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ANURAN ASSEMBLAGES IN CRASTO FOREST PONDS (SERGIPE STATE, BRAZIL): COMPARATIVE STRUCTURE AND CALLING ACTIVITY PATTERNS

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Individual anuran species are often restricted to a particular aquatic habitat (Heyer *et al.*, 1975; Smith, 1983; Diaz-Paniagua, 1990; Gascon, 1991; Rossa-Feres & Jim, 1994; Zimmerman & Simberloff, 1996). The preference of a species for a particular type of breeding habitat must reflect differential fitness of that species in the various habitats available to it (Grubb, 1972). Abiotic and biotic factors may determine the use of specific kinds of aquatic habitats by frogs with larval stages (Heyer *et al.*, 1975). Hydroperiod is particularly important in determining the survival of larval amphibians because it governs not only the amount of time that larvae will have to complete metamorphosis but also the way in which competition and predation affect the composition and trophic interactions of the community (see references in Dodd, 1993; Rowe & Dunson, 1995).

Among anurans, the most common and phylogenetically widespread site of oviposition is in free water - standing or flowing, permanent or temporary. Aquatic eggs and tadpoles are characteristic of most hylids. On the other hand, the construction of a foam nest on the surface of the water in ponds is characteristic of most leptodactyline leptodactylids (Duellman & Trueb, 1986). Heyer *et al.* (1975) suggested that ponds susceptible to drying may be typical habitats for certain frog species, such as those in which the tadpoles are more resistant to desiccation. Foam nests provide protection against desiccation. In ponds in which the water level fluctuates, many foam nests may be out of water for a day or two, but the interior of the nest remains moist. Thus recently hatched tadpoles may remain in the nest for a short period until the water level rises (Duellman & Trueb, 1986).

The objective of the present study was to compare nocturnal anuran assemblages at two adjacent aquatic breeding sites with different hydroperiods. Comparisons include species composition, predominant habitat (arboreal versus terrestrial) occupied by each assemblage as a whole, calling activity patterns and reproductive modes.

The natural ponds studied are in Crasto Forest (11°20'S; 37°25'W), a large, contiguous tract of remnant Atlantic Forest in the State of Sergipe (Sta. Luzia do Itanhy), north-eastern Brazil. Gururema is a permanent pond (70 m maximum length and 1.8 m maximum depth) on the edge of the forest and is located approximately 1350 m from Mangueira Grande, a temporary pond (30 m maximum length and 0.8 m maximum depth) also situated on the edge of the forest. About half of the margins of both ponds is therefore surrounded by medium or large trees and shrubs (especially Leguminosae, Malpighiaceae, Myrtaceae, and Verbenaceae) whereas the other half is surrounded by low (Cyperaceae, Gramineae, and Verbenaceae) or no vegetation. Within the Gururema pond, near the western edge, occurs an "islet" formed by emergent macrophytes. *Utricularia inflata* (Lentibulariaceae) covers much of the remaining surface area (Souza & Couto, 1997). The permanent pond contained water for the duration of the study, but was shallow during the driest months. The temporary pond contained water only from 1 July 1994 to mid-November 1994.

Field work was carried out from 1 July 1994 until 31 July 1995. Heavy rains occurred from July-October 1994 (569.5 mm) and from April-July 1995 (904.4 mm), and the dry season occurred from November 1994-March 1995 (192 mm). Data were collected during two visits per month to the study area. Observations were made from 1700 to 2200 hr or later. Calling males were counted along the margins of the ponds, aurally and/or visually. Four frequencies of calling males per species were discerned: (1) up to 5 individuals; (2) 5 to 10 individuals; (3) 10 to 50 individuals; and (4) 50 or more synchronously calling males in the pond (based on Aichinger, 1987). Amplexus and oviposition sites were only recorded for some of the species in the study area (*Hyla minuta*, *Scinax eurydice*, *S.* gr. *rubra*, *S. x-signata*, *Physalaemus cuvieri* and *P. kroyeri*). Amplexus and oviposition sites of other species were observed in other study areas by Arzabe (1991), Arzabe & Almeida (1997) and Arzabe (unpublished manuscript). Details of the techniques used and special considerations were described by Scott & Woodward (1994). As no other research about the anurans of Sergipe State was known to us, and basic questions regarding the distribution and taxonomic data of Atlantic Forest frogs remain unresolved, adult voucher specimens were deposited in the Museu Nacional, Rio de Janeiro, and in the Departament of Biology, Universidade Federal de Sergipe.

A total of 17 species belonging to three families (Hylidae, Leptodactylidae, and Microhylidae) were recorded calling. Eleven species were found at each breeding site (see Table 1). Five species occurred at both the permanent and temporary ponds: *Hyla branneri*, *H. minuta*, *Scinax eurydice*, *S.* gr. *rubra*, and *Scinax x-signata*.

Most species in herpetofaunal assemblages in Neotropical rainforests can be categorized as terrestrial

TABLE 1. Calling patterns, maximum number of synchronously calling males per species, reproductive modes, monthly rainfall (mm), water supply and number of species calling each month in the temporary and in the permanent ponds at Crasto Forest, from 1 July 1994 to 31 July 1995. No. males: maximum number of synchronously calling males during the study period; Rep. mode: reproductive mode according to Duellman & Trueb (1986).

SPECIES	NO. MALES	REP. MODE	MONTHS												
			J	A	S	O	N	D	J	F	M	A	M	J	J
TEMPORARY POND:															
Hyla minuta	>50	1	+	+	+	+	-	-	-	-	-	-	-	-	-
Scinax gr. *rubra*	10-50	1	+	+	+	+	-	-	-	-	-	-	-	-	-
Hyla branneri	>50	1	-	+	+	+	-	-	-	-	-	-	-	-	-
Scinax x-signata	10-50	1	+	-	+	-	-	-	-	-	-	-	-	-	-
Physalaemus kroyeri	10-50	8	+	-	+	-	-	-	-	-	-	-	-	-	-
Physalaemus cuvieri	10-50	8	+	-	-	-	+	-	-	-	-	-	-	-	-
Scinax eurydice	10-50	1	+	-	-	-	-	-	-	-	-	-	-	-	-
Leptodactylus labyrinthicus	≤5	21	+	-	-	-	-	-	-	-	-	-	-	-	-
Pseudopaludicola gr. *falcipes*	>50	1	+	-	-	-	-	-	-	-	-	-	-	-	-
Leptodactylus troglodytes	10-50	21	+	-	-	-	-	-	-	-	-	+	+	-	-
Leptodactylus spixii	10-50	21	-	-	-	-	-	-	-	-	-	+	+	+	-
PERMANENT POND:															
Hyla albomarginata	5-10	1	+	+	+	+	+	+	+	+	+	+	+	+	+
Hyla branneri	>50	1	+	+	+	+	+	+	+	+	+	+	+	+	+
Hyla faber	5-10	3	+	+	+	+	+	+	+	+	+	+	+	+	+
Hyla minuta	>50	1	+	+	+	+	+	+	+	+	+	+	+	+	+
Scinax gr. *rubra*	>50	1	+	+	+	+	+	+	+	+	+	-	+	+	+
Scinax x-signata	10-50	1	+	+	-	-	+	-	-	-	+	+	+	+	+
Hyla elegans	10-50	1	+	+	+	+	-	-	-	-	-	+	+	-	-
Scinax eurydice	>50	1	+	+	+	-	-	-	-	-	-	-	+	+	+
Scinax cf. *aurata*	≤5	1	+	+	+	+	-	-	-	-	-	-	-	-	-
Leptodactylus macrosternum	10-50	8	-	-	-	-	-	-	-	-	-	+	-	-	-
Dermatonotus muelleri	≤5	1	-	-	-	-	-	-	-	-	-	-	+	-	-
Rainfall (mm)			307	49	131	82	9	45	19	72	47	356	189	157	202
Temporary pond: water supply			+	+	+	+	+	-	-	-	-	-	-	-	-
Temporary pond: species calling			9	3	5	3	1	0	0	0	0	2	2	1	0
Permanent pond: water supply			+	+	+	+	+	+	+	+	+	+	+	+	+
Permanent pond: species calling			9	9	8	7	6	5	5	5	6	7	9	7	7

(including fossorial, leaf litter, and aquatic margin) or arboreal (bushes, tree trunks, and tree limbs) (Duellman, 1990). Among the anurans recorded in this study, nine are arboreal (hylids) and eight are terrestrial (leptodactylids and one microhylid). At the temporary pond we recorded terrestrial (*n*=6) and arboreal species (*n*=5) in almost equal proportions whereas in the permanent pond arboreal species (*n*=9) predominated. In the temporary pond calling activity was markedly seasonal, whereas in the permanent pond arboreal species such as *Hyla albomarginata, H. branneri, H. faber*, and *H. minuta* showed annual calling activity patterns (Table 1), with few calling males during the driest months. The annual calling activity pattern observed in the permanent pond probably resulted from the interrelationship between water supply and the potential of the arboreal environment (occupied by the majority of the species) to ameliorate the harsh effects of the wet-dry climate. Calling in frogs does not necessarily mean breeding (see Scott & Woodward, 1994), and observations of more explicit indicators, such as amplexus, egg masses or larvae, are needed to confirm annual reproductive activity.

Four reproductive modes (according to Duellman & Trueb, 1986) were associated with the species observed (see Table 1). Egg-deposition and larval development directly in water were characteristic of the majority of the anurans recorded in the permanent pond, whereas eggs in foam nests were characteristic of approximately 50% of the species observed in the temporary pond (*Leptodactylus labyrinthicus*, *L. spixii*, *L. troglodytes*, *Physalaemus cuvieri*, and *P. kroyeri*). Eggs and tadpoles in foam nests are protected during frequent filling/drying cycles of temporary ponds (see Heyer, 1969). On the other hand, the unstable hydroperiod of these breeding sites, especially during the critical first rains, is a limiting factor restricting the presence of species that deposit their eggs directly in water. Alternatively, these species may breed in these habitats during heavy and continuous rains or when these sites fill with rainwater and resemble permanent habitats (see Aichinger, 1987; Gascon, 1991).

The hydroperiod of temporary ponds is highly variable, depending upon elevation, basin characteristics, and rainfall patterns (Means, 1990). Some ponds may fill and dry on an annual basis whereas others may contain water only in the wettest years (see LaClaire, 1995). Therefore, frogs may not breed in a specific pond every year. During the heavy rains in 1994 when the temporary pond was filled with water, we recorded up to nine synchronously calling species at each breeding site. On the other hand, during the heavy rains in 1995, the temporary pond remained without water and only two leptodactylids, both with terrestrial foam nests (see Arzabe & Almeida, 1997), were heard calling. In contrast to the temporary pond, the permanent pond once again had up to nine species calling synchronously (Table 1).

Our results showed that the composition, reproductive modes, and calling activity patterns differed among the two anuran assemblages and we suggest that these differences are particularly associated with the different annual hydrological cycles of the breeding sites. As suggested for wetland plant communities (Mitsch & Gosselink, 1986 in LaClaire, 1995), hydroperiod may be the major factor influencing and maintaining assemblages of anurans in temporary ponds.

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