Some thoughts on a visit to the fish-ladder at Kurichhu hydropower project, Bhutan

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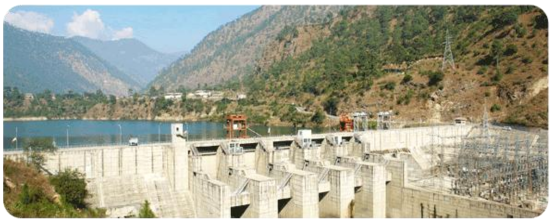
While hydro-power is projected as clean energy, there is sufficient evidence to the contrary, on various counts. One of the major concerns about hydropower projects, is that the dams, whether they be impoundment dams or diversion dams (the latter going under the misleading euphemism nowadays of run-of-the-river structures), critically fragment a river. Regulation and release of water at extreme lows (often nil) and sudden releases apart, dams are an impassable barrier for migratory fish, progressively depleting populations past critical thresholds, eventually leaving rivers bereft of life. Dead rivers affect not only the freshwater aquatic realm, but also all terrestrial life dependent on rivers, including large human populations. The impacts are known to cascade down the entire river continuum down to the oceans. Not only does such river regulation have serious political implications in terms of equity and justice between proximate and faraway users, but far-reaching cultural repercussions as well.

Kurichhu Fish Ladder Photo: Authors

In the on-going discourse on the large-scale build-up of hydro-power projects in the Himalaya, which will soon be the most densely dammed region on earth, one encounters proposed part-solutions, often billed as mitigation measures. Ofcourse, every attempt at addressing the serious problems created by hydropower projects is desirable and welcome. However, which of these actually mitigate or provide solutions to the problems created by hydro-power projects, and which of them only serve to provide camouflage from public gaze, or a cover of legitimacy for mandatory approvals, does require to be looked at more closely.



Kurichhu Project Photo: Druk Green

We have been hearing for long about fish passes of various designs constructed on hydro-power dams in the US and in Europe, to allow the passage of many species of migratory fish, to travel to their breeding grounds in distant mountain rivers. None of the numerous hydro-power projects under construction in Uttarakhand have incorporated any provision for the passage of seasonal migratory fish, and this is puzzling. How are hydro-power projects cleared on environmental grounds and approved despite their disastrous impact on fish movement and subsequently on fish populations?

One instance of a proposed mitigation measure is what was proposed by WAPCOS for NTPC's Rupsiabagar-Khasiabara HEP in the Gori river basin where we live. While the project has recently been denied Forest Clearance for diversion of forest land for the specific dam-site, it had earlier managed to secure overall Environmental Clearance on the basis of proposed mitigation measures, and is being cited here as a case in point. Addressing the problem of creating a barrier for movement of migratory fish, WAPCOS proposed an entire fish breeding-and-stocking programme. The proposal was for setting up facilities for producing seed of snow trout (Schizothorax richardsonii) at a cost of Rs. 16.05 million, for periodically stocking 3 cm long fingerlings with 100 fingerlings per km of river, for 10 km upstream and downstream of the dam structure, for 5 years. Serious money that could even sound like a serious effort. Only, anyone living close to the river knows that the proposed dam-site itself, let alone 10 km above it, is entirely uninhabited by any fish whatsoever. This was clearly a 'mitigation measure' proposed only to obtain environmental clearance. It is another matter that even WAPCOS's species fish-list for the river was just a wish-list.

In the context of addressing the problem of fish-passage, we were informed of a fish-ladder constructed by the NHPC for the Kurichhu HEP in Mongar in Bhutan, so we undertook to visit and see the fish ladder design, and to speak to the hydro-power company to understand how effective it was. The Kurichhu is a medium sized Himalayan river in Eastern Bhutan, forming the upper main-stem of the Manas river which originates in Tibet. Access to it by road is long and circuitous, and after a year of trying to get away for long enough to visit, we finally reached there on the cloudy afternoon of 11th January 2014. Prior permission had been sought for the visit through contacts in India, and we were received and shown around with rare grace and courtesy by officials of DrukGreen, the company running the hydro-power project after handover to it by the NHPC of India. The sight of the ladder was thrilling, and we were even permitted take photos of the fish ladder.

January is not the season for either upstream or downstream movement of fish in that zone, so we could not see fish movement in the ladder for ourselves. However, we gathered the following:

The dam is a 55 m high (from the foundation) concrete gravity dam located at an altitude of about 530 meters asl and is 285 meters across the beautiful, dark, blue-green Kurichhu river at Gyalpozhing. At full reservoir level 15.70 million m³ of water is impounded behind the dam. At the time of our visit, one of the four turbines was operational and there was a small release of water downstream of the dam. The fish ladder was in flow, releasing just 0.8 cumecs of water. The project authorities said that during such low-flows, this is the only flow from the dam, since there is no minimum flow required to be maintained by law in Bhutan. The ladder is a pool-and-weir type, with submerged orifices and centrally located notches. A pool and weir design is one of the oldest styles of fish ladders. It uses a series of small dams and pools of regular length to create a long, sloping channel for fish to travel around the obstruction, in this case the dam. The channel acts as a fixed lock to gradually step down the water level; and to head upstream, fish must either negotiate a slot, or jump over from box to box in the ladder.

The Kurichhu fish pass has a total of 98 baffles, each 1.5 m wide and 1.5 m deep, arranged at a distance of about 2.9 m. The total depth of each pool is 2 m. There are two exits (water entrances) to the fish pass, the lower exit placed 5 m lower than the other, to provide for flow at different draw-down levels. The vertical height between the water level of the 'stilling basin' (interesting name for a reservoir holding 15.7 million m³ of water) and the water entrance for fish from below the dam is 32 meters. To achieve this height, the fish-pass channel has to traverse a total distance of 320 m, leading to a slope of 1:10, and resulting in a drop in height per pool of 0.3-0.4 m. Quite impressive, except that the slot in the centre of each baffle does not exceed 25 cm in width. Clearly, no way for big fish, and Mahseer (Tor), the fish with the longest migration distance in this river, also happens to be the largest carp in the world.

We asked the project manager whether they know the fish ladder to be effective. He said that on a few occasions during the fish migration season, they had stopped the flow of water in the ladder and found some small fish in some of the drained pools. They did not know which species they were. We enquired whether there had been any systematic study of the efficacy of the fish ladder, in terms of comparing, with a baseline since commissioning the dam in 2002. Whether there was a change in species composition, or a significant change in upstream fish populations during this time? He replied that they had not.

Pond and Weir Fish Ladder, Bonneville Dam, United States Photo: Wikipedia

Discussion: It is understandable that project authorities in Bhutan were not familiar with names of fish species or other particularities, because people in Bhutan in general do not catch or eat fish. This could stem from Buddhist tradition, but also from funereal custom, where one of the traditional options is that the body of deceased adults is dismembered and consigned to the river for fish to consume.

On enquiring about any documentation with regard to the fish ladder design, they kindly shared a document titled ‘Feasibility Studies for fisheries development in Kurichhu reservoir, Bhutan’ prepared for NHPC, Faridabad, by CIFRI, Calcutta. While CIFRI has been hired by NHPC ostensibly for extending their expertise on fish, they could have spared us their use of tired narratives of ‘development’. It is clearly beyond their area of expertise. Prefacing their feasibility study on fish passes with statements such as “advancement of human civilization and distortion of natural habitat go hand in hand,” and “requirement of electricity is synonymous with the development of civilization”, and more, just exposes their fait accompli. We photographed relevant pages onsite, and along with discussions, have gathered the following:

Since every fish passage requires to be designed to cater to the specific behavioural propensities and physical capabilities of a particular set of fish species inhabiting the river in question, certain stretches of the river were sampled by CIFRI. The fish they caught can be grouped into three broad groups:

Snow trout, mahseers and minor carps: Schizothorax richardsonii. S. Progastus, Barbodes hexagonolepis, Labeo dolycheilus.

Loaches: Garra lyssorhinchus, G. gotyla,

Catfish: Glyptothorax coheni, G. brevipinnis, Pseudocheneis sulcatus.

CIFRI did not catch Tor during sampling, but during dam building many fish were caught by workers and staff from India, one 15 kg and another 20 kg fish near Kurizhampa bridge. Fish of this size cannot be Barbodes or Chocolate Mahseer, and seem to be Mahseer of the Tor genus (species tor or putitora).

The three functional categories of fish migration in general are: Reproductive (spawning) migration, feeding (trophic) migration and refuge migration. For this, hill-stream fish are known to migrate between three major habitats: A wintering habitat, a feeding habitat and their spawning habitat.

Dams and other diversions for river regulation are seen to impact fish in five major ways:

Obstruction in the ascent of fish in their migration for spawning.

Reservoirs can inundate spawning habitat, silting up gravels,

Changes in river water quality due to inter-basin transfers and stratification of water.

Natural flows downstream are radically altered. This includes abruptness of changes in flow, in volume, velocity and seasonality.

Prevention of young migratory fish and refuge migrants from descending to lower reaches.

In addition, adverse repercussions result from indirect effects such as the disruption of the food-webs downstream, stranding of fish during rapid flow fluctuations, and siltation in the reservoir above the dam. The chemical, trophic and thermal properties of a river are greatly altered. Additionally, changes in slope, riverbed profile, structure of the bottom surface, submergence of gravel zones, and changes in the thermal and trophic regimes, affect the habitability of certain stretches of the river.

Designs of fish passages are many, and can be broadly categorized as follows:

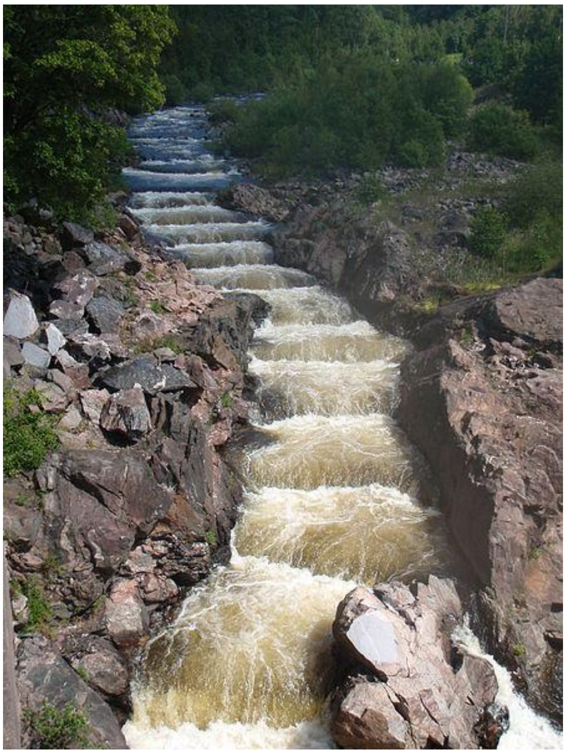
Fish ladders. Pool and weir, baffle fishways, rock-ramp fishways, vertical slot.

Fish lift locks

Fish elevators

Fish trapping and hauling.

PoolWeir-Bonneville_Ladder



Special Fish Ladder for Salmon Photo: Wikipedia

The basic information you need for designing a fish pass, is details about the species particularities such as normal cruising speed and burst speed of target species. Some important criteria are:

Provision of comfortable passage for all migratory species, including the poorer swimmers, over the entire length of the fish pass. To achieve this, provision for refuge against fast currents at regular intervals should be made.

Year-round functionality, under different flow regimes, temperatures and oxygen levels, notably to enable fish displaced by floods to return to their initial habitat.

Sufficient space or carrying capacity allowing massive upstream ascents during reproductive or trophic migration.

Positioning the entry of the fish pass so that it is readily identifiable and accessible to the migrants.

Attraction of fish to the fish pass entrance in the downstream (water exit) in case of upstream migration and deterring them from dead-ends and dangerous places.

Positioning of upstream outlet (fish exit) of fish passes far enough from spillways and turbines to minimize the risk of being swept downstream or being damaged.

Clearly, creating an artificial fish passage is complex and would not work if the multiple aspects are not considered and provided for. Ease of physical passage is just one important aspect. Migration is specifically timed to match various conditions, and even a delay in migration can nullify the purpose. For example, upwelling and excessive turbulence in the areas near the fish entrance are undesirable, as they can confuse migrating fish from finding the entrance. For this, the gates of the dam are required to be manipulated so that the heaviest spill is at the bank opposite the fish-way, with the result that the velocity barrier forms a diagonal lead, a traffic signal of sorts, across the river to the fish entrance. Apart from a sufficient 'attraction flow' at the entrance of a fish pass, projects elsewhere have experimented with directing fish traffic with the help of guiding screens, and the use of overblown 'traffic signals' such as acoustic arrays, strobe and mercury lights, and even electric fields.

At a fish passage such as the array at Kurichhu, it is critical that at the entrance of the fish-way, the gate is to be manipulated to ensure possible passage of fish. Depth and velocity to suit particular species need to be maintained. CIFRI recommended a 'compromised' depth of 25 cm to be sufficient to allow fish passage. In addition the gates should be regulated to ensure that all the baffles are submerged, allowing the fish to swim over them upstream comfortably. This was not the case, when we visited, the flow level did not allow for the baffles to be submerged, as visible in the photograph as well.

Even with a depth of 25 cm in the fish exit, the variable head-height as per the draw-down of the reservoir can create a higher velocity than desired. While CIFRI warns that this poses apprehensions regarding hindrance to fish migration, they dismiss these apprehensions summarily thereafter, stating that this high velocity is observed only for a short distance, which fish would be able to negotiate using burst speed (high speed, short duration). CIFRI mentions that it is only when the speed at the water entrance or any other point exceeds burst speed, (5-6 m per second) that fish would be unable to cross this speed barrier.

While variables such as water temperature and fish length are determinants of swimming speed of fish, CIFRI has assumed that Schizothorax and Barbodes can swim at 3-5 and 2-4 m per second respectively. They have taken the flow speed of water with head height, and fitted it to the equation for determining the velocity through the orifices in or over the baffles, and they are estimated to be ranging from 2.69 to 2.80 m per second, which they say, 'permits the fish to cruise through the fish-way comfortably.'

There are some doubts here. Even a short distance of one baffle, or at just the entrance is critical, because if that is unpassable, the entire fish-way is unsuccessful. Further, CIFRI has arrived at burst-speed of fish for this river not by actual studies on specific species, but by inference from studies on fish in other countries. What strikes as doubtful about this basis, is their assumption that all other things being equal, a fish of any species is capable of equal burst speed, provided it is of the same length. This does not match anything one sees as evidence in the occupation of different fish species in different river stretches, nor in their striking speed while feeding competitively.

In order to test whether the fish ladder was 'working', CIFRI officials operated the fish pass in March (the beginning of the migration season) for 3 days and then closed the sluice gates to check. They found Schizothorax richardsonii, Garra gotyla and G. lissorhinchus in the top-most pool. They did it again in June and found 8 species in the uppermost pool. While it is clear from this that some fish are making it up the channel right upto the top pool, they have no way of knowing for sure whether they were getting through the 25 cm gap at different draw-down levels.

The critical question here is not just whether some fish are making it up the channel, but which species, how many, and are breeding populations making it up on time? A relevant study cited on the April 2013 issue of the Yale Environment 360, titled 'Fish and hydropower on the U.S. Atlantic coast: failed fisheries policies from half-way technologies' by J.Jed Brown and 6 other co-authors (Conservation Letters, Vol 6. Issue 4, p 280-286, July/Aug 2013) is instructive. The discussion by co-author John Waldman is titled 'Blocked Migration: Fish Ladders on US dams are not effective', citing this study goes on to say that fishways on rivers in the U.S. Northeast are failing, with less than 3 percent of one key species making it upriver to their spawning grounds.

Waldman says that "in most major rivers in the U.S., maintaining some semblance of the integrity of migratory fish runs past hydropower dams is dependent upon the fish using ladders and elevators". They undertook a study of the success – or, rather, failure – of Atlantic salmon, American shad, river herring, and other species in migrating from the sea to their spawning grounds past a gauntlet of dams on three rivers in the northeastern U.S. – the Susquehanna, Connecticut, and Merrimack. Waldman says "what we found was grimmer than we expected. For one species, American shad, less than 3 percent of the fish made it past all the dams in these rivers to their historical spawning reaches. The sobering aspect of these contemporary studies is that they are based on the insubstantial number of fish today as compared to earlier massive migrations of these species, which numbered in the many millions. For the international community, the record of fish passage on rivers in the northeastern U.S. is a cautionary tale".

He goes on to say that "hydropower has often been billed as a clean source of renewable energy, and generating electricity without polluting the air or producing greenhouse gases is commendable. But 'clean' is in the eye of the beholder, and any claims to being sustainable ignore its multifarious aquatic effects, including blocking fish passage, fragmenting habitat, and undermining a river's fundamental ecological services."

What Brown and co-authors found was bleak. One metric used was the percentage of fish passing the first dam that also passed just the second dam. For shad, the numbers were 16 percent on the Merrimack, 4 percent on the Connecticut, and 32 percent on the Susquehanna. But on these rivers, Waldman says, the second dam is only the beginning of the journey, and these rivers have multiple dams blocking access to historical spawning reaches. It's important to put these results in perspective because they are merely relative to the present paltry numbers of fish that even attempt to migrate up these rivers.

The study says that there are three absolute numbers that matter. One is how many ran annually before the dam was created, the second is the numbers targeted for restoration in fish passage programs, and the third are the numbers that actually show up each year. On all the rivers examined by the study, restoration goals were in the hundreds of thousands of fish – at least one, if not two, orders of magnitude less than historic, pristine runs. Yet run sizes obtained across three decades ranged annually from a high of about 10 percent to, more commonly, 2 percent or less of the stated goals.

There are two significant aspects worth taking note of here. First, the three absolute numbers that matter, as mentioned in the paragraph above. The construction of a fish ladder must come with quantified stated goals, in terms of the number of fish that are required to pass as minimum, to achieve the desired stability of fish populations. This requires an estimate of populations prior to building the dam, and an estimate of the number that migrate unimpeded, as well as specific population dynamics. Fish migrations in large rivers can be in the millions, as already cited here from Brown and Waldman's study. Here at the Kurichhu, or any other fish-pass in India, population and migration estimates, let alone quantified goals are a far cry.

Secondly, the study clearly illustrates that every subsequent dam upstream has a cumulative impact on the numbers of fish succeeding upstream, diminishing in orders of magnitude. This brings to the fore the critical importance of considering cumulative impact of multiple projects, despite 'mitigation measures', along an entire stream-length, before any clearance is given piece-meal.

While on the design for fish-passes on specific hydro-projects, there are many aspects other than physical passability provided by a fish-pass, that determine its success or failure. Changed flow, turbulence, and volumes can be disorienting for fish leading to serial delays, making it unlikely that the many fish make it to the spawning reaches at the optimal time in the river's seasonal ecological cycle. The numbers of adults successfully returning downstream past the dams also sacrifice their future spawning potential. The flow out of an operating fish-ladder is often very small compared to the water going into the intake to the turbines, and fish will often choose the larger flow during descent, to their peril. At Kurichhu for example, the flow down the fish ladder is just 0.80 m^3 a second, which is a fraction of the flows for the 4.75 m diameter intake of any one of the four 15 MW turbines.

There is also the larger question of flows in a river being regulated by series of dams, and sometimes being too low to provide the necessary cues for hormonal change and migration, puts paid to fish even reaching fish-ladders in the first place.

While dams alone don't explain these results; overfishing, habitat destruction, and alien species contribute – but there is widespread consensus among fish biologists that dams (such fish-passes notwithstanding) are a primary cause. Surely, a cautionary tale for India.

And here is another cautionary tale for India, where unlike Bhutan, fish are eaten, readily. Thirty-three years ago, standing on the Sutlej Barrage at Ropar in Punjab, I witnessed a strange sight. At the base of the barrage, there was some urgent movement in the cold blue waters of the Sutlej in early spring.

Mahseer fish were attempting to migrate up and beyond the 10 meter high barrage. There, right along the buttress of the sloping spillway, one could see a living pyramid of thousands of fish upon fish, slithering up the side of the uni-dimensional triangle against the spillway, barely submerged in the leaking flow from one of the gates, and wriggling on top of and past each other, in a futile effort to make it over the barrage. While this may just have been a collective shoal strategy to get past smaller rapids, it was a death-trap for fish there, against a steep and high barrage. Some other men had already seen this, and I could see them wade up to the desperate and tenuous pyramid in knee deep water below the barrage, and carrying away fish in sack-loads.

Hydro-power projects in India may undertake to construct fish-ladders projected as mitigations measures to obtain environmental clearance, but that does not prevent the staff and others from making the best of the concentration of fish at the base of the fish-ladders and even at un-passable barrages and predating on them. The CIFRI study for the Kurichhu mentions that Indian workers hired by NHPC regularly fished at points of concentration during migration season, nullifying the purpose of the fish-pass. Clearly, the dam authorities will also need to be charged with the responsibility for protection of fish-passes, and other points of concentration even on dams without fish passes.

These are some of the aspects that require to be further investigated about fish-passes in our Indian context, and to be put on the table for discussion and closer scrutiny when mitigation measures are proposed by hydro-power projects.

Editor's Note from SANDRP: When the rivers in Himalayas are facing huge impacts of cascade hydropower projects, it is important to look at the role played by organisations like CIFRI (Central Inland Fisheries Research Institute) which is supposed to be Asia's "premier facility in the feild of inland fisheries research" CIFRI was hired as a consultant for recommending eflows for Teesta IV HEP in Sikkim and 780 MW Nyamjangchu HEP in Tawang, Arunachal Pradesh. In the case of Nyamjangchu, CIFRI recommended a flow of 3.5 cumces from the proposed barrage point, which is 14% lower than the lowest flows recorded (extrapolated) for that site. It is highly improbable that even CIFRI's target species of snow trout will be able to sustain these drastic flow reductions. CIFRI has not raised a voice when multiple dams are being planned without fish ladders or realistic mitigation measures across the country when protecting riverine fish and fisheries is a part of its mandate.

In a strange contradiction, although India's NHPC has built Kurichhu HEP and CIFRI has designed the fish ladder for a dam that is 55 mts high, the EAC of the MoEF in India unilaterally thinks that fish ladders do not work for dams, even as high as 42 meters, This EAC also includes representative from CIFRI.

Before concluding that fish ladders will or will not work in India, we need extensive studies on this subject for different rivers and projects. Unfortunately, none are being undertaken, in line with our overall apathy towards riverine fish diversity and fisheries. Good, scientific studies will help in designing ladders which can be useful for species specifically found in Indian rivers, or will conclude that ladders will not work in specific cases, in which case, the irreversible impact of the project will have to be looked at in a perspective beyond 'mitigation measures'.