Exploring Freshwater Science

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Freshwater ecosystems and associated habitats harbor incredible biodiversity. They offer various ecosystem services and sustain human livelihoods. However, due to increasing developmental pressure and rising water demand, these systems are under huge threat. As a result, many aquatic species are feared to become extinct in near future. Quantifying the patterns of aquatic species diversity and composition of river systems is urgently required. With this interest, we studied four river systems in the Western Ghats region, documenting the pattern of fish diversity and identifying the factors that influence fish species richness. Maintaining undisturbed streams and river basins, especially headwater regions is crucial for sustaining freshwater biodiversity in the tropical river ecosystems.

Freshwater Ecosystems - Most Threatened on Earth

The causes and consequences of freshwater habitat declines are multifaceted. But efforts to revive these habitats are minuscule in the country. Freshwater scientists opine that ecological studies can pave the way to restore these habitats by enriching and bridging the knowledge gaps on data deficient taxa. Systematic and long term studies on mapping freshwater biodiversity[1] can enhance our understanding regarding species in modified and unmodified habitats, and assess their current as well as future population status. Previously, scientists have conducted many studies and they have systematically reported the biodiversity of our freshwater habitats. However, many of these efforts have resulted only in creating species lists of study areas. Even today, we lack a complete ecological and behavioural understanding of many freshwater groups.

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With increasing population and developmental pressure on freshwater ecosystems, studies that directly quantify and link threats with ecology are much needed. It is broadly recognized that tropical river systems are complex entities due to the very nature of their size, amount of discharge and diversity of habitats and species they harbour. Due to their inherent hierarchical nature of spatial organization[2], managing river systems is often a difficult task [1]. Water abstraction done by upstream inhabitants will have severe negative impacts on downstream inhabitants, even though they are separated by hundreds of kilometers. When it comes to the taxonomic assessment of tropical freshwater taxa, almost every year, scientists are discovering new species. These discoveries suggest that still, a lot more work needs to be done in this field. Many ecologists agree that tropical regions have higher speciation rates[3] as compared to temperate regions. There are few plausible hypotheses for this that demand good attention. One is that tropical regions harbour diverse habitats and allow dispersal[4]. These habitats have not undergone any profound changes unlike higher latitudes of temperate regions in the Northern world, which has seen ice age. The ice age disconnected and isolated large areas. Animals and plant groups could not recolonize such areas and as a result, the speciation rates are lower here.

[2] River habitat is nested within a river stretch which is nested within a stream, which in turn is nested within a large river system.

[3] The rate at which new species are formed.

[4] Dispersal refers to movements of individuals from their birth site to their breeding site.

The hierarchical nature of stream organization offers opportunity to ecologists to ask diverse and interesting questions at various scales. For instance, how freshwater communities are organized at different spatial scales? What are the factors that determine their distribution? Does the species assemblage[5] change among different habitats?, etc.

[5] The smallest functional community of plants and animals.

Freshwater constitute a tiny fraction (less than 0.001%) on the surface of the earth, yet it holds extraordinary aquatic biodiversity. Species that are intolerant to salt and complete their life cycle exclusively in the freshwater environment are called as freshwater species.

Spatial organization from headstream region to downstream region also gives rise to different types of habitats along the river gradient. Broadly, there are four major habitats in river ecology (*Figure* 1). They are: (1) *Run* – a stretch of few meters in a river which has no turbulence and has medium to high water velocity, (2) *Riffle/Rapids* – stretches with stones and pebbles made turbulent by water of medium to high velocity, (3) *Cascades* – small

Figure 1. **(a)** Pool - standing water with less water current. Many *Puntius* sp., *Pethia* sp., and *Garra* sp. are known to occur in such habitats **(b)** Run - a stretch with gentle flow. *Salmophasia* sp. and *Dawkinsia* sp., are found here **(c)** Riffle - river stretch with turbulence, also called rapids. *Barilius* sp., *Bhavania* and *Homaloptera* sp. are found in such habitats **(d)** Cascade - a small waterfall abundant in the headwater region. *Bhavania* sp. and *Balitora* sp. are generally found here.

waterfalls and (4) *Pools*– stagnant water with minimal or negligible water current.

Once we are familiar with these special river habitats, then it becomes easier to focus on the types of organism that dwell in them. Notably, otters, fish, turtles, crabs, molluscs, odonates, caecilians, water snakes, macroinvertebrates, etc., comprise some of the major freshwater taxa. If you turned a stone in a stream bed, you will notice that it either has an algal carpet or aquatic insects that are crawling on its surface. These are stream macroinvertebrates: a freshwater group that still requires a lot of taxonomic and ecological study. Since they are considered biological indicators [2], even basic information on their identification, abundance and distribution are vital. Many freshwater fish primarily feed on these aquatic insects. Hence the presence of particular insect groups determines the presence of particular diet guilds of fish. In relatively undisturbed hill streams of the Western Ghats, the diet of some of the hill stream fish such as *Homaloptera* sp. and *Bhavania* sp. consist of aquatic insects and detritus.

Fishes are one of the most diverse group of vertebrates occupying almost every niche, ranging from hot water springs, estuaries, rivers and lakes to streams, pools and wells.

Field Notes

A closer observation of a fish will tell you the type of habitat it prefers to dwell in. For instance, a slender and longer bodied fish would often be found in running water since its body is adapted to flowing current. Such fishes are called rheophilic

or flow loving. Any hydrological modification that alter stream flow would first imperil such fish species. Examples are Deccan mahseer (*Tor khudree*), Malabar danio (*Devario malabaricus*), *Hypselobarbus* sp., razor-belly minnow (*Salmophasia boopis*), etc. A fish with flat or round abdomen often tends to occupy bottom areas, and are hence called eurytopic or bottom dwellers. They are pool loving species which can withstand inadequate oxygen supply, disturbance to a large extent and tolerate some amount of pollution. Many catfishes belonging to *Mystus* genus, comes under this group.

Interestingly, based on the type of mouth, fins, etc., one can tell a lot more about the biology of the fish. If the mouth of a fish is terminal,[6] it means that the fish is primarily mid-column dwelling (e.g. *Tor khudree*). Similarly, if the mouth is slightly inclined towards the upper surface then it is a surface-dweller since it prefers higher dissolved oxygen (e.g. *Salmophasia boopis*), while a bottom-dweller fish might have its mouth positioned downward. Due to such sectorial mouth adaptations, some of the bottom-dwelling fishes have easily adapted to torrential hill streams habitat [3, 4]. *Garra mullya* from the rivers of the Western Ghats is one such example.

[6] Mouth is located at the upper anterior-most part of the head with upper and lower jaws of equal length.

River ecology in India is a grossly neglected and an often overlooked subject. Inspired by the numerous Himalayan rivers, and the diversity of habitat and aquatic species they support, we decided to pick this thread in the web of ecology to better understand rivers and pursue our passion. We studied four river systems in the Western Ghats to understand ecological and anthropological factors influencing fish species diversity. These were Bhadra, Tunga, Malaprabha and Mhadei in the states of Goa and Karnataka. Bhadra and Tunga rivers are considered relatively less disturbed systems (lack of hydrological barriers) and Malaprabha and Mhadei are more disturbed systems due to numerous barriers. Mhadei is the only west-flowing river among the four rivers that we studied. Before initiating our fieldwork, we first collected Survey of India toposheets, digitized stream network for each river system and then delineated sub-basin boundaries using

Figure 2. **(a)** Cast net **(b)** Mosquito/seine net **(c)** Dragnet **(d)** A bamboo net **(e)** Measuring water velocity with the help of pygmy current water velocity meter **(f)** Water quality measurement in the field (dissolved oxygen, calcium hardness, pH, conductivity and water temperature).

Geographical Information System (GIS) tools. For fish sampling, we have used locally available traditional fishing gears such as cast net, dragnet and bamboo traps (*Figure* 2). Some of the unmodified river habitats can offer insightful observations such as species-habitat relationship, prey-predator interactions, etc. To understand such ecological processes better, it is highly important to leave rivers and streams undisturbed. We narrate two such field observations from the relatively undisturbed river habitats in the Western Ghats region.

It was mid-February, the end of winter. As was routine, we were accompanied by our field assistant Laxman and were sampling for freshwater fishes. We were sampling Karkan halla - a stream situated deep in the Kudremukh National Park. At one bend, a huge *Elaeocarpus* tree had fallen down in the stream. Many colourful barbs such as *Puntius*, *Dawkinsia* and *Rasbora* were sheltering in the fallen branches and some were nibbling on *Elaeocarpus* fruits. A small Indian civet had deposited fresh droppings (fishtail palm seeds) on the fallen log. The whole stretch was covered with pebbles, stones and dry leaves. As we marched slowly towards our next sampling location, Laxman showed us a pair of large predatory fish called the great snakehead (*Channa marulius*, local name - Aauul meen) guarding their brood of hundreds of fry (babies) along the stream edge. This fish can grow up to 180 cm long and are known to feed on a variety of animals like frogs, snakes, fish, insects, earthworms, tadpoles, rodents and even water birds [5]. The male had scattered spots all over his body, slightly bluish

Figure 3. **(a)** Checkered keelback water snake (*Xenochrophis piscator*). **(b)** A caecilian (*Gymnophiona* sp.). **(c)** Deccan mahseer (*Tor khudree*) – an endangered fish, native to Western Ghats region. **(d)** Bombay labeo (*Labeo porcellus*) – a carp first described from Bombay in 1884 by Heckel. **(e)** Goan catfish (*Ompok malabaricus*) – a rare fish. **(f)** Fringe-lipped peninsula carp (*Labeo fimbriatus*)- despite wide distribution, its wild population is declining due to pollution and over harvesting.

fins, and bright yellow eyes. Since it is a bottom-dweller fish and is known to prefer deeper pools, it is often difficult to spot. Parents guard their babies for about a month [5]. It requires extraordinary effort to catch this fish. Another interesting sighting was in Munje stream in Tunga River. While we were making a sketch of the stream bed in the field notebook, we spotted a checkered keelback (*Xenochrophis piscator*), a common water snake (*Figure* 3), looking for prey in the stream bed, close to our feet. Within a few seconds, it caught a caecilian (*Gymnophiona* sp.) in its mouth and twisted it around for few seconds before eating it. Caecilians are a group of limbless, serpentine amphibians. They are mostly found in the leaf litter and are hidden in the ground (*Figure* 3). Not much is known about their biology. All this happened in less than a minute! Such moments, we believe, are precious and only possible in relatively pristine streams.

Degrading Freshwater Systems

At the end of three years of fieldwork, we have found that stream order (5th and 6th)[7] and water quality variables (calcium hard-

[7] It is a measure of stream size. A stream size of 1st order is a trickle that originates in the headwater. When two 1st order streams join they become a 2nd order stream. Two 2nd order streams will become 3rd stream order and so on.

Figure 4. **(a)** Inter-basin canal construction near Kankumbi in 2011 (now completed). **(b)** Shows the growth of bracken fern (*Pteredium* sp.) along with Siam weed (*Chromolaena odorata*) in the Kudremukh National Park (KNP). **(c)** River sand mining at Kerekatte in KNP. **(d)** Invasive fish species from Khanapur fish market (rohu, catla). **(e)** New barrage under construction at Ustem in Mhadei. **(f)** Polluted stretch near Habbanhatti temple in Malaprabha.

ness, dissolved oxygen) are the main governing factors that influence fish species richness and distribution.

Today, water bodies across many regions are degrading and this trend is increasing without clear scientific understanding. The once, fresh, clear water of lakes and ponds is now murky, stinky and polluted. How can animal and plant life survive in such environments? Sensitive and habitat specialist species cannot tolerate such changes and they either die out or are replaced by other more tolerant and invasive (often non-native) species. Apart from these threats, freshwater systems are losing their aesthetic value (*Figure* 4). Who would want to wade through dirty water! Today avid anglers often travel great distances, to remote places deep in the forests in search of relatively pristine river stretches; and fisher folk is having to travel great distances to earn their daily livelihood in many parts of the country.

> Sensitive and habitat specialist species cannot tolerate environmental changes and they either die out or are replaced by more tolerant and invasive species.

For instance, fisher folk in Malaprabha river sub-basin in Khanapur taluk of Belgaum district travel daily up to a distance of 40 km upstream to fish. The river stretch near Khanapur has become increasingly polluted due to water abstraction and sewage generated from Khanapur town, and, as a result, fish catches have

been declining steeply. Many large bodied (weighing 4–5 kg) fish species such as *abher*, *kanagi*, *sumat*, *ghogari*, *khadasha* and *mangor* (mostly belonging to Cyprinidae family) seems to be extinct locally. Today fishermen mostly get only small sized fish. The situation of fishing communities living in the Dabhol estuary in Ratnagiri district of Maharashtra is even worse. Here, twenty years back, fishermen used to harvest heaps of fish (up to 2–4 kg) in just a few hours but now they are struggling to find even minuscule catch. The reason behind such declines are the ever-sprawling chemical industries in and around Chiplun town. Packs of smooth-coated otters (*Lutrogale perspicillata*) – a predator in river systems used to be a common sight for fishermen until a few years back. But their population has drastically reduced to just one or two individuals now. We were told by the fishermen that otter sightings used to be common near the stream confluences where the fish catch is usually higher. Many surface-dwelling fish occupy these crucial habitats and even if you randomly lay fish net at such confluences, fish catch is relatively high. We visited a couple of such confluences to try our luck for otter sightings but neither did we see them nor did we find their spraints (faecal matter).

Population of smooth-coated otters, along with fresh water fishes have drastically declined over years.

The situation in Kumta taluk in Uttara Kannada district is equally worrisome. Luckily, this coastal taluk is blessed with four major rivers (Sharavati, Bedati, Kali, and Aghnashini) that ultimately feed into the Arabian Sea. However, since the last couple of years, fish catch and mussel/clam production in this area seems to be declining due to over harvesting; clam being one of the most favoured coastal food. Fortunately, now there is an attempt to revive clam population. Bivalve seeds are being brought from the backwaters of Kerala and planted in the Aghanshini estuary.

Presently, traditional fishing gears are slowly being replaced by large commercial trawlers that literally scrape the bottom of the sea and catch almost everything. As a daily practice, catching even small bodied fish near estuarine water now has become rare. Fisher folk now have to spend days and nights together, far way in the sea to make a good catch. Among the four rivers, Aghanashini

is the most productive river system and supports and sustains livelihoods of millions of fishermen [6]. There is also growing fear amongst the fishing communities about the port development at Tadri village. The existing Tadri port is soon going to be revamped by the authorities for enhancing freight, cargo and fishery production about which there are mixed feelings among local communities.

Flow Regime-Species Relationship

Maintaining natural flow regime and associated biogeochemical and sediment fluxes in any river system is a key aspect of river ecology management. Populations of fish which are sensitive to flow conditions are known to decline due to the effects of hydrological barriers [7]. These barriers have homogenized running river habitats (i.e. runs) into stagnated ones (i.e. pools). Species that respond to natural flow generally have a long and cylindrical body shape. Our field observations suggest that species such as *Salmophasia boopis*, *Devario malabaricus*, etc., fits into this category. They are particularly agile and known to show preference to sites with higher dissolved oxygen concentration. As a result, one can easily encounter a good number of these fishes in any natural, unregulated river compared to regulated rivers. An impoundment or barrier is known to drastically reduce water connectivity downstream. A shallow trail of water gets heated up quickly, thereby depleting its dissolved oxygen concentration, hence changing the species composition [8].

Populations of fish, which are sensitive to flow conditions are known to decline due to the effects of hydrological barriers.

If a particular habitat in a river stretch is lost, fish may find new habitats if connectivity is maintained between the main channel and its tributaries. It is well known that dams have immediate as well as long-term impacts on fish species composition [9, 10]. There is an urgent need to design future projects to minimize negative impacts on freshwater ecosystems and to manage existing ones, improving ecological connectivity. Rigorous scientific studies, integrating knowledge from different disciplines is perhaps a way forward to protect some of the remaining free-flowing rivers.

Otherwise, there will be no difference between a man-made canal and a river. Should we allow our rivers to become man-made canals? The choice is ours!

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