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Review Article

Impacts of dams on fish populations and potential mitigative measures: a review

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Abstract
Dams are constructed for numerous purposes such as water storage, electricity generation, flood prevention, navigation, supplementation of water to cultivate land, and recreation. Dams have long been considered as a “green” source of energy because they generate power from water without using fossil fuels. However, dams have a several drawbacks too which are not considered by many people. Dams can alter the habitat quality and fish accessibility to their habitats that play detrimental role in population survival. Fish population could also be affected indirectly by change in water quality and discharge regime. In this frame of study, we review some very important dam associated impacts on fish migration and their recommended mitigation measures by combining different aspects. Some novel approaches for mitigating dams’ negative impacts on the fish populations dynamics especially, for downstream habitats have been concluded. The suggestive approached will potentially accommodate seasonal/climatic variations in the reservoir water to be discharged.
Key words: Dam construction, hydropower projects, electricity generation, mitigations

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INTRODUCTION

Dams are inescapable structures of the world’s riverine systems. All the way through history dams have watered farmland and prevented flooding by controlling water level. A hydropower dam often utilizes the potential energy of stored water to produce huge quantities of electricity (Francisco, 2004). Huge advantages made it easy to understand the importance of dams for our lives (Cumming, 2004) but everything about dams is not good. Dams act as barrier and consequently obstruct upstream and downstream migration of organisms (*e.g.,* fish) and thus alter the natural habitats (Roberts, 2001; Hall *et al*., 2011).

Dams create hindrance to the migration of fish for reproduction or feeding. The obstacle inhibits the function of upstream and downstream grounds due to varying water depths, water currents and patterns of sediment deposition leading to senescence before reaching to reproductive stage (Kruk and Penczak, 2003; McLaughlin *et al*., 2006). Movement through hydropower dam turbines also causes death, particularly of adult fish. For local or potamodromous fish, race for reproducing sites and food can increase as dams disconnect and decrease the number and size of habitats (Cambray *et al.,* 1997). Genomic pools of occupying populations may also become less with the isolation created by dams (Nielsen *et al*., 1997). Sometimes, this separation may prove helpful for native biota by blocking the entrance of intrusive species (McLaughlin *et al*., 2007) or of toxins, parasites, or ailments into the habitat.

The reduction in upstream migration is the most noticeable effect that occurs in areas with inadequate fish passage facilities left following construction of a dam (Holden, 1979; Ward and Stanford, 1987). Anadromous fishes are the ones that are affected most drastically and their populations’ densities can greatly decrease (Brooker, 1981; Ward and Stanford, 1987). Dams also disturb downstream communities by altering physico-chemical parameters of water and habitat conditions. Tributaries-resident fish species are also affected by quality of water and river habitat. In short, dams set up great hazards to species’

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diversity mainly that of fresh water throughout the world (Vorosmarty *et al*., 2010). They cause not only decline of native fish species but also lead to invasion by exotic species, partly because exotic species are more intended to establish in modified habitats (Thompson and Rahel, 1998; Nakamura, 2001; Poff *et al*., 2007). Seepage of water from the manmade lakes into the surrounding areas may have effects on the soils. Changes in the temperature and humidity levels of the immediate ambient environment may also exert impacts on the surrounding terrestrial habitats. In short, dam issues are of diverse kinds. Whereas frame of this study will address impacts of dams on fish populations and some migration measures.

The present review is an account of the following subtopics:

- **Primary impacts**
    - Disturbance in migration route
        - Upstream migration
        - Downstream migration
        - Delay in migration
    - Habitat alteration
    - Genetic isolation
- **Secondary impacts**
    - Modification of discharge
    - Variation in habitat
    - Water quality
    - Sediment transport
    - Flooding alteration
    - Blockage of nutrient flow
- **Recommended mitigation measures**
- **Conclusion**

Primary impacts

Disturbances which are directly associated with the construction of a hydropower project are considered as primary impacts. For examples, disturbance in migratory route, transformation of upstream habitat (dam reservoir) and genetic isolation of animals' species.

Disturbance in migration route

Migratory fishes require diverse environments for their sexual maturation, growth, reproduction and production of juveniles that are the major phases of their life cycles (Schlosser 1991; Schlosser and Angermeier, 1995; Pringle *et al*., 2000; Fausch *et al*., 2002). On the other hand, non-migratory fish species also show the directional movements (Schmutzand and Jungwirth, 1999; Bunt *et al*., 2001). Dams are barriers to fish species that interrupt their movement to complete their life cycle in large rivers (Larinier, 2001; Winter and Van Densen, 2001; Zigler *et al.,* 2004). A considerable decline in population of fishes occurs due to dam construction (Parrish *et al*., 1998; Jackson and Marmulla, 2001). The unfavorable costs of dam obstruction in term of disturbance in movements of many fish species all over the world are well documented (Pringle *et al*., 2000).

Dams can lessen short and long distance migratory species' diversity (Fernandes *et al*., 2009). The life cycle of diadromous species partly proceeds in sea and partly in river, whilst reverse situation has been recorded for catadromous species. On the other hand, potamodromous fish species migrate within the fresh water bodies for feeding and reproduction and do not migrate to sea. Mostly dams block access of fish species to their spawning destinations (FAO, 2001; GLLSWS, 2008).

To find out the effect of dams constructions on migratory fishes many studies have been carried out (Henriette*et al*., 2001; Morita and Suzuki 1999; Morita and Yamamoto, 2002; Reyes-Gavilán*et al*., 1996; Victor *et al*., 2005; Winston *et al*., 1991; Godinho and Kynard, 2008). Mostly world's large rivers are disjointed by dams. Migration patterns among fish populations become interrupted to varying intensities by fragmentation of the ecosystem of the rivers as free flowing rivers are changed into reservoir habitats. Severity of fish migration interruption depends on the location and geoclimatic environment of dams in addition to rivers flows and several other associated factors. Moreover, habitat division has adverse genetic effects on populations that raises the hazards of species, extinction (McCauley, 1993).

A single damming incident can separate neighboring river segments and block avenues of fish distribution (Schlosser and Angermeier, 1995). In the Columbia river basin, white sturgeon populations were historically migrating from the Columbia river estuary up into the Columbia river and beyond inland into the Snake river for spawning (Brown *et al*., 1992b, Schaffter 1997). In 1933, due to dam construction on the Columbia river the migration of white sturgeon to the estuary was blocked. From the time, the construction of additional dams has sequentially separated the river habitat into smaller segments, numerous of which were devoid of free flowing river habitation. Population fragmentation most likely contributed to the decline of some white sturgeon populations in the Columbia rivers. The effect of dam construction on *Salvelinus leucomaenis* white-spotted charr (stream dwelling fish) inhabitant of south western Hokkaido streams (Japan) was assessed and it has been reported that out of 52 upstream sampling locations from dams, *S. leucomaenis* speciemens were present at only 35 sampling sites. Whereas the fish specimens were present throughout undammed upstream areas, it was suggested that the damming would cause negative impact on charr population. After dam construction, the five habitats' analyses showed the disappearance of *S. leucomaenis* (Morita and Yamamoto, 2002).

In China, some fish species migrate between the upper reaches and the lakes adjacent to the middle and lower reaches of rivers for reproduction, overwintering and feeding. Due to the creation of Danjiangkou Dam on the Han river, links between the lakes and river became obstructed. This situation modified the fish behavior which continued living in the river. Among them, *Coreius heterodon* reproduced in river and their progeny survived (Yu *et al.,* 1981). Whereas some rare fish species, like *Myxocyprinus asiaticus* (Chinese sucker), *Psephurus gladius* (white sturgeon) and Chinese sturgeon *Acipenser sinensis* were threatened as a result of Gezhouba construction on Changjiang river, China (Zhou *et al.,* 1985;Yu *et al.,* 1985b; 1986b; Liu *et al.,* 1992). Before dam construction, the sexual development of Chinese sturgeon was greater than those caught below the Gezhouba Dam (Hu *et al*., 1992). In addition, various Chinese sturgeons were observed rigorously dead or damaged beneath the dam which were apparently injured while trying to ascend the Gezhouba Dam (Yu *et al.,* 1986a).

In addition to these examples, migratory fish had vanished from the East river, a branch of the river Pearl, by 1970, following building of numerous reservoirs in the superior parts of the river and five dams in the lower reaches.

Upstream migrations

Due to impoundments, the changes in fish population occur through several mechanisms (Holden, 1979; Ward and Stanford, 1987). The upstream migration of anadromous species may be prevented by dam from feeding to breeding zones.

Diadromous species have been under an uninterrupted and ever-increasing decline in France since the 19th century: in majority of cases, the constructions of dams have been the chief causes of decline that prevent free upstream migration. The harmful effects of such impediments on anadromous species (mainly Allis shad and Atlantic salmon) have been much more significant than habitat destruction, overfishing, and water pollution in the main rivers. Obstructions have been the major reason for extinction of whole stocks of salmon in the Seine. Rhine, and Garonne rivers or for the confinement of certain species to a very restricted part of the river basin like salmon in the Loire, shad in the Garonne or Rhone *etc*. (Porcher and Travade, 1992). The construction of hydroelectric dams on the Volga, Don and Caucasian rivers has been the major reason of depletion and extinction of Sturgeon stocks (Petts, 1988). Migrating species, mostly shad and salmon, in the Penobscott Connecticut, Merrimack rivers, on the East Coast of the USA, have been predominantly threatened by dams (Baum, 1994; Meyers, 1994; Stolte, 1994). Reduction in fish diversity due to interruption in migration by Xinanjiang dam, China has also been reported (Zhong and Power, 1996)

Victor et al. (2005) reported that, fragmentation by 15 dams on the Fox river, Illinois and the impoundment to the river's surface area influenced the distributions of about 30 species of fish by restricting their upstream movements. In Australia, a considerable decrease in fish population occurred due to blocked fish passage (Mallen-Cooper and Harris, 1990). The decline of biodiversity occurs not merely in the flooded segments but in the river under the dams, too. In the Snake river migrations of steelhead, juvenile Chinook salmon, *Salmo gairdnerial*, *Oncorhynchus tshawytscha* from tributaries were monitored. It was found that migrations of juveniles was delayed by new dams constructed on the Snake river and the fish survival was badly affected. In 1972 and 1973 major losses of juveniles were directly responsible for low returns of adults in 1974 & 1975 to the Snake river (Raymond, 1979).

Downstream migration

Passage through hydraulic turbines particularly over spillways are serious causes of injury of downstream migratory fish (FAO, 2001). Sometimes, forces at turbines and spillways are so severe and vicious that they become sufficient to cause shredding and or tissue bruising, decapitation and de-scaling of fish species (Norrnandeau *et al.,* 1996). According to

Larinier and Travade (2002), Eels, due to their body shape, are at particular risk and hydropower stations have been found as contributor to declines of *Anguilla* species throughout the world.

Increases in mortality and alterations in eel behavior allied to the downstream migration of silver eel at low-head dams were reported by Behrmann-Godel and Eckmann (2003) and Winter *et al*. (2006). Similarly, Up to 32 % of mortality rate has been reported for smolts that were released directly downstream from the dam spillway, in the Snake river (Ruggles and Murray, 1983). Liermann *et al.* (2012) quantified dam obstruction, of freshwater eco regions, at the biogeographic scale, that provided the spatial framework essential to evaluate the risk factor of loss of fish species due to hydropower schemes. Almost 50% out of the 397 assessed freshwater regions were found to be obstructed by large- and medium-sized dams, and nearly 27% faced other downstream obstruction. The study indicated that taxa such as shads *(Alosa spp.)*, lampreys (*Lampetra spp*.) and eels (*Anguilla spp*.) are at particular risk.

Delay in migration

Timing of downstream migration is badly affected by impoundments. The time requisite for the migration of juveniles to sea increases mostly in rivers flow by dams. In the Columbia basin, in duration of low flows, juvenile Chinook salmon arrived at the estuary after a delay of forty days than they did before dams were built, thus impoundments by dams had almost doubled the time required for juveniles to migrate to the sea. Such kind of delays have a severe effect by letting the fish to exposure of nitrogen tremendous saturation, rigorous predation and numerous other dangers such as direct exposure to parasites and through diseased organisms. Because of delay, a considerable part of the juvenile population undergoes residual zing and spendsa for a number of months in fresh water (Ebel, 1977).

Habitat alteration

Aquatic communities' habitats' modification is another serious consequence of dam construction. The lotic habitats, (fresh water) transformation takes place in lentic habitat as a result of river impoundment. Spawning areas in the rivers and floodplains are wrecked in regions flooded by reservoirs. Study of the threatened fish species revealed that 55% of the total man-induced species' reductions had been associated with loss of free-flowing freshwater habitats occurring due to flooding by reservoirs (Oklahoma, Hubbs and Pigg, 1976). Similarly, Zhong and Power (1996) reported that almost 40% of the spawning grounds were lost due to flooding in the Qiantang river above the Fuchunjiang dam.

The migratory *Hills ailisha* has become deprived of 60% of previous spawning grounds due to dams (Welcomme, 1985). The most spawning habitats, on the Columbia river and its main tributary; the Snake river, were flooded because of the construction of dams which created an uninterrupted series of impoundments (Raymond, 1979). During study of low-head dams constructed on Fox river, it was found that habitat quality seemed to be a significant variable (Victor *et al.* 2005). In general, free-flowing regions consist of a number of physical characteristics (such as runs, riffles, and natural pools) that provide a wide range of substrate types, cover features and water depths. In contrast, impoundment habitats become more homogeneous. Whereas, the aquatic species' conservation in rivers and streams requires habitat heterogeneity.

Genetic isolation

Genetic isolation is another problem caused by dams; some fishes become genetically isolated from other fish populations simply because they cannot move freely throughout the river habitat (Neraas and Spruell, 2000; Rosenberg *et al.,* 2000). Inbreeding and loss of genetic variation in isolated populations may contribute to their declines. Genetic studies of white sturgeon indicate that dam blocked populations have lower genetic diversity than populations having open access to oceans (Brown *et al*., 1992b).

Secondary impacts

The variations in physical and chemical variables which influence the health and growth on fish are termed as secondary impacts. For example, variations in water discharge habitat, water quality, water current sediment load, flooding alteration and blockage of nutrient etc., represent important secondary impacts.

Modification of discharge

Downstream modifications of riverine flow due to an impoundment of a dam may cause a number of harmful effects on fish population such as loss of stimulus for migration, migratory routes and spawning beds, diminished survival rate of eggs and juveniles and reduced fish food production. During the migratory period, stream flow regulation can cause changes in the daily and seasonal rythms of fish migration (FAO, 2001). For the production of hydroelectricity, river discharge regulation may cause changes in estuaries. Because of the habitat modification there has been a substantial change in the fish community's composition in the estuary of the Qiantang River (Zhong and Power, 1996). Chen *et al.* (1990) found that, salt water incursion into the estuary prominently expanded after the regulation of river flow and flood reduction. As a result, species number of freshwater fish reduced from 96 to 85, while marine species amplified from 15 to 80, in the affected region. Regulation of a river (by dams) can lead to a severe decline in a population of migratory fish, or even can be a cause of its complete elimination. As during migratory activity any alteration in river discharge can reduce the attractive potential of the river, thus the spawners entering the river are decreased. Fish migration towards the non-regulated parts of the river under the dam site can also be greatly affected by such river regulation. The initial flooding of the Tsimlyanskoye reservoir on Don river caused the entrance of two species *Huso huso* and *Acipenser gueldenstaedtii* (Russian sturgeon) in the tributary where they had never formerly been known to breed (Pavlov, 1989). According to Zhong and Power (1996) high discharge is significant for tempting anadromous species to ascend rivers for spawning. After the construction of Fuchunjiang dam above the Qiantang River, the capture of an anadromous fish *Coilia ectenes* ascending the river for spawning was found to be in direct correlation with discharge rate from the project.

Disturbanus in the downstream water flow can cause drastic changes in the aquatic fauna. Processings of hydroelectric power-dams cause variable flow regimes that can have substantial effects on fish fauna: 2 m to 3 m daily fluctuations of river-levels of Colorado under the Glen Canyon dam might had led to the drop in endemic fish population (Petts, 1988). Disappearance of a native fish *Tandanus tandanus (*eel-tailed catfish) in the Murray river, Australia, was related to the short-term variations in water level triggered by reservoir discharges. According to Petts (1988), the water-level fluctuations and changes in velocities due to reservoirs could have devastating influence on fish; as spawning behavior could be inhibited, as well as high flows could brush juveniles downstream, furthermore eggs or juveniles may be left aground due to sudden reductions in river flow. Dams may lead to changes in thermal and chemical properties of riverine water: the limnology of the impoundment, is used in determining the quality of dam-releases. Surface-release reservoirs perform the action of nutrient whereas traps and deep-release dams and heat exporters export nutrients and cold-waters.

Variation in Habitats

The altered habitats partly due to modification or degradation of water bodies not only lead to loss of native species but may also support invasion of exotic species (Thompson and Rahel, 1998; Nakamura, 2001; Poff *et al*., 2007). On Hokkaido Island, exotic *Oncorhynchus mykiss* (rainbow trout*)* and *Salmo trutta* (brown trout) were found to increase considerably and their negative effects on white-spotted charr have been recorded (Aoyama *et al*., 1999a, 1999b; Takami and Aoyama, 1999; Taniguchi *et al*., 2000; Takami *et al.,*2002). The additive effect of reduced current velocities, water temperature, diminished peak discharges and stabilized water levels below the dams had eradicated the spawning grounds for the Han and Qiantang rivers: consequently, 5 species favoring torrential habitats and 6 migratory fish underwent severe decline (Zhong and Power, 1996).

Water quality

Dams alter the water temperature and water quality downstream that can affect fish species and populations. Vannote *et al*. (1980) revealed that free-flowing rivers have a gradient of physical features that stimulate regular variations in aquatic communities extending from headwaters to the river mouth. Mostly disturbances in natural flow have been found to be happening by dams and associated impoundments. Changes in water temperature due to dams have often been recognized as a source of decline in native species, a phenomenon which occurs predominantly after spawning success of exotic species (Petts, 1988). Thermal clues affect salmon spawning such as, the larval emergence and the migration of smolts. Thus anthropogenic temperature changes may cause mismatches between environmental settings and fish life cycles (Stensenth and Mysterud, 2002). Moreover, premature emergence of larvae, as a result of an increase in temperature by dams, possibly expose them to floods, greater predation and limited food resources, and ultimately resulting in high mortality rate (Saltveit*et al.,* 2001). Laboratory studies which cold report response of induced premature hatched fish larvae challenged with relevant parasites and pathogenic microbes will be of great value assessing the river ecological drastic disturbances leading to fish population declines.

Lower water temperatures in summer under hydroelectric dams can have severe impacts on some fish species. The Danjiangkou dam, in the Han river caused delay in spawning for 20-30 days. This decreased the first year growth in impounded riverine contrast to the growth of the same species in the Changjiang river (Zhou *et al.,* 1980; Yu *et al.,* 1981).

High dams of the Colorado river caused decline in native fish abundance by cold water release (Holden and Stalnaker, 1975). The replacement of twenty native species by Salmon species, has been attributed to the conversion of warm-water to cold-water following the habitat distruction cause by.

Water-chemistry fluctuations can also have significant effects on fish. Below dams, anoxic water release by the hypolimnion, can lead to fish mortality (Bradka and Rehackova, 1964). In times of, high water, water spilling over the crest of the dam becomes over-saturated with some atmospheric gases such as oxygen and nitrogen to an extent which can be fatal for fish. Continued exposure to lethal concentrations can lead to mortality downstream the spillways. According to Raymond (1979) beneath the John Day dam (Columbia river) extensive mortalities of both adult and juvenile salmonid caused by high spillway flows producing high super saturation (120-145%) have been reported. Bechara *et al*. (1996) reported that the Yacyreta dam over the Parana river produced supersaturated levels of the dissolved gases that could have negative impacts on the fish health, hence in 1994, huge fish mortality rate was detected over 100 km reach beneath the dam. Similarly, Becker (2003) stated that above and below to dams, dissolved atmospheric gases are expected to be 130% saturated compared with 100% saturation level in areas having no impoundment.

Dissolved nitrogen in the water below dam (Gezhouba dam), has been recorded to cause gas-bubble disease in fry of four carp species: silver carp *Hypophthalmichthys molitrix,* bighead carp *Aristichthys nobilis,* grass carp *Ctenopharyngodon idellus, and* black carp *Mylopharyngodon piceus* (Chen, 1984a; Liu *et al.,* 1986). According to Wu (1987), in two observations, after passage through the Gezhouba dam, the mortalities were 19 to 59% for black carp and 38 to 60% for grass carp, respectively.

Impoundments cause decrease in algal washout and hydraulic flushing thus boost phytoplankton growth in rivers (Talling and Rzoska, 1967; Soballe and Kimmel, 1987; Lohman and Jones, 1999). Respiration and photosynthetic cycles of abundant phytoplankton algae, produce wide variations in dissolved oxygen and pH that very often lead to degraded water quality in impounded areas (Victor *et al*., 2005).

Sediment transport

Sediment from eroding uplands is transported to depositional areas by rivers. Dam interrupt the sediment transport continuity and the flow often become sediment-starving and tends to erode the channel beds and the banks, resulting in channel incision (down cutting), bed material coarsening, and loss of spawning gravels for trout and salmon species. Variation in sediment transport also affect receipt seas, with implications for estuarine, marine and diadromous species (Baisre and Arboleya, 2006). Excessive sedimentation can lead to various effects in fishes comprising gill irritation, obstructed movement, variation in foraging behaviour, alteration of physiology of blood and occasionally may lead to prompt mortality.

Flooding alteration

Dams purposefully or unintentionally amend downstream hydrology, including flooding. The altered hydrology can affect the overall fish production throughout the system negatively by inhibiting or eliminating historical and normal downstream floodings (Holcik and Bastl, 1977; Welcomme, 1985; 1986; Junk *et al.,* 1989). Redd dewatering or freezing of alevins or that of eggs may result by reduced flows in depleted reaches, exposing or rendering spawning areas too shallow (Gibbins *et al.,* 2008). Similarly, reduced flows may lead to compromise hypothetic flows for oxygenation of incubating eggs and also increase the fine deposition of sediments (Barlaup *et al.,* 2008). These aspects have undesirable penalties for survival and development of egg, larval emergence, and also could decrease recruitment of salmonids.

Rivers with flood pulses and floodplains have considerably greater fish yields per unit surface area than in nearby river where impoundments have reduced or eliminated flood pulses (Sparks, 1995). Flooding incorporates extra-channel organic material and terrestrial nutrients into the riverine ecosystem (Vannote *et al.*, 1980; Bayley, 1989; Junk *et al.,* 1989; 1995; Thorp and Delong, 1994; Sparks, 1995).Flooding has been reduced by dams in India's Punjab with consequencies of reduced total fish production of Indian major carps (Sandhu and Toor, 1984).

Blockage of nutrients flow

Flow of nutrients from oceanic environments upstream to freshwater environments is blocked by dams. This is predominantly factual for anadromous fishes, for example Pacific salmons that after spawning once, die in the rivers. Pacific salmon carcasses are vital contributions of energy and different nutrients to the ecosystem (Cederholm *et al.*, 1999). The blockage of these organic nutrients from the sea limits the recruitment of young salmonids in rivers directly by inhibiting ingestion of flesh of dead adults, and also indirectly by reducing production of planktons and benthic macroinvertebrates (Piorkowski, 1995).

Considerable decline in fish food sources under the Xinanjiang dam (china) had been associated with nutrients' retention in reservoir and lower temperatures of discharged water. Silver carp, grass carp, black carp, and big head carp almost all have disappeared from about 15 km division of river under the dam (Li, 1987).

Recommended mitigation measures

It is important to keep in consideration all the impacts that dams can have on aquatic animals during dam planning and construction in order to mitigate their impacts on fish fauna. Rivers can be reconnected by many ways including construction of traditional fish ways (*e.g.*Denil fish ways) or by building stony ramps at dams (Santucci and Gephard, 2003).

A number of mitigation measures have been recommended to diminish the negative impacts of hydropower projects:

Maintenance of flow level fish exclusion devices

The dewatering effect in downstream area due to damming and flow diversion in dry season can be overcome by discharging compensation water flow downstream to conserve the microflora. To guard the fish against impingement, fixing of suitable mesh size screens should be installed.

Fish passes

Fish passes are among the most suitable remedies to facilitate migration of fishes. The native fish resources can be conserved by fish passes. They are playing an important role for cyprinids in the Tigris, for salmon in the northern temperate riverive systems, for cyprinids, Euphrates and for Tor and Indian major craps in the Ganga (Bunt *et al*., 2001; Gubhaju, 2002; Santucci and Gephard, 2003).

Fish bypass criteria

- It must be modified according to the necessities of the concerned species.
- It must be a pool type, with rocky ramp or a vertical slot (Gubhaju, 2002).
- It should be according to fish sizes *i.e.* large and small.
- Suitable fencing with complete prohibition on fishing should be provided (Gubhaju, 2002).
- Flow velocities should exceed the swimming capability of fish (Gubhaju, 2002).

Bunt *et al*. (2001) stated that fish ways and bypass channels can improve connectivity in rivers fragmented by dams and allow several fish species to move upstream and downstream of the dams. However, these options do not improve water quality and habitat because dams and impoundment still remain.

Artificial destratification

To maintain a water quality of a reservoir, artificial destratification is the effective measure. The lifting of chiller bottom water to the surface of a stratified impoundment helps to mix water. Vertical distribution of dissolved oxygen and uniform temperature can be maintained by artificial destratification(Gubhaju, 2002).

Trapping and hauling

In this measure the fish is trapped beneath the dam and transported towards the reservoir or additional upstream for upholding fish variety as well as gene pool (Gubhaju, 2002). Trucking is a more exhaustive process as it demands high human effort and possibly injuring the fish during their removal from the river and placing them in trucks. The active transport is effective in some years, but depends on many variables such as timing of the event, age of the fish, and where they are released. Schilt (2007) pointed out that timing of fish arrival to the breeding site will have a large effect on fish reproduction because it affects the selectivity of the fish.

Trucking of the fish gets them to the breeding sites much faster than the fish that still migrate. This solution is a feasible one to the problem: despite the fact that it does not remove a power source, it is proved as an ineffective mean for fish to get upstream and it requires major human effort to catch the fish and transport them. However, even with the best intentions and efforts, there are still many fish that will not reach to breeding grounds because they cannot be trapped, they do not reach to dams in time, or they get hurt during capture and when they reach the site they do not breed and resultantly breeding selectivity may also be affected and could cause genetic bottlenecks (Gerritsen, and Young, 2008).

Fish lift and ladders

In few dams a fish lift may prove technically feasible as well as more effective than the scheduled fish stocking. Making fish ladders may be a feasible solution to the fish migration problem, but many studies have shown that fish ladders are successful only to some extent (Baxter, 1977; Neraas and Spruell, 2000). They may prove effective with large, powerfully swimming species, and have been shown to be disadvantageous to smaller weaker swimmers such as the American eel. Even though mechanisms are designed to direct fish to the ladder, migratory fish could delay for long periods at the ladder getting easily tangled by the types of signals they are getting.

This could be harmful for their breeding cycles as they may decide to breed at places where they did not breed at all before disturbed habitat. Fish elevators (lifts) work in the same way as fish ladders and attract the migrating fish with a discharge of water, and then enclose them in a sort of elevator, fish are raised to the upstream level of dam and then releases them. Lifts can prove to be more useful for the smaller, weaker fish that cannot readily steer strong currents (Schilt, 2007). Fish lifts may be more operative because they depend on on a timer system and not on the fish effort. Therefore, delays to the fish can be reduced through this and get them to their breeding sites at the appropriate times. For instance for sturgeon, fish use fish lifts for transporting them across dams have been used successfully.

Fish ladders or lifts can be expensive to build in dams, especially if the dam was designed without one, and the process requires an intensive process. Some dams are preferred to be without them, for the simple fact that the dams are too large and building a ladder would be a massive-scale project and gradual slope would be required to accommodate the migrating fish (Baxter, 1977).

Depositing gravel to increase the spawning habitat

At present it is preferred to maintain the spawning areas and fish hatcheries for increasing the fish stocks being affected by hydropower reservoirs. Some fish such as *G. pectinopterus (*catfish), *G. gotyla (*stone roller),*C. punctatus*and and *N. beavani* (stone loaches)face huge losses of breeding grounds immediately below dams. When needed, additional measures should be taken for the protection of breeding grounds and nursery gravel bed i.e., maintenance of spawning grounds.

- Angular and huge boulders are manipulated for creating pools for breeding and also as an escape cover for fish found in little water levels.
- Large boulders can be used to modify the downstream flow pattern.
- Gravel and stones (boulders) are kept together to generate spawning riffles for attraction of resident stocks to rapids.
- For rewatering the exposed gravel beds, flushing discharge can be released to sustain spawning gravel quality.
- To widen the shelter cover, shade along with drift food through tree plantation can be enhanced (Gubhaju, 2002).

Fish hatchery

A reservoir associated hatchery responsible for the production of seeds of some important fish that are affected considerably by dams can compensate for the dam associated negative impacts. Reservoir stocking and tail water will compensate the loss brought about by fading of the natural breeding grounds and from resignation of migration. The fisher men should be provided seed from the government hatcheries to grow fish well in ponds to market size (Gubhaju, 2002).

Dams removal; when mitigation processes do not work

When the ecological health of the river system is of principal concern, removal of the dam is the best option because it will not only eradicate obstructions to migration of all types of fish and their life stages, but also improve water quality and reestablish high-quality free-flowing habitat. Researchers found that fish passages installation to the dams did not lead to improvement of fish population significantly,because numerous fish species were either too large or too small for these devices. Based on these facts and other socioeconomic factors, *Federal Energy Regulatory Commission* **(**FERC) ordered to remove Edwards Dam in July 1999. In fact, almost 100 small dams have been removed until now in the U.S. (Born *et al.,* 1998) and many others are under consideration for removal (Wood, 1999). Denmark has also removed numerous small dams from highly effected riverine systems and as a result fish habitats were improved (Iversen *et al.,1*993). In addition to smaller dams, some larger dams in Europe also have been removed and many others are either scheduled or are under consideration for removal (Lovett, 1999). Dam removal is less expensive as compared to the other options presented, and it also lessens safety risks (such as drowning) as well as maintenance costs (Born *et al*., 1998).Though, the ramping of dams reconnects the river thus allowing fish to move upstream as well as downstream, but it does only little for the improvement of degraded water quality and disturbed habitat because the impoundment still remains. Studies have shown that eliminating dams does indeed increases the number of fish in the upstream reaches (Babbit, 2002). However, depending on how long the dam has been in place, removing a dam could have just as many startling consequences as building a dam. In case of dam removal accumulated sediment that took years and years to build up behind the dam would instantly be released to downstream areas, possibly causing some initial erosion as well as distributing any pollutants that may be in the sediment (Francisco, 2004).

According to Winter (1990) removal of Sweasey dam in California released the same amount of sediment as that which was released by a two years storm.In some cases, removal of dams led to the release of tons of Polychlorinated Biphenyls (PCBs), and due to high amounts of contaminants contained by the dam, some dam removal projects have been abandoned (Francisco, 2004).The resident organisms are affected by instant changes in river morphology, especially if the water is confined in an upstream reservoir. Water systems are very complex, so it is not impossible to forecast what would happen if a dam were abruptly removed. Therefore, before removing a dam the ecologists and dam owners must take the responsibility to make an educated, informed and profitable decision about whether or not to remove the dam (Babbit, 2002). Local fish are too adapted to the environment with the dam that it would be difficult for them to adapt to a sudden change in lifestyle without dam (Babbit, 2004). There is rarely only one dam on a river having any positive effect being removed will most likely be contradicted by the presence of another dam a few miles upstream. In order to make this solution most effective, all the dams must be removed along a stretch of a river. Sometimes, removing the dam may be economical than leaving it there and fixing it (Babbit, 2002). Establishing alternative sources of energy to replace what was produced by the dam may be difficult, especially because dams are already seen as “green” energy. The challenge lies in educating people about the negative effects dams can have, and convincing them to develop other sources of energy that are not petroleum-based or teaching them to reduce overall energy dependency.

Conclusion

In light of above presented text and descriptive examples it is concluded that fish populations are adversely affected by dams. The damaging impacts of dams are greater than their positive impacts. It is worth mentioning to specultate that many of the pollutants even cumulatively might had not caused the riverine fish population dynamic disturbances. In order to be of “low Impact,” the dams must come across certain qualifications criteria such as river flows, quality of water, fish passage way and protection, watershed defense, protection to both endangered and threatened fish species, cultural reserve protection, recreation, and be not prone to develop problems which warrant recommendation for their removal. We believe that various methods and resolutions must be applied to provide the best solution of the problems with dams.

For dams located in areas experiencing extreme of temperatures during a year, two categories of spillways might be constructed. During colder months the discharged water might be routed through wider channels to permit the shallow water get warmth from sunlight. Whereas during summer the water discharge might be passed through deeper channels for making water column charactertized with temperature zonation. Similarly the water discharged form hypolimnion with scarce dissolved oxygen may be passed by spcially constructed spillways which warrants through mixing of atmospheric oxygen with water. Although constructing various spillways for the same dam will cost additional inputs but considering the benefit of stability of fish population dynamics comparable to the pre-dam habitas it will add to the economics overall. Same approaches might be secured for upstream management while constructing fish passageways by passing the dam reservoir. It is hoped that future dam.

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