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Fish diversity of Mahanadi River (Odisha Part), threats and conservation measures

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ABSTRACT

The stretch of the Mahanadi River under the present study was divided into seven study regions for the purpose of sample collection to assess the fish diversity. The sampling sites on the stretch of the Mahanadi River were between upstream in Sambalpur and downstream in Jagatsinghpur in the State of Odisha. Site selections were based on the locality where the fishers' community are residing and actively participating in the fishing activity. Standard procedure and methods were followed during sampling and data collection and data analysis. The study recorded 57 fish species belonging to 36 genera,19 families and 7 orders from the seven regions along the stretch of the Mahanadi River. The analysis of compilation of the samples in the study further revealed that Cyprinidae was the most abundant family contributing 35% of the total species belonging to different families recorded from study region. It is observed from the pattern of distribution of species that the higher species richness is found in the regions where water dams, barrages or reservoirs are formed. Fish species like *Parambassis lala* (Ham.), *Parambassis ranga* (Ham.), *Chanda nama* (Ham.), *Amblypharyngodon mola* (Ham.), *Danio devario* (Ham-Buch.), *Osteobrama cotio* (Ham.), *Puntius sophore* (Ham.), *Puntius ticto* (Ham.), *Rasbora daniconius* (Ham.), *Glossogobius giuris* (Ham.) *and Notopterus notopterus* (Pallas) etc. documented good abundance in the study regions. The threat status of these species suggested that at least 26 % of fish fauna is threatened either being by Vulnerable or Near Threatened. There is a need to adopt requisite biodiversity conservation measures to protect the fish diversity of the Mahanadi river in order to conserve the natures' creation.

Keywords: Abundance, Biodiversity, Conservation Measures, Evenness, Shannon-Wiener Index,

INTRODUCTION

Biological Diversity was first defined by Norse and McManus in the year 1980. Its abbreviation into 'biodiversity' was apparently coined by Walter

1985. Biodiversity refers to the range of variation or differences within the living world. It is commonly used to describe the number, variety and variability of living organisms (MacArthur, 1997). The Convention on Biological Diversity defined biodiversity as variability among living organisms from all sources including *inter alia* terrestrial, marine and other aquatic ecosystems and their ecological complexes (UNEP, 1992). Biodiversity is also shortly defined as the totality of genes, species and ecosystem in a region (WRI, IUCN and UNEP, 1992). Biodiversity is considered as an umbrella term referring to all organisms found within the living world. It is assumed to be a synonym for 'life on earth', its variety and process. It is 'condition of being different' or 'life's endless forms'. Biodiversity is indeed 'the essence of life' (Krishnamurthy, 2003). The Indian National Biological Diversity Act, 2002 defines biological diversity as 'the variability among living organisms from all sources and the ecological complexes of which they are part and includes diversity with species or between species and of eco system' (MoEF, 2016). India occupies ninth position in the world in terms of freshwater mega-biodiversity (Mittermeier *et al*., 1997). The biological species in India and their percentage in the worlds' biological species state that India represents a good number of species in the world flora and fauna diversity. Out of 2, 246 indigenous fin fishes described in India, 765 fishes are categorised as freshwater species (Lakra *et al*, 2010).

The Mahanadi, the largest river of Odisha, stands third amongst the larger rivers in the peninsular India. The drainage basin of the river ($80^0$30'- $86^0$50'E and $19^0$20'- 23^0 35' N) passes through the States of Chhattisgarh, Maharashtra Jharkhand to reaches Odisha. While the States of Chhattisgarh has highest area of the river with 75136 km^2, Odisha has 65580 km^2), Jharkhand has 635 km^2 and Maharashtra has 238 km^2. Starting from the Bastar Hills of Chhattisgarh, it passes through different geological locations like Eastern Ghats to join the Bay of Bengal in the form of different branches passing along the coastline of Odisha. It has a total length about 860 km. The annual runoff of the river is 50×10^9 m^3 with a peak discharge of 44740 m^3 s^{-1}. The Hirakud Dam which was built on the river in 1957 is a big reservoir for fishes, located at 80^0 E longitudes and 21^0 30'N latitude. On the Mahanadi, at Jobra and Naraj, Cuttack barrages were built to irrigate more than 80,000 hectares of land in the Mahanadi Delta through the canals and also to control flood of the region ((Tamboli and Jha 2010; Singh *et al,* 2013, and Department of Water Resources, Odisha, 2016).

Studies on biodiversity losses indicate the threats and the reason of biodiversity losses. Aquatic biodiversity losses are very often considered as bio-indicators for assessment of implications on the entire ecosystem and the unprecedented species extinctions at global level. Biodiversity conservation aims at maintaining the diversity of living organisms, their habitats and interrelationships between organisms and their environments. It is needed to urgently address the concerned issues as aquatic animal species become extinct and many others are threatened and endangered (Kanwar *et al*, 2010). Indentifying exact cause and threat to aquatic biodiversity would help in chosing appropriate method of conservation as aquatic animals are extremely vulnerable to different threats and once lost cannot be replaced or otherwise properly conserved (Singh, 2014).

The present study revealed the fish diversity of the Mahanadi River within the State of Odisha, and analysed the main threat to its fish diversity. It also discussed the essentials of fish biodiversity conservation and conservation strategies for protecting the diversity losses.

REVIEW OF LITERATURE

The study on the fish diversity of the Mahanadi River was carried out by Day (1869) who reported 146 species mostly collected from Cuttack region. Hora (1940) reported 43 species; Chouhan (1947) listed 54 fish species from the Tel River, a tributary of river Mahanadi. David (1953) studied its fish fauna. Job *et al.* (1955) reported more than 103 species after a comprehensive study in a stretch of the Mahanadi. Jayaram and Majumdar (1976) reported 42 fish species. Patra *et al.,* 1984 surveyed the fish diversity and the rate of primary production in the Mahanadi River. The fish fauna of Ibb, a tributary of the Mahanadi was studied by Das *et al.,* 1987. Sugunan (1995) had complied the reservoir fisheries of Odisha and had emphasized on the Hirakud Reservoir. The fishery and biology of the Mahanadi Mahseer (*Tor mosal*, David) was studied by Badapanda (1996). The Saline freshwater interface structure in the Mahanadi delta region, Odisha was explored by Radhakrishna (1999).

Subsequently, the Status of the fisheries of the Hirakud Reservoir, Odisha was surveyed by Mahapatra (2003). Desai and Shrivastava (2004) reported 48 fish species from the Mahanadi River basin. Om Prakash *et al.*, (2004) reported 65 fish species. The cluster analysis for characterization of river and estuarine water system of the Mahanadi River had been undertaken by Panda *et al.*, 2006. Tamboli and Jha (2010) studied the fish fauna diversity of the River Mahanadi in Janjgir and Champa District of Chhattisgarh and reported 58 fish species. Das and Panda (2010) had studied the water quality and phytoplankton population in sewage fed the river Mahanadi, Odisha. A study on the status of the catfish diversity of the river Kelo and Mand, the tributaries of the Mahanadi River in Raigarh District of Chhattisgarh had been undertaken by Tamboli and Jha (2012). Singh *et al* (2013) had published a review on the fish biodiversity of Mahanadi river. Singh (2014) had studied the biodiversity of ornamental fishes in some parts of the Mahanadi river reporting 54 fish species. Patel *et al* (2016) studied fish fauna of the Mahanadi River in Raigarh District of Chhattisgarh and reported 54 fish species.

MATERIALS AND METHODS

Study Area

The sampling sites on the stretch of the Mahanadi River were between upstream in Sambalpur and downstream in Jagatsinghpur in the State of Odisha. These study regions were Hirakud (R1), Satakosia (R2), Kantilo (R3), Banki (R4), Cuttack (R5), Salipur-Tirtol Area (R6) and Jagatsinghpur (R7). Site selections were based on the locality where the fishers' community are residing and actively participating in the fishing activity. Systematic study was conducted during April, 2015 to March, 2016. The geographical locations of these study regions along the stretch of River Mahanadi are Hirakud Region (80^{0}30'- 86^{0}50'E and 19^{0}20'- 23^0 35' N) of Sambalpur district, Satakosia (84^{0}48'- 85^{0}00'E and 20^{0}34'- 20^0 48' N) Angul district, Kantilo (85^{0}13'E and 20^{0}22' N) Nayagarh district and Banki (85^{0}25'E and 20^{0}21' N) of Cuttack district[3]. Salipur-Tirtol Area site (20°18′–20° 28′ N and 86° 07′ – 86° 23′ E) in the Cuttack district, Jobra and Naraj of Cuttack (20° 29′ N and 85° 25′ E) and Jagatsinghpur area of Mahanadi (20° 16′ N and 86° 10′ E) under Jagatsinghpur district. The locations of sampling regions/sites were documented by using global positioning system (GPS) and indicative sites on the Mahanadi basin are given below.

Sample Collection and Taxonomy

Fish species were collected from different catchment area, landing centers and different fish markets of the study areas. For taxonomic study, fish samples were preserved in 5% formaldehyde solution. The taxonomic study was done by referring Day (1878), Talwar and Jhingran (1991) and Jayaram (1981). Further, the website of fish base was referred. Identifications were confirmed with the help of Zoological Survey of India, Kolkata (Fish Base, 2016).

Fig.1 Showing the study regions under the present study on the Mahanadi (Department of Water Resources, Odisha, 2016)

Calculation of Diversity Indices

The Shannon-Wiener index for the collected samples was calculated by following Shannon and Wiener (1963) formula, which is:

$$H = -\sum_{i=1}^{S} P_i \ln (P_i)$$

where; H= Shannon-Wiener index of diversity, S= total number of species, P*i*= (N*i*/N) proportion of total sample represented by species *i*, N= total number of individual of all species, N*i*= total number of specimens of each species.

Evenness of the diversity index was calculated by using the formula (Sarkar *et al*., 2013)

$E = H/H_{max}$, where $H_{max} = \ln(S)$

Similarity of the species recorded at both the region under the study was calculated using

Jacquard's index:

Sj = j/(x+y-j)

where: Sj *is* the similarity between any two zones X and Y, j is the number of species common to both the zones X and Y, x is the total number of species in zone X and y is the total number of species in zone Y (Magurran, 1988).

Abundance Index

Abundance Index as percentage of catch of fish at different sites was calculated using the following formula (Kurup *et al.,* 2004 and Sarkar *et al.,* 2013):

$$AI = (n \times 100)/N$$

where: n=Number of specimen of a particular species

N= Total number of fish specimen in the sample

Threat Status

The status of the available fishes were determined according to the Threatened Freshwater Fishes of India, National Bureau of Fish Genetic Resources, 2010 and IUCN Red list of Threatened Species, 2020.1 version (IUCN, 2020).

RESULTS AND DISCUSSION

Diversity of fishes and their Abundance:

All the collected specimens were identified and arranged according to their taxonomic order, family, genus and species as well as taking their IUCN status into consideration. The survey recorded 57 fish species belonging to 39 genera, 19 families and 7 orders from the seven regions along the stretch of the Mahanadi River in Odisha selected for this study. The survey of local markets in the regions under this study confirmed the presence of same species as recorded from fish catch. The fish species found at different study regions under the present study are in the Table-1. However, the sample from the local markets documented that a few fish species viz. the Indian Major Carps and the *Pangasius* spp. were also available in the market.

The analysis of compilation of the samples in the study further revealed that Cyprinidae was the most abundant family contributing 35% of the total species belonging to different families recorded from this region.

Family Cyprinidae was represented by 21 species belonged to 13 genera. Bagridae, Channidae and Siluridae each were represented by four species each (Fig. 2). Among the orders, Perciformes and Siluriformes were represented by 6 families each, Cypriniformes and Synbrachiformes each represented by two families and other each represented by one family (Fig.3). A comparative view of the fish species reported by different scholar at different point of time and in the present study is given in the Table-2.

The diversity indices calculated for the seven selected regions on the Mahanadi River on the basis of the Shannon–Weiner diversity index ranged between 1.51 (at Satakosia) and 3.59 (at Hirakud) (Fig.4). The results indicate that the species richness is high at Hirakud while it is low at Satakosia. The evenness varies between 0.65 (Satakosia) and 0.93 (Cuttack) (Fig.9). This reveals that Satakosia tiger reserve is low diverse in fish species and Cuttack is highly diverse in this regard. The calculated similarity indices indicate that the highest similarity is between Salipur Tirtol Region and Jagatsinghpur (0.756) and the lowest similarity is between Hirakud and Satakosia (0.178) (Fig.5).

The Abundance Index (AI) suggested that the most abundance species at all the sites of the different study regions were *Parambassis lala* (Ham.) (4.924-7.637), *Xenentodon cancila* (Ham.) (1.5-4.54), *Chanda nama* (Ham.) (0.75-5.81), *Chanda ranga* (Ham.) (1.09-3.23),

Gudusia chapra (Ham.) (2.63-6.06), *Lepidocephalichthys guntea* (Ham.) (3.86-7.95), *Amblypharyngodon mola* (Ham.) (4.54-11.637), *Osteobrama cotio* (Ham.) (4-15.27), *Puntius sophore* (Ham.) (2.20-40.35 (Satakosia), *Rasbora daniconius* (Ham.) (1.65-3.06), *Salmostoma bacaila* (Ham.) (4.96-35.08 (Satakosia), *Glossogobius giuris* (Ham.) (6.64-1.41), *Mystus tengara* (Ham.) (1.838-7.89), *Ompok pabda* (Ham.) (0.919-4.363), *Wallago attu* (Bl. & Schn.) (0.735-5.26).

The trend of distribution of the species revealed that the fish species namely, as *Parambassis lala* (Ham.), *Parambassis ranga* (Ham.), *Xenentodon cancila* (Ham.), *Chanda nama* (Ham.), *Lepidocephalichthys guntea* (Ham.), *Amblypharyngodon mola* (Ham.), *Osteobrama cotio* (Ham.), *Puntius sophore* (Ham.), *Salmostoma bacaila* (Ham.), *Glossogobius giuris* (Ham.), *Mystus tengara* (Ham.), *Ompok pabda* (Ham.), *Wallago attu* (Bl. & Schn.), *Catla catla* (Ham.), *Cirrhinus mrigala* (Ham.), *Labeo rohita* (Ham.), *Nandus nandus* (Ham.) and *Notopterus notopterus* (Pallas) were found in all the selected study regions while slightly differs at Satakosia Tiger reserves. *Eriethistes hara* (Ham.) was found only at Cuttack region.

It is observed that there are low similarities indices between Satakosia and other regions. This seems to be probably due to the less number of species found at Satakosia. However, it may be presumed that Satakosia Tiger Reserve has rich species diversity. But, sufficient data could not be available to support this fully as intensive fishing is banned in Satakosia by the Forests Department of Government of Odisha and only angling method fishing is permitted exclusively by the local fishers. Therefore, for the present study, the fishes sampled were collected by angling only. In addition, sample netting at the shore of the river was done to get an idea of the diversity of the smaller fish. In order to make an actual assessment of an elaborate and intensive fish sampling would be required. It is also observed from the pattern of distribution of species that the higher species richness is found in the regions where water dams, barrages or reservoirs are formed. This is why Hirakud Reservoir and Cuttack (Naraja dam and Jobra barrage) are more diverse in term of species richness.

Besides the indigenous fish species, 5 species of exotic fishes were also recorded from the river Mahanadi which were mainly distributed in the Hirakud Reservoir. These species were *Ctenophryngodon idella* (Val.), *Cyprinus carpio* (Linn.), *Hypophthalmichthys molitrix* (Val.), *Oreochromis mossambicus* (Peters), *Oreochromis niloticus* (Linn.). Among these species, only *Cyprinus carpio* (Linn.) and *Oreochromis mossambicus* (Peters) were found in Banki and Cuttack region in addition to Hirakud.

Based on the present study, the threat status of the fishes of River Mahanadi has been divided into six categories: LRnt: Low Risk near threatened, VU: Vulnerable, LRlc: Low Risk least concern, Intrd.: Introduced, NT: Near Threatened, DD: Data Deficient. The threat status of these species suggests that at least 26% of fish fauna is threatened either being by VU or NT. Out of recorded 57 species, the status of one species *Sperata aor* (Ham.) was not known due to data deficiency (DD), among the other remaining species, 26 species were categorized as LRlc, 10 as LRnt, 13 as VU, 2 as NT while the remaining five species were categorized as introduced (Fig.6).

Table-1 The Fish species found during the study and their threat status

Name of the Order	Name of the Family	Sl.No	Name of the species	Threat Status
1. Perciformes	1. Ambassidae	1	*Chanda nama* (Ham.)	LRlc
		2	*Parambassis lala* (Ham.)	LRnt
		3	*Parambassis ranga* (Ham.)	LRlc
	2. Anabantidae	4	*Anabas testudineus* (Bloch)	VU
		5	*Trichogaster fasciatus* (Bloch& Schn.)	LRnt
	3. Channidae	6	*Channa gachua* (Ham.)	VU
		7	*Channa marulius* (Ham.)	LRnt
		8	*Channa punctatus* (Bloch)	LRnt
		9	*Channa striatus* (Bloch)	LRlc
	4. Cichlidae	10	*Oreochromis mossambicus* (Peters)	Intrd.
		11	*Oreochromis niloticus* (Linn.)	Intrd.
	5. Gobiidae	12	*Glossogobius giuris* (Ham.)	LRlc

Table-1 Continued..

Name of the Order	Name of the Family	Sl.No	Name of the species	Threat Status
	6. Nandidae	13	Nandus nandus (Ham.)	LRnt
2.Beloniformes	7. Belonidae	14	Xenentodon cancila (Ham.)	LRlc
3.Clupeiformes	8.Clupeidae	15	Gudusia chapra (Ham.)	LRlc
4. Cypriniformes	9.Cobitidae	16	Lepidocephalichthys guntea (Ham.)	LRlc
	10. Cyprinidae	17	Amblypharyngodon mola (Ham.)	LRlc
		18	Catla catla (Ham.)	VU
		19	Cirrhinus mrigala (Ham.)	LRlc
		20	Cirrhinus reba (Ham.)	VU
		21	Ctenophryngodon idella (Val.)	Intrd
		22	Cyprinus carpio (Linn.)	Intrd.
		23	Danio devario (Ham-Buch.)	LRlc
		24	Danio (Brachydenio) rerio (Ham.)	LRlc
		25	Hypophthalmichthys molitrix (Val.)	Intrd.
		26	Labeo bata (Ham.)	LRlc
		27	Labeo calbasu (Ham.)	NT
		28	Labeo fimbriatus (Bloch)	LRlc
		29	Labeo gonius (Ham.)	LRlc
		30	Labeo rohita (Ham.)	LRlc
		31	Osteobrama cotio (Ham.)	VU
		32	Osteobrama vigorsii (Sykes)	VU
		33	Puntius sophore (Ham.)	LRlc
		34	Puntius ticto (Ham.)	LRlc
		35	Rasbora daniconius (Ham.)	LRnt
		36	Salmostoma bacaila (Ham.)	LRlc
		37	Systomus sarana (Ham- Buch)	VU
5. Siluriformes	11. Bagridae	38	Mystus tengara (Ham.)	LRlc
		39	Mystus vitatus (Bloch)	LRlc
		40	Sperata aor (Ham.)	DD
		41	Sperata seenghala (Sykes)	LRlc
	12. Siluridae	42	Ompok bimaculatus (Bloch)	VU
		43	Ompok pabda (Ham.)	VU
		44	Ompok pabo (Ham.)	LRnt
		45	Wallago attu (Bl. & Schn.)	LRnt
	13. Sisoridae	46	Eriethistes hara (Ham.)	LRlc
	14. Saccobranchidae	47	Heteropneustes fossilis (Bloch)	VU
	15. Claridae	48	Clarias batrachus (Linn.)	VU
	16.Schilbeidae	49	Ailia coila (Ham.)	NT
		50	Clupisoma garua (Ham.)	VU
		51	Eutropiichthys vacha (Ham.)	LRlc
6. Osteoglossiformes	17. Notopteridae	52	Chitala chitala (Ham.)	LRnt
		53	Notopterus notopterus(Pallas)	LRnt
7. Synbranchiformes	18. Mastacembelidae	54	Macrognathus aral (Bloch & Schn.)	LRlc
		55	Mastacembelus armatus (Lacepede)	LRlc
		56	Mastacembelus puncalus (Ham.)	LRlc
	19. Synbranchidae	57	Monopterus cuchia (Ham.)	VU

Note: LRnt: Low Risk near threatened, VU: Vulnerable, LRlc: Low Risk least concern, Intrd.: Introduced, NT: Near Threatened, DD: Data Deficient

Table- 2 Comparison of Fish Diversity of the Mahanadi River basin recorded under the present study with other studies

Sl. No.	Name of the species	Hora (1940)	Jayaram & Majumdar (1976)	Desai & Shrivastava (2004)	Om Prakash *et al* (2004)	Dahire V. (2008)	Tamboli and Jha (2010)	Patel G. *et al* (2012)	Present Study (2016)
	Ambassidae								
1	*Chanda nama* (Ham.)	-	+	+	+	+	+	+	+
2	*Parambassis lala* (Ham.)	-	-	-	-	-	-	-	+
3	*Parambassis ranga* (Ham.)	+	+	+	+	+	+	+	+
	Family- Amblycepidae								
4	*Amblyceps mangois* (Ham.)	+	-	-	-	-	-	-	-
	Family-Clupeidae								
5	*Gonialossa manmina* (Ham.)	-	+	-	-	-	-	+	-
6	*Gudusia chapra* (Ham.)	-	-	+	+	+	+	+	+
	Family- Cobitidae								
7	*Lepidocephalichthys guntea* (Ham.)	+	+	+	+	+	+	+	+
8	*Noemacheilus botia* (Ham.)	+	-	-	+	+	+	+	-
9	*Noemacheilus denisonii* (Day)	+	-	+	-	-	-	-	-
	Family-Cyprinidae								
10	*Amblypharyngodon mola* (Ham.)	+	+	+	+	+	+	+	+
11	*Cabdio morar* (Ham.)	-	+	+	-	-	-	-	-
12	*Barilius bendelisis* (Ham.)	+	+	+	+	+	+	+	-
13	*Barilius barna* (Ham.)	+	+	-	-	-	-	-	-
14	*Barilius barila* (Ham.-Buch.)	-	-	+	-	-	-	-	-
15	*Barilius vagra* (Ham.)	-	+	-	-	-	-	-	-
16	*Catla catla* (Hum.)	-	+	+	+	+	+	-	+
17	*Chela (Laubuca) lubuca* (Hum.)	+	-	+	-	-	-	-	-
18	*Cirrhinus mrigala* (Ham.)	-	-	+	+	+	+	+	+
19	*Cirrhinus reba* (Ham.)	-	-	+	+	+	+	+	+
20	*Ctenophryngodon idella* (Val.)	-	-	-	+	+	-	+	+
21	*Cyprinus carpio (Linn.)*	-	-	-	+	+	+	+	+
22	*Danio aequipinnatus*	+	-	-	-	-	-	-	-
23	*Danio devario (Ham-Buch.)*	-	-	+	+	+	-	-	+

Table 2 : Continued...

Sl. No.	Name of the species	Hora (1940)	Jayaram & Majumdar (1976)	Desai & Shrivastava (2004)	Om Prakash *et al* (2004)	Dahire V. (2008)	Tamboli and Jha (2010)	Patel G. *et al* (2012)	Present Study (2016)
24	*Danio (Brachydenio) rerio* (Ham.)	+	+	-	-	-	-	-	+
25	*Esomos danricus* (Ham.)	+	+	+	-	-	-	-	-
26	*Garra annandalei* (Hora)	-	-	-	+	+	+	-	-
27	*Garra gotyla gotyla* (Gray)	-	-	+	-	-	-	-	-
28	*Garra mullya* (Sykes)	+	-	-	-	-	-	+	-
29	*Gonoproktoptreus kolus* (Sykes)	-	-	-	+	-	-	-	-
30	*Hypophthalmichthys molitrix* (Val.)	-	-	-	+	+	-	-	+
31	*Hypophthalmichthys molitrix* (Rich.)	-	-	-	+	+	-	+	-
32	*Labeo angra* (Ham.)	-	-	-	+	+	-	+	-
33	*Labeo bata* (Ham.)	-	+	+	+	+	+	+	+
34	*Labeo boga* (Bloch)	-	-	-	+	+	-	+	-
35	*Labeo boggut* (Sykes)	+	-	-	+	+	+	-	-
36	*Labeo calbasu* (Ham.)	-	-	+	+	+	+	+	+
37	*Labeo fimbriatus* (Bloch)	-	-	+	-	-	-	-	+
38	*Labeo gonius* (Ham.)	-	-	+	+	+	+	+	+
39	*Labeo rohita* (Ham.)	-	+	+	+	+	+	+	+
40	*Orichthys cosuatus* (Ham.)	+	-	-	-	-	-	-	-
41	*Osteobrama cotio* (Ham.)	-	+	+	+	+	+	+	+
42	*Osteobrama vigorsii* (Sykes)	-	-	+	-	-	-	-	+
43	*Pethiia phutunio* (Ham-Buch)	-	-	+	-	-	-	-	-
44	*Pethia conchonius* (Ham.)	-	-	-	-	+	-	+	-
45	*Puntius chola* (Ham.)	-	-	-	+	+	+	-	-
46	*Puntius dorsalis*(Jerdon)	+	-	-	+	+	-	-	-
47	*Puntius gelius* (Ham.)	+	+	-	-	-	-	-	-
48	*Puntius guganio* (Ham-Buch.)	+	-	+	-	-	-	-	-

Table 2 : Continued...

Sl. No.	Name of the species	Hora (1940)	Jayaram & Majumdar (1976)	Desai & Shrivastava (2004)	Om Prakash *et al* (2004)	Dahire V. (2008)	Tamboli and Jha (2010)	Patel G. *et al* (2012)	Present Study (2016)
49	*Puntius sophore* (Ham.)	+	+	+	+	+	+	+	+
50	*Puntius tetraripagus* (Macclelland)	+	-	-	-	-	-	-	-
51	*Puntius ticto* (ham.)	+	+	+	+	+	+	+	+
52	*Rasbora daniconius* (Ham.-Buch.)	+	+	+	+	+	+	-	+
53	*Salmostoma bacaila* (Ham.)	+	+	+	+	+	+	-	+
54	*Salmostoma phulo* (Ham-Buch.)	-	-	+	-	-	-	-	-
55	*Systomus sarana* (Ham- Buch)	+	+	+	+	+	+	-	+
56	*Tor putitora* (Ham.)	-	-	-	-	-	-	+	-
57	*Tor tor (*Ham- Buch.)	-	-	-	-	+	-	+	-
	Family- Siluridae								
58	*Ompok bimaculatus* (Bloch)	-	+	+	+	+	+	+	+
59	*Ompok pabda* (Ham.)	-	-	-	-	-	+	+	+
60	*Ompok pabo* (Ham.)	-	-	-	-	-	+	-	+
61	*Wallago attu* (Bl. & Schn.)	-	+	+	+	+	+	+	+
	Family Bagridae								
62	*Mystus bleekeri* (Day)	-	-	+	+	+	+	-	-
63	*Mystus cavassius* (Ham.)	+	+	+	+	+	+	+	-
64	*Mystus tengara* (Ham.)	+	+	-	+	+	+	+	+
65	*Mystus vitatus* (Bloch)	+	+	+	+	+	+	-	+
66	*Sperata aor* (Ham.)	+	-	+	+	-	+	-	+
67	*Sperata seenghala* (Sykes)	-	+	+	+	+	+	+	+
68	*Rita rita* (Ham)	-	-	-	+	+	+	+	-
69	*Rita chrysea (Day)*	-	+	-	-	-	-	-	-
	Family-Sisoridae								
70	*Bagarius bagarius* (Ham.)	+	-	-	-	+	+	-	-
71	*Eriethistes hara* (Ham.)	+	-	-	-	-	-	-	+
72	*Gagata cenia* (Ham.)	-	+	-	-	-	-	-	-
73	*Gagata gagata* (Ham.)	-	-	-	-	-	-	+	-

Table 2 : Continued...

Sl. No.	Name of the species	Hora (1940)	Jayaram & Majumdar (1976)	Desai & Shrivastava (2004)	Om Prakash *et al* (2004)	Dahire V. (2008)	Tamboli and Jha (2010)	Patel G. *et al* (2012)	Present Study (2016)
	Family-Schilbeidae								
74	*Ailia coila* (Ham.)	-	+	-	-	+	+	+	+
75	*Clupisoma bastari* (Dutta &Kar.)	-	-	+	-	-	-	-	-
76	*Clupisoma garua* (Ham.)	-	+	-	-	+	-	-	+
77	*Eutropiichthys vacha* (Ham.)	-	-	-	+	+	+	+	+
78	*Eutropiichthys murius* (Ham.)	-	-	-	-	-	-	+	-
79	*Pachypterus atherinoides* (Bloch)	+	-	-	+	+	-	+	-
	Family- Pangasiidae								
80	*Pangasius pangasius* (Ham.)	-	-	-	+	-	-	+	-
	Family-Saccobranchidae								
81	*Heteropneustes fossilis* (Bloch)	+	-	-	+	+	+	-	+
	Family-Claridae								
82	*Clarias batrachus* (Linn.)	+	+	-	+	+	+	+	+
83	*Clarias gariepinus* (Linn.)	-	-	-	+	+	+	+	-
	Family-Belonidae								
84	*Xenentodon cancila* (Ham.)	+	+	+	+	+	+	+	+
	Family- Mugilidae								
85	*Rhinomugil corsula* (Ham.)	-	+	+	+	+	+	-	-
	Family-Channidae								
86	*Channa gachua* (Ham.)	+	-	-	+	+	+	+	+
87	*Channa marulius* (Ham.)	-	-	-	+	+	-	+	+
88	*Channa orientalis* (Bl.& Schn.)	-	-	+	-	-	-	-	-
89	*Channa punctatus* (Bloch)	+	+	-	+	+	+	-	+
90	*Channa striatus* (Bloch)	-	+	+	+	+	+	+	+

Table 2 : Continued...

Sl. No.	Name of the species	Hora (1940)	Jayaram & Majumdar (1976)	Desai & Shrivastava (2004)	Om Prakash *et al* (2004)	Dahire V. (2008)	Tamboli and Jha (2010)	Patel G. *et al* (2012)	Present Study (2016)
	Family –Notopteridae								
91	*Chitala chitala* (Ham.)	+	-	-	+	+	+	-	+
92	*Notopterus notopterus* (Pallas)	-	+	+	+	+	+	+	+
	Family-Sciaenidae								
93	*Johnius coitor* (Ham.)	-	-	-	-	-	+	-	-
94	*Johnius gangeticus* (Talwar)	-	-	-	-	-	-	+	-
	Family- Nandidae								
95	*Badis badis* (Ham)	+	+	-	-	-	-	-	-
96	*Nandus nandus* (Ham.)	+	-	+	+	+	+	+	+
	Family- Cichlidae								
97	*Oreochromis mossambicus* (Peters)	-	-	-	+	+	+	+	+
98	*Oreochromis niloticus* (Linn.)	-	-	-	+	+	-	-	+
	Family- Anabantidae								
99	*Anabas cobojius* (Ham.)	-	-	-	+	+	-	-	-
100	*Anabas testudineus* (Bloch)	-	-	-	+	+	+	+	+
101	*Trichogaster fasciatus* (Bl.& Schn.)	-	-	-	+	+	+	-	+
	Family- Gobiidae								
102	*Glossogobius giuris* (Ham.)	+	+	+	+	+	+	+	+
	Family-Mastacembelidae								
103	*Macrognathus aculeatus (Bloch)*	+	+	-	+	+	+	-	+
104	*Mastacembelus armatus* (Lacepede)	+	+	+	+	+	+	+	+
105	*Mastacembelus puncalus* (Ham.)	+	+	+	+	+	+	+	+
	Family- Tetrodontidae								
106	*Tetraodon cutcutia*	-	-	-	-	-	+	-	-
	Family-Synbranchidae								
107	*Monopterus cuchia* (Ham.)	-	-	-	-	-	-	-	+
Total		**43**	**42**	**48**	**65**	**67**	**58**	**53**	**57**

(+) = Reported, (-) = Not Reported

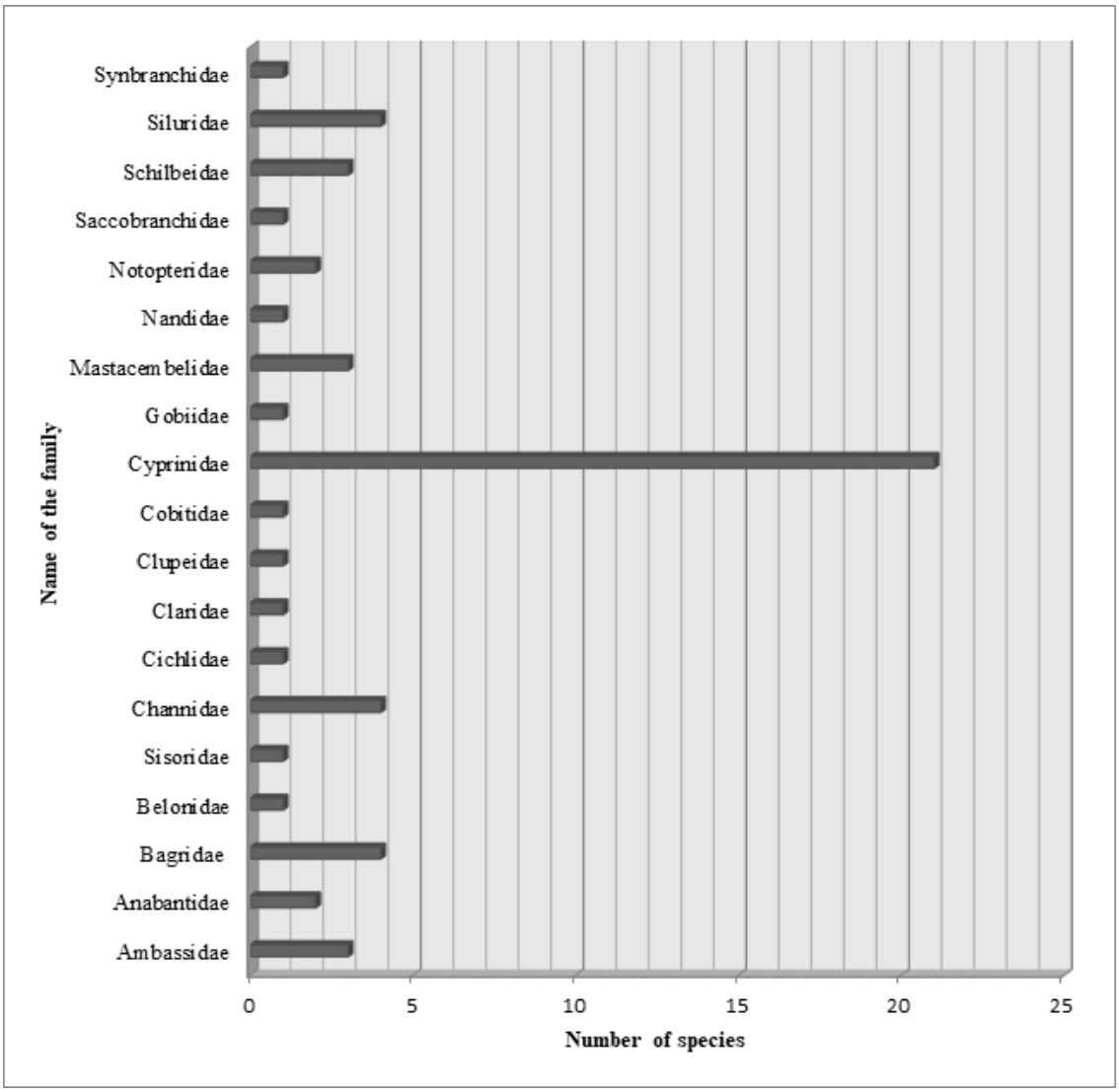

Fig.2 Number of species under different families recorded during the present study

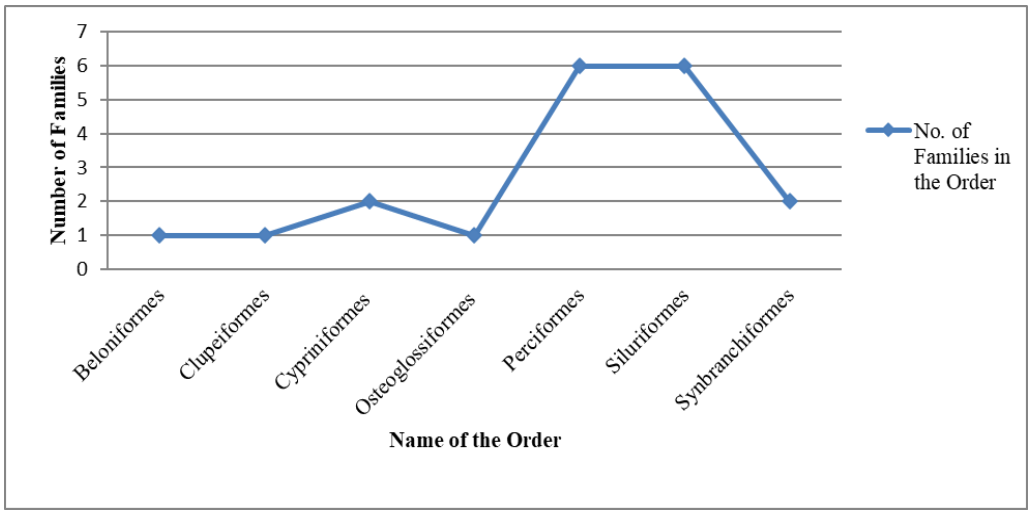

Fig.3 Number of families under different order reported under the present study

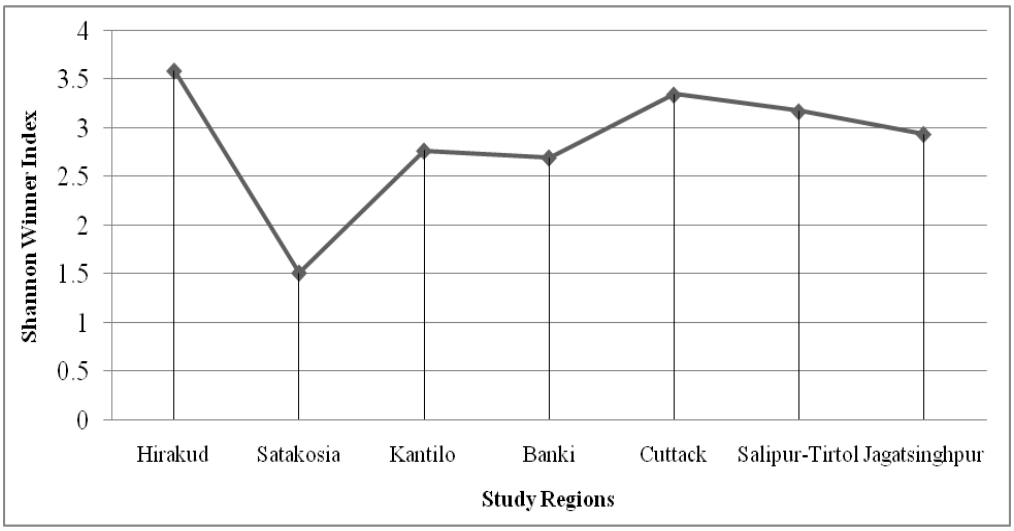

Fig.4 The Shannon Winner Index of the different regions under the study

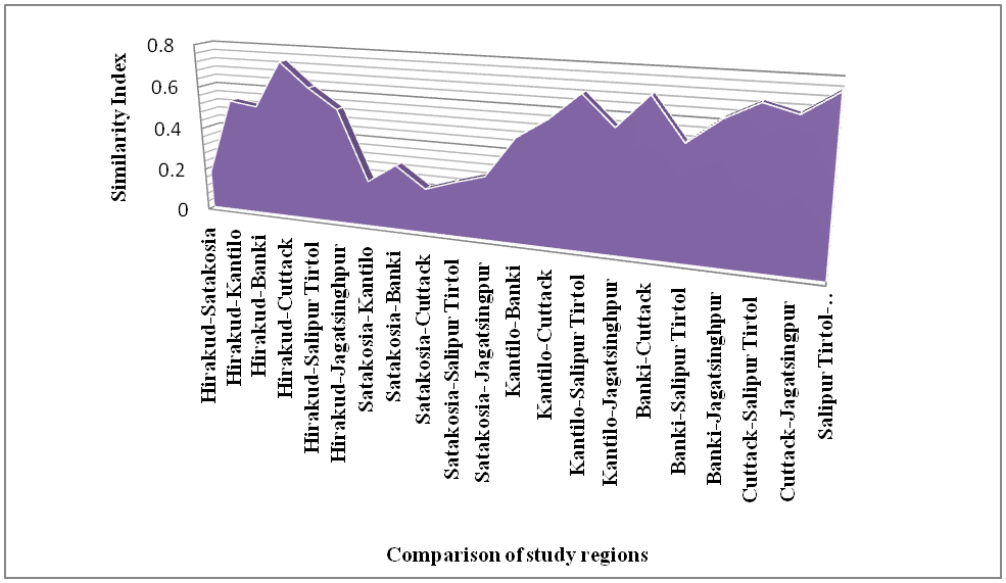

Fig.5 The Similarity Index of different regions under study

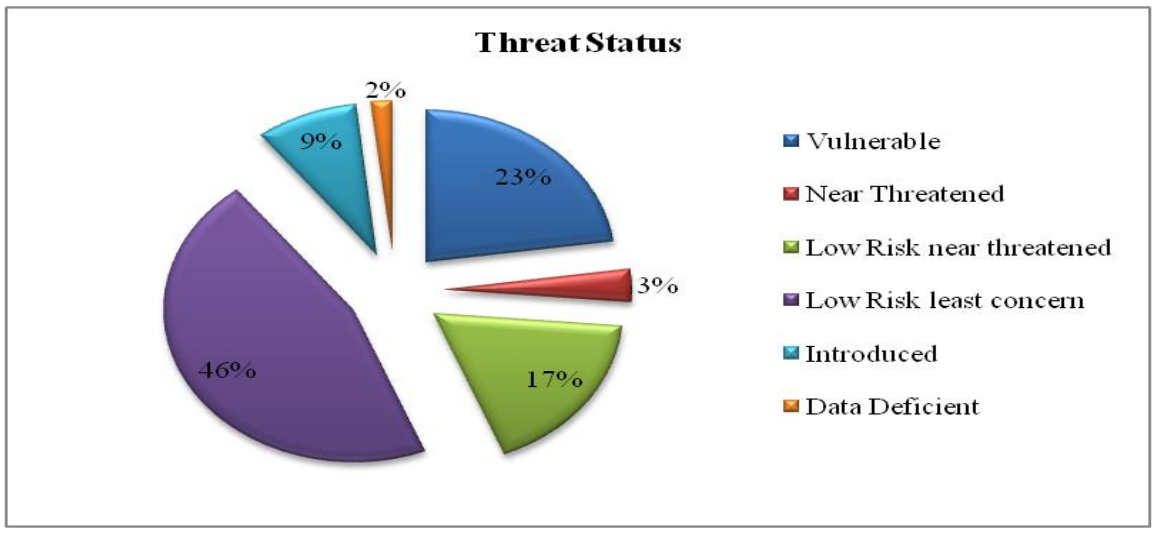

Fig.6 The IUCN threat status of the fish species reported under the present study

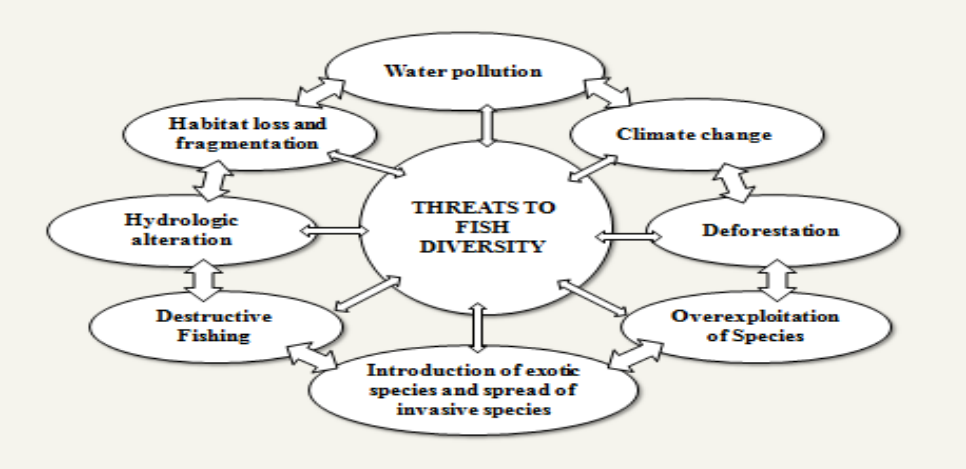

Fig.7 Potential threats of fish biodiversity and their inter-relationship

Threats

Freshwaters fishes are subjected to a number of anthropogenic threats including habitat loss and fragmentation, hydrologic alteration, climate change, overexploitation, pollution and the spread of invasive species (Dudgeon *et al.,* 2006). The end result is that freshwater fishes are among the most threatened faunas worldwide. The major threats impacted the fish biodiversity more often are habitat loss and destruction, hydrologic alteration, climate change, water pollution, destructive fishing, overexploitation of fish species, the spread of invasive species and deforestation. These threats are interlinked and cause substantial biodiversity losses. The most important aspect of this is that these are brought to the nature through targeted anthropogenic activities for developmental purpose including enhancement of aquaculture production and development. The figure 7 indicates the inter relationship between the threats to fish biodiversity.

The habitat loss and fragmentation and hydrologic alteration are the result of construction of multipurpose water development projects such as dams and anicuts in different parts of the river changing the ecology of the habitat. Construction of dams on river resulted upstream migration of fishes and displaces populations from their normal spawning grounds by separating them into small groups. As far as the situation of threat and conservation of fishes in the Mahanadi River is concerned many authors had shared their views. According to Mahapatra (2003), the fish catch in the Hirakud Reservoir had declined substantially during 1981-2001. This decline in catch has been attributed to indiscriminate fishing irrespective of species, fishing by using nets with small mesh size, lack of recruitment, lack of closed fishing season during monsoon etc. Besides this, destructive fishing methods using chemicals, plants extracts, dynamite and electric shock are major threats to the fish diversity. Use of explosive not only endangered some rare species but it also pollutes the water.

Overexploitation of fish species for various purposes, and by using small mesh size net is posing a great threat to the fish diversity. It affects the loss of genetic diversity and the loss in the relative species abundance of both individual and /or groups of interacting species. The population size gets reduced because of disturbances in structure of the fish group, sex composition and lack of recruitments of the species. Water Pollution is another major threat to fish diversity. The discharge of different waste such as sewage, industrial effluents and biomedical waste into the Mahanadi water has raised concerns about water pollution. The exhausted waste from different industries across the river are chemicals, metals, acids and phenol etc. cause mortality and their presence is high in concentration in the water affect the reproductive functionality of fish (Kime, 1995). Further, the suspended solids in water affects the respiratory processes and secretion of protective mucus making the fish susceptible to infection of various pathogens. Similarly, the sewage and organic pollutants cause shortage of oxygen in the ecosystem causing stress in the fish species and may lead to eutrophication resulting mortality in fishes.

Another threat to fish diversity is introduction of exotic fishes. According to Bhat and Singh (2012), a major threat for biological diversity throughout the world is considered as “biological pollutants” which

means introducing species accidentally or intentionally from one habitat into another. Considering the direct interactions between introduced and endemic species, introduced organisms can alter trophic relationships at least in three different ways. Their presence may significantly increase the number of prey available to native predators. Secondly, the feeding habits of introduced fish can reduce the amount of natural food available to native species through a dietary overlap or competition. Competition is not limited to trophic interactions but also to such other ecological limiting factors such as breeding space etc. The quality of fish stock in the environment can also deteriorate through stunting by the introduced species. Stunting is a process whereby the population of a species expands rapidly, producing large numbers of individuals which mature and breed at a much reduced size, thus diminishing considerably its recreational or commercial value. Fish species such as Tilapia, ornamental fishes etc. have been reported as producing stunted population on account of introduction. Stunted populations can overwhelm the existing ones and may even in extreme cases cause a shortage of oxygen. The introduction of exotic aquatic organisms has a negative impact on the habitat of native species. Impacts of introduction do not only concern biological and ecological parameters, but might also directly or indirectly affect socio economical factors. This could occur when an undesirable introduced species replaces a highly valuable native fish. Although introduction of exotic fishes is one of the recognised means of stock improvement, the issue has to be viewed in the light of its impact on the diversity of fish species already available. Such introduction needs to be preceded by careful evaluation of the potential and problems of the candidate species vis-à-vis the endemic fish and shell fish fauna or otherwise carrying out risk assessment. Introduction of new exotic species must be viewed cautiously and allowed only if absolutely necessary and feasible with no adverse impact on biodiversity, on ecological balance or danger to the endemic fauna.

Climate change also affects fish diversity by way of uneven season and climatic conditions. Deforestation leads to catchment area degradation by soil erosion which results into sedimentation and siltation. Therefore, it affects the breeding ground of fishes and also causes gill blockage of small fishes (Kime, 1995, Kanwar et al, 2010).

Conservation Measures

To maintain the fish diversity, protect their habitats and interrelationships between fishes and their ecosystem, biodiversity conservation is the only way forward. Conservation of biological diversity has attracted considerable attention at the national and global levels during the last few years. Nowadays, fish biodiversity and management of regional levels is also being catching attention (Kanwar et al, 2010). The crucial aspect of biodiversity conservation is choosing appropriate method of conservation as biological diversity entities are sensitive to handle and once the diversity is lost, difficult to be renewed. Biodiversity losses are the bio-indicators for assessment of implications of such losses on the entire ecosystem and the species extinctions. Hence the essentials of biodiversity conversation and conversation strategies are extremely important. The best way of biodiversity conservation is identifying exact cause and threat to biodiversity and accordingly chosing appropriate methods of conservation as bio-organisms are extremely vulnerable to different threats and once lost cannot be replaced or otherwise properly conserved. Therefore, biodiversity conservation is the need of the hour (UNEP, 1992, Singh *et al*, 2013).

The Convention on Biological Diversity (CBD), which was opened for signature on 5th June, 1992 at the United Nations Conference on Environment and Development (the Rio "Earth Summit") and came into force on 29th December, 1993 had also emphasized on conservation of biodiversity and management of aquatic animal biodiversity. This includes clear recognition of the importance of protocols to minimize the negative impact on aquatic biodiversity due to the movement of exotic species and uncontrolled spread of aquatic animal pathogens. Besides, Food and Agricultural Organisation (FAO) had chalked out the Asia Regional Technical Guidelines based on a set of Guiding Principles. These guidelines especially focus on movement of living aquatic animals within and across national boundaries as a necessity for economic, social, and development purposes and to manage the associated risk and threat thereunder to the native biodiversity.

It is felt at different levels and by different Governments that developing policy and planning for biodiversity conservation is not an easy task as biodiversity itself is complex and vast. Therefore, it is suggested at different time that the task of biodiversity conserva-

tion should always be specifically design. Without a precise measure of biodiversity, relative estimates of similarity or differences, derived by using partial measures, can be used for area prioritization (Sahotra & Margules, 2002). Freshwater ecosystems are recognized as system open to rehabilitation procedures. This means that fish and rivers themselves can do most of the restoration work when the main pressures disappear. In situ conservation measures need to be prioritized over the ex-situ ones. The best water management policies, together with the preservation of horizontal and longitudinal connectivity, are required at this juncture in order to preserve the ecosystem function and maintain the ability of fish to recolonize in fishless areas after natural or anthropic catastrophes. Otherwise, natural constraints and climate change may exacerbate the consequences of current anthropogenic impact.

As far as the conservation of fish diversity of Mahanadi is concerned, adoption of rational methods and new technology in fishing as first step towards conservation of fish diversity of the river Mahanadi. Some of the few effective measures of fish biodiversity conservation of Mahanadi are 1. establishing species specific reserves to protect both species and habitats, 2.prohibiting all kind of fishing activities in the bio-reservoirs would help smaller fishes to grow and maintained healthy ecosystem, 3.complete ban on the operation of fine meshed nets especially shore-seiners, 4. fishing by dragnets with permissible mesh size, 5. ban on operation of gill nets of less than 4" mesh size throughout the year, 6. encouragement of operation of specific gear to catch catfish so as to facilitate development of Indian major carp fisheries, 7. developing captive breeding and broodstock bank of economically important fishes so that these species can be conserved from endangered 8. avoid introduction of invasive species and if needed, species may be introduced only after conducting proper risk analysis. Besides, strengthening the fishery policies of Governments by special attention to management measures aimed at conserving freshwater fishes, broodstock maintenance centre by way of brood bank and hatcheries exclusively for endangered and critically endangered fishes for their in-situ conservation.

Concluding Remarks

The present study revealed that so far 107 fish species have been reported by number of scholar since 1940 by Hora. However, the review of literature states that 146 species were reported by Day in 1869 mostly from Cuttack region. Job *et al*. (1955) reported more than 103 species after a comprehensive study in a stretch of the Mahanadi. Since then studies have reported less number of fish species and the present study reported only 57 fish species. It is observed that a number fish species reported during initial studies since 1869 to 1976 have not been reported in the recent time. This implies that these species are almost endangered in the Mahanadi river despite theirs IUCN status. The fish species are *Channa orientalis* (Bl. & Schn.), *Badis badis* (Ham), *Eriethistes hara* (Ham.) *Gagata cenia* (Ham.), *Rita chrysea* (Day), *Amblyceps mangois* (Ham.), *Gonialossa manmina* (Ham.), *Barilius barila* (Ham.-Buch.), *Barilius vagra*(Ham.), *Danio aequipinnatus, Esomos danricus* (Ham.), *Garra gotyla gotyla* (Gray), *Garra mullya* (Sykes), *Puntius dorsalis*(Jerdon), *Puntius gelius* (Ham.), *Puntius guganio* (Ham-Buch.). It is observed from the present study that out of recorded 57 fish species, 15 species are threatened either being by VU or NT. Therefore, it is essential to adopt requisite biodiversity conservation measures to protect the fish diversity of the Mahandi river otherwise we are not left with much time when we may lose these beautiful fauna of nature.

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Conflict of Interest

The author declares that there is no conflict of interest.

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