Re-establishment of fish passage for conservation of threatened migratory species of Western Indian Himalayan river systems

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Abstract

Reestablishment of fish passage, including facilitating overcoming barriers presented by impoundments or restoration of defunct structures, is attracting interest amongst scientists and policy-makers as a mechanism to enable recovery of target fish species or fish communities. A diversity of multispecies fish passage designs are in place in North and South America, Europe, and Australia, with varying efficacy for different species. However, only a few such fish passes have been constructed in dams in the Indian Himalayan region, and their efficacy is largely unproven. Major problems associated with fish passage designs include uneven success across a range of species, and largely untested effectiveness at the large scale of many major dams. A new approach is therefore required to understand the operational drawbacks of the pass way, and to take an adaptive approach to both design and operational using field data to improve fish pass efficiency. These measures could contribute significantly to the conservation of threatened migratory fish in the increasingly impounded rivers of the Indian Himalayan region.

Background

Globally, artificial means promoting fish passage through man-made barriers such as dams have been designed and implemented since the late 1800s. In 1911, a “Fish Ladder” was constructed at Itaipana Dam on the Pardo River in Brazil, South America, to promote the passage of migratory river species (Pompeu et al. 2012); and a “Vertical slot” fish pass was constructed to conserve native fish populations at Queensland State in Australia (Jensen 2001). Clay (1995) reported that more than 37 fish passage designs had been constructed globally to promote the passage of a range of groups of fishes, including Cyprinids, Ictalurids and Salmonids. Similarly in England, the most commonly used fish pass design for Atlantic salmon (*Salmo salar*), sea trout (sea-run brown trout: *Salmo trutta*) and other anadromous fishes such as the sea lamprey (*Petromyzon marinus*) and shad (*Alosa* spp.) is the “Pool type” (Cardoso 2015). In Belgium, a diversity of types of fish pass have been constructed along the Lixhe hydroelectric dam on the river Meuse, supporting passage of the European eel (*Anguilla anguilla*), common bleak (*Alburnus alburnus*), tench (*Tinca tinca*), and Wels catfish (*Silurus glanis*), with reports of benefits for target fish species (Benitez 2015).

The Indian ichthyofaunal diversity comprises of over 2,500 species (Jayaram 1999), including over 900 reported from freshwater ecosystems (Talwar and Jhingran 1991). The Indian Himalayan region can be divided into the eastern and the western Himalayan regions. The western Himalayan region covers the states of Uttarakhand, Himachal Pradesh, and Jammu and Kashmir and contains over 120 fish species (Hussain 1995), a subset of the approximately 218 fish species (Sehgal 1999) recorded from the entire Indian Himalayan region. An estimated of 544 species of freshwater fishes occur in the warm waters of the Gangetic Plain, as well as 73 cold water and 143 brackish water fishes (Anon, 1992-93). Mahanta et al (2005) records 456 Plains fish species, 157 cold water and 182 brackish fish species. A study conducted revealed 133 fish species in Uttarakhand, 98 in Himachal Pradesh, 107 in Jammu and Kashmir (175 species altogether in the Western Himalaya); and out of 346 fish species (the Himalayan region), 273 were reported from the North-East Himalaya. Furthermore, 193 fish species were restricted only to the Himalayan region, and not found in other highland areas of peninsular India (Nautiyal and Singh 2009; Nautiyal 2010).

The Himalayan fish fauna has many specialized elements, in particular its adaptations to episodic torrential flows during monsoon rains. Any change in the flow (volume, current velocities and local variability of both) and connectivity of rivers has the potential to deprive these specialized fishes of the basic requirements necessary to maintain a flourishing population, potentially threatening the long-term viability of fish populations. A large number of Himalayan fish species are essentially cold water species, inhabiting glacier-fed perennial rivers such as the Tons, Yamuna, Bhagirathi, Bhilangana, Alaknanda, Dhauli Ganga, Mandakini, Nandakini, Pindar, Goriganga and Sharda as well as a number of perennial and seasonal tributaries. These rivers comprise a variety of suitable habitats (pool, run, riffle, etc.) supporting minnows, loaches and cat fishes (Das and Dijik 2013), and also serving the refuge, spawning and feeding needs of various other potamodromus fishes (Dudgeon 2006).

Impact of existing dams in the western Indian Himalayan region

A rapid survey of rivers in the western Himalayan region revealed an abundance of fish species including common snow trout species (*Schizothorax richardsonii*, *S. plagiostomus, S. progastus, S. esocinus, S. niger*) as well as rapidly depleting mahseer species such as the golden mahseer (*Tor putitora*) and red-finned mahseer (*Tor tor*), and other less common/abundant species stone roller (*Crossocheilus latius*), sucker head (*Garra gotyla*), Indian hill trout (*Barilius bendelisis*), Kalabans (*Bangana dero*), *Pseudechenis sulcatus* and *Glyptothorax spp*. among others (Gupta et al. 2015; 2017). However, artificial obstructions to the migratory routes of certain fish species has restricted their upstream migration, preventing access to spawning and nursery grounds contributing to a decline in their populations due to impaired recruitment and other adverse impacts on the aquatic ecosystem (Rao 1979; Carl 2007). These factors have knock-on detrimental impacts in terms of conserving genetic diversity in areas threatened by reduced fecundity, as well as inhibiting the attainment of maximum growth in the population (Larinier and Marmulla 2004; Dupont 2015).

Whilst dams are seen as essential for strengthening regional economies and for maximizing land cover under irrigation and generation of electricity (Richer and Thomas 2007), their construction nevertheless presents a global conservation issue (Everard, 2013). One option is to pay greater regard to the sensitivity of both the design and operation of proposed dams early in the planning stage and adaptively throughout operational life in terms of their potential and observed impacts upon adjacent aquatic and terrestrial ecosystems, seeking to mitigate potential environmental degradation. There is consequently a growing demand among freshwater scientists that habitat restrictions for fish imposed by dams need to be overcome, with fish passes representing one potential solution to maintain longitudinal connectivity as a means to protect or assist restoration of fish migration and population (Dupont 2015).

Fish passes

Fish passes are not a novel concept in India. Since the early 1890s, a number of such passes were constructed along the Ganges River at Haridwar, Uttarakhand and over the Yamuna River at Tajewala, Haryana. However, their effectiveness has generally been debatable, and commonly not assessed post-contruction. The Hathani Kund barrage on the Yamuna, Haryana, was constructed in 1999, equipped with a Denil-type (or baffle-type) fish pass and was found to be beneficial for the upstream migration of the golden mahseer (Larinier and Marmulla 2004), and Endanger species on the IUCN Red List (Jha and Rayamajhi, 2010). Recently, more fish passes have been constructed in the Western Indian Himalayan region, including for example the Larji Hydro Electric Project on the Beas River in Kullu, Himachal Pradesh. However, issues such as insufficiently submerged fish ladders, presence of debris in baffles, and improper ladder steepness have been described as compromising the effectiveness of the Larji Hydro Electric Project fish pass (pers. comm.). The Uri hydropower project in Jammu and Kashmir also has a pool-type fish pass for snow trout species, some of them variously assessed as Vulnerable or Endangered on the IUCN Red List, though utilization of the fish pass is poor in terms of the numbers of fish attempting to move upstream. A Denil-type fish pass was constructed on the Mahanadi River, Orissa. Downstream of the Indian Himalayas, In the Farakka barrage over the Ganges River in West Bengal, "fish lock" type passes were constructed to address the migratory requirement of the giant river prawn (*Macrobrachium rosenbergii*) and Hilsa shad (*Tenualosa ilisha*), both assessed as Least Concern on the IUCN Red List, though unfortunately technical requirements and structural limitations led to unsatisfactory fish migration through the impoundment (CIFRI 2007). In the Indian Eastern Himalayas, the Government of Arunachal Pradesh recently signed a Memorandum of Understanding (MoU) and Memorandum of Agreement (MoA) with India's Central Inland Fisheries Research Institute (CIFRI) in Kolkata for making provision of passage for native fish species at upcoming power projects in the state (The Economic Times, 2015).

Way forward

To maintain or promote the regeneration of fish populations in the Indian Himalayas, foresight in planning and an adaptive approach to ensuing management are important considerations before a fish pass is sanctioned and constructed on any dam construction project. This d foresight needs to take full account of fish species present and likely to be affected, their distribution, identification of critical phase site of life cycle, and determination of the cruising burst speed of each fish species (Theophilus 2014). Fish pass design has then to be tailored to the needs of multiple potentially affected species. Additionally, it has been observed that alternate solutions such as Eco Hatcheries on dams support only commercially important fishes like brown trout, and have little or no beneficial impact on species conservation in general. Artificial stock rearing practices also have limitations in terms of sustaining localised genetic variability, with difficulties observed in maintaining the population of catfishes, cyprinids and loaches through such practices (SANDRP 2012). Stocking of fish species in reservoirs to enhance production needs to be viewed with great caution (now also accepted by senior and retired fisheries scientists in the region), and such practices should not overlook the associated conservation issues in the region.

It is therefore vital that Government-authorized institutes and authorities study the requirement of native fish species near a dam site, and establish baseline data before suggesting the optimum fish pass type, ladder length and water speed to be maintained at fish ladders (SANDRP 2014). With multiple upcoming and proposed hydropower projects in the Indian Western Himalayan region, such an approach could be critical, supported by other relevant conservation strategies, for the protection of the threatened migratory fishes here. Simply assuming that a fish pass will work in any given setting is insufficient. There should be a record of the fish species that are able to negotiate such passes successfully, particularly vulnerable target species (snow trout, mahseer) that need to be conserved. All such structures should also ideally have installed monitoring technologies to count individuals of various fish species ascending and descending through them, data invaluable for improving both design and operation through an adaptive rather than a 'fit and forget' approach. Record from these counters should be screened by trained fishery scientists, ideally from nearby research institutions (Universities/Agriculture Universities/Fishery Institutes), to evaluate the performance of the fish pass, or in order to make it more transparent, with data made publicly available on websites with notifying emails to concerned institutions.

There is also a need to address additional critical operational issues in the region. The authors have been informed that persons in-charge of operating fish passes have been approached by 'poachers' to allow them access to the fish pass ways to set up traps and capture the ascending fish. Lack of knowledge about aquatic biodiversity in general, their role in the ecosystem, threats to biodiversity, the concept of endemic species, specialized fish species, threatened and endangered fish species, and a range of other factors have led to such poaching situations in the past exploiting fish clustered as they await passage. As a result, there have been cases where many brooders below the pass ways were killed in large numbers, resulting in fish researchers and scientists across India suggesting that fish passes should not be installed. This is an extremely worrying sign, and more awareness and education drives need to be conducted among the local fishing communities and hydropower people (not just barrage and dam operators). Also, accountability for such activities needs to be established to avoid such activities in the future. There is significant study elsewhere in the world of appropriate protection zones upstream and downstream of fish passes to prevent the exploitation of vulnerable, crowded fish populations waiting to ascend or descent fish passes, and this should be interrogated to inform relevant local management.

At present, there are not routinely applied mechanisms to checks on water discharge through fish passes, as flowing water is often viewed narrowly as a profitable commodity utilized for power generation. The required ecological flow of water through fish passes, bypassing hydropower plants, need to be maintained as it is extremely important for passing fishes downstream. Additionally, in-depth field research is required to understand the swimming dynamics and existing fish habitats in wake of the increasing anthropogenic threats and changing climatic variables for most of the species in the Indian Himalayan region. Further, responsibilities to manage these fish pass ways in an ecologically-friendly manner warrants the fixing of responsibilities on designated and accepting institutes/agencies by the Government. This will ensure that the onus lies on a particular authoritative body, and targeted and accountable approaches are ensured by them.

Addition issues of fish pass and dam design and operation beyond the scope of this brief review paper include the importance of siting of fish passes and adequate flow of water through them to maintain an 'attraction flow' for migrating fish (Silva et al. 2018), as well as closer emulation of dam releases to maintain downstream habitat and associated fish and other aquatic communities (Cross et al. 2011).

Existing institutions and agencies therefore need to be sensitized regarding the benefits of fish conservation, and the importance of fish migration for aquatic food webs. These basic, first steps represent building blocks towards a more nuanced and prioritized approach to local conservation efforts, and should be promoted vociferously by authorities with mandates for promoting aquatic biodiversity protection and conservation. Currently, there is a reluctance among concerned agencies as they claim to only have jurisdiction over water, but not on aquatic biodiversity. Above all, there is a requirement for the setting up of a monitoring and evaluation committee which can ensure that actions are happening on the ground, and one which can monitor its progress and sustainability. Summing up, although the conservation journey seems long, addressing the adaptive design and operation of fish passes may be a significant element of a longer-term culture change with respect to sustainable exploitation of India's Himalayan rivers.

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