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Feature Article

Bioacoustics of Sri Lankan Amphibians: a Review of Current Knowledge and Conservation Significance

De Silva S. and Wijayathilaka N.*

Department of Zoology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

Abstract

Acoustic inventory of Sri Lankan amphibians is still in a primitive stage. So far, only 20 amphibian species are known acoustically and are about 16% of the island amphibian fauna. Altogether, twelve publications provide primary acoustic characters, yet the majority of them are not quantitative. Bioacoustics is a powerful tool that can use in many disciplines, including taxonomy and conservation. This work emphasises that the current knowledge on the vocalisation of Sri Lankan amphibians is not adequate and highlighted its applications towards conservation and planning.

Keywords: Vocalisation, behavior, frogs, conservation planning

1. Introduction

Acoustic communication is one of the major methods of which the organisms use to convey information to each other. Anuran amphibians are well known for their vocalising behavior, and it represents a substantial portion of their behavioral repertoire. Acoustic signals of amphibians are known to encoded vital information such as reproductive fitness, species, and individual identity, size, fighting ability, mood and condition (Bradbury and Vehrencamp, 1998; Gerhard and Huber, 2002).

Detailed bioacoustic studies of amphibians are a critical step towards understanding their complex behaviors in the context of reproductive ecology. Acoustic data increasingly use in resolving taxonomic uncertainties integrating with morphological and molecular evidence (Meegaskumbura et al., 2015; Wijayathilaka et al., 2016). Moreover, can use in many research aspects, as a model to address essential evolutionary questions include sexual selection and speciation process (Kroodsma and Miller, 1996), to study the impact of the anthropogenic noise on the signal use and perception (Laiolo, 2010). Furthermore, basic knowledge of species-specific acoustic signals is much useful in the population census, remote monitoring, and discovering new populations as a non-invasive tool. On the other hand, integrating with other data sources, bioacoustics is vital for making effective conservation assessments, planning, and management.Sri Lanka is a paradise for amphibians currently is home to 120 anuran species, out of which 104 are endemic to the island (Amphibia Web, 2019). Though it is highlighted the importance of acoustic information, only a handful of studies have been done to reveal the vocal repertoire of Sri Lankan species. Aim of this review is to collect the literature available on vocalisation of Sri Lankan amphibians, highlight the knowledge gap, use, and significance in conservation assessments.

2. Current knowledge on the vocal repertoires of Sri Lankan amphibians

Out of the 102 extant species recorded in Sri Lanka, only 19 species are known acoustically, i.e. less than 18% (Table 1). As per the literature survey, only 12 publications mentioned the acoustic characters (Nelson, 1973; Arak, 1983; Manamendra-Arachchi and Pethiyagoda, 2001; Meegaskumbura

*Correspondence: nayanaw@sci.sjp.ac.lk
Tel: +94 713284804
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and Manamendra-Arachchi, 2005; Samarasinghe, 2011; Samarasinghe, 2012; Wikramasinghe et al., 2012; Meegaskumbura et al., 2015; Wijayathilaka and Meegaskumbura, 2016; Wijayathilaka et al., 2016; Wijayathilaka et al., 2018; Batuwita et al., 2019).

Table 1: Acoustically known anuran species in Sri Lanka (* Endemic species, n = no. of call recorded individuals).

Family	Species	Remarks	Reference
Microhylidae	*Microhyla karunaratnei**	100 calls (n=5)	Wijayathilaka and Meegaskumbura, 2016
	*Microhyla mihintalei**	100 calls (n=5)	Wijayathilaka and Meegaskumbura, 2016
		30 calls (n=3)	Wijayathilaka et al. 2016
	Microhyla ornata	100 calls (n=5)	Wijayathilaka and Meegaskumbura, 2016
	*Microhyla zeylanica**	53 calls (n=3)	Wijayathilaka and Meegaskumbura, 2016
	*Uperodon nagaoi**	50 calls (n=3)	Wijayathilaka et al. 2018
		No details	Manamendra-Arachchi and Pethiyagoda, 2001
	*Uperodon palmatus**	50 calls (n=3)	Wijayathilaka et al., 2018
	*Uperodon rohani**	50 calls (n=3)	Wijayathilaka et al., 2018
	*Uperodon obscurus**	50 calls (n=3)	Wijayathilaka et al., 2018
		2 calls. Reported as *"Ramanella obscura*"	Nelson, 1973
	Uperodon taprobanicus	10 calls (n=2) Reported as *"Kaloula pulchra*"	Nelson, 1973
Bufonidae	*Adenomus kandianus**	30 calls (n=3)	Meegaskumbura et al., 2015
	*Adenomus kelaartii**	30 calls (n=3)	Meegaskumbura et al., 2015
Rhacophoridae	*Polypedates ranwellai**	Seven calls	Wickramasinghe et al., 2012
	*Pseudophilautus asankai**	(n=3)	Meegaskumbura and Manamendra-Arachchi, 2005
	*Pseudophilautus conniffae**	(n=5)	Batuwita et al., 2019
	*Pseudophilautus hoffmanni**	(n=3)	Meegaskumbura and Manamendra-Arachchi., 2005
	*Pseudophilautus leucorhinus**	29 calls (N=6) Considered as extinct species. Only known from the holotype	Arak, 1983
	*Pseudophilautus popularis**	61 (n=15)	Samarasinghe, 2011
	*Pseudophilautus rus**	77 (n=7)	Samarasinghe, 2012
	*Pseudophilautus stuarti**	(n=3)	Meegaskumbura and Manamendra-Arachchi, 2005
	*Pseudophilautus viridis**	(n=4)	Meegaskumbura and Manamendra-Arachchi, 2005

The oldest known publication which, describe the vocal characteristics of Sri Lankan amphibians, *Uperodon taprobanicus* (reported as '*Kaloula pulchra*') and *Uperodon obscurus* (reported as '*Ramanella obscura*') are in 1973 by Nelson. He has analysed the calls recorded by C.M Bogert. Nelson has mentioned only one call type, probably the advertisement call for both species. Call duration (T), Dominant Frequency (F) and Pulse rate (R) are the three call characters has measured for *Uperodon taprobanicus* (T=0.5-0.8 s, F=400-700 Hz, R=54-70 s^{-1}) and *Uperodon obscurus* (T=0.4 s, F=2200 Hz, R=60-70 s^{-1}) respectively.

Arak in 1983, published vocal interactions, call matching and territoriality in *Pseudophilautus leucorhinus.* He has mentioned five call types which has used in different social contexts. He only provided the call duration of each type and call rate as call characters. So his study had mainly focused on describing the calling behavior, including call matching and territoriality. On a different note, Manamendra-Arachchi and Pethiyagoda (2005) suggested that the taxon is known only from the holotype and now extinct. Further they mention that *P. leucorhinus* closely resembles *P. folicola* and *P. limbus.* Probably, Arak might have misidentified *P. limbus,* as *P. leucorhinus*. Then in 2001, Manamendra-Arachchi and Pethiyagoda discovered a new microhylid, *Uperodon nagaoi* ('Ramanella nagaoi') from a small fragment of rain forest in southern Sri Lanka. They have provided the waveform and spectrogram of the advertisement call of the newfound species. The fundamental frequency and call duration have mentioned as 850 Hz and 90 ms, respectively.In 2005, Meegaskumbura and Manamendra-Arachchi integrated the call characters to delimiting the species boundaries with molecular and morphological data. In their work, they have described eight new species of the genus *Pseudophilautus* and four species (*P. viridis, P. stuarti, P. hoffmanni, P. asankai*) with acoustic data related to six common call characters.

After that, similar taxonomic assessments have been done integrating acoustic data of Sri Lankan amphibians to understand the species boundaries. Calls of endemic torrent toads, *Adenomus kandianus* and *A. kelaartii* has recorded and analysed by Meegaskumbura et al. in 2015. The Indian population of *Microhyla rubra,* and Sri Lankan population was compared using integrative taxonomy including bioacoustics and identified the Sri Lankan population is distinct by Wijayathilaka et al. in 2016 and subsequently described as a new species, *M. mihintalei.* Then Wijayathilaka and Meegaskumbura (2016) has done a comparative acoustic analysis including all four species (*M. mihintalei, M. ornata, M. zeylanica, M. karunaratnei*) of the genus Microhyla in Sri Lanka.In most of the recent discoveries of new amphibian species, authors try their best to provide relevant bioacoustic information together with other characters (Wikramasinghe et al., 2012; Wijayathilaka et al., 2016; Batuwita et al., 2019). Two short communications in 2011 and 2012, Samarasinghe had described the call characters of *Pseudophilautus popularis* and *P. rus* respectively.Highlighting the use of acoustic information in new population discoveries, Wijayathilaka et al. in 2018 published the vocalization of four species, *Uperodon obscurus*, *U. palmatus, U. rohani*, and *U. nagaoi*, a clade known as *Ramanella* (Figure 1).

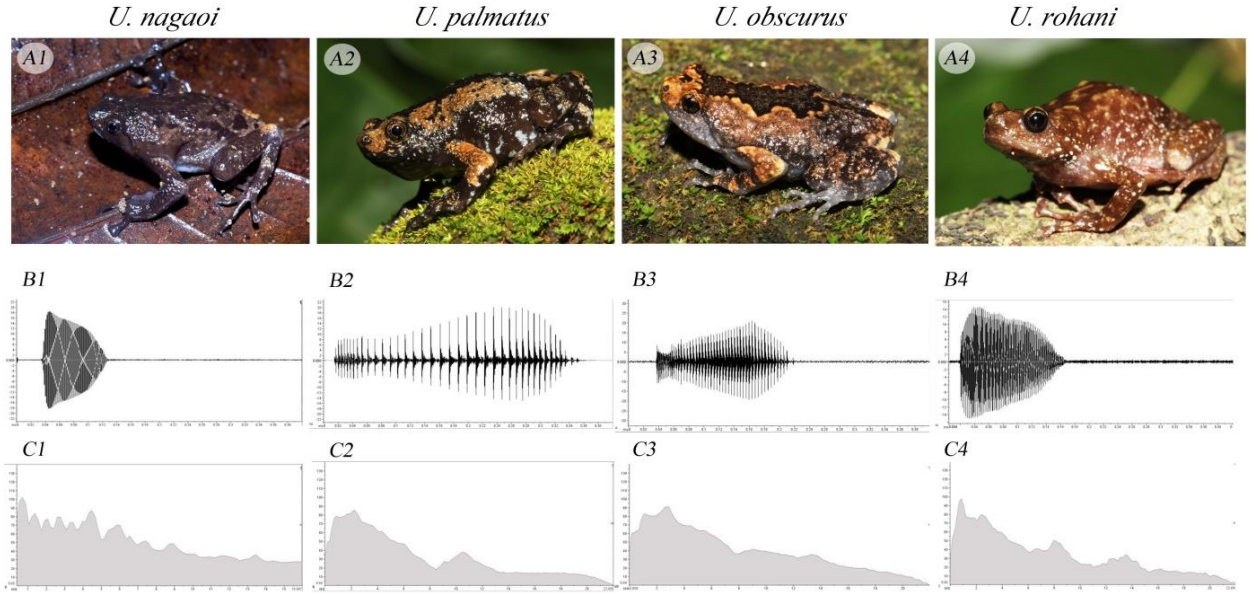

Figure 1: Four Uperodon species in life (A); Waveform (B) and power spectrum (C) of the advertisement call. Time showed 0.4 s. (Adopted from Wijayathilaka et al. 2018).

3. Uses and significance in conservation

Given the human-induced impacts on climate and biodiversity, amphibian conservation is more challenging than ever. Habitat loss, fragmentation, degradation, environmental pollution, climate change invasive species, and pathogens have identified as the major threats to the Sri Lankan amphibian fauna in general (Meegaskumbura and Manamendra-Arachchi, 2012). To battle with the increasing pressure on these versatile vertebrates, conservation tools are on much demand. Bioacoustics has long been identified as a non-invasive tool in conservation science (Laiolo, 2010) though; it has not received much attention until recently.

Even though, the species conservation and taxonomy often treated as two independent activities, taxonomic confusions and lack of taxonomic skills and information over where the boundaries of species to be set, cause problems for conservationists (Mace, 2004). Given the fact that the good alfa taxonomy central to biology, integrating multiple characters assist significantly to make correct taxonomic decisions. Bioacoustics has been identified as one good source of evidence to use in integrative taxonomy especially when morphologically cryptic species are involved (Glaw et al., 2010; Meegaskumbura et al., 2015; Wijayathilaka et al., 2016).

Amphibian explorations, surveys can largely be benefitted by efficient techniques like bioacoustics; especially in finding new species as well as new populations for known species. Tree hole breeding frog, *Uperodon nagaoi*, is one good example of such discoveries (*Pers. Com*. K. Manamendra-Arachchi). A case study using the genus *Uperodon* In 2018, Wijayathilaka et al. have discovered several new populations of two threatened species within two weeks. Understanding the home range of a species is essential in conservation prioritisation. Because, most of the threatened Sri Lankan amphibians have assessed in IUCN categories based on criteria B where the distribution parameters considered mostly such as Area of occupancy (AOO), Extent of occurrence (EOO) and the number of locations (IUCN, 2007).

Cumulative threat to the survival of amphibians been increasing continuously. Monitoring population persistence and reproductive fitness as well as estimating amphibian density and diversity need to be carried out frequently for a given population to understand the ongoing threats. When studying rare and cryptic species, conventional methods like capture-recapture methods, individual trapping and marking are not affordable. Bioacoustics is one of the best tools that can be used for the purpose effectively. Further, automated recording procedures and remote monitoring techniques have been developed and used successfully (Aide et al., 2013; Acevedo and Villanueva-Rivera, 2006; Ospina et al., 2013).

Sexual selection in reproductive behaviors in amphibians is an important drive in evolution (Ryan, 1985). Vocal communication plays an essential role in the reproduction of amphibians. The main function of an anuran call is to attract gravid females. Once documented the vocal repertoire descriptively and quantitatively, it can use in understanding the function of each call type using playback experiments. Further, it could find the specific call characters they alter to be more successful in different social contexts (Arak, 1983; Gerhardt, 1991; Gerhardt and Huber, 2002). Character evolution in the vocal repertories could also be analysed in a phylogenetic framework (Cocroft and Ryan, 1995; Ryan and Wilczynski, 2008)

Exploiting the conspecific attraction behavior using playback cues the distributions can slightly manipulate and encourage them to colonise and establish in newly restored habitats. Further fragmented amphibian populations can be connected using call broadcasts in created habitats (James et al., 2015). Such playback stations can even use to attract breeders to areas with decreased predation (egg/tadpole) such as predatory fish (Morgan and Buttemer, 1996). Also call playback can facilitate directional movement to increase the use of refuges to minimize the threat from unfavorable conditions (Robinson et al., 2013).

4. Conclusion

Given the advantages of precisely documented, accurately analysed vocalisations, still no information on more than 82% of extant anuran species in Sri Lanka. This review confirms that the attention on amphibian vocalisation studies on Sri Lankan amphibians is insufficient. Filling this knowledge gap is much needed for their future conservation planning.

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