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Reproduction and paternal care in the Asian bird poop frog, *Theloderma albopunctatum* (Liu and Hu, 1962)

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Knowledge on the natural history, behaviour and reproductive biology of many amphibians is still completely lacking. To collect such data, it is necessary to stay in the field and observe individuals over a long time period. This is a difficult task, as many species show certain behaviours only under specific conditions and at certain seasonal periods. Further, many species are small, inconspicuous and/or occupy hardly accessible habitats like the canopy or crevices. Collecting data on a species' biology is thus time-consuming and costly, if not impossible, in free living populations.

The herpetofauna of South-East Asia has gained enormous interest of researchers from all over the world resulting in the description of many new species in the last decades, while only a few studies had their focus on the ecology of the herpetofaunal community (Galoyan et al., 2017). Members of the rhacophorid genus *Theloderma* Tschudi, 1838 (known as warty tree frogs, bug-eyed frogs or mossy frogs) are arboreal frogs of a size of three to six centimetres, distributed from East India eastwards to South China and southwards to Borneo and Sumatra (Frost, 2019). The little knowledge on life history traits of *Theloderma* in the wild is based on few observations only (Li et al., 2016; Wassersug et al., 1981). In general mossy frogs occupy tree or bamboo holes filled with water in primary and secondary forests, but they were also observed in man-made water bodies in cultivated areas (Leong and Lim, 2003). The clutches of about half a dozen eggs are laid a few centimetres above the water surface and the tadpoles fall into the water after hatching (Kunz et al., 2010). Observations on behavioural data in context with the reproduction biology are only known from amateur herpetologists and hobbyists rearing mossy frogs at home (e.g. Arinin and Ryabov, 2006; Bagaturov, 2011; Kunz et al., 2010; Ryboltovsky, 2016; Tapley, 2009).

Motivated hobbyists with an interest in amphibians and reptiles are an important source for data on natural history traits and reproductive behaviour and can provide valuable information for ex-situ conservation (Michaels et al., 2014). Behavioural observation and collection of data on life history traits is much easier when the animals are kept as close to their natural conditions as possible, because artificial conditions might have substantial influence on a species' behaviour (e.g. Burghardt, 2013; Warwick, 1990). Here, I provide new observations on reproductive behaviour and data on life history traits of *T. albopunctatum* (Liu and Hu, 1962) kept in captivity.

Five individuals, four males and one female, of captive breed *T. albopunctatum* were received in August 2016. They were of an approximate age of three months after metamorphosis. The parental individuals had been imported from Vietnam in 2014. The group was kept in a tank of 40x25x30 cm, the bottom completely flooded with three to five cm water with low hardness. To maintain water quality, a third to half of the water volume was exchanged once a week. Further, alder cones and catappa leaves were used to introduce tannins to the water in order to prevent the growth of fungi and to simulate the natural state of an arboreal water pond. Pieces of oak bark and a small plant e.g. *Peperomia* sp. or *Ficus pumila* accomplished the furniture. A UV-emitting light source was set to a cycle of 12:12 hours of daylight to night. No additional heating was provided. Air temperature ranged between a minimum of 18°C at night up to 25°C, rarely to 28°C during the summer month, at daytime. Water temperature ranged around 21 to 23°C. As food various insects e.g. crickets, drosophila

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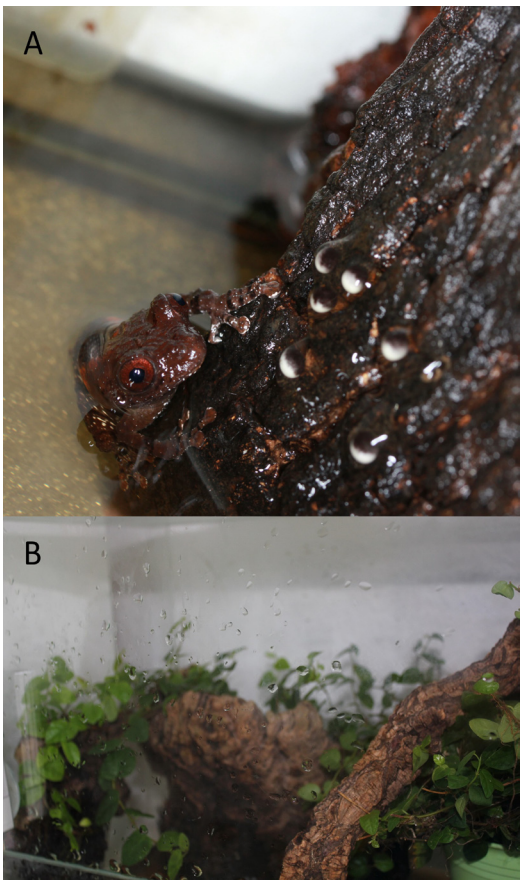

Figure 1. (A) Captive *Theloderma albopunctatum* male sitting under its clutch and (B) terrarium where the frogs were kept showing water splashed front during reproduction.

and cockroaches were provided every second to third day, enriched with supplements (Herpetal) to increase the nutritional value of the insects.

At an approximate age of five to six months after metamorphosis, males began to vocalize. The first egg clutch was observed when the animals were approximately six months old. During a period of 13 months, the female produced 38 egg clutches each containing two to seven eggs (mean 3.6). The clutches were laid regularly at intervals of four to 16 days (mean 8.3; n = 30). Clutches were deposited year-round but once a longer interval of about one month between the depositions of two consecutive clutches was observed. The eggs were attached to horizontal or slightly overhanging bark pieces a few millimetres to centimetres above the water surface. The amplectant pairs regularly splashed water around with the hind limbs, possibly to moisten the substrate they intended to attach the eggs to. After oviposition, males were observed in the water directly below the clutch splashing water with the hind limbs onto the eggs (Fig.1, video available on https://www.youtube.com/watch?v=_QkRmEv-hY4). The splashing of the eggs was repeated after a few minutes and also observed on the following day (although it is unclear if it was continued during the whole 24 hours).The identity of the splashing male could be revealed as the potential father of the eggs through comparison with photos of the amplectant pair taken the day before. These observations suggest that in *T. albopunctatum*, and possibly other mossy frogs, males provide paternal care to their clutches under certain conditions until some days after deposition of the eggs. Clutch-splashing behaviour was observed during heat periods in July 2017 and June-July 2018, when the temperature in the tank reached about 27 to 28°C. Water splashing was also observed regularly before and after egg deposition. I hypothesize that high temperatures and fast evaporation, representing a high threat to the eggs that are laid above the water body, were probably the environmental cues that elicited the male's observed behaviour. Future observations and an experimental induction of this behaviour is necessary to better understand its function and need, and if males can distinguish their own clutches from others. This is the first time that paternal care after egg deposition was observed in a rhacophorid frog species. This observation provides new evidence for the diversity of breeding behaviour in anurans and more novel findings are expected in the future (e.g. Gururaja et al., 2014). Rhacophorid frogs have developed diverse reproductive modes from aquatic breeding with a larval stage in basal taxa (*Liuixalus, Buergeria*) to terrestrial direct development in derived taxa (*Philautus, Raorchestes, Pseudophilautus*) (Meegaskumbura et al., 2015). An intermediate foam-nest-building form represent genera like *Chiromantis* and *Rhacophorus* (Coe, 1974; Dunce, 2016; Ryboltovsky, 2016). The foam nest is produced by scrubbing the hind limbs while excreting secretion (Ryboltovsky, 2016). The behaviour of water splashing in *Theloderma* might be a plesiomorphic trait within the Rhacophoridae, while in other genera such as *Rhacophorus* and *Chiromantis* this behaviour became more complex, leading to the evolution of foam nest builders (Grosjean et al., 2008; Meegaskumbura et al., 2015). For a better understanding of the evolution of this reproductive behaviour, it is of interest whether the

sister taxon of *Theloderma*, *Nyctixalus,* and further, the more basal genera *Liuixalus* and *Buergeria*, show any kind of such behaviour connected to reproduction.

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