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Anuran amphibians of Borneo as phytotelm-breeders – a synopsis

Anuren Borneos als Phytotelmenbrüter – eine Übersicht

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KURZFASSUNG

Wir geben eine Übersicht über die phytotelmenbrütenden Anuren aus Borneo. Außer den sich direkt entwickelnden Kaulquappen von *Philautus* wurden bisher auch Larven von elf Froscharten mit freischwimmenden Kaulquappen in Phytotelmen nachgewiesen. Beobachtungen an weiteren Arten deuten darauf hin, daß die Zahl der Phytotelmenbrüter noch höher sein könnte.

ABSTRACT

We provide an overview of the phytotelm-breeding anurans from Borneo. Besides the direct-developing tadpoles of *Philautus*, also the larvae of eleven frog species with free-swimming tadpoles have been recorded in phytotelms so far. Observations on additional species indicate that the number of phytotelm-breeders might be still higher.

KEY WORDS

Amphibia: Anura; phytotelm-breeding, tadpoles, larvae, ecology, Borneo

INTRODUCTION

THIENEMANN (1934) defined phytotelms as "periodic bodies of water resulted from accumulation of atmospheric precipitation or from secretion of fluids by the plant itself, in or on plants or parts of plants that are either living or about to die".

Miniature water bodies of that kind are widespread in lowland and montane rain forests of Borneo. They are found in chlorophyll containing (e.g. leaf axils of *Pandanus*, *Colocasia*, *Musa*, *Asplenium*) and lignified (cavities in tree trunks, branches, and lianas, buttress tanks, bamboo internodes) parts of living plants as well as in their dead remains (empty fruit capsules, large, curved, fallen leaves, senescent *Nepenthes* pitchers, stumps of bamboo and tree ferns, water accumulations in logs) (see also INGER 1985; MALKMUS et al. 2002). Phytotelms are extreme aquatic habitats, characterized by their relatively small size, isolated location, often limited food availability, and, in some cases, unpredictable continuance.

A special kind of phytotelm is the pitcher-like insect trap of the carnivorous genus *Nepenthes*. The opening of the pitcher is covered by a shield to prevent the digestive fluid, which is produced in these receptacles, becoming diluted by rain. Only in the ground pitchers of *Nepenthes ampullaria*, this shield is peculiarly folded back and has thus lost its sheltering function. As a result, the concentration of the digestive fluid of this species is weakened to such an extent that anuran larvae are able to develop in its pitchers. Senescent pitchers, that are permeable to water, are used by species of the genus *Philautus* as spawning depots (MALKMUS 2001). Because the known larvae of the Bornean species of *Philautus* completely develop within the jelly capsule of the egg, the eggs do not need to be stored in water. The pitchers serve as protecting containers, which guarantee a humid environment through contact with the wet ground. Up to now, eggs of *Philautus mjobergi* SMITH, 1925, *P. kerangae* DRING, 1987, and *P. saueri* MALKMUS & RIEDE, 1996 have been found in such pitchers (SMITH 1925; DRING 1987; MALKMUS 1995, 2001; MALKMUS & RIEDE 1996). *Philautus kerangae* deposits its eggs also in the fluid of semi-senescent pitchers

Figs. 1 & 2: *Philautus kerangae* DRING, 1987 deposits eggs in pitchers of *Nepenthes ampullaria* and *N. bicalcarata*. Photographs: J. M. DEHLING.

Abb. 1 & 2: *Philautus kerangae* DRING, 1987 legt die Eier in Kannen von *Nepenthes ampullaria* und *N. bicalcarata* ab. Fotos: J. M. DEHLING.

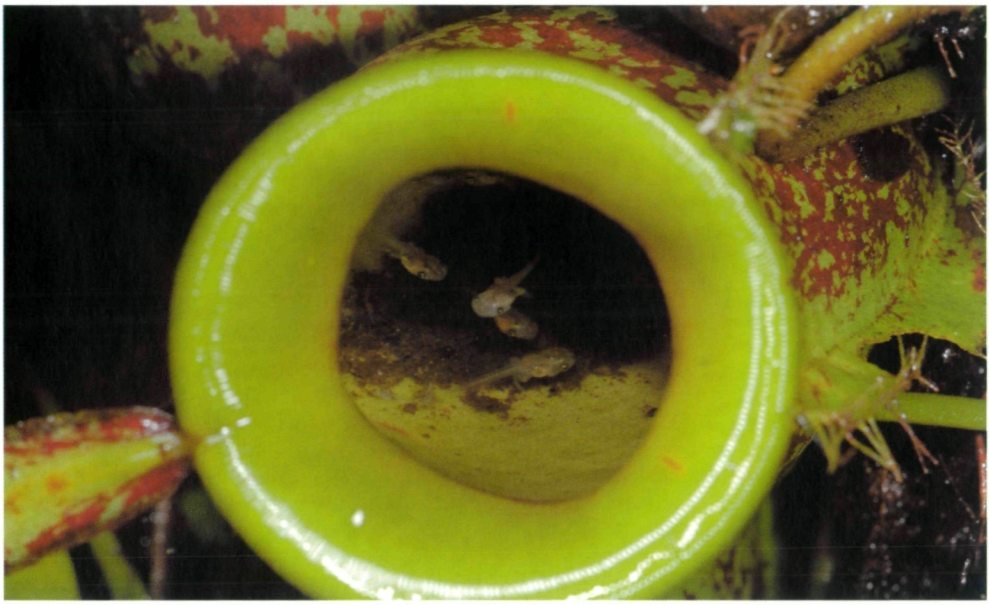


Fig. 3: Tadpoles of an undescribed species of *Microhyla* develop in the digestive fluid of the pitchers of *Nepenthes ampullaria* and *N. bicalcarata*. Photograph: J. M. DEHLING.

Abb. 3: Die Larven einer unbeschriebenen *Microhyla* Art entwickeln sich in der Verdauungsflüssigkeit der Kannen von *Nepenthes ampullaria* und *N. bicalcarata*. Foto: J. M. DEHLING.

Fig. 4: Male *Metaphrynella sundana* (PETERS, 1867) calling from a water-filled bamboo internode. Photograph: J. M. DEHLING.

Abb. 4: Männchen von *Metaphrynella sundana* (PETERS, 1867) aus dem wassergefüllten Internodium eines Bambushalmes rufend. Foto: J. M. DEHLING.

of *Nepenthes bicalcarata* (DRING 1987) and of digestively acitve pitchers of *N. ampullaria* (DEHLING, unpubl.; Figs. 1, 2). In the digestively active pitchers of all other *Nepenthes* species, larvae or spawn of amphibians had not been found so far, but recently, larvae of an yet undescribed *Microhyla* species were found in pitchers of *N. bicalcarata* (DEHLING, unpubl.).

LEHTINEN et al. (2004) reviewed phytotelm-breeding in anurans worldwide. However, concerning the Bornean species their list was incomplete. From the available literature, our own investigations, and information obtained from colleagues, we therefore aim to provide an overview of the phytotelm-breeding anurans of Borneo with free-swimming tadpoles.

SPECIES ACCOUNT

Bufonidae

Pelophryne api DRING, 1984: "Eggs are probably deposited in water collected in solution holes, hollowed dead leaves, logs, or senescent *Nepenthes* pitchers" (DRING 1984). So far, a concordant confirmation is lacking.

Pelophryne brevipes (PETERS, 1867): DENZER (1994a, 1994b) found an adult pair and tadpoles in a tree hole (depth 10-12 cm; diameter 6 cm) 1.5 m above the ground in the lowlands of Mt. Santubong/Sarawak (100 m elev.). On Mindanao in the southeastern Philippines, tadpoles were found in leaf axils of *Pandanus* 3-5 m above the ground (ALCALA & BROWN 1982). [Note: According to FROST (2007), the form found on Borneo is *P. signata* (BOULENGER, 1895), whereas the Philippine form is *P. brevipes*.]

Pelophryne misera (MOCQUARD, 1890): According to INGER & STUEBING (1992) this species "reproduces in water-filled leaf-cups of high altitude pitcher plants". Tadpoles were also found "in a depression of a large dead leaf" in the valley of Sg. Liwago/Mt. Kinabalu, 1500 m elev. (MALKMUS 1996a, 1996b; MALKMUS et al. 2002).

Microhylidae

Chaperina fusca MOCQUARD, 1892: Larvae were found "in holes in a log" (INGER 1966, 1985), in "open, water-filled bamboo internodes" (HOFFMANN 1995), and "in a buttress tank" ("surface area 20 x 30 cm, depth 25 cm, 1 m above the ground", locality: Sayap/Mt. Kinabalu; MALKMUS et al. 2002). ROZKOŠNÝ & KOVAC (1994) likewise found tadpoles in bamboo (*Gigantochloa levis*) internodes filled with rainwater (surface 10 cm x 40 cm, locality: near Poring/Mt. Kinabalu).

Kalophrynus eok DAS & HAAS, 2003: The holotype, a male, was found calling from a water-filled node of a fallen bamboo; locality: Long Re, east of Bario/Sarawak, 1050 m elev. (DAS & HAAS 2003). Because neither females nor tadpoles of this species have been found so far (the holotype is the only specimen known), the reproduction mode of this species remains unknown.

Kalophrynus pleurostigma TSCHUDI, 1838: INGER (1985) reported "larvae in a hole in a log", KOVAC (1998) "larvae in a bamboo internode lying on the ground", MALKMUS et al. (2002) "larvae in holes in logs and road ruts filled with rainwater".

On peninsular Malaysia (Bukit Timah), tadpoles were found in cups of *Nepenthes ampullaria* (LIM & NG 1991).

Metaphrynella sundana (PETERS, 1867) (Fig. 4): This species had very early been considered a tree hole breeder – though without a proof of reproduction (BOULENGER 1912; INGER 1966; WASSERSUG et al. 1981; INGER & STUEBING 1989; MALKMUS 1992, 1994). Only recently, reproduction was observed in the Poring region (Sabah, 500-700 m elev.) (HOFFMANN 2000; LARDNER & LAKIM 2004).

Microhyla borneensis PARKER, 1928: PARKER (1934) assigned larvae that he found in a *Nepenthes* pitcher to this species. Locality: near Kuching/Sarawak. INGER (1966), however, identified these larvae as belonging to a *Kalophrynus* species.

Microhyla sp.: Recently, eggs and tadpoles of a yet undescribed species of *Microhyla* were found in digestively acitive pitchers of *Nepenthes ampullaria* and *N. bicalcarata* in Gunung Mulu National Park, Sa-

rawak (DEHLING, unpubl.; Fig. 3). Tadpoles of the same species were also found in water-containing rock cuvettes in the karst of the Melinau limestone in the same area (A. HAAS, pers. comm.; DEHLING, unpubl.).

Ranidae

Limnonectes palavanensis (BOULENGER, 1894): "Tadpoles in a water-filled hole in a fallen tree" (INGER 1985). "Tadpoles in a low, shallow buttress tank and in a water-filled hole in a log" (INGER et al. 1986).

Rhacophoridae

Nyctixalus pictus (PETERS, 1871): INGER (1966): "Two sets of eggs were found on the walls of water-containing tree holes 5-10 cm above the water. [...] The tree holes were 1.3-2.6 m. above the ground". INGER (1985): "water-containing holes in tree trunks and logs". INGER & STUEBING (1989): "trunk diameters 30 cm". MALKMUS (1992) reported a set of 7 eggs on the wall of a water-containing hole (surface 30 cm x 80 cm, depth 15 cm) in a log, 3-5 cm above the water; locality: Liwago trail/Mt. Kinabalu (1750 m elev.). INGER & STUEBING (2005): "once we found tadpoles in a rotting hollow fruit that contained water". MALKMUS et al. (2002): "eggs hanging on the walls of water-filled tree holes 1-1.6 m above the ground, and in large empty fruit casks 3-10 cm above the water level."

Polypedates macrotis (BOULENGER, 1891): INGER (1985) took a tadpole "from a pool in a large stump".

Rhacophorus harrissoni INGER & HAILE, 1959: INGER (1985): Tadpoles in "water tanks formed by anastomosing buttresses", "holes in trunks", and "holes in large surface roots" ("only 15 cm above the ground"); "0.75-3.6 m high, and surfaces 8 x 10 to 30 x 50 cm". INGER & STUEBING (1989): "holes in large trunks, formed by the fused buttresses of giant mengaris trees (*Koompassia excelsa*)" (Fig. 6). MALKMUS et al. (2002): "Foam nests are attached to the bark above water-filled tree holes, tree trunks, or tanks formed by anastomosing buttresses, 1-4 m above the ground" (Fig. 5); locality: near Poring/Mt. Kinabalu (600 m elev.).

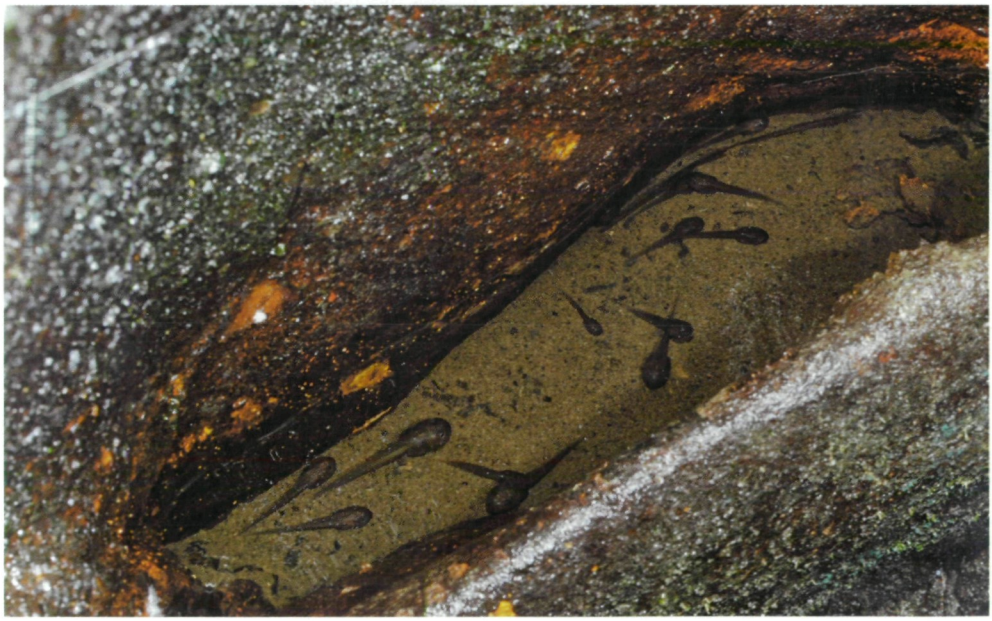
Theloderma horridum (BOULENGER, 1903): "Tadpoles were found in a water-containing tree hole about 1.5 metres above the ground" [in a lowland rain forest] (INGER & STUEBING 2005).

DISCUSSION

The earliest report referring to phytotelms as reproduction sites of Bornean anurans was made by the Italian botanist BECCARI (1904): On the summit of Mt. Santubong near Kuching/Sarawak he discovered in a pitcher of *Nepenthes veitchii* "a mass of frog spawn", presumably eggs of a *Philautus* species. The occurrence of anuran larvae in phytotelms is mentioned for the first time by PARKER (1934): Near Kuching he found "larvae of *Microhyla borneensis*" in a pitcher of a *Nepenthes* species. However, INGER (1966) assigned these larvae to the genus *Kalophrynus*.

Currently, 154 anuran species are known from Borneo (SUKUMARAN et al. 2006). They belong to six families: Bombinatoridae (1), Bufonidae (31), Megophryidae (21), Microhylidae (21), Ranidae (41), and Rhacophoridae (39). The 17 species of *Philautus* are direct developers; hence 137 species with free-swimming tadpoles occur on Borneo. The larvae of only 10 of these species (7.3%) and of an additional undescribed one from four families have been recorded in phytotelms for certain so far: *Pelophryne brevipes*, *P. misera*, *Chaperina fusca*, *Kalophrynus pleurostigma*, *Metaphrynella sundana*, *Microhyla* sp., *Limnonectes palavanensis*, *Nyctixalus pictus*, *Polypedates macrotis*, *Rhacophorus harrissoni*, and *Theloderma horridum*. Exotrophic are the larvae of *Chaperina*, *Metaphrynella*, *Microhyla*, *Limnonectes*, *Nyctixalus*, *Polypedates*, *Rhacophorus*, and *Theloderma*, endotrophic those of *Pelophryne* and *Kalophrynus*.

One has to bear in mind that almost no investigations have been conducted regarding larval occurrence in phytotelms in heights > 4 m above the ground and that even in the lower stratum of the forest the



Figs. 5 & 6: *Rhacophorus harrissoni* INGER & HAILE, 1959 attaches foam nests to the bark above water tanks formed by anastomosing buttresses (top). Later, emerging tadpoles drop into the tanks (bottom). Photographs: J. M. DEHLING.

Abb. 5 & 6: *Rhacophorus harrissoni* INGER & HAILE, 1959 befestigt sein Schaumnest an Rinde über Wasserbehältern, die von anastomosierenden Brettwurzeln gebildet werden (oben). Später fallen die schlüpfenden Larven in die Wasserbehälter (unten). Fotos: J. M. DEHLING.

circumstances are only insufficiently known. Numerous additional species can be considered potential phytotelm-breeders: Bufonidae: *Pelophryne* – *P. api* DRING, 1984, *P. exigua* (BOETTGER, 1900), *P. guentheri* (BOULENGER, 1882), *P. macrotis* (BOULENGER, 1895), *P. rhopophilia* INGER & STUEBING, 1996, *P. signata* (BOULENGER, 1895); Microhylidae: *Kalophrynus* – *K. baluensis* KIEW, 1984, *K. eok* DAS & HAAS, 2003, *K. heterochirus* BOULENGER, 1900, *K. intermedius* INGER, 1966, *K. nubicola* DRING, 1984, *K. punctatus* PETERS, 1871, *K. subterrestris* INGER, 1966, *Microhyla* (possibly several other species); Rhacophoridae: *Rhacophorus* (possibly several other species).

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