Are We Listening?

By Dr. Seshadri K. S.

One of the surest signs of the onset of monsoon is the incessant croaking of frogs and toads. The hot and humid days give way to a cool evening and with even the slightest trickle, myriad sounds fill the air. Soon, the trickle becomes a downpour and all one can hear is the thunder and the pounding of rain. It is a simple association that frogs are the harbingers of rain, the association of frogs and toads with the rains and the rains with the harbingers of rain.

**Animals communicate for a variety of reasons ranging from marking territories to attracting a mate. In every form of communication, there are two participants, one that sends out a signal and the other that receives it. Communication can take many forms: a peacock spreads out its wings and struts in front of a female — this is a form of visual communication. A male bushnell flutters up into the air and descends, singing an elaborate song, combining a visual and an auditory signal. A male toad sits in a small puddle of water and emits a loud, repetitive call, using sounds to possibly woo a female. Communication is a costly affair. One must expend energy to produce sounds. An added cost comes from the increased risk of predation. Predators can easily eavesdrop on an animal that is perched in the open and singing away. To be effective communicators, organisms would need to overcome these challenges. One way to do this is to have calls for different purposes and use them to contextualise information. For instance, a langur produces a loud “haark!” call upon spotting a potential threat and other langurs as well as other animals nearby pause, becoming vigilant of their surroundings. In contrast, the langur has a different set of calls for social contexts such as mating or foraging. Another way of achieving efficiency is to string together signals in temporal patterns, resulting in complex sequences. Birds do this to make elaborate songs, and perhaps there is no better example of syntactic structure in communication than humans.

**Animal Communication**

Anurans vocalise primarily to attract mates. Typically, males are vocal, and females tend to produce little or no sound. Anuran vocalisations have a wide range of functions from indicating the quality of the mate, advertising position, and warding off competitors of the same sex. Male anurans produce sounds by pumping air through their vocal cords into vocal sacs, which act like reverberation chambers. Unlike most other vertebrates, anurans have a cloud tympanum, where the air is recirculated between the lungs and the vocal sacs. Researchers have observed anurans to possess a repertoire of vocalisations, which are classified into different ‘call types’. Each call can comprise many 'notes', and the notes can be of many types. For example, the common toad *Bufo bufo* has a multi-note call that goes “turr turr turr turr turr...”; whereas the Kalpetta waterdrop frog *Raorchestes nerostagona* has a single-note call that goes “tuk-tuk”.

Describing anuran vocalisations using words would be challenging. An efficient technique would be to use spectrograms, where the frequency (number of waves) and amplitude (height of a wave) of a call can be plotted against time. The result will help determine the overall frequency of calls, visualise the number of notes in a call, and measure a set of parameters such as call duration, note length, number of notes, inter-note length, and so on.

Anurans have a repertoire of vocalisations or call types, each of which has been attributed to some function. The classic example is the Tungara frog, found in parts of Central and South America. Males of this species can produce two calls: a simple call where only a long-drawn ‘whine’ is produced, and a complex call where up to seven, short, high amplitude ‘chuck’ sounds are added to the whine. Do the two calls have varying functions? Indeed. The whine helps the female locate the calling male in a process called ‘phonotaxis’, and the chuck enhances the attractiveness of the male to the female. Vocalising males put themselves at risk by being susceptible to eavesdropping by unintended receivers such as predators. If a male vocalises consistently, it may indicate a higher level of genetic fitness, and the female uses multiple such cues to decide on a mate. Mating, however, is one of the contexts where anurans vocalise.

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Dr. Anand Krishnan, who studies animal communication, at the Jawaharlal Nehru Centre for Advanced Scientific Research, among other things, Shikhara was a student (now in the University of Mainz, Germany) and Anand was his advisor at the Indian Institute of Science Education and Research (IISER) in Pune. We had our work cut out for us in the form of a slew of research questions. Do other members of the genus Nyctibatrachus also have a repertoire of calls? Do frogs use different call types to convey context-specific information? If they are vocalising in the presence of a conspecific male, do they change the sequence of their call or switch to a completely different call type? Are the calls randomly stringed together or is there a syntactic (syntax-related) pattern to it? Soon, we outlined things we would do in the field, and Shikhara set off with a recorder and a camera to make observations.

Just about the time he was to head back to the field in 2020, the COVID-19 pandemic took the world by storm and all research work was grounded. When the lockdowns were partially lifted, Shikhara managed to get to Sirsi in Karnatka to make recordings, but the locals were hesitant to let an outsider into their town and he was confined to the homestead. At night, he began to wonder about the property and realised that there was another frog that was vocalising, and it appeared to have a repertoire of calls. The Amboli bush frog *Pseudophilautus amboli* is a small frog, measuring about half the size of a human thumb, and is found in the central Western Ghats. Observing them for a couple of nights, Shikhara was able to discern that the frogs had a repertoire of calls, which would vary depending on the context. This discovery came as a blessing in disguise. Instead of comparing

the vocalisations of two species within the genus, we were now able to ask questions across two families of frogs that separated from their ancestors nearly 60 to 100 million years ago.

**Anurans can convey context information despite having a limited repertoire size.**

**A** **NURANS CAN CONVEY CONTEXT** Shikhara returned to Bengaluru after several nights of recordings and observations. The pandemic-related restrictions on movement were still in place and we would meet online to analyse data. We found that both species *Nyctibatrachus humayuni* and *Pseudophilautus amboli* had a repertoire of calls. When compared to the existing classification of frog calls *N. humayuni* was comparable to other species, where only the frequency is modulated while the notes remain uniform. The males produced an ‘ascending’ note, and a ‘descending’ note after the ascending note. The notes are ascribed as ascending or descending based on the energy distribution in a spectrogram, which to the human ear appears as if the call is increasing or decreasing in amplitude. However, the other frog *P. amboli* belonged to a category of frogs modulating the notes. They produced six different note types at varying frequencies. Some notes were uttered more often than others. Despite different repertoire sizes, the frogs were contextualising their vocal signals. Having listened to the recordings and extracted information by annotating the calls on computer software, we were able to conclude that males of *N. humayuni* produced only the ascending note when alone, and added up to eight descending notes when in the presence of another male. The males of *P. amboli* in contrast, produced two sets of note types. One set, comprising three different notes, was produced when the males were alone, and the other set of two notes was produced when they were in the presence of another male. One of the six notes was so rarely produced that we did not consider it for statistical analysis.

**SYNTACTIC**

**C** **Ommunication** Frogs were always thought to be simple creatures that mindlessly croak. In statistical terms, they were thought to follow a Markov-chain where the next event is dependent

Having measured the number of note types and how often they are produced, we used the Shannon entropy framework to infer if the information is of higher or lower diversity depending on the context. Males of *N. humayuni* added a descending note to their vocalisation in the presence of a male, and this increased the Shannon entropy. However, the males of *P. amboli* switched to different note types and repeated them; this did not change the Shannon entropy value and the vocalisations were stereotypical.

**SIMPLE OR COMPLEX?** While it was clear that the two species could contextualise their signals, were they modulating the information being conveyed in different contexts as well? The Shannon diversity index is a measure used often to quantify biological diversity. It uses information about how many species are found and how often they are found. In 2019, the Malabar tree toad *Pedostibes tuberculatus* was an enigma from the Western Ghats. Recent citizen-sourced data suggests that the toad is fairly common. Most people may have missed it because they vocalise before the onset of rains and look like something that is hard to associate with a toad. They live among tree tops.

**Anurans can convey contextual information despite having a limited repertoire size. The ability to effectively communicate was likely present in the common ancestor of the two endemic species belonging to the families Rhacophoridae and Nyctibatrachidae.**

**Above** The Malabar tree toad *Pedostibes tuberculatus*.
Vocal Climate Challenges

Scientists from the University of California Los Angeles (UCLA) recorded changes in the vocalisations of the coqui frog, native to Puerto Rico. Known for the male’s unique two-note “co-qui” call, the frogs exhibit differences in time and call characteristics based on their habitat location. Those found on colder mountain peaks are larger than those in the warmer valleys. Those in mountain bases produced short, high-pitched calls at high rates while those in the peak had longer low-pitched less frequent calls. However, over two decades, the scientists found that the calls of every frog had become higher in pitch. The scientists also had to move higher up in the mountain to record calls with certain characteristics. They attempted to understand habitat shifts to temperature changes as a result of climate change. Lead researchers Peter Narins and Sebastian Wielandt worry that such temperature changes present could lead to a collapse of the coqui population and spell disaster for the Puerto Rican ecosystem.

Similar changes are being seen in other parts of the world. In Alaska, USA, warming temperatures are causing rapid changes to the inhabitants of wood frog’s habitat. Scientists used passive acoustic monitoring paired with some anuran detection of wood frog calling to create an accurate method for tracking changes in population-scale wood frog breeding. They found that less snow cover and warmer air temperatures are changing spring onset amounts and causing a decline in habitat availability for females. The scientists also suggest that the ability to effectively communicate much before us on the evolutionary timescale. Our work shows that anurans can convey contextual information despite having a limited repertoire. It also suggests that the ability to effectively communicate was likely present in the common ancestor of both species, enabling the families Rhacophoridae and Nyctibatrachidae. While we have made some significant discoveries, we are again at a point where we have more questions than answers. What do the females make of the different notes type? Are the different notes type intended to address both conspecific males and females? Is there a differential risk of predation to each note type and is that why some notes are rarely produced?

A NURAN VOCALISATION IN THE WESTERN GHATS

The Western Ghats is a renowned hotspot of biodiversity. Recent research has uncovered that there has been a long history of speciation in the Western Ghats. Despite the abundance of anurans and their vocalisations, existing studies were all limited to using vocalisations to identify species and use them as characteristics to describe new species. Anurans are facing the onrush of development and as natural spaces continue to be fragmented and destroyed, there will be cascading effects on them. Anuran vocalisations play an important role in how humans perceive natural landscapes as well. Those of us who have been around for more than two decades will recall the monsoon night filled with a cacophony of anuran vocalisations. Today, that has slowly been replaced by traffic noise or dreadful silence. With the loss of species, we are also going to lose out on the rich insights one can get by studying aspects such as animal communication.

Anurans can serve as excellent indicators of change. One could monitor anurans just like a teacher takes attendance. Listening and noting down when a species is calling over multiple years can give us incredible insights into how the anuran community is changing. There are several such efforts in the United States as well as Australia, where crowd-sourced data is being used to track changes. While there are some efforts at monitoring amphibians in India, there is a need to scale up the effort. Perhaps our work is one example that can inspire people and help them realise that there is more to anuran vocalisations. The next time you hear a sound in nature, pause, take a moment, and listen. There might be figurative pearls of wisdom that could help draw us out of the well of ignorance. If not, I am afraid, we may continue to remain a proverbial kappa mandosha – the frog in the well.


Sanctuary Asia, June 2024

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Both species, we annotated the calls to note types and compared them. To our surprise, we found that both species had a syntax in their vocalisation, and each note type had different probabilities. When alone, males of Nyctibatrachus humayuni were likely to remain silent if they were silent, to begin with, or produce one ascending note and then go silent. When in the presence of a conspecific male, the probability of a descending note following an ascending note was much higher. In contrast, however, the descending note following an ascending note was much higher. In contrast, the note was much higher. In contrast, however, the descending note following an ascending note was much higher. In contrast, however, the descending note following an ascending note was much higher. In contrast, however, the descending note following an ascending note was much higher. In contrast, however, the descending note following an ascending note was much higher.