STUDY ON ICHTHYOFAUNAL DIVERSITY, PRODUCTIVITY AND TROPHIC INDEX IN RELATION TO MACROPHYTE INFESTATION IN SELECTED BEELS OF KAMRUP DISTRICT OF ASSAM (INDIA)

Dissertation submitted in
Partial fulfillment of the requirements
for the degree of

M.F.Sc. (Fisheries Resource Management)

By

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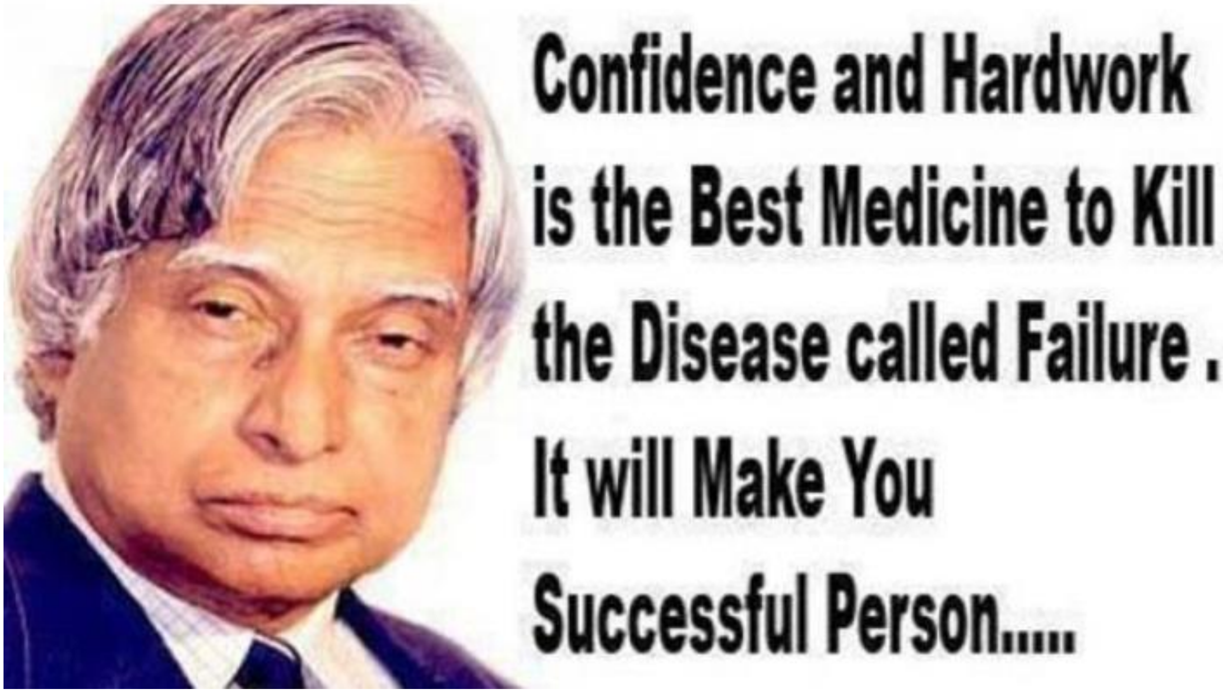
JUNE 2018

Kabin Medhi, 2018. Study on Ichthyofaunal diversity, Productivity and Trophic index in relation to Macrophyte infestation in selected beels of Kamrup district of Assam (India). M. F. Sc. Dissertation, ICAR-Central Institute Of Fisheries Education (University Established Under Section 3 of UGC Act 1956) Panch Marg, Off Yari Road, Versova, Andheri (W), Mumbai – 400 061



Dedicated to My

PARENTS & BELOVED BROTHERS

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Date: 30th June, 2018

CERTIFICATE

Certified that the dissertation entitled **"STUDY ON ICHTHYOFAUNAL DIVERSITY, PRODUCTIVITY AND TROPHIC INDEX IN RELATION TO MACROPHYTE INFESTATION IN SELECTED BEELS OF KAMRUP DISTRICT OF ASSAM(INDIA)"** is a record of independent bonafide research work carried out by **Mr. KABIN MEDHI** during the period of study from August 2017 to June 2018 under our supervision and guidance for the degree of **Master of Fisheries Science (Fisheries Resource Management)** and that the dissertation has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title.

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I hereby declare that the dissertation entitled "**STUDY ON ICHTHYOFAUNAL DIVERSITY, PRODUCTIVITY AND TROPHIC INDEX IN RELATION TO MACROPHYTE INFESTATION IN SELECTED BEELS OF KAMRUP DISTRICT OF ASSAM (INDIA)**" is an authentic record of the work done by me and that no part thereof has been presented for the award of any degree, diploma, associateship, fellowship or any other similar title.

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ACKNOWLEDGEMENT

At the very outset, I would like to be thankful to almighty whose blessings contributed incessantly to my success and given me enough strength to proceed ahead in the gloom of constraints and failure.

I would like to express my deep sense of heartfelt gratitude to my Major advisor Dr. B. K. Bhattacharjya, Principal Scientist & Head, ICAR -CIFRI, Regional Center, Guwahati, for his invaluable & constant guidance throughout the course of investigation and preparation of the thesis and has continually and convincingly conveyed a spirit of adventure in research and also has guided me with his affection and encouragement. I feel myself honoured to work under his guidance who is a dream guide of students and his guidance and blessings will help me in my journey in years to come.

My grateful thanks to my advisory committee member Dr. Z.J. Abidi, Senior Scientist, Dr. Shashi Bhushan, Scientist, FRHPHM Division, ICAR-CIFE, Mumbai, for their guidance, constant support, care and suggestions and making me comfortable to work during the course of study.

I am highly thankful to my advisory committee member Mr.Simanku Borah, Scientist,CIFRI Regional Centre,Guwahati,Assam for his brilliant ideas, constant efforts, guidance and motivations throughout the research work.

I would like to sincerely thank Dr. B. B. Nayak, Principal Scientist & HoD, FRHPHM Division for extending all support and inspiring me during the period of study and also Dr. S.K. Chakraborty , former HoD ,FRHPHM Division ICAR-CIFE, Mumbai for his kind help and affection during my study .

I sincerely thank to Dr. Geetanjali Deshmukhe, Principal Scientist, Dr. A.K Jaiswar, Principal Scientist,Dr. A. T. Landge Senior Scientist, Mr. Karan Kumar Ramteke, Scientist,Mr.Satish Kamat (Chief Technical Officer) FRHPHM Division, ICAR-CIFE, Mumbai, for valuable suggestions and affection.

It was a pleasant and great opportunity to work with Mr. Pradip Das (lesse of Garjan bullatjan beel, Hajo) and thankful to him for his kindness, constant help and support during the study period on the site.

I am thankful to all ICAR-CIFRI, Guwahati Regional Centre staff cum scientists, Mrs.Niti Sharma, Dr.Dipesh Debnath, Dr.Pranab Gogoi, Mr.A.K Yadav Dr. Sona Yengkopam, Mr.Amulya kakati, especially for their immense help during research work and moral support, affection .I also take this opportunity to thank Mr. Mukesh, Mr. Pandurang, Mr. Murty and Mr. Dattaram for their help and technical support.

My heartfelt thanks to my Seniors, Imtiaz Ahmed sir ,Abu sir , Hari sir , Amulya sir, Suman mam, ,Satish sir, Rinchen sir, Suraj sir, Dayal sir, Gladston sir, Nirmal sir, Shaya mam, Garima mam, Ajina mam, who supported me a lot in every moment and gave valuable suggestions. I sincerely thank my batch mates Mr. Abhijit, Amom , Siva, Kesavan , Bhargavi mam, Neethu, Jenishma , and Chellamanimegalai for their support and help.

I am indebted to my beloved roommate Mr. Arul for his generosity, help, support, which will always be embedded in my heart. I am also thankful to my batchmate, Mr. Ajay, Mr. Diganta Mrs. Barkha Mr. Deepjyoti Mr. Ikram for their valuable support. I am also thankful to my juniors Aditya , Samar , Abhinandan for their help and affection.My heartfelt thanks to my friends cum colleague Mrs. Parishmita Handique (MFSc Scholar in AAU, Raha Assam) and Rosy Bora (MSc Zoology, Darang College) for their constant help, support and affection during the course of study.

I would like to convey my heartfelt thank Dr. Gopal Krishna, Director& Vice Chancellor, and ICAR-CIFE for extending all support and help to conduct the research work.

I sincerely acknowledge ICAR, New Delhi for awarding the fellowship during my M.F.Sc. and without which I would not have been able to study.

Lastly, I express my wholehearted love, devotion and boundless gratitude to my parents. I am also thankful to my brothers Mr. Abhay Medhi, Mr. Manoj Medhi, Mr. Madhab Medhi who supported and made me confident in my journey of research. Last but not the least; I am again thankful to almighty Lord, my teachers and guide for giving me blessings and showing me right path.

30th June 2018 *(Kabin Medhi)*
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ABSTRACT

Present study was taken up to study the Ichthyofaunal diversity and to evaluate trophic status in relation to macrophyte infestation in Chatla and Urmal beel of lower Brahmaputra valley of Kamrup district, Assam, India. A total of 54 numbers of fish species belonging to 38 genera under 21 families from 8 orders were recorded from Chatla beel and 52 species belonging to 37 genera were recorded from Urmal Beel. In both beel fishes belonging to the family Cyprinidae were found to be most dominant. The result of present study reveals that the Gross Primary Productivity (GPP) & Net Primary Productivity (NPP) of both the beels were higher during pre-monsoon and minimum during monsoon season. Trophic status study revealed that the TSI values were higher during winter season, lower during pre-monsoon and post monsoon and moderate during monsoon in Chatla beel where as in Urmal beel the TSI values were found to be highest during monsoon season, lower during pre-monsoon and post monsoon and moderate during winter. TSI values based on SD (Secchi disk) and total phosphorus (TP) also exhibited similar patterns in both the beels. TSI based on Chlorophyll *a*, Secchi Disc and total phosphorus in Chatla beel placed it under moderately eutrophic whereas Urmal beel was placed under Eutrophic category. The occurrence of macrophyte associated fauna and air breathing fishes are more prominent in the closed beel. The overall results indicate that the decomposition and rapid growth of macrophyte play a vital role in nutrient status. The result of the present study will form the baseline for further study and the information generated can be used for the sustainable management of the resources.

सारांश

वर्तमान अध्ययन, असम के कामरूप जिले के ब्रह्मपुत्र घाटी में स्थित चतला और उर्मल बील में मछलियों की विविधता और बृहत् जलीय पादप पर्याक्रमण के संदर्भ में पौष्टिक स्थिति के मूल्यांकन करने के लिए संयोजित किया गया था। चतला बील से मछली की कुल 54 प्रजातियों पायी गयी, जोकि 38 श्रेणी, 21 परिवारों और 8 समुदाय के अंतर्गत थी, जबकि उर्मल बील से मछली की कुल 52 प्रजातियों दर्ज की गईं जोकि 37 परिवारों के अंतर्गत पायी गयी। दोनों बील में ज़्यादातर मछलिया कि प्रजातिया साइप्रिनिडे परिवार से संबंधित पायी गयी। वर्तमान अध्ययन के नतीजे बताते हैं कि दोनों बील में, सकल प्राथमिक उत्पादकता (GPP) और निवल प्राथमिक उत्पादकता (NPP) मानसून-पूर्व अधिकतम और मानसून के दौरान न्यूनतम थी। पौष्टिक स्थिति अध्ययन ने खुलासा किया कि चतला बील में टीएसआई(TSI) आदर्श, सर्दियों के मौसम के दौरान अधिक, पूर्व मानसून एवम मानसून के बाद न्यूनतम और मानसून के दौरान दौरान मध्यम थे, जबकि उर्मल बील में मानसून के दौरान सबसे ज्यादा, पूर्व-मानसून और मानसून के बाद न्यूनतम और सर्दियों के दौरान मध्यम पाए गए थे। सेचची डिस्क (SD) और कुल फास्फोरस (TP) के आधार पर टीएसआई(TSI) आदर्श ने दोनों बील्स में समान स्वरूप प्रदर्शित किए। कोलरोफिल ए, सेचची डिस्क और कुल फास्फोरस पर आधारित टीएसआई(TSI) आदर्शो ने चटला बील को मामूली सुपोषी के अंतर्गत पाया, जबकि उर्मल बील को सुपोषी श्रेणी के अंतर्गत पाया, । बृहत् जलीय पादप से जुड़े जीवों और वायु सांस लेने वाली मछलियों की संख्या इन संवृत बील में बहुतायत है। समग्र परिणाम इंगित करते हैं कि बृहत् जलीय पादप का तेजी से विकास और विघटन, पोषक तत्वों कि स्थिति में महत्वपूर्ण भूमिका निभाता है। वर्तमान अध्ययन के नतीजे आगे के अध्ययन के लिए आधारभूत जानकारी प्रदान करेंगे जोकि, संसाधनों के सतत प्रबंधन के लिए उपयोग किया जा सकते है।

CONTENTS

1. INTRODUCTION

Wetlands are most diverse and dynamic ecosystems and the most valuable natural resources on earth. Wetlands occupy approximately 1 % of the earth surface but provide habitat for about 20 % of world's species (Dugan and Davis, 1993; Dudgeon *et al.,* 2006). The ecological functions of the wetlands are regulating hydrological cycle, recycling of nutrients, abatement of pollution, reducing flood and erosions, sustaining ground water recharge, providing suitable habitat for fish, reptiles and furnishing food and services to human, feeding and nursing ground of migratory birds and control of flood. Besides the ecological services the water of wetlands are used for drinking purpose, bathing, washing, irrigation, extend place for cultivation, human settlement, energy production and production of food and fodder etc.

Floodplain wetlands in India occupy an estimated area of 354,213 ha which encompasses 18.4% of the country's total land. Floodplain wetlands are known as beels in Assam and cover an estimated area of over 100,000 ha. There are 1,392 beels in the state of Assam; out of which 1,070 beels are in Brahmaputra valley and rest 322 in Barak valley (Anon, 2006).

India is one of the mega diversity countries in the world and occupies ninth position in terms of freshwater mega diversity (Mittermeier and Mittermeier, 1997). India is endowed with a rich aquatic biodiversity of 3035 finfish species, which includes 1016 freshwater, 113 brackish water and 1906 marine fishes (Anon, 2017) .A total of 85 fish species belonging to 33 families along with 5 species of prawns of food value have been reported from floodplain wetlands of India (Anon, 2006).

The North East region of India is one of the biological hotspot for freshwater fish diversity in the world with 25 hotspots (Kottelat and Whitten, 1996). Assam, constituting 30% of North-eastern Region of India is enriched with Ichthyofaunal diversity. Till date 216 species belonging to 98 genera under 34 families have been reported from Assam (Bhattacharjya *et al.,* 2002). The diversity of fish is found to be more numerous in lower reaches of the Brahmaputra basin.

Fish yield of wetlands are estimated by primary productivity. The average yield of fish in wetlands of Assam has increased from 172.9 kg per/ha/year in the late nineties to 450kg/ha/year in stocked beels and 221 kg/ha/year in un-stocked beels. It is assumed that the scientific management of the beels can lead to a production potential of 1000-1500 kg/ha from current levels. Although Wetlands of Assam has got poor levels of phosphorous and nitrogen these wetlands have proved to be ideal habitat for biological production. Phosphorous and Nitrogen are less in closed water bodies and may be locked up in the soil or utilized by macrophyte and available phosphorus is relatively low in beels of Assam. The acidic soil of wetlands of Assam impedes in fish and fish food organisms production but the mean values of organic carbon showed that beels of Brahmaputra are more conducive.

Aquatic macrophytes play an important role in the structure and function of aquatic ecosystem and associated species. They also play a significant role in the dynamics of Physico-chemical and biological characteristics of the beels. Energy needed by the herbivores provided by aquatic plants as well as increase the strength of the detritus food chain of the Beel ecosystem which is most important for increasing the fish production. Many threats like climate change, eutrophication to fresh waters will result in reduced macrophyte diversity which in turn, threatens the faunal diversity of aquatic ecosystems (Bordoloi *et al.,* 2012).

A unique feature of the floodplain wetlands of Brahmaputra basin is the rich growth of marginal and submerged vegetation due to the allochthonous and autochthonous nutrient loading. These macrophytes often tend to replace the plankton community. Progressive replacement of plankton community with macrophytes as the main primary producer hastens the pace of eutrophication. This also leads to higher rate of evapo-transpiration and swampification of the lake (Sugunan *et al.,* 2000). However this process can be reversed through effective management. Open beels which generally harboured less macrophyte, when favourably disposed for energy transformation through phytoplankton. Closed beels are mostly choked with floating (water hyacinth), submerged (*Najas, Vallisneria, Hydrilla* and *chara*) and marginal (*Typha*) vegetation affecting productivity. By virtue of their high nutrient status, warmer water regime and the rich sunshine, beels of Assam are considered to be highly productive ecosystem. In fact many of them are passing through transient phases of eutrophication leading to weed choking (Sugunan *et al.,* 2000).

Eutrophication is one of the main problems in beels of Assam. This problem can be evaluated by calculating trophic state indices. The trophic state index (TSI) based on several biological, chemical and physical indicators, especially the Carlson- TSI offers the most suitable and acceptable method for evaluating lake eutrophication (Xu et al., 2001).

Carlson (1977) introduced a set of lake trophic state indices (TSIs) based on measurement of water column phosphorus TSI (TSI-TP), chlorophyll a TSI (TSI-Chl a) and Secchi disc depth TSI (TSI-SD). The average values of TSI of these three parameters are considered in determining the Carlson's trophic state index. Chlorophyll-a is given higher priority for classification, because this variable is the most accurate among the three for the prediction of algal biomass.

A huge volume of research has been carried out on the hydrological attributes including trophic status studies of wetland ecosystems over the years (Sugunan, 2000; Bhattacharjya, 2002). Fluctuation in the density of macrophytes may exert significant impact on fish diversity and resource abundance. In India, so far very few studies have been initiated to assess the ichthyofaunal diversity in relation to macrophyte infestation, environmental gradients (Shahnawaz *et al.,* 2010).

The floodplain wetlands are confronting enormous anthropogenic pressure and degrading day by day. The common problems of any open water body are influx of sediments load from catchment area, discharge of untreated and partially treated industrial sewage and entry of agricultural waste, industrial solid waste, improper management of storm water, overexploitation of lake for varied activities like recreation, fishing, land reclamation and encroachment, urbanization etc. are causing water scarcity and shrinkage and shoreline changes. This change in shoreline due to erosion has impacted hydrology, biodiversity, rendering deteriorating water quality.

Therefore it is utmost important to study and assess the present Ichthyofaunal diversity, productivity and status of the wetland for the future sustenance of this valuable ecosystem. In view of this the following objective has been chosen for the present study:

1. To assess the Ichthyofaunal diversity and productivity in relation to macrophyte infestation in selected beels of Kamrup district, Assam
2. To assess the Trophic State Index in relation to macrophyte infestation in selected beels of Kamrup district, Assam

2. REVIEW OF LITERATURE

2.1. Wetlands

The earth surface of the world is covered by 71 % of water and out of the total amount of water, 97.5% is salt water that makes up oceans and only 2.5% is fresh water. Most of the fresh water (68.7%) is stored in glaciers and the polar icecaps. The most accessible water resources available for human consumption and the ecosystems are contained in lakes and rivers, which correspond to only 0.27% of the fresh water and close to 0.007% of the total amount of water in the world. (USGS, 2018). Marshes, swamps and bogs have been well known terms for centuries but in recent years these landscapes have been grouped under single term "Wetlands".

In India wetlands are spread over from Himalayan region to coastal areas and have been classified under different categories based on certain criteria. Based on different criteria they are categorized as topographical (Upland and Low land), formation (natural and manmade), water retention period (perennial and seasonal), ecological status (oligotrophic, mesotrophic and eutrophic), water quality (freshwater and saline water) and productivity (productive and non-productive), floristic composition (macrophyte choked and macrophyte clear), thermal regime (cold-water and warm water). These wetlands are locally known as Tal, Jheel, Maun, Chaur, Dhar, Boar, Beel, Charha and Pat in different states There is no single ecologically sound and universally acceptable definition of wetland primarily because of their diversity and for the lack of clear demarcation between dry and wet environments (Haslam, 2004).

Floodplain wetlands represent the wetlands situated along the floodplains of rivers; mostly lentic in nature and excludes the lotic component of the river such as the main river channel, the levee region and the flats.

2.2. Ichthyofaunal diversity

India is blessed with vast geographical area comprising varied topographical features possesses diverse natural resources, which offer immense opportunities for livelihood support, besides maintaining its ecological integrity and valuable gene pool. Likewise copious aquatic resources are available in different regions, which are abode for myriads of germplasm resources. India is bestowed with immense fish genetic resources in different aquatic ecosystems viz., freshwater, brackish water and marine (Anon, 2017).

India is one of the mega biodiversity countries in the world and stand ninth position in terms of freshwater mega biodiversity. The Indian fish population represents 11.72 % of species, 23.96 % of genera, 57 % of families and 80 % of the global fishes (Chaudhuri, 2004). Presently, the database contains information on a total of 3535 finfish species of which 3035 are native species, representing 46 orders, 252 families and 1,018 genera. The 500 exotic fishes are also covered and majority of them are of ornamental types. Out of the 3035 native fishes, 1016 are fresh water, 113 are brackish water and 1906 are marine species (Anon, 2017).

Much work has been done for Ichthyofaunal diversity studies and review of literature indicates that in 1822, Hamilton recorded a taxonomic account of the fishes of Gangetic system. However, a comprehensive study of Indian fishes was worked out by Francis Day (1878, 1889) for the first time. Other researcher viz. Hamilton (1822); Mukherji (1931); Shaw and Shebbeare (1937); Hora (1940); Misra (1959); Dey (1973); Sen (1985, 2006); Jayaram (1981, 1999); Menon (1999); Talwar and Jhingran (1991); Nath and Dey (1997, 2000); Dey and Kar (1989a, 1989b, 1989c, 1990); Kar and Dey (1986, 2000, 2002); Kar and Barbhuiya (2000); Sarkar and Ponniah (2000); Kar *et al.* (2002a, 2002b, 2002c, 2003, 2004); Kar (2005); Vishwanath *et al.* (2007) etc. carried out considerable studies on Ichthyofaunal diversity from different fresh water bodies of India.

Jayaram (1981) recorded 742 freshwater species belonging to 233 genera, 64 families and 16 orders from the Indian region while in 1999, listed 852 freshwater species of fishes under 272 genera, 71 families and 16 orders, including both primary and secondary freshwater fishes from India, Bangladesh, Myanmar, Nepal, Pakistan and Sri Lanka. Talwar and Jhingran (1991) listed 930 species of fresh water fish belonging to 326 genera and 99 families. Menon (1999) made a check list for 446 primary freshwater species under 33 families and 11 orders from the Indian region alone.

North-east India is enriched with diversified fish fauna and is considered as one of the global biodiversity 'hot spots' of freshwater fish in the world (Kottelat and Whitten, 1996). The Northeast India is endowed with varied type of aquatic resources in the form of rivers (19,150 Km), reservoirs (23,792 ha); floodplain wetlands (beels in Assam Pat in Manipur), lakes and swamps (143,740 ha); ponds and mini barrage (40,808 ha) and low laying paddy cum fish culture systems (2,780 ha) (Mahanta *et al.,* 2003).

From the Ichthyofaunal diversity point of view, this region of the country is very rich with 267 fresh water fish species belonging to 114 genera under 38 families and 10 orders (Mahanta *et al.,* 2003) which is 33.13% (approximately) of the total freshwater fishes of India (Sen, 2000).

In Assam, the mighty river Brahmaputra which is also called as the life line of Assam and Barak are the two major drainage systems with lots of flood-plain wetlands exhibiting variety of fish diversity supported by the subtropical climatic condition, favourable ecological and geographical condition with about 3.9 lakh hector of water area with wealthy aquatic biodiversity having the largest number of fish species (217), followed by Arunachal Pradesh (167), Meghalaya (165), Tripura (134), Manipur (121), Nagaland (68), Sikkim (52) and Mizoram (48) (Mahanta *et al.,* 2003).

Assam, the second largest state of North eastern region of India is gifted with many extensive water bodies commonly known as beels that are the only source of fish for the poor people in the surrounding villages and has rich fishery resources comprises of riverine fisheries, floodplain wetlands (known as beels), swamps, low lying paddy fields etc. covering a total area of 3.47 lakh ha.

The floodplain wetlands (beels) and lakes are major fishery resources of Assam contributing to about 25% of the fish production (Chakravartty *et al*., 2012).

The vast and varied aquatic resources support a rich variety of fishes (Bhattacharjya *et al.,* 2003).

The fresh water Ichthyofaunal diversity of Assam was reported by Dey (1973, 1981) who is one of the pioneer workers of the fishes. Ghosh and Lipton (1982) reported 172 species in Assam while Sen (1985) reported 187 species of fishes from Assam. Following these, several workers had studied the Ichthyofaunal diversity of the *beels* of Assam. Goswami (1985) recorded 57 fish species from Chandubi beel. Kar and Dey (1986) studied the fisheries of Sone beel of the Barack valley. Yadav *et al*. (1987) studied the fisheries of Dhir, Dora and Sone beels of the state.

Sinha (1994) reported 185 species belonging to 98 genera under 34 families from Assam. Agarwala (1996) studied the fish diversity and ecology of the beel in Tamranga wetland. Bhattacharjya *et al.* (2003) recorded 217 fish species from Assam and revealed 150 species as potential ornamental value. Sarma *et al.* (2004) recorded 61 ornamental fish species from Central Brahmaputra Valley Zone of Assam.

Baishya and Bordoloi (2009) recorded 72 species from the beels of Hajo while Saha (2011) reported 59 species of fishes from two beels of Goalpara district. Kalita *et al.* (2011) reported 45 species of fishes of which 10 species fall under major group, 13 species fall under intermediate group and 22 species fall under minor group from Koya Kujiya Beel in the Goalpara district of Assam. Sarma *et al.* (2012) reported 97 species from lower reaches of the Brahmaputra River, Assam.

Baruah and Sharma (2013) reported 24 ornamental fishes from Silsako wetland. Bordoloi (2014b) studied fish and fisheries of two beels (Nahotia and Potiasola) of Jorhat district, Assam and recorded 51 fish species. Bora and Biswas (2015) reported 40 species, belonging to 13 families, where, Cyprinidae was the most dominant. Barhai *et al. (*2015) reported 30 species of fishes from Hasila beel; 27 species from Urpad Beel ,26 species from Kumri Beel, 29 Species from Sidli Beel and 31 fish species from Seksekia Beel and they revealed that fishes belonging to the order Cyprinniformes have been recorded as the most abundant and

Beloniformes the least in all the Beels except Urpad Beel where Perciformes were dominating over others.

Rahman *et al.* (2016) recorded 65 fish species including 5 exotic species belonging to 43 genera under 21 families from 7 orders from Charan Beel and Manaha Beel of Morigaon District. Chhetry and Deka (2016) studied Ichthyofaunal diversity of Era Kopili Beel of Karbi Anglong District, Assam and recorded 47 number of fish species including 4 exotic fish species belonging to 33 genera under 18 families from 6 orders where Cyprinidae was the most dominant family with 17 number of species contributing about 36.17% followed by Channidae (8.51%) .

2.3. Primary Productivity

Primary productivity means the rate at which organic matter is produced by producer in an ecosystem. In this process of photosynthesis, inorganic carbon is converted into organic form. The chlorophyll bearing microscopic organisms such as phytoplankton, periphyton, and macrophytes serve as primary producer in the aquatic food chain and act like a keystone species in the ecosystem. They produce a wide range of organic compounds by the mechanism of photosynthesis along with release of oxygen and depletion of carbon dioxide in the surrounding waters, thus contributing congenial environmental condition of aquatic ecosystem.

In any water system the rate of organic carbon fixed through the chlorophyll bearing phytoplankton provides the basic information for assessing the productive function of the system (Odum, 1960).

Bhaumik *et al.* (2006) studied the Impact of plankton structure on primary productivity in two beels of West Bengal, India where one beel was open type (Suguna beel) and another was closed beel (Amda beel) and found that gross primary production, depending on the plankton structure existed during various seasons, of the investigated systems fluctuated in both the beel. Being closed and nutritionally rich, the Suguna beel was highly productive with net primary productivity in the range of 0.101 to 0.986 gmC/l/m3 /day whereas in Amda beel ranged from

0.107 to 0.506 gmC/l/m3 /day. However, the average net production in Suguna beel were found to be maximum during winter and the value ranged between 0.200 gmC/l/m3 /day and 0.566 gmC/l/m3 /day. The least productivity were recorded in monsoon when the values of which ranged from 0.107 gmC/l/m3 /day to 0.406 gmC/l/m3 /day in Amda beel. They observed that the closed beel supported by the net production values, were found to be more productive compared to the open ones and found that further, the seasonal influence on primary production in the beels was pronounced with availability of plankton. They concluded that the net production was maximum during winter in both the beel.

The workers like Croome and Tyler (1975), Khan and Zutshi (1980) have reported high primary production during higher light intensity and vice-versa. Yadav *et al*. (1987) reported moderate primary productivity with little variation in values from tropical water.

Dash *et al.* (2011) studied the Primary productivity of Kharasrota river (India) and found that the maximum GPP during summer season and minimum in rainy season at all the six stations and the annual average GPP varied from 0.075±0.009 gC.m-3.h-1 to 0.938±0.103 gC.m-3.h-1 and the NPP value varied from 0.012±0.001 gC.m-3.h-1 to 0.832±0.081 gC.m-3.h-1 and finally exhibited an increasing trend from the month of September to February respectively at all the stations.

Koli *et al.* (2011) studied primary productivity and physico-chemical parameters in Ana Sagar Lake, Ajmer from September 2007 to August 2008 and he found that GPP value ranged between 1.93 and 6.24 gC/m²/day, NPP ranged between 0.72 and 4.99 gC/m²/day and Community respiration ranged from 0.26 to 3.6 gC/m²/day. Water temperature varied from 16.4°C to 31.2°C, pH and transparency ranged between 6.7 and 10.2 and 34 cm and 65 cm respectively. The Variation in dissolved oxygen (DO) was from 6.7 to 10.7 mg/l. Further they stated that primary productivity and physico-chemical values of the lake were found high, mainly due to sewage discharged, industrial effluents and the agricultural runoff by surrounding city population. High values of productivity and nutrients also exposed its eutrophic condition.

The productivity in relation to temperature and transparency in the euphotic zone of selected tropical freshwater floodplain wetlands of west Bengal were studied by Ziauddin *et al.* (2013) and they found the GPP was max (0.81 ± 0.03 gCm-2d-1) in pre-monsoon and minimum (0.25 ± 0.01 gCm-2d-1) in winter in Saguna beel. The gross primary production was max (0.94 ± 0.03 gCm-2d-1) in Monsoon and minimum (0.31 ± 0.01 gCm-2d-1) during winter in Kole beel. In contrast, the net primary production was maximum (0.56 ± 0.05 gCm-2d-1) in Pre-monsoon and minimum (0.13 ± 0.01 gCm-2d-1) in winter in Saguna beel, the net primary production was max (0.56 ± 0.05 gCm-2d-1) during monsoon and minimum (0.13 ± 0.01 gCm- 2d-1) during winter in Kole beel.

Barupal & Gehlot (2014) carried out a study to assess of primary productivity of phytoplanktons of kolayat lake, bikaner (rajasthan) and they found that the gross and net primary productivity of phytoplankton population were observed to be maximum during winter season and minimum during monsoon period.

Rajbongshi *et al.* (2016) carried out an investigation to study the primary productivity in terms of NPP and GPP along with CRV of water at dharapur area near to the channel khonajan of Deepor beel (wetland) with reference to physicochemical parameters. The high rainfall observed in March following a dry season in winter has elevated total alkalinity to 124 mg.l-1 and total hardness to 215 mg.l-1 along with organic matter. The rainfall creates dilution of water thus decreasing the phytoplankton density. They observed that the value of GPP and NPP are observed to decrease from February to March and in other months, the gross primary productivity (GPP) of the experimental site is found to be higher than those of other lentic waters in India.

Sarma (2016) conducted a comparative study of primary productivity estimation in the selected wetlands (Duani, Bomani and Jalikhora) of Dimoria tribal-belt in Kamrup district, Assam, India, where maximum gross primary production and net primary production were recorded during March and minimum during July. Further author concluded that the primary productivity of an aquatic ecosystem is governed by many factors like rainfall, water temperature, turbidity, phytoplankton diversity etc.

Deka (2017) assessed the primary productivity of two freshwater aquaculture ponds at Guwahati with reference to physicochemical parameters and found that, both the ponds possess comparatively high density of plankton in monsoon season with a luxuriant growth of *Microcystis aeruginosa* during late monsoon to early autumn. Study also revealed that the GPP and NPP of the studied ponds indicates bimodal pattern of increase, showing lower value in rainy monsoon season and higher during pre-monsoon summer months.

2.4. Trophic Status index

Carlson had developed trophic state index based on the productivity of the water body and is the classical and most commonly used method for characterizing a lake's trophic state or its overall health. This method generally uses Secchi Disc transparency, chlorophyll-a, and phosphorus measurements. The range of the index is from 0 to 100 and has an advantage over the use of raw variables. Trophic state can be defined as the total weight of the biomass in a water body at a specific location and time.

Trophic state is the biological response for nutrient additions to the water bodies (Nauuman, 1929).But these nutrient effects may be modified by parameters such as seasonal variations, grazing of phytoplankton by zooplankton and mixing depth of the water Carlson (1977).

Raghavendra and Hosmani, (2002) studied the trophic status at Mandakally lake observed that lake to be eutrophic due to impressive growth of phytoplankton. Garg *et al*. (2006) carried out study in Harsi reservoir and found that lake to be oligo-trophic in nature as there was no discharge of sewage and agricultural waste in to the reservoir and there are no agricultural practices in the vicinity of the reservoir.

Garg *et al*. (2006) found the Ramsagar reservoir to fall under the category of meso-trophic. Elmaci *et al. (*2009) carried out study on the trophic status of lake Uluabat, Turkey and they found that, phosphorus were the primary limiting nutrient in lake. They catezgorzed the lake under eutrophic state based on Carlson's trophic state index values.

Sharma *et al. (*2010) assessed the trophic State of Mansi Ganga Lake in India and their results indicated that the lake was under oligotrophic condition during 2006 which has become mesotrophic in the year 2008 showing increasing trend of pollution. The lake water was drained and sampling done in 2009 (pre-monsoon) indicated it to be eutrophic after the chemical treatment for the removal of algae. Ahangar *et al*. (2012) carried out study in Anchar lake and placed the lake under category of eutrophic due to drainage of sewage and agricultural load in the lake but Sexena & Saksena (2012) put it under meso-eutrophic category assuming large amount of agriculture practices in the vicinity and its subsequent drainage in to the basin therefore supporting rich plankton diversity.

Eutrophication is becoming one of the major problems in the floodplain wetlands (Manojlovic *et al.,* 2007; Choi *et al.,* 2008). This process can be assessed by determining the limiting nutrients such as phosphorus and by calculating trophic state indices. Phosphorus overloading is the most important cause of eutrophication of lake (Jin *et al.,* 2005).

Work done by Devi Prasad (2012) on Carlson's trophic state index for the assessment of trophic status of two Lakes in Mandya district Karnataka, India and their studies and found that the main parameter in deciding the trophic status of an aquatic water body is its phosphorus concentration and they mentioned that alteration of trophic status is mainly due the change in phosphorus concentration in any fresh water ecosystem. They have also suggested that periodic removal of algal biomass and macrophytes may be helpful for minimizing the pollution and conservation of those still water ecosystems.

Singh and Sharma, (2012) carried out a study on the Renuka lake and reported the lake to decrease from hyper eutrophic to eutrophic level during the study period. Niraula, (2012) studied the limonogical status of Beeshazar lake, a Ramsar site in Nepal and found the lake in eutrophic state based on nitrogen and transparency; hyper-eutrophic based on the phosphorous concentration.

Najeeb, *et al.* (2014) carried out the study on the evaluation of trophic status of Bhoj wetland on the basis of some chemical characteristics and they mentioned that the chemical characteristics of an aquatic ecosystem play key role in defining its trophic status. Their studies revealed that Bhoj wetland in Bhopal is under trophic evolution as it receives large quantities of agricultural and human wastes from its catchment, resulting in significant change in its environment. High phosphorus value ($\overline{x}$=0.31 mg l-1) puts Bhoj wetland into the eutrophic category. Over all study revealed that Bhoj wetland under eutrophic state.

Patidar (2014) assessed the nutrient concentration and trophic status of Brahma Sarover at Kurukshetra, India and catogorized the lake under mesotrophic and eutrophic state of the water body due the presence of high concentration of nutrients and Chlorophyll a.

3. MATERIALS AND METHODS

3.1. Study area

The study area, Gorjan Bulatjan beel Part-2 which also include Chatla and adjacent Urmal beel are situated under, Hajo Revenew circle (26˚50´ N and 91◦32´ E), Kamrup district, Assam. The Gorjan Bulatjan beel Part-2 is formed due to meandering activity of Puthimari River, a north bank tributary of river Brahmaputra. Gorjan Bulatjan beel Part-2 (Chatla and Urmal) lies between 26˚50´ N and 91◦32´ E. The total area of the Gorjan Bulatjan beel Part-2 is approximately 200 hectare. The shape of both the beel is rectangular and has a small connection during monsoon with river Puthimari. Most of the time both the beel exist as closed beel but there is a small connection exists in Chatla beel with Puthimari River. The approximate water spread area of Chatla and Urmal beel are 26ha & 33ha respectively. The approximate length and width of the Chatla and Urmal beel are 800m & 570 m and 1km & 750 m respectively. Average depth of Beel is around 0.94m and 1.02m for Chatla and for Urmal beel respectively. There is a sluice gate in the south near Suren Das College Hajo which is opened during monsoon to allow the riverine water to enter and influx the beel along with fish fauna. Both the beel are being heavily infested with water hyacinth followed by submerged macrophytes round the year. The macrophyte (water hyacinth) covers almost 80% of the total surface area of both the wetland. Out of total fish production, 70% of fish produced in beel is contributed by stocked fishes and rest 30% of the production is by un-stocked wild fishes, which enter from parent River to beels during inundations in monsoon.

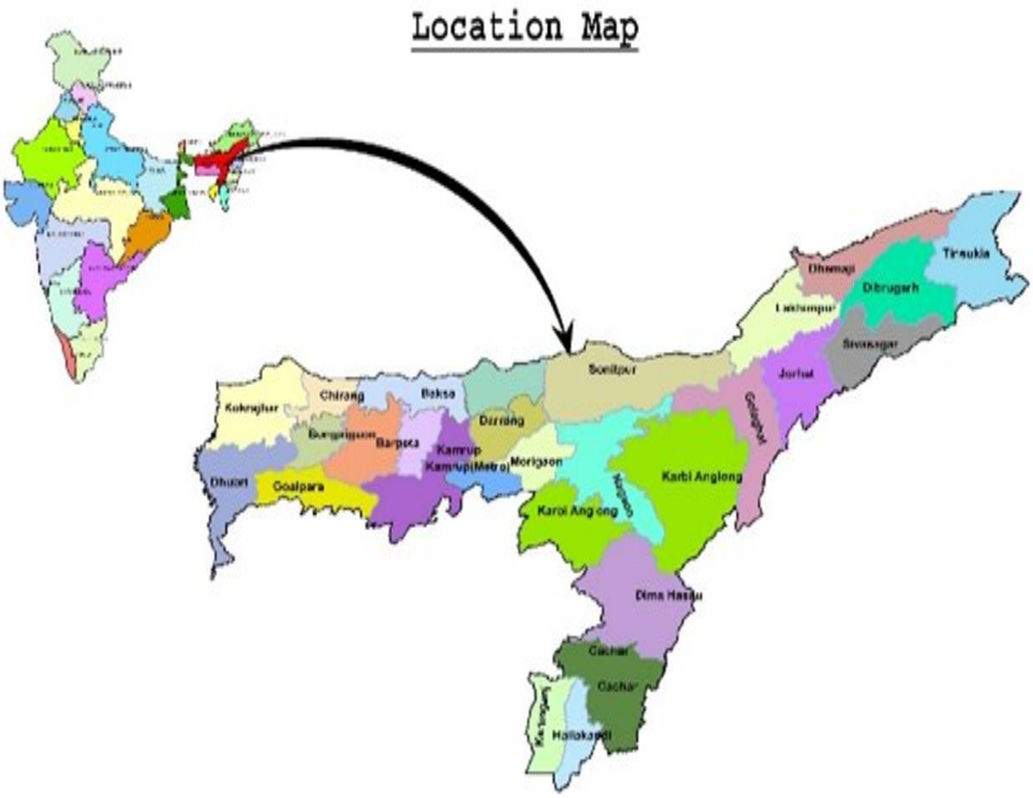


Figure 1: Map of Location of the study area (Assam, India)

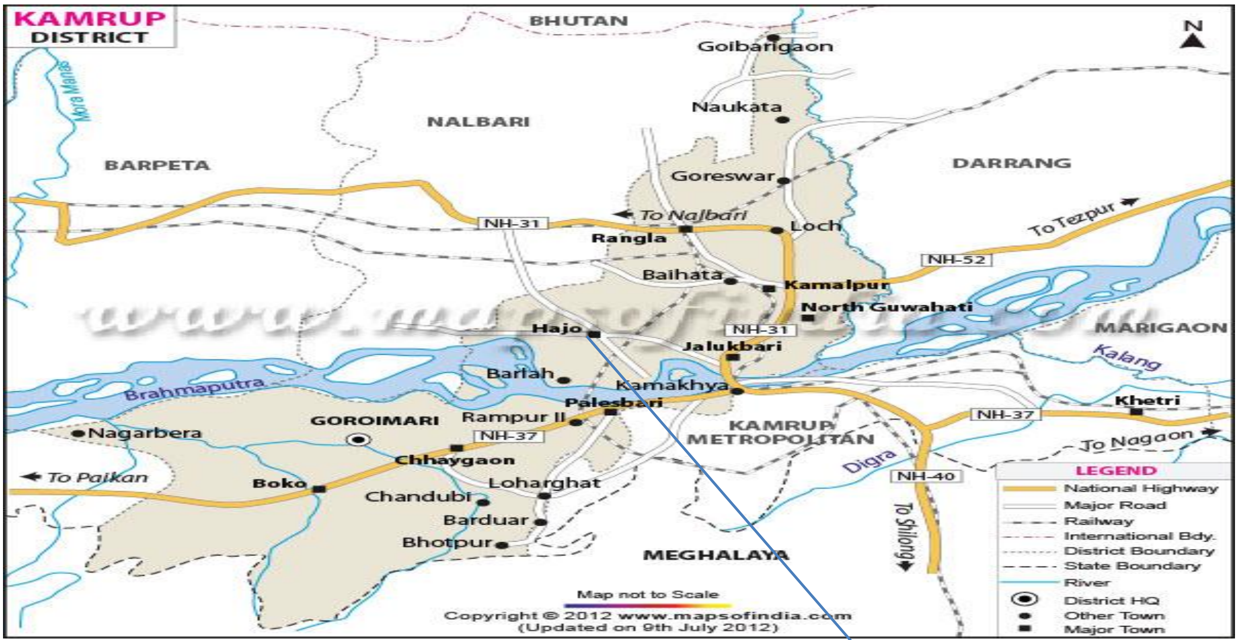


Figure 2. Map of Location of the study area (Kamrup district, Assam)

Hajo Revenue circle where both the beels are located

Figure 3 . Goggle map showing location of study site in Hajo, Kamrup

Figure 4 . Satellite view of Chatla beel

Figure 5. Satellite view of Urmal beel

3.2. Sampling procedure

The sampling was carried out from October, 2017 to June, 2018 from Chatla beel and Urmal beel, Kamrup district, Assam. Both the beels are located within the agro-climatic sub region of the lower Brahmaputra valley of Assam. Location of the study sites and the methods followed for the study are briefly described below. Sampling was planned to collect data in pre monsoon (March-April), Monsoon (May–June), post monsoon (October-November) and winter (December-January) months. Sampling was done on monthly basis.

3.3. Ichthyofaunal diversity

Three stations were selected from both the beel based on depth, occurrence of FAD (Fish aggregating device) to obtain a representative of all species and species aggregation towards selecting a particular type of station keeping a minimum distance of about 200 m between the stations. The entire area of each beel was divided in to three stations and sampling was carried out across three stations.

3.3.1Sampling stations in Chatla Beel

3.3.1.a: Station-1

The station-1, (26˚16´28´´N; 91˚31´47´´E) lies adjacent to household (Plate 1- Station 1), is a very shallow water area. Marginal weeds have grown along the inshore zone. Anchoring of boats is most common in this area.

3.3.1. b: Station -2

The Station-2 (26˚16´24´´N; 91˚31´41´´E) selected was located near a Fish aggregating device made up of branches of trees, bamboo splits which are set for a minimum period of 3-4 months to facilitate the growth of periphyton. Surface area of FAD is covered by dense water hyacinth(Plate 1- Station 2).

Station-1, 26˚16′28′′N;   91˚31′47′′E

Station-2, 26˚16′24′′N;   91˚31′41′′E

Station-3, 26˚16′35′′N;   91˚30′49′′E

Plate 1. Selected station for experimental fishing in Chatla beel

3.3.1. c: Station-3

The Station-3, (26˚16´35´´N; 91˚30´49´´E) located adjacent to periphery of the beel. This area is comparatively shallower and reasonably turbid and having less occurrence of floating macrophytes. The bank of this area is used for paddy cultivation (Plate 1- Station 3).

3.3.2 Sampling stations in Urmal Beel

3.3.2.a: Station-1

The station-1, (26˚16´35´´N; 90˚30´49´´E) lies adjacent to household (Plate 2- Station 1) is a very shallow water area. Marginal weeds have grown along the inshore zone. Anchoring of boat is common in this area.

3.3.2.b: Station -2

The station-2 (26˚17´0´´N; 91˚31´42´´E) was located on middle side of a Fish Aggregating Device (Plate 2- Station 2), made up of branches of trees, bamboo splits which are set for a minimum period of 3-4 months to facilitate the growth of periphyton. Surface area of FAD is covered by dense water hyacinth.

3.3.2.c: Station-3

The station-3, (26˚17´0´´N; 91˚31´43´´E) was located adjacent to shallow periphery of the beel having dense emergent macrophytes such as lotus (Plate 2- Station3). The bank of this area is used for paddy cultivation.

Station-1, 26°16´35´´N; 90°30´49´´E

Station-2, 26°17´0´´N; 91°31´42´´E

Station-3, 26°17´0´´N; 91°31´43´´E

Plate 2 .Selected station for experimental fishing in Urmal beel

3.4. Sampling of fish Fauna

Experimental fishing was carried out with the help of locally available fishing gear operated by local fishermen. A set of four gill nets having different mesh size of 25mm, 30mm, 35mm and 40mm of 10m length and 1m breadth. The gill net was set at night,hauled in the morning after a soaking period of 10-12 hours. Wooden plank built Canoe (Dinghi) was used during sampling. The average CPUE (Catch per unit effort) for gill net in all habitats was found to be 2-4 kg/day. CPUE was observed to be comparatively less in deeper waters in comparison to shallower waters. Cast net operated in shallow area to collect bottom dwelling fishes. Visual observation was made during Drag net operation for capturing fish. Fish fauna associated with macrophytes were collected by operating a hand held triangular scoop net of fine mesh. Apart from experimental fishing, fishes were also collected from landing centres twice in a month. Collected specimens were cleaned and photographed immediately at the site. Some of the unidentified specimens were preserved in 5-10 % Formalin solution for identification in lab. For identification and classification of various fish species, Talwar & Jhingran, 1991; Jayaram, 1999; Vishwanath, 2002 were referred.

3.5. Study of diversity index:

1. Species richness (Margalef's) (d):

It is the second major component of species diversity. It is a simple ratio between total species "S" and total number N (importance value). It is evaluated by a variety index (d) derived from Odum *et al.* (1960).

$$d = S-1/ \log N$$

2. Species Evenness (J):

It is the major component of species diversity, which shows the distribution (apportionment) of individuals among the species. H max is the maximum diversity, which would occur if the individuals where evenly distributed among the species. It is calculated as follows Pielou (1966)

$$H\ max = \log S$$

Where S = species present, the eveness in the distribution of the individuals between the species may be calculated by an equitability index (Sheldon, 1969)

$$J = H/H\ max$$

3. Species diversity (H):

Ratio between the number of species and importance value (number, biomass, productivity etc.) of individuals is called species diversity. It is computed according to Shannon and Weaver's index

$$H = \Sigma n / N \log n/N$$

Where N = Total number of individuals, S = Species number,N = Number of individuals in i species. The information content or diversity (H) is expressed as num er of bits / individual

4. Simpson index (ƛ'(1-D)) –

The index was calculated using the following formula

$$\lambda' = \sum_{i=1}^{s} \frac{ni(ni-1)}{n(n-1)}$$

where, ni is the total number of individuals in the i th species and n is the total number of individuals in the sample.

3.6. Collection of water samples for hydro-biological studies

Eleven(11) environmental variables (temperature, total dissolved solids, pH, dissolved oxygen, free CO_2, alkalinity, conductivity, transparency, chlorophyll a, total chlorophyll, total phosphorous) were taken into consideration for predicting fish diversity and out of these, three variables (transparency, chlorophyll a, total phosphorous) were taken into account for determining trophic state of both the wetland and primary productivity were determined through oxygen consumption method (Light and Dark bottle Method).Water samples were collected in the morning and brought to lab for further analysis following protocol of APHA.

3.6.1. Temperature

The temperature of the surface water was measured with a mercury thermometer, graduated at 0.1˚C intervals. The values are expressed in ˚C.

3.6.2. Alkalinity

The total alkalinity of water samples was estimated titriametrically by using phenolphthalein and methyl orange indicators as described by standard methods (APHA, 2005).

Calculation:

Total Alkalinity: No. of ml of N/50 H_2SO_4 consumed x 1000mg/ ml of sample

3.6.3. Dissolved oxygen

The dissolved oxygen content of the water was determined by Winkler' titrimetric method (APHA, 1998).

3.6.4. Free CO_2

The free Carbon dioxide content was determined by titrating 100 ml sample against 0.05 N NaOH. The values are expressed in mg/l

Calculation:

Dissolved Free CO_2= No. of ml of N/44 NaOH required x 1000 x 44/50 x 40 ppm

3.6.5. pH

The pH of water was measured in the field using a portable digital pH meter (Hanna).

3.6.6. Water Depth

Transparency of water related to depth of light penetration and strength of primary productivity. The water transparency was measured by using Secchi disc of 20 cm diameter and has been studied through visual observation by immersing the round disc in water until it just disappeared and reappeared and calculated the mean value by following calculation.

Calculation:

Light penetration:

Reading at Secchi disc disappears (in cm) + Reading at Secchi disc reappears/2

3.6.7. Conductivity

The total ionized substance in the water samples was estimated using a conductivity meter. The values are expressed in μ Siemens/cm.

3.6.8. Total Dissolved Solids:

The term solids refer to matters suspended or dissolved in water or waste water. Water with high dissolved solids generally is of inferior quality and may induce an unfavourable physiological reaction.

Calculation:

$$\text{Total dissolved solids} = \frac{\text{mg residue} \times 1000}{\text{ml of sample}} \text{ mg/l}$$

3.6.9. Total chlorophyll

Chlorophyll is a common indicator of phytoplankton biomass. All green plants contain chlorophyll a and for, planktonic algae, it constitutes about 1-2 % of the dry weight.

3.6.10. Chlorophyll a

Trichromatic method:

The water sample was filtered through 0.45 micron nylon filter paper (Millipore) by forcibly pushing with syringe. The sample was mixed in 90% acetone at the ratio of 90 parts Acetone: 10 parts water sample (v/v) formula and kept in fridge at 4^0C for 24 hours for extraction of pigment, chlorophyll a. Optical Density (OD) readings at 630nm, 647 nm and 664 nm were taken to measure the absorption using spectrophotometer.

Calculation:

$Ca=11.85(OD\ 664)-1.54(OD\ 647)-0.08(OD\ 630)$

Where,

Ca = concentration of chlorophyll a in mg/L

OD 664, OD 647, OD 630 =Corrected optical densities (with a 1-cm light path) at respective wavelength.

After determining the concentration of pigment in the extract, calculate the amount of pigment per unit volume as follows,

Chlorophyll a, mg/m^3= Ca x extract volume, L/Volume of sample, m_3

3.6.11. Total Phosphorus

Ascorbic acid (F) method with Optical density 880 mm was used to measure the absorption. For estimation of Total phosphorus .

3.7 Primary Productivity study

The oxygen method was followed for measuring primary production by exposing the sample of phytoplanktons in light and dark bottles (Gardner and Grann, 1927). Bottles were painted black besides wrapping them with black tape. All the samples were suspended at 0.5 metre depth for incubation period of 4-5 hrs. Changes in oxygen concentration were estimated by the Winkler's method (APHA, 1998). All oxygen values were converted to carbon by multiplying them with a factor 0.375 .The productivity values were expressed as g C/m3/hr. While another light and dark bottles were suspended vertically under water for a specific period of time that is three hours. After the incubation period the bottles were taken out and fixed the Dissolved oxygen concentration immediately by Winklers Volumetric method for further analysis.

Calculations for Primary productivity:

The Primary productivity is expressed in terms of Gross primary productivity, Net Primary productivity and Community Respiration

Di= Initial DO in mg/L

Dl= Light Bottle DO in mg/L

Dd= Dark Bottle DO in mg/L

t = Incubation period (hr)

a. GPP = Dl – Dd x 0.375 mgC/m3/hr

PQ x t

b. NPP = Dl – Di x 0.375 mgC/m3/hr

PQ x t

c. CRR = Di – Dd x 0.375mgC/m3/hr

PQ x t

Oxygen values (mg C-l was converted to carbon value by applying the equation suggested by Thomas *et al.,* 1980.

Primary production (mgC) = (O2mgL-1x 0.375) /PQ

Where PQ= 1.25

PQ represents respiratory gradient = respiration /photosynthesis and a comprised value of 1.25 was used. This represents metabolism of sugar, fat and proteins. The value 0.375 represents a constant to convert oxygen value to carbon value.

3.8. Trophic Status

Nutrient level of any water body is directly related to their trophic status. Lake or wetlands and such other water body can be classified as Oligotrophic, Mesotrophic and Eutrophic based trophic status index value. The index values ranging from 0 to 100 and can be used for classification of trophic state of the lakes (Carlson, 1977). To determine the trophic state of the lake Carlson's trophic state index (Carlson *et al*.,1977),which uses multi-parameter indices was computed from the three interrelated water quality parameters: Secchi disk depth (SDD), chlorophyll-a concentration (Chl-a), and total phosphorous (TP) concentration.The following formulas were used, ignoring the negative results. TSI was also calculated based on single parameter (i.e. TSI for TP, TSI for Chl. A and TSI for SD transparency), and based on combined parameter taking in to account all the three parameter. Both seasons wise and overall TSI during the study period was analysed

$$TSI(SD)=10\left(6-\frac{\ln SD}{\ln 2}\right)$$

$$TSI(Chl.a)=10\left(6-\frac{2.04-0.68\ln Chl.a}{\ln 2}\right)$$

$$TSI(TP)=10\left(6-\frac{\ln 48/TP}{\ln 2}\right)$$

3.9. Statistical tools

The software package such as Primer 6, PAST 2.17c were used for diversity index studies & for statistical analysis SPSS 16.0, and Microsoft Office Excel 2010 were used. The data on selected physico-chemical parameters of water was subjected to one-way analysis of variance (ANOVA).

4. RESULTS

4.1. Ichthyofaunal diversity.

4.1. 1. Ichthyofaunal diversity in Chatla Beel

A total of 54 species of fishes have been recorded from Chatla beel (seasonally open) belonging to 38 genera, 21 families and 8 orders (Table-1). The Order Cypriniformes was found to be most dominant group with 24 species which contributed 44.4 % to the total fish species in Chatla beel. This is followed by the Order Perciformes with 16 species (29.63%), Siluriformes with six species (11.11 %), Synbranchiformes with three species (5.56 %), Osteoglossiformes with two species (3.70%), Beloniformes, Cyprinodontiformes and Tetraodontiformes with single species (2.04 %) each. The number and percentage composition of families, genera and species under different orders are shown in Table 2 and Figure 6.

The family Cyprinidae was found as most dominant group in terms of genera as well as number of species. This family of fishes in Chatla Lake was represented by 21 fish species viz. *Amblypharyngodon mola, Gibelion catla, Labeo rohita, Hypophthalmichthys molitrix, Ctenopharyngodon idella, Cyprinus carpio, Cirrhinus mrigala, C. reba, Devario devario, Esomus dandricus, Labeo bata, L. gonius, L. calbasu, Systomus sarana, Rasbora rasbora, Rasbora daniconius, Pethia sophore, Pethia ticto, Pethia phutunio Pethia conchonius Salmostoma bacaila.* These fishes belong to 14 different genera, holding 38.89% of the total fish species recorded during the study period. The second dominant families are Channidae and Ambassidae with 4 species each, holding 7.41% share. The species *Channa marulius, Channa punctata, Channa gachua* and *Channa striata* represented the family Channidae and species such as *Parambassis ranga, Parambassis lala , Parambassis baculis ,Chanda nama* belong to family Ambassidae. This was followed by Osphronemidae and Mastacembelidae with 3 species each. Mastacembelidae was represented by *Mastacembelus armatus, Macrognathus pancalus and Macrognathus aral* and the family Osphronemidae includes *Trichogaster fasciata, Trichogaster lalius and Trichogaster chuna*, contributed 5.56% share. The next dominancy have been shown by Bagridae (*Mystus carcio and Mystas cavasius*), Siluridae (*Ompok pabda and Wallago attu*) and Notopteridae (*Notopterus notopterus* *and Chitala chitala*) with 2 species each which contributed 3.7 % and the remaining families such as Nemachilidae (*Acanthocobitis botia*), Aplocheilidae (*Aplocheilus panchax*),Heteropneustidae (*Heteropneustes fossilis*), Cobitidae (*Lepidocephalichthys guntea*), Badidae (*Badis badis*) Clariidae (*Clarias magur*), Belonidae (*Xenentodon cancila*), Synbranchidae (*Monopterus cuchia*), Nandidae (*Nandus nandus*), Anabantidae (*Anabas testudineus*) GobiIdae (*Glossogobius giuris*) and Tetraodontidae (*Tetraodon cutcutia*) were represented by single species each and contributed 1.85 % with each one species to the total fish species. The number and percentage composition of genera and species under different Families are shown in Table 3 and Figure 7


Labio rohita


C. idella


L. calbasu


G. catla


L. bata


L. gonius


C. mrigala


C. carpio


C. reba


S. bacalia


P. sophore


P. conchonius


P. ticto


H. molitrix


D. devario


R. daniconius


R. rasbora


S. sarana


A. mola

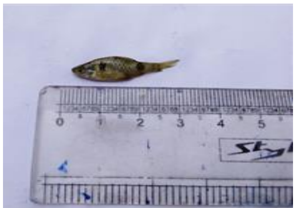

P. phutunio

Plate 3: Species belong to Order Cypriniformes

Plate 4. Species belong to Order Perciformes

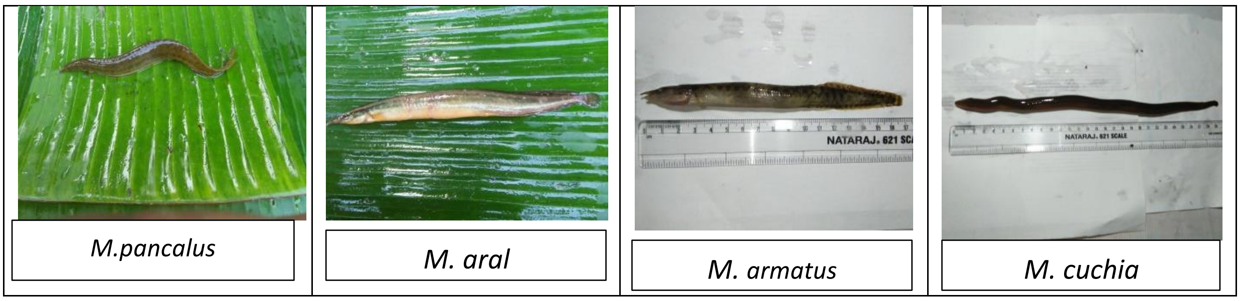
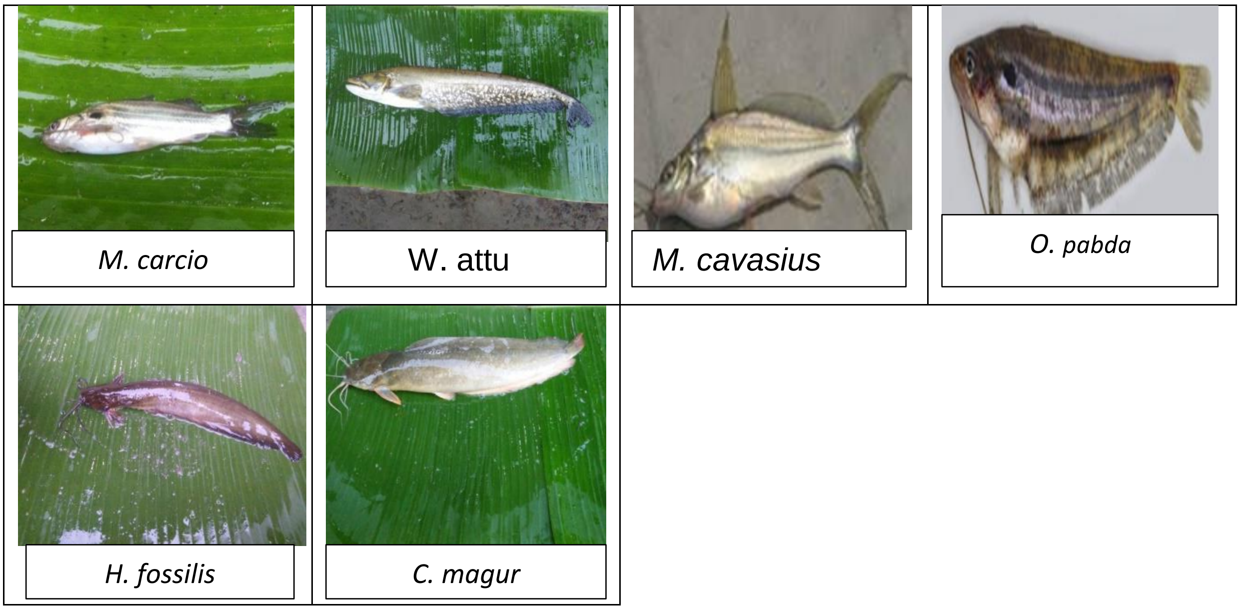


Plate 5. Species belong to Order Synbranchiformes



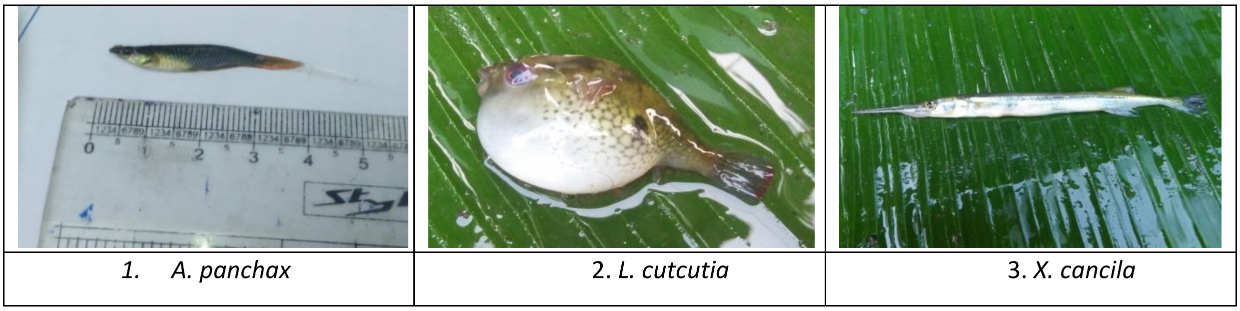
M. carcio | W. attu | *M. cavasius* | *O. pabda*

H. fossilis | *C. magur*

Plate 6. Species belong to Order Siluriformes

N. notopterus | *C. chitala*

Plate 7. Species belong to Order Osteoglossiformes



1. *A. panchax* | 2. *L. cutcutia* | 3. *X. cancila*

Plate 8. Species belong to Order 1.Cyprinodontiformes ,2.Tetraodontiformes, 3. Beloniformes

Table-1: List of Recorded Ichthyofaunal diversity from Chatla and Urmal

SL. No	Order	Family	Scientific name	Local Name	Chatla Beel	Urmal Beel
1	Cypriniformes	Cyprinidae	*Labeo rohita (*Ham.-Buch.)	Rou	√	√
2			*Labeo bata (*Ham.-Buch.)	Bhangone	√	√
3			*Labeo gonius (*Ham.-Buch.)	Kurhi	√	√
4			*Labeo calbasu (*Hamilton*)*	Bahu	√	√
5			*Gibelion catla (*Ham.-Buch.)	Bhokua	√	√
6			*Cirrhinus mrigala (*Ham.-Buch.)	Mirika	√	√
7			*Cirrhinus reba (*Ham.-Buch.*)*	Lachim	√	√
8			*Cyprinus carpio (*Linnaeus*)*	Common carp	√	√
9			*Hypophthalmichthys molitrix (*Valenciennes*)*	Silver Carp	√	√
10			*Ctenopharyngodon idella (*Valenciennes*)*	Grass Carp	√	√
11			*Amblypharyngodon mola* (Ham-Buch*)*	Moa	√	√
12			*Esomus dandricus (*Hamilton*)*	Dorikona	√	√
13			*Rasbora deniconius (*Hamilton *)*	Dorikona	√	√
14			*Rasbora rasbora (*Hamilton*)*	Dorikona	√	√
15			*Pethia ticto (*Hamilton*)*	Kani puthi	√	√
16			*Pethia conchonius (*Hamilton*)*	Haariputhi	√	√
17			*Pethia sophore (*Hamilton*)*	Bar Puthi	√	√
18			*Pethia phutunio (*Hamilton*)*	Vado puthi	√	√
19			*Systomus sarana (*Ham.-Buch.*)*	puthi	√	√
20			*Devario devario (*Hamilton*)*	Laoputhi	√	×
21			*Salmostoma bacaila (*Hamilton*)*	Selkona	√	√
22		Cobitidae	*Lepidocephalichthys guntea*	Batia	√	√

			(Ham- Buch)			
23		Nemachilidae	*Acanthocobitis botia* (Hamilton)	Gethu	√	√
24	Cyprinodontiformes	Aplocheilidae	*Aplocheilus panchax* (Hamilton)	uporchokua	√	√
25	Perciformes	Channidae	*Channa striata* (Bloch)	Sol	√	√
26			*Channa marulius* (Hamilton)	Sal	√	√
27			*Channa gachua* (Ham.-Buch.)	Cheng	√	√
28			*Channa punctatus* (Bloch)	Goroi	√	√
29		Ambassidae	*Parambassis ranga* (Hamilton)	Chanda	√	√
30			*Parambassis lala* (Hamilton)	Chanda	√	√
31			*Parambassis baculis* (Hamilton)	chanda	√	√
32			*Chanda nama* (Ham.-Buch.)	Chanda	√	√
33		Anabantidae	*Anabas testudineus* (Bloch)	Kawoi	√	√
34		Nandidae	*Nandus nandus* (Hamilton)	Gadgedi	√	√
35		Gobiidae	*Glossogobius giuris*(Ham.-Buch.)	Patimutura	√	√
36		Badidae	*Badis badis* (Hamilton)		√	√
37		Osphronemidae	*Trichogaster fasciata* (Schneider)	Kholihona	√	√
38			*Trichogaster lalius* (Ham.-Buch.)	Kholihona	√	√
39			*Trichogaster chuna* (Ham.-Buch.)	Vesseli	√	√
40		Cichlidae	*Oreochromis mossambicus* (Peters)	Japanese Kawo	√	√
41	Siluriformes	Bagridae	*Mystus carcio* (Hamilton)	Singora	√	√
42			*Mystus cavasius* (Hamilton)	Singora	√	×
43		Siluridae	*Wallago attu* (Schneider)	Barali	√	√
44			*Ompok pabda* (Hamilton)	Pavo	√	√
45		Clariidae	*Clarias magur* (Linnaeus)	Magur	√	√
46		Heteropneustidae	*Heteropneustes fossilis*	Singhi	√	√

			(Bloch)			
47	Synbranchiformes	Synbranchidae	*Monopterus cuchia* (Ham.-Buch.)	Kuchia	√	√
48		Mastacembelidae	*Macrognathus aral* (Bloch & Schneider)	Laobami	√	√
49			*Macrognathus pancalus* (Hamilton)	tura	√	√
50			*Mastacembelus-armatus*(Lacepède)	bami	√	√
51	Osteoglossiformes	Notopteridae	*Notopterus notopterus* (Ham.-Buch.)	Kandhuli	√	√
52			*Chitala chitala* (Hamilton)	Chitol	√	√
53	Tetraodontiformes	Tetraodontidae	*Leiodon cutcutia*(Hamilton)	Gongatop	√	√
54	Beloniformes	Belonidae	*Xenentodon cancila* (Hamilton)	Kokila	√	√

Table 2: Number and percentage composition of families, genera and species of fishes under various orders present in Chatla beel

Sl. No.	Order	Families	Genera	Species	% of families	% of genera	% of species
1	Beloniformes	1	1	1	4.76	2.63	1.85
2	Cypriniformes	3	16	24	14.26	42.11	44.44
3	Cyprinodontiformes	1	1	1	4.76	2.63	1.85
4	Osteoglossiformes	1	2	2	4.76	5.26	3.70
5	Perciformes	8	9	16	38.10	23.68	29.63
6	Siluriformes	4	5	6	19.05	13.15	11.11
7	Synbranchiformes	2	3	3	9.52	7.89	5.56
8	Tetraodontiformes	1	1	1	4.76	2.63	1.85
	Total	21	38	54			

Table 3: Number and percentage composition of genera and species under various families in Chatla beel

Sl. No.	Families	Genera	% of genera	Species	% of species
1	Cyprinidae	14	36.84	21	38.89
2	Cobitidae	1	2.62	1	1.85
3	Nemachilidae	1	2.62	1	1.85
4	Aplocheilidae	1	2.62	1	1.85
5	Channidae	1	2.62	4	7.41
6	Ambassidae	2	5.26	4	7.41
7	Anabantidae	1	2.62	1	1.85
8	Nandidae	1	2.62	1	1.85
9	Gobiidae	1	2.62	1	1.85
10	Badidae	1	2.62	1	1.85
11	Osphronemida	1	2.62	3	5.56
12	Cichlidae	1	2.62	1	1.85
13	Bagridae	1	2.62	2	3.70
14	Siluridae	2	5.26	2	3.70
15	Clariidae	1	2.62	1	1.85
16	Heteropneustida	1	2.62	1	1.85
17	Synbranchidae	1	2.62	1	1.85
18	Mastacembelida	2	5.26	3	5.56
19	Notopteridae	2	5.26	2	3.70
20	Tetraodontidae	1	2.62	1	1.85
21	Belonidae	1	2.62	1	1.85
Total		38		54	

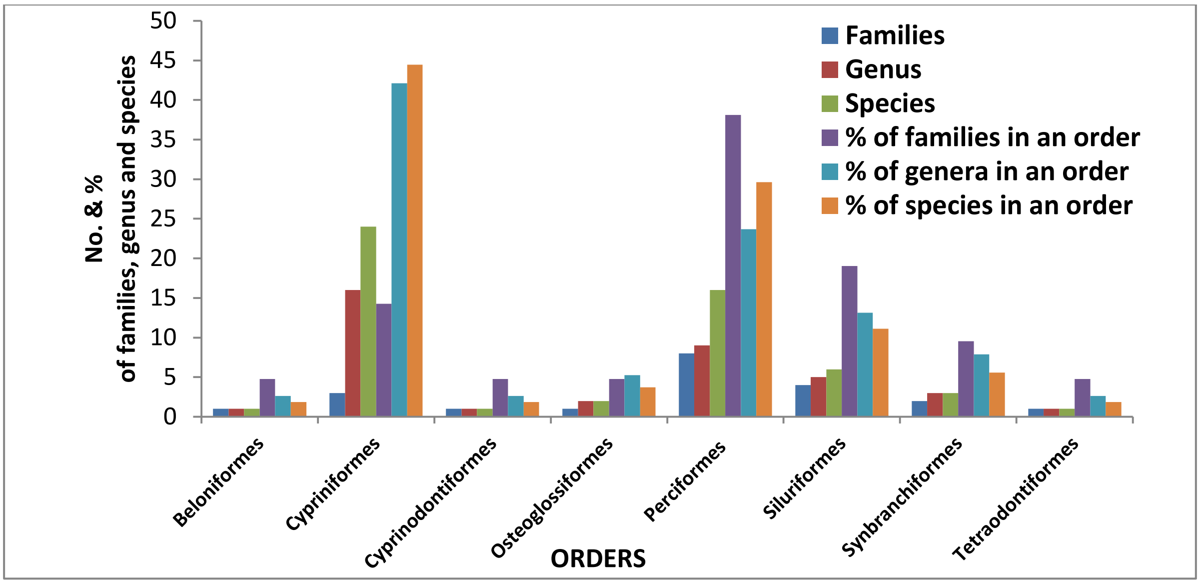


Figure 6. Number and percentage composition of families, genera and species of fishes belonging to various orders in Chatla beel

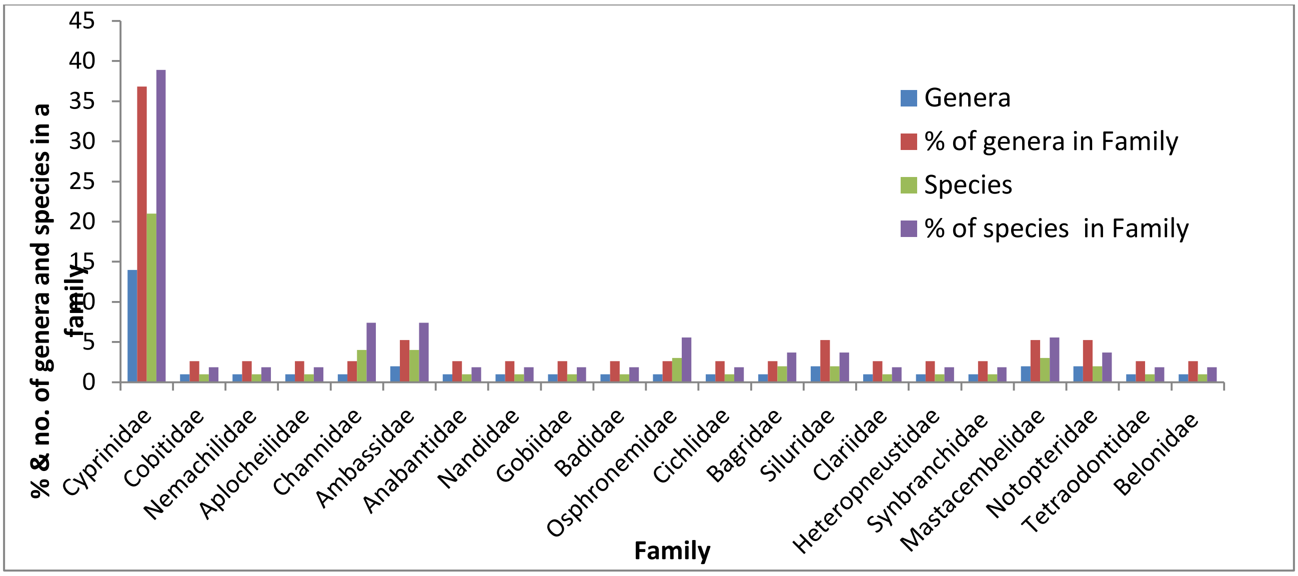


Figure 7. Number and percentage composition of genera and species of fishes under various Families in Chatla beel

4.1. 2. Diversity indices in Chatla beel

Season-wise diversity indices of Chatla beel are shown in Table 4 and Figure 8. Margalef's richness index (d) was found to be highest in pre-monsoon season (6.424) followed by winter (6.259), pre monsoon (6.019) and monsoon season (5.657). Whereas Pielou’s evenness index (J') was found to be highest in post monsoon season (0.8268) followed by monsoon (0.8108), winter season (0.8047) and was lowest in pre monsoon (0.8029). Shannon- Weinner index (H') was found to be highest during post-monsoon season (3.251) followed by winter (3.148) monsoon (3.139) and pre-monsoon season (3.125). Simpson index (1-D) was found to be highest during post-monsoon season (0.9424) followed by monsoon (0.9384), pre monsoon season (0.9377) and lowest in winter (0.935).

Table 4. Season wise diversity indices of Chatla beel

SEASON	Margalef's richness index (d)	Pielou's evenness index (J')	Shannon-Weinner Index (H')	Simpson diversity index (1-D)
POST MONSOON	6.424	0.8268	3.251	0.9424
WINTER	6.259	0.8047	3.148	0.935
PREMONSOON	6.019	0.8029	3.125	0.9377
MONSOON	5.657	0.8108	3.139	0.9384

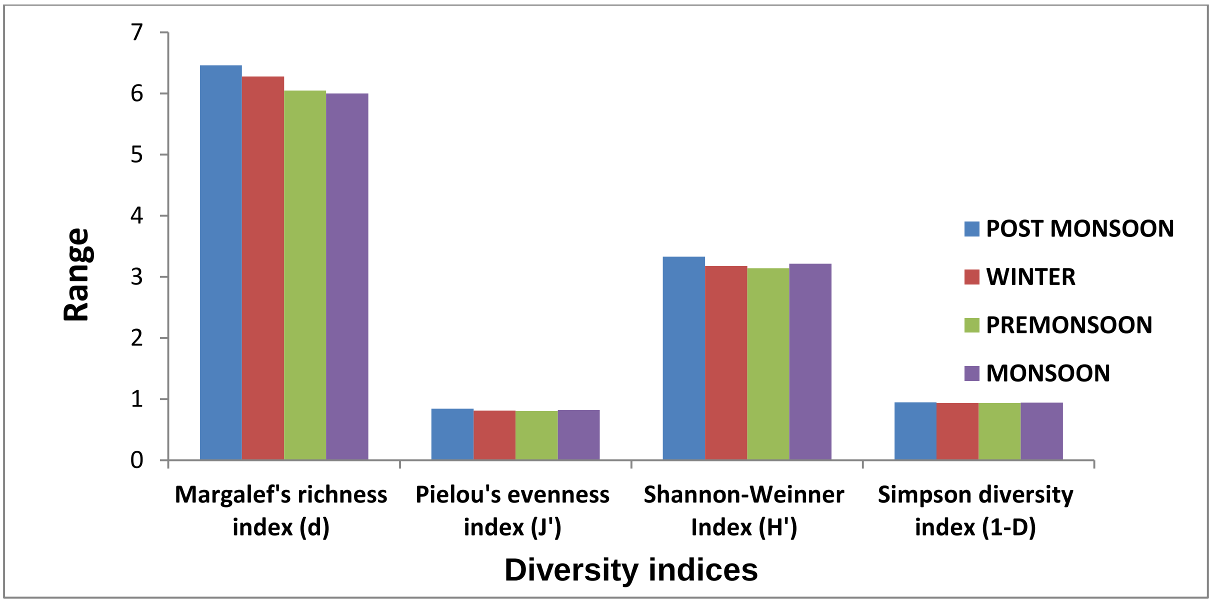


Figure 8. Season wise diversity indices in Chatla beel

4.1.3. Cluster analysis of Ichthyofauna in Chatla beel

The dendogram prepared for Chatla beel from Bray-Curtis similarity of species abundance with group average linking for the organisms showed 92.5 % similarity in seasonal abundance of fish fauna during winter and pre monsoon season while in monsoon season, it showed 85 % similarity with rest of the season. (Figure 9).

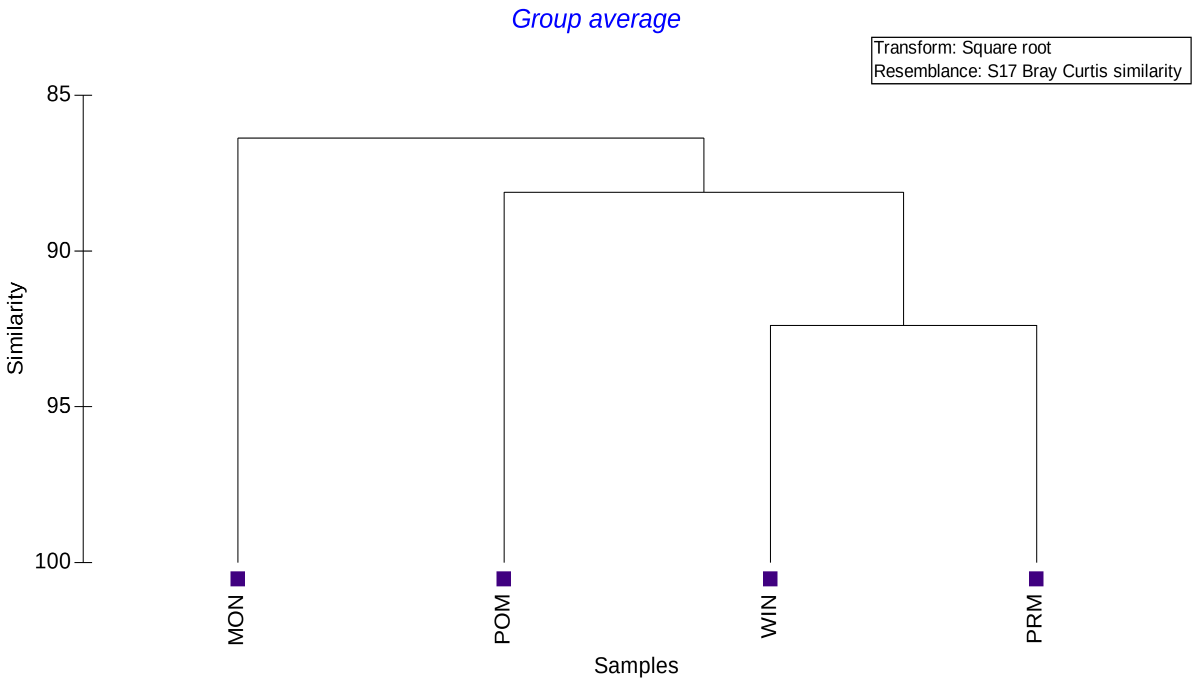


Figure 9. Dendrogram from Bray- Curtis similarity of season wise species abundance with group average linking for the ichthyofauna of Chatla beel

4. 1. 4. Ichthyofaunal diversity in Urmal beel

A total of 52 species of fishes have been recorded from the Urmal beel belonging to 21 families, 37 genera and 8 orders (Table-1). The species composition was similar to that of Chatla Lake except for family Cyprinidae and Bagridae. Here it has been observed that two species ,*Devario devario* (Hamilton) Laoputhi *& Mystus cavasius* were absent in Urmal beel *.* Table 5 and figure 10 show the number and percentage composition of families, genera and species of fishes under various orders in Urmal beel

Cyprinidae family was the most dominant one which includes 20 fish species contributed 38.46 % of total fish species recorded, followed by Channidae and

Ambassidae family with 4 species each holding 7.69% share. The third highest dominancy was shared by Osphronemidae and Mastacembelidae with 3 species each holding 5.77%. The next dominancy have been shown by Siluridae and Notopteridae with 2 species each, which contributed 3.85 % to the total fish species recorded during the study period and the remaining families such as Anabantidae, Aplocheilidae, Bagridae, Badidae, Belonidae, Cobitidae, Cichlidae, Clariidae, Gobidae, Heteropneustidae, Nandidae, Nemachilidae, Synbranchidae and Tetraodontidae were represented by single species .Table 6 and figure11 represents the number and percentage composition of genera and species under various families in Urmal beel.

The species composition of fishes belonging to different families revealed that 20 species belong to family Ciprinidae are *Amblypharyngodon mola, Gibelion catla, Labeo rohita, Hypophthalmichthys molitrix, Ctenopharyngodon idella, Cyprinus carpio, Cirrhinus mrigala, C. reba, Esomus dandricus Labeo bata, L. gonius, L. calbasu, Systomus sarana, Rasbora rasbora, R. daniconius, Pethia sophore, P.ticto, P. phutunio ,P.conchonius Salmostoma bacaila* .Four species namely *Channa marulius, C.punctata, C. gachua* and *C. striata* of family Channidae and *Parambassis ranga, P. lala , P. baculis and Chanda nama* of the family Ambassidae were recorded. Mastacembelidae in Urmal beel was represented by 3 species *Mastacembelus armatus, Macrognathus pancalus and M. aral* and Osphronemidae comprised of *Trichogaster fasciata, T. lalius* and *T. chuna* .Siluridae (*Ompok pabda and Wallago attu*), and Notopteridae (*Notopterus notopterus and Chitala chitala*) was represented by 2 species each. The families Nemachilidae (*Acanthocobitis botia*), Aplocheilidae (*Aplocheilus panchax*), Heteropneustidae (*Heteropneustes fossilis*), Cobitidae (*Lepidocephalichthys guntea*), Badidae (*Badis badis*) Bagridae (*Mystus carcio*), Clariidae (*Clarias magur*), Belonidae (*Xenentodon cancila*), Synbranchidae (*Monopterus cuchia*), Nandidae (*Nandus nandus*), Anabantidae (*Anabas testudineus*) GobiIdae (*Glossogobius giuris*) and Tetraodontidae (*Tetraodon cutcutia*) with single species, contributed 1.92 % to the total fish species in Urmal Beel.

Table 5: Number and percentage composition of families, genera and species of fishes under various orders in Urmal beel

Sl. No.	Order	Families	Genus	Species	% of families	% of genera	% of species
1	Beloniformes	1	1	1	4.76	2.70	1.92
2	Cypriniformes	3	15	23	14.26	40.54	44.23
3	Cyprinodontiformes	1	1	1	4.76	2.70	1.92
4	Osteoglossiformes	1	2	2	4.76	5.41	3.85
5	Perciformes	8	9	16	38.10	24.32	30.77
6	Siluriformes	4	5	5	19.05	13.51	9.62
7	Synbranchiformes	2	3	3	9.52	8.11	5.77
8	Tetraodontiformes	1	1	1	4.76	2.70	1.92
	Total	**21**	**37**	**52**			

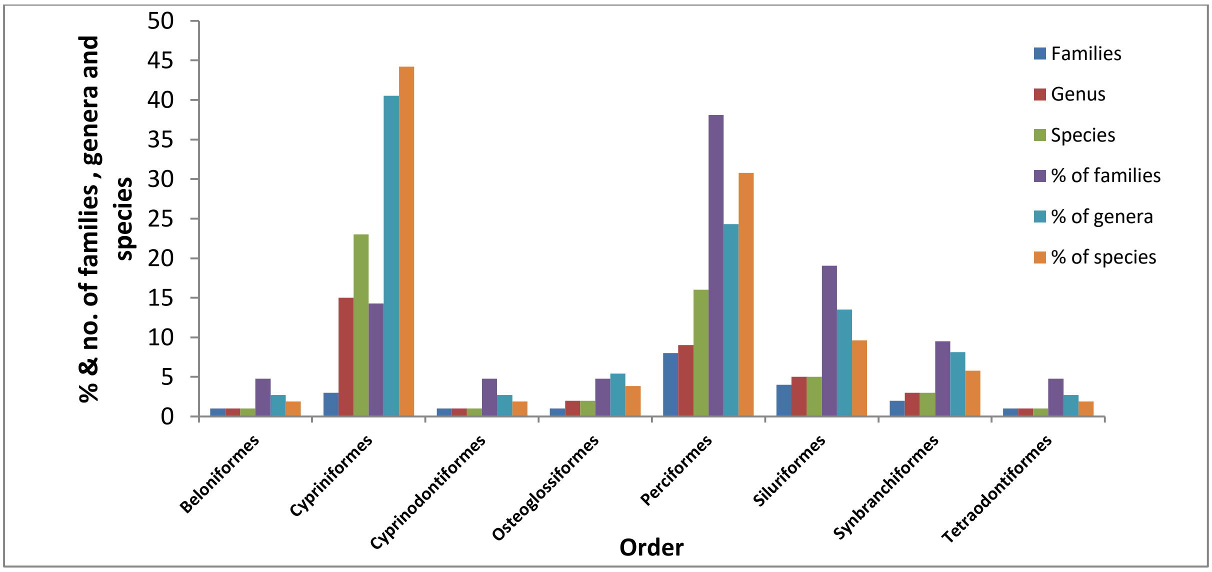


Figure 10. Number and percentage composition of families, genera and species of fishes under various orders in Urmal beel.

Table 6: Number and percentage composition of genera and species under various families in Urmal beel

Sl. No.	Families	No. of Genera	% of genera	No. of Species	% of species
1	Cyprinidae	13	35.14	20	38.46
2	Cobitidae	1	2.70	1	1.92
3	Nemachilidae	1	2.70	1	1.92
4	Aplocheilidae	1	2.70	1	1.92
5	Channidae	1	2.70	4	7.69
6	Ambassidae	2	5.41	4	7.69
7	Anabantidae	1	2.70	1	1.92
8	Nandidae	1	2.70	1	1.92
9	Gobiidae	1	2.70	1	1.92
10	Badidae	1	2.70	1	1.92
11	Osphronemida	1	2.70	3	5.77
12	Cichlidae	1	2.70	1	1.92
13	Bagridae	1	2.70	1	1.92
14	Siluridae	2	5.41	2	3.85
15	Clariidae	1	2.70	1	1.92
16	Heteropneustida	1	2.70	1	1.92
17	Synbranchidae	1	2.70	1	1.92
18	Mastacembelida	2	5.41	3	5.77
19	Notopteridae	2	5.41	2	3.85
20	Tetraodontidae	1	2.70	1	1.92
21	Belonidae	1	2.70	1	1.92
Total		**37**		**52**	

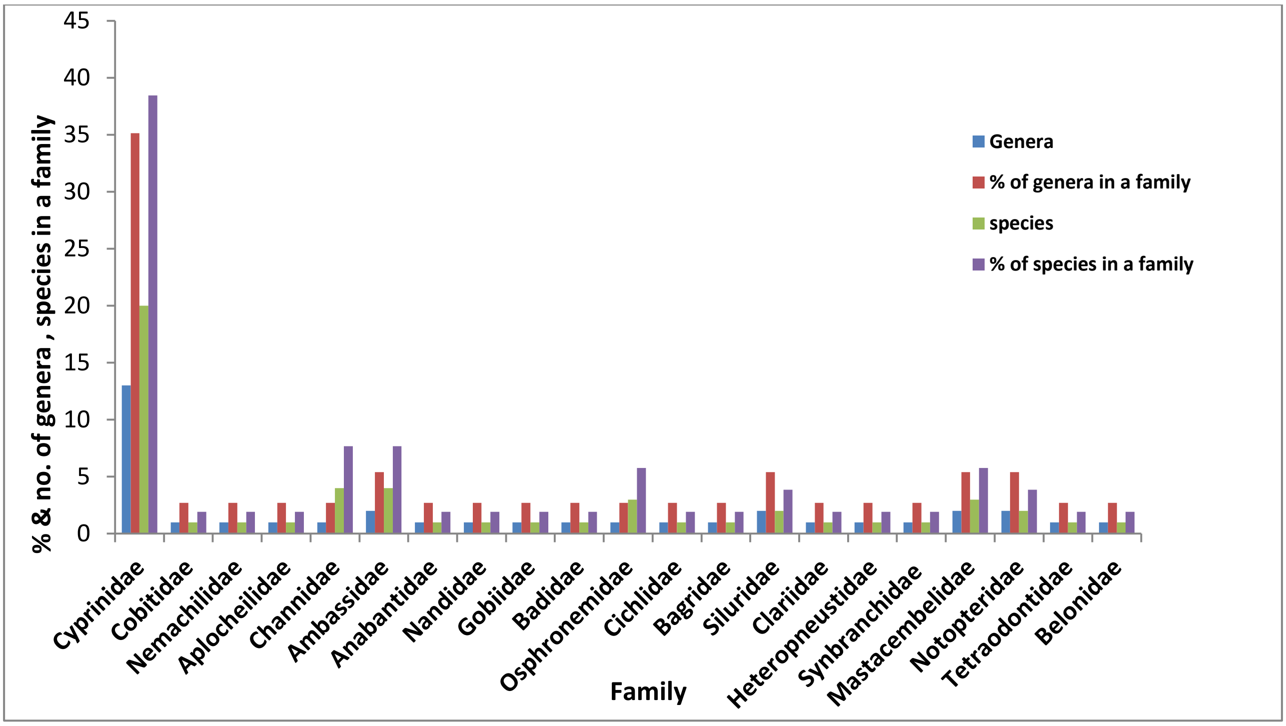


Figure 11. Number and percentage composition of genera and species of fishes under various families in Urmal beel

4.1.5 Diversity indices in Urmal beel

Season wise diversity indices of Urmal beel are shown in Table 7 and Figure 12. Margalef's richness index (d) was found to be highest in post monsoon season (6.463) followed by winter (6.278), pre monsoon season (6.05) and monsoon (6.002). Pielou's evenness index (J') was also found to be highest in post monsoon season (0.8419) followed by monsoon (0.8218), winter season (0.8117) and lowest in pre monsoon (0.8035). Shannon-Weinner index (H') was found to be highest during post-monsoon season (3.327) followed by monsoon (3.215), winter (3.176) and lowest in pre monsoon season (3.143). Simpson index (1-D) was found to be highest during post monsoon season (0.9454) followed by monsoon (0.9417), winter (0.9371) and recorded lowest during premonsoon season (0.9367).

Table 7. Season wise diversity indices of Urmal beel

SEASON	Margalef's richness index (d)	Pielou's evenness index (J')	Shannon-Weinner Index (H')	Simpson diversity index (1-D)
POST MONSOON	6.463	0.8419	3.327	0.9454
WINTER	6.278	0.8117	3.176	0.9371
PREMONSOON	6.05	0.8035	3.143	0.9367
MONSOON	6.002	0.8218	3.215	0.9417

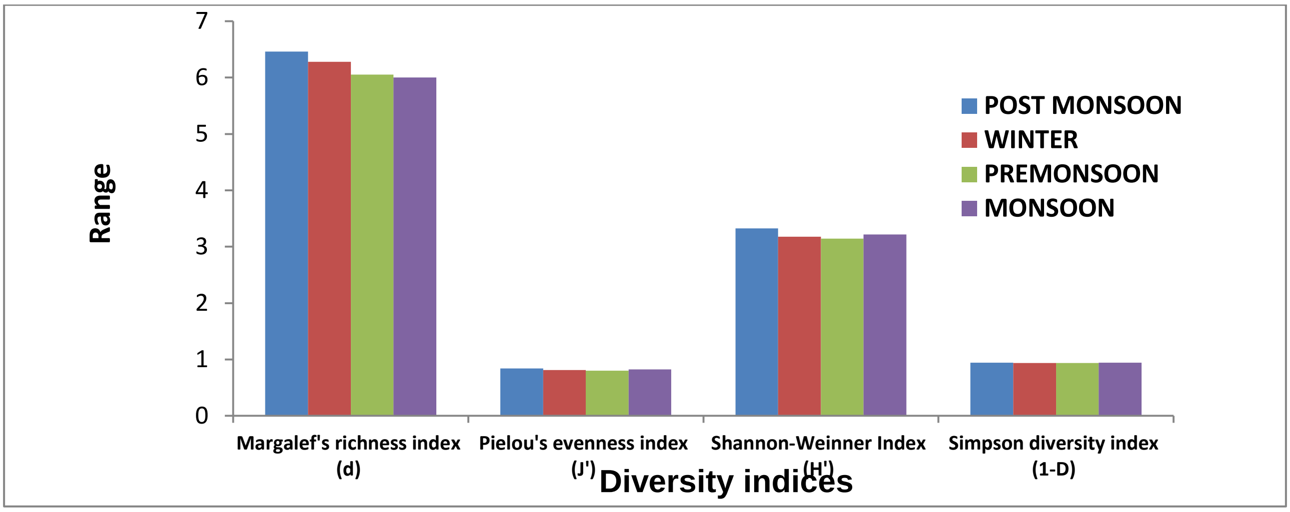


Figure 12 .Season wise diversity indices in Urmal beel

4.1.6. Cluster Analysis Ichthyofauna of Urmal beel

Seasonal abundance pattern of fish diversity in Urmal beel during the sampling period was analysed through cluster analysis using Bray-Curtis similarity measure and a higher level of similarity of fish fauna, stated 90 %, was found during winter and pre monsoon season. The post monsoon season revealed 86 % with rest of the seasons which was different from similarity obtained for Chatla beel .The pictorial presentation of cluster analysis of Urmal beel is shown in Figure 13.

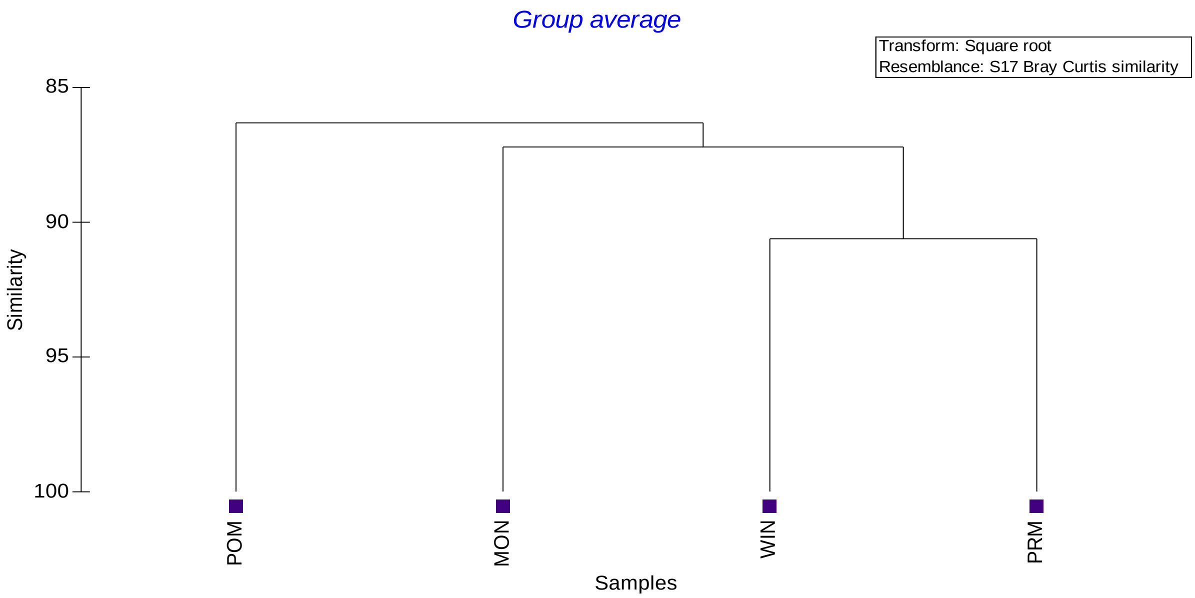


Figure 13. Dendrogram from Bray- Curtis similarity of season-wise species abundance with group average linking for the Ichthyofaunal of Urmal beel

4.2 Primary productivity

4.2.1 Primary productivity In Chatla beel

Primary productivity is an important parameter to assess the productivity of water body. When the nutrient status is poor, the primary productivity and the fish production is also poor (Singh and Desai,1980) indicating that the primary productivity is positively correlated with nutrient concentration. The results of primary productivity analysis, expressed in terms of Gross primary productivity and Net primary productivity, are shown in Table No.8 and figure 14. The present analysis was done based on seasonal variation by collecting samples in monthly interval from October 2017 to June, 2018. During the investigation period, the variation of primary productivity in terms of GPP and NPP across the four seasons has been observed. The averages Gross Primary Productivity (GPP) was recorded as 0.0225, 0.048, 0.05 and 0.01125 (mgC/m3/hr) in post monsoon, winter, pre monsoon and monsoon respectively. GPP shows the highest value during pre-monsoon (0.05 mg/C/m3/hr) followed by winter (0.048 mg/C/m3/hr), post-monsoon (0.0225 mg/C/m3/hr) and lowest during monsoon (0.01125 mg/C/m3/hr) season in Chatla beel.

Table 8. Primary productivity throughout the season in Chatla beel

PRIMARY PRODUCTIVITY	POST MONSOON	WINTER	PRE MONSOON	MONSOON	MEAN	SE
GPP (mgC/m3/hr)	0.0225	0.048	0.05	0.01125	0.0329375	0.0095625
NPP (mg C /m3/hr	0.011	0.026	0.03	0.00375	0.0176875	0.00618918

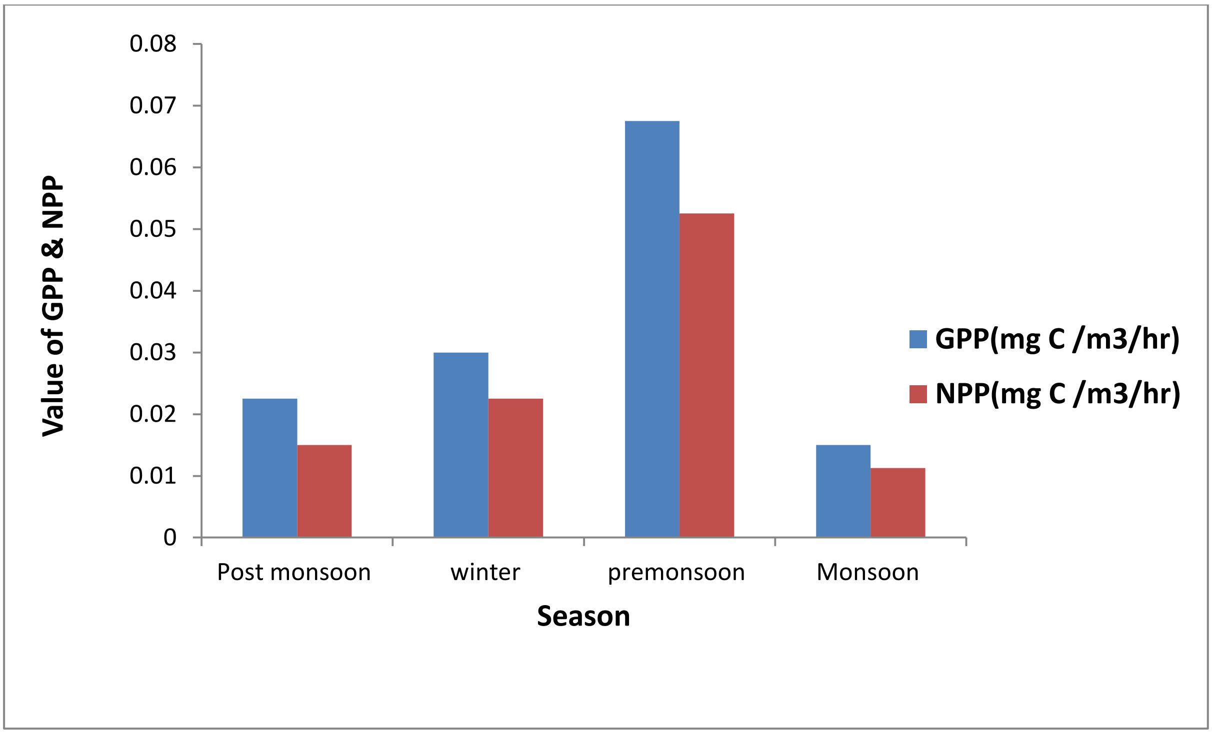


Figure 14. Primary productivity throughout the season in Chatla beel

4.2.2 Primary productivity in Urmal beel

In Urmal beel the variation of primary productivity in terms of GPP and NPP across the season has been observed and the average Gross Primary Productivity (GPP) have been recorded as 0.0225, 0.0300, 0.0675 and 0.0150 (mgC/m3/hr) in post monsoon, winter, pre-monsoon and monsoon respectively & Net Primary Productivity (NPP) were recorded as 0.01500, 0.0225, 0.0525 & 0.01125 (mgC/m3/hr) in post monsoon, winter, pre monsoon and monsoon respectively. GPP found to be highest during pre-monsoon (0.0675 mg/C/m3/hr) followed by winter(0.0300 mg/C/m3/hr), post-monsoon(0.0225 mg/C/m3/hr) and lowest during monsoon(0.01500 mg/C/m3/hr) season in Urmal beel. On the other hand NPP were observed to be the highest during pre-monsoon (0.05250 mg/C/m3/hr) followed by winter(0.0225 mg/C/m3/hr), post-monsoon (0.0150 mg/C/m3/hr) and lowest during monsoon(0.01125 mg/C/m3/hr) season, as shown in the Table no.9 & figure 15

Table 9. Primary productivity throughout the season in Urmal beel

PRIMARY PRODUCTIVITY	POST MONSOON	WINTER	PRE MONSOON	MONSOON	MEAN	SE
GPP (mgC/m3/hr)	0.0225	0.0300	0.0675	0.0150	0.0337	0.0116
NPP (mg C /m3/hr	0.0150	0.0225	0.0525	0.0112	0.0253	0.0093

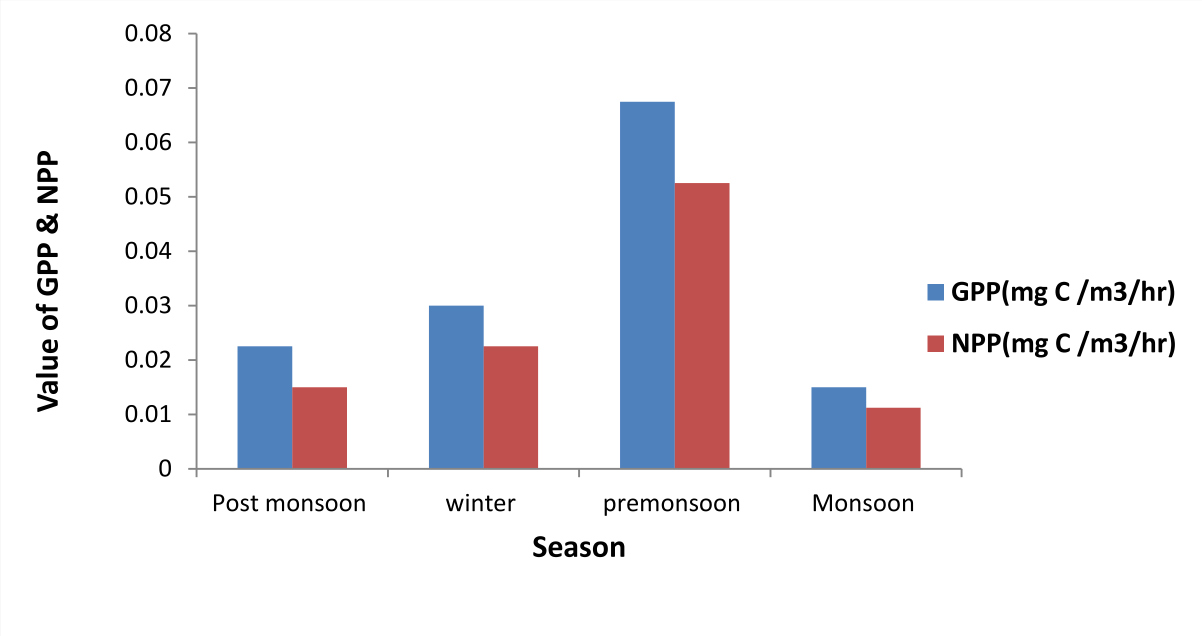


Figure 15. Primary productivity throughout the season in Urmal beel

From the present study we found that the GPP & NPP of both the wetlands exhibited higher values during pre-monsoon (March-April) followed by Winter(December-February) and post monsoon (October to November) and the minimum values were found during monsoon season (May-June)

4.3 Trophic status

The index for each of the parameters and their attributes for Chatla and Urmal beel recorded throughout the seasons is presented in Tables 10 and Table 11 respectively. The graphical representation of the Carlson's Trophic State Index of these two beels are given in the figure 16 and figure17. Our study revealed that the CTSI (Cumulative Trophic Status Index) values were higher during winter season, lesser during pre-monsoon and post monsoon and moderate during monsoon in Chatla beel. Whereas, in Urmal beel the CTSI (Cumulative Trophic Status Index) values were found to be highest during monsoon season, lesser during pre-monsoon and post monsoon and moderate during winter. During the study period, Chatla beel showed higher TSI (Trophic Status Index) values during winter and lesser values during pre-monsoon while TSI (Trophic Status Index) values were found as lowest during monsoon season which put the beel under mesotrophic state. On the other hand Urmal beel showed highest values during monsoon and lowest values during pre-monsoon. In the present study TSI (Trophic Status Index) based on SD and total phosphorus were having similar pattern, but TSI (Trophic Status Index-) based on Chlorophyll is contradicting to the TSI-SD (Trophic Status Index-Secchi disc depth) and TSI-TP(Trophic Status Index- Total phosphorus) in Chatla beel. In Urmal beel TSI based on TSI-TP found to be under mesotrophic and TSI-SD falls under moderately eutrophic while TSI-Chl.a(Trophic Status Index- Chlorophyll a) put the beel under hypereutrophic state throughout the season. Trophic status of the Chatla beel based on TP were found to fall under moderately eutrophic state where as Urmal beel was placed under mesotrophic state. While TSI based on SD and chlorophyll a for both the beels were found to fall under Eutrophic state with slight variation as shown in the figure 19.

In the present study, Cumulative TSI values based on combined parameters in Chatla beel were 76.55 and 70.83 during winter and monsoon seasons respectively, witnessed the water body to be hyper eutrophic during these seasons. Cumulative TSI value of 56.65 and 58.24 were found in Urmal beel during pre-monsoon and post monsoon respectively, indicated that the water body turned to be moderately eutrophic in these seasons (Figure. 18). Finally the overall mean TSI value of Carlson’s Trophic State Index for both the beels recorded were 65.57 for Chatla and to 62.74 for Urmal, as shown in Figure 20 indicated that both the beels were in eutrophic state and showed fluctuations throughout the season

Table 10: Seasonal variation of (TSI-TP, TSI-Chl a, TSI-SD) in Chatla beel

Season /parameter	TSI (SD)	TSI (CHL A)	TSI (TP)	Cumulative Mean TSI	Trophic Status
Post monsoon	60.0433459	72.32214408	42.3572706	58.24092019	MODERATELY EUTROPHIC
Winter	58.32642072	94.11340232	77.21828329	76.55270211	HYPEREUTROPHIC
Pre-monsoon	60.78563669	80.30094332	28.87525271	56.65394424	MODERATELY EUTROPHIC
Monsoon	60.51399153	88.75195942	63.22649262	70.83081452	HYPEREUTROPHIC
Overall TSI	59.91734871	83.87211229	52.9193248	65.56959527	EUTROPHIC

Table 11: Seasonal variation of (TSI-TP, TSI-Chl a, TSI-SD) in Urmal beel

Season /parameter	TSI (SD)	TSI (CHL A)	TSI (TP)	Cumulative Mean TSI	Trophic Status
Post monsoon	56.55171503	69.22197356	55.79341082	60.52236647	EUTROPHIC
Winter	57.40576848	94.1518013	51.33673116	67.63143365	EUTROPHIC
Pre-monsoon	59.71430848	86.52237183	16.04071324	54.09246451	MODERATELY EUTROPHIC
Monsoon	59.02389203	97.73976737	49.3797206	68.71446	EUTROPHIC
Overall TSI	58.173921	86.90897852	43.13764395	62.74018116	EUTROPHIC

NOTE: TSI= Trophic Status Index,TP= Total phosphorus, Chl a= Chlorophyll a SD= Secchi disc depth **.**

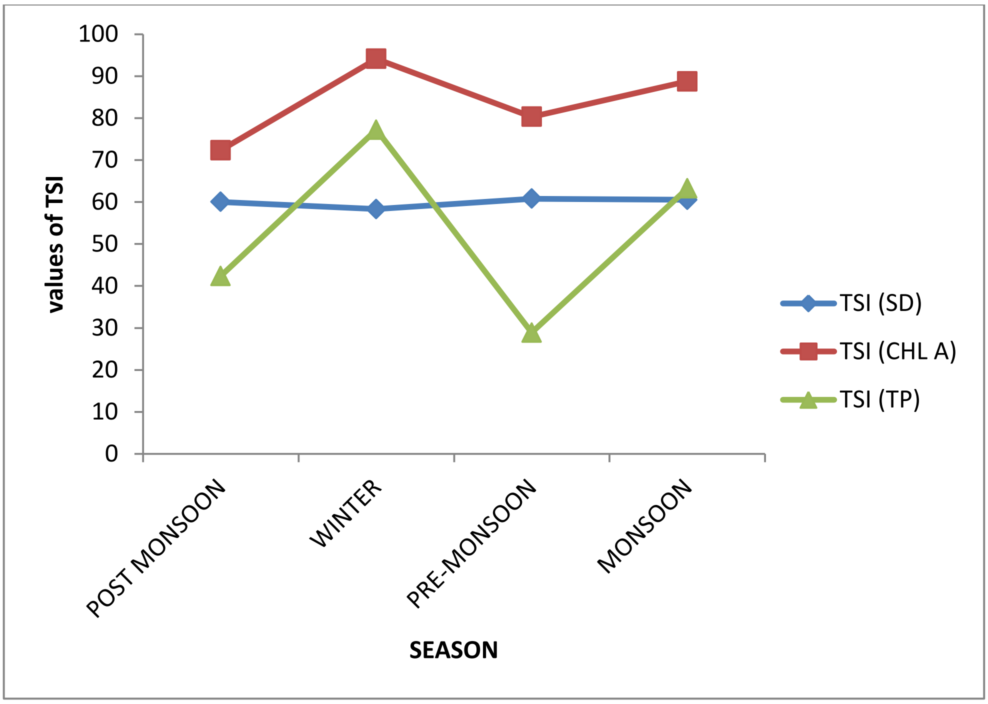


Figure16. Season wise TSI value based on single parameter in Chatla beel

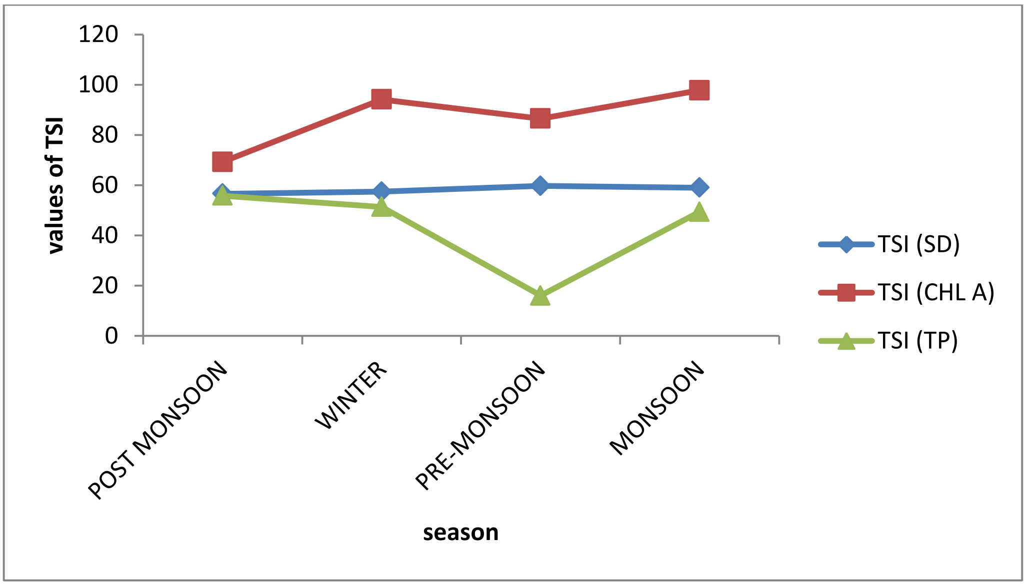


Figure17. Season wise TSI value based on single parameter in Urmal beel

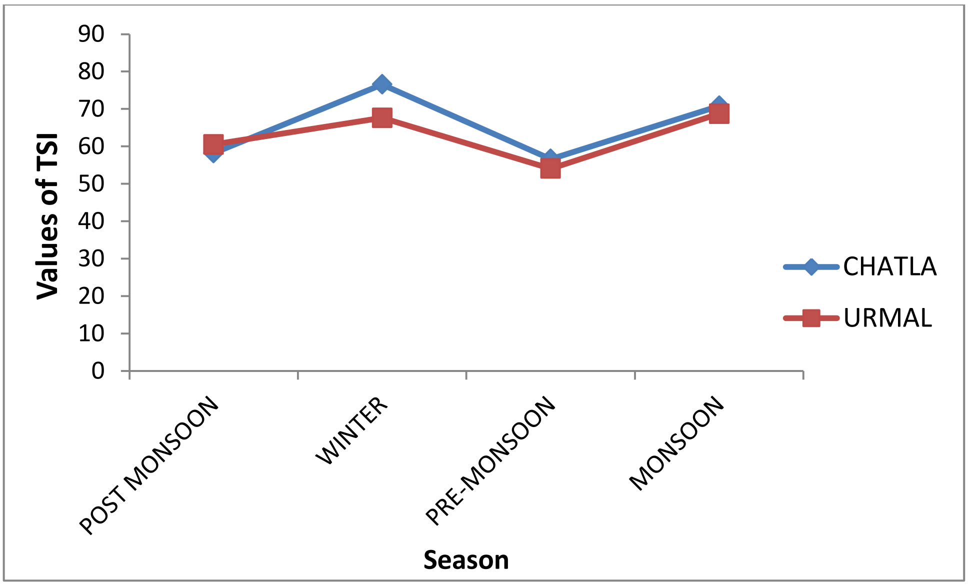


Figure 18. Season wise Cumulative TSI based on combined parameter in Chatla and Urmal beel

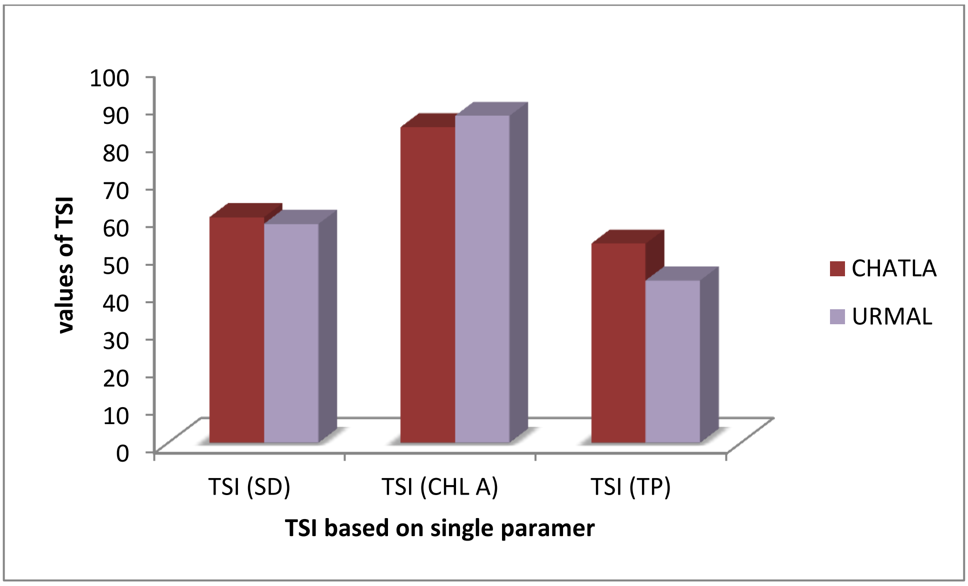


Figure 19.TSI based on single parameter throughout the season for Chatla and Urmal beel

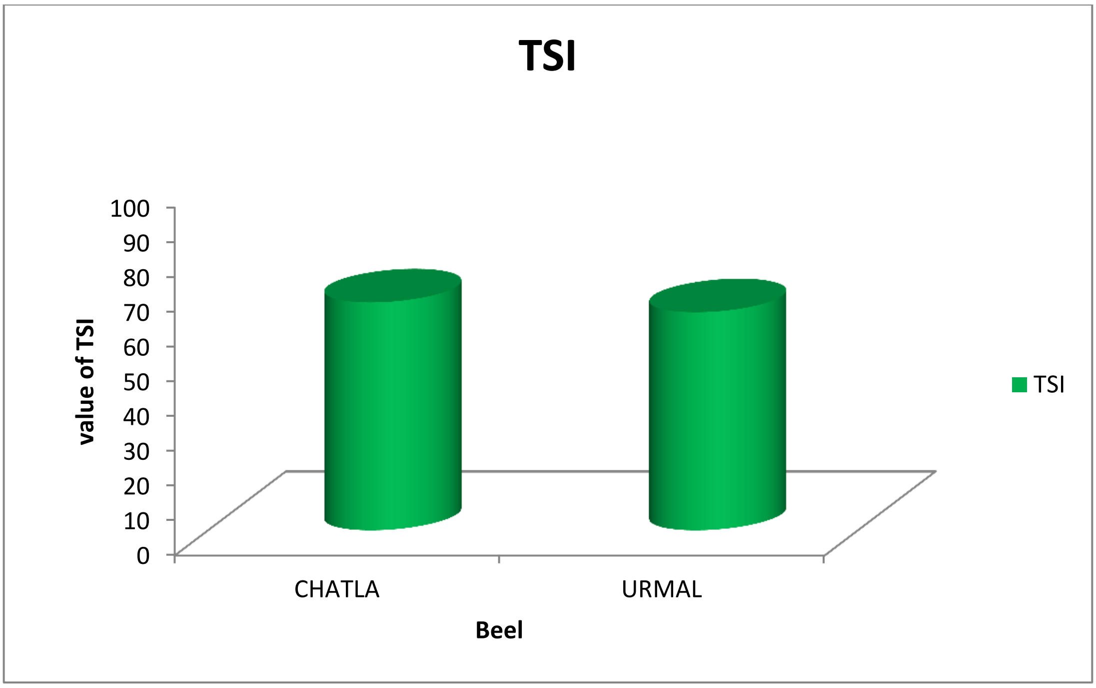


Figure 20. Overall TSI for both the Beels during the study period

4.4. Studies on Water Quality Parameter

Water quality play key role in aquatic ecosystem both singly and in a synergistic way and thus determine the primary productivity and fish production in the ecosystem. It is the most prime factor to understand to predict and manage the productivity of a particular aquatic system. The water quality directly and indirectly influences the food and feeding efficiency, growth and development, reproduction, health and habitat selectivity of the organisms. Therefore management of water quality parameters is a prerequisite to provide a comparatively stress free or comfortable environment that will allow the fishes to meet the physical, biological standards to have tremendous growth and production.

Table 12. ANOVA of water quality parameters of Chatla beel:

Parameter/Season	Post monsoon	Winter	Pre-monsoon	Monsoon	p-value
pH	7.90±0.5^{a}	7.06±0.1^{a}	7.33±0.1^{a}	7.90±0.2^{a}	0.189
DO(mg/l)	7.2±0.3^{b}	7.9±0.1^{b}	7.8±0.01^{a}	7.7±0.2^{ab}	0.157
EC (µS/cm)	276.6±12.5^{c}	322.3±6.3^{b}	370.3±21.8^{a}	275.1±4.4^{c}	0.003
TDS(mg/l)	179.7±8.1^{b}	209.3±3.8^{b}	240.3±14.3^{a}	181.2±6.1^{b}	0.004
Temp(0˚C)	24.2±0.2^{b}	19.9±0.1^{d}	23.3±0.1^{c}	26.3±0.1^{a}	0.001
Depth(m)	1.8±0.2^{a}	1.5±0.1^{ab}	0.9±0.1^{c}	1.2±0.2^{bc}	0.009
T.chl(µg/l)	166.4±15.5^{a}	173.0±52.0^{a}	236.2±41.8^{a}	163.7±17.6^{a}	0.461
T.Alk(mg/l)	64.0±1.2^{a}	64.7±1.8^{a}	66.7±1.3^{a}	64±1.2^{a}	0.508
FCO_2(mg/l)	0.7±0.03^{a}	0.7±0.1^{a}	0.8±0.1^{a}	0.8±0.1^{a}	0.528

Table13. ANOVA of water quality parameters of Urmal beel:

Parameter/Season	Post-monsoon	Winter	Pre-monsoon	Monsoon	p-value
PH	6.4±0.05^{d}	7.2±0.01^{b}	7.4±0.1^{a}	7.5 ±0.1^{c}	0.001
DO(mg/l)	7.6 ±0.2^{a}	7.9±0.1^{a}	7.7±0.1^{a}	7.6±0.2^{a}	0.421
EC(µS/cm)	195.7±10.3^{c}	266.3±1.7^{b}	342.7±11.6^{a}	203.4±11.8^{c}	0.001
TDS(mg/l)	128.7±5.5^{c}	173±1.5^{b}	222±7.5^{a}	133.3±6.0^{c}	0.001
Temp(0˚C)	24.3±0.3^{b}	20.3±0.2^{d}	23.3±0.2^{c}	26.3±0.1^{a}	0.001
Depth(m)	1.8±0.1^{a}	1.3±0.1^{bc}	1.02±0.1^{c}	1.6±0.1^{ab}	0.004
Tchl(µg/l)	158.2±16.0^{b}	106.0±17.9^{c}	238.9±9.4^{a}	160.3±16.1^{b}	0.002
TA(mg/l)	64±2.3^{a}	64.7±2.9^{a}	68±2.0^{a}	64.7±2.4^{a}	0.660
FCO_2(mg/l)	0.9±0.1^{ab}	1.03±0.1^{a}	0.8±0.1^{c}	0.9±0.03^{ab}	0.136

The One-way ANOVA showed that water quality parameters in Chatla beel like DO, EC, TDS, Temperature and Depth were statistically significant ($p<0.05$) between seasons. EC was significantly higher in pre-monsoon season followed by winter, post-monsoon and monsoon season. However, EC in monsoon and post-monsoon season didn't differ significantly. Similarly, TDS was significantly higher in pre-monsoon season that observed in winter, monsoon and post-monsoon season. However, it didn't differ significantly between winter, post-monsoon and monsoon seasons for Chatla beel. PH were found to be higher in Monsoon .Temperature is higher in monsoon followed by post monsoon, pre-monsoon and winter. DO was also found to be higher in Winter followed by pre-monsoon, monsoon and post monsoon for both the beel .The water temperature fluctuated from 19.9to 26.3 ^{0} C in the selected *beels*. Transparency (SD-Depth) was found minimum during monsoon month which could be due to ingress of silt laden water from surrounding area. In the present study, higher value of carbon dioxide was recorded during winter in the selected beels. Maximum range of free CO_2 was recorded in winter might be due to high rate of decomposition of organic matters by the microbes resulting in rapid production of free CO_2.

Table 14: Results of t-tests and Descriptive Statistics of water quality parameter for both the beels

Outcome	Beel				95% CI for Mean Difference	t (df=22)
	Chatla (n=12)		Urmal (n=12)			
	M	SD	M	SD		
pH	7.45	0.49	6.93	0.42	0.13, 0.91	**2.75***
DO(mg/l)	7.69	0.37	7.71	0.28	-0.30, 0.25	-0.18
EC(µS/cm)	311.10	45.24	252.01	63.11	12.61, 105.58	**2.64***
TDS(mg/l)	202.63	29.07	164.25	40.06	8.75, 68.02	**2.69***
Temp(0˚C)	23.43	2.43	23.57	2.30	-2.13, 1.87	-0.14
Depth(m)	1.9	0.40	1.43	0.33	-0.35, 0.28	-0.24
T Chl(µg/l)	184.83	60.83	165.85	54.40	-29.88, 67.84	0.81
TA(mg/l)	64.83	2.33	65.33	3.94	-3.24, 2.24	-0.38
FCO2(mg/l)	0.77	0.09	0.90	0.13	-0.23, -0.04	-2.97*

There are statistically significant differences, ($p<0.05$) between Chatla and Urmal beel in pH, EC, TDS, and free carbon dioxide. Results show that Chatla beel had higher pH, EC and TDS and Urmal beel had higher free carbon dioxide. No statistically significant difference exists between Chatla and Urmal beel in DO, Temp, Depth, Total Chlorophyll and Total Alkalinity values.

5. DISCUSSION

5.1. Ichthyofaunal diversity of the selected beels:

The present study reveals the rich Ichthyofaunal diversity in both the beels, where, 54 and 52 numbers of species of fishes were recorded from Chatla and Urmal beel respectively. The analysis of species composition indicates Cypriniformes and Cyprinidae as the most dominant order and family respectively in both the beels. Chhetry & Deka (2016) also reported that Cyprinidae is the most dominant family with 17 numbers of species sharing about 36.17% of the 18 recorded families from Era Kopili Beel of Karbi Anglong District, Assam.The result of Ichthyofaunal fish diversity is in agreement with the reports of earlier workers wherein, Goswami (1985) has reported 57 species from Chanddubi beels ,Lahon (1983), 62 species from Dora beels, and 60 species from Uropod beels by Saud *et al.* (2012) from the wetlands of the Assam. Rich Ichthyofaunal diversity (70 species) from Sone beel of Barak valley, Assam has been reported by Kar and Dey (1993), however during present study less Ichthyofaunal diversity was observed in its comparison .Loss of connection to river due to siltation in the channel and weed infestation and overfishing might have hindered the auto stocking during flood, which may be the reason for the lower diversity in the present study.

The exotic species recorded from the beels were *C. carpio, C. idella, H. molitrix,* which are most common in beels of Assam. The commercially important fish species found in the wetlands were *L. rohita, L. gonius, G. catla, C. mrigala, N. notopterus, C. chitala, W. attu, C. marulius, C. striatus, C. reba, H. fossilis, C. magur, O. pabda, A. testudineus, M. carcio* etc. The present record matches well with the report of Chakravartty *et al.* (2012) and Bordoloi and Hazarika (2015). Eutrophication, siltation, loss of connection with parent river, pollution and loss of habitat due to increased siltation in the periphery of the wetlands which lead to rapid growth of macrophytes in the peripheral area of the beel.

Major factors for declining trend of fishes in the wetlands ecosystems identified by different workers (Dutta, 1987; Bishaya, 1987; Deka *et al.,* 2005) are habitat loss, over exploitation, weed infestation, eutrophication, siltation , pollution, encroachment, etc. similar factor were also observed in the present study. The sequence of dominance of recorded species by respective order in Chatla beel was as Cypriniformes>Perciformes>Siluriformes>Synbranchioformes>Osteoglossiformes> Cyprinodontiformes>Beloniformes>Tetraodontiformes. The present findings are well supported by the report of Deka *et al.* (2005). The sequence of dominance of recorded species by respective order in Urmal beel was found to be same except the species such as *D. devario (*Hamilton*)* & *M. cavasius (*Hamilton*)* were found to be absent in Urmal beel and both the species are mostly found in river. As the Urmal beel is not connected with the parent river Puthimari, the absence of these species may be attributed to the same.

5.2. Biodiversity indices and Cluster Analysis studies

Biodiversity index is used to characterize the diversity of a population or community by a single number (Magurran, 1988). The concept of the species diversity involves two components; 1. The number of species or richness; 2. The distribution of individuals among species.

Species diversity index (H'), Simpson diversity index (1-D), Margalef‟s richness index (d) Pielou‟s evenness index (J) values in the present study exhibited temporal variation. The Shannon index is the most preferred index among the other diversity indices which is applied to biological systems. The Shannon index increases as both the richness and the evenness of the community increase (Magurran, 2004). The ratio of the observed value of Shannon index to the maximum value gives the Pielou Evenness Index (J). When the value is getting closer to 1, it means that the individuals are distributed equally. In ecology, it is often used to quantify the biodiversity of a habitat.

In the present study Shannon-Weinner Index of diversity and richness index found to be > 3.251 which indicated rich Ichthyofaunal diversity in Chatla beel, which is in agreement with the report of (Hazarika, 2013).

Simpson diversity index exhibited high value during post monsoon (0.9424) and monsoon seasons (0.9384) whereas, species evenness index evinced high value during post monsoon season (0.8268) in the Chatla beel. Shannon diversity index and richness index calculated in Urmal beel also showed highest value (3.327) during post-monsoon season followed by monsoon, winter and pre monsoon season with a mean value of 3.215, which is similar to the findings of Nath and Deka (2012) in Chandubi beels.

The Simpson diversity index showed higher value during post-monsoon (0.9454) and monsoon (0.9417) than winter (0.9371) followed by pre monsoon season (0.9367) and Pielous‟ evenness index was found to be highest during post monsoon season in Urmal beel. The calculated "H" value of the selected beels was above 3 which indicated its healthy status. The "J" value of Urmal beels was closer to 1 which signified that the individuals are almost evenly distributed than the Chatla beel. However, the lower value of richness and diversity during pre-monsoon compared to monsoon winter, post-monsoon, season in the selected beels may be attributed to less fishing during the pre-monsoon. A similar observation of the diversity indices was also observed by Nath and Deka (2012) in Chandubi beel and Hazarika (2013) in Satajan beel. The higher value of Shannon–Weinner index in Chatla beel than Urmal beel indicate rich diversity of fish which may be due the connection with the parent river which helps in entering of fish during the monsoon season.

In present study cluster analysis was also performed. The Cluster analysis encompasses several multivariate techniques that are used to group objects into categories based on their similarity or dissimilarities. The aim is to minimize within-group variation and maximize between-group variation in order to reveal well-defined categories of objects and therefore, to reduce the dimensionality of the data set to a few groups (James and McCulloch, 1990). The dendogram (Figure 9 & 13) prepared for both the *beels* from Bray-Curtis similarity of species abundance with group average linking for the organisms, similarity and combination pattern of occurrence of fish species was found to be almost same in both the beels. However 92.5 % similarity in seasonal abundance of fish fauna during winter and pre monsoon season was observed while monsoon season showed 85 % similarity with rest of the seasons in Chatla beel whereas, in in Urmal beel Bray Curtis similarity stated 90 % similarity of fish fauna during winter and pre monsoon season but post monsoon season revealed 86% similarity with rest of the seasons. This is the first report of cluster analysis from Chatla beel and Urmal beel

5.3. Primary Productivity studies

More light penetrations into the water body and higher temperature increase the photosynthetic performance which ultimately increased the primary productivity of an aquatic ecosystem during premonsoon season whereas, dilution of water during monsoon due to higher dissolved solids and suspended solids make the water body highly turbid which restricts the penetration of light and thereby less photosynthetic activities take place (Moharana *et al.,* 2013).

Gross Primary Productivity (GPP) and Net Primary Productivity (NPP) of both the wetlands evinced higher values during premonsoon (March-April) followed by winter (December-February) and post monsoon (October-November) and the minimum values were found during monsoon season (May-June). Results of present study revealed that maximum GPP and NPP were recorded during premonsoon season, which is similar to the findings of Mohapatra *et al.* (2012) and Sahoo *et al.* (2015). Present findings indicate that the productivity is governed by various factors e.g. water temperature, sun light, weather conditions, availability of nutrients and phytoplankton etc.

5.4. Trophic Status

The major problems of the lake include excessive influx of sediments from the catchment, discharge of sewage and industrial waste, entry of diffused nutrients source from agricultural and forestry, improper management of storm water, over abstraction, over-exploitation of lake for activities like recreation, fishing, encroachments, land reclamation, shoreline erosion which deteriorates water quality, impacting bio diversity.

The pollution status of a lake at given time can be done by measuring trophic state index (TSI) to know its trophic state (Sharma *et al*., 2010). Trophic state monitoring is an important aspect in assessing and managing aquatic ecosystems. Carlson,(1977) developed a trophic state index for lakes which was followed during present study. As per this index TSI value < 30 indicate the lake is oligotrophic, 30-40 and 40-50 indicates mesotrophic state, 50-60 and 60-70 indicates eutrophic state and above 70 indicates hyper eutrophic state.

In present study TSI was calculated based on total phosphorus (TSI-TP), Chlorophyll a (TSI- Chl.a) and Secchi disc transparency (TSI-SD). Taking in to account of all the three parameter, season wise and overall TSI was estimated. The findings revealed that the Carlson's TSI values were higher during winter season, lower during pre-monsoon and post monsoon and moderate during monsoon season in Chatla beel where as in Urmal beel the Carlson's TSI values were found to be highest during monsoon season, lower during pre-monsoon and post monsoon and moderate during winter season. During the study period Chatla beel showed higher values during winter (October–November) and minimum during pre-monsoon. Lower TSI value during monsoon season placed the beel under mesotrophic state during monsoon season .In case of Urmal beel, highest values during monsoon and lowest values during pre-monsoon was observed. TSI based on Secchi disc and total phosphorus exhibited similar pattern, but TSI based on Chlorophyll a is contradicting to the TSI-SD and TSI-TP in Chatla beel whereas in Urmal beel TSI based on TSI-TP found to be under mesotrophic and TSI-SD put under moderately eutrophic while TSI-Chl.a put the beel under hype-reutrophic state throughout the season especially during winter season, the reason attributed to this are the heavy fishing during Bihu festival season where community fishing is done by local community which continues upto 15-20 days. Due to heavy fishing, bottoms get disturbed which lead to release of phosphorus from sediments settled at the bottom. Trophic status of the Chatla beel based on TP were found moderately eutrophic whereas Urmal beel placed under mesotrophic while based on SD and chlorophyll a both the beel were found to be in eutrophic state. The present findings matches well with the findings of Sharma *et al.* (2010) in Mansi Ganga Lake and Ahangar *et al*. (2012) in Anchar Lake.

Cumulative TSI value based on combined parameter in Chatla beel were 76.55 and 70.83 during winter and monsoon season respectively, which indicates the beel is in hyper eutrophic state. In case of Urmal beel, cumulative TSI value of 56.65 and 58.24 were found during pre-monsoon and post monsoon respectively which placed the beel in moderately eutrophic state. Overall the mean TSI value of Carlson's trophic state index for both the beels recorded in between 65.57 to 62.74 indicated both the beels were in eutrophic state, but both the beels exhibited fluctuations throughout the season. TSI values calculated on the basis of SD, TP and chl. a showed a characteristic seasonal variation around the season in both the beel. The mean values of, TSI-TP, TSI –Chl.a and TSI -SD were 43.14, 86.91 and 59.92 for Urmal beel and 59.92, 83.87 & 52.92 for Chatla beel respectively. The present finding is supported by the Singh and Sharma (2012) and Devi Prasad. (2012).

Phosphorus is a limiting nutrient in algal growth (Horne and Goldman, 1994), similar observation has been found in present study. According to Stefansson *et al.* (2001), although eutrophication is a natural process, over a period of time it is often accelerated by human activities which is termed as cultural eutrophication which has been also noticed during my present study period which lead to eutrophication of both the beel .

Decrease in phosphorus content may be due to less transparency, increased weed infestation which uptake the nutrients along with phosphorus which lead to change in TSI value, fishing activity lead to turbidity of water and lead to decrease in photosynthetic activity.

Hosmani, (2010) reported that chlorophyll a measurement can be used as a primary index for trophic state classification and to infer the functioning of the lake.

Carvalho and Kirika, (2003) reported that decline in inflow of nutrients reduces phosphorus concentration in lakes which in turn reduces phytoplankton biomass. Moreover worldwide studies have shown that both submerged and free-floating macrophytes have a high capability of improving water quality by removing heavy loads of nutrients and toxic metals from the water (Srivastava *et al*., 2008).

Submerged macrophytes were found in the beels in considerable percentage. The presence of these macrophytes, has led to lower levels of total phosphorus. This has in turn affected the growth of plankton and ultimately the chlorophyll a levels. However, when Secchi disc transparency is considered, the beel is found to be in hyper-eutrophic condition. The run-off from nearby areas has resulted in the high load of suspended solids in the beel. Moreover agricultural activities at the beel periphery have also resulted in high load of suspended solids. North East India in general and Assam in particular receives high rainfall and this brings about huge influx of clay and mud particles from the adjoining areas to the beel resulting in increased turbidity and reduced transparency. This has resulted in hyper-eutrophic condition of the beel. When the TSI value is taken cumulatively i.e. considering all the three parameters both the beel Chatla and Urmal is found to be in eutrophic condition during the study period

6. SUMMARY

In the present investigation, a total of 54 fish species belonging to 38 genera under 21 families from 8 orders were recorded from the selected Chatla beel (seasonally open) which revealed rich and diversified fish fauna, where family Cyprinidae contributed highest percentage of the total population of fish species collected from lake, where as in Urmal beel (closed beel) a total of 52 fish species belonging to 37 genera under 21 families from 8 orders were recorded which also revealed rich and diversified fish fauna, with family Cyprinidae contributed highest percent of the total population of fish species, which is further confirmed by calculating diversity indices such as Shannon-Weinner Index and Richness index (Margalef's). An attempt was made to study the productivity of the lake in terms of Gross Primary Productivity (GPP) and Net Primary Productivity (NPP) for both the beels, where results indicates that productivity was highest during winter season and lowest during monsoon season.

Monitoring of trophic condition in wetlands are utmost important for assessment and management the health status of the ecosystem and it indicates the effects of weed decomposition, sewage loads, domestic waste and surface run-off on aquatic body. Anthropogenic activities like washing, bathing and paddy cultivation in the periphery were observed in the present study. Washing of cloths with detergent may significantly contribute to increased alkalinity and pH. Higher phosphorous concentration in the water body may affect the system and high decomposition of weeds also lead to release of phosphorus into the ecosystem. Use of inorganic fertilizers and pesticides in the paddy cultivation may have paramount impacts on the system and may influence the water body by increasing the concentration of phosphorous and nitrogen, which may cause over enrichment of nutrients in the water bodies leading to the algal blooms. Though the transformation in trophic phase from mesotrophic to eutrophic is common in nature, appropriate management measures may restrict the water body to further change to hyper-eutrophic phase. Although fluctuation in TSI value were prominent across the season, but, overall results indicated that both the beel comes under eutrophic state.

Conspicuous temporal variation of the Physico-chemical parameters of the selected beels obtained during the study period indicated that the water is productive and thus can be utilized for culture based capture fishery.

These selected floodplain wetlands are least exploited by researcher for studies like floral and faunal diversity, Trophic status index, ecological and economic studies. The present study provides comprehensive information diversity on Ichthyofaunal diversity, trophic status, water quality and productivity. The utility of this research are, baseline information on water quality parameters, productivity, Trophic status index, and fish species diversity of Chatla and Urmal beels, which will serve as baseline data for further study and information for formulation of better management plans and practices sustainable use of fisheries resources.

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