

Biodiversity and Conservation status of Ichthyofauna of Lake Kolleru, Andhra Pradesh, India



Zoology

KEYWORDS : Biodiversity, CAMP, Conservation, IUCN, Lake Kolleru

Ch. Sebastian Raju	Research Scholar, Department of Zoology & Aquaculture, Acharya Nagarjuna University Nagarjuna Nagar, Guntur (AP), India – 522 510
* J. Chandra Sekhara Rao	Research Scholar, Department of Zoology & Aquaculture, Acharya Nagarjuna University Nagarjuna Nagar, Guntur (AP), India – 522 510 * Corresponding Author
G. Simhachalam	Assistant Professor, Department of Zoology & Aquaculture, Acharya Nagarjuna University, Nagarjuna Nagar, Guntur (AP), India – 522 510

ABSTRACT

A survey was conducted on biodiversity of fish fauna of Lake Kolleru, a freshwater wetland of International importance with an objective to assess freshwater fish diversity and their conservation status. Regular monthly sampling was carried out from January, 2012 to December, 2013. Study revealed the presence of 92 species of fish belonging to 13 orders, 34 families and 57 genera. Order cypriniformes was the dominant group with 30 species followed by mugiliformes with 17 species, siluriformes with 15 species, perciformes with 14 species, cyprinodontiformes with 4 species, anguilliformes and mastacembeliformes each with 3 species and osteoglossiformes, elopiformes, gonorhynchiformes, characiformes, pleuronectiformes and tetraodontiformes each with 1 species. Out of 92 species, 5 species are endangered, 1 species is critically endangered, 2 species are at lower risk least concern, 15 are vulnerable, 27 are at lower risk near threatened, 40 species were not evaluated and for 1 species data is deficient according to CAMP (1998) conservation status. As per IUCN (2013) Red List category, 6 species are near threatened, 1 species is endangered, 1 species is vulnerable, 65 are least concern, 16 were not evaluated and for 3 species data is deficient. Habitat loss, pollution, over exploitation, human interference, trade and siltation are the major threats causing biodiversity loss of this Lake of which pollution and habitat loss are the most contributing factors. There is an urgent need to develop a sustainable fishery management to conserve the biodiversity of this lake.

INTRODUCTION

India has rich biological resources that qualify it as one of the mega diversity countries of the world. Fishes exhibit enormous diversity in their morphology, habitat they live in and biology. In India there are 2500 species of fishes out of which 930 are freshwater and 1,570 are marine [1]. Freshwater biodiversity has declined faster than either terrestrial or marine biodiversity over the past 30 years [2]. Stabilization of ecosystems such as wetlands is very essential for the sustainable utilization of resources. Freshwater fish are one of the most threatened taxonomic groups [3] because of their high sensitivity to the alterations of aquatic habitats [4, 5]. Fish are an integral part of the lake and appear to be good indicators of the aquatic environment [6]. In addition to being a nutritional resource, they play important role in energy flow, nutrient cycling and maintaining community balance and are often a key component in environ-

mental management [7]. Ichthyofaunal diversity of an ecosystem represents the diversity and abundance of fish fauna. Many fish species have become highly endangered in freshwater ecosystems where heavy demand is placed on freshwater.

Wetland is not only an important source of water for drinking, agricultural operations, recreation, and sewage disposal but also considerably supports a substantial fishery. It not only supplements to nutritious diet but also is a source of livelihood for local fishing community. Hence, information about fish fauna inhabiting wetlands and other aquatic ecosystems is prerequisite for the development of culture as well as capture fishery. We largely omit wetlands, even though they are ecologically important, biologically rich, and also imperiled by anthropogenic activities [8]. Present survey was conducted in Lake Kolleru, a RAMSAR site from Andhra Pradesh, India to explore the invaluable fishery resources of the lake.

MATERIAL AND METHODS

Study area

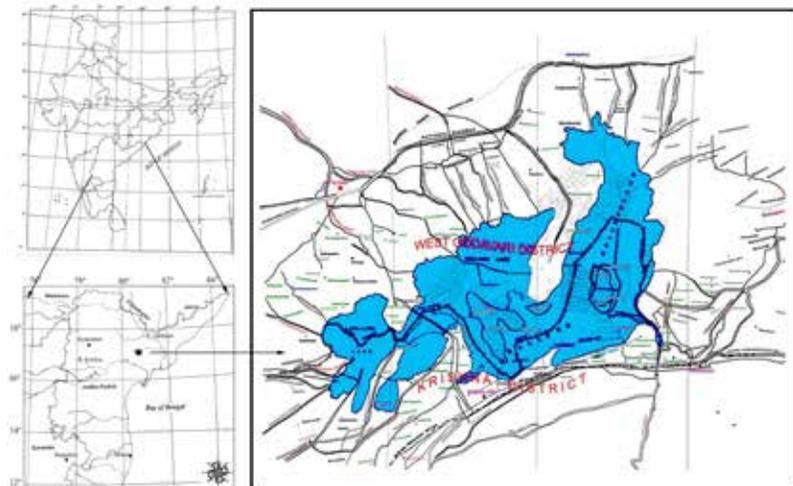


Figure 1. Geographical location of Lake Kolleru

The Lake Kolleru ($16^{\circ} 32'$ and $16^{\circ} 51' N$; $81^{\circ} 05'$ and $81^{\circ} 20' E$) is a vast shallow wetland ecosystem and the largest freshwater lake located between the deltas of two major Rivers Godavari and Krishna along the east coast of India (Figure 1). The lake functions as a natural flood-balancing reservoir for both the rivers [9]. In November 2002, lake was declared as a wetland of international importance by the RAMSAR convention for the conservation and sustainable utilization of wetlands [10, 11, 9]. It is the sole Ramsar designated wetland in Andhra Pradesh [12]. It is a source of water for domestic use and irrigation [13] and also traditionally supports a substantial fishery [14]. It is a highly productive lake [15] and provides habitat and good breeding and feeding ground for about 188 species of migratory and resident birds belonging to 46 families [16]. The imperial Gazette described Kolleru as "a peerless fishermen's paradise" and "bird heaven" [17]. Lake is contributing to habitat biodiversity and landscape aesthetics.

Fish Sampling

Experimental fishing was carried out with the help of artisanal fishermen using different types of nets namely cast nets (16 mm, 18 mm, 22 mm & 30 mm), gill nets (32 mm, 38 mm, 64 mm, 78 mm & 110 mm), drag nets (4 mm, 15 x 3 m), Scoop nets (1 mm & 2 mm). Fishes were also collected from catches of local fisher folk at the same sampling sites. Various types of gears, traps and other local contrivances were used by the fishermen for fish collection. Local fish markets and landing centers located in and around the lake were also visited to collect the fish which were not available during experimental fishing and natural collections from fishermen.

Fish Collection and Preservation

Since formalin decolorizes the colour of the fish on long preservation, photographs were taken immediately by Nikon camera (Model D90) in the field itself prior to preservation. Representative specimens of all fish species brought to the laboratory were preserved in 10% formalin solution according to their size. Small specimens were directly placed in the formalin solution while the larger ones were given an incision on the abdomen before preservation. Preserved fish were labeled giving

serial numbers, date and time of collection, locality from where collected, common name etc. All the fishes were preserved in the Museum, Department of Zoology and Aquaculture, Acharya Nagarjuna University, Guntur.

Fish Identification

Fishes were identified up to the species level using keys developed by Jayaram [18], Talwar and Jhingran [19], Jayaram [20] & Jayaram [21]. Identified fishes were confirmed by the experts in the field of fish taxonomy. Classification was carried out on lines of Day [22], Jayaram [23], Nelson [24] and Jayaram [18].

Assessment of Conservation Status

Data on current conservation status of fish was obtained from the report of the Conservation, Assessment and Management Plan (CAMP) workshop [25] on freshwater fishes of India and IUCN Red List Category of Threatened Species [26].

Assessment of Abundance, Threats, Feeding habits and Economic Importance of fish

Data regarding abundance of different fish species, threats faced by the fish fauna and economic importance was obtained from both primary sources (direct observations and interactions with the local stakeholders) and secondary (literature, reports and internet search tools) sources.

RESULTS AND DISCUSSION

Present investigation revealed the occurrence of 92 species from 13 orders, 34 families and 57 genera. List of fish including their conservational status was given in Table 1. Out of 92 species of fish, cypriniformes with 30 species contributed major number of fish species (32.60%) to the lake fishery followed by mugiliformes with 17 (18.47%) species, siluriformes with 15 (16.30%) species, perciformes with 14 (15.21%) species, cyprinodontiformes with 4 (4.34%) species, anguilliformes and mastacembeliformes each with 3 (3.26%) species and osteoglossiformes, elopiformes, gonorhynchiformes, characiformes, pleuronectiformes and tetraodontiformes each with 1 (1.08%) species (Table 2). Out of 92 species recorded, family cyprinidae was found to be the most dominant group with 30 species.

Table 1: Diversity and Conservation Status of Fish Fauna recorded from Lake Kolleru

Order / Family / Species	CAMP	IUCN	Habit	Habitat	Commercial Importance	Frequency	Threats
Order: Osteoglossiformes Family: Notopteridae 1. <i>Notopterus notopterus</i>	LRnt	LC	C, LV, P & SCF	BW & FW	CL, F, MD & O	A	HI, OE, P & T
Order: Elopiformes Family: Megalopidae 2. <i>Megalops cyprinoides</i>	NE	DD	O & SF	BW & FW	F & O	C	F, HL, OE, & T
Order: Anguilliformes Family: Anguillidae 3. <i>Anguilla bengalensis</i>	EN	LC	BF, O & P	BW & FW	CL, F & O	R	F, HL, & T
4. <i>Anguilla bicolor</i>	NE	LC	C	BW & FW	F & O	R	HI & HL
Family: Moringuidae 5. <i>Moringua raitaborua</i>	NE	NE	BF & O	BW & FW	F & O	C	F, HL, & T
Order: Gonorhynchiformes Family: Chanidae 6. <i>Chanos chanos</i>	NE	NE	BF & O	BW & FW	F & CL	A	HI, HL & OE
Order: Cypriniformes Family: Cyprinidae 7. <i>Catla catla</i>	VU	NE	H	FW	CL & F	A	HI, OE, P & T

8. <i>Cirrhinus mrigala</i>	LRnt	LC	O	FW	CL & F	C	HL, OE, S & T
9. <i>Cirrhinus reba</i>	VU	LC	SCF & O	FW	F & O	C	F, HI, HL, OE, P & S
10. <i>Ctenopharyngodon idella</i>	NE	NE	O	FW	F	C	No Threats
11. <i>Cyprinus carpio</i>	NE	VU	O & SCF	BW & FW	CL, F & O	C	No Threats
12. <i>Labeo bata</i>	LRnt	LC	H & CF	FW	CL & F	O	HL, OE, S & T
13. <i>Labeo boga</i>	LRnt	LC	CF & O	FW	F	O	H, HI, OE, P & T
14. <i>Labeo calbasu</i>	LRnt	LC	BF, H & O	BW & FW	CL, F & O	A	H, HI, OE, P & T
15. <i>Labeo fimbriatus</i>	LRnt	LC	C, CF, H & P	FW	CL & F	C	F & T
16. <i>Labeo rohita</i>	LRnt	LC	BF & H	BW & FW	CL& F	C	No Threats
17. <i>Labeo pangusia</i>	LRnt	NT	CF & P	FW	F	C	H, HI, OE, P & T
18. <i>Osteobrama cotio</i>	LRnt	LC	C & SCF	FW	F & O	O	HL, P & T
19. <i>Puntius chola</i>	VU	LC	BF & C	FW	F & O	C	HI, P & T
20. <i>Puntius conchonius</i>	VU	LC	O	FW	CL & O	C	HL, S & T
21. <i>Puntius dorsalis</i>	EN	LC	O	FW	F & O	A	F HL, P, & T
22. <i>Puntius gelius</i>	NE	LC	C	FW	O	C	No Threats
23. <i>Puntius guganio</i>	LRnt	LC	H	FW	O	R	HI, HL, OE, P & T
24. <i>Puntius sarana</i>	VU	LC	BCF & LV	BW & FW	F, O & WF	A	F, HI, HL & T
25. <i>Puntius sophore</i>	LRnt	LC	BCF, H LV & O	BW & FW	CL, F, O & WF	A	F, P & T
26. <i>Puntius terio</i>	LRnt	LC	O & CF	FW	O	C	F, HI, HL, P & T
27. <i>Puntius ticto</i>	LRnt	LC	BCF, H LV & O	BW & FW	CL, F, O & WF	C	F, HL & T
28. <i>Puntius vittatus</i>	VU	LC	H & SF	BW & FW	O & F	C	HI, HL, OE, P & T

29. <i>Chela cachius</i>	NE	LC	O & SCF	BW & FW	F & O	R	P & T
30. <i>Chela laubuca</i>	LRlc	LC	O & SCF	BW & FW	F & O	A	P & T
31. <i>Salmostoma phulo phulo</i>	NE	LC	LV & SF	FW	F & O	R	HL & P
32. <i>Amblypharyngodon mola</i>	LRlc	LC	H, LV & SSF	FW	CL, F & O	C	F & P
33. <i>Danio devario</i>	LRnt	LC	H, P & SF	FW	CL & O	A	HI, OE, P & T
34. <i>Esomus barbatus</i>	NE	LC	LV, O & SCBF	FW	O	A	P
35. <i>Esomus danricus</i>	LRnt	LC	LV, O & SCBF	BW & FW	O	A	OE
36. <i>Rasbora daniconius</i>	LRnt	LC	H, LV & SSF	BW & FW	O & WF	C	HL
Order: Characiformes Family: Characidae 37. <i>Serrasalmus nattereri</i>	NE	NE	CF & O	FW	O	C	No Threats
Order: Siluriformes Family: Bagridae 38. <i>Mystus armatus</i>	NE	LC	BCF, C, LV & P	BW & FW	F	C	HI & P
39. <i>Mystus bleekeri</i>	VU	LC	BF, C & P	FW	F & O	C	F, P & T
40. <i>Mystus cavasius</i>	LRnt	LC	BF, O & P	BW & FW	CL, F & O	O	F, HL, T & P
41. <i>Mystus gulio</i>	NE	LC	BCF, LV, O & P	BW & FW	F & O	C	OE & T
42. <i>Mystus vittatus</i>	VU	LC	BCF, C, LV & P	BW & FW	CL, F & O	C	OE & T
Family: Siluridae 43. <i>Ompok bimaculatus</i>	EN	NT	BCF, C & P	BW & FW	F & O	A	F, HL, OE, P, S & T
44. <i>Ompok pabda</i>	EN	NT	BCF, C & P	FW	F & O	C	F, HI, P & T
45. <i>Ompok pabo</i>	NE	NT	BCF, C & P	FW	F & O	R	F & HI
46. <i>Wallago attu</i>	LRnt	NT	BCF, C & P	BW & FW	CL & F	C	F, OE, S & T
Family: Schilbeidae 47. <i>Pseudotropius atherinoides</i>	EN	LC	SCF & O	BW & FW	O & WF	R	F, HL, P & T
48. <i>Pangasius pangasius</i>	CR	LC	SCF & C	BW & FW	F & CL	O	F, HI, HL, OE & T
Family: Clariidae 49. <i>Clarias batrachus</i>	VU	LC	BFSV, C, LV & P	BW & FW	CL, F, & O	C	T

50. <i>Clarias gariepinus</i>	NE	NE	BFSV, O & P	FW	CL, F & O	R	No Threats
Family: Heteropneustidae 51. <i>Heteropneustes fossilis</i>	VU	LC	BFSV, C, O & P	BW & FW	CL, F & O	C	F, HI, HL & T
Family: Loricariidae 52. <i>Plecostomus punctatus</i>	NE	NE	BF & O	BW	O	R	No Threats
Order: Cyprinodontiformes Family: Hemiramphidae 53. <i>Hyporhamphus limbatus</i>	NE	NE	C & SF	BW & FW	F & O	O	No Threats
Family: Belontiidae 54. <i>Xenentodon cancila</i>	LRnt	LC	C, LV, O & SF	BW & FW	CL, F, O & WF	R	F, P & T
Family: Oryziidae 55. <i>Oryzias dancena</i>	NE	LC	H, O & SF	BW & FW	O & WF	C	OE & T
Family: Aplocheilidae 56. <i>Aplocheilus panchax</i>	DD	LC	H, LV, O & SF	BW & FW	CL, O, & WF	C	F, HL, OE, P, S & T
Order: Perciformes Family: Centropomidae 57. <i>Lates calcarifer</i>	NE	NE	C & SCF	BW & FW	CL, F & O	C	No Threats
Family: Ambassidae 58. <i>Chanda nama</i>	NE	LC	C, LV, SCF & O	BW & FW	F, CL & O	A	F, HI, P & T
59. <i>Parambassis ranga</i>	NE	LC	C, LV, SCF & O	BW & FW	F & O	A	HL & P
Family: Teraponidae 60. <i>Terapon jarbua</i>	NE	LC	BF & O	BW & FW	CL & O	C	No Threats
Family: Lutjanidae 61. <i>Lutjanus johnii</i>	NE	NE	C & SCF	BW	F & O	R	No Threats
Family: Gerreidae 62. <i>Gerres filamentosus</i>	NE	LC	C, LV & SF	BW & FW	F	C	No Threats
Family: Scatophagidae 63. <i>Scatophagus argus</i>	NE	LC	BF & O	BW & FW	F & O	C	OF
Family: Nandidae 64. <i>Nandus nandus</i>	LRnt	LC	C & SCF	BW & FW	CL, F & O	C	HI, HL, P, S & T
65. <i>Badis badis</i>	NE	LC	C & SCF	BW & FW	O & WF	O	HL & S
Family: Cichlidae 66. <i>Etroplus canarensis</i>	DD	EN	O & SF	FW	O & F	O	OP & F
67. <i>Etroplus maculatus</i>	NE	LC	O & SF	BW & FW	F & O	C	HI, HL, P & T
68. <i>Etroplus suratensis</i>	NE	LC	O & SF	BW	C & O	A	HI, HL, P & T
69. <i>Oreochromis mossambica</i>	NE	NT	BCF, LV & P	BW & FW	F & O	A	No Threats

70. <i>Oreochromis niloticus</i>	NE	NE	BCF, H, LV & P	BW & FW	F & O	A	No Threats
Order: Mugiliformes Family: Mugilidae 71. <i>Mugil cephalus</i>	NE	LC	BCF, LV & O	BW & FW	F & O	C	OE & P
Family: Gobiidae 72. <i>Glossogobius guiris</i>	LRnt	LC	BF, C, LV, O & P	BW & FW	CL, F & O	C	HI & HL
73. <i>Gobiopsis macrostoma</i>	NE	NE	BF, C, O & P	BW & FW	F & O	O	No Threats
74. <i>Stigmatogobius sadanundio</i>	NE	NE	BF, C, O & P	BW & FW	F & O	O	No Threats
75. <i>Pseudapocryptes lanceolatus</i>	NE	LC	BF, C, O & P	BW & FW	F & O	C	No Threats
76. <i>Scartelaos histophorus</i>	NE	NE	BF, C, O & P	BW	F & O	R	No Threats
Family: Anabantidae 77. <i>Anabas cobojius</i>	VU	DD	SCF & O	FW	F	A	F, HL, OE & T
78. <i>Anabas testudineus</i>	VU	DD	C, CF, LV & P	BW & FW	F & O	A	F, HI, OE & T
Family: Belontiidae 79. <i>Macropodus cupanus</i>	NE	LC	CF, LV, O & P	BW & FW	F	O	HI, HL, OE & P
80. <i>Colisa fasciatus</i>	LRnt	LC	CF, LV & O	FW	CL, F & O	A	F, HI, P & T
81. <i>Colisa labiosus</i>	NE	LC	CF & O	FW	F & O	A	F, HI, P & T
82. <i>Colisa lalia</i>	NE	LC	CF, LV & O	FW	O & WF	R	HI, HL, OE & P
Family: Osphronemidae 83. <i>Osphronemus gorami</i>	NE	LC	SF & O	BW & FW	F & O	C	No Threats
Family: Channidae 84. <i>Channa gachua</i>	VU	LC	BCF, C & LV	FW	CL, F & O	C	HI, HL, OE & T
85. <i>Channa orientalis</i>	VU	NE	C	BW & FW	F	C	F, HL, & T
86. <i>Channa punctatus</i>	LRnt	LC	BCF, C, LV & P	BW & FW	CL, F & O	C	F, HL & OE
87. <i>Channa striatus</i>	LRnt	LC	BCF, C, LV & P	BW & FW	CL, F & O	C	F & T
Order: Mastacembeliformes Family: Mastacembelidae 88. <i>Macrognathus aral</i>	LRnt	LC	BF & C	BW & FW	F & O	O	F, HL, P & T
89. <i>Macrognathus pancalus</i>	LRnt	LC	BF, C & P	BW & FW	CL F & O	C	F, HL, P & T
90. <i>Mastacembelus armatus</i>	VU	LC	BF, C & P	BW & FW	CL, F & O	A	P
Order: Pleuronectiformes Family: Soleidae 91. <i>Euryglossa orientalis</i>	NE	NE	BF & C	BW & FW	F & O	R	HL

Order: Tetraodoniformes Family: Tetraodontidae 92. <i>Tetraodon cutcutia</i>	LRnt	LC	BCF, H & O	BW & FW	F & O	R	HI, OE, P & T
--	------	----	------------	---------	-------	---	---------------

Conservation Status: LC-Least Concern; DD-Data Deficient; NE-Not Evaluated; VU-Vulnerable; LRnt-Lower Risk near threatened, NT-Near threatened, LRLc-Lower Risk least concern;EN-Endangered; CR- Critically Endangered.
Habit: BF - Bottom feeder; BCF - Bottom columnar feeder; BFSV - Bottom feeder and surface visitor; C - Carnivore; CF - Columnar Feeder; H - Herbivore; LV - Larvivorous fish; O - Omnivore; P - Predatory fish; SF - Surface feeder; SSF - Sub-surface feeder; SCF - Surface columnar feeder; SCBF - Surface column bottom feeder.
Habitat: BW- Brackish water; FW- Freshwater.
Commercial Value: CL - Cultivable; F - Food fish; MD - Medicinal value; WF - Weed Fish.
Abundance: A-Abundant; C-Common; R-Rare; M-Moderate.
Threats: HI - Human Interference; HL - Habitat Loss; OE - Overexploitation; P - Pollution;; S - Siltation; T - Trade.

Table 2: Number and percent composition of families, genera and species under various orders

S.No	Order	Families	Genus	Species	% of Families in an order	% of Genera in an order	% of Species in an order
1	Osteoglossiformes	1	1	1	2.94	1.75	1.08
2	Elopiformes	1	1	1	2.94	1.75	1.08
3	Anguilliformes	2	2	3	5.88	3.50	3.26
4	Gonorhynchiformes	1	1	1	2.94	1.75	1.08
5	Cypriniformes	1	13	30	2.94	22.80	32.60
6	Characiformes	1	1	1	2.94	1.75	1.08
7	Siluriformes	6	8	15	17.64	14.03	16.30
8	Cyprinodontiformes	4	4	4	11.76	7.01	4.34
9	Perciformes	8	11	14	23.52	19.29	15.21
10	Mugiliformes	6	11	17	17.64	19.29	18.47
11	Mastacembeliformes	1	2	3	2.94	3.50	3.26
12	Pleuronectiformes	1	1	1	2.94	1.75	1.08
13	Tetraodontiformes	1	1	1	2.94	1.75	1.08
Total		34	57	92			

Out of 92 species, major percent (43.47%) of fish were not evaluated by CAMP, 1998 [25] but from the remaining 5.43% are endangered, 1.08% are critically endangered, 2.73% are at lower risk least concern, 16.30% are vulnerable, 29.34 % are at lower risk near threatened. As per IUCN [26] Red List category, 6.52% of species are near threatened, 70.65% are at least concern and 17.39% were not evaluated (Table 3).

Table 3: Number and percentage occurrence of fish fauna of Lake Kolleru under the conservation status CAMP, 1998 and IUCN, 2013

S. No	Threat category	CAMP		IUCN	
		Number	Percentage	Number	Percentage
1	Lower risk Near Threatened	27	29.34	--	--
2	Not Evaluated	40	43.47	16	17.39
3	Endangered	05	05.43	01	01.08
4	Vulnerable	15	16.30	01	01.08
5	Lower risk Least Concern	02	02.17	--	--
6	Data Deficient	02	02.17	03	03.26
7	Critically Endangered	01	01.08	--	--
8	Least Concern		--	65	70.65
9	Near Threatened	--	--	06	06.52

During the study period 30 species are encountered from freshwater region, 4 species from brackish water region, Uppureru channel which is the sole outlet for the lake and 58 species are collected both from freshwater as well as brackish water regions. Present study revealed the availability of 74 varieties of food fish, 35 cultivable species which are economically important. Maximum number (43 species) of fish is commonly found in the lake where as 22 species are abundant, 15 species are rare and only 12 species are occasional.

Use of fish for controlling mosquitoes was an important tool in the pre-DDT era [27, 28]. Our study revealed the occurrence of 29 larvivorous fish fauna in this lake. Demand for ornamental fish is increasing remarkably due to their important role in world trade for fish and fishery production [29]. A large number of beautiful ornamental fish species are still neglected which are abundant and easily available in the natural waters. Kolleru is endowed with a wide variety of fish species of which a significant number of species are considered ornamental fish. Chandra Sekhara Rao et al. [30] reported 58 ornamental fish species from Lake Kolleru. Present study added another 18 species to the existing ornamental fish fauna of Lake Kolleru. Introduced fish recorded during the study period are *Cyprinus carpio*, *Ctenopharyngodon idella*, *Oreochromis mossambica*, *Clarias gariepinus* (Aquaculture); *Osphronemus gourami*, *Plecostomus punctatus* (Ornamental trade). Native fish fauna is severely threatened by these introduced species.

Freshwater fish diversity is declining due to combined and interacting influences of overexploitation, pollution of aquatic habitat, flow modifications, habitat degradation and invasion of exotic species [31]. Ichthyofauna of this lake is also under threat due to several anthropogenic activities such as over exploitation, pollution, habitat loss etc (Table 4). Dominance of omnivorous fish (49 species) followed by Carnivores (39 species) and Herbivores (16 species) observed during the present study is the indication of the quality of the habitat.

Table 4: Number and percentage contribution of various threats to the fish fauna of Lake Kolleru

S. No	Threat category	Number of fish	Percentage
1	Human Interference	31	33.69
2	Over Exploitation	28	30.43
3	Pollution	40	43.47
4	Trade	52	56.52
5	Habitat Loss	38	41.30
6	Siltation	09	09.78

CONCLUSION

Lake Kolleru exhibits remarkably rich freshwater fish diversity including ornamental fish. The fish fauna of this lake is under severe threat as a result of several anthropogenic interferences. The major ecological problems to Kolleru Lake are encroachments, deterioration of water quality and loss of biological diversity.

A growing population and increasingly intense land use in the lake led to the rise in polluting inputs, including industrial effluents, pesticides and fertilizers from aquaculture, agriculture and domestic sewage [13, 32]. Entry of industrial effluents and other pollutants into the lake through 15 inflowing drains is the main reason for deterioration of water quality [33, 34]. The large scale industrialization and the consequent effluent discharge are making the lake vulnerable. Inorganic pollution of the lake due to industrial activities is another important threat to the fish fauna.

Introduced species for various purposes have been suggested as possible threats to the native fish fauna. Anthropogenic activities such as recreational activities are common in the lake. These practices seem to have caused severe habitat degradation and decline of many important native food fishes. The fish fauna of this Lake is also subjected to over exploitation for consump-

tion. Since the fish fauna of this lake supports the livelihood of several economic classes, there is an urgent need to design and implement conservation action plans.

Fish conservation measures on wide variety of factors must be taken into consideration to develop a comprehensive action plan. A holistic approach, integrating the concept of sustainable development and conservation measures could improve the situation. Considerable efforts should be made to conserve the biodiversity of fish. In order to conserve the valuable biodiversity of fish fauna of Lake Kolleru, the strategies should be adopted are: Restocking of economically important fish species; Proper introduction and control of exotic species; ban on indiscriminate and over fishing; implementing closed seasons, Establishment and maintaining fish sanctuaries; regular supervision and monitoring of the lake; enforcement of strict rules and regulations on overfishing, Alternative livelihood to the local people, Sustainable fish harvest, captive breeding, Mass awareness, Educating and activating the fishermen cooperative societies and research and development.

ACKNOWLEDGEMENT

Authors are thankful to the Department of Zoology & Aquaculture, Acharya Nagarjuna University for providing research facilities.

REFERENCE

1. Kar, D. 2003. Fishes of Barak drainage, Mizoram and Tripura, pp. 203-211. In: Kumar, A., Bohra, C. and Singh, L. K. (Eds). Environment, Pollution and Management. APH Publishing Corporation, New Delhi, p. 604. | 2. Jenkins, M. 2003. Prospects of Biodiversity. Science, 302: 1175-1177. | 3. Darwall, W.R.T. and Vie, J.C. 2005. Identifying important sites for conservation of freshwater biodiversity: extending the species based approach. Fish Management and Ecology, 12: 287-293. | 4. Laffaille, P., Acou, A., Guillouet, J. and Legult, A. 2005. Temporal change in European eel, *Anguilla Anguilla* stock in a small catchment after installation of fish passes. Fish Management and Ecology, 12: 123-129. | 5. Kang, B., He, D., Perrett, L., Wang, H., Hu, W., Deng, W. and Wu, Y. 2009. Fish and fisheries in the Upper Mekong: current assessment of the fish community, threats and conservation. Reviews in Fish Biology and Fisheries, 19: 465-480. | 6. Schneiders, A., Verhaert, E., Blust, G.D., Wils, C., Bervoets, L. and Verheyen, R.F. 1993. Towards an ecological assessment of water courses. Journal of Aquatic Ecosystem and Health Management, 2: 29-38. | 7. Schiemer, F. 2000. Fish as indicators for the assessment of the ecologist integrity of large rivers. Hydrobiologia, 422-423: 178-271. | 8. Zedler, J.B. and Kercher, S. 2005. Wetland resources: status, trends, ecosystem services, and restorability. Annual Review of Environment and Resources, 30: 39-74. | 9. Nagabhatla, N., Pattnaik, C., Sellamuttu, S., Prasad, S., Wickramasuria, R. and Finlayson, M. 2009. Investigation of aquaculture dynamics at a Ramsar site, using earth observation systems in conjunction with a socio-economic assessment. Lakes & Reservoirs: Research and Management, 14: 325-336. | 10. Rao, N., Krishna, G. and Malini, B. 2004. Kolleru lake is vanishing – a revelation through digital processing of IRS-1D LISS-III sensor data. Current Science, 86 (9):1312-1316. | 11. Nagabhatla, N. and Sellamuttu, S. S. 2008. Political Ecology of Wetland Management: the post aquaculture demolition case of Lake Kolleru in India. Rev. Geogr. Aademica, 2 (1): 10-19. | 12. FAO. 2006. State of World Aquaculture 2006, FAO Fisheries Technical Paper 500. Food and Agriculture Organisation of the United Nations. Rome 2006. | 13. Venot, J., Sharma, B. and Rao, K. 2008. The Lower Krishna Basin trajectory: Relationships between basin development and downstream environmental degradation. Colombo, Sri Lanka: International Water Management Institute. (IWMI Research Report 125). | 14. Ramsar 2002. Information sheet on Ramsar Wetlands (RIS)–Kolleru Lake. <http://www.wetlands.org/> (Accessed 19 August, 2013). | 15. Mangapathi Rao, K. 1987. Master plan for Kolleru lake development – An integrated ecological approach. Office of the Kolleru lake development Authority, Kaikaluru, Government of Andhra Pradesh. | 16. Anjaneyulu, Y. 2003. Assessment of environmental quality of Kolleru Lake and strategic management plans. Lake Kolleru Environmental Status (Past and Present), BS Publications: 3-15. | 17. Mittal, R. 1993. Management plan for Kolleru bird sanctuary. Forest Department, Government of Andhra Pradesh. 318p. | 18. Jayaram, K.C. 1981. The freshwater fishes of India, ZSI, 1-438. | 19. Talwar, P.K. and Jhingran, A. 1991. Inland fishes of India and adjacent countries. Oxford and IBH Publishing Co. New Delhi. 1 & 2: p. 1158. | 20. Jayaram, K.C. 1999. The freshwater fishes of the Indian Region. Narendra Publishing House, Delhi-6, 551. | 21. Jayaram, K.C. 2010. The Freshwater Fishes of the Indian Region. 2nd Edn. Narendra Publishing House, Delhi, pp. 625. | 22. Day, F. 1889. The Fauna of British India including Ceylon and Burma. Fishes, 1: 548: 2: 509. The London, Taylor and Francis. | 23. Jayaram, K.C. 1961. The proper generic names for some common Indian fishes of commercial importance. Journal of the Zoological Society India, 12(2): 239-242. | 24. Nelson, J.S. 1976. Fishes of the world, 3rd Edition, John Wiley and Sons, Inc., New York, p. 416. | 25. Molur, S. and Walker, S. 1998. Report of the Conservation Assessment and Management Plan. Workshop on freshwater fishes of India, Zoo outreach Organization/CBSG, Coimbatore, India. P. 156. | 26. IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 01 February, 2013. | 27. Floore, T.G. 2006. Mosquito larval control practices: past and present. Journal of the American Mosquito Control, 22: 527-533. | 28. Walker, K. and Lynch, M. 2007. Contributions of Anopheles larval control to malaria suppression in tropical Africa: review of achievements and potential. Medical and Veterinary Entomology, 21: 2-21. | 29. Sarma, S., Bhattacharjya, B.K., Zaidi, S.G.S., Landge, A.T. and Goswami, M. 2004. Indigenous ornamental fish biodiversity of central Brahmaputra valley zone, Assam. Journal of Inland Fisheries Society of India, 36(1): 29-35. | 30. Chandra Sekhara Rao, J., Simhachalam, G. and Sebastian Raju, Ch. 2013. Ornamental fish diversity of Lake Kolleru, the only Ramsar site in Andhra Pradesh, India. Bulletin of Environment , Pharmacology and Life Sciences, 2(7): 48-55. | 31. Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.I., Knowler, D. J., C. Leveque, C., Naiman, R. J., Richard, A.H.P., Soto, D., Stiassny, M.L.J., and Sullivan, C.A. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews, 81:163-182. | 32. Adhikari, S., Ghosh, L., Giri, B. and Ayyappan, S. 2009. Distributions of metals in the food web of fishponds of Kolleru Lake, India. Ecotoxicology and Environmental Safety, 72:1242-1248. | 33. Rao, S.A. and Rao, R.P. 2002. Environmental impact of aquaculture on Kolleru Lake. Indian Journal of Environmental Toxicology, 10: 1-4. | 34. Rao, P.M. and Sekhar, P. 2003. A Profile of Ecological Disturbances of Kolleru Lake of Andhra Pradesh, in A. Kumar, C. Bohra and L.K. Singh, Environment, Pollution and Management, New Delhi. |