



Mossy frogs

(*Theleoderma spp.*)



Only recently discovered - Khoi's mossy frog (*Theleoderma khoii*). Phot. T. T. Nguyen



General Introduction

Vietnam belongs to the global hotspots of biodiversity and is a megadiverse country. Regularly new species discoveries are reported from that country. Recently, in a review article about conservation gaps in amphibians from Vietnam published in the Journal Nature Conservation in the year 2022, a list of 275 amphibian species known from this country was provided. The actual number now certainly is higher, given the constantly growing number of amphibian descriptions. Of the 275 amphibian species recognized in the article from 2022, 95 (35%) were revealed to be endemic to the country, with more than half of them reported exclusively from a single locality, which makes them especially vulnerable to extinction. Vietnam's Central Highlands were identified as the region with the highest species diversity (130 species), the most regionally endemic species (26 of total 67 regionally endemic species), and the most species classified as threatened by the IUCN Red List (11 species), which highlights it as a site of particular amphibian conservation concern.

In terms of threat status, 50 of the 275 species recorded in 2022 from Vietnam (18%) were classified by IUCN as threatened with extinction. These included 27 endemic species. Most of them were frogs, followed by salamanders, where 60% of the listed species were classified as threatened with extinction. Alarmingly, 13 endemic species, including two threatened species, have been recorded exclusively from unprotected areas. For two-thirds of Vietnam's endemic amphibians, there is no conservation data available, as their IUCN Red List status is either missing or outdated. According to data from the Zoological Information Management System, 29 (11%) of the total 275 species reported to occur in Vietnam are represented in global zoos, including five threatened species, with the highest diversity concentrated in zoos in Europe and North America.

These facts revealed for the first time some obvious gaps in conservation. Importantly, they will provide a directory to authorities, conservationists, rescue centers/centres, and zoos, so that they can follow up with appropriate actions. In particular, the conservation of microendemic species can only be addressed by



organizations, NGOs or partner institutes on-site, for example in the form of field work, regulatory support or protected area establishment. Where species are at risk of disappearing rapidly, for example, species with a very limited distribution range, the establishment of ex-situ programs by local partners in cooperation with international zoos could help, in addition to in-situ conservation measures as part of the IUCN's One Plan Approach to Conservation, which combines in-situ and ex-situ efforts and various expertise for the optimum protection of a species.

Mossy frogs of the genus *Theleoderma*, that also belong to these frog groups with a high rate of new discoveries but also threat potential, need our support. The species *T. ryabovi* is one of the two threatened endemic species that have been recorded exclusively from unprotected areas. Vietnam also has more *Theleoderma* species than any other country; a total of 16 species have been recorded to date, and the current species' richness of the genus remains (still) underestimated.

Biology

The genus *Theleoderma* Tschudi, 1838 is a poorly known group of tree frogs in the family Rhacophoridae due to their cryptic habits and because they are infrequently encountered. Their common names are bug-eyed frogs, warty frogs or mossy frogs. Some species are contrastingly marked, but most are very well-camouflaged, resembling plant material (typically bark or moss) or bird droppings. The name "mossy frog" arises from the fact that in some species the skin resembles moss growing on tree bark and rocks, forming effective camouflage. But in some species, the skin is not warty or tuberculated but rather smooth. They are medium to small-sized frogs with maximum snout-vent lengths that range from 2 to 7.5 cm depending on the species. They are found from northeastern India and southern China, through Southeast Asia, to the Greater Sunda Islands, with the highest species richness in the Indochinese region.



Theلودerma is currently comprised of 27 species distributed throughout Southeast Asia, southern China and northeastern India. The genus is characterized/characterised (Eng sp.) by the combination of the following morphological characters: distinct tympanum; rounded canthus rostralis; the absence of bony ridges from canthus rostralis to occiput; skin of head not co-ossified to the skull; having some degree of tuberculate skin, sometimes with calcified warts on the dorsum; and Y-shaped terminal phalanges. However, derived morphological characteristics are lacking for the genus, and it is uncertain at this time whether *Theلودerma* is in fact a distinct frog group. In addition, many species were described based on a single or a few specimens only, and not enough is known.

To date, 17 species have been recorded from Vietnam: *T. albopunctatum*, until recently recorded as *T. asperum*; *T. annae*, described only recently, in 2016; *T. auratum*, also only recently described in 2018; *T. bicolor*; *T. gordonii*; *T. laeve*; *T. lateriticum*, described in 2009; *T. nebulosum*, described in 2011; *T. palliatum*, described in 2011; *T. petilum*, described in 2004; *T. rhododiscus*; *T. ryabovi*, described in 2006; *T. truongsongense*, described in 2005; *T. vietnamense*, described in 2015 and formerly recorded as *T. stellatum*, and *T. khoii*, the last discovered species, described last year only.

Little is known about their natural history, but they feed on small arthropods. Breeding, as far as is known, takes place in a small water pool in a cavity of a tree, bamboo or karst. The female places up to 20 eggs just above the water. After about one to two weeks, they hatch into tadpoles that drop into the water. After several months, they metamorphose into froglets. Being phytotelma breeders, all life stages – adults, as well as tadpoles and metamorphs - can be found around and in tree holes partly filled with water.



Status

24 *Theلودerma* species have a decreasing population status according to the IUCN Red List, with five of them – all of them occurring in Vietnam - being listed as threatened on the IUCN Red List: 3 as Endangered (*T. nebulosum*, *T. palliatum*, and *T. ryabovi*), and 2 as Vulnerable (*T. auratum*, *T. petilum*).

One of the three species listed as Endangered is *Theلودerma ryabovi*. Nothing is currently known about the size of this species' population except what is known from only a few individuals from its type locality, montane primary forest.

Deforestation continues to affect habitat in the species' range, and is very likely causing some declines.

The last discovered species is *Theلودerma khoii*. The discovery of Khoi's mossy frog was certainly among the most spectacular discoveries in 2022, as it is a large, gorgeous new mossy frog species. The moss-green coloration on the dorsal surface of the new species, which can blend remarkably well into a background of stones covered with lichens or tree leaves, seems to be an adaptation to the life mode associated with the karst environment. With a known distribution including only the type locality in northeastern Vietnam, it belongs to the group of range-restricted, so-called microendemic species, which will be lost first because of their presumably small population size. Therefore, the species likely qualifies as Endangered (EN) in accordance with the categories and criteria of the IUCN Red List of Threatened Species. It is another microendemic mossy frog species, like the Endangered *T. ryabovi*, which lacks any protected area coverage and clearly points to another conservation gap.

Conservation action

Afore mentioned *Theلودerma* species, *T. ryabovi* and *T. khoii* belong to the species which are known from only a few individuals and a single site. It is unclear whether this is due to true rarity or cryptic behaviour, and further



research is needed to determine the species' true abundance. They are not currently known to inhabit any protected areas. Protection of habitat at the species' known locality may be warranted if it is not found to occur in any nearby protected area following further research. However, addressing the lack of data is the first step towards ensuring this species' long-term persistence. Further research on their true distribution, threats, the size, and trends of its population, and whether it is represented in any protected areas would inform conservation decisions.

Also, more studies using an integrative approach, i.e., combining morphological and molecular data, will help to reveal the extent of species richness of *Theلودerma* in the poorly studied regions in particular of northern Vietnam.

There is also an urgent need for more studies that identify the gaps in species conservation so that proper action can take place, including reserve extension or new creation, receiving official threat status such as inclusion in the IUCN Red List, and in parallel the establishment of ex-situ programs by local partners in cooperation with international zoos. This is in line with the One Plan Approach to Conservation, developed by IUCN's Conservation Planning Specialist Group (CPSG), which combines in-situ and ex-situ efforts and various expertise for the optimum and timely protection of a species.

Some species, especially *T. corticale*, are also kept in zoos, with a few institutions having had breeding successes. In ZIMS, the following species are listed as being held among zoos (in part their specific identity after revision of species groups is not clear): *T. asperum*, *T. bicolor*, *T. corticale*, *T. gordonii*, *T. horridum*, *T. leporosum*, *T. licin*, and *T. stellatum*



Campaign objectives

To expand conservation measures for Vietnamese mossy frogs, the EAZA Vietnam campaign will foster, together with its partners from IEBR and the Institute for Genome Research, both Hanoi:

- monitoring (further research on the true distribution, threats, the size and trends of populations);
- using an integrative approach, i.e., combining morphological and molecular data, to help to reveal the extent of species richness of *Theلودerma* in Vietnam;
- Listing microendemic, not yet protected, threatened species on Vietnam Red Data Book, IUCN Red List;
- create in situ conservation measures for those species not yet benefitting from protected area coverage;
- for *T. khoii* the site Quan Ba, in Ha Giang Province, could be recommended, after population monitoring, for a nature reserve; also development of signboards would make sense here (this site is also famous for other species such as the Tonkin snubnose monkey, or the just recently discovered, threatened *Tylototriton ziegleri*, a crocodile newt also held by some zoos);
- build up ex-situ breeding stock for starting conservation breeding / network for these species not benefitting from ex-situ conservation.



Only recently discovered - Khoi's mossy frog (*Theلودerma khoii*). Phot. T. T. Nguyen



Vietnamese mossy frog (*Theلودerma corticale*) clutch. Phot. A. Rauhaus



Also held by zoos - Vietnamese mossy frog (*Theloderma corticale*). Phot. T. Ziegler



South-Vietnamese Bug-Eyed Frog (*Theloderma vietnamense*). Phot. T. Ziegler



The dorsal surface of the White-spotted bug-eyed frog (*Theloderma albopunctatum*) resembles a bird dropping. Phot. T. Ziegler



Anna's treefrog (*Theloderma annae*) – named in 2016 after Cologne Zoo's terrarium section keeper Anna Rauhaus for her amphibian conservation commitment – belongs to the smaller *Theloderma* species and those which have a more smooth skin. Phot. C. T. Pham