Trachemys dorbigni in an anthropic environment in southern Brazil: I) Sexual size dimorphism and population estimates

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Trachemys dorbigni is the southernmost species of its genus, and is subject to strong pressure from harvesting for the pet trade. We collected 377 individuals of *T. dorbigni* in an urban marsh in southern Brazil between February 2006 and January 2007, to document sexual dimorphism and to provide data on the structure of the population. The sex ratio was not different from 1:1. Animals that exceeded 127 cm in carapace length (CL) were considered adults. Females were, on average, heavier and larger than males but had a smaller carapace and plastron terminal distance (CPD). The weekly recapture probability for juveniles was constant (4%). However, adults varied in weekly recapture probability, which may be associated with their reproductive behaviour. Weekly survival was constant for juveniles (94%) and adults (97%). Future investigations should analyse how survival and recapture fluctuate in an environment where a large proportion of the eggs and young are collected for the pet trade.

Key words: activity, D'Orbigny's slider turtle, Emydidae, population parameters, sexual dimorphism, Testudines

INTRODUCTION

The survival of at least two-thirds of existing chelonian species is threatened to some degree, because of loss or modification of habitats and indiscriminate collection by humans for the pet trade, food and traditional medicine (Klemens, 2000). In urban environments, increases in roadkill rates (Gibbs & Shriver, 2002) and water pollution (Close & Seigel, 1997) are among the factors that threaten the survival of this group. However, some species have demonstrated resilience in terms of surviving in degraded habitats (*Trachemys scripta*, *Emys marmorata* and *Phrynops geoffroanus*; Gibbons, 1970; Lindeman, 1996; Souza & Abe, 2000; Spinks et al., 2003), which are characterized by less competition for food, since the increase in organic matter can lead to an increase in prey species (Spinks et al., 2003).

The genus *Trachemys* has one of the largest distributions of all vertebrate genera and comprises 26 distinct species and subspecies (Seidel, 2002). Whereas *T. scripta* is probably the best-known turtle in the world (Ernst, 1990), the biology of the southernmost species, *T. dorbigni*, is much less known (Krause et al., 1982; Bager et al., 2007). Pereira & Diefenbach (2001) established a relationship between the age and size of individuals, but only Bager (2003) evaluated the species' sexual dimorphism based on its morphometry.

Trachemys dorbigni is not included in any conservation category in the state of Rio Grande do Sul, Brazil (Di-Bernardo et al., 2003). However, the species suffers from the collection of eggs and juveniles to supply the pet trade (Lema & Ferreira, 1990; Barco & Larriera, 1991), at a level that can cause population declines (Molina & Gomes, 1998). Despite these potential threats, populations of *T. dorbigni* in anthropogenically altered environments have never been evaluated.

In the present paper we assessed sexual dimorphism and sex ratio, population structure, activity and weekly variation in recapture and survival for male, female and juvenile *T. dorbigni* in an urban environment in southern Brazil, to evaluate if these characteristics show any differences from populations living in less disturbed environments. Capture and survival data were tested for heterogeneity, because these parameters contribute to sampling biases in population-estimate studies; correcting estimates for bias have rarely been reported (Kazmaier et al., 2001). For a related study on reproductive activity in the same population, see Fagundes et al. (2010).

MATERIALS AND METHODS

Study site

The study area is situated on the coastal plain of Rio Grande do Sul, Brazil (Rambo, 2000) and lies within South America's largest lagoon complex, comprising the Patos, Mirim and Mangueira lagoons. This area encompasses important coastal, limnetic and terrestrial ecosystems, most notable of which are the extensive marshes. The region's soil is sandy with creeping herbaceous vegetation (Calliari, 1998). According to Maluf (2000) the climate

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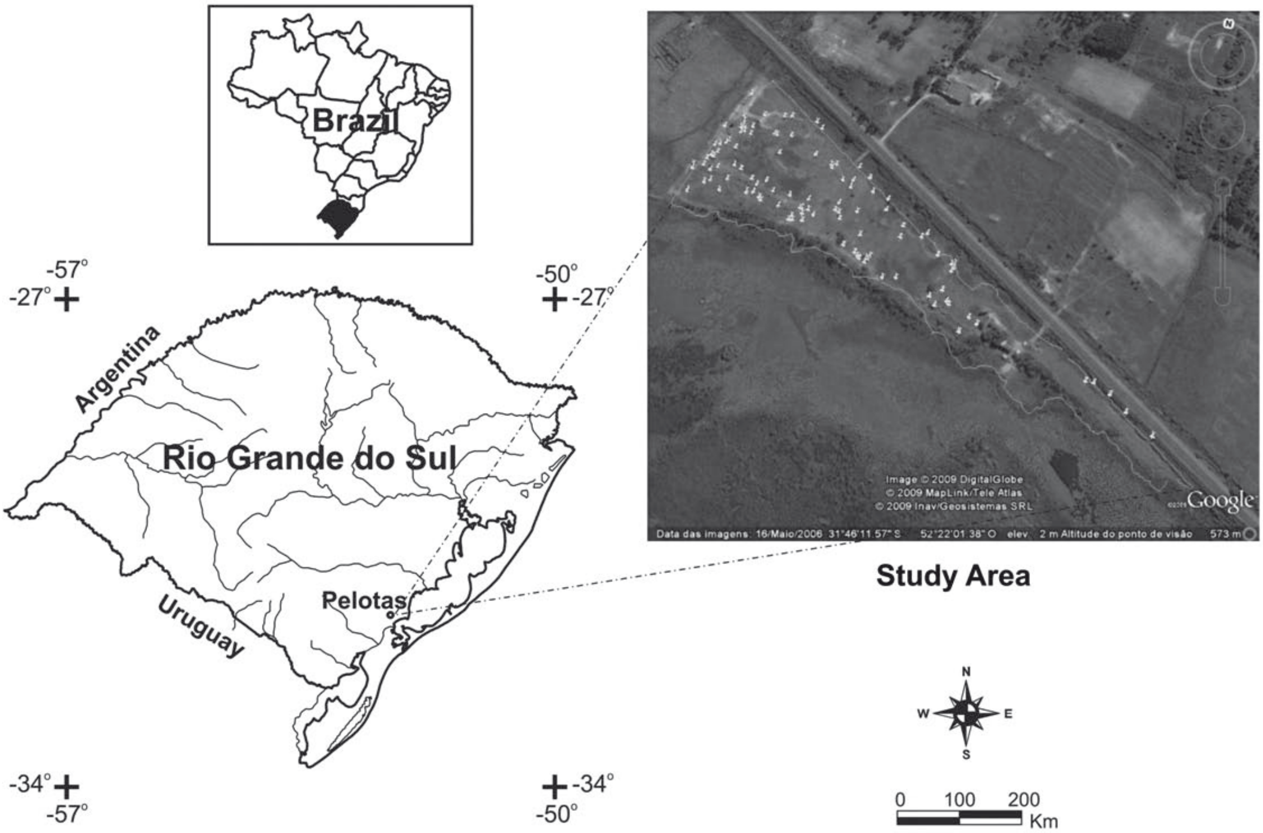

Fig. 1. Study area in southern Brazil.

is classified as Temperate Superhumid (Te Su) with an annual mean temperature of 19.2 °C. Rainfall is more or less evenly distributed throughout the year, with an annual mean of 1708 mm (Maluf, 2000).

The study was carried out on the banks of a marsh (52°36'82.1"S, 31°76'94.7'"W) formed by the waters of the Santa Barbara Creek, with an approximate area of 5.7 ha, in the city of Pelotas (Fig. 1). The sampling area borders a highway (BR 392) for a distance of 680 m, located near the entrance to the city of Pelotas. The water in the marsh has a mean depth of about 80 cm and is characteriszd by floating macrophytes. Untreated domestic sewage is discharged into the marsh.

Data collection

Study individuals were collected using two models of baited traps (Vogt, 1980) in two sampling periods, from February to April 2006 and from September 2006 to January 2007. A total of eight traps were used; four fyke net traps, with a single opening measuring 30.4 cm in width and 14.7 cm in height, and four crab traps, each with four openings (one on each side) measuring, on average, 40.5 cm around the perimeter. The traps were set at approximately 6 m intervals and were checked every day. When the traps were found empty, they were refilled with bait.

Turtles were marked with individual notches on the marginal shields, using the method described by Cagle (1939) with some modifications. They were released at the capture site immediately after capture, with the exception of some males collected during the first sampling period; these individuals were sent to a commercial breeding centre according to a determination of the Brazilian federal environmental agency (IBAMA record: 268286).

The sex of each turtle was determined through evaluation of secondary sexual characters (Bager et al., 2007). Animals that exceeded a cut-off line in size without showing male secondary sexual characters were considered females, and smaller turtles were considered juveniles.

The following morphometric measurements were taken for each individual with a vernier caliper (precision 1 mm): carapace length (CL), carapace width (CW), plastron length (PL), posterior lobe width (PLW) and carapace height (CH). Carapace and plastron terminal distance (CPD) measurements were made with a vernier caliper (precision 0.1 mm). In the first sampling period, all the individuals were weighed.

Statistical analysis

Data were tested for statistical normality using the Shapiro–Wilk method. Non-normal data were transformed using natural logarithms. Linear regression analyses were carried out to test the relationships between morphometric measures. We used carapace length (CL) as the independent variable and the other measurements as dependent variables. Outliers were removed using the equation described in the Statistica'98 program (Statsoft, 1995):

$$\text{Upper limit} = \bar{x} + SE + 2 * o.c. * [(\bar{x} + SE) - (\bar{x} - SE)] \quad (1)$$

$$\text{Lower limit} = \bar{x} - SE - 2 * o.c. * [(\bar{x} - SE) - (\bar{x} - SE)] \quad (2)$$

Table 1. Models for estimating adult and juvenile survival (φ) and recapture rates (ρ) of marked *Trachemys dorbigni* in a marsh in southern Brazil. Par = number of parameters; AICc = Akaike information criterion; ΔAICc = differences in the AICc value from the best-fit model (ΔAICc). Description of the model for each parameter: (.) = constant through time; (t) time-variance in survival or recapture; (g) group-variance in survival or recapture.

	Model	AICc	ΔAICc	AICc weight	Model likelihood	Par	Deviation
Adults	φ (.) ρ (t)	942.6	0	0.8	1.0000	28	369.5
	φ (g) ρ (t)	944.8	2.2	0.2	0.3	29	369.4
	φ (g) ρ (g)	953.9	11.4	0.003	0.003	4	432.9
	φ (.) ρ(g)	955.3	12.7	0.001	0.002	3	436.2
	φ (.) ρ (.)	960.5	17.9	0.00009	0.0001	2	443.5
	φ (t) ρ (g)	983.5	40.9	0	0	29	408.1
	φ (t) ρ (.)	988.8	46.3	0	0	28	415.8
	φ (.) ρ (g*t)	991.2	48.7	0	0	55	351.6
	φ (g) ρ (g*t)	991.7	49.2	0	0	56	349.4
	φ (t) ρ (t)	995.8	53.3	0	0	52	364.1
	φ (g*t) ρ (g)	1045.9	103.3	0	0	56	403.6
	φ (g*t) ρ (.)	1050.2	107.7	0	0	55	410.6
	φ (t) ρ (g*t)	1050.6	108.1	0	0	78	346.1
	φ (g*t) ρ (t)	1071.0	128.5	0	0	80	360.4
	φ (g*t) ρ (g*t)	1129.8	187.2	0	0	103	344.1
	φ (.) ρ (.)	333.2	0	0.9	1.0	2	214.1
Juveniles	φ (.) ρ (t)	348.2	14.9	0.0006	0.0006	28	161.8
	φ (t) ρ (.)	379.3	46.0	0	0	28	192.9
	φ (t) ρ (t)	425.2	91.9	0	0	49	154.5

where SE is the standard error and o.c. is the outlier coefficient. An o.c. of 3 was used in all analyses. Parallelism tests were used to compare the linear regression results for males and females in the bivariate analysis. When the parallelism test indicated a non-significant difference, we used covariance analyses (with the carapace length as the covariable parameter) to compare the intercept.

Activity was examined by catch per unit effort (CPUE), where the number of individuals collected in each month was divided by the hours of sampling effort in each month. The capture variation between sexes and between adult and juvenile individuals in the two types of traps was analysed using the chi-square test. This test was also used to assess sex-ratio differences in the two sampling periods separately. Analysis of variance (ANOVA) was used to evaluate the monthly difference between the CPUE of females, males and juveniles, as well as the size differences (CL) of the individuals collected in both types of traps. The relationship between the average monthly values for environmental temperature and precipitation and those for the CPUE were determined through regression analysis. Climate variables were obtained from the Agroclimatology Station in Pelotas.

Estimation of population parameters

In order to estimate survival (φ) and recapture (ρ) probabilities, the capture history of each individual was constructed based on its capture or non-capture in each week (capture occasion). We used the Cormack–Jolly–Seber (CJS) method in the MARK program (White & Burnham, 1999) to find the φ and ρ models that best fit the data obtained. For the adults, 15 possible models were constructed. The general model included the effect of the variables time (t) and sex (g) on the survival (φ) and capture (ρ) rates. For juveniles, four models were constructed and the effect of time (t) on the φ and ρ values constituted the general model. These general models included all possible variations for each group. The selection of the model that best fit the data was based on a small number of likelihood ratio tests for specific hypotheses and on the minimum values of the Akaike information criterion (AIC_c) (Lebreton et al., 1992). The models tested are listed in Table 1.

Goodness-of-fit (GOF) tests of the RELEASE program incorporated in MARK were performed to investigate the presence of significant deviations from the general model of our data. The males removed during the first sampling period were not included in this analysis. The low recapture percentage for males resulted in insufficient data for the GOF tests in the RELEASE program. Test 2 in the RELEASE program was used to evaluate the assumption that every animal in the population at the time of the ith sample had the same probability of capture. Test 3 in the RELEASE program was used to evaluate the assumption

Table 2. Morphometric measurements used for the characterization of *Trachemys dorbigni* individuals captured in southern Brazil.

		CL (mm)	MCW (mm)	MPL (mm)	PLW (mm)	MCH (mm)	CPD (mm)	MASS (g)
Males	*n*	146	146	146	146	146	23	120
	Mean	163.2	125	148	79.3	67.1	20.1	674
	Min.	127	99	118	63	53	13	294
	Max.	215	163	199	108	94	26	1392
	1 SD	18.23	11.02	16.01	8.19	7.22	2.91	207.79
Females	*n*	160	160	160	160	160	31	127
	Mean	182.4	141.3	170.9	90.5	77.6	18.6	1016.6
	Min.	127	102	119	62	54	12.4	337
	Max.	255	190	236	118	107	26	2527
	l SD	25.12	23.21	170.87	19.86	10.38	3.76	481.81
Juveniles	*n*	71	71	71	71	71	20	49
	Mean	102.5	88.3	96.4	53.1	45.9	8.9	215.4
	Min.	39.3	37.2	35.1	16.7	15	3.5	46
	Max.	126	108	120	67	60	15	336
	1 SD	21.02	15.6	20.31	10.94	9.46	3.53	93.42

that every marked animal in the population immediately after the i^{th} sample had the same probability of survival until the $(i + 1)^{th}$ sample.

RESULTS

Sexual dimorphism and size structure

A total of 377 individuals were captured (71 juveniles, 146 males, 160 females), with adults comprising the majority (81.2%; *n*=306). The sex ratio did not deviate from 1:1 in the first (χ^2=0.20, df=1, *P*=0.66) or second (χ^2=0.45, df=1, *P*=0.50) sampling period.

Tail length was used to determine sex and maturity. The smallest male identified by tail length measured 127 mm CL. Therefore, individuals that exceeded this cut-off line were considered adults (Table 2). The majority of males and females ranged between 160 and 180 mm and 180 and 200 mm in CL, respectively (Fig. 2). On average, females were larger and heavier than males in all morphometric measurements except for CPD (Table 2).

In females and juveniles, all morphometric measurements depended on CL. For males, the only exception was CPD (Table 3). Because CPD differed between males and females, this measurement is an important sexually dimorphic character. The ANCOVA analysis was significant (*P*<0.05), demonstrating the independence of the equations calculated for females and males for the same variables. The parallelism analysis showed significant differences (*P*<0.05) in the slopes of the CPD measurements.

Activity

We carried out 4776 h of collection in the first sampling period and 19,090 h in the second period. More individuals were captured in the first sampling period (*n*=299, χ^2=128.38, df=1, *P*<0.05). The fyke net traps were more efficient in catching the turtles (*n*=312, χ^2=160.52, df=1, *P*<0.05). In this trap type, there was no difference in captures between sexes (χ^2=1.37, df=1, *P*=0.24), but we collected significantly fewer juveniles (*n*=48) than males (*n*=122, χ^2=31.35, df=1, *P*<0.05) and females (*n*=142, χ^2=45.52, df=1, *P*<0.05). In the crab traps, there was no difference between the proportion of males (*n*=24) to females (*n*=18) (χ^2=0.59, df=1, *P*=0.44) or the proportion of adults to juveniles captured (*n*=23, χ^2=0.95, df=2, *P*=0.62). However, the mean CL of individuals captured in the crab traps was smaller than those captured in the fyke nets ($F_{1, 375}$ = 22.92, *P*<0.05).

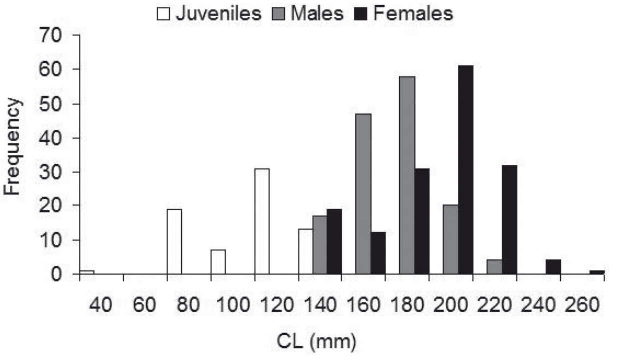

Fig. 2. Frequency distribution of carapace length (CL) for juvenile, male and female *Trachemys dorbigni* in southern Brazil, February–April 2006 and October 2006–January 2007.

Table 3. Regression analysis of morphometric measurements for juveniles, males and females, and covariance and parallelism analysis of body measurements of male and female *Trachemys dorbigni* captured in southern Brazil. Carapace width (CW), plastron length (PL), posterior lobe width (PLW), carapace height (CH), carapace and plastron terminal distance (CPD) and mass (M).

		Regression parameters						Covariance		Parallelism	
		n	a	B	r^2	*F*	*P*	*F*	*P*	*F*	*P*
CW	Females	156	–27.1	1.5	94.9	2899.1	<0.05	89.6	<0.05	0.5	0.5
	Males	146	–34.2	1.6	91.7	1540.4	<0.05				
	Juveniles	71	0.2	0.9	99.1	7786.4	<0.05				
PL	Females	160	–0.0001	1.1	97.3	5640.7	<0.05	150.7	<0.05	0.5	0.5
	Males	145	–1.8	1.1	96.5	3772.3	<0.05				
	Juveniles	71	0.9	0.9	95.8	1605.3	<0.05				
PLW	Females	158	–3.9	2.1	90.8	1550.8	<0.05	47.5	<0.05	0.3	0.6
	Males	138	–2.4	2.1	88.5	1057.1	<0.05				
	Juveniles	68	2.2	2.2	96.0	1590.1	<0.05				
CH	Females	160	0.5		92.1	1854.2	<0.05	60.4	<0.05	0.02	0.9
	Males	136	–2.3	2.5	86.9	896.3	<0.05				
	Juveniles	19	42.4	5.9	65.4	34.9	<0.05				
CPD	Females	31	75.5	5.6	70.2	69.4	<0.05	13.3	<0.05	7.9	<0.05
	Males	22	136.0	1.0	–2.6	0.5	>0.05				
	Juveniles	49	2.9	0.3	98.7	3579.5	<0.05				
M	Females	126	2.9	0.3	96.2	3189.9	<0.05	41.1	<0.05	5.5	0.02
	Males	119	2.8	0.3	95.1	2277.8	<0.05				

The CPUE values for females ($F_{1,6}$=4.56, P<0.05) and juveniles ($F_{1,6}$=3.20, P<0.05) were highest in February and March. For males, CPUE was highest in February, followed by April ($F_{1,5}$=7.19, P<0.05) (Fig. 3). The CPUE value obtained for *T. dorbigni* in each month was not correlated with mean monthly temperature ($F_{1,6}$=0.43, P=0.54) or rainfall ($F_{1,6}$=0.28, P=0.62).

Estimation of population parameters

Of the 256 individuals that were marked and returned to the marsh, 33.6% were recaptured (51 females, 11 males, 24 juveniles). For adults, the model with the greatest parsimony showed a constant survival (φ) over time (t) and between sexes (g). According to this model, the survival for both sexes and sampling occasions was 0.97. In the best model, the recapture rate (ρ) was constant between sexes, but ranged from 0.003 to 0.13 (Table 4). Survival (φ) and recapture (ρ) probabilities for juveniles were constant among sampling occasions in the most parsimonious model. The estimate for juvenile φ was 0.94 and for ρ was 0.04.

The survival homogeneity test (GOF Test 3) indicated that previously marked and non-marked adults (χ^2=4.53, df=19, P=0.99) and juveniles (χ^2=8.35, df=8, P=0.4) had the same survival probability. However, for the last group, on two occasions (third week of February and second week of November) this assumption was not verified. The test also demonstrated that the survival of females (χ^2=1.64, df=6, P=0.95) and juveniles (χ^2=0.63, df=2, P=0.73) was not dependent on the period in which they were captured.

The recapture homogeneity test (GOF Test 2) showed that the recapture rate of juveniles was not dependent on the capture occasion (χ^2=1.94, df=11, P=0.99). The same result was obtained for the females (χ^2=19.02, df=24, P=0.75), except for the last week of October, where this premise was violated. The combination of Tests 2 and 3 (χ^2=36.12, df=74, P=0.99) indicates that the assumptions of equal capture and survival were verified.

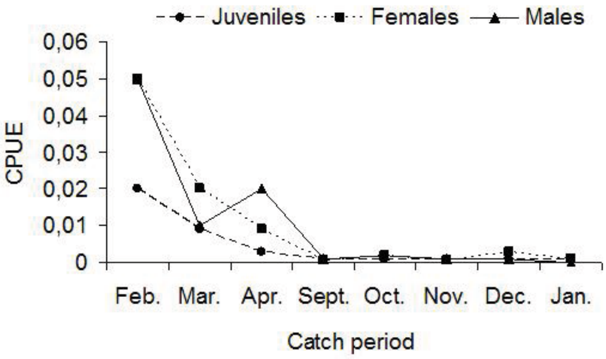

Fig. 3. Number of juvenile, male and female *Trachemys dorbigni* captured in each month (February–April 2006 and October 2006–January 2007) per unit effort.

Table 4. Estimates of adult and juvenile survival (φ) and recapture (ρ) probability for *Trachemys dorbigni* for the model with the highest parsimony.

Group	Para-meters	Estimates	3 SE	IC (95%)
Adults	φ	0.97	0.01	0.93–0.99
	ρ 2	0.09	0.04	0.03–0.22
	ρ 3	0.08	0.04	0.03–0.19
	ρ 4	0.13	0.04	0.06–0.23
	ρ 5	0.05	0.03	0.02–0.13
	ρ 6	0.03	0.02	0.01–0.1
	ρ 7	0.004	0.004	0.006–0.03
	ρ 8	0.04	0.02	0.02–0.12
	ρ 9	0.01	0.01	0.001–0.07
	ρ 10	0.06	0.03	0.03–0.14
	ρ 11	0.01	0.01	0.001–0.07
	ρ 12	0.01	0.01	0.001–0.07
	ρ 13	0.01	0.01	0.001–0.07
	ρ 14	0.02	0.01	0.005–0.08
	ρ 15	0.003	0.003	0.005–0.02
	ρ 16	0.02	0.01	0.005–0.08
	ρ 17	0.04	0.02	0.01–0.1
	ρ 18	0.02	0.01	0.004–0.06
	ρ 19	0.06	0.02	0.03–0.12
	ρ 20	0.04	0.02	0.02–0.08
	ρ 21	0.03	0.01	0.01–0.08
	ρ 22	0.04	0.02	0.02–0. 09
	ρ 23	0.06	0.02	0.03–0.11
	ρ 24	0.02	0.01	0.007–0.05
	ρ 25	0.005	0.005	0.007–0.04
	ρ 26	0.01	0.007	0.002–0.04
	ρ 27	0.04	0.02	0.02–0.09
Juveniles	ρ 28	0.004	0.004	0.006–0.03
	φ	0.95	0.02	0.89–0.97
	ρ	0.04	0.009	0.02–0.06

In mid January 2007 (after completion of the study), more than 90% of the nests had their eggs removed for the pet trade. Local residents reported that this practice is very common, as is the removal of juveniles from the study area.

DISCUSSION

Sexual dimorphism and size structure

The majority of the turtles collected were adults. This pattern is very common in chelonians, since adults have high survival rates (Congdon et al., 1993; Litzgus & Mousseau, 2004; Verdon & Donnelly, 2005) and the mortality rate of juveniles is high (Bury, 1989). However, the estimates for juvenile weekly survival in our study were also high. This might have occurred because the majority of juveniles captured by our collection method were not newly born (between 100 and 120 mm CL). These differences in adult capture rates between weeks may be related to movement patterns linked to the reproductive behaviour of females and males (Kazmaier et al., 2001).

The sampling technique used in a study may bias estimates of size and the sex ratio (Gibbons, 1990), but he sampling effort with two trap models may have helped to collect a sample that was representative for the population (Girondot & Pieau, 1993). Koper & Brooks (1998) found that the accuracy of sampling increases with sample size. Even the removal of some males from the population in the first capture period did not change the sex ratio estimated from subsequent captures. The large number of adults in the population and the similar mortality rates of the sexes may contribute to this result (Girondot & Pieau, 1993). In addition, it is possible that males from adjacent areas migrated to the study location (Gibbons, 1990).

As with many species of the genus *Trachemys* (Lovich et al., 1990), males of *T. dorbigni* show progressive melanization of the carapace. However, the melanization is thought to occur after the tail lengthens. Based on the tail length, the smallest distinguishable male measured at least 127 mm CL. Bager (2003) found the same model of sexual dimorphism in their population, where the smallest distinguishable male had a CL of 132 mm. We did not establish the carapace length after which melanization becomes evident; Freiberg (1969) commented that this dimorphism begins when males reach 150 mm CL.

Different factors are involved in determining the optimal size for mature individuals of each sex (Berry & Shine, 1980). Size divergences between sexes may indicate differences in their ecology and physiology and also evolutionary aspects (Dunham & Gibbons, 1990). Our measurements indicated, as observed in many species of emydids (Berry & Shine, 1980), that females are larger than males, probably to increase their reproductive potential (Lovich & Gibbons, 1992). In the present study, males exceeded females only in CPD, and this was not correlated with the growth of CL. Thus, possibly, CPD increases faster in relation to CL in the period before sexual maturity because of the increase in tail length, which also occurs in this phase.

On average, the females were 30 mm smaller and the males were 18 mm smaller than those studied by Bager (2003) in a protected area about 100 km from our study area. Differences between populations may occur because of the quantity and quality of food available in different environments (Gibbons, 1967), or due to other local habitat characteristics such as annual precipitation and hunting pressure (Daza & Páez, 2007). Studies in polluted environments have found rapid growth of other species, as a high amount of organic matter in such environments can lead to an increased prey base (Knight & Gibbons, 1968; Gibbons, 1970; Lindeman, 1996), contrary to our data. The anthropogenic impacts on the marsh may have reduced growth of the turtles, as observed by Moll (1980) in *Chrysemys picta.*

Activity

Lebreton et al. (1992) and McMaster & Downs (2006) observed that variations in sampling effort influence capture levels, and accuracy increases with sample size in mark–recapture estimates with different sampling methods (Koper & Brooks, 1998). We employed a greater capture effort in the second sampling period, but captured fewer individuals in this period. This may reflect an annual variation in the activity pattern of the species.

The fyke net trap directs the turtles more effectively to its interior. However, the larger opening of this trap enables it to collect, on average, larger individuals than those captured in the crab traps. It is also probable that juveniles can escape more easily than the adults. Frazer et al. (1990) commented that *C. picta* and *T. scripta* frequently escaped from the traps that they used.

The largest numbers of females and juveniles were collected in February and March. Gibbons et al. (1990) reported that the majority of freshwater turtles migrate in spring and summer. The February–March period coincides with the end of the breeding season, when females presumably search for food to replace energy losses from breeding (Peterson, 1996). The large number of males captured in April, however, may be associated with the search for females for mating. Climate conditions can also affect the species' activity level (Duda et al., 1999), but in this study, *T. dorbigni* did not show any correlation with rainfall or mean monthly temperature.

Estimation of population parameters

Survival rates of adults and juveniles were constant during the collection period, as also observed by Kazmaier et al. (2001) and Casale et al. (2007), whereas Langtimm et al. (1996) found a weekly variation in survival rates of *Terrapene carolina bauri* (0.94–1.00). The marking process may have affected adult recapture rates, because they might have learned to avoid the traps (also observed by Langtimm et al., 1996). The recapture rates for juveniles remained constant.

As reported for many chelonian populations (Congdon et al., 1993; Litzgus & Mousseau, 2004; Verdon & Donnelly, 2005), the estimates of weekly survival for juveniles were lower than those for adults. Considering the intense pressure on eggs and juveniles collected for the pet trade, and that all captured individuals were between 100 and 120 mm in CL, we would expect higher mortality rates in juveniles of smaller size classes. The two sexes showed the same survival indexes, similar to other studies (Langtimm et al., 1996; Verdon & Donnelly, 2005). Tucker et al. (1999) found higher mortality among the smallest and youngest nesting females for *Trachemys scripta*.

Although we did not find any heterogeneity in recaptures between sexes, this does not mean that all the individuals were equally subject to capture during each sampling event, as the population may include transient animals (Prévot-Julliard et al., 1998). Mostly, the rejection of the hypothesis of recapture variation between the sexes suggests that the sampling method had a very small influence on this difference. On two occasions, the assumptions of Test 3 were not verified for the juveniles. These transients were detected in the summer, when chelonians migrate most actively (Gibbons et al., 1990; Langtimm et al., 1996). The GOF tests showed that the assumptions for survival and recapture were not violated by females and juveniles. Thus, the males may have been responsible for the temporal heterogeneity in the adult recapture data.

The estimates for population size of *T. dorbigni* are larger than previous estimates for other emydid species (Chase et al., 1989; Lindeman, 1990; Litzgus & Mousseau, 2004). The habitat investigated may offer benefits such as the absence of predators, accumulation of organic matter and extensive locations available for nesting (Moll & Moll, 1990). The survival rate of *T. dorbigni* in the marsh may be underestimated, since the CJS method does not distinguish mortality from emigration, which is particularly important for males. Certainly, the short sampling period also influenced the estimation of this parameter. However, high survival rates were also recorded in longer studies (Heppell et al., 1996; Langtimm et al., 1996; Freilich et al., 2000; Chaloupka & Limpus, 2002).

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REFERENCES

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. PhD. thesis. Porto Alegre, Brazil: Universidade Federal do Rio Grande do Sul (UFRGS).

Bager, A., Freitas, T.R.O. & Krause, L. (2007). Nesting ecology of a population of *Trachemys dorbigni* (Emydidae) in southern Brazil. *Herpetologica* 63, 56–65.

Barco, D.M. Del & Larriera, A. (1991). Sobre la validez de las subespécies de *Trachemys dorbigni* y su distribucion geografica (Reptilia, Chelonia, Emydinae). *Revista de la Asociación de Ciencias Naturales del Litoral* 22, 11–17.

Berry, J.F. & Shine, R. (1980). Sexual size dimorphism and sexual selection in turtles (Order Testudines). *Oecologia* 44, 185–191.

Bury, R.B. (1989). Population ecology of freshwater turtles. In *Turtles: Perspectives and Research*, 417–434. Harless, M., Morlock, H. & Robert, E. (eds). Florida: Krieger Publishing Company.

Cagle, F. (1939). A system of marking turtles for future identification. *Copeia* 3, 170–173.

Calliari, L.J. (1998). O ambiente e a biota do estuário da Lagoa dos Patos. In *Os Ecossistemas Costeiro e Marinho do Extremo Sul do Brasil*, 13–18. Seeliger, U., Odebrecht, C. & Castello, J.P. (eds). Rio Grande: Ecoscientia.

Casale, P., Mazaris, A. D., Freggi, D., Basso, R. & Argano, R. (2007). Survival probabilities of loggerhead sea turtles (*Caretta caretta*) estimated from capture–mark–recapture data in the Mediterranean Sea. *Scientia Marina* 71, 365–372.

Chaloupka, M.Y. & Limpus, C.J. (2002). Survival probability estimates for the endangered loggerhead sea turtle resident in southern Great Barrier Reef waters. *Marine Biology* 140, 267–277.

Chase, D.J., Dixon, K.R., Gates, J.E., Jacobs, D. & Taylor, G.J. (1989). Habitat characteristics, population size, and home range of the bog turtle, *Clemmys muhlenbergii*, in Maryland. *Journal of Herpetology* 23, 356–362.

Close, L.M & Seigel, R.A. (1997). Differences in body size among populations of red-eared sliders (*Trachemys scripta elegans*) subjected to different levels of harvesting. *Chelonian Conservation and Biology* 2, 563–566.

Congdon, J.D., Dunham, A.E. & Van Loben Seals, R.C. (1993). Delayed sexual maturity and demographics of Blanding´s turtle (*Emydoidea blandingii*): implications for conservation and management of long-lived organisms. *Conservation Biology* 7, 826–833.

Di-Bernardo, M., Borges-Martins, M. & Oliveira, R.B. (2003). Répteis. In *Livro Vermelho da Fauna Ameaçada de Extinção no Rio Grande do Sul*, 165–188. Fontana, C.S., Bencke, G.A. & Reis, R.E. (eds). Porto Alegre: EDIPUCRS.

Duda, J.J., Krzysik, A.J. & Freilich, J.E. (1999). Effects of drought on desert tortoise movement and activity. *Journal of Wildlife Monographs* 63, 1181–1192.

Dunham, A.E. & Gibbons, J.W. (1990). Growth of the slider turtle. In *Life History and Ecology of the Slider Turtle*, 135–145. Gibbons, J.W. (ed.). Washington: Smithsonian Institution Press.

Ernst, C.H. (1990). Systematics, taxonomy, variation, and geographic distribution of the slider turtle. In *Life History and Ecology of the Slider Turtle*, 57–67. Gibbons, J.W. (ed.). Washington: Smithsonian Institution Press.

Fagundes, C.K., Bager, A. & Cechin, S.T.Z. (2010). *Trachemys dorbigni* in an anthropic environment in southern Brazil: II) Reproductive ecology. *Herpetological Journal* 20, 195–199.

Frazer, N.B., Gibbons, J.W. & Owens, T.J. (1990). Turtle trapping: preliminary tests of conventional wisdom. *Copeia* 1990, 1150–1152.

Freiberg, M.A. (1969). Una nueva subespécie de *Pseudemys dorbigni* (Duméril et Bibron) (Reptila, Chelonia, Emydidae). *Physis* 28, 299–314.

Freilich, J.E., Burnham, K.P., Collins, C.M. & Garry, A. (2000). Factors affecting population assessments of desert tortoises. *Conservation Biology* 14, 1479–1489.

Gibbons, J.W. (1967). Variation in growth rates in three populations of the painted turtle, *Chrysemys picta*. *American Midland Naturalist* 79, 517–519.

Gibbons, J.W. (1970). Reproductive characteristics of a Florida population of musk turtles (*Sternothaerus odoratus*). *Herpetologica* 26, 268–270.

Gibbons, J.W. (1990). Sex ratios and their significance among turtle populations. In *Life History and Ecology of the Slider Turtle*, 135–145. Gibbons, J.W (ed). Washington: Smithsonian Institution Press.

Gibbons, J.W., Greene, J.L. & Congdon, J.D. (1990). Temporal and spatial movement patterns of sliders and other turtles. In *Life History and Ecology of the Slider Turtle*, 201–215. Gibbons, J.W. (ed.). Washington: Smithsonian Institution Press.

Gibbs, J.P. & Shriver, W.G. (2002). Estimating the effects of road mortality on turtle populations. *Conservation Biology* 16, 1647–1652.

Girondot, M. & Pieau, C. (1993). Effects of sexual differences of age at maturity and survival on population sex ratio. *Evolutionary Ecology* 7, 645–650.

Heppell, S.S., Limpus, C.J., Crouse, D.T., Frazer, N.B. & Crowder, L.B. (1996). Population model analysis for the loggerhead sea turtle, *Caretta caretta*, in Queensland. *Wildlife Research* 23, 143–159.

Heppell, S.S., Crowder, L.B., Crouse, D.T., Epperly, S.P. & Frazier, N.B. (2003). Population models for Atlantic loggerheads: past, present, and future. In *Loggerhead Sea Turtles*, 255–273. Bolten, A.B. & Witherington, B.E. (eds). Washington: Smithsonian Institution Press.

Kazmaier, R.T., Hellgren, E.C., Synatzske, D.R. & Rutledge, J.C. (2001). Mark–recapture analysis of population parameters in a Texas tortoise (*Gopherus berlandieri*) population in southern Texas. *Journal of Herpetology* 35, 410–417.

Klemens, M.W. (2000). *Turtle Conservation*. Washington: Smithsonian Institution Press.

Knight, A.W. & Gibbons, J.W. (1968). Food of a painted turtle, *Chrysemys picta* in a polluted river. *American Midland Naturalist* 80, 558–562.

Koper, N. & Brooks, R.J. (1998). Population-size estimators and unequal catchability in painted turtles. *Canadian Journal of Zoology* 76, 458–465.

Krause, L., Gomes, N. & Leyser, K.L. (1982). Observações sobre a nidificação e desenvolvimento de *Chrysemys dorbignyi* (Duméril & Bibron, 1835) (Testudines, Emydidae) na Estação Ecológica do Taim, Rio Grande do Sul. *Revista Brasileira de Zoologia* 1, 79–90.

Langtimm, C.A., Dodd Jr., C.K. & Franz, R. (1996). Estimates of abundance of box turtles (*Terrapene carolina bauri*) on a Florida island. *Herpetologica* 52, 496–504.

Lebreton, J.D., Burnham, K.P., Clobert, J. & Anderson, D.R. (1992). Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. *Ecological Monographs* 62, 67–118.

Lema, T. & Ferreira, M.T.S. (1990). Contribuição ao conhecimento dos Testudines do Rio Grande do Sul (Brasil). Lista Sistemática comentada (Reptilia). *Acta Biologica Leopoldensia* 12, 125–164.

Lindeman, P.V. (1990). Closed and open model estimates of abundance and tests of model assumptions for two populations of the turtle, *Chrysemys picta*. *Journal of Herpetology* 24, 78–81.

Lindeman, P.V. (1996). Comparative life history of painted turtles (*Chrysemys picta*) in two habitats in the inland Pacific northwest. *Copeia* 1996, 114–130.

Litzgus, J.D. & Mousseau, T.A. (2004). Demography of a southern population of the spotted turtle (*Clemmys guttata*). *Southeastern Naturalist* 3, 391– 400.

Lovich, J.E. & Gibbons, J.W. (1992). A review of techniques for quantifying sexual size dimorphism. *Growth, Development and Aging* 56, 269–281.

Lovich, J.E., McCoy, C.J. & Garstka, W.R. (1990). The development and significance of melanism in the slider turtle. In *Life History and Ecology of the Slider Turtle*, 233–254. Gibbons, J.W. (ed.). Washington: Smithsonian

Institution Press.

Maluf, J.R.T. (2000). Nova classificação climática do estado do Rio Grande do Sul. *Revista Brasileira de Agrometeorologia* 8, 141–150.

McMaster, M.K. & Downs, C.T. (2006). Population structure and density of leopard tortoises (*Geochelone pardalis*) on farmland in the Nama-Karoo. *Journal of Herpetology* 40, 495–502.

Molina, F.B. & Gomes, N. (1998). Incubação artificial dos ovos e processo de eclosão em *Trachemys dorbigni* (Duméril & Bibron, 1835) (Reptilia, Testudines, Emydidae). *Revista Brasileira de Zoologia* 15, 135–143.

Moll, D. (1980). Dirty river turtles. *Natural History* 5, 42–49.

Moll, D. & Moll, E.O. (1990). The slider turtle in the neotropics: adaptation of a temperate species to a tropical environment. In *Life History and Ecology of the Slider Turtle*, 152–161. Gibbons, J.W. (ed.). Washington: Smithsonian Institution Press.

Pereira, F.E. & Diefenbach, C.O. (2001). Growth in *Trachemys dorbigni* (Testudines, Emydidae). *Biociências* 9, 21–31.

Peterson, C.C. (1996). Anhomeostasis: seasonal water and solute relations in two populations of the desert tortoise (*Gopherus agassizii*) during chronic drought. *Physiological Zoology* 69, 1324–1358.

Prévot-Julliard, A.C., Lebreton, J.D. & Pradel, R. (1998). Re-evaluation of the adult survival of black-headed gulls (*Larus ridibundus*) in presence of recapture heterogeneity. *Auk* 115, 85–95.

Rambo, P.B. (2000). A *Fisionomia do Rio Grande do Sul: Ensaio de uma Monografia Natural*. São Leopoldo: Editora Unissinos.

Seidel, M.E. (2002). Taxonomic observations on extant species and subspecies of slider turtles, genus *Trachemys*. *Journal of Herpetology* 36, 258–292.

Souza, F.L. & Abe, A.S. (2000). Feeding ecology, density and biomass of the freshwater turtle, *Phrynops geoffroanus*, inhabiting a polluted urban river in south-eastern Brazil. *Journal of the Zoological Society of London* 252, 437–446.

Spinks, P.Q., Pauly, G.B., Crayon, J.J. & Shaffer, H.B. (2003). Survival of the western pond turtle (*Emys marmorata*) in an urban California environment. *Biological Conservation* 113, 257–267.

Statsoft (1995). *Statistica for Windows*. Tulsa: Statsoft.

Stickel, L.F. (1950). Populations and home range relationships of the box turtle, *Terrapene c. carolina* (Linnaeus). *Ecological Monographs* 20, 351–378.

Tucker, J.K., Moll, D. & Moll, E.O. (1999). Growth of slider turtle (*Trachemys scripta*) from temperature and tropical populations. *Chelonian Conservation and Biology* 3, 464–467.

Verdon, E. & Donnelly, M.A. (2005). Population structure of Florida box turtle (*Terrapene carolina bauri*) at the southernmost limit of their range. *Journal of Herpetology* 39, 572–577.

Vogt, R.C. (1980). New methods for trapping aquatic turtles. *Copeia* 2, 368–371.

White, G.C. & Burnham, K.P. (1999) Program MARK: survival estimation from populations of marked animals. *Bird Study* 46, 120–138.

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