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Tadpole consumption is a direct threat to the endangered purple frog, *Nasikabatrachus sahyadrensis*

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Amphibians across the world are suffering alarming population declines with nearly one third of the ca 7,300 species being threatened worldwide (Stuart et al. 2008, Wake & Vredenburg 2008, IUCN 2014). Major factors attributed to the decline include habitat destruction (Houlahan et al. 2000, Sodhi et al. 2008), chemical pollution (Berger 1998), climate change (Adams 1999, Carpenter & Turner 2000), diseases (McCallum 2007, Cushman 2006), and invasive species (Boone & Bridges 2003). The Western Ghats of India, a global hotspot for amphibian diversity and endemism (Biju 2001, Biju & Bossuyt 2003), has more than 40% of its amphibian fauna threatened with extinction (IUCN 2014). The major threat to amphibians in this hotspot is the alteration of natural habitats by an ever-increasing human population, resulting in large areas being converted for settlement and agricultural use (Biju et al. 2008). The problem is exacerbated by the fact that approximately one third of the 203 amphibian species in this hotspot are still categorized as Data Deficient, lacking sufficient knowledge about their biology, distribution, population structure, population dynamics, and threats faced (IUCN 2014).

Of late, utilization of frogs for food, traditional medicine, research purposes and the pet trade has also been considered a major contributor to amphibian declines, along with threats such as habitat destruction and fungal infection (Bishop et al. 2012, Chan et al. 2014). Recent studies have shown frog utilization to be one of the major threats affecting about 280 amphibian species globally, more than half of which are listed as Vulnerable, Threatened or Critically Endangered as per the IUCN Red List (Mohneke et al. 2009). Consumption of frogs by humans is a major form of utilization that can potentially drive even common species towards extinction (e.g., Carpenter et al. 2007, Warkentin et al. 2008, Chan et al. 2014). A number of commonly consumed species in America, Europe, and Southeast Asia have witnessed drastic population declines caused by overexploitation over the last couple of decades (Warkentin et al. 2008). Often, natural populations are harvested without regard of the consequences or implications of this practice on the dynamics or sustainability of the exploited populations (Getz & Haight 1989). When the extent of exploitation is greater than the sustaining capacity or turnover rate of a species, there is every possibility that the species may become locally extinct, which would subsequently have drastic ecological implications in the particular region (Duffy 2002, Wright et al. 2006, Carpenter et al. 2007). Recent evidence also suggests that the impact of overexploitation of amphibians is greatest on rare and restricted species, as in the cases of the Lao warty newt, *Paramesotriton laoensis* (DD), Kaiser's spotted newt, *Neurergus kaiseri* (CR), and the Chinese giant salamander, *Andrias davidianus* (CR), all of which are subjected to commercial exploitation, either for the pet trade or dietary purposes, leading to their populations declining massively (Lau et al. 2008).

Nasikabatrachus sahyadrensis (purple frog) is a rare, unique and endemic frog of the Western Ghats that has also been considered as a flagship species for amphibian conservation in this region (Biju & Bossuyt 2003, Aggarwal 2004). This fossorial species is an explosive seasonal breeder, which completes its developmental cycle (eggs to juveniles) in ephemeral streams (Zachariah et al. 2012). Breeding activities (vocalization and oviposition) take place during the months of April–May, synchronized with the onset of pre-monsoon showers (Zachariah et al. 2012, Thomas et al. 2013). The tadpoles of this species are found adhering with their uniquely adapted suctorial mouthparts to the rocky substrate of fast-flowing to torrential streams (Zachariah et al. 2012, Raj et al. 2012). The species is listed as Endangered B1ab(iii) in the IUCN Red List based on its restricted distribution range (less than 5,000 km²) and

lack of adequate information about the threats faced (Biju 2004). Major threats reported to date are indirect factors that include habitat fragmentation and destruction due to urbanization, cultivation (Biju 2004), and dam construction (Dutta et al. 2004, Aggarwal 2004). However, measuring the effects of these threats is difficult and would require long-term monitoring studies to understand their magnitude and impact (Beebee & Griffiths 2005). Extensive surveys and studies for investigating threats to this species are lacking as of now and no immediate or direct threat has been reported.

Here we provide the first report of a direct threat to *Nasikabatrachus sahyadrensis* in the form of collection for human consumption of its tadpoles by tribal or indigenous communities dwelling in and around forest areas of Kerala state. We present a quantitative evaluation of harvesting in one tribal settlement area during five consecutive years (2008–2012), discuss the implications of this threat and suggest possible conservation measures.

The study site, the Nadukani-Moolamattom-Kulamaav tribal settlement area (09°49' N, 76°53' E), is situated on public land maintained by the Kerala Forest Department and located approximately 10 km from the type locality (Double Cutting, Kattapana, Idukki District) of the species (Biju & Bossuyt 2003). The altitudinal range of the area is between 200–700 m a.s.l. This region experiences southwest monsoon, with pre-monsoon showers occurring during the months of April and May, followed by the monsoon season that begins towards the end of May or beginning of June and continues until October. The study area is adjacent to the northwestern border of the Idukki Wildlife Sanctuary (IWS), near the Kulamaav Dam. There are approximately 100–150 tribal households in this area.

The study was conducted over a period of five years, 2008–2012. We conducted two types of surveys for this study, interview surveys and field surveys, during April to September every year. Interview surveys were informal and focused on gathering information about various aspects such as the history of tadpole harvesting, harvesting techniques used, method of consumption, and social and economic importance of the purple frog to the local people. During the five-year study period, a total of 50 people were interviewed from the entire tribal settlement area. Each person was interviewed only once and no two people belonged to the same household (i.e., living in the same house). Ages of interviewees ranged from 19–75 years.

For the field study, three streams were selected where tadpole harvesting was known to take place or observed. We marked a 500 m stretch in each stream, beginning as close as possible to their respective origins. To estimate the number of tadpoles present in the streams, a wooden frame of 1 × 1 m was used. The frame was held flat, close to the surface of the stream without disturbing the tadpoles clinging to the substrate. In order to reliably detect the tadpoles in the fast-flowing drainage, a thin wooden slab (1 × 0.2 m) was held about half a metre upstream of the frame to reduce the water flow speed. This measure rendered tadpoles sufficiently visible, and all those present inside the frame were counted. Tadpole counts were taken every 10 m along the entire stretch of the marked area, producing 50 readings for each stream segment. All tadpole counts were taken in the middle of a stream's main drainage bed, because tadpole density was observed to be highest in this region. The total number of tadpoles counted in the quadrants for each stream was then multiplied by a factor of 10 to obtain an estimate of the average number of tadpoles in the middle of the 500 m marked stretch of the stream. This value was then rounded to the nearest multiple of 50 for ease of analysis. During all five sampling years, tadpole census was conducted during the second week of July, when tadpoles had attained a considerable size and were relatively easy to spot in the fast-flowing water. Also, no harvesting was observed before the fourth week of July during the entire study period.

To quantify and assess the impact of tadpole harvesting, we constantly kept an eye on any harvesting activity in the three streams within the area marked for our study, from June to September (2008–2012). Since the tribal people did not engage in harvesting activity at night, our surveys were conducted between 06:00–18:00 h daily. After every harvesting event by the tribal people, the numbers of tadpoles captured were counted manually and recorded to the nearest multiple of 10. Based on a rapid morphological examination, tadpoles were sorted into three categories according to their developmental stages (staging follows Altig & McDiarmid 1999) and the total number of tadpoles in each category was recorded. The three categories are; (a) category 1 – stages 26–38, hindlimbs at various stages of development, (b) category 2 – stages 39–41, hindlimbs well developed, visible outside the flap of the vent tube, forelimb bud visible; and (c) category 3 – stages 42–46, all four limbs fully developed and visible, tail atrophied to various levels. The data obtained from the above methods were used to plot two graphs. First, the annual data of the total number of tadpoles found in the stream and total tadpoles harvested between 2008–2012 were plotted on a bar graph. Second, the monthly harvesting data (April–September, compiled for five consecutive years) were plotted against the developmental cycle of *Nasikabatrachus sahyadrensis* (Zachariah et al. 2012) on a line graph to assess the impact of harvesting relative to the frog's larval development.

Our interviews revealed that human consumption of *Nasikabatrachus sahyadrensis* tadpoles is an old practice amongst the local tribal people. Specifically in this area, consumption has been taking place at least for the last 30–40 years since the tribal people first settled in this region, as per information obtained from some of the elders (aged above 60 years). We also found that these people have considerable knowledge about the life cycle and behaviour of this species. Tribal people who engage in harvesting these tadpoles are mainly of the age group of 20–40 years. On average, a household of four people consumes approximately 3 kg (~1,500) tadpoles per season. Tadpoles are always consumed fresh after harvesting and never stored for later use. The method of processing the tadpoles was found to be similar in all households that were known to consume

them. In short, the abdomen of each tadpole is made to burst by pressing it with the thumb and the coiled gut is completely removed. Tadpoles are then washed, and seasoned with salt, readily available spices, and grated coconut. They are then steamed and usually eaten with boiled rice or tapioca. For a family of four, about 300 tadpoles are used for a single meal that takes about 30–40 minutes of preparation time. Since tadpoles are available only for a short period every year, they are considered a delicacy, especially amongst the children. During the study period, we did not observe the harvest being sold for a profit. Furthermore, out of the 50 interviewees, only 19 (and their respective households) admitted to consuming tadpoles. Some respondents also volunteered that tadpole consumption was common practice in other tribal areas as well. Apart from tadpoles, it was found that some tribal people also consumed the adult individuals (both male and female) of *N. sahyadrensis*. Although no direct observation of adult frog consumption was made, we were informed that the frogs were consumed in a spicy soup or curry dish. Adults are consumed both as regular food and for purported medicinal properties (as a cure for burns, asthma, and other lung ailments). Adults are mostly captured during the breeding season (April–May) when they emerge from their

Figure 1. A tadpole-harvesting event of *Nasikabatrachus sahyadrensis* in a tribal settlement area in Kulamaav. A–B) An area of stream being "swept" by a tribesman while his companion collects the tadpoles downstream in a basket; C) Tribal people landing their catch of tadpoles; D) A basket trap is held against the current for capturing the tadpoles; E) Collection of tadpoles after the harvesting event.

underground dwelling for mating. Almost all respondents confirmed that there was a substantial decrease in purple frog sightings over the last decade in this region.

Tadpole-harvesting was prevalent in the monsoon season during July–September every year. The tribal people have developed an indigenous method for collecting these uniquely adapted suctorial tadpoles. Usually, about 2–5 individuals would participate in each harvesting event. Selecting a rocky section of a stream with a steep slope, one side of the stream is blocked by creating a barrage of rocks and vegetation to reduce the water flow and partially expose the tadpoles. This region is then swept with a broom made of short branches from nearby vegetation and blades of grasses growing alongside the stream (Figs 1A+B). As the tadpoles are brushed downstream, they are intercepted and captured with basket traps. These basket traps are conical in shape with a rounded base. When the basket is held or moved over the rocky surface against the current, the water flows out through the interspaces while the tadpoles are trapped inside (Figs 1C+D). Trapped tadpoles are then transferred to plastic containers (Fig. 1E) and shared amongst the people who participated in harvesting.

Our study shows a substantial tadpole population decline during the course of the study period (12,150 in 2008 to 4,900 in 2012; 59% decline; Fig. 2). The number of tadpoles harvested by the tribal people follows a similar trend and declined during the five-year period (6,350 in 2008 to 3,160 in 2012; 50% decline; Fig. 2). However, the ratio of tadpoles harvested (number of tadpoles harvested relative to number of tadpoles available) increased from 52% in 2008, to 70% and 64% in 2011 and 2012, respectively. It is worthy of mentioning that the tadpole population was particularly low in 2011 and 2012, when the population had decreased by about half (51% and 47%, respectively) as compared to 2010. Interestingly, in both 2011 and 2012, the pre-monsoon showers were very erratic in comparison to previous years, with both the amount of rainfall and its frequency of occurrence considerably reduced at the study site. This resulted in streams drying up quickly and remaining so for long periods during the breeding period (April–May) of the purple frog. We also observed a few egg clutches (n = 4 in 2011, 5 in 2012) of the species in the study area that were destroyed due to desiccation. The rapid drying of the stream could also have affected the development of hatchlings and early stages of the tadpoles. Thus, the marked decline of tadpoles in the study area during 2011 and 2012 could possibly be a cumulative effect of scanty pre-monsoon rains and harvesting. Such a possibility indicates that even if harvesting is carried out at sustainable levels in the region, other direct and indirect threats (most of which are either subjective or undocumented until now) could significantly augment the threat of harvesting in the near future and lead to a substantial decline of local population of the purple frog. However, to place the results of our survey in a proper perspective, the five-year data from our study may not be sufficient to confidently infer a relation between tadpole decline and harvesting in this region. Amphibian populations are known to fluctuate considerably in size from year to year due to stochastic factors, especially in the case of seasonal and/or explosive

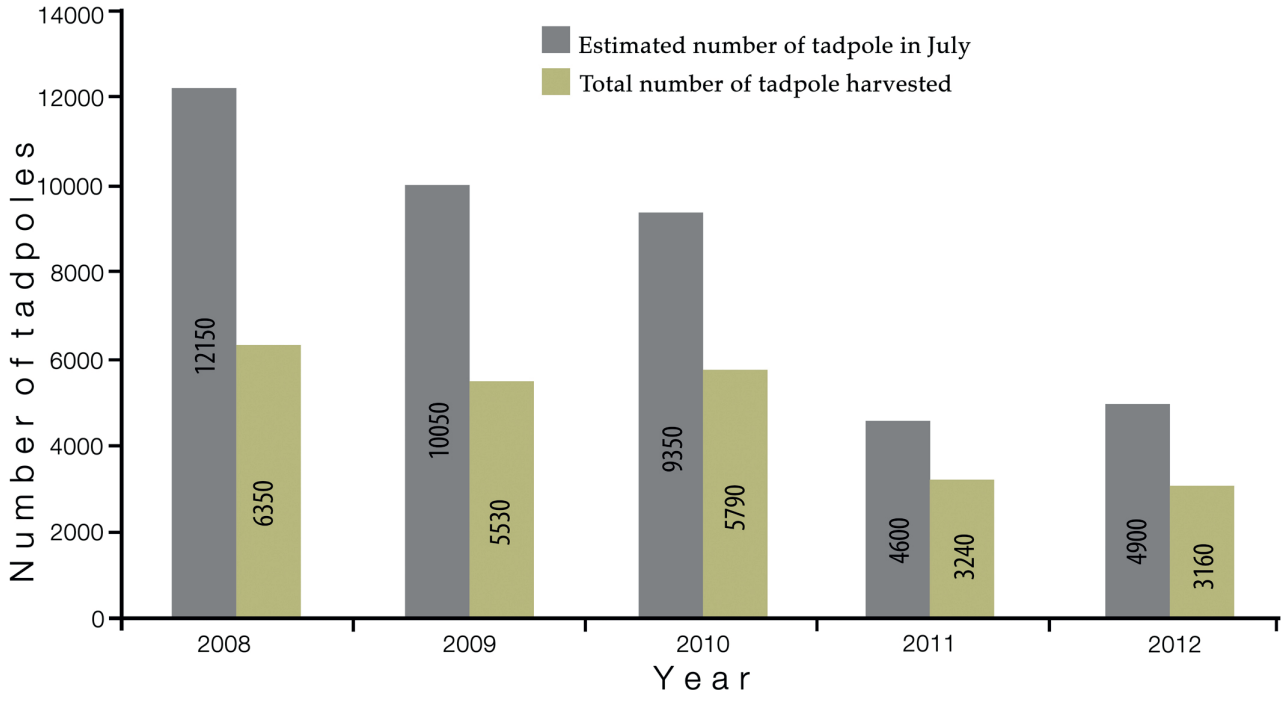

Figure 2. The estimated total number of *Nasikabatrachus sahyadrensis* tadpoles and the total number of tadpoles harvested during the study period from 2008–2012.

breeders (Semlitsch et al. 1996, Meyer et al. 1998, Marsh 2001, Gower & Wilkinson 2005). Hence, it is imperative to conduct long-term monitoring studies to identify the influence of this direct threat on local populations of the purple frog.

The long-term implications of harvesting on natural populations are also dependent upon a number of other factors, including the life stage or age of individuals collected (Cameron & Benton 2004), the frequency and season of harvesting (Freckleton et al. 2003), and the overall population size, structure and range. In the case of the purple frog, the harvesting season (July–September) is critical, because it coincides with the period when tadpoles are at the advanced stages of development. Between 15 July and 15 August, 76% of the harvested tadpoles were in categories 2 and 3 (stage 39 or above) and between 16 August and 15 September, this increased to 85%, a high proportion (58%) of which were metamorphs (Fig. 3). Generally, in explosive breeders with large clutches, only about 10–20% of the total number of eggs develop into metamorphs because the majority of eggs and developmental stages are lost to predation and other natural factors that affect hatching success and development (Wells 2007). Since metamorphosis itself is a very vulnerable period in anuran life history (Wassersug & Sperry 1977, Arnold & Wassersug 1978, Crump 1984), few metamorphs finally transform into juveniles that can be recruited into the population.

Frog harvesting and trade, which used to be very common practice in India, have been banned since 1987 (Pandian & Marian 1986, Altherr et al. 2011). However, in cases where indigenous communities utilize natural, even if threatened, resources exclusively for local consumption and as part of their livelihood, conservation measures need to be taken sensitively. A lack of awareness of consequences in such communities is one major factor that needs to be addressed. Even during our surveys, people seemed willing to try and understand when explained what conservation concerns regarding the purple frog and the importance of amphibians in general were about. Some families even discontinued harvesting tadpoles. We suggest that conducting awareness campaigns among tribal and local people will be an important conservation management step for this species. Because most tribal people involved in harvesting tadpoles are unemployed youths, an underlying factor might be that they are not engaged elsewhere and look for easy means of obtaining food for their families. Society and conservation managers could design specific measures to educate tribal people and provide them with basic amenities and employment opportunities. Education will help with raising awareness, and job opportunities will certainly keep them better engaged in their everyday life. Further studies need to focus on evaluating the long-term effects of tadpole and adult consumption on local populations of the purple frog. Our report reveals an urgent need

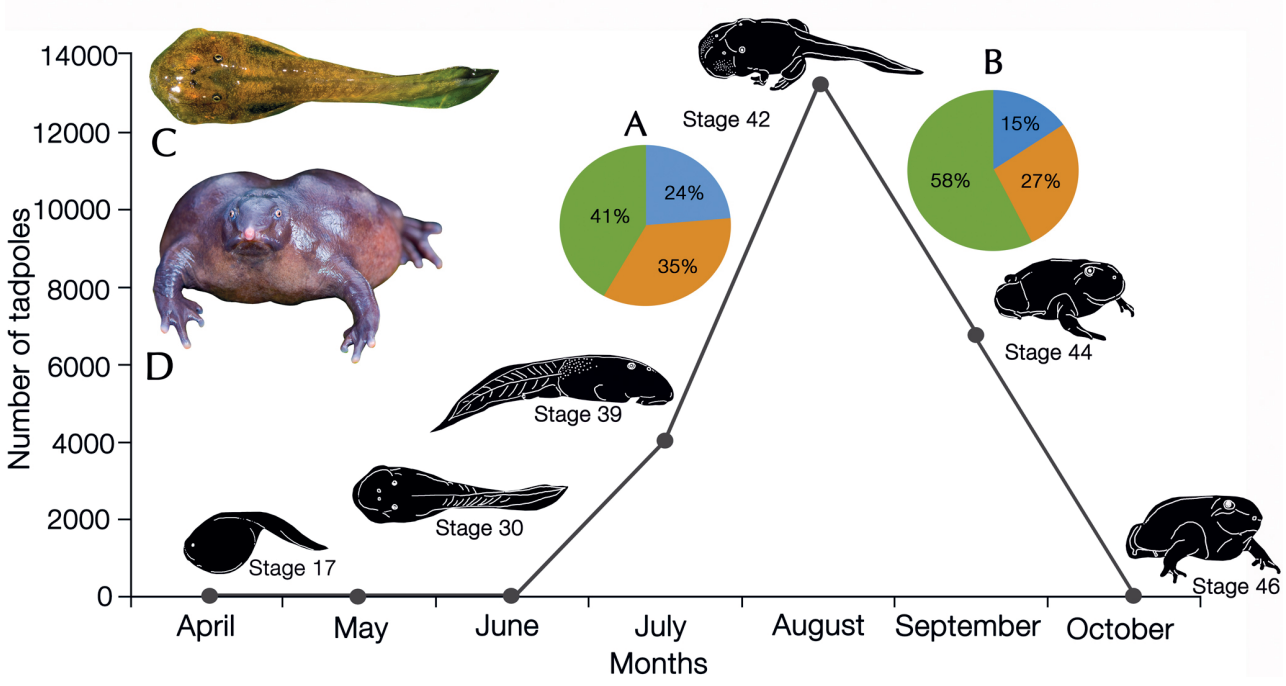

Figure 3. Line graph showing the compiled monthly harvesting data of *Nasikabatrachus sahyadrensis* during the study period 2008–2012. The illustrations represent the dominant developmental stages of purple frogs found in the stream during different months. A–B) Pie charts showing the proportion of tadpoles harvested with respect to the three categories devised for the study during A) 15 July through 15 August, and B) 16 August through 15 September. Category 1 (stages 26–38) – blue; category 2 (stages 39–42) – yellow; and category 3 (stages 43–46) – green, see text for details; C) A typical tadpole at stage 38, (total length 6.0 mm, total mass 2.1 g); D) Adult female *Nasikabatrachus sahyadrensis* (SVL 86.4 mm, total mass 165 g).

for taking steps to conserve this flagship amphibian species of the Western Ghats. It also highlights the importance of conducting extensive surveys in the distribution range of the species to possibly identify additional anthropogenic threats that may be detrimental to local populations. Most importantly, we propose that there is an urgent need to reassess the conservation status of the purple frog based on currently available information, which would be helpful for planning and implementing effective conservation strategies for this species.

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