The Special, Spatial Lives Of Amphibians

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Tiny Forest Pathways

On a rainy night in the dense evergreen forests of Sirsi in the Western Ghats, my team and I (Deyatima) were engrossed in tracing a blue-eyed yellow bush frog's call, when we were distracted by an unfamiliar call. Curious, we followed the source and came upon two frogs sitting in close proximity, about a foot above the ground. Chances were, this was either a male and female, or two males. However, it was rare to find two males in the same tree that close and not engaged in a tussle. Further investigation revealed a cluster of tiny eggs glued to a leaf few inches above the "parent" frogs. Evidently, they were guarding their eggs against the owner of the unfamiliar call, which came from the same species as the pair. I wondered how these tiny frogs were not lost or confused, because we were in a complex habitat with dense, evergreen trees that made it difficult even for our research team to locate previously identified study sites at night.

Frogs are proficient in using egocentric (right turn/left turn), visual, and spatial cues. Edward Tolman in 1948 first explained that animals have a 'map' of their surroundings, which allows them to select the correct route while navigating. Most of the tasks performed by animals in the wild such as mate choices, foraging, and escaping from predators, include learning about their physical environment, and can be collectively grouped under 'spatial learning'. Learning about one's immediate environment requires associating some features with conspicuous cues and memorising them to navigate back to the correct place (a territory or a brooding site). Whatever the underlying mechanism, pathfinding entails spatial learning.

Blue-eyed yellow bush frogs, endemic to the Western Ghats, have been recorded only from the state of Karnataka. **Photo: Angad Achappa/Sanctuary Photolibrary.**

How Amphibians Navigate Space

Amphibians show surprising navigational skills while parenting, in which either or both the parents invest in post-mating activities such as guarding eggs, tadpoles or young ones. In amphibians, females exercise mate choice, therefore sexual pressure is mostly exerted on males. This often results in males showing territoriality and parental care and playing the role of 'Mr. Mom'. Such selection can influence an animal's ability to learn and remember information flexibly.

The Western Ghats evergreen landscape has unique bioclimatic conditions and geography, which have given rise to an astounding diversity of amphibians and reptiles. The continued discovery of new species from this landscape highlights the need for urgent conservation measures. **Photo: Publid Domain/Pooja Rathod.**

Parental Care in Amphibians

Kentwood D. Wells in his book *The Ecology and Behaviour of Amphibians* describes eight parental caring acts – egg attendance, egg transport, egg brooding, tadpole attendance, tadpole transport, tadpole brooding, tadpole feeding, and froglet transport. Apart from these, there is also evidence of nest-building in some species.

Parental care is widespread in amphibians and is seen in 22 of 55 families and roughly 10 to 20 per cent of all species. Some frogs demonstrating parental care include poison dart frogs *Dendrobatidae* in Central and South America, common coquí *Eleutherodactylus coqui* in Puerto Rico, Microhylid frogs in Papua New Guinea, Aromobatid frogs in Peru and French Guiana, La Palma glass frog *Hyalinobatrachium valerioi* in Costa Rica, *Rohanixalus hansenae* in Thailand and night frogs *Nyctibatrachus sp.* in India. Male night frogs *Nyctibatrachus kumbara*, endemic to the Western Ghats, stand on their hind legs and pack mud on the laid eggs to keep them moist and camouflaged from potential predators. Tree frogs *Rachophorus sp.* make foam nests and protect their tadpoles after the female departs. The male bubble-nest frog *Raorchestes chalazodes* has been observed near bamboo reeds. They enter the bamboo through a small slit to cater to their offspring while evading

the predator's vision. Females of most of these species mate and deposit eggs within male territory and desert them soon after.
India, especially the Western Ghats, has the maximum diversity of frogs, most of which are understudied. Given this diversity, there are reports of various forms of parental care including territoriality, nest-building to nurture offspring, egg protection from predation or desiccation, guarding the tadpoles and eggs, and more. However, tadpole transport has not yet been described for any species. Nevertheless, spatial learning is present in every frog species, and they exhibit it in myriad ecological contexts.

Differing Needs

Females require spatial learning mostly to return to the best males, while comparing potential mates from a selection of competitors engaged in a display. Females move from one male to the other as they are polyandrous (able to mate with more than one male), while males are more territorial. The part of an amphibian's brain known as the mammalian hippocampal homolog is active during the period of parental care, and it is associated with learning and memory. On my field survey in the Western Ghats, I was surprised to find blue-eyed yellow bush male frogs in the same tree for five consecutive days, one male per tree. These trees were possibly ideal locations to call for females. Additionally, if any of the males had a female with it, the pair would be found together in the same tree the next day as well. This is an admirable demonstration of the extremely detailed map they form of their habitat, in this case the tree where they would raise their offspring in the near future.

Males can return from distances of almost 800 m. when they are displaced from their home territory, following a direct path with high orientation accuracy. This ability comes with experience i.e. familiarity with cues around their home range. Thus, frogs navigate using a 'spatial map'. Males of Savage's Cochran frog *Centrolene savage* have a higher tendency to return home to care for their babies rather than unmated males. Finding their way back is also related to finding their own territory, including 'calling sites' that ensure female attention. After tadpoles hatch in terrestrial microhabitats such as leaf litter, male poison dart frogs carry their babies on their backs and transport them to temporary water pools to deposit them. Fathers do this without prospecting the surrounding because they rely on their spatial memory and experience of the pool location. They can remember and identify up to six deposition pools, using place cues. They can differentiate their own tadpoles from others based on spatial location. A study in 2017, led by Kristina B. Beck, a postdoctoral researcher at the University of Oxford, found father frogs to be stationary near pools that were removed recently. While in 2016, Andrius Pašukonis, Senior Researcher at Vilnius University, and his team observed male frogs revisiting pools even after two months after they were removed. This confirms the presence of spatial memory.

Male poison dart frogs carry tadpoles on their backs and transport them to temporary water pools to deposit them. When the distance is further away, fathers carry more tadpoles per trip to reduce travel time – somehow, they even anticipate the travel distance. **Photo: Jason Brown.**

Father frogs who have to transport their tadpoles safely to a pool need to be well informed about the nature of the deposition sites; these pools need to provide hydration long enough for the tadpoles to develop while being ephemeral enough to avoid predators. Such precise judgement each time they travel to deposit their babies indicate they are capable of recognising some positional cues near the deposition sites. What they actually do is create a navigation map by integrating the olfactory, visual, acoustic, and magnetic cues. These are referred to as 'sketch maps'. More time to travel and explore pools can dehydrate the tadpoles or attract predators, and they also run the risk of losing their own territory if kept unattended for long. Referring to the roadmap helps in accomplishing the task efficiently and is less time-consuming. Quickly relocating to an already familiar pond is the best strategy that improves the reproductive fitness of the species. They can even learn, unlearn and relearn spatial cues. Learning and acquiring information while traveling makes decision-making more reliable. Male frogs might be updating their knowledge about their area while traveling and returning home during tadpole transport. When the distance is further, fathers carry more tadpoles per trip to reduce travel time – somehow, they even anticipate the travel distance. Such spatial knowledge in due course of time can lead to stronger selection for spatial memory and improve flexibility for more efficient detours. The cognitive faculties used by amphibians include vision and olfaction. In an experiment conducted by the University of Vienna, parent frogs displayed highly oriented movement that brought them to suspended buckets with tadpoles from a distance of 10 km. While in another study with the Zimmermann's poison frog *Ranitomeya variabilis*, frogs avoided depositing offspring with cannibalistic conspecific tadpoles based on olfaction. However, learning is not that easy. The

time and energy spent on exploration can be costly in that it affects other fitness-related activities such as territory defence, advertising for mates, and exposes amphibians to sit-and-wait predators.

Mud-packing behaviour displayed by the Kumbara night frog is a unique behavioral aspect, unrecorded in any other frog species in the world. Males dab mud and sand on the laid eggs to to prevent their predation and dessication. Nyctibatrachus kumbara*, comes from the word kumbar in Kannada, which means potter, a person who shapes mud into pots.* **Photo: Dr. K.S. Seshadri.**

More Unique Strategies

The Indian bubble-nest frog has another interesting strategy. Unlike poison dart frogs, a father bubble-nest frog does not desert the babies after they are translocated to a suitable pond. Rather, they continue guarding their tadpoles. Their breeding site is also unique – a hollow internode bamboo. Fathers are very particular about their brooding sites; the bamboo they select (*Ochlandra travancorica*) for the eggs are endemic to the Western Ghats. We have no information about why these fathers only choose endemic bamboos, or how they assess their quality as a home for their offspring. Further, they look for bamboos with a small slit, so small and thin that it is nearly impossible to believe it is used as a pathway! Father frogs squeeze their bodies through the slit with extreme agility to attend to the eggs. What spatial cues allow the father frog to select such breeding sites and how this father remembers which bamboo shoot to return to in a dense and diversely vegetated patch is no less than a mystery. We also have no idea how many such dedicated frog parents are doing their daily chores to ensure the survival of their species.

Bubble nest frogs prefer the endemic bamboo Ochlandre travancorica to lay their eggs. A male frog is observed guarding eggs inside the hollow of the bamboo stem. **Photo: Dr. K.S. Seshadri.**

The deeper I venture into forests, the more I am amazed by the innumerable instances of animal intelligence in nature, and amphibians are only one such example. They show fantastic evidence of the evolution of the forebrain, and the related complex cognition that was necessary for a transition from aquatic to terrestrial life.

The discovery that small animals like frogs have a spatial understanding of their surroundings should make us ponder the implications. Tropical regions like India and other neotropical regions are rich in amphibian diversity and are also threatened by rapid habitat transformation. Many Indian species of amphibians display parental care. Since parenting influences offspring survival and reproduction, parental decisions often impact reproductive success and population dynamics. What happens to their cognitive abilities with the rising threats from deforestation and habitat loss? How does that impact or improve cognitive maps and how can that eventually impact population dynamics? Updating our knowledge about the cognitive cues they use to navigate, select breeding sites, tadpole deposition pools, and to make many other such decisions can help in crafting better conservation action plans.

Male poison dart frogs carry tadpoles on their backs and transport them to temporary water pools to deposit them. When the distance is further away, fathers carry more tadpoles per trip to reduce travel time – somehow, they even anticipate the travel distance. **Photo: Public Domain/John P. Clare.**

I am certain of one thing: there is still so much more we need to explore to unravel the secret lives of amphibians.

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