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Demographic and growth analysis of broad snouted caiman (*Caiman latirostris*) in a disturbed environment in southeastern Brazil

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Crocodylian life history traits exhibit strong size and age dependence, which is determined, ultimately, by how fast individuals grow. Crocodylian population dynamics are dependent on environmental conditions such as local temperatures and hydrology. From February 2010 to October 2011 we conducted monthly spotlight surveys to study a broad-snouted caiman population at the Três Marias Hydro-electric Reservoir, southeast Brazil. A total of 12 spotlight surveys were conducted (17.3 to 48.0 km in length), and animals were captured, measured and marked whenever possible. Data were obtained on population size, sex structure, survival, distribution and growth. The number of caimans counted, including hatchlings, varied from 6 to 78 per survey. Marked individuals showed a growth rate that varied between 0.0 and 0.3 cm*day⁻¹ SVL, and between -6.0 and 8.0 g*day⁻¹ body mass. Polyphasic growth was associated with rainfall and water level, which in turn were associated with changes in temperature and diet. The species seems to be resistant to the ecological impacts of damming, an important conservation conclusion considering the large number of hydroelectric dams within the species' range in Brazil.

Key words: Brazil, *Caiman latirostris*, demography, growth analysis

INTRODUCTION

Patterns of growth vary considerably in vertebrates. Mammals and other endothermic vertebrates typically present a monophasic pattern in which growth rate decreases with body size. Such patterns can be described using monotonic functions such as the von Bertalanffy, Gompertz or Richard models (Coutinho, 2000). For ectothermic vertebrates such as crocodylians, on the other hand, polyphasic growth linked to environmental variables such as type of prey, water temperature and water level has been reported for several species (*Crocodylus porosus* and *C. johnsoni*: Webb et al., 1978; 1983; *C. niloticus*: Hutton, 1987; *Caiman crocodylus*; Magnusson & Sanaïotti, 1995; *C. yacare*: Coutinho, 2000).

Crocodylians highly depend on environmental conditions such as thermal parameters and local hydrology (Markwick, 1998). The construction of dams for hydroelectric power plants leads to instability of hydrological regimes, and could thus have serious consequences for crocodylian population dynamics.

Studies on the impact of the construction of hydroelectric power plants on the density and reproduction of crocodylians are, however, still scarce.

Caiman latirostris is widely distributed in central and eastern South America. In Brazil, it is found primarily in densely vegetated and quiet waters including marshes, swamps and mangroves along the Atlantic coast (Medem, 1983). Despite the fact that the majority of the species' distribution range is located in Brazil, most studies on wild *C. latirostris* have so far been conducted at the southern edge of its distribution (i.e. Argentina). Filogonio et al. (2010) found that, despite hunting pressure and human impact on natural habitats, populations of *C. latirostris* are widely distributed throughout the São Francisco basin (southeast Brazil). However, Verdade et al. (2010) suggested that hydroelectric dams, wetland drainage and pollution are negatively affecting the species' distribution, in line with Mourão & Campos (1995) who investigated the potential impact of damming such as the destruction of floating vegetation used for nesting. The aim of this study was to document growth and survival of *C. latirostris* inhabiting a dammed environment.

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Table 1. Spotlight survey data for broad-snouted caiman at the Pirapitinga Ecological Station, Minas Gerais, Brazil. asl=above sea level.

Date of survey	Length of survey (km)	Number of caimans	Rate of encounter (ind/km)	Water Level asl (m)	Air temperature range (°C)	Water Temperature range (°C)
Feb/2010	9.70	41	4.22	567.44	23.8–27.8	26.9–30.3
May/2010	20.20	42	2.07	568.1	16.4–22.4	22.6–26.9
Jul/2010	24.54	30	1.22	566.24	18.1–20.4	21.2–24.7
Oct/2010	17.25	41	2.37	562.98	23.1–27.4	25.1–28.0
Nov/2010	28.38	28	0.98	562.64	23.2–26.2	25.0–28.1
Dec/2010	28.02	12	0.42	564.11	22.7–25.6	29.4–31.3
Feb/2011	21.25	15	0.70	568.86	23.4–27.9	30.3–32.4
Mar/2011	48.14	23	0.47	571.01	21.4–24.6	26.7–27.4
May/2011	17.40	6	0.34	572.34	21.8–25.6	26.9–29.2
Jun/2011	20.75	13	0.62	571.88	17.8–22.2	23.6–24.6
Aug/2011	18.66	20	1.07	569.95	19.4–22.1	23.5–24.8
Oct/2011	20.55	78	3.79	567.35	21.6–24.3	24.5–27.3

MATERIALS AND METHODS

The Três Marias Hydroelectric reservoir, built in 1957, is located in Minas Gerais, Brazil, at 538 metres above sea level in the high São Francisco river region (18° 12' 51"S, 45° 15' 51"W). Pirapitinga Ecological Station (ESEC Pirapitinga) is an artificial island in this reservoir, which was formed because of reservoir flooding. The ecological station has an area of approximately 1,000 ha, which varies according to the reservoir's water level. The vegetation of this artificial insular system comprises different Cerrado vegetation physiognomies (Sato & Sampaio, 2006). The east of ESEC is characterised by strong winds and rocky shores, while the west is characterised by flooded areas covered with mud, grass and shrubs.

A total of 12 spotlight surveys were conducted from February 2010 to October 2011, lasting 5 days each. Caiman surveys were conducted after dusk using a 4.8 m long boat powered by a 15-hp outboard motor. A standard 12-V spotlight was used to locate animals by

eyes shine; individuals were captured whenever possible. Captured individuals were weighed, sexed and their snout-vent length (SVL) measured from the tip of the snout to the posterior margin of the cloaca using a measuring tape with 0.5 mm accuracy. Individuals were categorised by size class based on their snout-vent length (SVL) as follows: Class I (<25 cm - hatchlings and juveniles), Class II (25–49.9 cm - juveniles), Class III (50–79.9 cm - subadults) and Class IV (>80 cm - adults, Filogonio et al., 2010). Sexing techniques are more reliable for individuals >40 cm SVL; therefore smaller individuals were categorised as juveniles to avoid sexing errors. All captured individuals were marked by removing tail scutes according to a prescribed sequence (Webb et al., 1978, Moulton et al., 1999, Garcia-Grajales et al., 2012). This marking technique has been widely used in crocodylian studies worldwide and has no effect on growth or survival of marked individuals (Jenning et

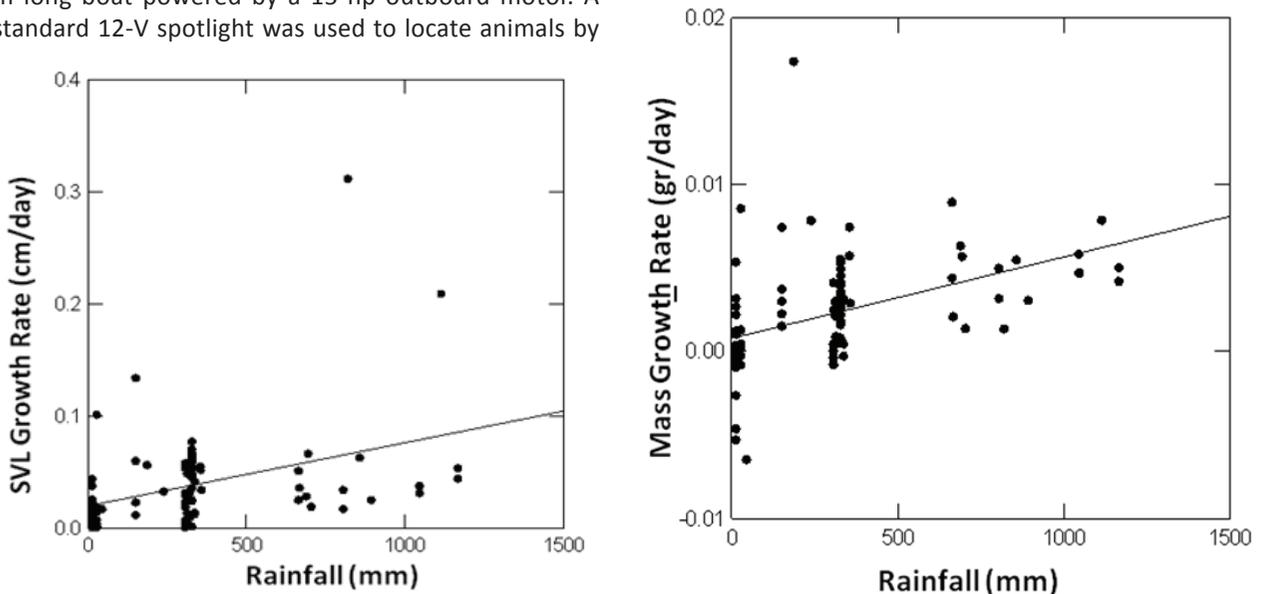


Fig. 1. (A) Relationship between rainfall and snout-vent length (cm/day) and (B) mass (gr/day) growth rates of *Caiman latirostris* at Pirapitinga Ecological Station, Minas Gerais, Brazil.

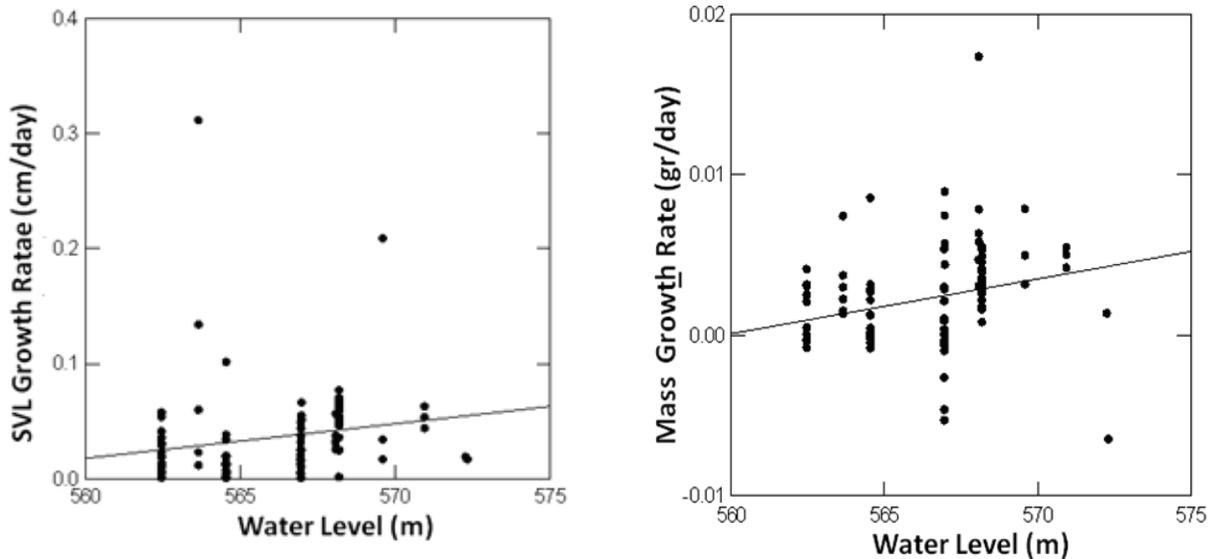


Fig 2. (A) Relationship between water level (above sea level in meters) and snout-vent length (cm/day) and (B) mass (gr/day) of *Caiman latirostris* at Pirapitinga Ecological Station, Minas Gerais, Brazil.

al., 1991), and was approved by IBAMA (the Brazilian Government's environmental agency) for this study. Information on growth and survivorship was obtained using mark-recapture techniques (Webb et al., 1978). Individuals were released at their capture site on the same night they were marked, and all sites were registered using a GPS device (Garmin GPSMAP 60Cx) at an accuracy of 4 m.

Somatic growth rates (SGR) were expressed by changes in SVL (Δ SVL). For each recapture interval (Δ T), the specific growth rate was given by $SGR = (1/SVL)(\Delta$ SVL/ Δ T), and defined as the proportional increase in SVL (mm) and mass (grams) per unit of time (days). This was plotted against mean SVL for each individual's recapture interval. Growth rates were calculated using body mass and SVL rather than total length (TL) to avoid errors resulting from tail tip loss (Webb et al., 1978).

Age specific survival rates were calculated by applying a stepwise approach of the catch curve method as described by Krebs (1989). Accordingly, instantaneous annual mortality rates were calculated separately for individuals from age one and two, and two to four years of age. For age one, survival was calculated using the ratio method, whereas for ages two to four, the regression method (log of frequency regressed against age) was applied (Coutinho, 2000). We could not determine whether the animals died or moved outside the study area. Nevertheless, the estimates are meaningful to foster an understanding of the effect of a protected area on caiman population dynamics. The data were analysed using the software Systat v. 11, with the significance level set at 5%. Mean values are presented with standard error of the mean.

RESULTS

Population surveys

Survey length ranged from 17.3 to 48.0 km, and the number of caimans counted varied from 6 to 78 per survey. The rate of encounter ranged from 0.3 to

3.8 individuals*km⁻¹, with an average of 1.5±0.38 individuals*km⁻¹ (Table 1). On the last survey 60 hatchlings were found, explaining the high numbers (Table 1). No nests were found.

The caiman population in Pirapitinga was mainly composed of juveniles (Class I and II). Adult (Class IV) animals were in low numbers ($n=4$), wary and difficult to catch. Previous field trips provided data on individual ages from three previously marked clutches, but no data on size and weight were available. These animals were monitored during the study using capture-recapture procedures. The population sex ratio was estimated based on a sample of 22 individuals with an SVL above 40 cm. The overall sex ratio was 1.2:1 in favour of males.

The estimated survivorship for caimans at age one, obtained by the ratio method, was 0.433, whereas the regression method used for age classes two to three revealed a survival estimate of 0.456. In other words,

Table 2. Number of *Caiman latirostris* captured and recaptured for each month in Pirapitinga Ecological Station, Três Marias dam, São Francisco River, Minas Gerais, Brazil. Δ t=days between captures; SVL=snout-vent length.

Survey	Month/Year	Δ t	n Capture	n Recapture
1	Feb/2010	-	39	-
2	May/2010	102	32	29
3	Jul/2010	60	21	20
4	Oct/2010	83	21	20
5	Nov/2010	49	17	17
6	Dec/2010	27	7	7
7	Feb/2011	43	8	5
8	Mar/2011	47	7	3
9	May/2011	43	3	2
10	Jun/2011	42	2	1
11	Aug/2011	65	5	5
12	Oct/2011	45	67	7

43.3% of new born caimans persisted to two years of age, and 45.6% of the two years old individuals reach three years of age.

Growth analysis

Growth rates varied between 0.0 and 0.07 cm*day⁻¹ SVL (mean: 0.033±0.004 cm*day⁻¹). Body mass varied between -6.0 and 8.0 g*day⁻¹, with a mean rate of 2.0 (±2.7 SD) g*day⁻¹. Table 2 shows the number of caimans captured and the mean SVL and mass value for each sample.

Growth rate, expressed as centimeters of SVL per day, was plotted against mean SVL between captures; that is, $[(l_2+l_1)/2]$, where l_1 and l_2 refer to lengths at capture and recapture. The relationship between growth rate and size was, firstly, examined fitting a distance weighted least square smoothing curve (DWLS) to the data set. From this analysis, it was observed that no single growth model would fit the data set. In fact, attempts to fit a linear regression equation to the entire data set revealed that it could not be used to generalise growth of these caimans ($r^2=0.028$; $n=79$; $p=0.14$). The SVL and age relationship indicated that caiman growth followed a polyphasic model, rather than a monophasic growth model.

A high variation of growth rates between individuals precluded a significant size-growth relationship ($F_{1,71}=0.66$; $p=0.42$). A tendency for the growth rate of larger individuals to decrease was noticeable, but the small sample size did not permit the definition of a better curve for larger individuals. As most individuals were <2 years of age, the lack of data limited any attempt to define an age-specific growth rate function.

We observed a positive relationship between rainfall and growth rate for both SVL ($r^2=0.123$; $n=79$; $p=0.002$; Fig. 1A) and body mass ($r^2=0.207$; $n=111$; $p<0.001$; Fig. 1B). Furthermore, water level was positively related with growth rates in SVL ($r^2=0.116$; $n=79$; $p=0.002$) and mass increase ($r^2=0.17$, $n=104$, $p<0.001$, Fig. 2).

DISCUSSION

We observed a high number of juvenile *C. latirostris* at Três Marias Reservoir. The low encounter rate of subadults and adults (Classes III and IV) may be related to sampling bias. It is known for other species (*M. niger* and *C. yacare* Pacheco, 1996; *C. porosus* Webb & Messel, 1979) that crocodilian wariness increases with size, which may have affected the count results during spotlight surveys. Individuals might become wary of humans because of negative experiences associated with hunting, capture and habitat alteration (Espinal & Escobedo-Galván, 2011; Webb & Messel, 1979; Pacheco, 1996).

Without strong hunting pressure, crocodilian populations tend to have even sex ratios (Thorbjarnarson, 1997; Mourão & Campos, 2004). The sex ratio observed at this reservoir demonstrates that hunting is likely not a major threat for the local caiman population; the data, however, suffer from a low sample size. The survival rates found during this study are high when compared to American alligators (Woodward et al., 1987; Magnusson,

1979; Webb & Messel, 1978a). Recapture rates at a given locality are also affected by movement patterns (Woodward et al., 1987). For *C. porosus*, Webb & Messel (1978a) found that 42% of hatchlings were found near the nesting sites after 13 months, whereas Magnusson (1979) found only 21% of individuals after one month. Mortality of caiman hatchlings during their first years of life is expected, as their small size and tendency to congregate in crèches in shallow waters make them an easy target for predators (Coutinho, 2000). Piña et al. (2003) found that, in captivity, survival rates for *C. latirostris* vary between 50 and 80% depending on the incubation regime.

Caiman growth rates at Três Marias reservoir were similar to the only other study on wild *C. latirostris* (Moulton et al., 1999). Studies from captive populations showed that growth of *C. latirostris* is negatively related to population density (Poletta et al., 2008), and positively related to temperature (Piña & Larriera, 2001). The polyphasic nature of caiman growth can be due to fluctuating water level, size, age and dietary shifts (Coutinho, 2000, Garcia-Grajales et al., 2012). Hatchlings prey mostly on invertebrates, but a diet composed of invertebrate prey is not energetically compatible with accelerated growth as individuals increase in size, and a shift to vertebrate prey can explain observed changes in growth rates (Coutinho, 2000). A number of studies have shown an increase in body size related to larger prey size for *C. porosus*, *A. mississippiensis*, *C. niloticus*, *C. acutus* and *C. crocodilus* (Webb & Messel, 1978b). Growth rates can also be affected by the different challenges animals face in the wild such as low temperatures (Lang, 1987) and shortage of food (Rice, 2004). Piña & Larriera (2001) found that growth rates in a captive experiment range from 0.03 to 0.18 cm/day depending on different temperature treatments. Population density can also affect caiman growth. Relatively high densities may increase competition for food, leading to decreased growth rates (Saalfeld et al., 2008; Elsey et al., 1990; Polleta et al., 2008). When compared to other Brazilian caimans such as *M. niger*, *C. crocodylus* (Villamarín et al., 2011) and *C. yacare* (Coutinho, 2000), densities found during this study are low and should not affect growth rate. However, the deficiency of data on wild broad-snouted caiman populations precludes comparative analyses.

Crocodylians are a climate-sensitive group (Markwick, 1998; Garcia-Grajales et al., 2012). Variation in water level and temperature can affect their ability to find and digest food, and consequently their growth (Webb et al., 1978; Piña & Larriera, 2001). Caimans are opportunistic predators that ambush their prey (Medem, 1983), a behaviour which is favoured by high vegetation growth during the rainy season, coupled with an increase in food availability (Fonseca, 2005). Higher water levels likely allow caimans to exploit new feeding areas where insects, crustaceans and mollusks may be more abundant (Webb et al., 1978). Periods of high water level are normally associated with rainy seasons, which generally also exhibit higher temperatures, favouring caiman activity, digestion and, thus, growth.

The broad-snouted caiman can be considered as an umbrella species in its local ecosystem (Amavet et al., 2012), and our results suggest that this species forms a sustainable population in a reservoir environment. We, however, lack comparative data from other areas and especially from other reservoirs. Given the large number of dams in the species' distribution (Verdade et al., 2010) it is important to understand how caimans are coping with a reservoir environment in order to implement efficient conservation measures.

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