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Effects of extreme drought in the dry season on an anuran community in the Bolivian Chiquitano region

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Abstract. This article describes a decline of amphibian populations in a study area in the Chiquitano region, Bolivia, as observed during acoustic surveys from 2005 to 2007. The total number of calling species in three survey nights per year changed from 14 in 2005, to 13 in 2006, and eight in 2007; average number of calling species in each survey night changed from 10 (2005), 8.7 (2006) to 6.3 (2007). Of the 13 species calling in 2006, 76.9% (n = 10) had lower call index values in 2007 or even had no calling activity at all. The results suggest a significant decline in the reproductively active local population in 2007. This decline is possibly related with a strong decrease of precipitation during the 2006 dry season, where 153 consecutive days without rainfall were recorded. The lack of humidity during the aestivation period in terrestrial habitats may have had a negative effect on the survival rate of the frogs. The study implies that the knowledge of abiotic environmental factors is an important need for conservation concerns and should be an aim of future research. Moreover, the impacts of frequent extreme weather events in the Chiquitano region on amphibian populations should be in focus of long-time studies to achieve a better understanding of the interrelations between climate and biodiversity.

Key words. Amphibia, aestivation period, Bolivia, surazo event, acoustic monitoring, population decline, climate variation, mortality.

Resumen. El presente artículo describe un declive en las poblaciones de anfibios en el área de estudio de la región de Chiquitano, Bolivia, observado durante muestreos auditivos desde el 2005 hasta el 2007. El número total de especies vocalizando en tres noches de muestreo varió entre 14 en el 2005, 13 en el 2006 y 8 en el 2007; el promedio de vocalizaciones en cada noche muestreada varió entre 10 (2005), 8.7 (2006) y 6.3 (2007). De las 13 especies que efectuaban vocalizaciones en el 2006, 76.9% (n = 10) tenían una actividad de canto menor en el 2007 o no cantaban en absoluto: Lo resultados sugieren un significante declive poblacional en el 2007. Este declive esta posiblemente relacionado con la fuerte reducción de las precipitaciones durante la estación seca del 2006, donde se reportaron 158 días consecutivos sin lluvia. La ausencia de humedad durante el período de estivación en hábitats terrestres ha podido repercutir negativamente en la supervivencia de las ranas. Este estudio implica que el conocimiento de factores medioambioentales abióticos es de importancia para la conservación y debería ser objeto de futura investigación. Adicionalmente, los impactos de los extremos eventos climáticos frecuentes en la región del Chiquitano en las poblaciones de anfibios deberían estar contemplados en estudios a largo plazo para poder tener un mejor entendimiento de las relaciones entre el clima y la biodiversidad.

Bolivia is a country with high biodiversity, and regarding amphibians, research efforts in the last decades led to the recognition of actually more than 250 species for this country. The Chiquitano region only recently turned out to be an example for an under-studied region of the Bolivian lowlands with respect to its herpetofauna (e.g., Jansen et al. 2007, Reichle 2007, Jansen 2008, Jansen & Köhler 2008, Jansen et al. 2009). Climatically, this region is frequently suffering from extreme weather events, such as drastic annual changes of total rainfall, differences in the duration of the dry respectively the rainy sea-

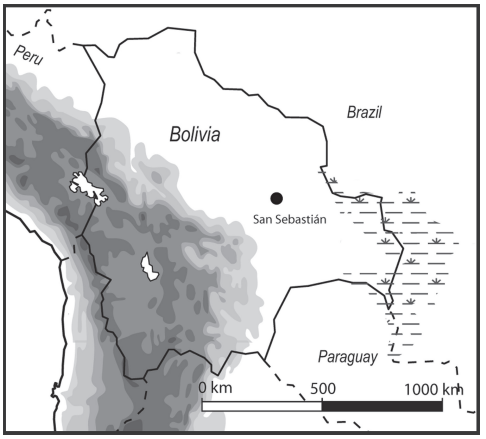

Fig. 1. Schematic map indicating the location of the study site San Sebastián in Bolivia (dot).

son, and an influence of cold southerly winds (surazos) (Ibisch & Mérida 2004). However, it is not known whether these strong weather fluctuations have effects on the amphibians of that region concerning behaviour, population size, structure and/or composition. During the rainy seasons of 2005 through 2007 the amphibian community of the San Sebastián study area was investigated using acoustic surveys (Schulze 2007, Schulze et al. 2009).

The Chiquitano region is located on the Precambrian shield in the eastern lowlands of Bolivia. The climate of this region can be characterized by annual average temperatures of 21-28 °C, three to eight dry months and an average of 600-2,300 mm annual rainfall. The study site was the cattle ranch San Sebastián (16°21.732' S, 62°00.135' W, 500 m a.s.l.), 24 km south of the town of Concepción, Province of Ñuflo de Chávez, Santa Cruz Department, Bolivia (Fig. 1). San Sebastián covers an area of 3.265 ha, and the landscape is characterized by a mosaic of various habitats: Chiquitano Dry Forest, Cerrado savannas, which are partially used as pasture, and nu-

Tab. 1. Frog species calling in the months of January and February in three survey nights in the years 2005, 2006 and 2007 at San Sebastián, Bolivia (no quantitative data available for 2005). x = calling; 0 = no calling activity, 1 = call of single individual, 2 = low calling activity, 3 = medium calling activity; 4 = high calling activity.

	Dendropsophus leucophyllatus	*Dendropsophus minutus*	*Dendropsophus nanus*	*Dendropsophus rubicundulus*	*Hypsiboas punctatus*	*Hypsiboas raniceps*	*Phyllomedusa hypochondrialis*	*Scinax fuscovarius*	*Scinax nasicus*	*Scinax nebulosus*	*Trachycephalus venulosus*	*Leptodactylus diptyx*	*Leptodactylus fuscus*	*Physalaemus albonotatus*	*Physalaemus centralis*	*Physalaemus cuvieri*	*Elachistocleis* sp.
18.2.2005	x	x	x	x	x	x		x	x	x			x	x	x		
21.2.2005	x		x		x	x		x		x				x			x
23.2.2005	x	x	x		x	x				x			x	x		x	x
27.1.2006	3		4	2	2				1	1	3		1		3		
27.2.2006	1		4		2	2	1			1						2	1
28.2.2006	1		4		2	3				2			1		2	2	2
5.2.2007	2		3		2					1		2			2	1	
6.2.2007	1		3		2					1						1	
7.2.2007	2		3		2				1	2					1	1	

Fig. 2. The study area in San Sebastián, Bolivia.

merous temporary wetlands, ponds and artificial lakes. Average annual precipitation in San Sebastián from 1998 to 2006 was 1223 mm/year. A more comprehensive description of the study area is given by Schulze et al. (2009). We analyzed survey data from a wetland near the main buildings of the cattle ranch (Area I in Schulze et al. 2009). This area is located in a depression, which is partially used as pasture and is partially flooded during September to October (Fig. 2).

In the study area acoustical surveys (AS) were performed from a fixed point in the wetland (Area I) to detect calling species. The site was chosen because of the high diversity and abundance of calling frogs and available water bodies for reproduction. Each year we analysed data of three survey nights (Tab. 1). During these surveys, the calling activity was measured using call indices (Heyer et al. 1994; Schulze et al. 2009) in the years 2006 and 2007. In a time frame of 10-15 minutes, calling intensities were estimated using the following categories: 0 = no calling activity, 1 = call of single individual, 2 = low calling activity (several divided calls), 3 = medium calling activity (several overlapping calls); 4 = high calling activity (full chorus). For the specific identification of calls we used Marquez et al. (2002), and De La Riva et al. (2000), applying the nomenclature of Faivovich et al. (2005), Frost et al. (2006) and Chapparo et al. (2007).

During the study period, 17 species were calling (Tab. 1). The total number of calling species in three survey nights per year varied from 14 in 2005, 13 in 2006, and 8 in 2007 (Tab. 3). The average number of species call-

Tab. 2. Annual amounts of rainfall at San Sebastián, Bolivia, from 1998 to 2006 in mm.

year	precipitation [mm]	% of annual average
1998	1466	119.8
1999	1217	99.5
2000	1140	93.5
2001	1505	123.0
2002	1246	101.8
2003	1007	82.3
2004	1216	99.4
2005	1167	95.4
2006	1052	86.0

Tab. 3. Distribution of average rainfall (in mm) during the dry seasons of 1998 to 2006 at San Sebastián, Bolivia.

year	May [mm]	June [mm]	July [mm]	August [mm]	September [mm]	average [mm]
1998	107	30	0	109	236	96.4
1999	28	30	10	0	56	24.8
2000	32	53	97	21	1	30.2
2001	63	6	30	0	111	42.0
2002	45	85	4	4	30	33.6
2003	25	30	10	0	50	23.0
2004	68	78	0	0	67	42.6
2005	63	61	17	41	70	50.4
2006	**12**	**0**	**0**	**0**	**10**	**4.4**
average	49.2	41.4	18.2	19.4	70.1	33.9

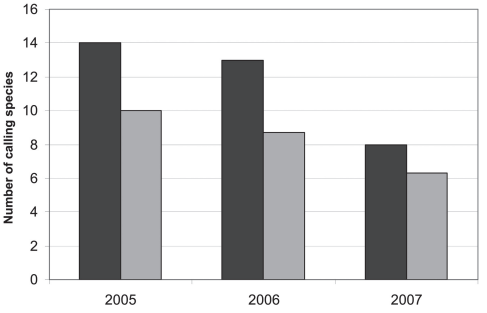

Fig. 3. Total number of frog species calling (black bars); and average number of calling species (grey bar) during three survey nights in 2005, 2006, and 2007, respectively.

ing ranged from 10 in 2005, 8.7 in 2006, and 6.3 in 2007. During the surveys in 2006 and 2007, 14 species were calling in total (Tab. 4). Of the 13 species calling in 2006, ten (76.9%) had a lower calling activity or were not calling at all in 2007 (six species, 46.2%). Only one species was calling in 2007 but not in the preceding year (*Leptodactylus diptyx*).

In addition to the data collected during the AS, the following observations were made during the entire rainy season 2006/2007: The characteristic call of *Leptodactylus labyrinthicus*, which was heard in all rainy season since 2000 (observation of L. Werding), could not be heard in 2006/2007, indicating absence of reproductive activity in that species. Furthermore, the abundant and frequently chorusing species *Physalaemus albonotatus* and *Eupemphix nattereri* were heard only sporadically or in small groups during the rainy season, and *Rhinella schneideri*, normally seen frequently near the main building, was only observed in a single individual in 2006/2007.

Thus, in the year 2007 a reduced calling activity was observed at San Sebastián suggesting a decline in reproductively active populations of amphibians. The extreme drought in the year 2006 might be responsible for that: for 2006 only 1052 mm rainfall was recorded, i.e. 14% below the average annual rainfall recorded between 1998 and 2006 (1223 mm/a, Tab. 2). Although the year 2003 was even drier, there were no indications of reduced amphibian calling activity in the following rainy season (observation of L. Werding). However, comparing the amount of rainfall in the months of the dry season (May to September) in 1998 to 2006, there was significantly less rainfall in the year 2006 (Tab. 3). Only 10 and 2 mm on 16 and 17 May, and 10 mm on 23 September was recorded in 2006, i.e. 153 consecutive days without rain, and only 13% of the average amount of monthly rainfall from May to September (4.4 mm vs. 33.9 mm).

The lack of rainfall probably had a negative effect on the survival of the frogs during

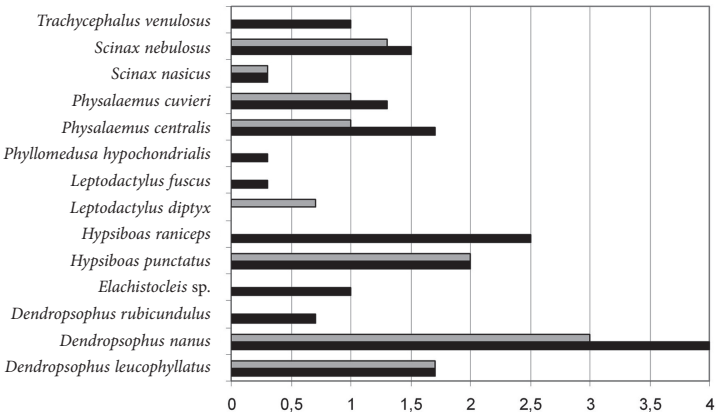

Fig. 4. Average calling activity of frogs during three survey nights at San Sebastián, Bolivia. 2006 (black bars) and 2007 (grey bars). Call indices: 0 = no calling activity, 1 = call of single individual, 2 = low calling activity, 3 = medium calling activity; 4 = high calling activity.

their aestivation period in terrestrial habitats. Unfortunately, only few data on the ecology of amphibians in the tropics during aestivation are available, although many amphibians spend a substantial period of their lifetime in fossorial habitats (e.g. Gibbons 2006, Pellet et al. 2006). A better knowledge of aestivation strategies and refuges of frogs during the dry season is an important prerequisite for conservation concerns, and further research should target these aspects for frogs worldwide (see as well Johnson 2003).

Also, further research in the Chiquitano region should focus on the questions, how the frog populations are actually influenced by the severe weather events, as observed during cold southerly winds in Peru (Doan 2004). For example, what combination of parameters during those extreme weather events prove lethal for the amphibians? Research on this topic would allow for evolutionary implications of paleo-climatic influences. Answers to these questions would be an important contribution for understanding the interrelation of climate and biodiversity (Carey & Alexander 2003), and furthermore would lead to a better understanding of possible consequences of climate change on amphibians.

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