Ecosystem and Biodiversity Management in Indian Lakes

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Abstract—The Ecosystem-based fisheries management (EBFM) framework is a significant step forward for the integrated management of natural resources by enabling all assets and issues relevant to stakeholders and government to be holistically considered at a regional level in India. We assessed the feasibility of EBFM in south India. This analysis documents the reasons for emerging interest in EBFM and relates this management model to others. It highlights the central challenges to EBFM in south India. A monitoring framework with process and output criteria is applied to Fisheries Improved for Sustainable Harvest (FISH) to establish progress to date , especially in India, where major institutional and governance challenges for EBFM will require monitoring, evaluation, and adaptation. Fisheries management desires sustainable yield, but must rethink this concept within the ecosystem context in India. The freshwater fishes in south Indian which are at risk of extinction are listed by their family, state, basin/region along with the causes. Of the 108 known species, 32 species are at risk, and 8 species are believed to be extinct.. The biodiversity status of freshwater fishes is assessed according to IUCN criteria in selected Agro Ecological Zones (AEZ) of south India such as: Karnataka, Andhra Pradesh and Tamil Nadu. With the exception of Western Ghats (Uttar Kannada) Karnataka, other states are largely located in arid or semiarid regions. Concentrations of 5 metalloids were investigated in the bloom-forming Cyanobacteria and ambient water samples collected season wise between the periods from 2006 to 2009 at the Agro Ecological Zones (AEZ) of south India. The metal (loids) concentrations in water decreased in the order Fe>Zn>Ni>As>Mn while those in cyanobacteria followed a sequence Fe>Mn>Zn>Ni>As. The reduction occurred is due to cyanobacteria uptake.

Keywords—Fish diversity, conservation, Agro ecological zones, Bloom-forming cyanobacteria, metalloid.

I. Introduction

AGRO ecological zones are defined as, a land resource mapping unit, in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use (FAO, 1996).The assessment of agro ecological resources is to provide the followings: A baseline assessment of fish, in the selected Agro Ecological Zones (AEZ) Table 1, including identification of species and estimate levels of abundance. A species monitoring program, as a basis for potential sustainable use. Assessing the status, trends and threats to fish diversity in selected agro ecological zones.

Historically, fisheries assessment and management efforts have been concerned only with species that are commercially or recreationally important and are subject to widespread fishing exploitation (Reynolds et al., 2002).Unlike these, an effort has been put in order to study the fish status, their distribution and conservation in the agro ecological zones. The agro ecological zones of south India particularly, Tamil Nadu, Andhra Pradesh and Karnataka, were studied. Heavy cyanobacterial blooms have broken out frequently in the lake every year. In the bloom forming process, uptake of metals by cyanobacteria critically influence the cyanobacterial growth, bloom mechanisms, and toxin production, in addition to phosphorus and nitrogen stimulated growth(Baptista and Vasconcelos, 2006; Gadd, 2010). Furthermore, the sequestration, reclamation, immobilization or detoxification of metalloids by cyanobacteria represents an opportunity for bioremediation of metal pollutants, using the cyanobacteria as scavengers of metals from water bodies (El-Enany and Issa, 2000; Meja ´re and Bu¨low, 2001; Gadd, 2010). We therefore investigated the uptake and bioconcentration of metals and metalloids in bloom-forming cyanobacteria in South Indian lakes, to clarify the interactions of cyanobacterial blooms with metals and metalloids..

II. Materials And Methods

A. Sampling

The sampling survey for the present study, in selected AEZs took place between the years 2006 - 2009. Due to the flooding condition and the limited number of surveying days, comprehensive active collecting fish

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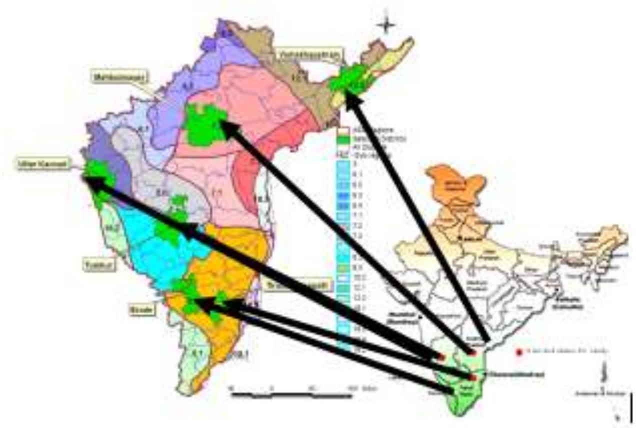

Fig. 1 Selected south Indian lakes in Agro Ecological zones of India

Specimens were not always possible. Five working days had been used to carry out the field survey and one day to check the fish market in selected fishing villages. Engine boats were used to travel along the canals inside and outside the protected area (Fig 1). All specimens were collected from fishermen and hunters at canals, right next to the reserve and connected to the canal system inside the reserve such that species collected appear to reflect the fish fauna of the reserve and as well as of the region. Fishing activities in the area around the reserves are heightened with different methods engaged to catch fishes. The fish sampling method is roughly categorized in four groups as follow: checking the fishing activities next to the reserve, collecting species from fishermen next to their fishing sites, and hiring fishermen for fishing by gill net, trap net cast net, fyke net, and dip net. Inside the reserve, gill net and dip net are used to collect some species. Participatory Rural Appraisal (PRA) a method for gathering fauna data in the area were carried out by interviewing experienced fishermen for overview on fish species.

TABLE I

DESCRIPTION AND LOCATION OF THE AEZ ZONES OF FRESHWATER FISH SURVEY SITES IN SOUTHERN INDIA

Site/ Physical Characteristics	**Lukkeri Tank**	**Masoor Tank**	**Ungra Shimsha River**	**Laxmipuram Lake**	**R R pet Creek**	**Dokur Tank**	**Kempanaickenpala yam Reservoir**
Width (m)	10 -30	20 - 50	15 - 60	70 - 495	2 - 8	5 -3 4	255 - 450
Depth (m) Size (Acres)	0.1 -3 2 acres	0.1 - 2 3 acres	0.1 - 5 275 kms	0.1- 7 610 acres	0.1 - 1 8 kms	0.1 - 3 68 acres	0.1 - 6 442 acres
Stream type and major habitat	Flows through lowland rainforest. Riparian plants along creek edge.	Flows through a lowland rainforest Riparian plants along river edge.	Ferns are the dominant riparian plants on the river edge	Paragrass and ferns are the dominant riparian plants on the river edge	on the river edge paragrass and ferns are the dominant riparian plants	Flows through low land	Riparian plants along river edge. Satyamangalam rainforest.
Major substrate type	Soft, muddy bottom	Soft, muddy bottom Boulders in the river with sand and gravel bottom	Gravel and sand on river bottom Muddy on the river edge	Muddy edge	Soft, muddy bottom sand and gravel bottom	Rock with gravel bottom	Rocky river edge, boulders in the river with muddy and gravel bottom

The nearby local fish markets in selected villages are checked, wherein all the fishes collected in the area around the reserve are gathered. The identification is based on various taxonomy literatures for the region (Mai DìnhYên *et al.*, 1992; Rainboth, 1996; Poulsen *et al.*, 2004).

Stream habitat was measured along with fish community sampling. Habitats measures included physical variables and water quality parameters. Within a sample site, five evenly spaced transects were placed across the stream channel. Stream wetted width was measured across each transect. Depth (cm), water column velocity (cm/sec), and substrate type (modified Wentworth Scale) were measured at three evenly spaced points along each transect (Orth , 1983). Water quality parameters such as temperature (ºC), dissolved oxygen (D/O mg/L), and specific conductance (µS) were measured using YSI meter. Since the streams along eastern side dry up during summer season, samples were collected during post-monsoon period. Apart from systematic sampling, opportunistic sampling was also carried out in many places so as to cover as many localities as possible.Species diversity and relative abundance were calculated from fish collection data. Fish species were classified into taxonomic and ecological guilds (Etnier and Starnes, 1993). Pearson's correlation determined if species abundance, fish abundance, or ecological guilds correlated with environmental variables (SAS V8), because the abundance of many fish species was low, correlation between habitat variables to species abundance, fish abundance, and guild was limited. Linear regression was used to determine if the traditional RCC concepts (Vannote *et al.*, 1980, Schlosser, 1987) linked fish community indices to habitat variables (SAS V8).The study was conducted in selected villages between the years 2006-2009. Trawl nets, boats, were used for assessing the fishes in Participatory Rural Appraisal (PRA).Methods adopted to gather detailed and qualitative descriptions of fishery resources, trends, status and pattern of use changes in the status of fishery resources over the years. Information on local name, economic value and behaviour patterns were obtained from fishermen residing in the region. Fish species collected during the field survey were noted and excess fishes were released to their original habitat. The water–bloom-forming cyanobacteria (the blooming season being from May to November) and water samples were collected seasonally from the river, brackish water Streams, Reservoir and Canals of south India like Karnataka, Andhra Pradesh and Tamil Nadu and transported to the laboratory, between the years 2006 to 2009. (Table 2), where heavy cyanobacterial blooms occur every year.

TABLE II
SELECTION OF VILLAGES LOCATION AND SOURCES

State	District	Village	Sources	Reason for selecting the villages
Karnataka	Uttar Kannada Tumkur	Lukkeri Masoor, Ungra	Aghanashini river and Brackish water Streams and Canals Shimsha river, Canal and Stream	Past data related to fishing pattern, production and consumption was available. This data provides valuable opportunity to analyze the trends in fisheries status.
Andhra Pradesh	Vishakhapatnam Mahaboobnagar	Laxmipuram RR Pet Dokur	Tank, Stream and Canal Streams and Canal Tank	---------do-------------
Tamilnadu	Coimbatore	Kempanaickenpalayam	Reservoir	-------------do-----------

Water was first filtered by 0.22 µm syringe Millex filters (Millipore Co. Ltd., USA). The cyanobacteria were concentrated through 75 µm sieves, rinsed six times with Milli-Q water dried to a constant weight at 80^0C for 24 h, and measured for moisture content (Average ±SD: 95.61±1.5 %). Dried samples were homogenized by grinding in a porcelain mortar, then packed with weighing paper, and then stored in a desiccator until required. A 0.1±0.005 g amount of dried cyanobacteria per sample was weighed in a Teflon PTFE tube (Milestone Inc., Italy) to which 10 mL of purified nitric acid (MOS grade; Sinopharm Chemical Reagent Co., Ltd., Shanghai, China) was added. After decomposing with an ETHOS A T260 microwave digestion system (Milestone Inc., Italy), the solution was diluted to a final volume of 200 mL with Milli-Q water and transferred into acid washed polypropylene bottles. Concentrations of Fe, Mn, Zn, Cu, Ni, As, were determined by an Agilent 7500ce ICPMS (Agilent Technologies, USA) using Li, Sc, Ge , Y, In and Bi as internal standards. Quality assurance and quality control was checked by spike recoveries (94.2 %–110 % for water samples; 83.1 %–131 % for cyanobacteria samples). The average ranges of Physico-chemical parameters of the south Indian lakes during different seasons are shown in Table 3 and were found within the suitable range. Changes in these Physico-chemical parameters may cause mass mortalities of fish eggs and larvae, apart from various abnormalities in the fish stocks. The various physico-chemical parameters of metalloids are shown in Table 3.

TABLE III
AVERAGE RANGE OF PHYSICO-CHEMICAL PARAMETERS AND METAL AND METALLOIDS IN THE AEZ ZONE

Parameters	Range	Parameters	Range
pH	7.6--9.23	Chlorides	32.2-96.5
Water temp (deg C)	18.0-33.0	Nitrites	0.08-0.2
TDS	160-1362	Nitrates	0.2-1.02
Total hardness	130-290	Ammonia nitrogen	10.5-65.0
Total alkalinity	125-320	Phosphates	0.05-0.35
EC (mhos)	287-1450	Sulphates	6.5-182.6
DO	3.6-14.2	Bicarbonates	125-386
Free CO_2	Nil-44.0	Fe (µg/L)	10-180
BOD **Calcium** **Magnesium**	0.64-8.5 10.2-45.5 15.6-86.2	Mn (µg/L) Ni (µg/L) As (µg/L) Zn (µg/L)	0.4-8.0 2.0- 4.0 0.08-4.0 3-70

All values are in mg/ l except pH, electrical conductivity and water temperature. TDS = Total dissolved Solids, EC = Electrical conductivity, DO = Dissolved oxygen, COD = Chemical oxygen demand, BOD = Biological oxygen demand

B. Results: Fish Species composition

Many species have been recorded in smaller than standard sizes during the survey period as they are probably bred in the beginning of rainy season and developed in flooded areas inside the reserve. Observations in local market revealed some more species like *Ctenophore idella* and *Gonoproktopterous dubious.* These are also native fishes of the areas. The Marble goby *Channa spp*, a high economic value species, was also observed in the market but in few numbers. During the survey, about 108 species have been recorded (Table 4). A number of fish specimens have not been identified to species level due to a few reasons such as; bad specimens collected from fish market, not enough literature or young specimens that have not been described in taxonomical literatures, some groups that are being reviewed are among the limiting factors. A most important large range migratory species is the Giant carp that has been observed in small size individuals only. The area is probably one of the feeding areas of this species in lower AEZ zones. As shown in Fig1 (Indian Map selected south Indian lakes). The fish fauna is typically the lowland AEZ zone river fauna with many common economic species like snakeheads *Channa spp.*, Climbing perch *Anabas testudineus*, Walking catfish *Clarias spp.*, Bronze feather back *Notopterus*. The highest number of individuals recorded in gill nets and trap nets are *Cyprinus carp, Labeo rohita, cirrhinus mrigala, Catla catla, Oreochromis mossambicus, Garra gotyla Stenorhynchus, and Mystus vittatus.*The most common native farmed fish in the area is the Chevron snakehead *Channa striata*. Other important economic snakehead fish such as *Channa micropeltes* not farmed commonly in the area. Interviews of local people revealed that the snakehead fish is sold and transported live while *Channa micropeltes* not well survived for such transportation conditions. There are several different fishing methods that have been used by local fishermen such as: weir, trap net, gillnet, seine, hook and line, lift net. The species composition varies depending on the fishing method. It was seen that the highest number of species resulted in trap net. It is a non-selective fishing method; therefore most likely all of common mid-water and surface-water species are caught by this method, except for some very small/very large species and species that don't move much. This method also seems to be the highest threat to the fish fauna in the area in the long run.

C. Assessment of species Threatened status

The risk of extinction for each species was assessed according to the *IUCN Red List Categories and Criteria: Version 3.1* (IUCN 2001). Extinction is a chance process. Thus, a listing in a higher extinction risk category implies a higher expectation of extinction, and over the timeframes specified in the guidelines, more taxa listed in a higher category are expected to go extinct than those in a lower one (without effective conservation action). All taxa listed as Critically Endangered, Endangered or Vulnerable are described as threatened.

D. Ecosystem-Based Fishery Management (EBFM)

This approach examines current fishery management practices and postulates that an improved understanding and management of stock interactions, stock-prey relation¬ships, and stock-habitat requirements will result in more sustainable fisheries in Aghanashini estuary. A prerequisite is the ability to control and account for. harvests and fishing effects by controlling overfishing and reducing by catch and impacts of fisheries on the ecosystem. A set of ecosystem principles is posited and policies to implement them are indicated. Management decisions would be oriented toward precautionary manage¬ment to better take into account risk and uncertainties as well as to anticipate or plan for trends or changes over time in the overfished ecosystem.

III. Results

A. Biodiversity Status of the Freshwater Fishes Delineated

A total of 108 fish species under 14 orders, 29 families and 65 genera were collected and identified from the rivers and streams of south India. The name of the species, together with their commercial importance, status as per IUCN criteria and the river sources from where their occurrence has been recorded are shown in Table 4.

This includes 4 species that are exotic and alien. Among the species listed under threatened category, 18, were critically endangered while 38 species are endangered, whereas 28 species are vulnerable. There are 48 species under the non-threatened category, among which 21 are nearly threatened with low risk whereas 34 species belonged to low risk of least concern. Based on present study, evaluating the morphological characters of river with plenty of spawning and rearing grounds, rich water quality and fish diversity, the whole study area was observed to be intact and undisturbed. More survey works at different seasons are needed to cover the complete information regarding the fish species and their aquatic habitat. Dominant species in Kempanayak palya Sathaymangalam Coimbatore District: The dominant are *Danio aequipinnatus, Garra Gotyla Stenorhynchus* , *Puntius sophore*, Channa maurilius, Channa striatus, Channa punctatus and Cirrhinus reba. Dominant species in RR pet Vizag District: In RR pet Vizag District Dominant fish species *Salmostoma sardinella, Puntius sophore, Salmostoma Untranchi and Puntius chola*. 12 species have disappeared.Dominant species in Laxmipuram: In Laxmipuram Dominant fish species are *Channa maurilius Cyprinus carpio, Dania aequipinnatus, Glossogobius giuris, Puntius aurulius, Puntius filamentosus, Cirrhina mrigala, Labeao rohita, Grass carp, Catla catla, Channa striatus, Channa punctatus, and O. mossambicus.*No fish species are disappeared over the years. In Dokur Mahaboobnagar District Dominant fish species are *Channa maurilius, Channa punctatus. Puntius saphore and Puntius filamentus and Puntius ticto, Sirsi (Sirsimakki and Allusargi)* the dominant fish species are *Dania aequipinnatus, Garrhagotlastenorhynchus, Puntius sophore* and *Rasbora daniconius*. No fish species are disappeared over the years. In Shimsha River the dominant fish species are *Puntius sophore, Garra Gotyla Stenorhynchus, Chandanama, Rasbora daniconius* and *Salmostoma Untranchi*. Eight fish species are disappeared over the years. We observed 15% percentage of disappeared species, 40% fish yield reduction, 30% impacts on livelihood and 60% fish reduction and 40% consumption pattern in south Indian lakes.

TABLE IV
LIST OF FRESH WATER FISH SPECIES REPORTED FROM SOUTH INDIAN LAKES

No	Name of Species	Ornamental/Food fish	IUCN Status	River Source
1.	Ambassis gymnocephalus	Ornamental	LRlc	Shimsha river
2.	Ambassis nalua	Food fish*	DD	Kempanayakapaly river
3.	Amblypharyngodon chakaensis	Ornamental*	CR	Aghanashini river
4.	Amblypharyngodon melettinus	Ornamental**	DD	Shimsha river
5.	Amblypharyngodon microlepis	Ornamental**	LRnt	Kempanayakapaly river
6.	Amblypharyngodon mola	Ornamental*	LRlc	Aghanashini river
7.	Anabas testudineus	Ornamental*	VU	Laxmipuram lake
8.	Anguilla bengalensis	Food fish**	EN	Kempanayakapaly river
9.	Anguilla bicolor	Food fish**	DD	Aghanashini river
10.	Aorichthys aor	Food fish*	DD	Shimsha river
11.	Aplocheilus blockii	Ornamental*	DD	Kempanayakapaly river
12.	Aplocheilus lineatus	Ornamental*	LRlc	Laxmipuram lake
13.	Awavousgutum	Ornamental*	LRlc	Kempanayakapaly river
14.	Balitora brucei	Ornamental*	DD	Aghanashini river
15.	Balitora mysorensis	Ornamental*	DD	Laxmipuram lake
16.	Barilius bakeri	Ornamental**	LRnt	Shimsha river
17.	Barilius barna	Ornamental*	LRnt	Aghanashini river
18.	Barilius bendelesis	Ornamental**	LRnt	Laxmipuram lake
19.	Barilius canarensis	Ornamental**	DD	Kempanayakapaly river
20.	Barilius gatensis	Ornamental**	LRlc	Aghanashini river
21.	Batasio travancoria	Ornamental*	EN	Laxmipuram lake
22.	Bhavania australis	Ornamental**	LRnt	Shimsha river
23.	Catla catla	Food fish***	VU	Kempanayakapaly river
24.	Chandanama	Ornamental*	LRlc	Kempanayakapaly river
25.	Channa gachua	Food fish**	VU	Aghanashini river
26.	Channa striatus	Food fish**	LRlc	Aghanashini river
27.	Chela dadiburjori	Ornamental**	DD	Shimsha river
28.	Chela fasciata	Ornamental**	EN	Kempanayakapaly river
29.	Chela laubuca	Ornamental**	LRlc	Shimsha river
30.	Cirrhinus mrigala	Food fish**	LRlc	Kempanayakapaly river
31.	Cirrhinus reba	Food fish	VU	Aghanashini river
32.	Clariasdayi	Food fish**	DD	Laxmipuram lake
33.	Clarias dussumieri	Food fish**	VU	Shimsha river
34.	Clarias gariepinus	Food fish***	Intr.	Kempanayakapaly river
35.	Crossocheilus latius latius	Ornamental*	DD	Aghanashini river
36.	Crossocheilus periyarensis	Food fish*	VU	Laxmipuram lake
37.	Ctenopharyngodon idellus	Food fish***	Intr.	Kempanayakapaly river
38.	Dania aequipinnatus			
39.	Dayellamalabarica	Ornamental*	CR	Shimsha river
40.	Eleotris fusca	Ornamental*	LRlc	Kempanayakapaly river
41.	Esomus danricus	Ornamental**	LRlc	Aghanashini river
42.	Esomus thermoicos	Ornamental**	LRlc	Shimsha river
43.	Etroplus suratensis	Food fish*	LRlc	Aghanashini river
44.	Garra gotyla	Ornamental*	VU	Laxmipuram lake
45.	Garra hughi	Ornamental*	EN	Shimsha river
46.	Garra periyarensis	Food fish*	EN	Kempanayakapaly river
47.	Garra surendranathinii	Ornamental***	EN	Aghanashini river
48.	Glossogobius giuris	Food fish*	LRlc	Aghanashini river
49.	Gonoproktopterus kurali	Food fish**	EN	Shimsha river
50.	Gonoproktopterus thomassi	Food fish**	EN	Aghanashini river
51.	Homaloptera menoni	Ornamental**	EN	Kempanayakapaly river
52.	Homaloptera montana	Ornamental**	CR	Laxmipuram lake
53.	Homaloptera pillai	Ornamental**	VU	Shimsha river
54.	Horaglanis krishnai	Ornamental*	CR	Kempanayakapaly river

55.	Horalabiosa joshuai	Ornamental*	CR	Aghanashini river
56.	Labeo ariza	Food fish*	CR	Aghanashini river
57.	Labeo calbasu	Food fish**	LRnt	Shimsha river
58.	Labeo dussumieri	Food fish**	EN	Kempanayakapaly river
59.	Labeo rohita	Food fish**	LRlc	Aghanashini river
60.	Macrognathus guentheri	Food fish*	VU	Laxmipuram lake
61.	Macropoduscupanus	Ornamental*	LRlc	Shimsha river
62.	Mystus keletius	Food fish*	DD	Aghanashini river
63.	Mystus menoda	Food fish*	DD	Laxmipuram lake
64.	Mystus oculatus	Ornamental**	LRlc	Shimsha river
65.	Nandus nandus	Ornamental**	LRnt	Shimsha river
66.	Nemacheilus botia	Ornamental***	LRnt	Kempanayakapaly river
67.	Nemacheilus denisoni	Ornamental***	VU	Aghanashini river
68.	Nemacheilus evezardii	Ornamental*	EN	Laxmipuram lake
69.	Nemacheilus nilgiriensis	Ornamental*	DD	Aghanashini river
70.	Nemacheilus pambarensis	Ornamental***	DD	Laxmipuram lake
71.	Nemacheilu speriyarensis	Ornamental***	DD	Shimsha river
72.	Nemacheilus pulchellus	Ornamental**	DD	Kempanayakapaly river
73.	Ompok malabaricus	Food fish**	CR	Aghanashini river
74.	Oreochromis mossambicus	FOOD FISH**	Intr	Laxmipuram lake
75.	Osteobrama bakeri	Ornamental***	EN	Aghanashini river
76.	Osteochilichthyslongidorsalis	Ornamental*	CR	Laxmipuram lake
77.	Osteochilichthysnashii	Food fish**	VU	Aghanashini river
78.	Osteochilus thomassi	Food fish**	EN	Kempanayakapaly river
79.	Osteochilus brevidorsalis	Ornamental*	EN	Shimsha river
80.	Pangasius pangasius	Ornamental*	CR	Kempanayakapaly river
81.	Pangio baashai	Ornamental*	DD	Aghanashini river
82.	Pristolepis fasciata	Ornamental**	DD	Kempanayakapaly river
83.	Pristolepis marginata	Ornamental**	VU	Shimsha river
84.	Pseudambassis ranga	Ornamental*	LRlc	Kempanayakapaly river
85.	Pseudeutropius mitchelli	Food fish*	DD	Aghanashini river
86.	Puntius amphibius	Ornamental*	LRlc	Shimsha river
87.	Puntius barmanicus	Ornamental*	DD	Kempanayakapaly river
88.	Puntius denisonii	Ornamental***	EN	Aghanashini river
89.	Puntius micropogan	Food fish**	DD	Shimsha river
90.	Puntius ophicephalus	Food fish*	CR	Kempanayakapaly river
91.	Puntius saranasubnasutus	Food fish**	VU	Aghanashini river
92.	Puntius Sinhala	Ornamental**	DD	Shimsha river
93.	Puntius sophore	Ornamental**	LRnt	Kempanayakapaly river
94.	Puntius ticto	Ornamental**	LRlc	Aghanashini river
95.	Puntius vittatus	Ornamental**	VU	Laxmipuram lake
96.	Rasbora daniconius	Ornamental**	LRnt	Kempanayakapaly river
97.	Salmostoma clupeoides	Ornamental*	LRlc	Shimsha river
98.	Salmostoma Sardinella	Food fish*	LRnt	Aghanashini river
99.	Schismatogobius deraniyagalai	Food fish*	DD	Laxmipuram lake
100	Sicyopterus griseus	Ornamental**	EN	Shimsha river
101	Silonia childreni	Not categorized	EN	Kempanayakapaly river
102	Silurus wynaadensis	Food fish*	CR	Aghanashini river
103	Tetraodon travancoricus	Ornamental**	VU	Shimsha river
104	Tor Khudree	Food fish**	VU	Kempanayakapaly river
105	Tor mussullah	Food fish**	CR	Aghanashini river
106	Tor putitora	Food fish**	EN	Kempanayakapaly river
107	Tor tor	Food fish**	EN	Aghanashini river
108	Travancoria jonesi	Ornamental**	EN	Shimsha river

*Important, **Highly important EN-Endangered, ***Very highly important, CR - Critically endangered
DD - Data deficient, Intr– Introduced, LRlc - Low risk least concern, LRnt - Low risk nearly threatened
VU – Vulnerable

B. EBFM in the west coast of India: Challenges and Opportunities

The toxic metals As, and Zn showed visible temporal fluctuations throughout cyanobacterial bloom season in South Indian Rivers (Table 4). The highest concentrations of cyanobacterial As were in July, whereas Zn was in May. Cyanobacteria, as effective metal sorbents, are an important sequestration for metals in aquatic environment and may play an important role in determining metal speciation and bio availability (Baptista and Vasconcelos, 2006). Therefore, the fate of Cyanobacterial metal(loids) need to be primary concern, if they are transferred and accumulated through the food web of south Indian lakes due to the dominant role of cyanobacteria as primary producers. The highest concentration of As, Mn, Fe, Ni and Zn in water–bloom-forming cyanobacteria were in July. Generally, the maximum concentration of the metal (loids) seen in decreasing order: Mn>Fe >Ni >Zn>As (Table 5).The impetus to change fisheries management in the India is strong, but EBFM faces considerable challenges and in many tropical, developing country contexts. Indian marine fisheries are in a state of severe degradation. The biomass of fish stocks in several important fishery bays in the India is less than 15% of what it was in 1960 with fisheries catch-per-unit effort declining in most places (Sannadurgappa, 2010).

TABLE V
CONCENTRATIONS OF METAL (LOIDS) IN WATER BLOOM FORMING CYANOBACTERIA (μG/G DRY WEIGHT)

	May -July(n=5)	Aug-Sep(n=5)	Oct- Nov(n=5)
Fe	500-9000	500-300	10-0
Mn	200-500	100-150	50-30
Ni	20-40	20-10	20-10
As	5-10	5-10	-
Zn	30-80	15-30	15-40

C. Central challenges to EBFM in the India

While important to take into consideration when designing and evaluating EBFM programs in the west coast of India, some contextual issues will likely remain outside the direct impudence of EBFM initiatives. Well engrained colonial and neo-colonial conditions that result in weak formal institutions, cronyism, and corruption similar to many developing countries are centrally important (but underrepresented in fisheries management literature). The general realization that declining fisheries conditions are linked to imbalanced fisheries policies is evolving slowly toward a state more favorable to EBFM. Empirical evidence supports this conclusion with such trends identified decades ago despite the mounting (Sannadurgappa, 2010).Description and location of the AEZ zones of freshwater fish survey sites in southern India shown in the Table 6.

TABLE VI
BIOCONCENTRATION INDICATIONS OF BLOOM FORMING CYANOBACTERIA

	May -July(n=5)	Aug-Sep(n=5)	Oct- Nov(n=5)
Fe	1000-5000	500-1000	5-10
Mn	5000-15000	500-1000	100-500
Ni	500-1000	100-300	100-200
As	200-500	50-100	0
Zn	500-1000	10-20	0

– Not detected in water, 0 not detected in cyanobacteria

D. Impacts of Alien Species on Biodiversity in Agro Ecological Zones

Fish introduction, which results in alien (i.e., exotic) species, is considered to be one of the biggest threats to finfish biodiversity (Sannadurgappa, 2010). In the present contribution, we do not loosely use the term ''invasive'' to describe any introduction of non indigenous species or introduced species that spread rapidly in the agro ecological zone. This is because there is no strong link between invasion and its impact. Alien species can impact biodiversity, directly or indirectly and these impacts can be immediate or long term. The potential impact of alien species on biodiversity cannot be ignored easily because high-impact invaders are more likely to belong to genera not already present in the system. Most watersheds within continents cover vast areas in selected agro ecological zones, impacts of alien species spread far and wide, and translocated organisms even become invasive. Currently, aquatic habitats, particularly in the agro ecological zones also semi arid in Tamil Nadu and Andhra Pradesh, are under serious threat from anthropogenic activities such as dam building, sand mining, agricultural pollution and other developments in the watersheds. Most of the cultured alien species are somewhat non-Catholic in their habitat requirements, and habitat deterioration often facilitates the invasiveness of alien species, a good example being the spread of tilapias throughout Asia.

The reduction in the population of few species in AEZ sometimes is difficult to attribute with certainty to predation or competition from an exotic, and on occasion both influences may act in concert.

E. Threats to freshwater fishes in Agro Ecological Zone

Currently there are many major threats to the freshwater fishes of AEZ; Over harvesting of freshwater fishes during the spawning season;The mass harvesting of juvenile fish during migration from ocean to freshwater, and Sedimentation of streams and rivers due to soil erosion caused by extensive logging.Furthermore, these pollutants pose a major threat by significantly altering the chemical and biophysical characteristics of the water, making the habitat non-conducive to aquatic life. Insecticides and pesticides are used as a fish catching method, specifically for fishes that are either nocturnal or dwelling in small caves or crevices thus it destroys river ecosystem. The use of small meshed fishing gears is prevalent. Such practices, which are adopted for short-term profit, kill the fry and fingerlings of the fishes thus ultimately leading to regular growth over fishing and consequent reductions in populations. Fishing using chemical and herbal poisons, diverse types of fish poisons both of plant chemical origin are widely used which kills fish species thus resulting in reduction. Leaves, stems and seeds of different types of plants are used as poisons in shallow or low velocity waters. *Synadenium grantii* plants are regularly used for fishing that leads decrease in fish production. Dynamite blasting is a major method for catching food fishes but is less commonly used to catch ornamental varieties since it kills fishes instantaneously. Destruction of fish habitat is another major cause of the decline in the ornamental fish population. Dams, bunds and levees act as barriers for free migrations of fish in the river. Deforestation accelerated the decline of fish populations due to excessive siltation and soil erosion. Agriculture in the catchments area has aggravated water pollution by the application of pesticides and insecticides as well as having brought about a reduction in the available space for the free movement of the fishes thus it effects river ecosystem. Over fishing of native stocks is becoming an ever-increasing issue. Over fishing has caused major disruption of whole populations of people and species-occurrence data are used for monitoring stocks. Detergent pollution is also a major issue in rural villages as most of villagers carry out washing cloths in rivers which led to decline in fish population.

IV. Conclusion

The present study shows that the rivers and streams of south India have exceptional fish biodiversity with a high degree of endemism due to the presence of many rare and localized forms. The freshwater fish of Agro Ecological Zones are excellent indicators of watershed health. As the majority of species inhabit areas with high water quality and intact riparian vegetation, declines in the diversity and abundance of these species from a waterway is often a reliable early indication that water quality is deteriorating and/or riparian vegetation is being removed.

In order to maintain a healthy biodiversity and abundance of freshwater fishes on AEZ we recommend that the following activities/conservation measures be put in place; Not to harvest freshwater mullets during their spawning period in June and July of each year; Not to mass harvest juveniles migrating up river; Not to introduce invasive species such as tilapia, mosquito fish and guppies into the streams; To educate locals about the life cycles of freshwater fish and about the negative impacts of logging on the environment including the freshwater ecosystem; and To conduct freshwater fish surveys of additional streams and using alternative techniques (e.g. electro fishers) on AEZ to obtain a complete inventory.The survey is carried out during the flood season and it is seen that the area is important for the development of many species because the young ones hatching in the beginning of rainy season and are recorded with large quantities inside flooded areas of the reserve. However in order to make the appropriate comparisons and to see how important fish diversity and fishery, the survey on fishery on adjacent areas is needed. The fishing activities in some periods of time in the reserve that is approved by management board needs a scientific study and monitoring. Suggestions for changing and modifications of this activity based on scientific studies could be very useful for the management board to help them manage the area better to secure the fish resources. Due to a great importance of freshwater fish in a wetland reserve, skilled personnel are required to carry out basic study and to monitor some important species in order to better understand the ecology of those species and protect them. Local fishermen also should be involved in these activities to help them understand better the importance of the reserve in terms of securing the fish resources for local people.While substantial progress has been made recently, large gaps in the information needed to support ecosystem-based management still exist in west coast of India. In addition, attention needs to be given to the identification and selection of appropriate objectives and indicators for ecosystems. Methods to design and evaluate operational management strategies have advanced considerably during the last decade. Ecosystem-based management is an important complement to existing fisheries management approaches. An ecosystem-based management strategy for marine fisheries is one that reduces potential fishing impacts while at the same time allowing the extraction of fish resources at levels sustainable for the ecosystem. When fishery managers understand the complex ecological and socio-economic environments in which fish and fisheries exist, they will be able to anticipate the effects that fishery management will have on the ecosystem, as well as corresponding effects on fisheries. Implementation of an ecosystem-based assessment approach, such as proposed in this paper, should proceed despite current uncertainties regarding ecosystems and their responses to human actions, because the potential benefits of implementation are as large as or greater than the potential risks of inaction. As predicting the results of any management action is difficult because the dynamics of ecosystems are complex and poorly understood. The highest concentrations of metals were Fe and Zn in water samples of the South Indian Rivers. The water borne metal and metalloid concentrations generally decreased in the order Fe>Zn>Ni>As>Cu>Mn> (Table3). Highest Fe levels were generally confined to July–October, coinciding with dramatic increases in cyanobacterial biomass during the same season (Su et al., 2011). This suggests that Fe might play an important role during the occurrence and development of cyanobacterial blooms in South Indian Rivers. Copper has been found to be poisonous to green algae *Chlorella pyrenoidosa* when dissolved Cu was 31.8lg/L (Yan et al. 2001). Dissolved Mn increases the growth and reproduction of Prorocentrum at 0–20 µmol/mL (Zhang et al., 2002). Nickel and As are major toxic metal(loid)s. Algae growth could be enhanced by waterborne Ni at 0.1 mg/L, and inhibited at 0.4 mg/L, respectively (Jiang and Lin1995). Elevated level of the form of arsenate (As^{+3}) is highly toxic to algae cell structure, and also reduces algae community diversity (Gao et al., 1997). Surprisingly, As^{+3} favors fast growth of Microcystis and stimulates microcystin production (Gong et al. 2009). Zinc levels ranged from 15 to 80 µg/L and showed an appreciable increase in December (p>0.05), and reached the highest level in July.The potential of bloom-forming cyanobacterial biomass for metal uptake must lead to the focus on the ecological and commercial significance of removal and recovery of metal(loid) in south Indian lakes, because bound metal(loid) loads will come back into water bodies from cyanobacteria when they die and decay after the bloom season, possibly playing a role in future eutrophication. The results of the present study strongly suggest that bloom-forming cyanobacteria can also possible used as an important scavengers of metals, due to their huge amount of biomass and high bioconcentration of the metal(loids). In addition, as the highest concentration of most metal (loids) were in July, this month seems to be the most important time for cyanobacterial biomass removal in South Indian rivers.

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