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A Review on the Fish Communities in the Indian Reservoirs and Enhancement of Fisheries and Aquatic Environment

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Abstract

The reservoirs play an important role in the developmental process of a Nation and also have an integral role in fisheries and livelihood security of the local community. With the increase in population growth reservoirs are becoming important provider of animal protein and for generation of employment in particular to poorer sectors of the people. Reservoirs have many uses from generation of electricity to irrigation purpose and also providing habitat to fishes and other aquatic life and in turn also help to provide feed and create revenue for fish communities. In India, reservoirs are playing a crucial role in the fisheries. Fish communities are often used as indicators of environmental quality. In terms of fish diversity altogether 117 fish species were recorded from Indian reservoirs exhibiting rich fish diversity. These reservoirs have both positive and negative impacts on fishes and other aquatic environment. Therefore, present study is emphasized on synthesizing the available information on fish diversity and community structure of the potential Indian reservoirs and its effects on fisheries and other aquatic environment in reservoirs in India. Some strategies have been suggested for sustaining river and reservoir fish biodiversity.

Keywords: Reservoirs; Biodiversity; Fisheries; Aquatic environment; Potentials; Management issues

Introduction

Freshwater is critical to human society and sustains all terrestrial and aquatic ecosystems [1]. India has a large spread of freshwater resources that exist in the form of rivers, canals, reservoirs, lakes etc. More than 10.86 million people are depended on these different water systems in India and their fisheries. Fisheries play an important role in livelihood and nutritional security of the rural India. The climate of India has wide range of weather conditions from extreme cold to very hot. From past decade the weather in India has become less predictable due to climate change, so these situations make it important to store river water in the form of reservoirs. In India, reservoirs form an important source of fish production and presently, the area under reservoir fisheries has been estimated at about 3.0 million hectares and with the constant addition of new reservoirs and impoundments, this area is likely to further increase in the coming years [2].

A reservoir is an impoundment obstructing the surface flow of a river, stream or any water course [3]. The Indian reservoirs are distributed from Himalayas to Southern peninsula. Reservoirs are classified as small (<1,000 ha), medium (1,000 to 5,000 ha) and large (>5,000 ha) based on their hectrage by National Consultation held in 1997 at Central Institute of Fisheries Research Institute, Barrackpore [4]. The cumulative area of reservoirs in India are estimated to be 1,485,557 ha, 507,298 ha and 1,160,511 ha of small, medium and large reservoirs, respectively [5].

Reservoirs can generate a vast array of economic impacts—both in the region where they are located, and at inter-regional, national and even global levels. These impacts are generally evaluated in terms of additional output of agricultural commodities, hydropower, navigation, fishing, tourism, recreation, prevention of droughts and reduction in flood damages, and are referred to as direct impacts. With the constant evaluation of effect of dams on aquatic life and use of Environmental Impact Assessment (EIA) Indian Government has undertaken several initiatives like stocking dams with different fish species, rehabilitation of fishes getting extinct due to construction of dams, ranching programmes, environmental modeling, fish ways etc. for protection of aquatic biota. Stocking of dams with fishes are generally provided that can result in many benefits such as creating new fisheries and also to enhance existing fisheries. Beside all these conservation programmes we also need to focus on the study of fish biodiversity of reservoirs. Study of fish yield from dams need to be focussed for the conservation purpose. The present paper highlights the potential of reservoirs in India with reference to fish community and biodiversity perspectives for conservation as well as stock enhancement and management challenges and advocates for planning innovative strategies for sustaining river and reservoir fish biodiversity.

Role of Reservoirs in Fisheries

Reservoirs 'the man-made lakes' are constructed with the aim of generation of electricity and water storage for purpose of irrigation. Along with that these water bodies have tremendous potential for fisheries that in turn has several economic and social advantages. But so far reservoirs in India are concerned they are not contributing to that extent towards fisheries. According to Associated Chambers of Commerce and Industry of India (Assocham) fish production in India can grow at a compounded annual growth rate (CAGR) of about 7 per cent till 2016 from level of over 3.5 per cent in 2012. Reservoir fisheries development in India has received some importance only recently when a World Bank funded Shrimp and Fish Culture Project (7 years from 1992-93 onwards) was implemented for reservoir fisheries

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development in the states of Andhra Pradesh, Orissa and Uttar Pradesh during ninth plan period.

In India, natural flow of all major rivers have been regulated for fulfilling water demand of agriculture and power sector, without giving much attention to fisheries sector. As a result, rivers have lost their character and fisheries have suffered huge losses. Severe and drastic changes in the entire hydrological cycle of the river by dams and water abstractions has affected recruitment of most species, especially large carps, which like flowing water. Larger dams are major cause of degradation of aquatic environment and disruption of livelihood communities dependent upon the fishery along the rivers [6]. Table 1 showing distribution of medium, large and total reservoirs in India [7]. Reservoirs are inextricable parts of our natural landscapes. Reservoirs offer immense scope for increasing fish production and can be developed as tourism sites by using sport fishing. Application of new technologies and innovations would be required to fully utilize the optimum fish production from the reservoirs.

Socio-Economic Effect of Reservoir Fisheries

As compared to crop farming and forestry, fisheries production can generate relatively higher incomes for rural households [8]. Therefore, average income of fishers is much higher than the income from agriculture. On the other hand, fishing and aquaculture in reservoirs are relatively tough occupations compared to other economic activities such as agriculture and as such, they are less attractive to the younger generation. We need to search possible links between dams and economic growth and to measure systematically the actual effects of dam reservoirs on local economic growth and development. A cost-benefit analysis suggests that the dams are, on average, only marginally cost-effective, although there is large variation from dam to dam.

Policy Constraints

Reservoir fisheries are a relatively small contributor to the national fisheries industry so it receives very limited attention from the government [9]. In general, reservoirs are located in remote areas where it is relatively difficult to access support systems such as technical extension services and marketing related infrastructure is usually weak. Fishers and aquaculture operators are more vulnerable to natural disasters. Various policy analysts have analysed the conscious of indirect impacts of dams on fisheries and felt the need for their proper appraisal and quantification. The World Commission on Dams (WCD) Report and numerous other studies have discussed the importance and difficulties of evaluating indirect impacts of dams [10]. Utilization of dams for fisheries can act as a powerful vehicle for poverty alleviation.

Fish Biodiversity and Dams

To date the efforts to counter the ecosystem impacts of large dams have had only limited success, which is due to limited efforts to understand the ecosystem and the scope and nature of impacts. There are reports that, dams can enhance riverine fisheries, particularly tail water fisheries immediately below dams that benefit from discharge of nutrients from the upstream reservoir. The nature of cumulative impacts to river system may be significant, but a lack of research on the topic makes predictive assessment difficult [11]. The biodiversity of fish in reservoirs is basically formed on the biodiversity of the original rivers, particularly the principal river system. However, after impoundment there may be significant changes in fish fauna due to changes of the hydrological regime and biological conditions. The fishery productivity of reservoirs is more within the first few years of their existence [12] that is because during the filling period of reservoir, the water leaches nutrients from newly inundated soils, submerged plant debris and other

States	Medium		Large		Total Storage	
	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Tamil Nadu	9	19,577	2	23,222	8,906	358,740
Karnataka	16	29,078	12	179,556	4,679	437,291
Andhra Pradesh	32	66,429	7	190,151	2,937	458,507
Orissa	6	12,748	3	119,403	1,442	198,198
Gujarat	28	57,748	7	144,358	711	286,230
Rajasthan	30	49,827	4	49,386	423	153,444
Bihar	5	12,523	8	71,711	125	96,695
Uttar Pradesh	22	44,993	4	71,196	66	334,840
Madhya Pradesh	21	169,502	5	118,307	32	460,384
Kerala	8	15,500	1	6,160	30	29,635
West Bengal	1	4,600	1	10,400	6	15,732
Northeast	2	5,835	-	-	6	8,074
Tripura	1	4,500	-	-	1	4,500
Manipur	-	-	-	-	1	100
Meghalaya	-	-	-	-	3	650
Assam	-	-	-	-	1	98
Mizoram	-	-	-	-	1	32
Nagaland	1	2258	-	-	1	2258
Cover Assam and Meghalaya both	1	1,335	-	-	-	1,335
Himachal Pradesh	-	-	2	41,364	3	41,564
Maharashtra	-	39,181	-	115,054	-	273,750
Haryana	-	-	-	-	4	282
Total	180	527,541	56	1,140,268	19,370	3,153,366

Table 1: Distribution of medium, large and total reservoirs in India (source: http://www.nih.ernet.in/rbis/india_information/dams.htm.

organic matter. Therefore, the impounded water is of high fertility, which encourages the growth of bacteria, phytoplankton, zooplankton and benthos. These organisms serve either directly or indirectly as food for fish consequently, fish feeding on these organisms become more abundant as do also the predacious species which in turn feed on the small fish. Table 2 presents common fish species found in reservoirs of India [13].

Fish Biodiversity and Utilization of Some Important Reservoirs

The Doyang reservoir of Nagaland is usually stocked with fingerlings of Indian major carps and exotic carps. 25 fish species diversity was found in this reservoir. The stocking is done at the rate of catla (30%), rohu (25%), mrigal (20%), grass carp (10%), silver carp (5%) and common carp (10%). Aliyar reservoir of Bharathapuzha basin in Tamil Nadu harboured a total of 44 endemic species and 7 introduced species. Thirumoorthy reservoir of Bharathapuzha basin in Tamil Nadu has 28 numbers of faunal species and revealed poor species diversity. Markonahalli reservoir in Karnataka has only 28 species of fishes out of which 23 are indigenous, 4 stocked and one exotic species have been recorded. Umiam reservoir at Meghalaya having 27 fish species out of which 24 are indigenous and 3 are exotic fish species [14].

In terms of fish diversity approximately 117 fish species are present in consolidated form in Indian reservoirs (Table 4) thus exhibiting rich fish species diversity. Indian reservoirs are rich in food fishes 96.5% that are helpful in providing protein rich diet to the locality of the people living in nearby areas. So, far sport fishing is concerned the number of fish species present in Indian reservoirs is very low approx 23.0% as per Table 4. Thus we need to stock dams with more fishes having value as sport. Pong dam in Himachal Pradesh is famous for mahseer fishing. Sport fishing needs to be developed on the concept of ecotourism. Therefore, development of sport fishing in dams needs different strategies and plans for fish species richness as dams have different environment than river system. The ornamental fish sector is more vibrant and remunerative and Indian reservoirs are rich in ornamental fish species like *Puntius* sp, *Rasbora* sp. (56.4%). These fishes can be used in market trade by local people that will help them to increase their economic strength. The keeping of aquarium fishes has emerged as second popular hobby in World after photography. Demand for ornamental fish is increasing day by day especially in international markets. Newly constructed dam in district Doda, Jammu and Kashmir was stocked with 15000 number of quality fish seed with the aim of providing protein rich commodity to the people of the area. 28 fish species belonging to 7 families with 2 specimens of family Bagridae, 19 of Cyprinidae, 2 of Channidae, 1 of Siluridae, 1 of Belontidae, 1 of Mastacembelidae and 2 of Sisoridae were collected from Pong Dam Reservoir, Himachal Pradesh [15]. Bacchra reservoir in Allahabad, Uttar Pradesh consisted mainly of rheophilic species of low population density and after impoundment the lentic body harbours 51 species of fish. Yerrakalva reservoir in Andhra Pradesh is medium productive and 13 species of fish have been recorded from this reservoir along with freshwater prawn *M. malcolmsonii*. Kulgarhi reservoir, Madhya Pradesh is the first reservoir in India where *Hypophthalmichthys molitrix* was first introduced on experimental basis. Bhatghar reservoir of Pune, Maharashtra is one of the important reservoir in India. In this reservoir 48 species of fish are available commonly.

Effect of Dams on Fish Migration

Presence of 46 freshwater fishes from Rajghat dam representing

Group	Species
Indian major carps	*Labeo rohita, L. calbasu, L. fimbriatus, Cirrhinus mrigala, Catla catla*
The mahseers	*Tor tor, T. putitora, T. khudree, Acrossocheilus hexagonolepis, A. hexastichus*
Minor carps	*Cirrhinus cirrhosa, C. reba, Labeo kontius, L. bata, L. dero, L. gonius, L. boggut,L. dussumeri,Puntius sarana, P. dubius, P. carnaticus, P. kolus, P. dobsoni, P. chagunio, P.pulchellus, P. jerdoni P. curumuca, P. shalynius, Thynnichythys sandhkhol, Osteobrama vigorsii*
Snow trouts	*Schizothorax sp., S. plagiostomus*
Large/medium catfishes	*Wallago attu, Sperata aor, S. seenghala, Pangasius pangasius, Silonia childrenii, Silonia silondia, Ompok bimaculatus, O. pabda, Glyptothorax* spp.
Featherbacks	*Chitala chitala , Notopterus notopterus*
Air breathing catfishes	*Heteropneustes fossilis, Clarias magur, C. batrachus*
Murrels	*Channa marulius, C. striatus, C. punctaus, C. gachua*
Garra species	*Garra gotyla, G. lissorhynchus, G. mccllendi*
Minnows and miscellaneous species	*Puntius sophore, P. ticto, Ambassis nama, Esomus dandricus, Aspidoparia morar, Amblypharyngodon mola, Oxygaster bacilla, Laubuca laubuca, Barilius barilia, B. vagra, B. bola, Osteobrama cotio, Gadusia chapra, Salmostoma bacaila, Johinus coitor, Lepidocephalus guntea, Glossogobius giuris, Danio dangila, Badis badis, Chanda nama, C. baculis, Changunius chagunio*
Exotic fishes	*Oreochromis mossambicus, Hypophthalmichthys molitrix, Cyprinus carpio specularis, C. carpio communis, C. carpio koi, Gambusia affinis, Ctenopharyngodon idella, Clarias gariepinus*

Table 2: Fish species recoded in reservoirs/dams of India. Source [13,18].

Type of habitat alteration	Location	Effects
Blockage by dam/ habitat fragmentation	Tocuri dam, tocantins river, Brazil	Interrupted upstream, reproductive migration of long distance migratory species; population of these species were negatively affected in lower Tocantins, downstream of dams [33].
	Upper Volga river, Russian Federation	Change to fish fauna following construction of four major reservoir; 7 species (mainly anadromous rhcophils) disappeared, and more of these 9 are reproducing naturally and will probably disapared when stocking is discontinued [34].
Habitat simplification	Upper Volga river, Russian Fedration, River Rhine, Lower Rhhone river, Europe	Limited bio productivity in reservoirs because of considerable changes “typical riverine fish habitat remain only in the upper reaches of tributaries and in the forewater of dams and account for no more than 1% of the total water surface area”[34].
Unnatural discharge regimes	Colorado river, USA	Elimination of 2 year classes of endemic Colorado squawfish from its most productive remaining nursery habitats in the Green River Catch, perhaps because extreme flow fluctuating and alteration of seasonal flow regimes [35-36].

Table 3: Examples of world -wide biodiversity impact from habitat alteration resulting from hydrological development [24].

Sl. No.	Species	Food	Sport	Ornamental
1.	*Amblypharyngodon mola* (Hamilton)	+	-	+
2.	*Anguilla bengalensis* (Gray and Hardwicke)	+	-	+
3.	*Sperata seenghala* (Sykes)	+	-	+
4.	*Cabdio morar* (Hamilton)	+	-	+
5.	*Barilius gatensis* (Valenciennes)	+	-	+
6.	*Barilius barilia* (Hamilton)	+	+	+
7.	*Barilius vagra* (Hamilton)	+	-	+
8.	*Rajamas bola* (Hamilton)	+	+	+
9.	*Catla catla* (Hamilton)	+	+	-
10.	*Chanda nama* (Hamilton)	+	-	+
11.	*Pseudambassis baculis* (Hamilton)	+	-	+
12.	*Parambassis ranga* (Hamilton)	+	-	+
13.	*Channa gachua* (Hamilton)	+	-	+
14.	*Channa marulius* (Hamilton)	+	-	+
15.	*Channa striata* (Bloch)	+	-	+
16.	*Channa punctata* (Bloch)	+	-	+
17.	*Cirrhinus cirrhosus* (Bloch)	+	-	-
18.	*Cirrhinus fulungee* (Sykes)	+	-	-
19.	*Cirrhinus mrigala* (Hamilton)	+	-	+
20.	*Cirrhinus reba* (Hamilton)	+	-	-
21.	*Clarias batrachus* (Linnaeus)	+	-	+
22.	*Ctenopharyngodon idella* (Valenciennes)	+	+	-
23.	*Cyprinus carpio communis* (Linnaeus)	+	+	+
24.	*Cyprinus carpio koi* (Linnaeus)	+	+	+
25.	*Cyprinus carpio* var. nudus (Bloch)	+	+	+
26.	*Cyprinus carpio* var. Specularis (Lacepede)	+	+	+
27.	*Devario aequipinnatus* (McClelland)	+	-	+
28.	*Devario devario* (Hamilton)	+	-	+
29.	*Danio dangila* (Hamilton)	+	-	+
30.	*Etroplus canarensis* (Day)	+	-	-
31.	*Esomus danricus* (Hamilton)	+	-	+
32.	*Etroplus maculatus* (Bloch)	+	-	+
33.	*Gagata itchkeea* (Day)	+	-	-
34.	*Garra lamta* (Hamilton)	+	-	+
35.	*Garra lissorhynchus* (Mcclelland)	+	-	+
36.	*Garra gotyla* (Gray)	+	-	+
37.	*Garra mcclellandi* (Jerdon)	+	-	+
38.	*Glossogobius giuris* (Hamilton)	+	-	+
39.	*Glyptothorax housei* (Herre)	-	-	+
40.	*Glyptothorax* spp.	+	-	+
41.	*Hypselobarbus curmuca* (Hamilton)	+	-	-
42.	*Hypselobarbus dubius* (Day)	+	-	-
43.	*Hypophthalmichthys molitrix* (Valenciennes)	+	-	-
44.	*Labeo boga* (Hamilton)	+	-	-
45.	*Labeo calbasu* (Hamilton)	+	+	+
46.	*Labeo fimbriatus* (Bloch)	+	-	-
47.	*Labeo kontius* (Jerdon)	+	-	-
48.	*Labeo porcellus* (Heckel)	+	-	-
49.	*Labeo rohita* (Hamilton)	+	+	-
50.	*Labeo bata* (Hamilton)	+	-	-
51.	*Bangana dero* (Hamilton)	+	+	-
52.	*Labeo gonius* (Hamilton)	+	-	-
53.	*Labeo boggut* (Sykes)	+	-	-
54.	*Labeo dussumieri* (Valenciennes)	+	-	-
55.	*Macrognathus guentheri* (Day)	+	-	+
56.	*Mastacembelus armatus* (Lacepede)	+	-	-
57.	*Mystus cavasius* (Hamilton)	+	-	+
58.	*Mystus malabaricus* (Jerdon)	+	-	-
59.	*Nemacheilus denisonii* (Day)	-	+	+
60.	*Notopterus notopterus* (Pallas)	+	-	+
61.	*Chitala chitala* (Hamilton)	+	-	+
62.	*Ompak bimaculatus* (Bloch)	+	-	-
63.	*Oreochromis mossambicus* (Peters)	+	-	-
64.	*Osteobrama cotio cotio* (Hamilton)	+	-	+
65.	*Osteobrama vigorsii* (Sykes)	+	-	-
66.	*Osteochilus neilli* (Sykes)	+	-	+
67.	*Rasbora daniconius* (Hamilton)	+	-	+
68.	*Pristolepis marginata* (Jerdon)	+	-	+
69.	*Neotropius atherinoides* (Bloch)	+	-	+
70.	*Puntius filamentosus* (Valenciennes)	+	-	+
71.	*Puntius amphibius* (Valenciennes)	+	-	-
72.	*Barbodes carnaticus* (Jerdon)	+	-	-
73.	*Puntius chola* (Hamilton)	+	-	+
74.	*Chagunius chagunio* (Hamilton)	+	+	-
75.	*Hypselobarbus curumuca* (Hamilton)	+	-	+
76.	*Puntius denisonii* (Day)	+	-	+
77.	*Puntius dorsalis* (Jerdon)	+	-	+
78.	*Puntius jerdoni* (Day)	+	-	+
79.	*Hypselobarbus kolus* (Sykes)	+	-	-
80.	*Puntius mahecola* (Valenciennes)	-	-	+
81.	*Haludaria melanampyx* (Day)	+	-	-
82.	*Hypselobarbus punctatus* (Day)	+	-	+
83.	*Puntius pulchellus* (Day)	+	-	-
84.	*Systomus sarana* (Hamilton)	+	+	+
85.	*Puntius sophore* (Hamilton)	+	-	+
86.	*Pethia shalynius* (Yazdani and Talukdar)	+	-	-
87.	*Pethia ticto* (Hamilton)	+	-	+
88.	*Megarasbora elanga* (Hamilton)	+	-	-
89.	*Rhinomugil corsula* (Hamilton)	+	-	+
90.	*Rohtee ogilbii* (Sykes)	+	-	-
91.	*Salmophasia untrahi* (Day)	+	-	-
92.	*Tor khudree* (Sykes)	+	+	-
93.	*Tor malabaricus* (Jerdon)	+	+	-
94.	*Hypselobarbus mussulah* (Sykes)	+	+	-
95.	*Tor putitora* (Hamilton)	+	+	+
96.	*Neolissochilus hexagonolepis* (Mcclelland)	+	+	-
97.	*Neolissochilus hexastichus* (Mcclelland)	+	+	-
98.	*Thynnichthys sandhkhol* (Sykes)	+	-	-
99.	*Schizothorax* sp.	+	+	-
100.	*Schizothorax plagiostomus* (Heckel)	+	+	-
101.	*Sperata aor* (Hamilton)	+	+	-
102.	*Pangasius pangasius* (Hamilton)	+	+	-
103.	*Silonia childreni* (Sykes)	+	-	-
104.	*Silonia silondia* (Hamilton)	+	+	-
105.	*Ompok pabda* (Hamilton)	+	-	+
106.	*Wallago attu* (Schneider)	+	+	+
107.	*Xenentodon cancila* (Hamilton)	+	-	-
108.	*Salmophasia bacilla* (Hamilton)	+	-	+
109.	*Laubuca laubuca* (Hamilton)	-	-	+

110.	*Gadusia chapra* (Hamilton)	+	-	+
111.	*Salmophasia bacaila* (Hamilton)	+	-	+
112.	*Johnius coitor* (Hamilton)	+	-	-
113.	*Lepidocephalus guntea* (Hamilton)	+	-	+
114.	*Badis badis* (Hamilton)	+	-	+
115.	*Chagunius chagunio* (Hamilton)	+	+	-
116.	*Gambusia affinis* (Baird and Girad)	+	-	+
117.	*Clarias gariepinus* (Burchell)	+	+	-

Table 4: Consolidated list total species diversity of Indian Reservoirs.

73% of total fish diversity recorded in river Betwa was reported [16]. They showed distinct variation in distribution pattern, size classes and abundance of some of the migratory species like *Bagarius bagarius*, *Pangasius pangassius*, *Wallago attu*, *Silonia silondia* and *Chitala chitala*. The distribution of all migratory fishes except *C. chitala* above dam sites indicate less adverse effects. The dam and reduction in river flow due to water diversion for irrigation would made the spawning migration of these fish impossible in the extreme upper and in lower stretch of river Betwa [17]. The similar kind of observation was reported by [18]. In another study, occurrence of about 75% fish species in the nearby dam site of river Gerua (under protected area) was reported out of total diversity biodiversity (87 species) recorded from the different sites of river Gerua, a tributary of river Gharga were reported [19]. They concluded that freshwater protected areas commonly result in increased fish abundances for those threatened fishes which are extremely important for biodiversity conservation and management.

The number of fish species decreased from 107 to 83 because the migration was interrupted by the Xinanjiang dam (China) [20]. Several studies reported that dams have serious impacts on fish assemblage structure and fish species richness [20,21]. The negative effect of dams on diadromous species was more significant at lower elevations [22]. Narmada river system on the west coast experienced significant decline (68.24%) in hilsa catch in 2004-05 (4866t) as compared to 1993-94 (15319t) and this decline was prominently recorded from 1998-99 onwards. Constructions of dams have badly affected migratory fishes like mahseer and hilsha. Mahseer the most prestigious fish of our country is very badly affected due to dam construction and now this fish is categorized under endangered status. This fish was once in abundance in river Narmada but now it has wiped out because of dams. Tehri dam on Bhagirathi is another example of loss of mahseer due to dams [23].

There is huge loss to our indigenous fish species due to construction of dams across the Nation. The frequent water level fluctuations in the reservoirs lead to deposition of silt and other suspended particles. Thus adversely affecting existence of biotic communities in the reservoirs. The most obvious effect of reservoirs is the permanent destruction of terrestrial ecosystems through inundation. Construction of reservoirs affects fish species diversity by sudden environmental changes from lotic to lentic due to which many species either escape to new conducive environments, few species get adapted to changed environment. Reservoirs are obstacles for longitudinal exchange along rivers and disrupt many natural environmental processes. Hilsa fisheries in Cauvery collapsed in the upstream after construction of Mettur dam. Puntius species also disappeared in Cauvery post dam, which formed 28% of the landings prior to dam construction [5]. Fisheries has not been given due priority till recently in the Indian reservoirs. There is no control over the level of water fluctuation as required for hydel, major and minor irrigations affecting fishery to a great extent. Table 3 showing examples of world-wide biodiversity impact from habitat alteration resulting from hydrological development [24].

Mitigation Programmes

Mitigation is the process to minimize the damages caused by dam construction to natural habitats. They may include restoration, enhancement, or creation. Mitigation can be as simple as changing the location of the planned activity on the site or as difficult as building new areas, such as wetlands, to compensate for the area being destroyed. Before construction of dams we need to plan programmes for the preservation and protection of these important gems of our Country from getting extinct. The Mahseer project started in 1970 at Lonavla can be described as the biggest Indian conservation effort after Project Tiger and is best example for the conservation and development of ecotourism. Tata electric farm Lonavla, devoted to conservation of mahseer species through breeding and other programmes are running with good result.

Generating Fish Ways

Fish ladders and even water-filled fish elevators can be built across dams in order to improve the survival of fishes specially migratory fishes. In most of the dams in India there is no fish passage for either juvenile or adult fish. Good research practices and other refinement techniques can be used in the construction of fish passage that in turn can improve the fish-passage efficiency of the screens and bypass systems. Before dam construction plans including construction of fish ways should be taken into consideration.

Modelling Approach for Fishery Management

Software aided modelling approach towards environmental protection can be used in conservation and restoration of fish species. These software's can be helpful in evaluating dynamics of exploited fish population with in a dam.

Potential of Reservoir Fisheries

India having 19,370 small reservoirs with total water surface area of 3 153 366 ha. At least 100 of them have been subjected to scientific studies. In reservoirs along with protection of natural fish biodiversity tourist recreation and boating can also be maintained that will also help to generate employment for people of the area. Different culture practices can be adopted in reservoir system to enhance production in fisheries. Fish production in reservoirs can be enhanced by using various cultural aspects for fish culture viz cage culture, pen culture etc. These culture systems not only will be helpful to increase fish production of the reservoirs but can also help fishermen's to increase their livelihood by adopting these simple method of fish culture. Thus, reservoirs offer immense scope for increasing fish production. Cage culture and pen culture in reservoirs are the two most adopted systems of fish culture in India. But this system is used mostly for experimental purpose till date not adopted for commercialization or in order to enrich population in reservoirs. Indian reservoirs with water spread of 3.15 m ha, and yield potential of 50, 20 and 8 kg/ha/year only from small, medium and large reservoirs respectively, leave enough scope of enhancing fish yield from such resources through culture based capture fisheries.

Cage and Pen Culture

Amongst the known modern aquaculture systems for increased fish production, cage and pen culture are about the cheapest to operate. A cage is a system that confines the fish or shellfish in a mesh enclosure and Pen is an enclosure to grow fish or prawn in a large water body. Modern cage culture began in the 1950s with the advent of synthetic materials for cage construction. Today cage culture is receiving more attention by both researchers and commercial producers. Factors such as increasing consumption of fish, some declining wild fish stocks, and a poor farm economy have produced a strong interest in fish production in cages [25].

Cage aquaculture technology is of recent introduction in India and has advantages in many respects to increase fish production levels. Cage culture is i) compatible and not competitive with other fish production system and complementary to some, ii) raising of fish in cages is an alternative means of fish production, iii) applicable to most aquaculture species, including predatory fishes, iv) ideally applicable in open waters where fish yields are low and other fishery development is difficult or impracticable, v) cage fish culture provides accelerating growth in fish production in comparison with traditional aquaculture, vi) as the technology is very simple it could be easily adapted by poor and landless farmers and vii) harvesting of fish is easy and provides scope for year-round supply of fish to the markets. Therefore, the practice of cage aquaculture to grow fish seed for in situ stocking or to grow them for marketing has definite advantages with respect to technical application and ecological, social and economic performance over conventional system. Cage culture is applicable to all water bodies including non-drainable, non-seinable and flood-prone areas, otherwise not suitable for aquaculture. Even in macrophyte-choked water bodies, a selected area can be cleaned and utilised for cage culture [26].

Pen culture is very useful to keep the captive stock of fish/prawn in the reservoir. CIFRI has developed a low-cost and simple technology for fish culture in pens erected in reservoir margins [27]. Pen culture is useful in water bodies, where use of fishing gear is difficult. There are three types of rearing done in the pens: i) from fry to fingerlings ii) from fingerlings to table size fishes and iii) from fry larval stages to table size prawn. Except from IMC and Prawn, catfishes and exotic fishes can be grown in the pen. Fishes can be reared even in weed chocked reservoir. Fish in the pens are protected from predators. Pen makes fish growing, easier and bigger by feeding and managing. Advantages of pen and cage culture are already reflected by several workers [28].

Cove Culture

Other than cage and pen culture another system of fish culture called Cove culture, is adopted in some Asian countries like China, Vietnam. In this system of culture the cove separates the alternatively flooded and exposed bay from the main reservoir using either earthen dam or barried net. A cove has several advantages over cage and pen culture as the use of coves neither competes with agriculture for land nor affects the normal water storage and discharge of the reservoir and the use of coves neither competes with agriculture for land nor affects the normal water storage and discharge of the reservoir. Cove culture involves partitioning off the reservoir with a barrier net fixed across the cove mouth. The net is hung usually from a steel cable strung between floats. To prevent fish escape, the top of barrier net can be extended above water surface and the net bottom can be embedded in bottom mud by heavy stone bags. Cove culture in India is not practiced till date but it can be used as an alternative method to increase fish production in dams. Some cases of cove culture have been reported in China [29], Vietnam [30] and Bangladesh [31]. In China, Cove culture by building earthen dams has been practiced since 1960s [32]. Coves can provide fishes with abundant natural foods and natural habitat, and can be an ideal alternative for biodiversity conservation.

Conclusion

Along with these cultural practices we need to increase priorities on many other things like environmental flows, installing reliable and effective fish passes or ladders, enhancement of economic fishery resources, application of effective fishing gear and methods, more strict rules for protection of fishes in dams, effective elimination of harmful organisms and development of integrated fish-farming systems (e.g., fish-livestock-forestry or fish-agriculture-livestock). Stocking of the reservoirs with indigenous and other commercially important fishes can also enhance the fish production of reservoirs. This step is followed by various government agencies across the country like Madhya Pradesh Fisheries Federation has stocked Kerwa dam in Bhopal with the seed of golden mahseer (*Tor putitora*) brought from Directorate of Cold Water Fisheries (DCWFR), Bhimtal.

Reservoirs have both positive and negative effects on fisheries. Dams have somewhat positive impact socially but all that is at the expense of our nature and other form of life. Construction of dams has resulted in mixing of several fish species that have generated new gene pool, introduction of many invasive species. Dams can thus improve fisheries biota to a large extent particularly tail water fisheries as the area below dams are rich in nutrients from the upstream reservoir.

Efforts should be made to stock dams with local fish as they are well adapted to the environmental conditions, likely to survive well and these fishes are frequently available and this will also help to conserve diversity of the reservoir. Exotic fish can also be stocked in the dam using cage and pen culture but proper care should be taken as if they enter into the wild, they can become serious pests which compete with native species and cause environmental damage. Most importantly at first priority we need to conserve biodiversity of our reservoirs by adopting various scientific technologies. Gobindsagar in District Bilaspur, Himachal Pradesh is one such example where scientific development has yielded positive results (120 kg/ha/yr.). An effective method for data collection and its strengthening leading to development of reliable database at regional and global level can also be generated. These databases can compile the information related to a particular reservoir viz. location, geographical features, fish diversity etc. that will be helpful for further effective reservoir management. Through better understanding of ecological principles playing role in defining trophic status and reservoir biodiversity along with sound and sustainable methods, the fisheries could be enhanced manifold. It is obvious that water resources are essential for sustaining the life on the earth and all kinds of socio-economic developmental activities and therefore, appropriate planning and management of aquatic resources are important since India, already suffering from the increasing population and shortage of all kind of natural resources like water. However, there is need to visualize many relevant issues of the sustainable aquatic biodiversity conservation. The concepts like water and aquatic resource conservation, best regulation of existing facilities, rainwater harvesting, watershed and river basin management, water reuse etc. will continue to be highly relevant. Effective and innovative strategies can be taken up by the conservation agencies for sustaining river and reservoir fish biodiversity. Therefore, a more refined biotic assessment program is required for protection of fish resources.

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