Distribution of populations of broad-snouted caiman (*Caiman latirostris*, Daudin 1802, Alligatoridae) in the São Francisco River basin, Brazil

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(With 1 figure)

Abstract

We surveyed populations of the broad-snouted caiman, *Caiman latirostris*, throughout the São Francisco River basin, from Três Marias reservoir, State of Minas Gerais, to the river delta, at the boarder of Sergipe and Alagoas states. We registered the occurrence of crocodilians in 61% of all surveyed localities (n = 64), in which the presence of *C. latirostris* was confirmed in 44% of the surveyed sites. Caimans occurred in both lentic and lotic habitats, although there was a preference for small dams, oxbow lakes and wetlands. Despite the hunting pressure and human impact on natural habitats, our results indicate that the populations of *C. latirostris* in the São Francisco basin are not fragmented.

Keywords: Caiman latirostris, São Francisco River basin, broad-snouted caiman, population distribution.

Distribuição das populações de jacaré-do-papo-amarelo (*Caiman latirostris*, Daudin 1802, Alligatoridae) na bacia do Rio São Francisco, Brasil

Resumo

Fizemos o levantamento de populações do jacaré-de-papo-amarelo, *Caiman latirostris*, ao longo da bacia do rio São Francisco, a partir do reservatório de Três Marias, no Estado de Minas Gerais, até a foz do rio, na divisa entre os Estados de Sergipe e Alagoas. Registramos a ocorrência de jacarés em 61% das localidades visitadas (n = 64), nas quais a presença de *C. latirostris* foi confirmada em 44% dos casos. Os jacarés ocorreram em ambientes lênticos e lóticos, muito embora tenhamos observado uma preferência por pequenas represas, lagoas marginais e áreas alagáveis. Apesar da pressão de caça e da modificação dos hábitats naturais, nossos resultados são evidências de que as populações de *C. latirostris* ao longo da bacia do São Francisco não estão fragmentadas.

Palavras-chave: Caiman latirostris, bacia do rio São Francisco, jacaré-de-papo-amarelo, distribuição das populações.

1. Introduction

The broad-snouted caiman, *Caiman latirostris*, is a native species from Brazil, Argentina, Bolivia, Paraguay and Uruguay. It is distributed throughout the Paraná, Paraguay, São Francisco and Uruguay River basins (Borteiro et al., 2006), being the crocodilian with the southernmost distribution among neotropical species. The species distribution within Brazil ranges from the north-eastern state of Rio Grande do Norte reaching the south of the Rio Grande do Sul state (Verdade and Piña, 2006).

Caiman latirostris was considered an endangered species in Brazil until 2003, when the species was withdrawn from the Brazilian List of Endangered Fauna (Martins, 2005). On the other hand, Brazilian populations are still listed in Appendix I of the Convention of International Trade of Endangered Species – CITES (Verdade, 1998). Few studies have dealt with the status or dynamics of Brazilian populations in the wild and most of them were conducted in the Paraná River basin or on the coastal south-eastern part of the species distribution range (e.g., Mourão and

Campos, 1995; Grigg et al., 1998; Verdade et al., 2002; Fusco-Costa et al., 2008). On the other hand, there has been considerable research effort focused on captivity animals (e.g., Verdade, 2004; Verdade and Santiago, 1992). The lack of information on wild populations imposes serious constraints to the development of broader conservation and management plans like those currently being carried out in Argentina, as reported by Larriera and Imhof (2006). Moreover, there are virtually no available data on natural populations of *C. latirostris* from the São Francisco River basin, which accounts for an extensive portion of the species distribution range (Verdade and Piña, 2006; Villela et al., 2008). The aim of our study was to evaluate the distribution pattern of wild populations of *C. latirostris* throughout the São Francisco River basin (SFB).

2. Materials and Methods

2.1. Study area

The SFB is an important Brazilian water resource, draining the states of Bahia (BA), Minas Gerais (MG), Pernambuco (PE), Alagoas (AL), Sergipe (SE), Goiás (GO) and Distrito Federal (DF). Human population estimates in the SFB reaches over 13 million people (ANA, 2005). Along its 2,863 km of extension (ANA, 2005), the river basin is divided into four sub-regions according to the prevailing biome, temperature and rainfall: the high and medium sub-region are primarily covered by the Cerrado biome, where the mean temperature and annual rainfall are 23 °C and 24 °C and 1372 mm and 1052 mm, respectively. The sub-medium presents a mean temperature of 27 °C and the annual rainfall drops to 693 mm, being covered mostly by the Caatinga biome. The Atlantic Forest covers the low sub-region and the mean temperature and annual rainfall are 25 °C and 957 mm, respectively (ANA, 2005; Mark, 1963). The biomes Cerrado and Atlantic Forest are considered hotspots, with high conservation priority (Myers et al., 2000). Natural and suitable artificial habitats for *C. latirostris* such as wetlands, oxbow lakes, small dams and reservoir are distributed throughout the basin.

Since the early Portuguese colonisation, the basin has been used intensively by human population, although there remain fragments of well preserved habitats along the river basin. Such intensive uses are associated with gallery forest deforestation and the erosion of its margins, intense irrigation and high number of hydroelectric power plants (SEPLANTEC, 2000). Hunting pressure on *C. latirostris* has also been reported. In the state of Alagoas, for example, the species is sold in local markets as salted fish meat, known as the "São Francisco codfish", probably provided by local fishermen (Verdade, 2001). Recently, discussions about transposing waters from the São Francisco River to irrigate dry regions of the Brazilian Caatinga have drawn attention to the basin environmental issues. In order to restore and minimise human impacts, since 2001, the Brazilian Federal Government has launched a revitalisation plan for the basin, which includes a broad evaluation of the status of the biotic components of the São Francisco basin (Andrade, 2002).

2.2. Survey methods

Survey sites were spread along the main river course, covering most of the SFB extension (see Figure 1). Population surveys started from the high sub-region, at Três Marias reservoir, State of Minas Gerais, reaching the river delta, in the municipality of Penedo, in the state of Alagoas. Surveys were conducted during two field trips, the first one was held from March to May 2006 and the second, from November to early December 2007. The search for caimans was made by night-light surveys using a 5 m open boat powered by a 25 hp outboard engine, at an average constant speed of 8 km/h. In many cases, however, when the locality was inaccessible with the boat, the surveys were conducted by walking at the margins of the water body. The searches usually started 20-30 minutes after sunset, around 7:00 PM, and ended around 11:00 PM. The caimans were located with a sealed-beam powered by a 12 V battery and headlights. Because another caiman species, *Paleosuchus palpebrosus* (Cuvier, 1807), occurs in the SFB (Campos et al., 1995), we approached the individuals in order to identify the species. We also interviewed local people to evaluate whether or not caimans occur in the area.

Our surveys included the main channel of the São Francisco River and its tributaries as well as oxbow lakes, dams and wetlands. Each surveyed site was georeferenced and characterised according to the hydrography, vegetation type and human impacts using a standard protocol developed specifically to attend the studies in the SFB. Site hydrography was classified as main river or small tributaries main channels, which were grouped as lotic environments, and dams, oxbow lakes and wetlands which were grouped as lentic environment. The prevailing vegetation type (Cerrado, Caatinga and Atlantic Forest) was noted, whereas human impacts were characterised observing the presence of pasture, monoculture, erosion, roads and urbanisation. To test the relationship between presence of caimans and human impact, we summed the number of respective impacts observed in each locality visited according to the categories cited above. The sites were then assigned with a specific rank of impact intensity, which ranges from 0 (when no impacts were observed) to 5 (when all the impacts listed were observed). The relationship between the occurrence of caimans, type of water body and human impact was tested using the χ^2 Pearson correlation statistic carried out with Systat (Wilkinson, 1998).

3. Results

We checked 64 localities for the presence of caimans over 17 municipalities along the SFB (see Figure 1).

With the exception of Pilão Arcado (BA), in which we registered the presence of caimans based on interviews, and Remanso (BA), in which we did not register the presence of caimans, we sighted caimans directly in all municipalities along the studied area (n = 15). Caimans were present in 39 localities surveyed (61%) and were widely distributed along the river basin, occurring in all sub-regions, in the three biome types, Cerrado, Caatinga and Atlantic Forest. *Caiman latirostris* was sighted directly in 28 localities (44%), and *Paleosuchus palpebrosus* was present in three different sites, whereas the other sightings corresponded to unidentified individuals (indicated as "Eyes only", see Table 1).

Caimans were observed using both lotic and lentic environments. However, caimans were found more frequently in lentic environments, to which occurrence was positively

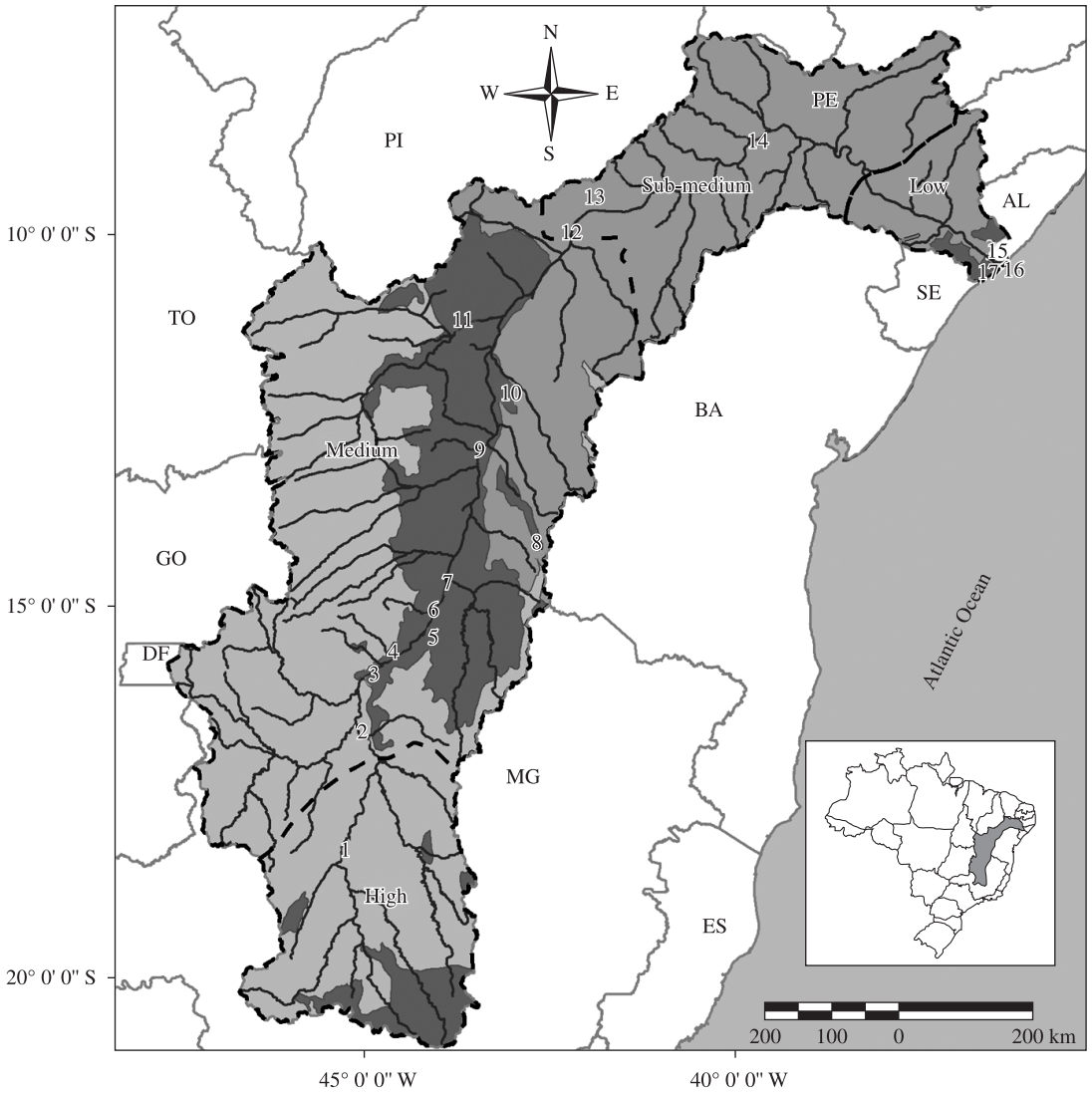

Figure 1. Map of the São Francisco River basin, Brazil, showing the municipalities visited during the 2006 and 2007 surveys. Spaced lines delimitate high, medium, sub-medium and low sub-regions. States are delimited by grey lines. The basin drains the states of Minas Gerais (MG), Bahia (BA), Pernambuco (PE), Alagoas (AL), Sergipe (SE), Goiás (GO) and Distrito Federal (DF). The Cerrado biome is represented by the region in light grey, the Caatinga biome, in medium grey, and the Atlantic Forest biome, in dark grey. Numbers represent the municipalities visited: 1 – Três Marias (MG); 2 – São Romão (MG); 3 – São Francisco (MG); 4 – Januária (MG); 5 – Itacarambi (MG); 6 – Pedras de Maria da Cruz (MG); 7 – Manga (MG); 8 – Guanambi (BA); 9 – Sítio do Mato (BA); 10 – Ibotirama (BA); 11 – Barra (BA); 12 – Pilão Arcado (BA); 13 – Remanso (BA); 14 – Santa Maria da Boa Vista (PE); 15 – Penedo (AL); 16 – Piaçabuçu (AL); 17 – Brejo Grande, (SE). Modified from "Plano decenal de recursos hídricos na bacia hidrográfica do Rio São Francisco (2004-2013)" (ANA, 2005).

related ($\chi^2 = 2.5$, df = 1, p = 0.01). Therefore, caimans can use the São Francisco River main channel and its tributaries as dispersion routes, however, populations composed of individuals of all age/sizes occurred mainly in lentic environments. Most of the surveyed sites present some degree of human impact. Pasture was found in 46 surveyed localities (72%), followed by roads (25 localities; 39%), urbanisation (23 localities; 36%) and monocultures (20 localities; 31%; see Table 2). We expected to observe a negative relationship between impact intensity and the presence of caimans. However, no significant trend was found ($\chi^2 = 7.5$, df = 5, p = 0.19), indicating that caimans are resistant to the impact measured in this study. We also confirmed hunting pressure in most of the visited sites, as many people claimed to be hunters themselves. People justified hunting caimans primarily for food acquisition. Many fishermen also killed caimans because caimans feed on the fishes attached to their fishing nets, which also destroy their nets. On one occasion, in the municipality of Ibotirama (BA), in the medium sub-region, local people showed us a *C. latirostris* skin of approximately 1.8 m total length. Because of the hunting pressure, spotlighted individuals were very wary, thus explaining the relatively high percentage (12%) of occasions in which attempts to approach and identify the species were frustrated.

4. Discussion

Based on our surveys we have demonstrated that *C. latirostris* is widely distributed throughout the SFB. Such distribution pattern is an indication that the populations within the river basin are not fragmented. The fact that we observed caimans in lotic habitats, and considering that river channels are important routes to crocodilian dispersal (Magnusson, 1979), we can predict a consistent genetic flux within the river basin. This is in agreement with the findings of Villela et al. (2008), who demonstrated that the genetic variations of *C. latirostris* are closely related to macrogeographic patterns of big river basins rather than geographic distance itself, and that genetic flux occurs even in large distances, say thousands of kilometres. Moreover, our findings are in agreement with those of Borteiro (2005), who also found *C. latirostris* widespread in Uruguay, occurring in 29 of the 36 localities surveyed (81% of the sampled areas).

We did not attempt to estimate population size. However, we observed a number of populations with low number of individuals, which were scattered distributed throughout the survey sites. Such pattern differs from that observed in other species of the same genus, such as the *Caiman crocodilus* in the Brazilian Amazonia (Da Silveira et al., 1997) and *Caiman yacare* in the Pantanal (Coutinho and Campos, 1996), which occur in habitats relatively free from human impacts, particularly when compared to the SFB. *Caiman latirostris* from the SFB occurred in preserved habitats as well as in habitats affected strongly by human occupation. In fact, we did find individuals in sewage and highly urbanized areas, showing that the species is rather resistant to human impacts and that habitat modification has limited effect on the species distribution. On the other hand, habitat modification seems to be more important to determine the small size of natural populations, rather than affecting the species distribution pattern. In this sense, current levels of hunting pressure seems to be playing a major role in reducing population size, but it does not seem to drive populations to local extinction. Certainly, hunting is affecting the wary behaviour of the caimans, as pointed out by a number of crocodilian studies (e.g., Ron et al., 1998).

Caiman latirostris is one of the Brazilian crocodilian species with the highest commercial value (Magnusson and Mourão, 1997). In the Amazon region, black caiman populations (*Melanosuchus niger*) were overexploited because of the value of its skin (Rebêlo and Magnusson, 1983). However, by means of protection measures and management programs, natural populations had recovered steadily and are currently included in Appendix II of CITES (RAN, 2007). The success of management efforts to recovering crocodilian populations have been reported worldwide (Thorbjarnarson, 1999). For instance, previous reports on the successful ranching program of *C. latirostris* in Argentina (Larriera and Imhof, 2006) show the potential for conservation through the sustainable use of wild populations. We expect that protecting suitable habitats of *C. latirostris* will probably lead to an increase in population growth rates, which, in turn, may make ranching programs feasible from both conservation and socioeconomic perspectives. Further efforts must be towards implementing such programs in the SFB, in order to protect wild populations of caimans and to promote the development of sociobiodiversity value chains in the region.

Table 1. Number of sites where caimans were observed by direct sighting and/or interview according to the localities and municipalities, during the 2006 and 2007 surveys in the São Francisco River basin, Brazil. Percentages were calculated in relation to the total number of water bodies surveyed.

Sites	Type of observation			
	Occurrence of caimans (%)	Direct sighting		Interview
		C. latirostris	Eyes only	
Localities (n = 64)	39 (61%)	28 (44%)	8 (12%)	3 (5%)
Municipalities (n = 17)	16 (94%)			

Table 2. Caimans registered by direct sighting and/or interview, according to the sites and habitats observed during the 2006 and 2007 surveys in the São Francisco River basin, Brazil.

Site			Presence of caimans			Habitat		
Sub-region	**Municipality**	**Locality**	***Caiman latirostris***	**Eyes only**	**Interview**	**Hydrography***	**Vegetation**	**Human impact****
High	Três Marias (MG)	Pirapitinga Ecological Station	1	0	0	D	Cerrado	
		Grota da Onça	0	0	0	D	Cerrado	
Medium	São Romão (MG)	São Francisco River	0	0	0	RC	Cerrado	P
		Luciano Creek	0	0	0	RC	Cerrado	P
		Lake Desdém	1	0	0	OL	Cerrado	P
		Porto Dam	1	0	0	D	Cerrado	P, M
		Pichuá Dam	1	0	0	D	Cerrado	
		Vale das Aroeiras Farm's Dam	1	0	0	D	Cerrado	P
		Lake Paracatu	1	0	0	OL	Cerrado	P
		Lake Intam	0	0	0	OL	Cerrado	R
		Lake Carboreto	1	0	0	OL	Cerrado	P
	São Francisco (MG)	São Francisco River	0	0	0	RC	Cerrado	P, U
		Lake Daniela	0	0	0	OL	Cerrado	P
		Lake Prata's Vereda	0	1	0	WET	Cerrado	P
		Lake Grande	1	0	0	OL	Cerrado	P, R, U
		Lake Piãozeiro	1	0	0	OL	Cerrado	P
		Lake Vaqueta	1	0	0	OL	Cerrado	P
	Januária (MG)	Lake Comprida	0	1	0	OL	Cerrado	P
		Pandeiros River	1	0	0	RC	Cerrado	P
		Mr. Pedro' Lake	1	0	0	OL	Cerrado	U
	Itacarambi (MG)	São Francisco River	0	0	0	RC	Cerrado	P, E, U
		Cauê Farm's Lake – 1	0	0	0	D	Cerrado	P, U
		Cauê Farm's Lake – 2	0	0	0	OL	Cerrado	P
		Jota Alves Farm' Lake	1	0	0	D	Cerrado	P, R,U
		Lake Jatobá	1	0	0	D	Cerrado	R, U
		Lake Azul	0	0	0	OL	Cerrado	R
		Olaria's Lake	0	1	0	D	Cerrado	P, M, R
	Pedras de Maria da Cruz (MG)	Cantagalo's Lake -1	0	1	0	D	Cerrado	P, R
		Cantagalo's Lake -2	1	0	0	D	Cerrado	P, M, U
	Manga (MG)	Lake Prata	0	0	0	OL	Cerrado	P
		Mata Seca Reserve's Lake – 2	0	1	0	WET	Cerrado	P, M, R

* Letters in the "Hydrography" column represent: D = Dam; OL = Oxbow lake; RC = River channels; WET = Wetlands. ** Letters in the "Human Impact" column represent: E = Erosion; M = Monoculture; P = Pasture; R = Roads; U = Urbanisation.

Table 2. Continued...

Site			Presence of caimans			Habitat		
Sub-region	**Municipality**	**Locality**	***Caiman latirostris***	**Eyes only**	**Interview**	**Hydrography***	**Vegetation**	**Human impact****
Medium	Guanambi (BA)	Highway BR-122	0	1	0	D	Caatinga	P, U, R
	Sítio do Mato (BA)	São Francisco/ Corrente River	1	0	0	RC	Caatinga	P, M, E
		Lake Araçá	0	1	0	D	Caatinga	P
		Lake Papa Cachorro	0	0	0	D	Caatinga	P
	Ibotirama (BA)	São Francisco River	0	0	0	RC	Caatinga	U, E
		Lake Comprida	1	0	0	OL	Caatinga	P
		Lake Serra – 1	1	0	0	OL	Caatinga	P, U
		Lake Serra – 2	0	0	0	OL	Caatinga	P
		Lake Serra – 3	1	0	0	OL	Caatinga	P
		Highway BR-242	0	1	0	OL	Caatinga	U, R
	Barra (BA)	Lake Piranhas	1	0	0	OL	Caatinga	M, R, E
		Lake Golfo	1	0	0	OL	Caatinga	M, R, E
		Grande River	0	0	0	RC	Caatinga	P, M, E, R
		Lake Timbó – 1	0	0	1	OL	Caatinga	P
		Lake Timbó – 2	0	0	1	OL	Caatinga	P
		Lake Lameiro	0	0	0	OL	Caatinga	P, M, U, E
		Afonso's Lake	0	0	0	OL	Caatinga	P
		Catú Ceek	0	0	0	RC	Caatinga	P, M, E, U, R
		Bonfim wetland	0	0	0	WET	Caatinga	P, M, E, U, R
		Tapera Creek	0	0	0	RC	Caatinga	
		Lake Peixe	0	0	0	OL	Caatinga	
Sub-Medium	Pilão Arcado (BA)	Poeirão	0	0	1	RC	Caatinga	E, U, R
		Passagem's Lakes	0	0	0	OL	Caatinga	P, M, U, R
	Remanso (BA)	Remanso Velho	0	0	0	RC	Caatinga	P, M, E, U, R
	Santa Maria da Boa Vista (PE)	São Francisco River	0	0	0	RC	Caatinga	U, R
		Lake Barra	0	0	0	OL	Caatinga	M, R
		Igarapé da Barra	1	0	0	OL	Caatinga	M, R
Low	Penedo (AL)	Lake Chaves	1	0	0	OL	Atlantic Forest	M, U, R
		Lake Uricuré – 1	1	0	0	OL	Atlantic Forest	P, M, E, U
		Lake Uricuré – 2	1	0	0	OL	Atlantic Forest	P
	Piaçabuçu (AL)	Pau-à-pique wetland	1	0	0	RC	Atlantic Forest	P, M, E, U, R
	Brejo Grande (SE)	São Francisco River	1	0	0	RC	Atlantic Forest	P, M, E, U, R
		Lake Capivara	1	0	0	OL	Atlantic Forest	P, M, E, R

* Letters in the "Hydrography" column represent: D = Dam; OL = Oxbow lake; RC = River channels; WET = Wetlands. ** Letters in the "Human Impact" column represent: E = Erosion; M = Monoculture; P = Pasture; R = Roads; U = Urbanisation.

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