SALAMANDRA 53(4) | 537–540 | 30 October 2017 | ISSN 0036–3375

Correspondence

Remarkable aggregation of squamates and caecilians associated with flood events during El Niño in southern Brazil

Ruth Anastasia Regnet[1], Fernando Marques Quintela[1], Omar Machado Entiauspe-Neto[1], Victor Hugo Teixeira[1], Franck Lira da Silveira[2] & Daniel Loebmann[1,2]

[1)] Universidade Federal do Rio Grande, Instituto de Ciências Biológicas, Laboratório de Vertebrados. Av. Itália km 8, CEP: 96203-900, Vila Carreiros, Rio Grande, Rio Grande do Sul, Brazil

[2)] Programa de Pós-graduação em Biologia Animal. Universidade Federal de Pelotas, Departamento de Zoologia e Genética. Campus Universitário s/n, CEP: 96010-900, P.O. Box 354, Capão do Leão, Rio Grande do Sul, Brazil

Corresponding author: Daniel Loebmann, e-mail: contato@danielloebmann.com

Manuscript received: 14 February 2017
Accepted: 23 March 2017 by Jörn Köhler

Animal congregation can be defined as "any concentration of individuals in a relatively small area in such a way that density of individuals in the aggregation contrasts sharply with that found in the surrounding area" (Gregory et al. 1987). For amphibians and reptiles, most aggregations occur occasionally and have been associated with high food availability (e.g., Arnold & Wassersug 1978), reproduction events (Arnold & Wassersug 1978, Ford & Bleness 1986, Graves & Duvall 1995), water availability (Graves et al. 1986, Reinert & Zappalorti 1988), thermoregulation (Graves et al. 1986), and defence (Graves 1989, Graves & Duvall 1988). However, massive reptile aggregations may also occur due to incidental circumstances. For example, a large number of snake individuals can be actively displaced by flood waters, resulting in their accumulation in a certain region (Lema 2002).

Effects of the El Niño Southern Oscillation (ENSO) on biota are poorly known, and so far, the phenomenon has, in principle, shown to negatively influence both aquatic and terrestrial life forms (Glantz 2001). In the extreme south of Brazil, El Niño events are associated with periods of increased rainfall (Grimm et al. 2000). Garcia et al. (2004) demonstrated that the ichthyofauna of the Patos Lagoon, the world's largest choked lagoon, located on the central coast of the state of Rio Grande do Sul, suffered several changes in its composition and abundance during two strong ENSO episodes (1982–1983 and 1997–1998). In October 2015, in the middle of the last ENSO event, the margins of the Patos Lagoon were severely flooded, prompting a massive movement and possible translocation of snakes, which are herein described.

This flood occurred after ten days of consecutive rainfall, which resulted in an accumulated precipitation of 174 mm/m² (according to the weather station of Pelotas), and amphibians, lizards and snakes in unusually large numbers were reported from the margins of the Patos Lagoon (Fig. 1), causing concern to most residents of these areas and alerting official authorities (Brazilian Law Enforcement and Wildlife Services). Amphibians and reptiles arrived at the beach once the rainfall elevated water levels of the Canal São Gonçalo, a waterway that connects the Patos and Mirim Lagoons, transporting a great volume of grass (*Typha* sp., predominantly), which accumulated in patches of vegetation along the shoreline (Fig. 1). In order to quantify this invasion, we conducted a survey along a transect of 1,000 m in linear length and 25 m of width, set up along the coast of Praia de Laranjal (31°46' S, 52°13' W, ca. 2 m above sea level), a tourist beach in the Patos Lagoon estuary, municipality of Pelotas, state of Rio Grande do Sul, Brazil. In total, five days of field collections were conducted. Voucher specimens were deposited in the Herpetological Collection of the Rio Grande Federal University (see Appendix). Specimens were euthanised with an intracelomatic injection of barbiturate at a lethal dosage of > 50 mg/kg.

During the five days of field collecting, a total of 2,013 snakes were captured, comprising five species: *Erythrolamprus jaegeri* (n = 2), *Erythrolamprus semiaureus* (n = 2), *Helicops infrataeniatus* (n = 2,002), *Philodryas patagoniensis* (n = 6), and *Thamnodynastes hypoconia* (n = 2). Surprisingly, most specimens (99.5 %) were the Pampean water snake, *Helicops infrataeniatus*. Individuals of *Chthonerpeton indistinctum* (Amphibia: Gymnophiona) (n = 99) and an undescribed species of *Ophiodes* (Squamata: Diploglossinae) (Entiauspe-Neto et al. 2017) (n = 40), were also encountered during the event. While the recorded snake species are common in the study area, the cryptic habits of *C. indistinctum* and *Ophiodes* sp. do not allow to determine whether these species are rare in nature or just hard to be sampled.

Reports of aggregations of snakes associated with flood events are poorly represented in the literature (e.g., Covacevich 1974, Lema 2002) and seem to be associated to ENSO events in southern South America,. Carreira et al. (2005) described the presence of snakes on the coast of Uruguay that had been rafted there by floating vegetation. In the Patos Lagoon, an instance of snake aggregation from 1941 was reported on by Lema (2002). Aside from current data, similar events were observed in the years of 1997/98 and 2004 (F. M. Quintela & D. Loebmann unpubl. data). All these aggregation events in southern Brazil occurred in ENSO years. The observed low species diversity within

Figure 1. Photographs of the event observed on Laranjal Beach, municipality of Pelotas, Rio Grande do Sul, Brazil. (A) Ventral views of captured individuals of *Helicops infrataeniatus*; (B) individuals of *Chthonerpeton indistinctum* found in rafts of vegetation on the shore; (C) allochthonous vegetation that accumulated on the beach after the flood event.

aggregations could be associated with certain habitat preferences, since the sampled species occur in estuarine lowlands and therefore might be more susceptible to flooding resulting from the ENSO. We assume that these aggregation events may occur recurrently and be strongly correlated with the ENSO phenomenon.

The occurrence of island species closely related to continental ones or even the presence of the same species in both environments is undoubtedly one of most exciting fields of biogeographic research worldwide. Dispersal by rafting on vegetation has been pointed out as an important mechanism to promote the introduction of pulses of continental fauna to islands (e.g., Nagy et al. 2003, Vences 2004, Ali & Huber 2010). However, there are few proven examples to support the hypothesis that viable populations of terrestrial vertebrates can be transported over water and settle in new environments. One of the most remarkable examples was reported by Censky et al. (1998), who described the simultaneous arrival of several individuals of *Iguana iguana* (Squamata: Iguanidae) on the beaches of the Caribbean island of Anguilla in the wake of a hurricane. In the past years, the use of molecular tools has provided insights into the mechanisms of island colonization as well as into the radiation of faunae, including examples involving amphibians (Vences et al. 2003, Measey et al. 2007, Stoelting et al. 2014), lizards (Mausfeld et al. 2002, Jesus et al. 2005a, b, Townsend et al. 2010) and snakes (Jesus et al. 2009). Our finding of a massive, naturally facilitated aggregation of amphibians and squamates on the shores of an estuary, accompanied by masses of plant materials, provide a piece of evidence for the extant probability of over-sea dispersal of animals surviving on rafts of vegetation. Colonization of new areas by amphibians and squamates (including fossorial forms) by such events appear more likely in view of our observations. They may occur naturally and recurrently, particularly in El Niño years.

Acknowledgements

We thank I. S. Vaz for the assistance in the field and with the transport of specimens. Rebeca Alves reviewed grammar and style of the manuscript. RAR is grateful to CAPES for providing a MSc Scholarship. Collection permits were authorized by ICMBio (proc. 43658).

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Appendix

Voucher numbers of examined specimens collected in the municipality of Pelotas, state of Rio Grande do Sul, Brazil

Chthonerpeton indistinctum (CHFURG 4054–4078, 4453–4468, 4700–4710); *Erythrolamprus jaegeri* (CHFURG 4692–4693); *Erythrolamprus semiaureus* (CHFURG 5574); *Helicops infrataeniatus* (CHFURG 3477–3512, 3514–3543, 3546–3557, 3558–3560, 3590–3752, 3754–3877, 3896–3979, 4018–4041, 4080–4108, 4109–4140, 4324–4370, 4640–4641); *Ophiodes* sp. (CHFURG 3564–3589); *Philodryas patagoniensis* (CHFURG 5508–5513); *Thamnodynastes hypoconia* (CHFURG 5526, 5575).