimar os parâmetros de vida das populações, estas técnicas podem identificar fatores que influenciam na detecção dos espécimes, aprimorando os resultados (Pollock et al., 1990; Lebreton et al., 1992; Nichols, 1992). Devido a heterogeneidade de captura dos espécimes no campo (variações individuais, grupos, clima, observador, etc), é necessário saber quanto da população estamos vendo, para que as estimativas sejam mais realistas, esta detecção pode ser muito baixa se estivermos lidando com espécies difíceis de amostrar no tempo e no espaço. Estas técnicas atribuem ao histórico de captura fatores bióticos e abióticos que supostamente estão relacionados com a detecção dos indivíduos, mitigando o problema da detecção imperfeita nos estudos e aprimorando as estimativas dos parâmetros. Dentre as técnicas nas quais se enquadram para analisar dados de marcação e recaptura estão os Modelos Lineares Generalizados Mistos (MLGM) utilizados no presente trabalho.

A região do presente estudo faz parte da área prioritária para a conservação da mata atlântica e uma das poucas unidades de conservação continentais litorâneas do estado do Rio Grande do Sul e do país (MMA, 2017). No estado do Rio Grande do Sul, a Mata Atlântica e seus ecossistemas associados são reconhecidos pela UNESCO como Reserva da Biosfera na qual abrange 11% do território nacional (Duarte e Bencke, 2006). Devido ao acelerado crescimento populacional humano dentro das delimitações do Bioma, a Mata Atlântica segue sendo um dos Biomas mais ameaçados do mundo. Estratégias de conservação como Unidades de Preservação amparadas por projetos de conservação são estratégias primordiais para a manutenção da biodiversidade (Terborgh e Schaik, 2002).

Assim, dada a falta de informações sobre história natural de quelônios brasileiros, assim como para *Acanthochelys spixii* ao longo de sua distribuição, somado com a dificuldade de se obter informações sobre parâmetros de vida de espécies longevas como os cágados de água doce, nosso objetivo foi enriquecer o conhecimento sobre a espécie através de amostragens que abrangeram 10 anos de intervalo no parque estadual de Itapeva, extremo sul da Mata Atlântica.

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CAPITULO 1.

DIFFERENCE IN LIFE PARAMETERS A DECADE LATER: A SEMIAQUATIC TURTLE IN SOUTHERN ATLANTIC FOREST

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Gabriel Schettini Armiliato

Federal University of Rio Grande do Sul, Department of Zoology

Avenida Bento Gonçalves 9500, CEP 91540-000, Porto Alegre, Rio Grande do Sul, Brazil

55 51 991133131

gabarmiliato@gmail.com

Difference in Life Parameters a Decade Later: a semiaquatic turtle in southern Atlantic Forest

GABRIEL SCHETTINI ARMILIATO,[1] *Federal University of Rio Grande do Sul, Department of Zoology, Avenida Bento Gonçalves 9500, CEP 91540-000, Porto Alegre, Rio Grande do Sul, Brazil*

PRISCILA SAIKOSKI MIORANDO, *Federal University of Western of Pará, Oriximiná Campus*

MURILO GUIMARÃES, *Federal University of Rio Grande do Sul, Department of Zoology, Avenida Bento Gonçalves 9500, CEP 91540-000, Porto Alegre, Rio Grande do Sul, Brazil*

LAURA VERRASTRO, *Federal University of Rio Grande do Sul, Department of Zoology, Avenida Bento Gonçalves 9500, CEP 91540-000, Porto Alegre, Rio Grande do Sul, Brazil*

[1] *Email: gabarmiliato@gmail.com*

ABSTRACT

To predict the threats that make long-term animal population decrease, leading them to extinction, is important maintain long-term monitoring programs. As the life parameters of these populations are difficult to measure, modeling techniques are an effective tool to analyze data. Freshwater turtles are among the most threatened species in the world and their conservation face problems due to their late recompositing from anthropogenic impact. We sampled a population of *Acanthochelys spixii* (Chelidae, Testudines) into a protected area in southern coast of Atlantic Forest of Brazil to fill the gap in its published knowledge. After two sampled years spaced for a decade our results showed a decrease in survivorship of adults and a smaller survivorship of males compared to females throughout study. Some important parameters as detectability, emigration and abundance demonstrate relationship of the individuals with their surrounding outside water. We suggest protection of the entire area given the dependence of the specie with landscape of water and land showed by our results, and the change that habitat alteration usually negatively impact freshwater turtle populations.

KEY WORDS survival, chelonian, drought, wetlands, robust design, climatic factors, life parameters.

Long-term studies are important to estimate life parameters of populations and serve as basis for conservation and management programs (Congdon and Dunham 1997). Techniques to analyze data from long-term population through mark-recapture studies are being improved for the last two decades. In addition to estimate population's parameters, they can identify factors which affect detection of the individuals, minimizing errors and improving understanding population structure

(Pollock et al., 1990; Lebreton et al., 1992; Nichols, 1992). Understand oscillation of life parameters into a population can be of great value to predict the effect of threats (Gibbons, 1987; Gibbons, 1990; Klemens, 2000). Some species may have peculiarities which make their populations vulnerable to react against changes, moreover changes in life parameters can be difficult to notify when adult individuals live so long that recruitment problems becomes late detected. Such features make them claim for long-term monitoring because short-term studies may create a false impression about species (Congdon and Dunham 1997; Klemens, 2000).

Freshwater turtles have long life span with high adult survivorship, delayed maturity and low hatchling survivorship, features that make them vulnerable to recover from a declining situation and make them part of the most threatened taxa in the world (Congdon 1993, Iverson 1991). Threats as population isolation, road mortality, human poaching and competition with exotic species are the main reason of freshwater turtle declining (Garben and Burger 1995; Klemens 2000). Signs of impacted population can be noticed by difference in body measures through time, even by behavior and ecological features (Congdon and Dunham 1997). Terrestrial and aquatic movement in freshwater turtle have been strongly related with population dynamics, with temperature and rainfall presumably influencing activity in different parts of the year, resulting in strong impacts on overall sex ratio of hatchlings and population ecology, these abiotic factors must be taken into account to analyses relationship between species and environment (Gibbons, 1970; Janzen, 1994).

To determine the real threat status of the species and to implement management actions, it is crucial to fill all the gaps of knowledge throughout their range, improving effectiveness of conservation projects (Browne and Hecnar 2007). Protected units are considered a basis for maintenance of biodiversity, although they do not provide ecological security if not monitored through conservation projects. Even under the habitat protection, species persistence may continue to be threatened by isolation effects and internal and external threats (Jansen 1983; Meffe and Carroll 1997; Browne and Hecnar 2007).

Great results were obtained with long-term demographic studies of freshwater turtle in North America, not only to predict threats but to better understand the pattern of some life parameters of the species inside and outside protected units (Congdon and Dunham, 1997; Gibbons, 1987; Folt et al 2016). In south America, population models are poorly explored when dealing with freshwater turtle studies. The longest study evolving freshwater turtle and demography parameters covered approximately a decade to get estimates of the neotropical *Hydromedusa maximiliani,* a freshwater turtle endemic of Atlantic Forest of Brazil (Martins and Souza, 2009).

The *Acanthochelys spixii* has a Near Threatened status into the IUCN Red List (IUCN, 2017). There are a few studies in captivity that encompasses biology of the specie and demography studies in nature are scarce (Molina and Rocha 1990; D'amato 1992; Horta 2008; Bager et al 2016). A new record into the Cerrado biome spread the knowledge about the range of the specie in the last two decades and resulted in the first population well studied of this specie throughout its distribution (Brandão et al, 2002; Brasil et al, 2011; Fraxe-Neto et al, 2011).

We analyzed the population demographic parameters of *Acanthochelys spixii* in the extremely south coast of Atlantic Forest in southern Brazil in two sample periods with a gap of ten years. The study was done inside a protected unit which harbor one of the last remnant of Atlantic Forest face to Atlantic Ocean in south America.

STUDY AREA

Surveys were conducted over two years on a 20-ha dune slack along a sand-prairie habitat into the Parque Estadual de Itapeva (PEVA), state of Rio Grande do Sul; 29° 21' 30.22" S and 49° 45' 12.09" W which is in a biome transition zone between northern pampas and southern coast of Atlantic Forest of Brazil. The PEVA is a state protected unit with about 1.000 ha of a natural remaining area covered by marshy and dry forest on the northwest and an open area with restinga formations, wetlands and dunes bounded to Atlantic Ocean on the southeast (Figure 1). The region is characterized by humid subtropical climate with average annual precipitation of 1.385 mm and rains distributed all year round with monthly mean rainfall of 115 mm. The highest mean temperature is during the summer (February- 23.3ºC) and the lowest during the winter (July- 14.8ºC) (INMET, 2017). The study area was a dune slack composed by a mosaic of temporary wetlands with interspersed patches of psamophilous vegetation between frontal and mobile dunes (Figure 1). All over the wetlands, the water levels can rapidly rise from 0 to 1.5m during heavy rains but also can fall rapidly afterwards.

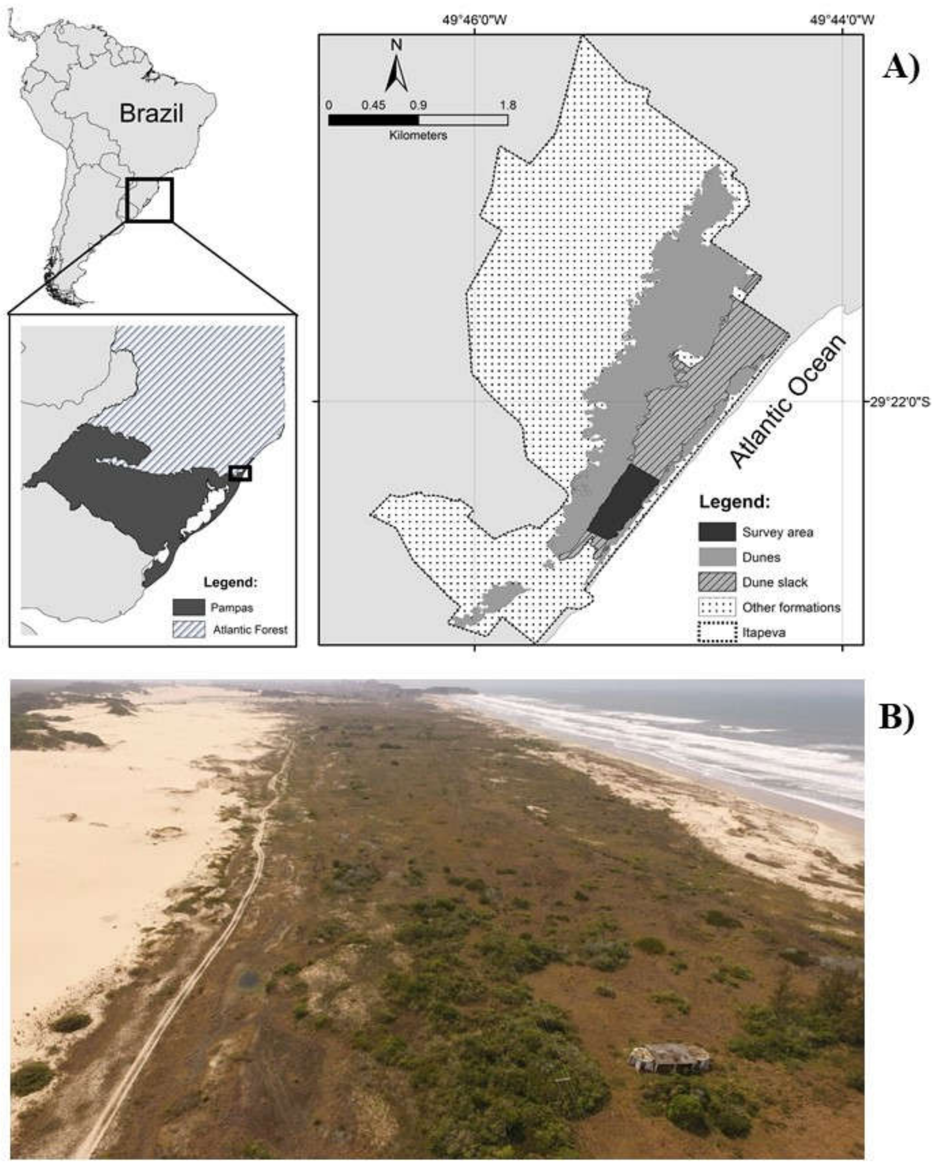

Figure 1. A) Map of the Itapeva State Park and study area, south coast of Atlantic Forest, southern Brazil. B) Aerial photography of the study area, a dune slack with permanent and temporary wetlands bounded by the dunes and facing the Atlantic Ocean.

METHODS

Field Methods

Mark-recapture effort were conducted from March 2005 to February 2006 and a decade later from

May 2016 to April 2017 resulting in 11 and seven occasions respectively, totaling 18 sampling events. Each sampling session consisted of two-five consecutive days of search and the entire area was sampled every day.

Turtles were visually located, and hand collected along the wetlands mainly during the night hours when the specie is most likely to be active (Lema and Ferreira 1990). Sex was determined by secondary sexual characteristics and juveniles were distinguished from adults by the absence of it (Molina and Rocha 1990). Individuals were marked by marginal scute notching (Cagle, 1993) before being released at the point of capture. For each capture we used a ± 0.01-mm digital Mitutoyo calipers to record, shell height, carapace length, carapace width, plastron length and plastron width and a ± 5 g Pesola spring scale to measure body mass.

Statistical Analyses

Chi-squared test was used to check hypothesis related with sex ratio in both period sampled (Zar, 2010). To check the presence of sexual dimorphism into each period and any difference in measures of the same sex over two sample periods we applied ANOVA test, normality and homogeneity of variance were tested with Shapiro-Wilk and Levene test respectively, all the measures were taken from the first capture of each specimen and all turtles first marked in 2005-2006 period and recaptured a decade later were removed from the 2016-2017 data.

We modeled our data using closed robust design model (Kendall et al. 1997; Kendall 1999) in Program Mark (White and Burham 1999). The robust design is structured to have open sampling events (primary periods) which gains, and losses are assumed to occur between them (births, deaths, emigration and immigration) and within each primary event there are many temporal closed sampling events (secondary periods) which those gains, and losses are not allowed. Our primary periods were based in the 18 months of sampling with two-five secondary periods (days) within each of them. The robust design assumes these assumptions to estimate parameters as: the probability of apparent survival (φ), the probability of temporary emigration (γ'', γ'), the probability of first capture (p), the probability of recapture (c) and the abundance of animals which are inside the study area for each primary period (N). As the time interval was not equal through the samplings we set them to get an annual apparent survival.

For better explain the process of temporary emigration, two parameters are used, γ'' which determine the probability of an animal been into the study area at a given primary occasion is unavailable for capture at the next primary occasion and γ' which is the probability of remaining outside of the study area between two primary occasions. Three models of temporary emigration are considered under a robust design: random ($\gamma'' = \gamma'$), where both temporary parameters are equal, no movement ($\gamma'' = \gamma' = 0$), which consider no temporary emigration are occurring and Markovian emigration ($\gamma'' \neq \gamma'$), where the probability of occurrence of an animal at a given primary occasion depends if whether it was present at study area at previous occasion. To test our hypothesis minimizing the number of parameters and considering making biological sense we modeled our study just using random temporary emigration.

We excluded from the encounter histories all juveniles because their sex could not be determined, and which were infrequently recaptured. A “global” model was constructed by estimating fully interactive sex and time-specific model parameters. We subsequently eliminated factors from the global model one at a time to determine which were most important. We included average temperature of the days of capture and previous month rainfall as a potential climatic factor affecting overall capture and recapture rates, we also analyzed if survivorship and capture and recapture probabilities were different between two sample periods including effort on models. Akaikes's Information Criterion (AIC) modified for overdispersion was used to evaluate relative support for candidate models and identify the most parsimonious, with lower number showing greater support and the AIC <4 indicating the top models (Akaike, 1973; Burnham and Anderson, 2002; Anderson 1998). There is no goodness-of-fit test for robust design, however, a Cormack-Jolly-Seber framework using primary periods was tested into package RELEASE in MARK, both to check overdispersion factor. If $\hat{c}>1$, there is a greater variability in data than would be expected given the model assumptions, moreover AICc values adjusted for overdispersion (QAICc) is used in this case (White and Burham 1999, Burnham and Anderson 2002).

To test if the population size would change through time, robust design generates population abundance monthly through derived parameters from the individual capture histories. We checked abundance into the best ranked model to analyze if there was any difference of population size after a 10 years period between both sample periods.

RESULTS

During the study, 50 turtles (24 females, 22 males and four juveniles) were captured 87 times over 2005-2006 period, whereas the 2016-2017 effort resulted in 70 turtles (36 females, 17 males, 17 juveniles) being captured 124 times. Over the samples, 15 adult turtles were marked during 2005-2006 and were recaptured along 2016-2017 period (12 females and three males).

Sex ratio of marked population was significantly 1:1 in 2005-2006 period (1.09:1; $\chi^2= 0.08$; $p=$

0.76) and strongly female biased in 2016-2017 period (2.11:1; χ^2= 6.81; p= 0.009). The sexual dimorphism occurred during 2005-2006 period with adult females were significantly larger and heavier than males while there is no difference between sexes during 2016-2017. Analyses between the same sex over both periods showed equal measures of males and a significant decrease in some measures of females (Table 1).

Table 1. Difference in mean measures of males and females during each period and between samples.

Measures	2005-2006				2016-2017				Between samples			
	Female (n= 23)	Male (n= 21)	F	p	Female (n= 23)	Male (n= 14)	F	p	Females		Males	
									F	p	F	p
Body mass (g)	387.72 (±117.8)	282.36 (±112.97)	9.98	0.003	289.54 (±83.59)	281.42 (±81.94)	0.08	0.77	8.36	0.006	0.001	0.96
Shell high (mm)	52.71 (±6.98)	45.65 (±6.67)	14.14	0.0005	46.45 (±6.57)	44.49 (±6.45)	0.79	0.37	7.61	0.008	0.78	0.35
Carapace length (mm)	138.25 (±13.45)	130.64 (±13.03)	3.65	0.06	126.06 (±11.96)	129.18 (±11.67)	0.62	0.43	9.55	0.003	0.13	0.69
Carapace width (mm)	98.04 (±9.88)	90.62 (±9.74)	7.05	0.01	89.75 (±8.52)	90.29 (±8.36)	0.03	0.85	8.02	0.006	0.01	0.89
Plastron length (mm)	126.17 (±27.25)	117.77 (±27.92)	1.04	0.31	114.13 (±21.44)	118.39 (±21.05)	0.35	0.55	2.32	0.13	0.007	0.92
Plastron width (mm)	67.56 (±17.83)	64.52 (±18.28)	0.31	0.57	70.59 (±8.44)	67.96 (±8.32)	0.88	0.35	0.39	0.53	0.75	0.30

Size class distribution slightly differed between periods mainly into females. Both periods showed higher concentration of individuals into intermediate body size class. During 2005-2006 period more female were detected into 150.1-160 mm class and no female were represented into first class of size (100.1-110 mm). In 2016-2017 period, females were concentrated into first classes, with just one female into 150.1-160 mm class (Figure 2).

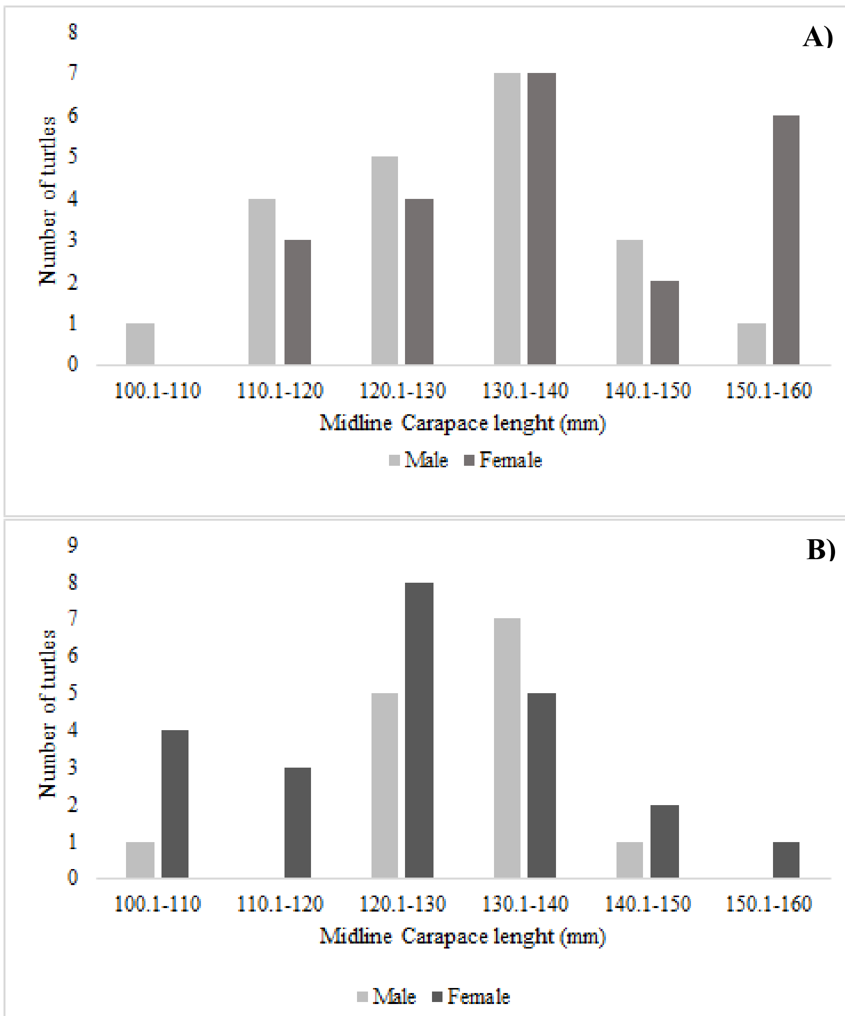

Figure 2. Size class of Carapace Length of adult marked individuals: A) males and females of 2005-2006 period. B) Males and females of 2016-2017 period.

Goodness-of-fit testing for CJS suggested no overdispersion of the data (ĉ =-0.50). Estimates from the both best models were similar, the first model to explain encounter history was S(group) Gamma” = Gamma’ *p*(.) *c*(.), indicating that capture and recapture rates are constant while survivorship varied among males and females (Akaike weight = 0.34). The second best ranked model was S(group) Gamma” = Gamma’ *p*(rain+temp) c(rain+temp) with a similar Akaike weight (0.21), including climatic factors influencing probability of capture and recapture. However, many models have obtained some degree of explanation (AICc Weight) (Table 2), for this reason we averaged estimates and standard errors.

Table 2. Model results of survivorship (S), emigration (Gamma” = Gamma’), capture probability (*p*) and recapture probability (*c*) under Pollok’s Robust Design of adult *Acanthochelys spixii* in Itapeva State Park, southern Atlantic Forest of Brazil. For each model, (g) indicates parameters are group sex specific, (.) indicates parameters are constant over time, (rain+temp) indicates parameters are related with climatic factors (rainfall and temperature), (period) indicates changes in estimates between two period samples, (*) indicates an interaction in parameters, (+) parameters act independently. AICc= Akaike’s Information Criterion, Delta AICc= the difference in AICc from the top model, AICc Weight= Akaike’s weight, K= the number of parameters in the model and Dev= the Deviance.

Model	AICc	Delta AICc	AICc Weight	K	Dev
{S(g) Gamma" = Gamma' p(.) c(.)}	823.6020	0.0000	0.34675	5	605.9343
{S(g) Gamma" = Gamma' p(rain+temp) c(rain+temp)}	824.5669	0.9649	0.21404	9	598.1448
{S(g+period) Gamma" = Gamma' p(.) c(.)}	825.4804	1.8784	0.13556	6	605.6641
{S(g) Gamma" = Gamma' p(g) c(g)}	826.4550	2.8530	0.08327	7	604.4638
{S(g+period) Gamma" = Gamma' p(rain+temp) c(rain+temp)}	826.6506	3.0486	0.07551	10	597.9715
{S(g*period) Gamma" = Gamma' p(.) c(.)}	827.6553	4.0533	0.04569	7	605.6641
{S(g) Gamma" = Gamma' p(period) c(period)}	827.7353	4.1333	0.04390	7	605.7441
{S(.) Gamma" = Gamma' p(.) c(.)}	828.4185	4.8165	0.03120	4	612.8734
{S(g*period) Gamma" = Gamma' p(rain+temp) c(rain+temp)}	828.9360	5.3340	0.02409	11	597.9715
{S(.) Gamma" = Gamma' (p = c)}	863.2681	39.6661	0.00000	3	649.8203

The results showed a slightly decrease in survivorship of males and females in the second period of samples, as well as similar values of detectability between both sexes. The apparent annual survival of males in 2005-2006 period was 0.90 (credibility interval= 0.66-0.97) which was lower than females 0.97 (credibility interval= 0.85-0.99), however both sexes showed a decrease in the annual survivorship values to 0.86 (credibility interval= 0.75-0.93) and 0.96 (credibility interval= 0.89-0.99) in the 2016-2017 period respectively (Figure 3).

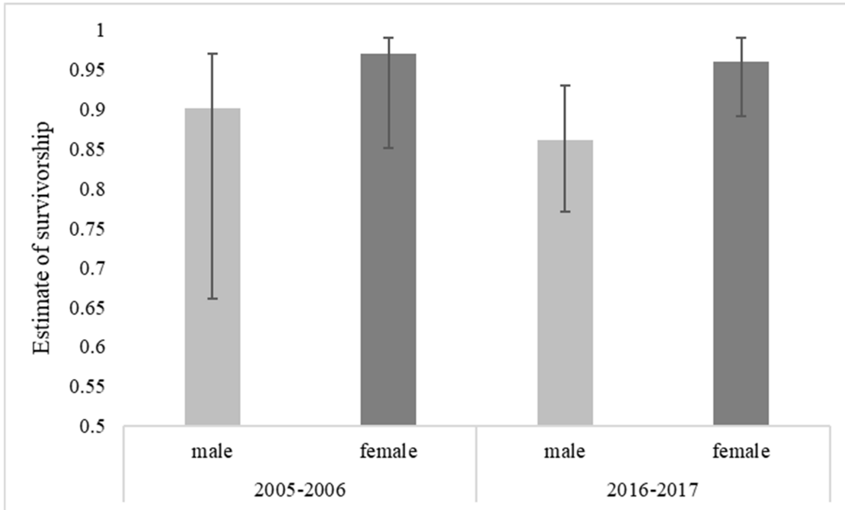

Figure 3. Survivorship of males and females over two samples with ten years gap.

Emigration values were considered constant over two periods showing a high value of 0.81 (credibility interval= 0.72-0.87). Capture probabilities ranged from 0.40 to 0.55 for males and females and there was no strong difference between primary occasions and periods. Recapture probabilities showed a great difference from capture probabilities ranging from 0.05 to 0.07 for both sexes in both periods (Figure 4A). Rainfall of 2005-2006 was 1577.8 mm with not significant difference from 2016-2017 period (1584 mm) (INMET, 2017). Climatic factors were found to have positive effect on captures and recapture rates on the second best supported model, however beta estimates of rainfall of the previous month suggested that this effect was uninformative for "*p*" and "*c*" (βrain(*p*)= 0.003, SE= 0.003, 95% CI= -0.002 to 0.010; βrain(*c*)= 0.004, SE= 0.005, 95% CI= -0.005 to 0.014), while average temperature of primary occasions showed an uninformative effect on recapture probabilities (βtemp= 0.100, SE= 0.081, 95% CI= -0.058 to 0.259) (Figure 4B).

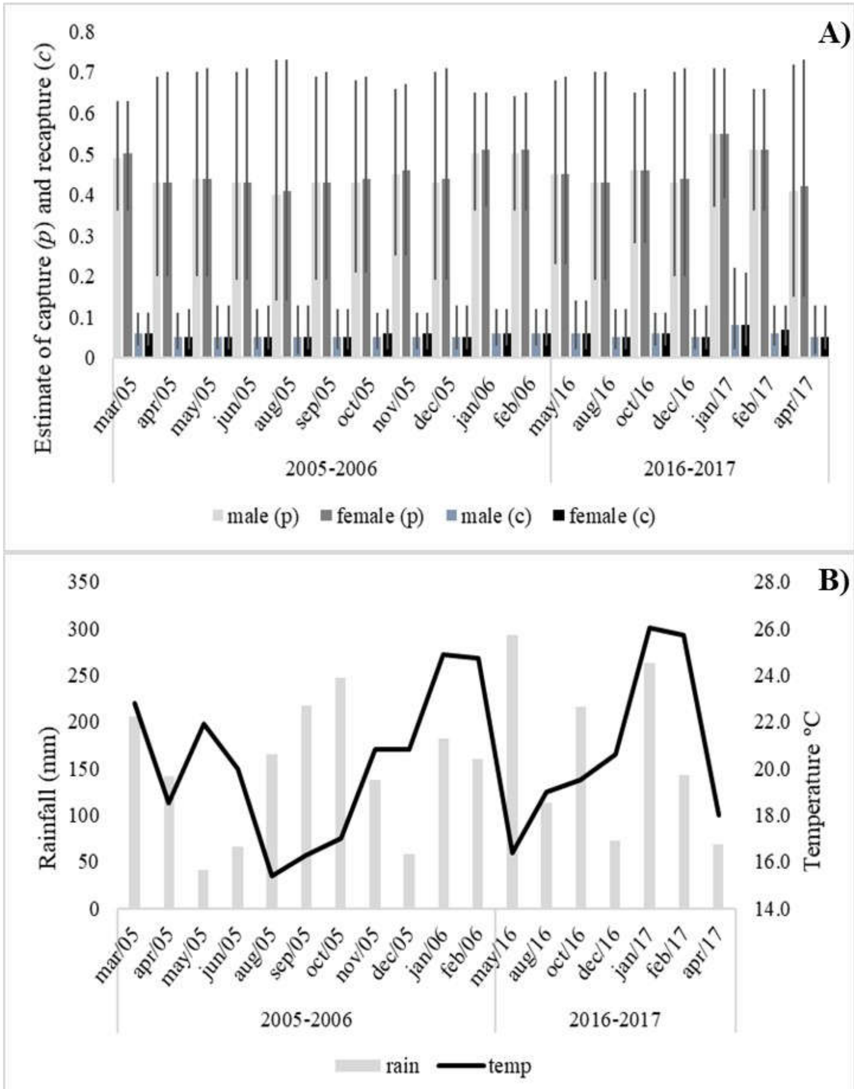

Figure 4. A) Estimate of capture and recapture over the 18-primary occasion. B) Average temperature of the primary occasions and rainfall of the previous month.

Monthly population size was taken from the derived estimates of the best ranked model. The estimates of the population size showed to be similar between 2005-2006 and 2016-2017 periods and slightly female biased. The estimate of the population varied from zero to 11 male adult turtles and from zero to 16 adult female turtles within the search area (Figure 5).

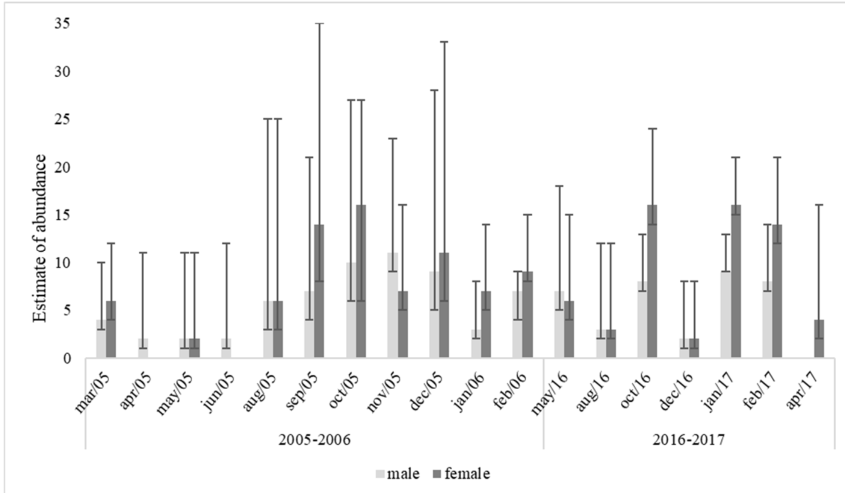

Figure 5. Estimate of monthly abundance within the search area over 18 primary occasion of the study.

DISCUSSION

The mechanism which determine sex in freshwater turtles can be done by genes or temperature of the nest (Bull and Vogt, 1979; Vogt and Bull, 1984). A few studies have been tested which mechanism freshwater turtle families are adapted to determine the sex of their individuals, despite *Acanthochelys spixii* has not been studied in this field, the chelidae shows evidences of a genotypic sex determination (GSD) (Jansen and Paukstis, 1991). In species with GSD, adult sex ratio is constrained to be 1:1, but sex bias is considerable by ecological and methodological factors (White et al, 2006). Agreeing with population of *Acanthochelys spixii* in Cerrado, northern Atlantic Forest and open areas of southern Brazil (Fraxe-Neto et al, 2011; Bager, 2016), our results showed a sex ratio of 1:1 during the first period of samples. One decade later, the population showed a strongly female biased sex ratio of 2:1 which can be a sign of oscillation in dynamic of the population throughout the years. Some anthropogenic factors as crossing roads around study area can be a significant explanation for mortality and consequently bias in sex ratio into the freshwater turtle populations (Aresco, 2005). As there are no roads surrounding area, either difference in capture and recapture probabilities between sexes, besides the higher survivorship of females, we suggest that ecological factors are driving this oscillation in sex ratio. Otherwise, these results must be analyzed with caution once not every month were sampled after the cold period (June-July) during 2016-2017 which represent the activity time of the specie after aestivation (Molina and Rocha, 1990). The mating period in captivity was found from November to January hereby is the most propitious moment to find males running for females (Molina and Rocha, 1990; Molina, 1998).

The sexual dimorphism in *Acanthochelys spixii* has been reported in other studies (Molina and Rocha, 1990; Molina, 1998; Fraxe-Neto et al, 2011 and Bager, 2016), with females being larger and heavier than males as we demonstrated in our first period of sample. This pattern of dimorphism seems to be present in most chelidae species (Cox et al, 2007; Ceballos et al, 2012). In most semiaquatic turtles, the male combat is less common which would be the main reason for bigger size. Being smaller, males would waste more energy searching females than combating with each other (Berry and Shine, 1980). Despite there are indications of higher mean measures for both sexes during second period of samples (2016-2017), there is no significance sexual dimorphism. During 2016-2017, females appears to decrease in body size from a previous decade, although the reason of this difference must be analyzed carefully. Both sexes in freshwater turtles can reach sexual maturity by size or age which can affect mean population body size and structure (Bowden et al, 2004; Congdon and Van Loben Seals, 1993). In studies of semiaquatic turtles, smaller females can produce less eggs and intensify their size (Risley, 1933; Legler, 1960), but a positive relationship of egg size and female body mass can also happen (Congdon and Tinkle, 1982). The decrease of size females a decade later can be reinforced by the size class of individuals marked. The higher number of females into higher size class in 2005-2006 and the concentration of females into first class of size in 2016-2017 must be driven the difference between mean body measures of females in both periods. The difference in chelonian population structure can be related with predation, anthropogenic pressure and overexploitation (Hailey et al, 1988), as our study area seems do not suffer much pressure by human's occupancy, we suggest that ecological features can be related with changes in size class distribution found throughout study. To better understand the causes of oscillation in body size is essential to maintain monitoring the population to analyze reproduction and recruitment throughout years.

Our estimate of annual survival for both sexes in both periods were consistently high. To provide longevity of the population, high values of adult survivorship are important to mitigate the loss of hatchlings and the late maturity of the young survivors (Congdon et al, 1993; Congdon and Dunham, 1997). The juveniles were not added into the model estimates, but the higher number of young turtle found during second period (2016-2017) may be a sign of increase in recruitment which can be related with a healthy population (Congdon et al, 1993).

In population isolated by roads and other threats, male and female bias in survivorship is common to happen as the mortality increase during mating, nesting and dispersal time in which demand different period of activity for each sex (Gibbons et al, 1990). However, with the absence of potential road killers surrounding our study area, the lowest survivorship of males even during the period which the sex ratio was 1:1 seems to be the pattern of this population. In most freshwater turtle, males are known to move overland more often than females (Morreale et al, 1984; Gibbons et al, 1990), and we suggest this may be related with lower survivorship of males in our study area.

The strongly difference between probability of capture and recapture (40-55% to 5-7% respectively) and the high probability of emigration (81%) from the search area give an ecological base in the management of this population. Our results suggest an invasive mark-recapture method in which seems to induce specimens to hide or emigrate from the search area in the subsequent primary occasions after been first marked. The walk of researchers through wetlands seems to cause turbidity in water, influencing perception of males and females which seems increase avoidance to stay in the search area during secondary samples (personal observation). As the probability of emigration in robust design means that individuals temporarily leave the search area (wetlands) and we found recaptures a decade later in proximity of their first encounter, we suggest that the *Acanthochelys spixii* is a territorial and strongly semiaquatic specie which is dependent of the land around water to seek place to aestivate and protection. Not only as a reflect to methodology, the freshwater turtle can emigrate from wetlands as a response to drought (Gibbons et al, 1983; Owen-Jones et al, 2015; Ferronato et al, 2016), increasing road mortality (Anthonysamy et al, 2013) and predation for exposure (Lindeman and Rabe, 1990). We also found a positive effect of rainfall in capture and recapture rates which can prompt higher dependence of land in the drought period by males and females. Decrease in survivorship of both sexes during second sample period (2016-2017) also can be related with prolongated periods of drought in the area, inducing individuals to dispersal and being more vulnerable to predation (Ferronato et al, 2016). We did not find any significant difference in rainfall between two sample periods, moreover the rain was less distributed throughout 2016-2017 consequently draining wetlands more often as usually happen during La Nina years in southern Brazil (Grimm et al, 2000). Owen-Jones et al (2015) found that the survival of European pond turtle (*Emys orbicularis*) decrease during long-term drainage from 0.99 to 0.63 and suggest the reason as the increase of mortality caused by movements among wetlands.

Our study is the first to use robust design to estimate life parameters of a freshwater turtle in south America. Robust design is the best model to obtain unbiases estimates in the presence of temporary emigration (Kendall et al, 1997). We cannot fairly compare our probabilities of abundance with freshwater turtle open model's studies once robust design estimate the size of population within the search area that in our case did not covered land outside water even they cannot be disassociated. The open models as CJS and Jolly-Seber estimate a superpopulation of the entire area studied and did not differ permanently emigration from death reaching consequently higher numbers of individuals (Lebreton et al, 1992; Kendall et al, 1997). We found a slightly female biased estimate of monthly abundance throughout the study with total population size ranging from two to 26 individuals. During four years of sample in Brazilian Cerrado, in a much smaller study area than ours (4ha), a superpopulation of *Acanthochelis spixii* was estimated in 30 individuals monthly (Fraxe-Neto et al, 2011). Hamer et al (2017) found a positive relationship in probability of survival of a chelidae specie (*Chelodina longicollis*) and proportion of green areas around wetlands in Australia. Population size restricted to wetlands, as our models provide us, is important to show the relationship between individuals and the landscape of water and land that our study area is composed. Our female biased abundance results reinforce the higher survival of females in which is reflected in the number of adults, furthermore the small number of turtle inhabiting permanent and temporary wetlands may be a sign of dependence of land which is supported by high rate of temporary emigration. The highest peaks of abundance (September to February) contribute as a tool to management of specie, reinforcing the activity time of both sexes after overwintering as has been reported in captivity (Molina e Rocha, 1990; Molina 1998).

There is no much information about the life parameters of this specie all over its distribution. We contribute to understanding of life history of this chelidae adding knowledge to the literature already been published. Our study provides evidences of change in structure and some important life parameters of a population of *Acanthochelys spixii* over the past ten years in one of the last protected remnant of Atlantic Forest in southern coast of Brazil.

MANAGEMENT IMPLICATIONS

Our results suggest alternative methods to tagging individuals to reach homogeneity of capture and recapture, maintaining monitoring of the population for more information on breeding and recruitment. The dependence of the specie to move between wetlands and vegetated dunes is a tool to keep the entire landscape protected. Regardless, heavier developments (e.g., construction of roads) should be avoided to adverse impacts on *Acanthochelys spixii* population which is a

Near Threatened specie in IUCN.

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CONSIDERAÇÕES FINAIS

Devido ao cenário alarmante dos Testudines em todo o mundo e a necessidade de preencher as lacunas de conhecimento na distribuição de suas espécies, o presente estudo contribui com informações sobre morfometria e estimativas de parâmetros populacionais de uma população de *Acanthochelis spixii* no extremo sul da região costeira da Mata Atlântica. Os parâmetros de vida, nos quais são essenciais para se compreender o verdadeiro status de conservação das espécies, só eram conhecidos para o cágado-preto em uma localidade do bioma Cerrado na qual é muito pouco representativa frente a ampla distribuição deste quelônio.

Através do conhecimento adquirido durante o período de esforço amostral foi possível não somente entender aspectos particulares da população como comparar os resultados com o conhecimento já gerado em algumas das populações já estudadas. Variações nos aspectos populacionais de táxons com ampla distribuição são esperados e nossos resultados servirão como base não somente para o manejo da espécie, mas também para melhor compreender como se comportam frente às mudanças no ambiente e servirão de modelo para o manejo de outros quelônios.

A utilização de modelos para estimar os parâmetros de vida se mostraram de grande utilidade para aprimorar nossos resultados, auxiliando no refinamento das probabilidades e proporcionando a solução das hipóteses. O presente estudo faz parte de um restrito número de trabalhos que aplicou modelos a fim de corrigir a detecção imperfeita em populações de quelônios sul americanos. Assim como outros trabalhos demográficos de quelônios brasileiros, podemos contribuir para futuras novas reavaliações sobre o status de conservação destes táxons tão vulneráveis.

O conhecimento sobre a população de *Acanthochelys spixii* em uma Unidade de Conservação da Mata Atlântica irá auxiliar na criação de estratégias para a conservação da espécie, mesmo que estas unidades protegidas muitas vezes não assegurem proteção integral.

Acreditamos que os nossos resultados somados aos estudos efetuados no Bioma Cerrado podem dar início a uma reavaliação do status de conservação da espécie, no qual não é atualizado junto à IUCN desde 1996.

Amparado por uma avaliação do status de conservação mais atualizado, juntamente com o conhecimento gerado por trabalhos *in locu* como o presente estudo, pode-se dialogar com outras frentes sobre as maneiras menos invasivas de interferência nas áreas de vida destes táxons. Apesar de serem associados à ambientes aquáticos, os indivíduos demonstraram relação íntima com o ambiente terrestre a sua volta, evidenciando o cuidado necessário do manejo das populações e de seus sistemas associados.

A manutenção do monitoramento desta população e a ampliação das áreas de amostragem para fora da Unidade de Conservação é uma importante estratégia a ser tomada a partir dos nossos resultados, possivelmente podendo enriquecer o conhecimento sobre a espécie e a importância da manutenção de áreas protegidas monitoradas ao longo do território brasileiro.

O Parque Estadual de Itapeva vem sendo alvo de uma forte especulação imobiliária e a faixa de praia é a região mais ameaçada neste sentido. A cidade de Torres é circundada pelo rio Mampituba ao norte e pelo PEVA ao sul, resultando em uma forte pressão política para que seja criado um acesso que consequentemente acarretaria no crescimento da cidade para dentro do parque no sentido norte-sul. Através dos nossos resultados podemos demonstrar a dependência dos indivíduos da espécie pelas áreas de dunas e restinga que circundam os banhados amostrados, como referenciado durante todo o presente estudo, as estradas podem ser ranqueadas como uma das principais ameaças à fauna de quelônios, fragmentando seu habitat e consequentemente matando os indivíduos durante a dispersão, dizimando as populações. A construção de qualquer tipo de acesso na baixada úmida e suas redondezas pode ser classificada como uma drástica atitude frente a conservação da população de *Acanthochelys spixii* do PEVA na qual não justifica o crescimento econômico da região.