Biodivers Conserv (2008) 17:2495–2511
DOI 10.1007/s10531-008-9396-2

ORIGINAL PAPER

# Conservation of freshwater fish resources of India: new approaches, assessment and challenges

**U. K. Sarkar · A. K. Pathak · W. S. Lakra**

Received: 25 October 2007 / Accepted: 3 April 2008 / Published online: 18 April 2008


**Abstract** The freshwater resources of India are currently experiencing an alarming decline in fish biodiversity due to several factors and as a result, a sizeable portion of fresh water fishes have been categorized as threatened. This emphasizes an immediate need for initiating research and actions for alternative management techniques to protect these aquatic systems. One such option that has potential to protect freshwater ecosystem from numerous threats is the creation of freshwater aquatic sanctuary (FAS) within protected area network. Though similar conservation practices are well established in the terrestrial and marine ecosystem, however, the work on freshwater systems has been very slow and negligible. In the present communication we conceptualized the need and approach for developing FAS within the protected area network based on our observations in the water bodies of the selected wildlife sanctuaries in Northern India as well as success stories of some other countries. In this study we assessed the fish diversity in the selected protected areas of Northern India. The assessment indicated that these sanctuaries harbor 28.26–31.13% of freshwater fishes, which are threatened in other areas. Apart from Indian Major Carps, *Tor putitora*, *Chitala chitala, Pangasius pangasius*, *Clupisoma gerua*, *Ailia coila*, *Aorichthys aor*, *Wallago attu*, *Rhinomugil corsula*, *Ompok pabda*, *Ombok pabo etc.* were the important species encountered in the protected waters. The various issues related to FAS including objectives, approach, potential tools, implementation and management are discussed towards saving endangered fish germplasm resources. Approaches, tools and

U. K. Sarkar (✉) · A. K. Pathak
Fish Conservation & Management, National Bureau of Fish Genetic Resources,
Canal Ring Road, P.O. Dilkusha, Lucknow 226002, India
e-mail: usarkar1@rediffmail.com; uksarkar@nbfgr.res.in

A. K. Pathak
e-mail: akpathak@nbfgr.res.in

W. S. Lakra
Fish Biotechnology, National Bureau of Fish Genetic Resources, Canal Ring Road,
P.O. Dilkusha, Lucknow 226002, India
e-mail: lakraws@hotmail.com

*modus operandi* proposed in this communication could be utilized by other developing countries in the region.

**Keywords** Conservation · Freshwater fish diversity · India · Protected area · Strategies · Assessment

## Introduction

Throughout the world, freshwater environments are experiencing serious threats to both biodiversity and ecosystem stability (Suski and Cooke 2006), and many strategies have been proposed to solve this crisis (Williams et al. 1989; Warren and Burr 1994; Cowx 2002; Suski and Cooke 2006). Stress caused by anthropogenic environmental degradation due to urbanization, construction of dams, abstraction of water for irrigation and power generation, and pollution. in the last few decades had many negatives effects on freshwater fish genetic biodiversity, particularly in rivers. This was coupled with irreversible genetic changes in natural populations by introductions of exotic species and diseases. Freshwater fishes, for example, may be the most threatened group of vertebrates on earth after amphibians (Bruton 1995; Duncan and Lockwood 2001) and the global extinction rate of fishes is believed to be in excess of higher vertebrates (Bruton 1995; Sisk et al. 1994).

Studies have shown that changes to the relative abundance of individuals or species within an aquatic community can negatively impact species richness, ecosystem biomass, the age of first maturity for fishes, or food web dynamics (Shutter and Koonce 1977; Rochet and Trenkel 2003) underscoring the need to maintain the structure of aquatic communities. Current approaches to conservation and protection of biodiversity in the freshwater are substantially lacking in effectiveness, and thus more effective management techniques and feasible tools are required. One of the options is to create aquatic sanctuaries within water bodies (rivers, streams, wetlands, reservoirs, lakes and beels) of existing wildlife-protected areas. While this approach to freshwater conservation is by no means novel, we propose that this is an underused and overlooked option for freshwater a conservationist that deserves wider consideration, application, and research.

## Background

According to Convention of Biological Diversity in 1992 (the CBD), the conservation of biodiversity including aquatic biodiversity, require the protection of representative examples of all major ecosystem types, coupled with the sympathetic management of ecosystems outside those protected areas. The future extinction rate of freshwater animals is predicted to be five times greater than that for terrestrial animals and three times that of coastal marine mammals (Ricciardi et al. 1999). Therefore, freshwater protected areas are one strategy that may be used to protect fresh waters from the threats of land use to protect freshwaters from the various threats (Saunders et al. 2002). The need of protected areas for target freshwater habitats, representative habitats, rare or endangered species, and intact habitat remnants are emphasized by various authors (Lake 1980; Moyle and Sato 1991; Doppelt et al. 1993) and some attempts have been recently conducted worldwide, with variable success, to develop protected areas (Keith 2000; Saunders et al. 2002). Freshwater protected areas have played an important role in the rehabilitation and conservation of a number of freshwater species. Freshwater preserves have been used in the conservation of

several species in the western United States beginning primarily in the 1960's (Miller and Pister 1971; Williams 1991; Means and Johnson 1995). A no-fishing reserve in a Zimbabwe lake proved successful at increasing both the number and size distribution of several freshwater fish families (Sanyanga et al. 1995), and the establishment of no-fishing refuges has played a large part in the rehabilitation of exploited lake trout populations in lakes (Reid et al. 2001; Schram et al. 1995). A number of researchers have strongly suggested developing freshwater refugia to aid in the conservation and protection of different aquatic species. Li et al. (1995) called for the identification of areas of high species diversity that can be protected by refuges to lower extinction risks for aquatic fauna in Oregon, while Moyle and Yoshiyama (1994) called for the creation of Aquatic Biodiversity Management Areas (ABMAs) to protect endangered and threatened aquatic species in California.

Research and earlier studies have shown that freshwater protected areas have been a successful management option for conserving threatened fishes (Miller and Pister 1971; Cowx 2002). The conservation of threatened fishes through the creation of endangered fish sanctuaries is well recognized in countries like USA (Miller and Campbell 1994; Pearse 1998). Recently, the importance of monitoring biodiversity in protected areas has been realized by the developing countries (Danielsen et al. 2000). Effects of marine reserves protection on abundance and size at Tonga Island Marine Reserve, New Zealand have been reported by Davidson et al. 2002. The creation of numerous marine reserves throughout New Zealand has offered the opportunity to investigate populations of many species in un-harvested situation (Creese and Cole 1995). In China, closed seasons and sanctuaries are well established as management measures (Qizhe and Qiulingh 1994). In Australia, endangered fish have been nominated for protection under the Victorian Flora and Fauna Guarantee Act of 1988. Pullin (1990) emphasized habitat protection as the best tool for conserving fish. Currently, Danielsen et al. (2000) have developed a simple system for monitoring biodiversity in protected areas for the developing countries.

## Indian scenario

India is blessed with a very rich and diverse natural water resources in the form of rivers, streams, estuaries, backwaters, impoundments, mangroves, floodplain wetlands, man-made reservoirs, lakes tanks and ponds. The country is also endowed with a rich fish genetic biodiversity (2,200 fish species) and ranks 9th in term of freshwater mega biodiversity (Mittermeier and Mittermeier 1997). A significant portion of the freshwater fish production in India is still based on the harvest from wild population. Attempt to assess the Indian freshwater fishes for conservation was made by NBFGR which enlisted several species under threatened category (Anon 1992–1993, CAMP 1998; Lakra and Sarkar 2007). The first assessment (Anon 1992–1993) categorized 46 freshwater fish species as threatened. In the second assessment, of 320 freshwater fishes assessed according to IUCN criteria (CAMP 1998), 43 freshwater fish species are critically endangered, 90 are endangered and 81 are vulnerable. The recent assessment for central India reported 41 species (56.58%) of freshwater fishes as threatened under different categories (Lakra and Sarkar 2007). Some of the critically endangered and endangered freshwater finfish species are *Horabagrus brachysoma*, *Tor mussullah*, *T. putitora*, *T. tor*, *Pangasius pangasius*, *Osteobrama belangeri*, *Ompok pabda*, *Chitala chitala* and *Chaca chaca*.

In India, studies on the diversity of freshwater fishes in the major basins were primarily focused on the catch data of major taxonomic groups at spatial scale (Vishwanath et al. 1998) and information on the species abundance, distribution and priority habitat attributes required for conservation are very limited except few studies (Singh and Sharma 1998 Bhatt 2003;

Dahanukar et al. 2004; Biswas and Barua 2000). So far waterbodies of the PA is concerned; scant data is available on fish diversity studies. Recently, the status of fish germplasm resources in 4 water bodies in a protected areas in the North East region of India have been studied by NBFGR, Lucknow along with two wildlife sanctuaries in Uttar Pradesh. Previous studies (Husain 1983; Manimekalan 1998; Arunachalam and Sankarnarayanan 1999) carried out survey in the water bodies of the wildlife sanctuaries of India which was related to fish taxonomy but aspects related to habitat, species composition, distribution and occurrence of different life stages of endangered fish species of conservation significance, were not considered. Singh et al. (2000) reported that recent Biodiversity Conservation Prioritized Project (BCCP) highlights the inadequacy of data on many wetlands, which otherwise would have deserved protected status. In India, NBFGR is the only research organization that has initiated extensive studies in the waterbodies of protected areas for conservation of threatened fishes and reported research findings which can be used as baseline information for the policy makers in declaring conservation areas for the endangered fishes (Kapoor and Sarkar 2004; Sarkar et al. 2005). Sarkar et al. (2004) also reported preliminary studies on freshwater aquatic sanctuary management (FASM) of the selected area using GIS tools.

## Protected area network

India has developed a network of protected areas (Singh 1985; Rodgers and Panwar 1988; Pande et al. 1989). Areas of significant ecological value in terms of flora and fauna and landforms are representative of biogeography and theories of conservation biology (Caughley and Gunn 1996). The current protected area network (Fig. 1) encompasses almost 4.74% (1,55,978.04 km$^2$) of India's geographical area in the form of 500 sanctuaries, 95 National Parks and two conservation reserves (ENVIS–Wildlife and 2006). Rodgers et al. (2000) recommended adding more protected areas to the network to total 858 or 5.69% of the country's geographical area. In recent years, a plethora of guidelines (Davey 1996), approaches (Johnson 1995) and strategies (Braatz 1992) have been developed to conserve biological diversity in both terrestrial and aquatic ecosystems. However, a review of protected area network in India reveals a poor representation of aquatic areas in the network. Though a wealth of information has been generated over the years on terrestrial biodiversity, the freshwater fish

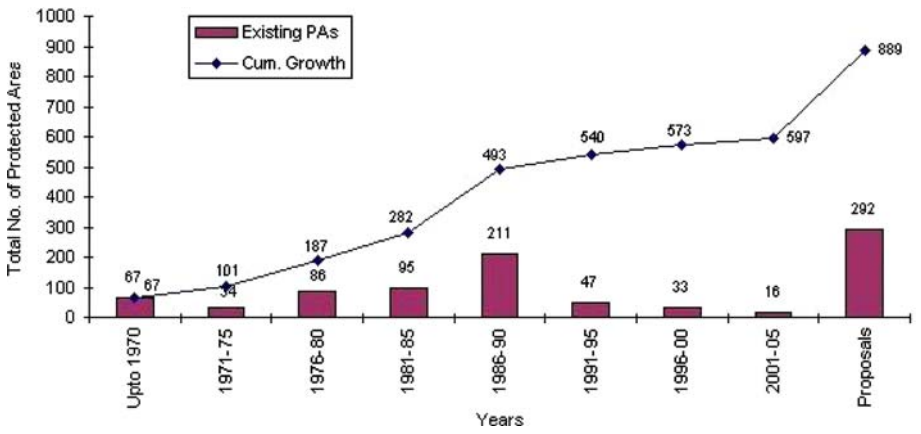


**Fig. 1** Growth of Protected Areas in India (Source: ENVIS–Wildlife and Protected area database, Wildlife Institute of India, Dehradun. website: www.wii.gov.in/envis/pa_database.html)

species richness within many protected areas is poorly understood. Out of 597 protected areas, only 55 are exclusive wetland protected areas (Hussain 1996) and about 10% of the protected areas in the country have no specific aquatic habitat. The Wildlife Protection Act of India (1972) provides legal protection to terrestrial and some of the aquatic animals and marine mammals but less emphasis was given on freshwater fish biodiversity. The recent studies undertaken by NBFGR indicated higher species richness of some the threatened fishes and described new records in the water bodies of the selected Wildlife sanctuaries in Uttar Pradesh (Sarkar et al. 2002a, b). These findings highlight the fact that there is a need for proper biodiversity inventory in the water bodies of the PA network which covers a variety of bio-geographical zones. The creation of comprehensive network of freshwater aquatic sanctuary within protected area network should be key components in conservation policy of the PA'S.

## Categories of protected areas

To date, the use of protected area for freshwater fish conservation strategies has not proliferated to the same level as Marine Protected Areas. Different authors have used different terminologies in the use of protected areas (Table 1), and many of these have been successful at protecting aquatic habitat biodiversity. A review of literature indicates use of protected areas for conservation of freshwater resources with different focus (Table 2). We recommend the use of Freshwater Aquatic Sanctuary (FAS) to standardize the terms.

Protected Areas have been categorized by International Union for the Conservation of Nature & Natural Resources (1994) as follows, (i) strict nature reserve or protected area managed mainly for science (ii) wilderness area or area managed mainly for wilderness (iii) national parks or protected area managed for ecosystem conservation and recreation (iv)

**Table 1** Terminologies used for different types of protected areas under different nomenclature. Below is a list of terminology commonly used to describe different protected areas along with their intended meanings

| Terminology | Description | Examples/References |
|---|---|---|
| Refuge | Areas managed specifically for one or few species rather than general biota | Williams (1991); Moyle and Yoshiyama (1994) |
| Sanctuary | Typically focused on a species that is targeted for harvest such as game fish or waterfowl. Implies no harvest or fishing activity rather than no use. Can be voluntary or mandatory | Suski et al. (2002) |
| Aquatic Diversity Management Area (ADMA) | Area designed to protect and maintain aquatic diversity. Uses compatible with the ADMA are permitted which may include some fishing activities and harvest | Moyle and Yoshiyama (1994) |
| Fishing Reserve | Small areas designed to protect against habitat degradation and to limit exploitation | Crivelli (2002) |
| Preserve | Biological community is left to function in its natural state and managed to protect natural features | Williams (1991); Moyle and Yoshiyama (1994) |
| Closed area | Implies no use or passage-cultural or natural resource protection. Some locations are closed to the public but used by specialized groups such as the military | No examples |
| Freshwater protected area (FPA) | Any area of fresh water terrain, together with its overlying water and associated flora, fauna, historical and cultural features, including riparian regions and groundwater, which has been reserved by law or other effective means to protect part or all of the enclosed environment | Kelleher and Kenchington (1992) |

**Table 2** A compilation on the use of freshwater protected areas along with major recommendations by different experts

| Author | Year | Focus | Recommendations |
|---|---|---|---|
| Williams | 1991 | Historical perspective of protected areas for freshwater fishes in western United States | Set species—specific goals for recovery plans, protect areas of high diversity with refuges |
| Lyle and Maitland | 1992 | Overview of the use of the nation nature reserve system for fish in the United Kingdom | Nature reserve can improve fish conservation; Focus on acquisition of new reserve for threatened species |
| Keith | 2000 | Overview of the use of freshwater protected areas in France | Must inventory species, develop site specific management plans for each threatened fish species |
| Cowx | 2002 | Threats to freshwater fishes; problems with current conservation practices; option for future conservation | Conservation efforts should integrate research to identify problem areas; utilize protected areas to promote stability; consider multiple-user framework |
| Fitzsimons and Robertson | 2005 | Directions and challenges for the development of freshwater reserves in Australia | Establishment of a freshwater reserves in a comprehensive, adequate and representative manner (CAR); importance of qualitative data for reservation status and protection measures |

natural monument or protected area managed for specific natural features (v) habitat/species management area or protected area managed mainly for conservation through management intervention (vi) protected landscape/seascape or PA managed mainly for landscape/seascape conservation and recreation and (vii) managed resource protected area or PA managed mainly for the sustainable use of natural ecosystems. Based on the biological richness, economics, endemicity and ecological values as well as sustainability for management the categories for aquatic germplasm conservation may be prioritized.

A review of the protected area network of India reveals an inadequate representation and poor coverage of aquatic biodiversity within protected areas. This also does not reflect their ecological, socioeconomic and cultural significance. The earlier PA network of India did not fully represent several biologically important regions, communities and species. Recently, classification made by Rodgers et al. (2000) recommends 10 biogeographical zones, divided in to 26 provinces. These are Trans-Himalaya, Himalaya, Desert, Semi-Arid, Western Ghats, Deccan, Gangetic Plains, Coasts, North East India and Islands. This classification indicates that the percentage cover under PA is maximum in Islands (18.54) followed by Western Ghats (10.12) and both Himalayas and Trans-Himalayas (19.12).

## Ramsar sites

The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty, which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. Recently, India has designated six new wetlands to the Ramsar Convention on Wetland's list of wetlands of international importance and this brings the number of Ramsar sites in India to 25. The new areas include: Hokera Wetland and Surinsar-Mansur Lakes in the northwestern Himalayan province of Jammu &

Kashmir; Chandertal Wetland and Renuka in Himachal Pradesh; Rudrasagar Lake in the northeastern state of Tripura; and Upper Ganga River in Uttar Pradesh.

## In-situ conservation of fish diversity

The two protected areas (PA's) in Northern India were identified for the present research programme. The waterbodies of the two areas were investigated from April 2000 to March 2004. Katerniaghat Wild Life Sanctuary (KWS) established in 1976 (under 1972 Wildlife Protection Act of India) is situated in Bahraich district of Uttar Pradesh and located in the foothills region close to the Indo-Nepal border. The Gerua River originates in the Himalayan mountains, crosses through the Royal Bardi National Park in Nepal, and enters India at the Katerniaghat Wildlife Sanctuary in the Terai region, Bahraich district, Uttar Pradesh. The river Gerua has a mean annual discharge of about 1,500 $m^3$ (Agarwala et al. 2003, estimated at 1392 $m^3/s$ by AQUASTAT 2005). Positional coordinates of the water bodies within sanctuary were N 28°21.889, E 081° 11983, mean altitude 146 m. msl, spread over 400.69 $km^2$ with 12,000 ha of rivers, small creeks, streams, beels, and wetlands. The Gerua River is typically 950.62 m wide, and has eight channels, 12 islands and side channels. The water quality is good and no major degradation of the habitat exists. River substrata are mainly composed of boulders, pebbles, and sandy clay. Most of the sampling sites had soft water and were shaded by dense riparian vegetation. The surrounding land in the sanctuary is protected for conservation purposes and is composed of grasslands (5,000 ha), deep forest, terrestrial wild animals, marshy lowlands and ten villages. Downstream of the sanctuary the Girijapuri Barrage diverts some of the flow of Gerua River for irrigation and the river then joins the Ghagra River, which is a major tributary of River Ganges. The second PA is situated in the Raebareilly district of U.P. The water body is 'S' shaped, lentic in nature comprising six beels(myriads of small and large natural waterbodies) interconnected with each other within an overall area of 720 ha and water area of 320 ha. The *beels* are perennial in nature and main water resources are the various tail ends of canals, which are connected to these lakes. On the basis of a pre-study survey, the water bodies of the two protected areas were divided in to different zones. The criteria's for identifying zones were topography and other physical habitat conditions like depth, intensity and type of aquatic vegetation, riparian cover, nature of human interference and type of habitat. Monthly experimental sampling for fish and major habitat parameters were carried out. Gill nets, cast nets and dragnets were used for fishing. The early life stage of fish was collected by fry collecting nets in selected areas. The species diversity, relative abundance, occurrence of the water bodies were quantified.

## Species diversity and assessment in the PA's

A total of 9,824 fish were collected from river Gerua flowing within KWS and were classified into 87 species representing 22 families and 52 genera. The list of species along with local name, status, length data and relative abundance are presented in Table 3 which is self explanatory. The Cyprinidae was the most dominant family accounted for 49.43% (40 species) of the total number of fish species collected, followed by the family bagridae 8.04% (7 species) and Schilbeidae 5.74% (5 species). A total of 87 fish species were collected belonging to 22 families, 87 species and 52 genera. Fish abundance and diversity was significantly different ($P < 0.05$) between the protected area of river Gerua and fishes area

**Table 3** Details of the fish species recorded in Katerniaghat Wildlife Sanctuary (KWS) and Samaspur Bird Sanctuary (SBS), Uttar Pradesh, India

| Sl. no. | Scientific name | Local name | Status as per CAMP | Total nos. | | Total mean length (cm.) (KWS & SBS) | | Relative abundance (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | KWS | SBS | Max. | Min. | KWS | SBS |
| 1. | *Chitala chitala* (Hamilton) | Moye | EN | 142 | 70 | 90.0 | 30.2 | 1.44 | 2.03 |
| 2. | *Notopterus notopterus* (Pallas) | Patra | LRnt. | 554 | 155 | 29.5 | 11.1 | 5.63 | 4.5 |
| 3. | *Gudusia chapra* (Hamilton-Buchanan) | Suhia | LRlc. | 172 | 250 | 22.5 | 5.2 | 1.75 | 7.26 |
| 4. | *Setipinna phasa* (Hamilton-Buchanan) | Phasi, Bindi | NE | 67 | A | 18.5 | 14.2 | 0.68 | A |
| 5. | *Amblypharyngodon mola* (Hamilton-Buchanan) | Dhawai | LRlc. | 265 | 175 | 18.2 | 4.3 | 2.69 | 5.08 |
| 6. | *Aspidoparia morar* (Hamilton-Buchanan) | Pirohia, Kenwacchi | LRnt | 25 | A | 15.3 | 13.5 | 0.25 | A |
| 7. | *Barilius barila* (Hamilton-Buchanan) | Persee | VU | 67 | A | 12.5 | 8.5 | 0.68 | A |
| 8. | *Barilius barna* (Hamilton-Buchanan) | Daranghi | LRnt | 54 | A | 9.0 | 4.5 | 0.54 | A |
| 9. | *Barilius bendelisis* (Hamilton-Buchanan) | Angura | LRnt | 72 | A | 9.9 | 7.9 | 0.73 | A |
| 10. | *Barilius tileo* (Hamilton-Buchanan) | Tilwa | LRnt | 16 | A | 5.6 | 4.0 | 0.16 | A |
| 11. | *Brachydanio rerio* (Hamilton-Buchanan) | Anju | LRnt | 72 | A | 4.1 | 3.2 | 0.73 | A |
| 12. | *Bengala elanga* (Hamilton-Buchanan) | Malang | LRnt | 75 | A | 5.8 | 4.5 | 0.76 | A |
| 13. | *Aristichthys nobilis* WU | Big-head | NE | A | 2 | 45.0 | 40.2 | A | 0.05 |
| 14. | *Catla catla* (Hamilton-Buchanan) | Bhakur, Katla | VU | 125 | 85 | 71.0 | 30.0 | 1.27 | 2.46 |
| 15. | *Chela atpar* (Hamilton-Buchanan) | Kachni | NE | 76 | A | 5.0 | 3.9 | 0.77 | A |
| 16. | *Chela laubuca* (Hamilton-Buchanan) | Chelwa | LRlc | 162 | A | 4.1 | 3.1 | 1.64 | A |
| 17. | *Cirrhinus mrigala* (Hamilton-Buchanan) | Nainee | LRnt | 195 | 77 | 66.5 | 18.0 | 1.98 | 2.23 |
| 18. | *Cirrhinus reba* (Hamilton-Buchanan) | Rewa bata | VU | 279 | A | 32.0 | 29.5 | 2.83 | A |
| 19. | *Cyprinus carpio* Linnaeus | China rahu | NE | 1 | A | 45.3 | 20.5 | 0.01 | A |
| 20. | *Danio devario* (Hamilton-Buchanan) | Patukari | LRnt. | 87 | 108 | 8.9 | 3.1 | 0.88 | 3.13 |
| 21. | *Gara gotyla gotyla* (Gray) | Siltoka, Patharchatta | VU | 92 | A | 12.5 | 10.5 | 0.93 | A |
| 22. | *Labeo angra* (Hamilton-Buchanan) | Kharsa rewa | NE | 10 | A | 15.3 | 13.1 | 0.10 | A |
| 23. | *Labeo bata* (Hamilton-Buchanan) | Bata | LRnt. | 288 | 230 | 38.0 | 10.0 | 2.93 | 6.68 |
| 24. | *Labeo calbasu* (Hamilton-Buchanan) | Kauranchi | LRnt. | 127 | 80 | 57.3 | 16.1 | 1.29 | 2.32 |
| 25. | *Labeo dero* (Hamilton-Buchanan)a | Gola raria | VU | 36 | A | 25.6 | 13.0 | 0.36 | A |
| 26. | *Labeo dyocheilus* (McClelland) | Boalla | VU | 25 | A | 37.5 | 35.3 | 0.25 | A |
| 27. | *Labeo gonius* (Hamilton-Buchanan) | Kursha | LRnt | 57 | 125 | 56.0 | 20. 5 | 0.58 | 3.63 |
| 28. | *Labeo pangusia* (Hamilton-Buchanan) | Rewa | LRnt | 15 | 68 | 29.8 | 24.0 | 0.15 | 1.97 |
| 29. | *Labeo rohita* (Hamilton-Buchanan) | Rohu | LRnt | 147 | 89 | 75.0 | 39.0 | 1.49 | 2.58 |

**Table 3** continued

| Sl. no. | Scientific name | Local name | Status as per CAMP | Total nos. | | Total mean length (cm.) (KWS & SBS) | | Relative abundance (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | KWS | SBS | Max. | Min. | KWS | SBS |
| 30. | *Osteobrama cotio* (Hamilton-Buchanan) | Mutheri, Gurda | LRnt | 18 | A | 13.2 | 9.1 | 0.18 | A |
| 31. | *Puntius conchonius* (Hamilton-Buchanan) | Pothi | VU | 77 | A | 5.3 | 4.0 | 0.78 | A |
| 32. | *Puntius chola* (Hamilton-Buchanan) | Puthi, Siddhari | NE | A | 77 | 11.5 | 3.5 | A | 2.23 |
| 33. | *Puntius puntio* (Hamilton-Buchanan) | Pothi | LRlc | 65 | A | 6.5 | 5.5 | 0.66 | A |
| 34. | *Puntius sarana* (Hamilton-Buchanan) | Puthi | VU | 42 | 93 | 22.5 | 7.5 | 0.42 | 2.7 |
| 35. | *Puntius sophore* (Hamilton-Buchanan) | Pothi | LRnt | 73 | 85 | 12.5 | 2.6 | 0.74 | 2.46 |
| 36. | *Puntius terio* (Hamilton-Buchanan) | Teri pungti | NE | 21 | A | 7.5 | 4.2 | 0.21 | A |
| 37. | *Puntius ticto* (Hamilton-Buchanan) | Pothia | LRnt | 42 | 75 | 8.6 | 2.0 | 0.42 | 2.17 |
| 38. | *Raimas bola* (Hamilton-Buchanan) | Gulabi machli | VU | 16 | A | 23.8 | 22.0 | 0.16 | A |
| 39. | *Rasbora daniconius* (Hamilton-Buchanan) | Dendua | LRlc | 46 | A | 9.8 | 8.6 | 0.46 | A |
| 40. | *Rasbora rasbora* (Hamilton-Buchanan) | – | LRnt | 15 | A | 11.6 | 9.6 | 0.15 | A |
| 41. | *Salmostoma bacaila* (Hamilton-Buchanan) | Chelwa | LRlc | 1113 | 190 | 15.6 | 2.91 | 11.32 | 5.51 |
| 42. | *Securicola gora* (Hamilton-Buchanan) | Darai challo | LRlc | 10 | A | 22.1 | 18.6 | 0.10 | A |
| 43. | *Schizothoraichthys progastus* (McClelland) | Dinnawah | LRnt | 15 | A | 30.2 | 28.5 | 0.15 | A |
| 44. | *Schizothorax richardsonii* (Gray) | Trout | VU | 20 | A | 38.5 | 32.5 | 0.20 | A |
| 45. | *Tor putitora* (Hamilton-Buchanan) | Mahseer | EN | 210 | A | 90.8 | 33.5 | 2.13 | A |
| 46. | *Tor tor* (Hamilton-Buchanan) | Mahseer | EN | 198 | A | 35.5 | 32.6 | 2.01 | A |
| 47. | *Acanthocobitis botia* (Hamilton-Buchanal) | Natwa | LRnt | 76 | 45 | 7.5 | 3.4 | 0.77 | 1.3 |
| 48. | *Botia lohachata* Chaudhuri. | Bagha | EN | 45 | A | 6.8 | 2.5 | 0.45 | A |
| 49. | *Aorichthys aor* (Hamilton-Buchanan) | Tengra | LRlc. | 95 | 70 | 76.0 | 21.5 | 0.96 | 2.03 |
| 50. | *Aorichthys seenghala* (Sykes) | Ari,Tengan | LRlc | 51 | A | 47.5 | 35.2 | 0.51 | A |
| 51. | *Mystus cavasius* (Hamilton-Buchanan) | Sutahawa tengra | LRnt | 85 | A | 45.8 | 30.5 | 0.86 | A |
| 52. | *Mystus menoda* (Hamilton-Buchanan) | Tengra | NE | 16 | A | 37.2 | 28.5 | 0.16 | A |
| 53. | *Mystus tengara* (Hamilton-Buchanan) | Tengra | LRlc | 49 | A | 16.5 | 11.8 | 0.49 | A |
| 54. | *Mystus vittatus* (Hamilton-Buchanan) | Tengra | VU | 82 | 55 | 17.5 | 6.5 | 0.83 | 1.59 |
| 55. | *Rita rita* (Hamilton-Buchanan) | Hunna | LRnt | 110 | 60 | 40.7 | 16.3 | 1.11 | 1.74 |
| 56. | *Ompok bimaculatus* (Bloch) | Pabda | EN | 369 | A | 24.2 | 22.5 | 3.75 | A |
| 57. | *Ompok pabda* (Hamilton-Buchanan) | Pabda | EN | 76 | 32 | 15.5 | 9.3 | 0.77 | 0.92 |
| 58. | *Ompok pabo* (Hamilton-Buchanan) | Pabda | VU | 69 | 41 | 20.5 | 7.8 | 0.7 | 1.19 |

**Table 3** continued

| Sl. no. | Scientific name | Local name | Status as per CAMP | Total nos. | | Total mean length (cm.) (KWS & SBS) | | Relative abundance (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | KWS | SBS | Max. | Min. | KWS | SBS |
| 59. | *Wallago attu* (Schneider) | Parhen, Barari | LRnt | 132 | 66 | 81.0 | 12.6 | 1.34 | 1.91 |
| 60. | *Ailia coila* (Hamilton-Buchanan) | Banspatti, Patasi | VU | 215 | 110 | 13.5 | 4.8 | 2.18 | 3.19 |
| 61. | *Eutropichthys vacha* (Hamilton-Buchanan) | Bachwa | EN | 766 | 135 | 30.5 | 11.6 | 7.79 | 3.92 |
| 62. | *Pseudeutropius atherinoides* (Bloch) | Patasi, Puttahra | NE | 15 | A | 8.8 | 6.7 | 0.15 | A |
| 63. | *Clupisoma garua* (Hamilton-Buchanan) | Baikeri | VU | 525 | 83 | 42.5 | 11.7 | 5.34 | 2.41 |
| 64. | *Pangasius pangasius* (Hamilton-Buchanan) | Pangas | CR | 32 | A | 37.5 | 32.5 | 0.32 | A |
| 65. | *Bagarius bagarius* (Hamilton-Buchanan) | Gonch | VU | 479 | A | 120.5 | 43.5 | 4.87 | A |
| 66. | *Glyptothorax telchitta* (Hamilton-Buchanan) | – | LRnt | 35 | A | 8.0 | 7.4 | 0.35 | A |
| 67. | *Nangra nangra* (Hamilton-Buchanan) | – | NE | 9 | A | 9.7 | 8.2 | 0.09 | A |
| 68. | *Clarias batrachus* (Linnaeus) | Mangur | VU | 72 | 37 | 29.7 | 14.3 | 0.73 | 1.07 |
| 69. | *Heteropneustes fossilis* (Bloch) | Singee | VU | 95 | 35 | 26.8 | 10.3 | 0.96 | 1.01 |
| 70. | *Xenentodon cancila* (Hamilton-Buchanan) | Kakhya, Thona | LRnt | 110 | 60 | 23.0 | 7.6 | 1.11 | 1.74 |
| 71. | *Monopterus (Amphipnous) cuchia* (Hamilton-Buchanan) | Cuchia | NE | 10 | 21 | 75.7 | 60.0 | 0.1 | 0.6 |
| 72. | *Chanda nama* Hamilton-Buchanan | Chanari | LRlc | 96 | 80 | 4.5 | 2.0 | 0.97 | 2.32 |
| 73. | *Parambassis ranga* (Hamilton-Buchanan) | Chanari | LRlc | 105 | 77 | 5.3 | 2.0 | 1.06 | 2.23 |
| 74. | *Parambassis baculis* (Hamilton-Buchanan) | Chanari | LRnt | 56 | A | 3.7 | 3.6 | 0.57 | A |
| 75. | *Glossogobius giuris* (Hamilton-Buchanan) | Bulla | LRnt | 82 | 18 | 6.3 | 3.1 | 0.83 | 0.52 |
| 76. | *Nandus nandus* (Hamilton-Buchanan) | Vaadhul | LRnt | 48 | 37 | 17.0 | 11.3 | 0.48 | 1.07 |
| 77. | *Anabas testudineus* (Schneider) | Kobai | VU | 55 | 17 | 17.1 | 9.5 | 0.55 | 0.49 |
| 78. | *Colisa fasciatus* (Schneider) | Khosti | LRnt. | 38 | 62 | 10.0 | 2.5 | 0.38 | 1.8 |
| 79. | *Colisa lalia* (Hamilton-Buchanan) | Khosti | LRnt. | 32 | 53 | 7.6 | 2.6 | 0.32 | 1.53 |
| 80. | *Channa marulius* (Hamilton-Buchanan) | Sauri | LRnt. | 59 | 42 | 55.5 | 6.0 | 0.60 | 1.21 |
| 81. | *Channa orientalis* Bloch & Schneider | Girohi | VU | 32 | 39 | 45.2 | 3.7 | 0.32 | 1.13 |
| 82. | *Channa punctatus* (Bloch) | Girohi | LRnt. | 65 | 36 | 26.8 | 3.2 | 0.66 | 1.04 |
| 83. | *Channa stewartii* (Playfair) | Sauri | NE | 15 | A | 18.2 | 15.2 | 0.15 | A |
| 84. | *Channa striatus* (Bloch) | Sauri | LRlc. | 43 | 20 | 45.5 | 7.2 | 0.43 | 0.58 |
| 85. | *Macrognathus aral* (Bloch and Schneider) | Patyia, Bami | LRnt | 15 | A | 30.4 | 28.3 | 0.15 | A |
| 86. | *Macrognathus pancalus* Hamilton Buchanan | Bami, Pataya. | LRnt. | 39 | 22 | 16.2 | 10. 5 | 0.39 | 0.63 |
| 87. | *Mastacembelus armatus* (Lacepede) | Baam | LRlc. | 92 | 34 | 56.0 | 7.2 | 0.93 | 0.98 |

**Table 3** continued

| Sl. no. | Scientific name | Local name | Status as per CAMP | Total nos. | | Total mean length (cm.) (KWS & SBS) | | Relative abundance (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | KWS | SBS | Max. | Min. | KWS | SBS |
| 88. | *Rhinomugil corsula* (Hamilton-Buchanan) | Korsul, Answari | NE | A | 22 | 11.5 | 10.3 | A | 0.63 |
| 89. | *Tetraodon cutcutia* (Hamilton-Buchanan) | Galphulani | LRnt. | 35 | A | 6.8 | 4.3 | 0.35 | A |
| 90. | *Tetraodon fluviatilis* (Hamilton) | Potoka | NE | 15 | A | 6.1 | 5.7 | 0.15 | A |

KWS = Katerniaghat Wildlife Sanctuary; SBS = Samaspur Bird Sanctuary; A = Absent; VU = Vulnerable; LRnt = Lower Risk near threatened; LRlc = Lower Risk least concern; EN = Endangered; CR = Critically endangered; NE = Not Evaluated

studied up to 200 km lower stretch of the river. The study indicated that river Gerua supports many river dependent fish species including *Eutropichthys vacha* (a catfish), *Chitala chitala* (featherback), *Notopterus notopterus*, *Clupisoma garua* (gerua vacha, a catfish), *Bagarius bagarius* (dwarf goonch, a catfish), *Ompok bimaculatus* (buttercatfish), *Cirrhinus reba* (rewa bata, a cyprinid), *Catla catla* (catla, a cyprinid) yellowtailcatfish *Pangasius pangasius*, putitor mahseer or golden mahseer *Tor putitora* and *Tor tor*. Out of 87 fish species six species were recorded first time with maximum total length (TL) which was not reported earlier in Indian waters and a new record size (TL 20.5 cm) of *Salmostoma bacaila* (a cyprinid) was recorded (Sarkar et al. 2005). The mean size group of fish sampled in the protected area was higher in many fishes as shown in Fig. 2. Comparative fish occurrence indicated much lower species richness outside of protected areas. One of the important findings was that populations of 31.13% of threatened fish species (as per NBFGR 1998; not IUCN Red list) were found to be the stable in the protected area of river Gerua indicating that Katerniaghat Wildlife Sanctuary could be important for conservation of the fish biodiversity of the Terai region, especially for local and endangered fish species (Unpublished data). Sarkar et al. (2004) arranged fish distribution data, assemblage, fish life stages, habitat variations and assessing biological parameters on a GIS platform at reach level which can be useful for the protected area managers. Also a set of priority habitat types used by groups of freshwater fish species were developed for the Gerua River and species and life stages found occupying a statistically distinct subset of the protected river habitats (Sarkar and Bain 2007). The study also indicated that conservation of large river fish should strive to maintain both erosional and depositional channel habitats.

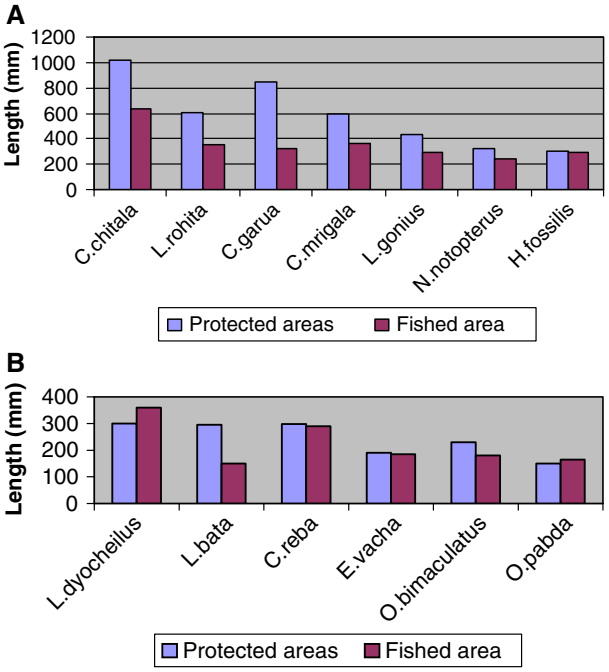


**Fig. 2** Variation of total length (TL) of some fishes in the protected and fishes area of Katernighat Sanctuary (KWS)

From another PA (Samaspur Bird Sanctuary) a total of 46 fish species were collected under 7 orders, 19 families, and 33 genera (Table 1). The analysis showed that 28.26% of fish species which are reported to be threatened as per IUCN were found to be stable population in the inside waters of the sanctuary. One of the important observations was that about 28.26% fishes that come under threatened category in other areas were stable in the sanctuary waters. Apart from Indian Major Carps and above mentioned species, *Chitala chitala*, *Clupisoma gerua*, *Ailia coila*, *Aorichthys aor*, *Wallago attu*, *Rhinomugil corsula*, *Ompok pabda*, *Ombok pabo etc.* were the important species having high conservation significance in the Ganga basin, India. The study confirms that protected freshwater area is important for conservation of the regional fish biodiversity, especially for local and endangered fish species. The literature indicates that fish densities are generally higher in protected areas (Bell 1983) and demographic structure differs significantly in the relative abundance of larger individuals (Bell 1983; Bayle-Sempere and Ramos-Espla 1993; Dufour et al. 1995), both of which in turn result in greater biomass (Francour 1991).

## Challenges

Developing freshwater aquatic sanctuaries for any area will require scientists and managers to overcome a number of challenges, which may vary with geographical location. The primary obstacle is to identify areas or aquatic species that are needed for additional protection. A number of workers have encountered this problem and many papers have been published to share ideas and approaches (Sedell et al. 1994; Moyle and Yoshiyama 1994; Li et al. 1995; Filipe et al. 2004; Higgins et al. 2005). Protection of functional and representative samples of freshwater ecosystems often conflicts with existing human use and human dependency on aquatic resources. There is need to consider many issues like legislation and its enforcement, socioeconomic concerns that may develop from dealing with multiple stakeholders and local community.

The following threats to fish germplasm were identified in the PA's studied. These are (i) occasional use of insecticides by the local fishermen (ii) occasional illegal catch by the local people in the protected water body (iii) fishing by small mesh sized net throughout the year just after the sanctuary area (iv) heavy infestation of exotic aquatic weeds. Release of water for irrigation in KWS, which is not synchronized with the requirements of different life stages. This also resulted in concentrations of fish in smaller volume of water leading to easy poaching. Conflicts between local fishing communities and government departments will have to be resolved by dialogue and accommodation of each other's interests. Local fishing communities should be involved as partners in planning and carrying out the fishery enhancement and conservation measures. However, for this to happen, inter-departmental conflicts and ambiguity among different government departments over the jurisdiction/control of water bodies and fishing rights, will have to be resolved, so that the fish germplasm resources are duly conserved.

## Baseline information for creating sanctuary

Creation of the freshwater aquatic sanctuary within the wild life protected area need to be evaluated on following baselines based on our practical experience.

(a) Inventory of fish germplasm and habitat parameters on the water body under the protected area based on prioritization of species and waterbodies.
(b) Species composition, richness, abundance and conservation status of indigenous and commercially important species.
(c) Frequency of species and water level monitoring and strategies adopted for harvesting over the time outside of the sanctuary area in order to save early life stages.
(d) Evaluation of habitat suitability index for different life stages of endangered fishes
(e) Evaluation of introduced species if any and relation with other species
(f) Suitable protocol for multi species management.
(g) Ecological and socio economic sustainability.
(h) Regulation of prey by predators and management of predators.
(i) Involvement of conservation breeding specialist group.
(j) Evaluation and management of disturbance factors, threats, and other obstacles

The factors described above may vary depending on the environment. A clear-cut guideline needs to be prepared to involve the government and private research agencies working to create and manage the fresh water aquatic sanctuary.

## Conclusion

Protected areas could play an important role in the conservation of fresh water fish diversity of India, but there is need to identify the conservation value of these areas in relation to biogeographical diversity of fishes and the factors impacting on fish communities. The efficiency of FPA's in the inland ecosystems remains to be assessed properly in India since it appears to be a promising management measures for the conservation of regional species. Until now most of the water bodies within protected areas have been insufficiently recognized. The primary objectives for successful conservation of the high fish diversity within protected area network should aim to develop effective controls and management practices that enable life cycle completion, dispersal and population maintenance within aquatic systems. Drastic ecological and anthropogenic changes of forest and aquatic habitat within protected water bodies are great deal of threats for fish biodiversity as well as aquatic habitat.

Biological evidences suggest that protected areas have the potential to protect freshwater environments deleterious stressors, and positively improve declines in biodiversity. The NBFGR's observation also indicate that in spite of absence of specific measures adopted to protect the freshwater fishes, the areas within wildlife sanctuaries can serve as freshwater aquatic sanctuary (FAS) if additional measures are taken to protect these resources against the threats. However, this has to be integrated in to management plan of the respective areas. More studies are required for examining the impacts on the protection of biodiversity and habitat restoration despite their inherent challenges. The creation of protected areas in innovative ways to address the conservation issues will increase our knowledge for developing techniques and models supporting socioeconomical and enforcement issues, and their implementation in future. Joint action oriented research efforts involving research institutes like NBFGR, Lucknow, Wildlife Institute of India, Dehradun, National Biodiversity Authority, Salim Ali Centre for Ornithology and Natural History, Coimbatore, Bombay Natural History Society, Mumbai, Zoological Survey of India of the Ministry of Environment & Forests are required in this direction in order to effective implementation of the conservation programmes in the priority areas. It is also necessary for sensitizing the local people also to develop interest in fish conservation for sustained protection of the threatened species.

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