Herpetological Conservation and Biology 13(2):355–365.
Submitted: 25 March 2016; Accepted: 14 January 2018; Published 31 August 2018.

Population Ecology of the Freshwater Turtle *Mesoclemmys vanderhaegei* (Testudines: Chelidae)

Elizângela Silva Brito[1,7], Richard C. Vogt[2], Rafael Martins Valadão[3], Leonardo Fernandes França[4], Jerry Penha[5], and Christine Strüssmann[6]

[1]*Programa de Pós-graduação em Ciências Veterinárias, Universidade Federal de Mato Grosso, Avenida Fernando Correa da Costa 2367, Cuiabá 78060-900, Mato Grosso, Brazil*
[2]*Coordenação de Biodiversidade, CEQUA, Instituto Nacional de Pesquisas da Amazônia, Avenida André Araújo 2936, Manaus 69080-971, Amazonas, Brazil*
[3]*Centro Nacional de Pesquisa e Conservação de Répteis e Anfíbios, Instituto Chico Mendes de Conservação da Biodiversidade, Rua 229, 95, Goiânia 74605-090, Goiás, Brazil*
[4]*Departamento de Ciências Animais, Universidade Federal Rural do Semiárido, Avenida Francisco Mota 572, Mossoró 59625-900, Rio Grande do Norte, Brazil*
[5]*Programa de Pós-graduação em Ecologia e Conservação da Biodiversidade, Centro de Biodiversidade, Instituto de Biociências, Universidade Federal de Mato Grosso, Avenida Fernando Correa da Costa 2367, Cuiabá 78060-900, Mato Grosso, Brazil*
[6]*Faculdade de Medicina Veterinária, Universidade Federal de Mato Grosso, Avenida Fernando Correa da Costa 2367, Cuiabá 78060-900, Mato Grosso, Brazil*
[7]*Corresponding author, e-mail: eliz.chelidae@gmail.com*

***Abstract*.—We sampled *Mesoclemmys vanderhaegei* in the Upper Paraguay River Basin, in the Cerrado ecosystem of Central Brazil. Populations were sampled between 2010 and 2013, and we used capture-mark-recapture methods to determine the catchability, density, population size structure, and sex ratio of the populations. We sampled two protected areas (Chapada dos Guimarães National Park [CGNP] and Serra das Araras Ecological Station [SAES]) and we captured 300 individuals (77 at CGNP and 223 at SAES) and made 343 recaptures in the two areas. Some individuals were recaptured more than once. We estimated population sizes to be 90 turtles at CGNP and 245 turtles at SAES. Sex ratio was not significantly different from 1:1 at CGNP, whereas at SAES there were more females than males. The population structure varied significantly between the two sampled populations with carapace lengths of turtles at CGNP normally distributed but not at SAES. Although both areas occur within the same ecosystem and are close to each other (180 km straight line distance), the populations possessed distinct demographic characteristics, possibly resulting from local patterns of environmental conditions and biological interactions.**

Key Words.—catchability; capture-mark-recapture; population structure; sex ratio; size structure; Vanderhaege's Toad-headed Turtle

Introduction

Chelonians are typically thought to be long-lived animals (Gibbons 1987), characterized by high fecundity, slow growth, delayed sexual maturation, high adult survivability, and low levels of survivorship in egg and early developmental stages (Congdon et al. 1994; Litzgus and Mousseau 2004; Daigle and Jutras 2005). These life-history characteristics complicate the management of chelonian populations in decline (Congdon et al. 1994; Litzgus and Mousseau 2004; Daigle and Jutras 2005) because, although adults produce large numbers of juveniles during their lifetime, few of these survive to sexual maturity (Iverson 1991; Heppell 1998; Chaloupka and Limpu 2002; O'Brien et al. 2005). The vulnerability of chelonians is exacerbated even more by environmental problems, such as habitat fragmentation, pollution, introduction of exotic species, hunting, and global climate change (Gibbons et al. 2000; Luiselli 2003). In addition, most species of freshwater turtles in South America are poorly known and little studied (Souza 2004), which increases the risk of local and/or regional extinctions (Gibbons et al. 2000). Ecological studies that focus on population dynamics are integral for the development of management plans and to address slow responses to both anthropogenic and natural environmental change (Brooks et al. 1991; Congdon et al. 1993, 1994; Heppell 1998).

Little has been published about the ecology of *Mesoclemmys vanderhaegei* due to its limited distribution (see Vinke et al. 2013; Marques et al. 2014). This species is often recorded in small water bodies in oligotrophic upland areas: mountains and plateaus between 600 and 800 m above sea level (Brandão et al.

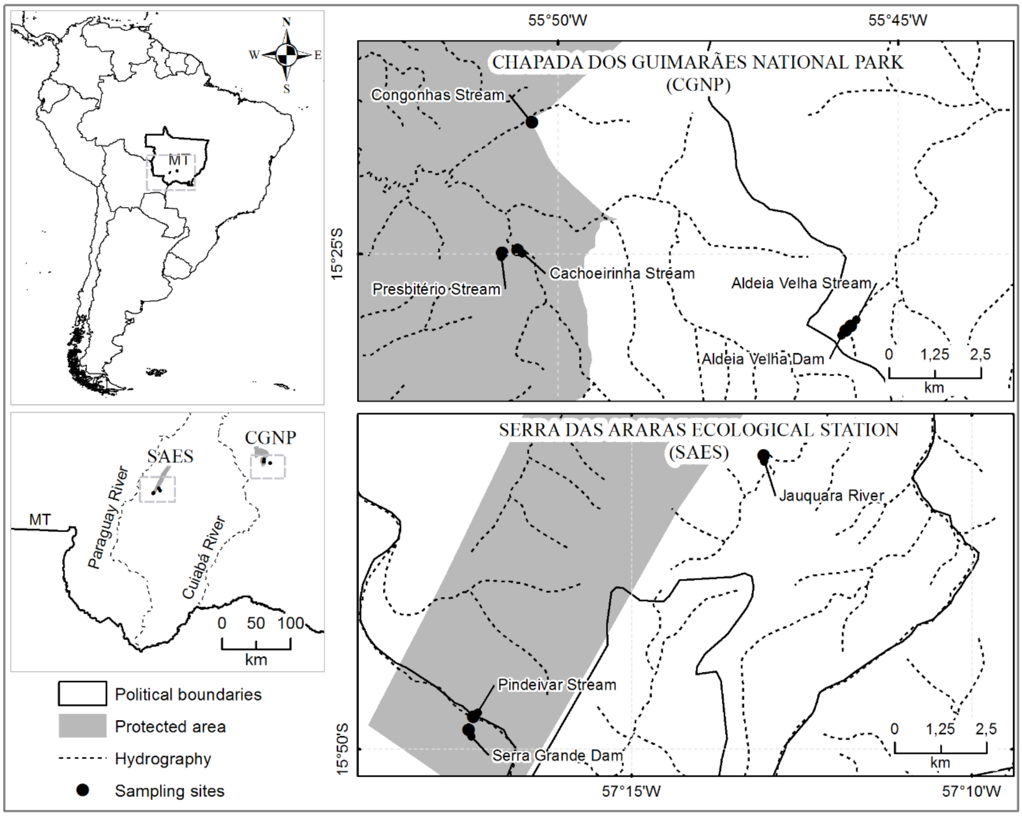

Figure 1. Location of study areas of *Mesoclemmys vanderhaegei* at Chapada dos Guimarães National Park (CGNP) and Serra das Araras Ecological Station (SAES) in the state of Mato Grosso (MT), Brazil.

2002; Brito et al. 2009b, 2012; Marques et al. 2014). The species can also be found in swampy environments, as well as in medium-sized rivers, dams, ponds, and even in urban environments (Brito et al. 2012; Marques et al. 2013, 2014; Vinke et al. 2013).

In the last 10 y, only short-term studies on population structure and sex ratio (Brito et al. 2009b; Marques et al. 2013), courtship behavior (Brito et al. 2009a), parasitism (Ávila et al. 2010), digestive system anatomy (Pinheiro et al. 2010), diet (Brito et al. 2016), morphology of the female genital organs (Silva et al. 2017), and trophic niche (Marques et al. 2017) have been published, along with two general species accounts (Vinke et al. 2013; Marques et al. 2014). Our study provides information on the population size, sex ratio, size structure, catchability, and recapture rates during a 34-mo period of two populations of *Mesoclemmys vanderhaegei* from the Upper Paraguay River Basin, midwestern Brazil, including the largest population ever studied.

Materials and Methods

Study area.—We sampled populations of *Mesoclemmys vanderhaegei* at two sites that are federally controlled and provide full protection for wildlife as Conservation Units (in Portuguese, *Unidades de Conservação*; hereafter, UC) located in the state of Mato Grosso, midwestern Brazil (Fig. 1). Both UC occur in the Cerrado ecosystem and lie within the Upper Paraguay River Basin. The Chapada dos Guimarães National Park (CGNP) covers 32,630 ha and is located in the municipalities of Chapada dos Guimarães and Cuiabá. The 28,637 ha Serra das Araras Ecological Station (SAES) is located in the municipalities of Porto Estrela and Cáceres, along a corridor of parallel low mountains connecting the Amazon Forest, Cerrado, and Pantanal ecosystems (Ross 1991). The straight-line distance between the two protected areas is 180 km. The climate is similar in both areas, with two distinct seasons: dry (April to October) and rainy season (November to March). Rainfall is most intense between January and March, reaching 2,000 mm/y, with temperatures ranging from 12–25° C.

The water bodies we sampled were narrow streams characteristic of Cerrado savanna areas of the Brazilian Central Plateau (Wantzen et al. 2006). Locally known as *córregos*, these Cerrado streams are perennial, poor in nutrients, and slightly acidic. They typically have low electrical conductivity, and are narrow, shallow, shaded, and surrounded by gallery forest (Ribeiro et al. 2001), which contributes to a low variation in water temperature (between 17–20° C; Fonseca 2005).

Table 1. Location (Datum: WGS84), area and type of water body sampled, total number of captures (Cap.), number of recaptures in the sampling sessions 2nd to 9th, and total number of recaptures (Recap.) of individuals of *Mesoclemmys vanderhaegei* in two sampling sites: Chapada dos Guimarães National Park (CGNP) and Serra das Araras Ecological Station (SAES), Brazil.

Sites/streams	Sampled area (m²)	Sampled habitat	Coordinates	Cap.	Number of recaptures on each sampling session 2	3	4	5	6	7	8	9	#Recap
CGNP													
Congonhas	2400	lotic	15°23'02"S 55°50'28"W	27	2	5	3	1	3	4	5	2	25
Independência	8020	lotic	15°24'59"S 55°50'29"W	12	1	5	1	1	3	1	2	2	16
Presbitério	1270	lotic	15°25'02"S 55°50'49"W	26	4	6	3	1	2	4	5	2	27
Aldeia Velha 1	1455	lotic	15°26'09"S 55°45'43"W	2	1	1	1	0	0	0	0	1	4
Aldeia Velha 2	496	lentic (dammed)	15°26'08"S 55°45'45"W	10	0	0	0	0	0	0	1	1	2
SAES													
Jauquara	2860	lotic	15°46'09"S 57°13'10"W	23	1	3	0	0	0	0	0	0	4
Pindeivar	2120	lotic	15°49'31"S 57°17'14"W	62	8	7	8	2	3	5	14	6	53
Serra Grande	3456	lotic and lentic (dammed)	15°49'43"S 57°17'23"W	138	44	44	27	21	14	14	20	28	212

Cerrado streams usually have rapids and waterfalls of various sizes (Fonseca 2005). However, two of the sampled water bodies were dammed and, consequently, more lentic in some sections (Table 1).

We sampled eight 1st and 2nd. order water bodies; three at SAES, located at about 800 m the plateau of Serra Grande to about 550 m the Jauquara River valley, and five at CGNP on the Guimarães plateau at about 600 m above sea level (Table 1, Fig. 1; see also Vinke et al. 2013; Marques et al. 2014). Three water bodies had been previously sampled at CGNP in 2007 (see Brito et al. 2009b), resulting in 38 captured-marked-released individuals: Aldeia Velha (n = 17), Independência (n = 8), and Congonhas streams (n = 13). Although all the water bodies sampled are located in protected areas, there is still evidence of disturbances from livestock raising, practiced in the vicinity of the reserves or even (more rarely) inside them. Tourists visiting the waterfalls may also have some negative impacts on turtles.

Species data.—We collected data between November 2010 and August 2013, during nine sampling sessions at each site (SAES: November 2010; June, September and November 2012; April, June, August and November 2012; May 2013; CGNP: December 2010; April and September 2011; May, September and November 2012; April, June and August 2013). Sampling did not occur during heavy rains (between January-March each year), because most streams have a solid bedrock channel and any sudden increase in the volume of water could lead to the drowning of animals captured in traps. We used funnel traps 1.2 m in length (Brito et al. 2009b), baited with a mixture of beef and fish-flavored cat food (Legler 1960; Vogt et al. 2012; Balestra et al. 2016). For each sampling, we installed 10 traps on the margins or in the center of each stream. In lotic streams, we installed the traps at an average distance of 50 m from each other over a 500 m stretch of stream. In dammed streams, we installed four traps on the Aldeia Velha 2 and six traps on the Serra Grande. In all streams, we operated the traps continuously for six 24-h periods, and we checked once a day, early in the morning. We sampled each site for a total of 54 d (6 d × nine samples). Our sampling effort totalled 10,800 trap-hours at each sampled lotic stream, 4,320 trap-hours at the Aldeia Velha 2, and 6,480 trap-hours at Serra Grande.

We marked each captured turtle individually using a system of rectangular cuts in marginal scutes of the carapace, adapted from Ferner (1979). We determined the sex of the captured individuals by examining secondary sexual characteristics (males having a more elongated tail than females) and measured carapace length (CL; to the nearest 0.05 mm) with a 300 mm Vernier calliper. We obtained the body mass with Pesola® spring balances (Pesola AG, Chaltenbodenstrasse, Schindellegi, Switzerland) of the following capacities: 100 g (0.1 g precision), 1,000 g (1.0 g precision), and 5,000 g (100 g precision). We could not determine the sex of individuals < 116 mm CL with certainty and hence we classified them as juveniles. We classified the

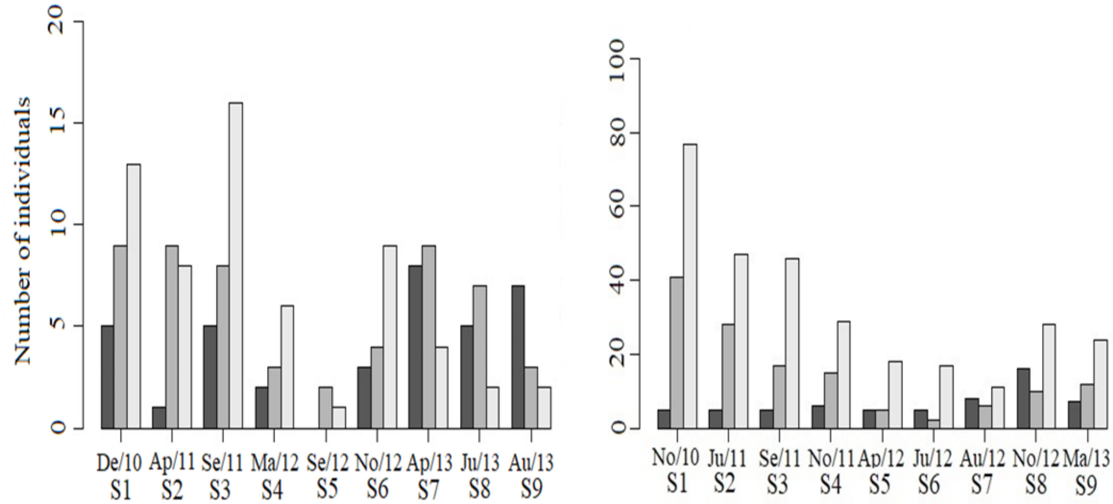

Figure 2. Total number of captures+recaptures in nine samples (S1-S9) of juveniles (J; dark grey bars), males (M; medium gray bars), and females (F; light grey bars) of the turtle *Mesoclemmys vanderhaegei* in Chapada dos Guimarães National Park (CGNP; left graph) and Serra das Araras Ecological Station (SAES; right graph) in the state of Mato Grosso, Brazil.

individuals >116 CL as male or female, irrespective of their reproductive status, as the age of sexual maturation for both sexes is unknown in *M. vanderhaegei*. After labeling and biometrics, we released the individuals in their place of capture.

Statistical analyses.—We estimated populations using a hierarchical closed population mark-recapture model (Kéry and Schaub 2012). Under such a hierarchical model structure, it is possible to separate the effect of detectability (observer error) from the estimate of population size, the variable of interest (Royle and Dorazio 2008). We used parameter-expanded data augmentation (Royle et al. 2007) and a zero-inflated version of the model to run the analysis. The procedure consisted of randomly including a number of individuals with all-zero encounter histories in the data matrix. We included 400 individuals in SAES, and 150 individuals in CGNP encounter-history matrices. We estimated the parameters in a Bayesian structure using WinBUGS, operated by R with the R2WinBUGS package. We used three chains, with 10,000 iterations each, and discarded the first 2,500 in the burn-in phase (Kéry and Schaub 2012). We estimated the parameters only for the model with a time effect on detection probability (p)—the model Mt from Otis et al. (1978).

We generated two cumulative frequency plots for each population, one using data on new individuals captured during the study, the other using all individuals (including recaptures). We used a chi-square test to determine whether the sex ratio differed from 1:1 in each of the two populations, employing only those individuals captured for the first time for which we could determine sex. We also used a chi-square test to determine whether the sex ratio differed seasonally, considering all captures and recaptures in both of the two per stream samplings. We recorded the recapture instances only once per sampling period. We used a Kolmogorov-Smirnov test to compare the size (CL) distribution of individuals among the two sampled populations, considering only the number of captures, and a Shapiro-Wilk test to check normal distribution of the size class frequencies. We performed all statistical analyses using R software (R Development Core Team 2014) and used $\alpha = 0.05$ for all tests.

Results

Over all nine samples, we captured 300 specimens: 77 (26%) from CGNP and 223 (74%) from SAES. At CGNP, we captured males most frequently (31; 40%), followed by females (27; 35%) and juveniles (19; 25%). At SAES, we captured females in greatest numbers (110; 49%), followed by males (73; 33%) and juveniles (40; 18%) (Figure 2). We captured individuals of both sexes and life stages over all samples at CGNP, with juveniles only being absent from the smallest sample (September 2012). We captured juveniles in lower numbers at SAES, though they were recorded in all the samples from this location (Fig. 2).

The first sample returned the highest number of captures in both areas. However, the first four samplings at SAES accounted for 80% of all captures (n = 177). At CGNP the captures were more evenly distributed over the nine samples, with the first four accounting for just over half the captures (64%; n = 50; Table 1). We recaptured 343 turtles, 74 (22%) at CGNP and 269 (78%) at SAES (Table 1), and we recaptured 163 turtles (54%) at least once. At CGNP, we recaptured more females, including up to four sequential recaptures of the same

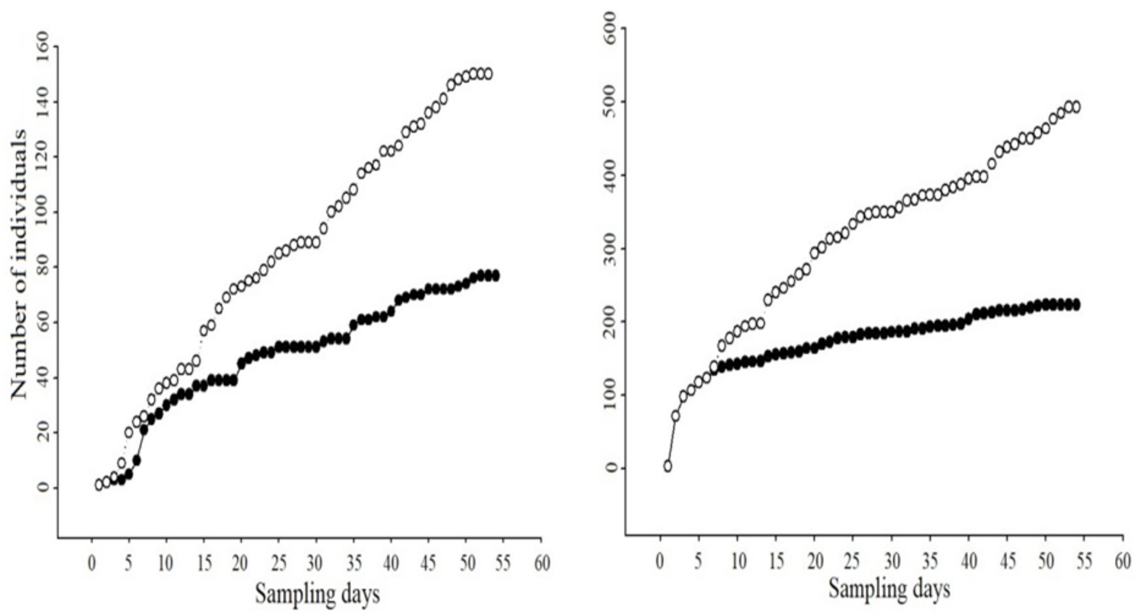

Figure 3. Cumulative frequency of the number of individuals of *Mesoclemmys vanderhaegei* captured (closed circles) and the number of individuals captured+recaptured (open circles) along 54 sampling days between November 2010 and August 2013 in: Chapada dos Guimarães National Park (CGNP; left graph) and Serra das Araras Ecological Station (SAES; right graph), state of Mato Grosso, Brazil.

individual, while at SAES que recaptured the males most frequently, with individual records of up to eight recaptures, the maximum number of recaptures across the nine samples (Table 2). The cumulative frequency of individuals captured at SAES showed a tendency to stabilize, unlike that from CGNP. However, when the recapture rates are included, neither site showed a tendency to stabilize (Fig. 3). Of the 38 individuals captured in 2007 at CGNP, we recaptured just one animal (a female) in the two years following the start of re-sampling (2012). This is equivalent to a recapture rate of 2.6% after 5 y since initial capture. Population size was estimated to be 91 individuals (SD = 5.00; 95% credible interval/Bayesian confidence interval = 83–103; ĉ = 1.001) at CGNP, and 245 individuals (SD = 5.70; 95% credible interval/Bayesian confidence interval = 235–257; ĉ = 1.001) at SAES. Detection probability (p) varied along the capture sessions in both populations (Table 3).

Table 2. Number of females, males, and juveniles of *Mesoclemmys vanderhaegei* recaptured from one to eight times during nine sampling sessions in the Chapada dos Guimarães National Park (CGNP) and Serra das Araras Ecological Station (SAES), Brazil.

	Number of individuals							
	1	2	3	4	5	6	7	8
CGNP								
Females	6	1	6	2	0	0	0	0
Males	14	4	0	0	0	0	0	0
Juveniles	3	5	0	1	0	0	0	0
Total	23	10	6	3	0	0	0	0
SAES								
Females	34	13	14	13	6	0	0	0
Males	19	9	6	0	0	0	0	1
Juveniles	12	5	0	0	0	0	0	0
Total	65	27	20	13	6	0	0	1

The overall sex ratio for the SAES population was significantly skewed to females (1.0M:1.5F; χ^2 = 8.13, df = 1, P = 0.004), a result that was repeated in six out of nine sampling sessions. Overall, the sex ratio at CGNP was 1.0M:0.87F, which is not significantly different from 1:1 (χ^2 = 0.27, df = 1; P = 0.599), and there was no variation among the nine samples at this location (Table 4). The frequency distribution of population size classes varied significantly between the two sampled areas (D = 0.18; P = 0.043). The distribution departed from normality at SAES (W = 0.95; P < 0.006), with a higher frequency of individuals in the 151–170 mm CL size category. At CGNP, the distribution of population size classes was normal (W = 0.98; P = 0.542), even though there were two peaks of higher capture frequency, one between 91–110 mm CL and another (larger) peak between 131–150 mm CL (Fig. 4).

Discussion

The population size of *Mesoclemmys vanderhaegei* at SAES is the largest recorded for the species. Previous studies have reported 80 individuals in small streams at CGNP and adjacent areas (Brito et al. 2009b), and 31 individuals in ponds within a silvicultural system

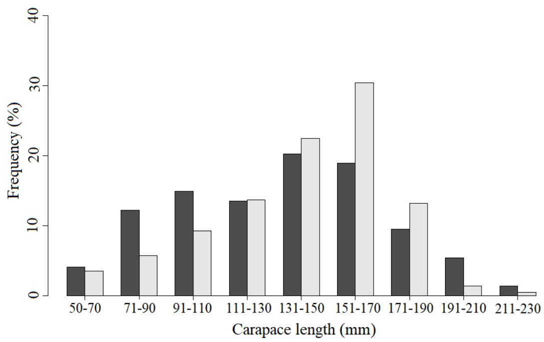

Figure 4. Frequency distribution of size classes of *Mesoclemmys vanderhaegei* captured at Serra das Araras Ecological Station (SAES; light grey bars) and Chapada dos Guimarães National Park (CGNP; dark greybars) in the state of Mato Grosso, Brazil.

in southeastern Brazilian (Marques et al. 2013). The overall recapture rate of 54%, recorded for the two populations studied during our medium-length study, is higher than the maximum rate recorded (39%) in a previous short-term study (24 h sampling intervals along seven consecutive days) of a closed population from CGNP (Elizangela Brito, unpubl. data). In the present study, only one of the individuals previously marked and released in 2007 by Brito et al. (2009b) was recaptured, five years after initial capture. Terrestrial movements, possibly in the search for more suitable habitats, were recorded for *Mesoclemmys vanderhaegei* from Chapada dos Guimarães (Brito et al. 2012) and could explain this low recapture rate. Low recapture rates after long sampling intervals could also be due to mortality, migration, or extensive home ranges.

Studies of *Hydromedusa maximiliani* (Souza and Abe 1997) and *Acanthochelys spixii* (Neto et al. 2011), two other chelids in small streams and ponds, reported similar rates of recapture (52 and 77%, respectively) to those recorded in the present study. However, the recapture rates were much lower (2.4%) in another chelid species, *Phrynops geoffroanus*, which inhabits both small streams in urban environments (Souza and Abe 2001) and large rivers such as the Guapore in western Brazil (Richard Vogt, unpubl. data). Podocnemidid species have also demonstrated variation in recapture rates, for example: *Podocnemis unifilis* (recapture rates around 5%; Fachín-Terán and Vogt 2004) and *P. sextuberculata* (3.5%; Fachín-Terán et al. 2003), compared with *P. erythrocephala* (16%; Bernhard and Vogt 2012) and *Peltocephalus dumerilianus* (29–31%; De La Ossa and Vogt 2011). The high recapture rates recorded in the present study may be a consequence of an interaction between sampling method and the type of environment studied. Funnel traps, adapted in our study to capture turtles in small aquatic habitats with reduced flow rates, were apparently efficient and did not cause trap shyness nor subsequent trap avoidance. *Mesoclemmys vanderhaegei* is omnivorous and readily attracted to baited traps, while most *Podocnemis* species are primarily vegetarian and not attracted to baited traps because food is not a limited resource for these species (Richard Vogt, unpubl. data).

The first sampling session returned the highest number of captures in both areas. In the dammed Serra Grande stream, 26 individuals were captured in one trap. We credit this to the level of water in the water bodies on that occasion, the lowest observed during the study period. In some cases, newly released individuals were found to have returned to the traps within 10 min of their release, suggesting that these turtles had become trap-happy (Nichols et al. 1984; Deforce et al. 2004). In addition to the bait, insects and fish got caught in the funnel traps; such items would represent easy prey and could therefore attract the turtles.

Streams located on the plateau area at the top of Serra Grande in SAES (the Pindeivar stream and the

Table 3. Detection probability (p) and population size (n) for two populations of *Mesoclemmys vanderhaegei*, sampled in Chapada dos Guimarães National Park (CGNP) and Serra das Araras Ecological Station (SAES), state of Mato Grosso, Brazil (SD = standard deviation).

	CGNP				SAES			
Sampling	mean	SD	2.5%	97.5%	mean	SD	2.5%	97.5%
n	91.219	5.004	83.00	103.00	244.534	5.702	235.000	257.000
p[1]	0.301	0.05	0.21	0.405	0.503	0.034	0.437	0.569
p[2]	0.204	0.043	0.127	0.295	0.329	0.031	0.27	0.392
p[3]	0.323	0.052	0.228	0.428	0.28	0.029	0.224	0.338
p[4]	0.129	0.035	0.068	0.205	0.207	0.026	0.158	0.261
p[5]	0.043	0.021	0.012	0.094	0.118	0.021	0.08	0.161
p[6]	0.184	0.042	0.111	0.273	0.102	0.019	0.067	0.143
p[7]	0.236	0.046	0.153	0.331	0.105	0.02	0.07	0.146
p[8]	0.162	0.039	0.093	0.245	0.215	0.027	0.166	0.269
p[9]	0.14	0.037	0.076	0.221	0.175	0.025	0.129	0.226

Table 4. Sex ratios for two populations of *Mesoclemmys vanderhaegei*, sampled in the Chapada dos Guimarães National Park (CGNP) and Serra das Araras Ecological Station (SAES), state of Mato Grosso, Brazil. The results of χ^2 and a probability value (*P*) lower than 0.05 (values in bold) indicate whether the sex ratio deviates significantly from 1:1; "*n*" represents the total number of catches (including captures and recaptures) during each sampling session. Missing values could not be calculated due to small sample sizes. All analyses had df = 1.

	CGNP				SAES			
Sampling session	Sex ratio (M:F)	n	χ^2	P	Sex ratio (M:F)	n	χ^2	P
1	1:1.44	22	0.72	0.39	1:1.87	118	10.98	< 0.01
2	1:0.89	17	0.05	0.80	1:1.67	75	4.81	0.02
3	1:2.00	24	2.66	0.10	1:2.70	63	13.34	< 0.01
4	1:2.00	9	-	-	1:1.58	44	2.27	0.13
5	1:0.50	3	-	-	1:3.6	23	7.34	< 0.01
6	1:2.25	13	1.92	0.16	1:8.50	19	11.84	< 0.01
7	1:0.44	13	1.92	0.16	1:1.83	17	1.47	0.22
8	1:0.28	9	2.77	0.09	1:3.5	36	11.11	< 0.01
9	1:0.66	5	-	-	1:1.91	35	3.45	0.06

Serra Grande dammed stream) had the highest numbers of individual *M. vanderhaegei* among the studied water bodies. The Serra Grande plateau is isolated by waterfalls and cliffs and had a lower number of aquatic predators, such as the Green Anaconda, *Eunectes murinus*, the Cuvier's Dwarf Caiman, *Paleosuchus palpebrosus*, and Neotropical River Otter, *Lutra longicaudis*, compared to larger, lower altitude water bodies at at SAES (Instituto Chico Mendes de Conservação da Biodiversidade 2016). In addition, in lower altitude habitats, *Phrynops geoffroanus*, a possible competitor, occurs sympatrically with *M. vanderhaegei*. There are no records of *P. geoffroanus* in the water bodies studied at CGNP, although this species, together with *E. murinus* and *P. palpebrosus*, occur in nearby streams and rivers (Strüssmann 2000). The population of *M. vanderhaegei* at CGNP is less abundant than at SAES but appears stable since 2007 when it was quantitatively evaluated for the first time (Brito et al. 2009b). Besides predation pressure and competition, other ecological constraints such as food and shelter availability, as well as recruitment, can directly influence turtle abundance (Vogt and Benitez 1993; Freilich et al. 2000; McMaster et al. 2006).

In turtles, a skewed sex ratio is often related to such demographic factors as temperature-dependent sex determination, differential mortality of the sexes, differential activity (emigration, imigration, habitat use), as well as to sample size and sampling methods (Bury 1979; Gibbons 1990; Edmonds and Brooks 1996; Smith 2002). Several of these aspects are unknown for *M. vanderhaegei* or are not yet published. At SAES, older males with carapace lengths of 159–202 mm have lower annual apparent survival probabilities than females in the same size category (Elizangela Brito, unpubl. data), which may explain the female-biased sex ratio observed at this location. The sampling method was the same in the two areas studied, and we recorded sex ratio deviations in only one of them. Therefore, we cannot attribute the recorded differences in *M. vanderhaegei* sex ratios to a possible selectivity of traps.

Very small and very large individuals were less abundant than intermediate-sized individuals, in both populations of *Mesoclemmys vanderhaegei* studied, as is common in other populations of freshwater turtles (e.g., Edmonds and Brooks 1996; Souza and Abe 2001; Fachín-Terán and Vogt 2004; Litzgus and Mousseau 2004). Size structure, however, differed in the two *Mesoclemmys vanderhaegei* populations studied: the distribution of population size classes was normal at CGNP, and right-skewed at SAES. There are a number of factors that are capable of imposing changes on the population structure of turtles including, isolation, human disturbance, and differential mortality between size classes or sex (Nazdrowicz et al. 2008). In marine turtles, developmental migration and adult movements between feeding and breeding sites can also determine changes in population structure (Meylan et al. 2011). Because the area of occupancy of *M. vanderhaegei* is not subject to severe fragmentation, and because individuals in our study, especially those > 116 mm CL, were mostly recaptured in the same location of the first capture, it is unlikely that isolation and migration events have impacted the structure of the populations during the 34 mo of study. Even though we failed to detect any single local factor responsible for the differences found during the study in population attributes, our study contributes to a better understanding on how natural populations of *Mesoclemmys vanderhaegei* are structured and how their attributes can vary, even in apparently similar landscapes within the Cerrado ecosystem.

Acknowledgments.— The authors are grateful to the staff of the Chico Mendes Institute for Biodiversity Conservation (ICMBio) at the National Park of Chapada do Guimarães and Serra das Araras Ecological Station, for their support during data collection; to the National Center for Research and Conservation of Reptiles and Amphibians (RAN) for the license authorizing captures of *M. vanderhaegei* (SISBio #25225-2); to the ComCerrado research network for partial funding of the fieldwork; to the colleagues who helped in the field data collection; for the *Coordenação de Aperfeiçoamento de Pessoal de Nivel Superior* (CAPES) for a doctoral scholarship to ESB at the time of data acquisition and, presently, for the National Postdoctoral Program (PNPD) fellowship; for the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) for a Research Productivity Grant, Level 2 to C.S. (process #309541/2012-3). Gina Maffey helped with the English and gave suggestions that improved the text.

Literature Cited

Ávila, R.W., E.S. Brito, T.H. Barrella, C. Strussmann, and R.J. Silva. 2010. Endoparasites new to the Neotropical freshwater turtle, *Mesoclemmys vanderhaegei* (Bour 1973) (Testudines, Chelidae), from central Brazil. Pan-American Journal of Aquatic Sciences 5:478–480.

Balestra, R.A.M., R.M. Valadão, R.C. Vogt, R. Bernhard, C.R. Ferrara, E.S. Brito, R.B. Arias, A. Malvásio, A.P.G. Lustosa, F.L. Souza, et al. 2016. Roteiro para Inventários e Monitoramentos de Quelônios Continentais. Biodiversidade Brasileira 6:114–152.

Bernhard, R., and R.C. Vogt. 2012. Population structure of the turtle *Podocnemis erythrocephala* in the Rio Negro Basin, Brazil. Herpetologica 68:491–504.

Brandão, R.A., G.N.J. Zerbini, A. Sebben, and F.B. Molina. 2002. Notes on distribution and habitats of *Acanthochelys spixii* and *Phrynops vanderhaegei* (Testudine, Chelidae) in Central Brazil. Boletín de La Asociación Herpetológica Española 13:11–15.

Brito, E.S., F.L. Souza, and C. Strüssmann. 2016. Feeding habits of *Mesoclemmys vanderhaegei* (Testudines: Chelidae). Acta Herpetologica 11:1–13.

Brito, E.S., C. Strüssmann, R.A. Kawashita-Ribeiro, D.H. Morais, R.W. Ávila, and V.A. Campos. 2012. New records and distribution extensions of three species of *Mesoclemmys* Gray, 1863 (Testudines: Chelidae) in Mato Grosso state, Brazil, with observations on terrestrial movements. Check List 8:294–297.

Brito, E.S., C. Strüssmann, and C.M. Baicere-Silva. 2009a. Courtship behavior of *Mesoclemmys vanderhaegei* (Bour, 1973) (Testudines: Chelidae) under natural conditions in the Brazilian Cerrado. Herpetology Notes 2:67–72.

Brito, E.S., C. Strüssmann, and J.M.F. Penha. 2009b. Population structure of *Mesoclemmys vanderhaegei* (Bour, 1973) (Testudines: Chelidae) in the Cerrado of Chapada dos Guimarães, Mato Grosso, Brazil. Biota Neotropica 9:245–248.

Brooks, R.J., G.P. Brown, and D.A. Galbraith. 1991. Effects of sudden increase in natural mortality of adults on a population of the Common Snapping Turtle (*Chelydra serpentina*). Canadian Journal of Zoology 69:1314–1320.

Bury, R.B. 1979. Population ecology of freshwater turtles. Pp. 571–602 *In* Turtles: Perspectives and Research. Harless, M., and H. Marlock (Eds.). John Wiley & Sons, New York, New York, USA.

Chaloupka, M., and C. Limpus. 2002. Estimates of survival probabilities for the endangered Loggerhead Sea Turtle resident in southern Great Barrier Reef waters. Marine Biology 140:267–277.

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

Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1994. Demographics of Common Snapping Turtles (*Chelydra serpentina*): implications for conservation and management of long-lived organisms. American Zoologist 34:397–408.

Daigle, C., and J. Jutras. 2005. Quantitative evidence of decline in a southern Quebec Wood Turtle (*Glyptemys insculpta*). Journal of Herpetology 39:130–132.

De La Ossa, V.J., and R.C. Vogt. 2011. Ecologia populacional de *Peltocephalus dumerilianus* (Testudines, Podocnemididae) em dois tributários do rio Negro, Amazônas, Brasil. Interciencia 36:53–58.

Deforce, E.A., C.D. Deforce, and P.V. Lindeman. 2004. *Phrynops gibbus* (Gibba Turtle). Trap-happy behavior. Herpetological Review 35:55–56.

Edmonds, J.H., and R. J. Brooks. 1996. Demography, sex ratio, and sexual size dimorphism in a northern population of Common Musk Turtles (*Stenotherus odoratus*). Canadian Journal of Zoology 74:918–925.

Fachín-Terán A., R.C. Vogt, and J.B. Thorbjarnarson. 2003. Estrutura populacional, razão sexual e abundância de *Podocnemis sextuberculata* (Testudines, Podocnemididae) na Reserva de Desenvolvimento Sustentável Mamirauá, Amazonas, Brasil. Phyllomedusa 2:43–63.

Fachín-Terán, A., and R.C. Vogt. 2004. Estrutura populacional, tamanho e razão sexual de *Podocnemis unifilis* (Testudines, Podocnemididae) no rio Guaparé (RO), norte do Brasil. Phyllomedusa 3:29–42.

Ferner, J.W. 1979. A review of working techniques for reptiles and amphibians. SSAR Herpetological Circular 1979:9–41.

Fonseca, C.P. 2005. Caracterização dos ecossistemas aquáticos do Cerrado. Pp. 416–429 *In* Cerrado: Ecologia, Biodiversidade e Conservação. Souza-Silva, J.C., and J.M. Felfili (Eds.). Ministério do Meio Ambiente, Brasília, D.F., Brasil.

Freilich, J.E., K.P. Burnham, C.M. Collins, and C.A. Garry. 2000. Factors affecting population assessments of Desert Tortoises. Conservation Biology 14:1479–1489.

Gibbons, J.W. 1987. Why do turtles live so long? BioScience 37:262–269.

Gibbons, J.W. 1990. Sex ratio and their significance among turtle populations. Pp. 171–182 *In* Life History and Ecology of the Slider Turtle. Gibbons, J. W. (Ed.). Smithsonian Institution Press, Washington, D.C., USA.

Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, J.L. Greene, T. Mills, Y. Leiden, S. Poppy, and C.T. Winne. 2000. The global decline of reptiles, déjà vu amphibians. BioScience 50:653–666.

Heppell, S.S. 1998. Application of life history theory and population mode analysis to turtle conservation. Copeia 1998:367–375.

Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio). 2016. Plano de Manejo da Estação Ecológica Serra das Araras. ICMBio, Brasília, D.F., Brazil. 247 p.

Iverson, J.B. 1991. Patterns of survivorship in turtles (Order Testudines). Canadian Journal of Zoology 69:385–391.

Kéry, M., and M. Schaub. 2012. Bayesian Population Analysis Using WinBUGS: A Hierarchical Perspective. Academic Press, San Diego, California, USA.

Legler, J.M. 1960. A simple and inexpensive device for trapping aquatic turtles. Proceedings of the Utah Academy of Science 37:3–66.

Litzgus, J.D., and T.A. Mousseau. 2004. Demography of a southern population of the Spotted Turtle (*Clemmys guttata*). Southeastern Naturalist 3:391–400.

Luiselli, L. 2003. Comparative abundance and population structure of sympatric Afrotropical tortoises in six rainforest areas: the differential effects of "traditional veneration" and of "subsistence hunting" by local people. Acta Oecologica 24:157–163.

Marques, T.S., S. Böhm, E.S. Brito, M.R. Cabrera, and L.M. Verdade. 2014. *Mesoclemmys vanderhaegei* (Bour 1973) – Vanderhaege's Toad-headed Turtle, Karumbé-hy. Pp. 083.1–083.8 *In* Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, Chelonian Research Monographs No. 5. Rhodin, A.G.J., P.C.H. Pritchard, P.P. Van Dijk, R.A. Saumure, K.A. Buhlmann, J.B. Iverson, and R.A. Mittermeier (Eds.).

Marques, T.S., E.S. Brito, N.R.F. Lara, L.M. Beloto, R.M. Valadão, P.B. Camargo, and L.M. Verdade. 2017. The trophic niche of *Mesoclemmys vanderhaegei* (Testudines: Chelidae): evidence from stable isotopes. Zoologia 34: 1–6 https://doi.org/10.3897/zoologia.34.e19985.

Marques, T.S., N.R.F. Lara, L.A.B. Bassetti, B.O. Ferronato, A. Malvásio, and L.M. Verdade. 2013. Population structure of *Mesoclemmys vanderhaegei* (Testudines, Chelidae) in a silvicultural system in southeastern Brazil. Herpetology Notes 6:179–182.

McMaster, M.K., and C.T. Downs. 2006. Population struture and density of Leopard Tortoises (*Geochelone pardalis*) on farmland in the Nama-Karoo. Journal of Herpetology 40:495–502.

Meylan, P.A., A.B. Meylan, and J.A. Gray. 2011. The ecology and migrations of sea turtles 8: tests of the developmental habitat hypothesis. Bulletin of the American Museum of Natural History 357:1–70.

Neto, H.J.F., M.A. Brasil, G.F. Horta, T.O. Barros, G.B. Falcon, and G.R. Colli. 2011. Demography of *Acanthochelys spixii* (Testudines, Chelidae) in the Brazilian Cerrado. Chelonian Conservation and Biology 10:82–90.

Nichols, J.D., J.E. Hines, and K.H. Pollock. 1984. Effects of permanent trap response in capture probability on Jolly-Seber capture-recapture model estimates. The Journal of Wildlife Management 48:289–294.

Nazdrowicz, N.H., J.L. Bowman, and R.R. Roth. 2008. Population ecology of the Eastern Box Turtle in a fragmented landscape. Journal of Wildlife Management 72:745–753.

O'Brien, S., B. Robert, and H. Tiandry. 2005. Consequences of violating the recapture duration assumption of mark-recapture models: a test using simulated and empirical data from an endangered tortoise population. Journal of Applied Ecology 42:1096–1104.

Otis, D.L., K.P. Burnham, G.C. White, and D.R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildilife Monographs 62:3–135.

Pinheiro, J.N., I. Godoy, E.S. Brito, C. Strüssmann, and R.H.S Ferraz. 2010. Macroscopia do aparelho digestório do Cágado sul–americano *Mesoclemmys vanderhaegei* (Bour, 1973). Brazilian Journal of Veterinary Research and Animal Science 47:429–438.

R Development Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing. www.R-project.org/.

Ribeiro, J.F., and B.M.T Walter. 2001. As matas de galeria no contexto do bioma Cerrado. Pp. 29–47 *In* Cerrado: Caracterização e Recuperação de Matas de Galeria. Ribeiro, J.F., C.E.L. Fonseca, and J.C.S. Silva (Eds.). Embrapa Cerrados, Planaltina, D.F., Brasil.

Ross, J.L.S. 1991. Contexto geotectônico e a morfogênese da Província Serrana de Mato Grosso. Revista do Instituto de Geografia 12:21–37.

Royle, J.A., and R.M. Dorazio. 2008. Hierarchical Modeling and Inference in Ecology: The Analysis of Data from Populations, Metapopulations and Comunities. Academic Press, San Diego, California, USA.

Royle, J.A., R.M. Dorazio, and W.A. Link. 2007. Analysis of multinomial models with unknown index using data augmentation. Journal of Computational Graphical Statistics 16:67–85.

Souza, F.L. 2004. Uma revisão sobre padrões de atividade, reprodução e alimentação de cágados brasileiros (Testudines, Chelidae). Phyllomedusa 31:15–27.

Souza, F.L., and A.S. Abe. 1997. Population structure, activity, and conservation of the Neotropical freshwater turtle, *Hydromedusa maximiliani*, in Brazil. Chelonian Conservation and Biology 2:521–525.

Souza, F.L., and A.S. Abe. 2001. Population structure and reproductive aspects of the freshwater turtles, *Phrynops geoffroanus*, inhabiting an urban river in southeastern Brazil. Studies on Neotropical Fauna and Environment 36:57–62.

Silva, F.S., R.L. Lima, J.N. Pinheiro, E.S. Brito, and R.H.S. Ferraz. 2017. Morfologia de órgãos genitais femininos do quelônio semi-aquático *Mesoclemmys vanderhaegei*. Pesquisa Veterinária Brasileira 37:1015–1024.

Smith, G.R. 2002. Sex ratio of Common Musk Turtles (*Stenotherus odoratus*) in a north-central Indiana Lake: a long-term study. American Midland Naturalist 148:185–189.

Strüssmann, C. 2000. Herpetofauna. Pp. 153–189 *In* Fauna Silvestre da Região do Rio Manso, MT. Alho, C.J.R. (Ed.). Ministério do Meio Ambiente/Edições IBAMA/Centrais Elétricas do Norte do Brasil, Brasília, D.F., Brasil.

Vinke, T., S. Vinke, and G. Kohler. 2013. What is known about *Mesoclemmys vanderhaegei* (Bour, 1973): a systematic review of the available literature. Paraquaria Natural 1:21–31.

Vogt, R.C. 2012. Detecting and capturing turtles in freshwater habitats. Pp. 335–337 *In* Reptile Biodiversity: Standard Methods for Inventory and Monitoring. Foster R.W., M.S. Guyer, J.W. Gibbons, and N. Chernoff (Eds.). University of California Press, Berkeley, California, USA.

Vogt, R.C., and J.L.B. Villareal. 1993. Species abundance and biomass distribution in freshwater turtles. Pp. 210–218 *In* Proceedings of the Conservation, Restoration and Management of Tortoises and Turtles – An International Conference. Abbema, J.V. (Ed.). State University of New York, Purchase, New York, USA.

Wantzen, K.M., A. Siqueira, C.N. Cunha, and M.F.P. Sá. 2006. Stream-valley of the Brazilian Cerrado: impact assesment and conservation scheme. Aquatic Conservation: Marine and Freshwater Ecosystems 16:713–732.

Elizangela Silva de Brito is a Biologist who received her Ph.D. at the National Institute of Amazonian Research (INPA), Manaus, Amazonas, Brazil. She has been studying turtles for 15 y, and her research has always been focused on freshwater turtles, which includes the lesser known and studied species of turtles in Brazil. (Photographed by Luiz Solino de Carvalho).

Richard C. Vogt is Curator of Amphibians and Reptiles at the National Institute of Amazonian Research (INPA) and is director of Study Center of Amazonian Chelonians (CEQUA), Manaus, Amazonas, Brazil. He received his Ph.D. at the University of Wisconsin, Madison, Wisconsin, USA. He has spent the last 50 y studying behavior and ecology of river turtle communities from the Mississippi River, Neotropical Mexico, and the Amazon Basin. Among other topics his research has revolved around TSD (Temperature-dependent Sex Determination), and more recently underwater vocalizations in turtles. (Photographed by Gloria Moreria).

Rafael Martins Valadão is a Biologist and works as an Environmental Analyst, at the Brazilian National Center for Research and Conservation of Reptiles and Amphibians (MMA/ICMBio/RAN, Goiânia, Goiás, Brazil). He is currently involved in the Conservation Biology of Brazilian Continental Chelonia. He is working on projects focused on inventories and natural history of chelonian species inhabiting in a great geographic region called 'Brazilian Open Diagonal' (which comprises parts of biomes Caatinga, Cerrado and Pantanal). (Photographed by Tiago Quagio).

Leonardo F. França received his Ph.D. in Ecology from the Universidad of Brasília (UnB), Brazil. He is currently a Research Professor at the Federal University of Semi-Arid, Mossoró, Natal, Brazil. His scientific production is concentrated in the areas of population ecology and species conservation and focuses on understanding demographic aspects of Caatinga Bird (a semiarid region of northwester Brazil) and others vertebrate taxa at Neotropical environments. (Photographed by Luciana Vieira de Paiva).

Jerry Penha is an Associate Professor in Population Ecology at the Botany and Ecology Department, Bioscience Institute, Federal University of Mato Grosso (UFMT), Cuiabá, Mato Grosso, Brazil. He received his Ph.D. and M.S. in Ecology and Conservation of Natural Resources at the Federal University of São Carlos (UFSCar), São Carlos, São Paulo, Brazil. His research program focuses on use field data and statistical modelling to describe population dynamics to set conservation advices. (Photographed by Lúcia A. F. Mateus).

Christine Strüssmann is an Associate Professor at the Veterinary School, Federal University of Mato Grosso (UFMT), Brazil. She received her Ph.D. in Zoology from the Pontifical Catholic University of Rio Grande do Sul (PUCRS), Porto Alegre, Rio Grande do Sul, Brazil. She teaches Ecology, Herpetology, and Animal Toxinology for graduate students in Veterinary Medicine, Zootechny, and Biological Sciences. Her research focus includes taxonomy, distribution, population and community ecology of Neotropical herpetofauna. (Photographed by Elizângela Silva de Brito).