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Fishes of River Bharathapuzha, Kerala, India: diversity, distribution, threats and conservation

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Abstract: We present here a comprehensive account of the diversity, distribution, threats, and suggest conservation measures for the fishes of Bharathapuzha, the largest west flowing river in the southern Indian state of Kerala. A total of 117 species under 43 families and 81 genera were recorded from the river, of which 98 were primary freshwater and 19 were secondary freshwater and/or diadromous species. Six species of non-native fish were also recorded, of which three were exotic to the country and three were transplanted from the gangetic plains. Twenty-eight percent (S = 33) of species that occur in the Bharathapuzha are endemic to the Western Ghats, while three species (*Balitora jalpalli*, *Mesonoemacheilus remadevii* and *Pseudolaguvia austrina*) are restricted in their distribution to the river system. A little more than one-tenth (11%; S = 13) of species that occur in the river are listed under various threatened categories on the IUCN Red List. As part of this study, we also extend the distribution range of *Osteochilichthys longidorsalis* to the Bharathapuzha River system, based on its collection from the Thoothapuzha tributary. Several anthropogenic stressors including deforestation and loss of riparian cover, dams and other impoundments, pollution, sand mining, non-native species and destructive fishing practices are threatening the rich ichthyofaunal diversity and endemism in the Bharathapuzha. There is hence an urgent need to develop and implement conservation plans, some of which are discussed.

Keywords: *Osteochilichthys longidorsalis*, Nila, river conservation, Silent Valley National Park, Western Ghats.

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INTRODUCTION

Information on diversity and distribution of species is crucial for appropriate and timely decision making in biodiversity conservation. Collation and dissemination of such information is especially important for poorly known yet threatened taxa such as freshwater fish, and for critical biodiversity areas such as 'Hotspots'. The Western Ghats part of the Western Ghats - Sri Lanka Biodiversity Hotspot in peninsular India is an exceptional region of freshwater biodiversity (Dahanukar et al. 2011), where in spite of more than 200 years of research the ichthyofauna continues to be influenced by both the Linnaean and Wallacean shortfall (Dahanukar et al. 2011; Raghavan 2011). Although there are hundreds of papers including checklists on freshwater fishes of Kerala, in both peer-reviewed and gray literature, few provide data that can be validated. Most checklists from this region are not supported by voucher specimens, photographs and/or taxonomic notes and are mere compilations of secondary information from some of the earlier 'dated' papers/checklists.

The Bharathapuzha River, also known as 'Nila' and 'Perar', originates from the northern and southern tips of the Palakkad gap in the Western Ghats, as well as from the gap. The minor tributaries join together to form four major tributaries: Gayathripuzha, Chitturpuzha, Kalpathipuzha, and Thoothapuzha (Image 1). It is the second longest (209km) and largest (annual discharge of 3.94km^3) among the west flowing perennial rivers in the state of Kerala (Raj & Azeez 2012), as well as the river with the most extensive basin area, second in length and third in yield by thousand million cubic feet (TMCF; Anon 1998). The Bharathapuzha watershed lies between 10^{0}25'–11^{0}15'N and 75^{0}50'–76^{0}55'E, and is located in the Palakkad, Thrissur and Malappuram districts of Kerala State. Bharathapuzha has a total basin area of 6,186km^2, of which 4,400km^2 is in Kerala and the remaining in Tamil Nadu (Raj & Azeez 2012).

The earliest ichthyological investigations in the Bharathapuzha drainage (then Ponnani drainage of erstwhile Malabar state in India) were carried out by Jerdon (1849) and Day (1865). This was followed by the works of Herre (1942, 1945), Silas (1951, 1958) and subsequently Indra & Devi (1981), Devi & Indra (1984; 1986), Easa & Basha (1995), Easa & Shaji (1997), Bijukumar & Sushama (2001), Shaji (2002), Kurup et al. (2004), Sushama et al. (2004) and Devi et al. (2005). However, most of these studies were restricted to one or a few regions and/or tributaries of the Bharathapuzha, and a comprehensive study has not yet been realized.

Here, we provide a comprehensive and consolidated checklist of fishes of the Bharathapuzha River system (backed by voucher specimens) and discuss their distribution, threats and conservation. We also report on the extension of range of an endemic cyprinid, *Osteochilichthys longidorsalis* Pethiyagoda & Kottelat 1994, and a new site record for *Pseudolaguvia austrina* Radhakrishnan, Kumar & Ng 2010, in the Bharathapuzha River system.

MATERIALS AND METHODS

Study area

Bharathapuzha has four major tributaries, Gayathripuzha, Chitturpuzha (Kannadipuzha or Amaravathipuzha), Kalpathipuzha and Thoothapuzha (Image 1). From the confluence of Kalpathipuzha and Chitturpuzha at Parali, the river acquires the name 'Bharathapuzha'. The flow regime of the river includes highlands (>76m), midlands (76–8 m) and lowlands (<8m) (Raj & Azeez 2009). A series of large dams have been constructed across the Bharathapuzha River and its tributaries; two dams are located in Tamil Nadu (Thirumoorthy and Aliyar) and seven in Kerala (Kanjirapuzha, Malampuzha, Walayar, Meenkara, Chulliar, Pothundy and Mangalam). Further, there are two major diversion schemes, Moolathara and Cheerakkuzhy, in addition to a Thrithala-Velliyamkallu regulator-cum-bridge. A series of check dams are built across the lower reaches of Bharathapuzha in order to retain water temporarily.

The Reserved Forest area in the Bharathapuzha Basin in Kerala is around 625km^2, while it is 800km^2 including forest vegetation in Tamil Nadu (Image 2). While Chitturpuzha watershed has forest cover in the Anamalai hills of Tamil Nadu State (Aliyar tributary), the forest patches in Kalpathipuzha, Gayathripuzha and Thoothapuzha are represented by 177km^2, 196km^2, and 252km^2 of forest areas respectively in the State of Kerala. The Bharathapuzha and its tributaries also drain three important protected areas, the Indira Gandhi Tiger Reserve, the Parambikulam Tiger Reserve, and the Silent Valley National Park, apart from many areas declared as reserved forests.

Sampling sites and methods

As part of the present study, surveys were carried out in all the four tributaries, viz., Gayathripuzha, Chitturpuzha, Kalpathipuzha (Image 3) and Thoothapuzha (Image 4) of the Bharathapuzha River and

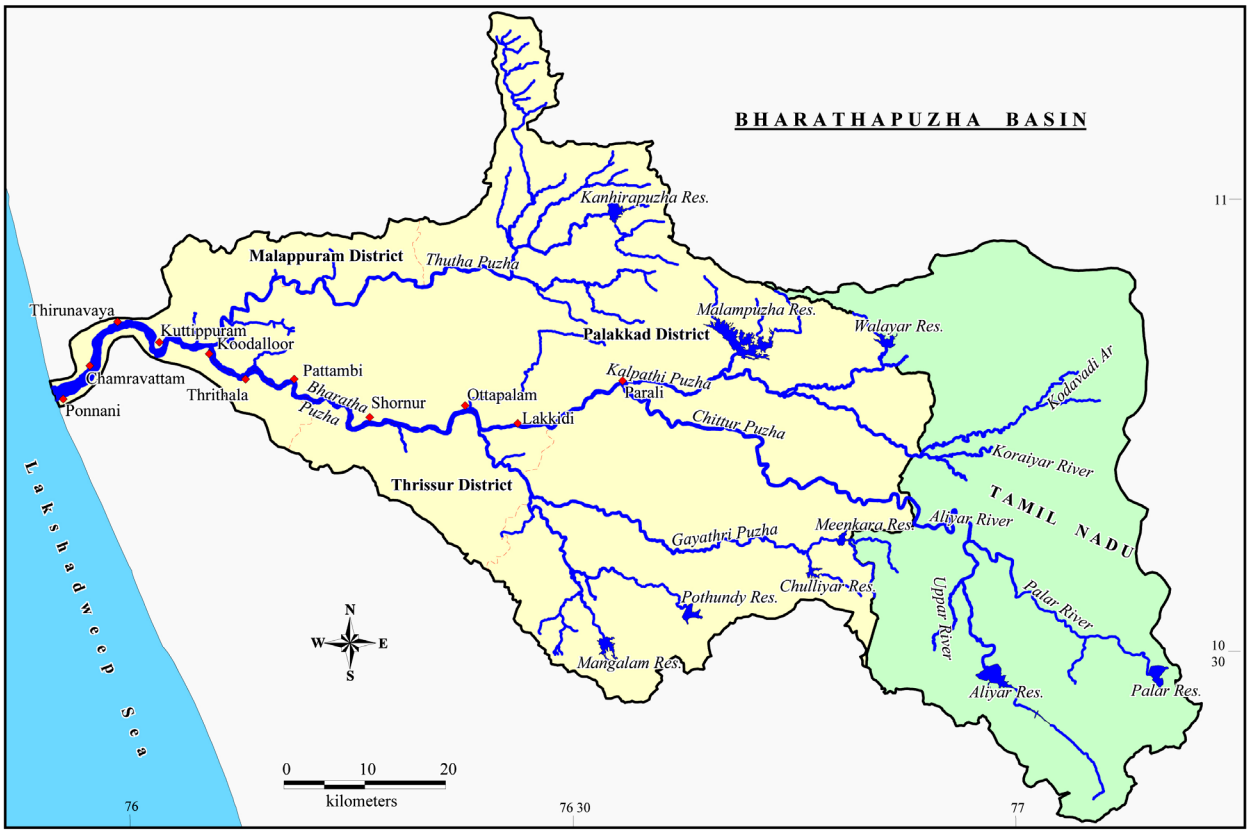

Image 1. Bharathapuzha River basin showing the major tributaries and streams

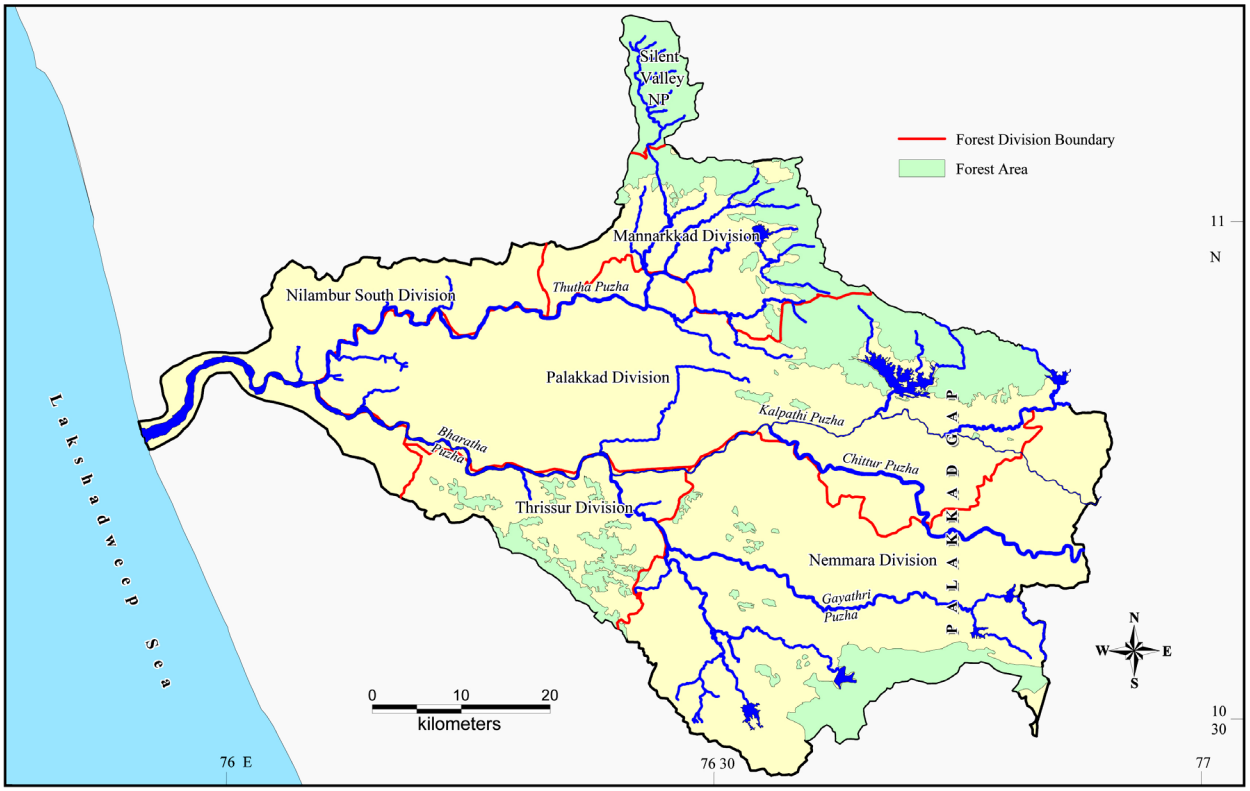

Image 2. Extent of forest cover in the Bharathapuzha River basin

Image 3. Stream in the upper reaches of the Kalpathipuzha tributary of Bharathapuzha River

Image 5. Kunthipuzha stream inside the Silent Valley National Park

Image 4. A cascade in Meenvallam in the Thoothapuzha tributary of Bharathapuzha River

the Kunthipuzha stream (of Thoothapuzha tributary) flowing through the Silent Valley National Park (Image 5) at multiple intervals from January 2004 to February 2013. Fishes were collected using a variety of active and passive gears such as scoop nets, drag nets, cast nets, gill nets and specially designed and fabricated net made of mosquito nets. Random surveys were also carried out in the major markets and landing centers along all the five tributaries. Voucher specimens were preserved in 4% formaldehyde and whenever possible tissue samples were preserved in 95% ethanol, and transferred to the laboratory for further identification.

Species identification and morphometry

Fishes were identified by comparing measurements and counts of the voucher specimens, with those of the type/type series and/or as mentioned in the original description. All measurements were taken point to point using dial calipers to the nearest 0.1mm. Voucher specimens of all species recorded in this paper are deposited at the Museum of the Department of Aquatic Biology and Fisheries, University of Kerala (DAB-UoK), Thiruvananthapuram, Kerala, India and the Conservation Research Group, St. Albert's College (CRG-SAC), Kochi, India. All species names except for the members of the super family Cobitoidea, adhere to the Catalog of Fishes (Eschmeyer 2013) unless otherwise mentioned. For species within the super family Cobitoidea, a recent checklist by Kottelat (2012) has been followed.

RESULTS AND DISCUSSION

Diversity and distribution

A total of 117 species under 42 families and 81 genera were recorded from the Bharathapuzha River system (Table 1). Of these, 98 species were primary freshwater, and 19 were secondary freshwater and/or diadromous species. Six species of non-native fish were also recorded of which three (*Cyprinus carpio*, *Oreochromis mossambicus* and *O. niloticus*) are exotic

to the country; while the rest were the Indian major carps (*Catla catla*, *Cirrhinus mrigala* and *Labeo rohita*) transplanted from the gangetic plains.

The main channel of the Bharathapuzha from Parali to Purathoor estuary had the highest species richness (S=75) followed by the Thoothapuzha (S=57) and Kalpathipuzha (S=40) (Fig. 1). Of the 75 species found in the main channel, 19 were secondary freshwater species. Thoothapuzha tributary (excluding the Kunthipuzha stream) has the highest species richness, when only primary freshwater fish species are considered. Although Kunthipuzha stream of the Thoothapuzha tributary flowing through the Silent Valley National Park had the lowest species richness (S=25), it has very high conservation value, as two endemic species, *Balitora jalpalli* and *Mesonoemacheilus remadevii* are restricted to this stream.

Thirty-three species (28%) that occur in the Bharathapuzha River are endemic to the Western Ghats, eight species are endemic to the rivers of Kerala, and three species (*Balitora jalpalli*, *Mesonoemacheilus remadevii* and *Pseudolaguvia austrina*) are endemic to the river system. One more species (listed as *Garra* sp. in Table 1; see also appendix 1) may be endemic to the Western Ghats, once its taxonomic identity is cleared. All three species endemic to the Bharathapuzha River have a restricted distribution in the Thoothapuzha tributary. While *B. jalpalli* and *M. remadevii* are found in the Kunthipuzha stream, *P. austrina* occurs as small fragmented populations in the Kanjirapuzha and Thoothapuzha streams.

A little more than one-tenth of species (11%; S=13) that occur in the Bharathapuzha are listed as threatened in the IUCN Red List of Threatened Species (Fig. 2). This

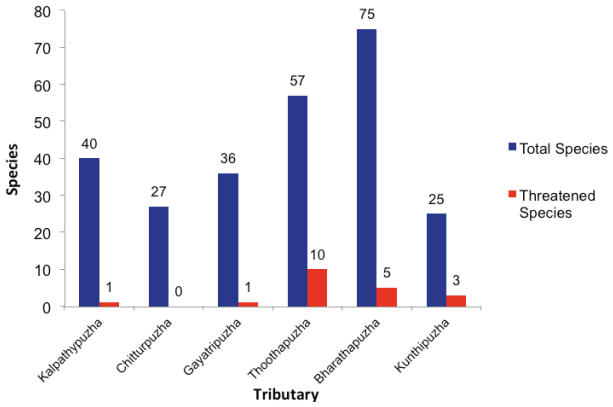

Figure 1. Fish species richness in different tributaries of the Bharathapuzha River and the Kunthipuzha stream in the Silent Valley National Park

Table 1. Fishes of the Bharathapuzha River, their micro-level distribution, endemism and IUCN threat status

Family/Species	Distribution	IUCN Status
Notopteridae		
Notopterus notopterus (Pallas, 1769)	S3	LC
Elopidae		
Elops machnata (Forsskål, 1775)[S/D]	S5	LC
Megalopidae		
Megalops cyprinoides (Broussonet, 1782)[S/D]	S5	DD
Anguillidae		
Anguilla bengalensis (Gray, 1831)	S4, S5	LC
A. bicolor McClelland, 1844	S5	LC
Clupeidae		
Dayella malabarica (Day, 1873)[¶]	S4, S5	LC
Ehirava fluviatilis Deraniyagala, 1929	S5	NE
Engraulidae		
Stolephorus commersonii Lacepède, 1803[S/D]	S5	NE
Thryssa dussumieri (Valenciennes, 1848)[S/D]	S5	NE
Chanidae		
Chanos chanos (Forsskål, 1775)[S/D]	S5	NE
Cyprinidae		
Catla catla (Hamilton, 1822)	S1, S3, S5	LC
Cirrhinus mrigala (Hamilton, 1822)	S1, S3, S5	LC
Cyprinus carpio Linnaeus, 1758	S1, S3	-
Hypselobarbus kurali Menon & Remadevi, 1995[¶¶]	S1	LC
Labeo fimbriatus (Bloch, 1795)	S1	LC
L. rohita (Hamilton, 1822)	S1, S3, S5	LC
Osteochilichthys longidorsalis Pethiyagoda & Kottelat, 1994[¶]	S4	EN
O. nashii (Day, 1869)[¶¶] (Image 11)	S6	LC
Barbodes carnaticus (Jerdon, 1849)[¶¶] (Image 12)	S6	LC
Dawkinsia filamentosa (Valenciennes, 1844)	S1, S2, S3, S4, S5	LC
D. assimilis (Jerdon, 1849) [¶¶]	S4	VU
Haludaria fasciata (Jerdon, 1849) [¶¶] (Image 13)	S4, S6	LC
Pethia conchonius (Hamilton, 1822)	S2	LC
P. ticto (Hamilton, 1822)	S1, S2, S3, S4, S5	LC
Puntius amphibius (Valenciennes, 1842)	S1, S3, S4	DD
P. chola (Hamilton, 1822)	S4, S5	LC
P. mahecola (Valenciennes, 1844) [¶¶]	S1, S4	DD
P. parrah Day, 1865[¶¶]	S1, S2, S3, S4, S5	LC
P. sophore (Hamilton, 1822)	S2	LC
P. vittatus Day, 1865	S1, S2, S4, S5	LC
Sahyadria denisonii (Day, 1865) [¶¶]	S4	EN
Systomus sarana (Hamilton, 1822)	S1, S2, S3, S4, S5	LC
Tor malabaricus (Jerdon, 1849)[¶¶]	S4, S5	EN

Family/Species	Distribution	IUCN Status
Laubuca dadiburjori Menon, 1952¶¶	S5	LC
L. fasciata Silas, 1958¶	S4, S6	VU
Salmophasia balookee (Sykes, 1839)	S1, S2, S3, S4	LC
S. boopis (Day, 1874) ¶¶	S5, S6	LC
Amblypharyngodon melettinus (Valenciennes, 1844)	S5	LC
A. microlepis (Bleeker, 1853)	S2, S3, S4, S5	LC
Barilius bakeri (Day, 1865)¶¶	S1, S6	LC
B. bendelisis (Hamilton, 1807)	S3, S4, S5	LC
B. gatensis (Valenciennes, 1844) ¶¶	S4, S6	LC
Devario malabaricus (Jerdon, 1849)¶¶	S1, S2, S4, S5, S6	LC
D. aequipinnatus (McClelland, 1839)	S1, S3, S4, S5	LC
Esomus danricus (Hamilton, 1822)	S5	LC
Rasbora dandia (Valenciennes, 1844)	S1, S2, S3, S4, S5	NE
Garra menoni Indra & Rema Devi, 1984¶ (Image 14)	S6	VU
G. mullya (Sykes, 1839) (Image 15)	S1, S2, S3, S4, S5, S6	LC
G. joshuai Silas, 1954¶¶	S4, S6	EN
Garra sp[a]	S6	-
Balitoridae		
Balitora jalpalli Raghavan et al., 2013[£]	S6	NE
Bhavania australis (Jerdon, 1849)¶¶	S4, S6	LC
Homaloptera menoni Shaji & Easa, 1995¶	S6	LC
H. pillai Indra & Remadevi, 1981¶ (Image 16)	S6	LC
Nemacheilidae		
Mesonoemacheilus guentheri Day, 1867¶¶ (Image 17)	S4, S5, S6	LC
M. remadevii Shaji, 2002[£]	S4, S6	LC
M. triangularis Day, 1865¶¶	S2, S4, S5	LC
Nemacheilus monilis Hora, 1921¶¶ (Image 18)	S6	LC
Schistura denisoni Day, 1867¶¶	S4, S6	LC
S. semiarmatus Day, 1867¶¶ (Image 19)	S6	LC
Cobitidae		
Lepidocephalichthys thermalis (Valenciennes, 1846)	S2, S4, S6	LC
Pangio goaensis (Tilak, 1972)¶¶	S5	LC
Bagridae		
Batasio travancoria Hora & Law, 1941¶	S5	VU
Hemibagrus punctatus (Jerdon, 1849)¶¶	S4	CR
Mystus seengtee (Sykes, 1839)	S1, S2, S3, S4, S5	NE
M. gulio (Hamilton, 1822)	S5	LC
M. malabaricus (Jerdon, 1849)¶¶	S1, S2, S3, S4	NT
M. montanus (Jerdon, 1849)	S1, S2, S5	LC
M. oculatus (Valenciennes, 1840) ¶¶	S3	LC
Siluridae		

Family/Species	Distribution	IUCN Status
Ompok bimaculatus (Bloch, 1794)	S1, S3, S4	NT
O. malabaricus (Valenciennes, 1840)	S1, S4, S5	LC
Schilbeidae		
Pseudeutropius mitchelli Günther, 1864¶	S4	EN
Sisoridae		
Glyptothorax anamalaiensis Silas, 1952¶¶	S4, S5	EN
G. annandalei Hora, 1923¶¶	S4, S6	LC
Pseudolaguvia austrina Radhakrishnan et al. 2010[£]	S4	NE
Clariidae		
Clarias dussumieri Valenciennes, 1840¶¶	S1, S3	NT
Heteropneustidae		
Heteropneustes fossilis (Bloch, 1794)	S1, S2, S3, S5	LC
Ambassidae		
Ambassis ambassis (Lacepède, 1802)[s/d]	S5	LC
Parambassis dayi (Bleeker, 1874)¶¶	S1, S5	LC
P. thomassi (Day, 1870)¶¶	S1, S2, S3, S4, S5	LC
Scatophagidae		
Scatophagus argus (Linnaeus, 1766) [s/d]	S5	LC
Hemirhamphidae		
Hyporhamphus limbatus (Valenciennes, 1847)	S1, S5	LC
H. xanthopterus (Valenciennes, 1847)	S5	VU
Belonidae		
Xenentodon cancila (Hamilton, 1822)	S4	LC
Aplocheilidae		
Aplocheilus blockii Arnold, 1911	S4, S5	LC
A. lineatus (Valenciennes, 1846)	S1, S2, S3, S4, S5	LC
Syngnathidae		
Microphis cuncalus (Hamilton, 1822)	S5	LC
Platycephalidae		
Grammoplites scaber (Linnaeus, 1758)[s/d]	S5	NE
Centropomidae		
Lates calcarifer (Bloch, 1790)[s/d]	S5	NE
Sillaginidae		
Sillago sihama (Forsskål, 1775)[s/d]	S5	NE
Carangidae		
Carangoides malabaricus (Bloch & Schneider, 1801)[s/d]	S5	NE
Leiognathidae		
Leiognathus equulus (Forsskål, 1775) [s/d]	S5	LC
Lutjanidae		
Lutjanus argentimaculatus (Forsskål, 1775)[s/d]	S5	NE
Gerreidae		
Gerres filamentosus Cuvier, 1829[s/d]	S5	LC

Family/Species	Distribution	IUCN Status
Teraponidae		
Terapon jarbua (Forsskål, 1775)[S/D]	S5	LC
Nandidae		
Nandus nandus (Hamilton, 1822)	S3, S4, S5	LC
Pristolepis marginata Jerdon, 1849[¶¶]	S4	LC
Cichlidae		
Etroplus maculatus (Bloch, 1795)	S1, S2, S3, S4, S5	LC
E. suratensis (Bloch, 1790)	S1, S2, S3, S4, S5	LC
Oreochromis mossambicus (Peters, 1852)	S1, S2, S3, S4, S5	-
O. niloticus (Linnaeus, 1758)	S5	-
Mugilidae		
Chelon parsia (Hamilton, 1822)[S/D]	S5	NE
Mugil cephalus Linnaeus, 1758[S/D]	S5	LC
Eleotridae		
Eleotris fusca (Forster, 1801)	S5	LC
Gobiidae		
Glossogobius giuris (Hamilton, 1822)	S1, S2, S3, S4, S5	LC
Sicyopterus griseus (Day, 1877)	S5	LC
Anabantidae		
Anabas testudineus (Bloch, 1792)	S1, S2, S3, S4, S5	DD
Osphronemidae		
Pseudosphromenus cupanus (Cuvier, 1831)	S1, S3, S5	LC
Osphronemus goramy Lacepede, 1801	S3	LC
Channidae		
Channa marulius (Hamilton, 1822)	S5	LC
C. gachua (Hamilton, 1822)	S4, S6	LC
C. striata (Bloch, 1793)	S1, S2, S3, S4, S5	LC
Mastacembelidae		
Macrognathus guntheri (Day, 1865)[¶¶]	S1, S3, S4, S5	LC
Mastacembelus armatus (Lacepède, 1800)	S1, S2, S3, S4, S5, S6	LC
Cynoglossidae		
Cynoglossus macrostomus Norman, 1928[S/D]	S5	NE
Soleidae		
Brachirus orientalis (Bloch & Schneider, 1801)[S/D]	S5	NE
Tetraodontidae		
Carinotetraodon travancoricus (Hora & Nair, 1941)[¶¶]	S1, S3, S4, S5	VU

[S/D] Secondary freshwater/diadromous;
[¶¶]Endemic to Western Ghats; [¶]Endemic to Kerala; [ɛ]Endemic to Bharathapuzha river system
Distribution: S1: Kalpathipuzha; S2: Chitoorpuzha; S3: Gayatripuzha; S4: Thoothapuzha; S5: Bharathapuzha (Parali to Purathoor estuary); S6: Kunthipuzha/Silent Valley National Park
IUCN Status: CR - Critically Endangered, EN - Endangered, VU - Vulnerable, NT - Near Threatened, LC - Least Concern, DD - Data Deficient, NE - Not Evaluated
[a]See Appendix 1 for a discussion on *Garra* sp.

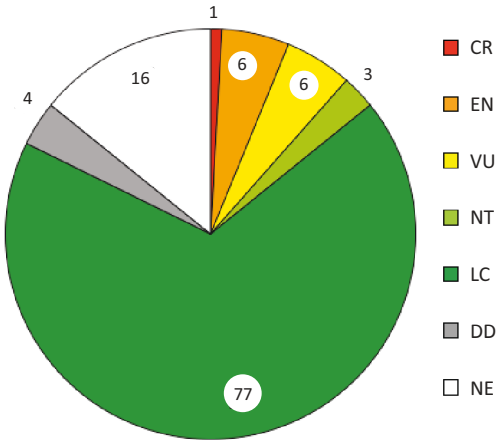

Figure 2. Conservation status of fish species occurring in Bharathapuzha River (only 113 species are listed here as 3 species were exotic to the country and the identity of 1 species needs confirmation).

includes one species listed as 'Critically Endangered' (CR) (*Hemibagrus punctatus* - however, see discussion in Ali et al. 2013), six species listed as 'Endangered' (EN) (however, see note on *Garra joshuai*) and six species listed as 'Vulnerable' (VU). Majority of species (65%; S=77) are listed as 'Least Concern' (LC). Thoothapuzha tributary had the highest number of threatened species (S=10) (Fig. 2).

Fishes of the Silent Valley National Park

The Silent Valley National Park (NP) (core area of 89.52km^2 and a buffer zone of 14.70km^2), and an altitude ranging from 200–2383 m) (Hosagoudar & Riju 2013) is one of the most important conservation areas in the Western Ghats. Two streams, the west flowing Kunthipuzha draining the core area and the east flowing Bhavani draining the eastern segment of the buffer zone of the Silent Valley National Park (see Easa & Basha 1995) comprise the type locality of four species, viz., *Balitora jalpalli* (Image 6), *Garra menoni* (Image 14), *Homaloptera pillaii* (Image 16) and *Mesonoemacheilus remadevii* (Image 7).

The Kunthipuzha stream of the Silent Valley National Park has been surveyed in the past by Devi & Indra (1986) and Easa & Basha (1995) who both recorded 11 species. During our surveys carried out in 2010, we recorded 25 species (Table 1), thereby increasing the number of freshwater fishes known from the Silent Valley NP. However, this number cannot be considered as the actual diversity of the National Park because several additional species are found in the east flowing Bhavani River and the Kadalundi River (draining the western segment of the buffer zone), which is not mentioned herein.

Range extension of *Osteochilichthys longidorsalis* Pethiyagoda & Kottelat, 1994

Osteochilichthys longidorsalis was hitherto known to be endemic to the Chalakudy and Periyar river systems where it had a very restricted distribution (see Raghavan & Ali 2011). During recent (February 2013) field work in the Thoothapuzha tributary, we collected a single specimen (CRG-SAC.2013.01; 79.98mm SL) (Image 8) of a fish that resembled *O. longidorsalis*. Detailed examination of the specimen indicated that the measurements and counts (Table 2) were within the range of topotypic material collected from Vettilapara, Chalakudy River, and those mentioned in the original description of Pethiyagoda & Kottelat (1994). We therefore extend the range of *O. longidorsalis* to the Bharathapuzha River system.

We believe that *O. longidorsalis* could have had a much more extensive range of distribution north and south of the Palakkad Gap in stream habitats providing a very specific niche. But over time, the continuity in the range of distribution was broken and inadequacy of geographical coverage during surveys left isolated

Table 2. Morphometric characteristics of *Osteochilichthys longidorsalis* collected from Bharathapuzha River

	CRG.SAC.2013.01	Pethiaygoda & Kottelat (1994)
Standard length (SL) in mm	79.9	102-235
% SL		
Total length	136.5	126.8 - 138.1
Depth of body	30.9	29.2 - 33.2
Depth of caudal peduncle	13.2	11.3 - 13.1
Length of caudal peduncle	15.7	na
Lateral head length	25.0	20.8 - 25.3
Dorsal head length	21.4	20.7 - 23.4
Pre dorsal length	48.3	na
Pre anal length	75.8	na
Pre pelvic length	51.2	na
Maximum head width	16.1	14.2 - 16.8
Maximum body width	20.8	16.0 - 19.5
Pectoral fin length	24.4	22.7 - 26.3
Pelvic fin length	24.5	23.1 - 26.2
Dorsal fin length	28.4	24.1 - 46.6
% lateral HL		
Snout length	37.2	37 - 45
Eye diameter	31.9	22 - 29
Inter orbital distance	43.8	36 - 51
Inter nares distance	26.2	28 - 36

Image 6. *Balitora jalpalli*, a balitorid loach endemic to the Kunthipuzha stream of Silent Valley National Park [adapted from Raghavan et al. 2013b]

Image 7. *Mesonoemacheilus remadevii*, a balitorid loach endemic to the Bharathapuzha River system.

Image 8. Specimen of *Osteochilichthys longidorsalis*, collected from the Bharathapuzha River system.

Image 9. *Pseudolaguvia austrina*, a sisorid catfish endemic to the Bharathapuzha River system.

Image 10. Specimen of *Hemibagrus* cf *punctatus* recorded from Kanjirapuzha tributary of Bharatapuzha River in 2008. [Scale in cm] [Adapted from Ali et al. 2013]

Image 11. *Osteochilichthys nashii*

Image 12. *Barbodes carnaticus*

Image 13. *Haludaria fasciata*

Image 14. *Garra menoni*

Image 15 . *Garra mullya*

Image 16. *Homaloptera pillaii*

Image 18. *Nemacheilus monilis*

Image 17. *Mesonoemacheilus guentheri*

Image 19. *Schistura semiarmatus*

populations unreported. Thus, there is also a possibility that this species might occur in the upper reaches of the neighbouring Chaliyar basin.

We prefer to retain the generic name *Osteochilichthys* instead of *Osteochilus* as mentioned in the Catalog of Fishes (Eschmeyer 2013). The reason being that no

taxonomic revision of this species has taken place and Eschmeyer (2013) merely cites Thomas et al. (2002), who, without any justification and discussion, chose to use the name *Osteochilus* over *Osteochilichthys* in their paper on the fishes of southern Kerala (see additional discussion in Appendix 1).

New site record for *Pseudolaguvia austrina* Radhakrishnan, Suresh Kumar & Ng, 2010

Pseudolaguvia austrina (Image 9) was the first member of this genus described from peninsular India near the town of Mannarkad (Kunthipuzha stream) in the Bharathapuzha River system (Radhakrishnan et al. 2010). During a recent survey (February 2013), one specimen of *P. austrina* (CRG-SAC-2013. 11.1 30.34mm SL) was collected from Thoothapuzha (~20km downstream of the type locality). This forms a new site record.

Threats to the riverine ecosystem and biodiversity

Bharathapuzha comprise one of the 16 catchments in the southern Western Ghats that has the highest species richness and endemism of freshwater taxa including fish, mollusc and odonates (Molur et al. 2011). It is also one of the five catchments along with Periyar, Pamba, Manimala and Chaliyar that qualify as potential freshwater 'Key Biodiversity Areas' (KBAs) (Molur et al. 2011). In spite of this, Bharathapuzha is one of the most degraded and threatened river systems in the region. Several anthropogenic stressors including deforestation and loss of riparian cover, dams and other impoundments, pollution, sand mining, non-native species, climate change and destructive fishing practices are threatening the fish diversity of Bharathapuzha River system.

Deforestation and loss of riparian vegetation: The Bharathapuzha River basin has undergone large-scale deforestation due to construction of several dams (Raj & Azeez 2011). Deforestation is prominent in several catchment areas such as Mangalam, Nelliyampathy, Walayar, Malampuzha, Nellipuzha, Dhoni and Kalladikode. Forest lands have been transformed into largely monoculture plantations (Raj & Azeez 2010a). During the period 1973–2005, the natural vegetation cover in the river basin declined by 31%, as a result of the increase in area under plantations (Raj & Azeez 2010b). The riparian vegetation along the Bharathapuzha and its tributaries are severely disturbed or in some cases totally destroyed. In addition, there is also a threat from invasion by exotic plants all along the river basin. The loss of forest cover at such high rates impact freshwater fishes since a significant proportion of the riverine species in the Western Ghats region exploit allochthonous food resources (Arunachalam 2000). Increased sedimentation as a result of deforestation changes the river bed habitat and thus degrades the breeding substrate of many fish species (Dahanukar et al. 2011). In this way, the deforestation in the upstream catchments of the Bharathapuzha can impact several hill stream loaches of the family Balitoridae, Cobitidae and Nemacheilidae which require pebbles and gravel in their microhabitats for breeding (Dahanukar et al. 2011). There are at least 10 species of loaches inhibiting the various hill streams tributaries of Bharathapuzha.

Dams and other impoundments: Dams are a major threat to freshwater biodiversity (Vorosmarty et al. 2010). Dams remove turbulent river sections and create tranquil water bodies, thereby affecting flow and temperature regimes, sediment transport, and species communities (Liermann et al. 2012). Several dams worldwide now impair habitat and migration opportunities for many freshwater fish species (Liermann et al. 2012) including those that are endemic and threatened (Xie et al. 2007).

Bharathapuzha has been dammed extensively, mainly for irrigation and water diversion purposes. Eleven irrigation projects and several surface dams in the river basin cater to 493.06km^2 agriculture lands (Raj & Azeez 2010a). In addition, there are many check dams - temporary or permanent small impoundments for regulating water flow, on the Bharathapuzha. These small dams retain excess water flow during monsoon rains in a small catchment area behind the structure, thereby replenishing nearby groundwater reserves and wells. The dams and other impoundments along the Bharathapuzha River have impacted the movements of diadromous and catadromous species such as eels as evident from the lesser abundance of eels in the river in the recent past (A. Bijukumar & R. Raghavan pers. obser. 2012). The check dams in the river are also reported to affect the water quality in upstream and downstream areas (Bijukumar & Kurian 2008).

Pollution: Asian rivers are heavily polluted and degraded (Dudgeon 2000). Pollution has also been identified as the important threat to the fish fauna of the Western Ghats (Dahanukar et al. 2011). Bharathapuzha River basin supports extensive area under agriculture and plantations. Agro-based pollutants such as chemical fertilizers, pesticides, weedicides and nutrients are frequently washed down into the river, constituting a major ecological problem. Eutrophication has resulted in the abundance of filamentous algae and weeds in the lower reaches of the river, particularly from Chamravattom to Purakkad. In addition to agro-based

pollutants, Bharathapuzha and its tributaries also receive substantial amount of urban sewage. For example, the town of Pattambi is one such polluted area along the river, where the urban sewage canals directly open into the river, through which the municipal waste is dumped. Such large scale pollution not only degrades the habitat but also causes endocrine disruptions and several other physiological imbalances in fish including breeding failure which could ultimately lead to their extirpation.

Limestone mining is being carried out in the catchment areas of Malampuzha in the Kalpathipuzha tributary, leading to siltation and pollution in the streams and the reservoir. Silicate content of water in this area has been found to be very high (Sushama 2003). Massive dumping of mining debris and wastes has also completely destroyed the Seemanthinipuzha, one of the streams joining the Malampuzha.

Sand mining: Over the years, indiscriminate sand mining has caused irreparable damages to several river systems on the southwestern coast of India (Sreebha & Padmalal 2011). Indiscriminate sand mining from Bharathapuzha has contributed immensely to the destruction of the river, and is now the dominant threat to the ecosystem and biodiversity of the river basin. The entire river bed is dug up, and a large number of trucks ply through the river bed daily to collect river sand. The situation is most alarming between Pattambi and Thirunavaya, where both legal and illegal sand quarrying goes on unabatedly. We observed that in the Ottapalam Revenue Division, in addition to the 18 stations (kadavus) fixed by the Kerala Government for sand quarrying, there are several 'private' kadavus operating in parallel possibility with the connivance of authorities. The quantity of sand collected from these private kadavus exceeds those from legal ones. In addition, small-scale removal of sand by local people is also damaging the river bed in many areas. In Navalin Kadavu near the village of Peringottukurussi, sand is collected in large quantities from within the check-dams using large rafts made of rubber tubes. The sand thus collected is then loaded on to trucks and transported. In many places small-scale removal of sand is not to cater for the local demands, but for supplying the big contractors. Studies conducted by Centre for Earth Science Studies (CESS), Thiruvananthapuram (CESS 1997) have shown that the rate of sand removal from the Bharathapuzha is several times more than the natural rate of replenishment. Such massive sand removal will have a highly detrimental impact on ichthyofauna of the river as sand is the preferred breeding substrate for many fish species. In addition, sand mining alter aquatic food web as well as nutrient cycles, and is a direct threat to the survival of several species such as *Glossogobius giuris* and *Sicyopterus griseus* that prefer sand substratum.

Non native species: Six species of non-native fish occur in the Bharathapuzha (Table 1) of which three (*Cyprinus carpio*, *Oreochromis mossambicus* and *O. niloticus*) are exotic to the country, while the remaining three are the Indian major carps (*Catla catla*, *Cirrhinus mrigala* and *Labeo rohita*) which were transplanted from the gangetic plains for stock enhancement and aquaculture. Many reservoirs in the Bharathapuzha basin have been stocked with the non-native carps as well as the giant freshwater prawn (*Macrobrachium rosenbergii*) during the last several decades and have even been considered to be one of the success-stories of capture based culture fisheries (Peters & Feustel 1998; Kutty et al. 2008). Collections of these non-native carps from the lower reaches of the river indicate their escape from the reservoirs.

The first record of the Nile Tilapia, *O. niloticus* from the rivers of Kerala was made from Bharathapuzha (Bijukumar 2008). In addition, the Mozambique Tilapia, *O. mossambicus* has established viable populations throughout the river, including the estuarine areas. The African catfish, *Clarias gariepinus* is being clandestinely cultured in many regions of the Bharathapuzha basin and may have found its way into the river system. However, we have not been able to record any specimens as yet from the wild.

Climate change: Freshwater fish are known to be at an increasing risk to climate change especially given the inextricable link between fish physiology and temperature (see Ficke et al. 2007). The Bharathapuzha watershed experiences an average annual rainfall of 2500mm, which is about 17% less than the state average (Anon 1998). Recent studies have observed changes in both rainfall and temperature in the river basin (Raj & Azeez 2010a, Raj & Azeez 2011). An overall upward trend in annual and daily temperature was observed in the river basin during 1969 to 2005 (Raj & Azeez 2011). The impacts of climate change phenomena on the ichthyofauna of Bharathapuzha remains to be investigated further.

Unregulated aquarium fish exports: Unmanaged aquarium fish collection and exports is an emerging threat to the endemic fish diversity of Western Ghats (Raghavan et al. 2013a). In Thoothapuzha tributary, the endangered *Sahyadria denisonii* is being collected in massive quantities for the ornamental fish trade, even by government supported agencies such as Kerala Aquatic Ventures Private Limited (KAVIL). In addition,

species such as *Mesonoemacheilus remadevii*, restricted to the Silent Valley National Park have been found to be occurring in the trade (Raghavan et al. 2013a). This shows a clear lack of co-ordination between various government departments highlighting a serious lapse in policy decisions.

Destructive fishing practices: The destructive fishing methods recorded in the river basin include use of plant poisons, dynamiting and the use of small mesh nets. Dynamiting is more prevalent in the tributaries where traditional fishermen are less in number.

Conservation measures

Like in other parts of the Western Ghats (see Dahanukar et al. 2011), the multi-stakeholder issues related to the use of fresh water in the Bharathapuzha basin has meant that indigenous fish species are least valued, and their conservation has never been a priority. Dudgeon et al. (2006) considers the protection and management of freshwater biodiversity as a conservation challenge and suggests that a combination of strategies and action plans would be highly essential to conserve freshwater ecosystems and their resources. Based on local conditions, we suggest a set of strategies that will help protect the ecosystem and facilitate the conservation and management of the native aquatic fauna of Bharathapuzha.

Integrated watershed development programs should be given top priority. To stop further ecological degradation of the river and to ensure sufficient water discharge downstream, any proposals for new check dams should be treated with caution. Similarly, we suggest that clearance should not be given to any new medium or large dam in the Bharathapuzha River basin.

Ecorestoration activities should be taken up in several stretches of the river using the River Management Fund available with district authorities. The ecorestoration activities can also be integrated into ongoing government assisted programmes such as Mahatma Gandhi National Rural Employment Generation Programme (MGNREGP) and Western Ghats Development Programme. We also suggest that all local self governments within the river basin should include ecorestoration of river as an integral component in their project planning and implementation.

As sand mining is one of the most important threats to the ecological integrity of the Bharathapuzha River system, effective enforcement mechanisms should be put into place to curb this menace. Suitable eco-friendly alternatives to sand should also be popularised by adopting awareness campaigns. Large scale cultivation and farming activities should be prohibited within the river basin, and mechanisms should be adopted to spread awareness to minimize the use of pesticides and other agro-chemicals in the plantations located in the upstream areas.

Spatial conservation options such as 'aquatic biodiversity management zones' (ABMZ) and 'fish refugias' should be declared for conserving important areas rich in endemic and threatened species. The thootha tributary is a potential site for consideration as ABMZ as it harbours several endemic and threatened species, and the habitat is subjected to considerable illegal fishing including collection of endemic and threatened fishes for the aquarium trade.

There is also a need to revise the Red List status of several species of fishes including those that are endemic to the Silent Valley National Park. Many endemic species of this protected area were categorised as 'Least Concern' in view of the absence of any current or plausible future threats. However, recent studies (for e.g., Raghavan et al. 2013a) have revealed that endemic and restricted range species such as *Mesonoemacheilus remadevii* are being collected and exported for the aquarium pet trade thereby raising concerns on the wild populations of the other endemic balitorid and nemacheilid loaches as well.

Regulations should be brought into place to stop the unmanaged collection of endemic and threatened aquarium fishes from many areas in the river basin. Stronger enforcement is also required to prohibit the use of destructive fishing practices, especially dynamiting. Though the Ministry of Agriculture, Government of India has issued "Guidelines for the Import of Ornamental Fishes into India" based on the recommendations of the National Committee on Introduction of Exotic Aquatic Species into India, it has failed to prevent the entry of exotic fishes into the natural ecosystems of the country including the Bharathapuzha. A legally binding strategy is therefore required to regulate exotic fish into the country, and to restore the ecosystems already debilitated by the invasion of alien species.

Finally, there is a need for increased education and awareness programs to improve the conservation needs and profile of the Bharathapuzha River system. Since information on the river and its ecology is lacking, students and teachers from local schools and colleges within the river basin can be employed for data collection, monitoring and eco-restoration activities. The Biodiversity Management Committees (BMCs) at the local Panchayaths formed as per the Biological Diversity Act of India (2002), as well as the traditional

Appendix 1: Taxonomic notes

For the sake of clarity, we provide notes on some of the generic/species names mentioned in this paper, which may be different from previous papers published from the Western Ghats/Kerala region.

Garra sp (listed in table 1). This pertains to a species of *Garra* that has been routinely identified in the literature as *Garra gotyla stenorhynchus*. Until the identity of *Garra gotyla* Gray is established with a neotype, and the species validity of the materials identified as *Garra gotyla* and *G. stenorhynchus* from the Western Ghats is validated, we prefer to treat the Bharathapuzha material as *Garra* sp.

Hypselobarbus: There is considerable taxonomic ambiguity on the generic name (*Gonoproktopterus* vs. *Hypselobarbus*) of this group. We follow Arunachalam et al. (2012) and Yang et al. (2012) and use the name *Hypselobarbus* instead of *Gonoproktopterus*.

Horalabiosa: *Horalabiosa* is a genus with a complex taxonomic history. For several years, *Horalabiosa* was considered to be a hybrid between *Garra* and *Rasbora* (See Jayaram 2010). Subsequently, the type species, *H. joshuai* was considered to be a synonym of *Garra mullya* (Talwar & Jhingran 1991). Devi (1993) established the validity of, and re-described *H. joshuai* based on the examination of more than 500 individuals. However, recent molecular studies have re-proposed *Horalabiosa* as a junior synonym of Garra (Yang et al. 2012), which we follow.

Osteochilichthys: We follow Pethiyagoda et al. (2012) and Karnasuta (1993) and use the generic name *Osteochilichthys* (for *O. longidorsalis*) instead of *Osteochilus* as mentioned in the Catalog of Fishes (Eschmeyer 2013). The reason being that Eschmeyer (2013) merely cites Thomas et al. (2002) who without any justification and discussion, chose to use the name *Osteochilus* over *Osteochilichthys* in their paper on the fishes of southern Kerala.

Barbodes: Pethiyagoda et al. (2012) mentions that Jerdon's (1849) description of *B. carnaticus* is uninformative, and there is no known surviving type material; and as a result, subsequent authors have followed Day's (1878: 563, pl. 137) conception of the species. However, Pethiyagoda & Kottelat (2005) suggested that the figure of *Barbus carnaticus* in Day (1878: pl. 137) possibly illustrates a species of *Neolissochilus.* However, examination of Day's materials in the Australian Museum (see Pethiyagoda et al. 2012) reveals that they differ from *Neolissochilus*. The exact generic status of this taxon is therefore uncertain (Pethiyagoda et al. 2012), and we retain the name *Barbodes*, pending detailed taxonomic investigations. Although Arunachalam et al. (2012) placed *Barbodes carnaticus* into another unresolved genus '*Hypselobarbus*', this was not based on taxonomical evidence and/or range wide sampling. In addition, there is no mention whether they had used topotypic material of *B. carnaticus*. There are also several inconsistencies in the results of Arunachalam et al. (2012) as they illustrate a specimen of *Gonoproktopterus dubius* and wrongly identify it as *B. carnaticus* (Arunachalam et al. 2012; Fig 1. p 64).

Sahyadria: A new genus, *Sahyadria* has been proposed to include the two species of Redline Torpedo Barbs, *Sahyadria denisonii* and *S. chalakkudiensis* (see Raghavan et al. 2013)

fishing communities, students involved in the National Green Corps (NGC) and eco-club networks could be effectively used to monitor and conserve fish habitats. in the Bharathapuzha River basin.

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