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Density, population structure and activity pattern of *Hydromedusa tectifera* (Testudines-Chelidae) in a mountain stream of Córdoba province, Argentina

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Abstract. The Snake-necked Turtle (*Hydromedusa tectifera*) is mainly distributed in the northeastern provinces of Argentina; however, some isolated populations occur in central Córdoba. This is the first report on some ecological aspects of one of these populations. Population density and annual activity pattern were characterized at Toro Muerto Stream in the Sierras region of the Córdoba province, central Argentina. Turtles were hand-captured and sex and carapace length were determined for each individual. Mark-recapture data were used to estimate population density, variation in monthly capture rates, and sex ratios throughout the sampling months. A total of 96 turtles were captured and density was estimated at 218 individuals ha^{-1}. Individuals were captured all year round, but showed activity peaks in spring and summer. This seasonal pattern has also been observed in other freshwater turtles. During the mating season a higher number of males were captured, which suggested a seasonal difference in activity patterns between sexes.

Keywords: Argentina, ecology, freshwater turtles, *Hydromedusa tectifera*.

Introduction

Studies on biology, ecology, and population dynamics of species are of great importance in generating population models for management purposes. Such models are necessary for evaluating the effects of environmental changes on wildlife populations (Morrison, Marcot and Mannan, 1992).

There is a great amount of information available on the population ecology of many freshwater turtles from the Northern Hemisphere (Iverson, 1982; Daigle and Jutras, 2005; Dreslik, Kuhns and Phillips, 2005; Stone, Powers and Babb, 2005; Verdon and Donelly, 2005; Smith, Iverson and Rettig, 2006). In contrast, only a few quantitative studies have been conducted on the ecology of freshwater turtles from South America. Two important studies, however, have been conducted on Brazilian populations of *Hydromedusa maximiliani* in mountain streams of the Atlantic forest (Souza and Abe, 1997) and on *Phrynops geoffroanus* in some urban areas of southeastern Brazil (Souza and Abe, 2000). The high population densities reported for these two species (193 and 750 turtles/ha, respectively) highlight their importance as predators and in terms of biomass in the ecosystems in which they inhabit.

The ecology and biology of most of the neotropical freshwater turtles in the family Chelidae are poorly documented. Moreover, activity pattern is one of the ecological attributes that are least understood in this family (Souza, 2004). Variations in activity or movement of reptiles throughout the year are related both to biological (e.g., hibernation, feeding, mate search, migration, etc.) and environmental factors (e.g., long drought periods, seasonal rainfall and periods of frost) (Zug, Vitt and Caldwell, 2001). High and low activity periods during warm and cold conditions have been documented in many species (Pough et al., 1998). In freshwater turtles, the relationship between activity intensity and different climatic or environmental variables often determines seasonal activity (Plummer, 1977; Lovich and Herman, 1992;

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Souza and Abe, 1997; Souza and Abe, 2000; Souza, 2004).

The South American Chelid genus *Hydromedusa* is represented by two species. Of these, *Hydromedusa tectifera* has been the least studied (Souza and Abe, 1997; Souza, 2004; Souza and Martins, 2006; Kurzmann Fagundes and Bager, 2007). The few scientific reports available about this species are on reproduction (Chinen, Lisboa and Molina, 2004; Kurzmann Fagundes and Bager, 2007) and natural history observations in captivity (Gallardo, 1956; Astort, 1983). Non-systematic data collection in the wild, which is often anecdotical, can be found in the literature (see Freiberg, 1975, 1977; Lema and Sarmento Ferreira, 1990; Cei, 1993; Cabrera, 1996, 1998; Richard, 1999; Souza, 2004; Lescano, Bonino and Leynaud, 2007).

Hydromedusa tectifera is distributed in eastern and southeastern Brazil, central and eastern Argentina, Paraguay, and most of Uruguay. In Argentina, it inhabits the Paraná, Uruguay, and Rio de la Plata river basins (Cabrera, 1998). In the province of Córdoba (central Argentina), disjunct populations are present in rivers and streams in a small mountainous area of Córdoba (Cabrera, Haro and Monguillot, 1986; Cabrera, 1996, 1998).

It was suggested that these populations are relicts of a species that was once more widely distributed (Cabrera, Haro and Monguillot, 1986). These currently isolated populations deserve special attention since natural environments in the Córdoba mountains are seriously threatened by urban expansion and deforestation (Gavier and Bucher, 2004).

In the study of isolated populations, population dynamics, recruitment rates and food availability are especially important (Andrén and Nilson, 1983; Forsman, 1991; Dodd, Franz and Smith, 1994; Pearson, Shine and How, 2002). The aim of this study was to make the first quantitative contribution on the demographic characteristics, in particular population density and biomass, of an isolated population of *Hydromedusa tectifera* inhabiting a stream within a mountain area in central Argentina. This paper also addresses some aspects of the population's structure and annual activity pattern of this species.

Materials and methods

Study site

This study was conducted in a stretch of the Toro Muerto stream, located in a mountain area in Córdoba province, Argentina, at 800 m a.s.l. (31°23′12.94″S; 64°36′08.56″W) (fig. 1). The stream has a mean depth of 70 cm and flows irregularly over granitic rock. The physiognomy of the surrounding vegetation is that of sierras secondary forest and thorny shrublands, typical of the Chaco region (Cabrera, 1976; Luti et al., 1979). Annual rainfall is 950 mm and is mainly concentrated in spring and summer. Mean annual temperature is 18.9°C, with peak values in summer that may exceed 38°C and frosts in winter (Capitanelli, 1979).

Turtle sampling

Individuals were located after sunset during visual encounter surveys because *Hydromedusa tectifera* has mostly nocturnal habits (Cabrera, 1998). They were captured by hand along both margins of a 2-km stream stretch. A total capture effort of 125 person-hours was uniformly distributed on 50 sampling dates from November 2004 to July 2006 including two spring, two autumn, two summer and one winter seasons. No surveys were conducted in January because the usual abundant rainfalls at this time of the year produce flash floods, making observation and capture impracticable.

Date, time, and geographical location were recorded for all captured turtles. Mass, measured to the nearest 0.1 g with a Pesola hanging scale, and carapace length (straight-line), measured to the nearest 0.1 cm with vernier calipers were recorded. Sex was determined according to secondary sex characteritics (males have concave plastrons and longer tails) (Cabrera, 1998). Turtles were individually marked using a coded sequence of notches filed into their marginal scutes, following a modification of Cagle's technique (Cagle, 1939). After sampling, individuals were released at their capture sites. Water temperature at 50 cm depth and air temperature at 50 cm above ground were also recorded using a mercury thermometer.

Population size and density

Population size was estimated with the Popan method using MARK 4.3 software (White and Burnham, 1999). Turtles were classified as adults (male or female) or subadults based on carapace length. Individuals with a caparace length < 13 cm were considered subadults (i.e., secondary sex characters were not evident in individuals smaller than 13 cm). Population size of *Hydromedusa tectifera* was calculated for the three groups (males, females and

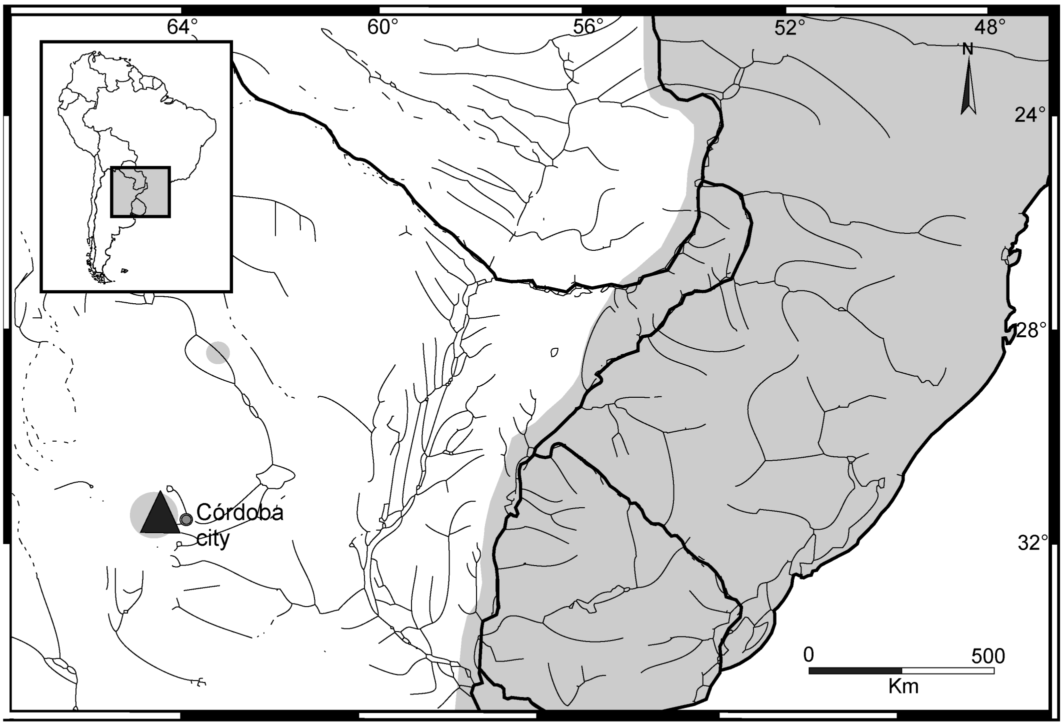

Figure 1. Geographical distribution of *Hydromedusa tectifera* in South America. (▲) Location of the isolated population in Sierras de Córdoba, central Argentina.

subadults) and overall mean population size was then estimated. Using this value, mean population density was calculated relative to the stream area sampled. Turtle biomass (kg of turtle per ha) was estimated using mean body mass and population density.

Population structure and activity pattern

To characterize population structure, turtles were assigned to five size classes according to carapace length: Class I = 30-100 mm; Class II = 100.1-150 mm; Class III = 150.1-200 mm; Class IV = 200.1-250 mm and Class V = >250 mm. Deviations from expected sex ratio (1:1) were analysed with a Chi-square (χ^2) test.

Activity pattern was determined through the number of individuals captured on each sampling date (Capt) relative to the man-hour invested in capture effort (Capt/h), and a mean value of capt/h was calculated for each month. The variation in activity of turtles was determined by estimating the relative monthly sampling effort, dividing the number of sampling dates in each month by the number of sampling dates in the whole study period. Using a null hypothesis of equal activity among months, the expected number of turtles active each month was generated by multiplying the total number of turtles captured by the relative sampling effort for each month. Finally, observed and expected values were compared using the χ^2 test (Rugiero, Capizzi and Luiselli, 1998). The relationship between the number of turtles captured each month and mean water and air temperature in that month was estimated using linear regression and Pearson correlation coefficient.

Results

Population structure, density, and biomass

A total of 94 turtles (26 males, 20 females and 48 juveniles) were captured and marked during the whole sampling period (fig. 2). Nearly half (47%) of these were recaptured at least once. A total population size of about 153 individuals was estimated for the 2-km stretch of stream sampled (table 1).

The stream surface work area was approximately 0.7 ha (mean width 3.5 m over 2 km), thus the population density estimated was about 219 turtles ha^{-1}. Mean weight of turtles was 0.439 ± 0.405 kg (mean $\pm$ 1 SD; $n = 90$), resulting in an estimated mean biomass of 96.1 kg ha^{-1}.

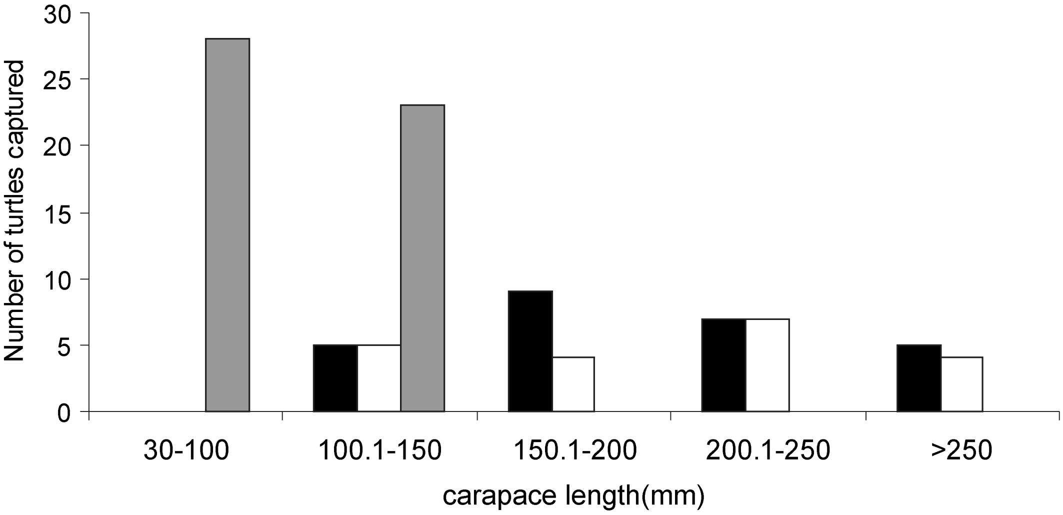

Figure 2. Population structure of *Hydromedusa tectifera* at Toro Muerto Stream, Córdoba, central Argentina, from November 2004 to July 2006. Adult males = black bars, adult females = open bars, subadults = grey bars.

Table 1. Number of marked individuals and estimated population size of *Hydromedusa tectifera* at Toro Muerto Stream, Sierras de Córdoba, Argentina. Values are mean ± SD, 95% confidence interval given in parentheses

Marked individuals	Males	Females	Subadults
	26	20	48
Estimated population size	44.9 ± 5.7	37.8 ± 5.74	70.4 ± 5.8
	(33.7-56.2)	(26.6-49)	(59-81.8)

The male to female sex ratio was 1.3 :1, which was not significantly different from 1 (Chi-square: $\chi^2 = 0.78$, df $= 1$, $P = 0.37$). The separate analysis of captures obtained in the different seasons during the sampling period did not show significant differences from the expected sex ratio in summer ($\chi^2 = 0.44$, df $= 1$, $P = 0.078$; $\chi^2 = 0.385$, df $= 1$, $P > 0.09$), autumn ($\chi^2 = 0.54$, df $= 1$, $P = 0.062$; $\chi^2 = 0.57$, df $= 1$, $P = 0.06$) or spring ($\chi^2 = 0.54$, df $= 1$, $P = 0.06$; $\chi^2 = 0.43$, df $= 1$, $P = 0.079$); but in winter, the male to female sex ratio was 7 :1, which was significantly different from the expected sex ratio 1 :1 ($\chi^2 = 0.88$, df $= 1$, $P < 0.05$).

Annual activity pattern

Turtles were captured all year round, but showed significant monthly fluctuations, with a higher number of captures in spring and summer (fig. 3). Summer captures exceeded the expected numbers, whereas in winter and autumn months the number of captures was lower than expected ($\chi^2 = 30.7$; df $= 18$; $P < 0.05$) (fig. 4).

Water temperature was positively correlated with captures, which partially explains variation in the number of turtles captured on each sampling date (Regression: $r^2 = 0.22$, $P < 0.001$; Pearson correlation: $R = 0.47$, $P < 0.05$; $n = 50$), whereas the relationship between captures and air temperature was not significant ($r^2 = 0.12$, $P > 0.05$; Pearson correlation coefficient $R = 0.36$, $P = 0.08$; $n = 50$).

Discussion

Population size and density

Estimates of density and biomass of *Hydromedusa tectifera* for the study area suggests that

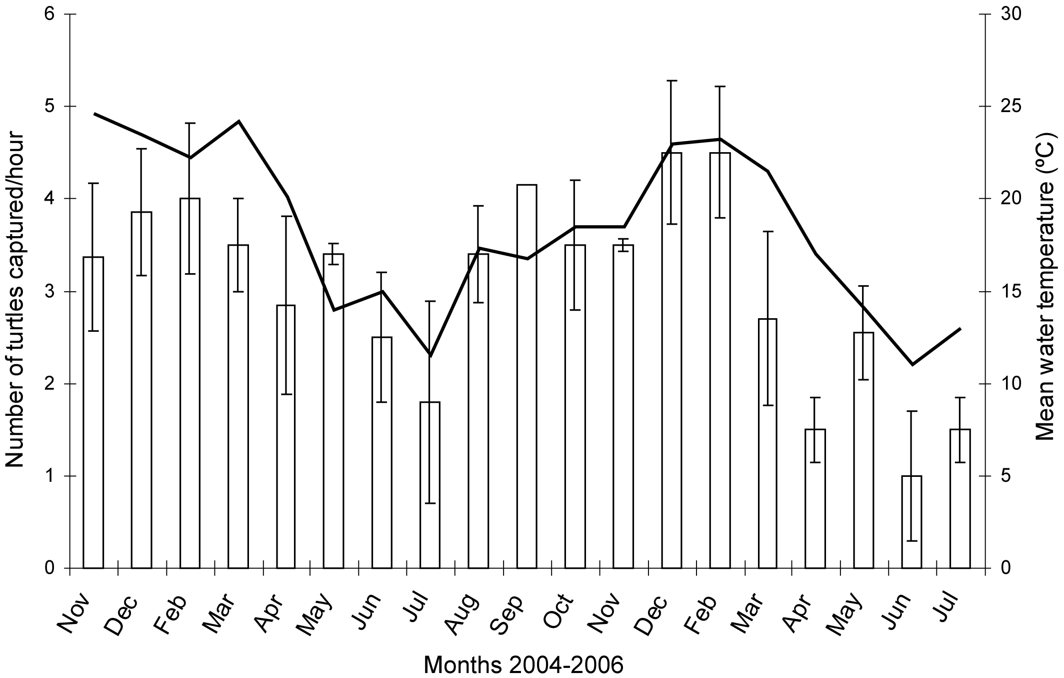

Figure 3. Monthly number of turtles captured/hour (bars) and ± SD, and mean monthly water temperature (line) recorded at Toro Muerto Stream, Córdoba Province, Argentina, from November 2004 to July 2006. No surveys were conducted in January 2005 and January 2006.

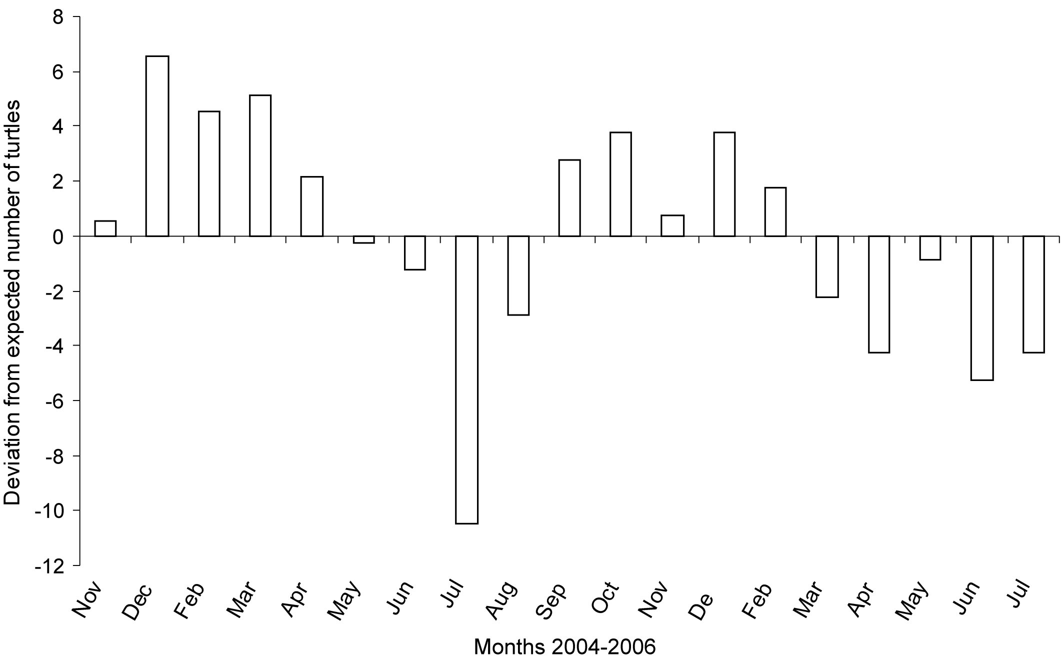

Figure 4. Monthly deviation from expected numbers of *Hydromedusa tectifera* at Toro Muerto Stream, Córdoba Province, central Argentina, from November 2004 to July 2006. No surveys were conducted in January 2005 and January 2006.

this species is an important faunal component of their aquatic ecosystems. The high density and biomass values found for the species in the study area are similar to those found in Brazil for *H. maximiliani* (193 turtles ha^{-1} river) in mountain streams of the Atlantic rainforest (Souza and Abe, 1997). Likewise, previous reports provide high density values for freshwater turtles in Central and South America, which contrast with the low density values found for some turtle species in North America (Iverson, 1982; Souza and Abe, 2000; Dreslik, Kuhns and Phillips, 2005; Smith, Iverson and Rettig, 2006).

Hydromedusa tectifera is the only turtle species present in the stream studied (*Phrynops hillari*, whose distribution range in Córdoba partially overlaps that of *H. tectifera*, is not present at Toro Muerto stream; pers. obs. J.N.L.). Interspecific relationships may play an important role in relative abundances of the different species (Dreslik, Kuhns and Phillips, 2005). Thus, the absence of other turtle species in the study area might determine the high population size of *H. tectifera* in the sampling sites.

The proportion of juvenile turtles captured at Toro Muerto stream (see fig. 2) is greater than the values found for other freshwater turtle species in different environments (Moll and Legler, 1971; Cooley et al., 2003; Litzgus and Mousseau, 2004a; Verdon and Donelly, 2005; McMaster and Downs, 2006). A low proportion of juveniles and subadult stages would suggest low recruitment and/or survival rate but also habitat-related visibility or capture bias of smaller size classes (Litzgus and Mousseau, 2004a; McMaster and Downs, 2006). The proportion of small-sized individuals captured in this work suggests a high recruitment rate as well as the efficacy of manual captures in shallow and clear water streams.

Activity pattern

Like other freshwater turtles (Plummer, 1977; Lovich and Herman, 1992; Souza and Abe, 1997, 2001), *Hydromedusa tectifera* showed seasonal differences in activity levels, whith peaks in spring and summer (figs 3 and 4). However, active individuals were recorded in all months of the year. These results differ from observations made by Lema and Sarmento Ferreira (1990) in Brazil, who found that the species buries itself in the mud in winter when flooded areas dry, and then emerge in spring. These somewhat contrasting results may simply reflect behavioural plasticity among populations subject to different environmental conditions.

Similary to *Hydromedusa maximiliani* (Souza and Martins, 2006), the activity of *H. tectifera* (except for nesting) is confined to water bodies. During the entire two-year study period, we did not record any individuals on land. This would explain the importance of water temperature for the species activity and the lack of a relationship between the number of captures and air temperature.

The seasonal variation observed in sex ratio agrees with several reports (Souza and Abe, 1997, 2001; Swannack and Rose, 2003) and suggests that activity and behaviour is different between the sexes. Activity in males was greater than in females during winter and spring; thus, males were easier to see and therefore easier to capture. This aspect would be associated with the reproductive behaviour of the species, since previous observations in the study area indicate that *H. tectifera* mates during winter and early spring (Lescano, Bonino and Leynaud, 2007). As in other freshwater turtles, the increased activity in males in certain periods of the year is related to the active mate search of females. This differential activity between sexes in freshwater turtles is supported by the reproductive strategy hypothesis (Gibbons, Greene and Congdon, 1990), which suggests that activity and movement would be greater in males during the mating season when they are searching for mates, whereas females would have similar or greater activity and movements than males during the nesting season when searching for nesting sites (Gibbons, Greene and Congdon, 1990; Doody, Young and Georges, 2002; Litzgus and

Mousseau, 2004b). The differential activity pattern between sexes in *H. tectifera* may reflect their reproductive strategy, which adjusts to the hypothesis mentioned.

The data presented in this study provides baseline information that may be applied towards a deeper analysis of this species' ecology, and is a contribution to the demographic parameters of this little-known freshwater turtle from Argentina.

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