# BIODIVERSITY OF HILL STREAM FISHES IN ARAVALLI REGION OF SOUTH RAJASTHAN

**A THESIS**

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By


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**FACULTY OF SCIENCE**

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# DECLARATION

I **KAILASH CHANDRA NAGAR** S/o Mohan Lal Nagar hereby declare that the research work incorporated in the present thesis entitled **"BIODIVERSITY OF HILL STREAM FISHES IN ARAVALLI REGION OF SOUTH RAJASTHAN"** is my own work and is original. This work (in part or in full) has not been submitted to any University for the award of a Degree or a Diploma. I have properly acknowledged the material collected from secondary sources wherever required. I solely own the responsibility for the originality of the entire content.

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# CERTIFICATE

I feel great pleasure in certifying that the thesis entitled **"Biodiversity of Hill Stream Fishes in Aravalli Region of South Rajasthan"** by **Kailash Chandra Nagar** is submitted under my guidance. He has completed the following requirements as per Ph. D. regulations of the University.

(a) Course work as per the University rules.

(b) Residential requirements of the University.

(c) Regularly submitted annual progress report.

(d) Presented his work in the Departmental committee.

(e) Published/accepted minimum of one research paper in a referred research journal.

I recommend the submission of thesis.

Date: (**Dr. Madhu Sudan Sharma**)

Place: Supervisor

# Dedication

**To my Parents,**

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*It is my great pleasure and privilege to convey deepest gratefulness to my respectable and esteemed Supervisor,* ***Prof. Madhu Sudan Sharma****, former Vice- Chancellor, University of Kota, Kota and Ex Dean and Chairman, Faculty of Science ,Retd. Professor and Head Department of Zoology, University College of Science, Mohan Lal Sukhadia University, Udaipur, for his constant inspiration, valuable guidance, constructive criticisms, firm determination and availability at odd hours have helped me to achieve this far distance goal. His enormous knowledge of the subject and interpretation of research findings made a lasting imprint in my mind. I feel very fortunate to have an opportunity to work under his patient supervision.*

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**( Kailash Chandra Nagar)**

# CONTENTS

# CHAPTER – I
# INTRODUCTION

The earth holds an immense variety of habitats and ecosystems. The total diversity and variability of organisms and of the system of which they are a part is generally defined as biological diversity, *i.e.* the total variability of life on earth. In other words it also refers to the totality of genes, species and ecosystems in a region. Biodiversity includes diversity within species, between species and of ecosystems. (Kuswaha and Kumar, 1999).The term biodiversity, the short form of biological diversity, was coined by Walter G. Rosen in 1985, however the origin of the concept go far back in time. Perception of biodiversity varies widely among different segments, such as biologists, sociologists, lawyers, naturalists, conservationists, ethnobiologists and so on. Thus, biodiversity issues have been unifying force among people of various professions and pursuits.

Global biodiversity is mainly divided into three categories *viz.,* genetic, species and ecosystem. Genetic diversity is the variation of genes within species, while species diversity refers to a variety of living species. Ecosystem diversity includes broad differences between ecosystem types, including the diversity of habitats and ecological processes occurring within each ecosystem type.

Biodiversity is the source of genetic pool, therefore management and conservation of biological wealth are mandatory for our own survival and benefits as well as that of a species (Odum, 1989). It is estimated that about 40% of the annual biological product of the earth planet is now appropriated for human use (NAGA, 1994), but we have only poor grasp of ecosystem services. Thus preservation of biodiversity becomes a major environmental issue of the 21$^{st}$ century.

Biodiversity is distributed heterogeneously across the earth. Some areas are full with biological variations (e.g. tropical forests) others are virtually devoid of life (e.g. some deserts and polar regions) and most fall somewhere in between. The regions where a large number of species are found are described as megacentres of biodiversity or mega diversity zone. India is recognized as one of the World's 12 mega diversity zones. Myers (1988) developed the 'hot spots' concept to designate priority areas for *in situ* conservation. The hotspots are the richest and the most threatened reservoirs of plant and animal life on earth. The main criteria for determining a hot spot are:

(1) Number of endemic species, *i.e.* the species which are found nowhere else, and

(2) Degree of threat which is measured in terms of habitat loss.

Thirty four terrestrial hot spots for conservation of biodiversity have been identified worldwide, out of which three (Western Ghats , Eastern Himalayas and Indo-Burma region) are found in India.

The presence or absence of particular species has a profound effect on the rest of the natural community. These species are called "keystone species" (Paine, 1969, 1974). A keystone species is a "food resource" (Terborgh, 1986) or a habitat modifier, sometimes called as "ecosystem engineer" (Jones *et al.* 1994) in the ecosystem and is interdependent and forms the food web. Hence a loss of even single species results in a great loss of ecosystem and the native fish community. Nature has put her eggs in a few basket "hot spots" where their rare endemic species are concentrated (Lombord *et al.*, 1997). For the proper management and balance of ecosystem, the principles of biological outputs of a harmonic community, such as production and yield are largely dependent on other "keystone species" which usually are terminators, predators, and associated with three or four secondary species, hence, harmonic community is an integral species association with high level of niche complexity (Ryder and Karr, 1990).

The diversity of fish species comprises total number of species in a defined area (species richness), relative number of species(species abundance) and relationships between different groups of species(polygenetic diversity).

India is blessed with remarkable aquatic resources harbouring one of the richest fish fauna in the world. The Indian fish fauna enlists 2,200 fish species, constituting 11% of the world's fish germplasm. Out of this, 73 species (3.32%)

are found in upland coldwater, 544 species (24.75%) dwell in water bodies located in plains, 143 inhabit brackish water and remaining 1440 species are marine (Kapoor *et al.*, 1998; Das, 2000).

The hill streams are small bodies of water in mountain regions, flowing in a channel or water course. It is also commonly referred as brook. These streams ultimately enter the rivers. Both rivers and streams are considered as running waters (Cummins , 1975, Cummins *et al.*, 1984, Allen, 1995 ).

The Aravallis are geologically oldest folded and stable mountains not only in India but in the whole world. These hills run across the Rajasthan like a curve from S.W. to N.E. This range though not of uniform width extends for about 692 Kms. from Delhi to Palanpur, Gujarat. The loftiest and most clearly defined section of the Aravalli range is in Mewar, South Rajasthan where it forms an unbroken range (Bhalla, 1996). On the basis of slope, dimension, relief and drainage patterns the Aravalli range in Rajasthan can be subdivided into following physiographic sub units:–

a) The North Eastern hill tracts of the Alwar region.

b) The Central Aravalli region of Sambhar, Shekhawati and Merwara hills.

c) The Mewar rocky region and Bhorrat region.

d) The Abu block region.

Out of the above mentioned sub units the third one *i.e.* Mewar region and Bhorrat region was undertaken for study. Besides major rivers like Banas, Bedach, Khari, Luni and Mahi there are number of small tributaries and streams in Aravalli region of South Rajasthan. The Aravallis divide the drainage of the Bay of Bengal and Arabian sea in Rajasthan. Unfortunately no scientific study on hill stream fishes of this region has been done so far hence this investigation was undertaken.

The habitat has been identified as one of the primary criteria on which many biological communities are organized (Schoener 1974, Galacatoes *et al.* 1996). The hill streams have well defined habitats like runs, riffles, pools and rapids. The pools are the deeper areas than the other habitat types.

Investigations have been carried to know the relationship between habitat composition and fish distribution (Probst *et al.* 1984, Mc clendon and Rabeni 1987). Patterns of the habitat use by the fish have always been a very complex process and are not easily recognized in streams with high environmental variability (Angermeir and Schlosser 1989). The investigations on the Indian fresh water fishes have mainly been restricted to taxonomy (Datta Munshi and Srivastava 1988, Talwar and Jhingran 1991, Jayaram 1999). The research on the fish assemblage structure and their habitat preference/requirements in the Indian streams are few though pioneering work was done in the late 1980's on Western Ghats in South India (Arunachalam *et al.* 1988, 1997 a, b, c) and on Sri Lankan streams (Moyle and Senanayake 1984. Wickrananyake and Moyle 1989, Kortmulder *et al.* 1990).

Proposed investigation was further aimed to compare ichthyofauna of this region with hill stream fishes of Himalayas . Further most of Aravalli region is inhabited by tribal population thus conservation measures suggested would strengthen tribal economy.

The fishes of hill streams are highly adapted to flood and drought, fluctuating temperature etc. Now they are facing the new challenges resulting from activities of the humans.

The diversity of running water environment is enormous. The hill streams, which constitute an integral part of any river system, have been observed to serve as nursery grounds for most of the fish species that abode in the rivers. They provide congenial conditions for the development and growth of all the fishes that form the fishery of the rivers/reservoirs.

The fish diversity, community structure and species assemblages in the streams are interdependent on many abiotic and biotic factors. These factors determine the success or failure of fish species assemblages in the streams within the range of spatial distribution limits (Minns, 1989). The altitude plays an important role in the change of fish diversity and stream morphology because weather, climate and precipitation depend on temperature which in turn on altitude. Hence, altitude and stream morphology are deciding parameters for the fish diversity and abundance. Changes in species composition along the river's length establish longitudinal zonation that is commonly observed in fishes (Huet, 1954, 1959).

The study of hill stream fishes and their habitats is a fascinating endeavour. The hill stream of any order can determine the quantity of river water and morphology of the river which is dependent on the local geomorphology and climate. Climate, geology and soil factors that combined to produce certain plant associations, woody debris and nutrient input to a particular stream, will also influence the type of algae and invertebrate assemblages. Fish assemblage is strongly influenced by the availability of algae and other invertebrates. The use of habitats as feeding morphology and feeding abilities further determine the type of fishes present in the streams. Feeding ability in microhabitat is strongly influenced by morphology, hydrodynamics and inter-specific or intra-specific interactions. Hence modifications in fishes include flattening of the body, attainment of streamline or round body in cross-section and development of suckers and related structures. Abiotic factors not only govern the fish distribution abundance but also act as deciding factors for algae and other invertebrates. Fishes also serve as environmental indicators. Change in the composition of fish communities often indicates a variation of pH, salinity, temperature regime, solutes, flow clarity, dissolved oxygen, substrate composition or pollution level. The change in global climates, with their potential to alter the pattern of precipitation and temperature, may play a growing role in aquatic system (APHA, 1998).

Biotic features such as food composition, predators and disease may further restrict distribution and abundance.

Hill streams are classified into a number of types according to the location within channels, patterns for water flow (cascades, riffles, rapids or pools) and nature of flow (Bisson *et al.*, 1981), which mainly depend upon the bed materials (Leopold *et al.*, 1964) and gradient (Rosgen, 1996). Habitat for fish includes physical, chemical, and biological factors to sustain life which comprises suitable water quality, migration routes, spawning grounds, feeding and resting sites, shelter from predators and adverse environmental conditions (Orth and White, 1993). Thus local physical phenomena which directly have an impact on fish population composition include size of habitat, pool development permanency of water and habitat structure as well as microhabitat phenomenon such as flow pattern, oxygen concentration, temperature, depth, substrate type, cover and gradient (Wellborn *et al.*, 1996).

Substrates comprising sand, gravel, cobbles, pebbles, boulders and rocks not only provide the cover but also are spawning, breeding and feeding grounds for most of the organisms. Hence, stream morphology is an integral part of geomorphic nature, catchment area, riparian vegetation, substratum and water resources.

According to Hynes (1970), human activity has profoundly made an impact on flowing waters in all parts of the world to such an extent that it would be nearly impossible to find an unaffected stream. In the developing countries, the freshwater aquatic habitats are under stress and as a result, the first casualty is the fish biodiversity. CAMP (1998) listed 397 fish species, out of which 227 freshwater fishes are threatened, 98 of them are currently considered endangered, 82 vulnerable, 66 lower risk near threatened, 16 lower risk least concern and the correct data of 26 fish species are not available. Loss of fish diversity may occur when climatic or environmental changes (natural and anthropogenic) occur beyond its tolerance limits. Various physical factors such as rain, snow, temperature, wind *etc.* have direct reducing effect on fish biodiversity. An instantly sharp decline of fish diversity may have been caused due to natural calamities like floods, drought, earthquake, typhons, forest fire etc. The major factors leading to decline of fish biodiversity are exploitation (irrational use of gears), habitat degradation, and deforestation. Degradation or loss of habitat is due to removal of channel materials (cobbles, gravels, and sands), riparian vegetation, wide spread dumping of human refuse and release of effluents. These pollute the streams and cover the substratum with silt (sedimentation), which reduces groundwater recharge and lowers the oxygen level affecting greatly the fish communities, reduces spawning or breeding grounds and shelters of the endemic species (Almaca, 1995, Berkman and Rabeni, 1987 and Armontrout, 1995). Besides recreation, grazing, habitat fragmentation, surface water diversion (damming), impoundments and urbanization contribute for degrading the fish habitats. The other leading cause of loss of biodiversity is the exotic introductions, which typically replaces native fauna through competition, predation or parasitism and may change the dynamics of system function.

In the past there has been no appreciable effort to assess the status of fishes, their distribution and ecological requirements other than baseline inventories. Hence, the information regarding their distribution, population dynamics and merely listing of threats are not adequate to formulate any successful strategy for fish conservation. Hence present investigation is aimed at following objectives:-

- To identify and locate the lotic and lentic habitats of Aravalli region inhabiting hill stream fishes.
- To study the ecology of selected water bodies of Aravalli region inhabiting hill stream fishes.
- To study ichthyofauna of selected water bodies in Aravalli region of South Rajasthan.
- Population studies and length –weight relationship of hill stream fishes in one river system of Aravalli region.
- To study the food and feeding habits of hill stream fishes (only two species) of Aravalli region.
- To study association and assemblages of the hill stream fishes in relation to ecology of streams.
- To study the causes of decline and conservation of hill stream fishes in Aravalli region of South Rajasthan.
- To study the Scanning Electron Microscopic Structure of adhesive organ of *Garra* species.

# CHAPTER – II

# REVIEW OF LITERATURE

The review of literature is necessary to know past and present status of hill stream fishes.

The information regarding their habits, habitats, bionomics, feeding and reproductive behaviour was scattered in several publications. In order to collect all such available information this review has been prepared.

The literature has been reviewed under the following heads:

- **FISH POPULATION**
- **STREAM MORPHOLOGY**
- **ABIOTIC FACTORS**
- **BIOTIC FACTORS**
- **POPULATION STUDIES**
- **MORPHOLOGICAL ADAPTATIONS**
- **CAUSES OF DECLINE AND CONSERVATION**

## FISH POPULATION

Fishes are more diverse at all taxonomic levels and have more species than all other vertebrate groups. They constitute half of all the described vertebrates (24, 618 species out of the total of 48, 170) and comprising 482 families. (Maitland, 1995).

India is rich in fish fauna, representing 11.72% of species,23.96% of genera , 57% of families and 805 of orders of the world ( Barman,1998) . Day (1889) described 1418 species of fish under 342 genera from British India . Jayaram (1981a) listed 742 freshwater species of fishes coming under 233 genera, 64 families and 16 orders from the Indian region. Talwar and Jhingran, (1991) recorded 930 freshwater species belonging to 326 genera and 99 families in Indian waters. India constitutes 11% of world fish diversity with 2200 listed fishes (Kapoor *et al.*, 1998).

Indian fresh water fish fauna is highly diverse. Extensive literature on freshwater fishes in India is available but mostly concerned with taxonomy (Hamilton, 1822; Day, 1875; Mishra, 1976; Datta Munshi and Srivastava, 1988; Talwar and Jhingran, 1991; Menon, 1992; Jayaram, 1999).

Studies on the fish fauna of the Ganga river and its tributaries were started by the pioneering work of Hamilton (1822) and Day (1875,1878).

Hora (1927) made his study on some new or rare species of fishes from the Eastern Himalayas. Mahajan (1961) studied the fish fauna of Muzzaffarnagar district, U.P., Dhawan (1968,1969) studied ichthyofauna of Rajasthan waters. Badola and Pant (1973) made a study on fish fauna of the Garhwal hills. Erik and Sers (1992) reported the fish assemblage in Swedish streams.

Arunachalam and Soranam (1997) and Arunachalam (2000) made a report of the fish diversity in Chittar rivers of Western Ghats . Johal and Tandon (2002) described the fish diversity in different habitats in the streams of Northern and lower middle Western Himalayas.

Ichthyofauna of different states of India have been described by several workers (Hora, 1922b; Menon, 1954; Tilak and Husain, 1977; Srivastava, 1980; Johal and Tandon, 1979, 1980, 1981; Johal, 1998 , NBFGR, 1998),Biju (2003), Bagra *et al.* ( 2009) ,Goswami *et al.*( 2012) ,Gohil and Mankodi (2013),Vishwakarma and Vyas (2014),Pawara *et al.*( 2014), Vijayasree and Radhakrishnan (2014), Debnath (2015) and Shrotriy(2015) .

The state of Rajasthan has great potentialities for the growth of Inland fisheries. There are a large number of rivers, streams, lakes, tanks and seasonal ponds. However, very little is known about the hill stream fish fauna of Rajasthan. But the important work has been done by Mathur (1952), Krishna and Menon (1958), Datta Gupta *et al.*(1961), Dhawan (1968,1969), Roonwal (1969), Datta and Majumdar (1970), Mathur and Yazdani (1971), Durve (1976),Sharma and Kulshreshta (1981), Johal (1982), Sharma and Johal (1982 & 1984), Johal and

Sharma (1986) ,Kumar and Asthana (1993), Chauhan (2001), Sharma and Chaudhary(2007), Gaur (2011) and Banyal and Kumar (2014).

In Indian streams, fish diversity, assemblage and their habitat requirements are lacking, though a few initiatives started in South Indian streams (Arunachalam *et al.*, 1988, 1997a, b, c and Arunachalam, 2000), Himalayas (Edds, 1993) and in Western Himalayan streams (Johal *et al.*, 2001a and Singh 2002).

The diversity of hill stream fishes is found maximum in tropical regions. The greatest stream fish diversity is seen in Appalachian and Ozark uplands of North American region with some river system having as many as 100 to 200 species (Etnier and Starner, 1993). In Europe the entire Nida River (Poland) has about 25 fish species, and the Colorado river basin of Western North America has about 32 native fish species. In contrast, Mississippi river has 375 fish species (Burr and Mayden, 1992).

Ichthofaunal diversity is declining all over the world. The major threats to the aquatic resources are overexploitation, introduction of exotic species, habitat degradation and anthropogenic activities. In general decline of native fishes is attributed to pervasive, complex habitat and degradation across the landscape that reduce and fragment ranges and increase isolation of fish population (Angermeier, 1995 and Warren *et al.*, 1997). The existing large river dams and associated flow alterations have reduced or altered spawning grounds of many migratory fish species (Moyle and Leidy, 1992; Angermeier, 1995 and Warren *et al.*, 1997). Atleast 214 fish species mostly Salmon and Steel heads in US and Canada are at the risk of extinction (Nehlsen *et al.*, 1991 and Pacific River Council, 1993). Physical habitat alterations in the form of channalization, impoundments, sedimentation, and flow modification are frequently associated with species decline and continue to threaten southern fishes (Walsh *et al.*, 1995; Etnier, 1997 and Burkhead *et al.*, 1997).

Rapid population growth and concomitant increases in comparison of natural resources are the greatest challenge to aquatic resource management (Noss and Peters, 1995; Folkerts, 1997 and Cordell *et al.*, 1998). The current status of fishes in United States were reported by Williams *et al.* (1989) and Warren and Burr (1994) and by CAMP (1998) in Indian waters.

## STREAM MORPHOLOGY

Geomorphic features such as stream gradient, basin size, drainage density, and geologic type which all form the catchment area influence the productivity and composition of stream habitat types within a watershed and therefore, fish species composition and abundance (Bisson *et al*., 1982 and Armantrout, 2001).

Stream morphology is the integrative process of eight major variables including channel width, depth, velocity, discharge, channel shape, roughness of channel materials, sediment load and sediment size. Change in any of these variables leads to a change in channel adjustment (Leopold *et al.*, 1964).

Montgomery and Buffington (1997) classified the stream morphology into seven distinct reach types in mountain drainage basins: colluvial, bedrock, and five alluvial channel types (cascade, step-pool, plane bed, pool-riffle, and dune ripple). The bed materials have been divided into six categories *viz*., bedrocks, boulders, cobbles, pebbles, gravels, sand or silt (Armantrout, 1998).

The streams are classified into 7 major categories (A, B, C, D, E, F, & G) by Rosgen (1994, 1996) using channel characteristics derived from 450 streams or rivers throughout U.S., Canada and New Zealand. He described that all stream types are differrent in entrenchment ratio, gradient, width/depth ratio and sinuosity in various land forms involving a great diversity of hydro-physiographic, geomorphic provinces from small to larger rivers and catchment from streams in the mountains to the coastal plains. Each major category has six additional types-delineated by dominant channel material from bedrock to silt/clay along a continuum of gradient ranges.

The distribution of organisms in streams is determined by stream geomorphology which interacts with sunlight, air temperature, precipitation, and geology to produce a distribution of environmental changes (incident radiation, discharge, water-temperature, nutrients) (D' Angelo *et al.*, 1997).

Habitat features have been identified as major determinants in distribution and abundance of fishes from earlier times (Shelford, 1911) .The influence of habitat structure and complexity on fish assemblage structure has been tested in North American streams (Winn, 1958; Gorman and Karr, 1978; Smart and Gee, 1979; Baker and Ross, 1981; Schlosser, 1982, 1985 ; Capone and Kushlan, 1991 ), Australian streams (Bishop and Forber, 1991; Pusey *et al.*, 1993) and South Indian streams (Arunachalam *et al.*, 1997a, b, c and Arunachalam, 2000 and Johnson and Arunachalam, 2010 ).

Longitudinal distribution of fishes is influenced by environmental factors (microhabitat i.e. depth, flow, temperature, gradient, and substrate), temporal variation in climate, and fish movements (Evans and Noble, 1979; Stalnaker, 1979).Different type of habitat in the streams/channels i.e. pools, backwaters, riffles, run or rapids and coarse substratum (ranging in size from sand particles to bed-rock or woody-debris) are important as they provide refuge and nursery areas for juveniles of many stream fishes (Northcote, 1978 Schlosser, 1982, 85; Holland, 1986; Bain *et al.*, 1988; Copp. 1989; Gleason and Berra, 1993).

Arunachalam (2000) described macrohabitat in 10 streams of Western Ghats and found that high habitat diversity was associated with high species diversity. In all streams, cyprinids (35 species) were dominant group, almost confined to pool habitat whereas catfishes (*Glyptothorax*) in riffle habitat.

Now a days, fish assemblages have been used as indicators of environmental degradation (Scott and Hall, 1997), ecosystem health in streams (Fausch *et al.*, 1990 and Karr, 1991) and environment stress (Cairns *et al.*, 1993).

Hill streams are important part of river system and support diverse life but with increase in population stress has increased on the natural systems. Stream fishes have been greatly affected due to overexploitation, exotic introductions, habitat alteration and anthropogenic activities.

The loss of the habitat and degradation of fish diversity can be attributed to channel alterations, groundwater pumping, surface water diversion, impoundments, removal of riparian vegetation, alteration of flooding regimes, and urbanization.

## ABIOTIC FACTORS

Aquatic ecosystems derive their characters primarily from the watershed area. Physical characteristics are controlled by the physical characters of the stream water depending upon the interaction of precipitation falling on its catchment area with land use and substratum (rocks) on which it flows. The distribution and abundance of organisms are determined by the physical and chemical habitats created in these watersheds (Likens and Bormann, 1974; Hynes, 1975; Karr and Schlosser, 1978 and Thibert, 1994).Boyd (1973) studied the seasonal fluctuations of nutrients, which were closely correlated with diatom growth. High turbidity affected distribution and delayed algae production but higher temperature stimulated zooplankton production.

Hynes (1970) inferred from his study that water flow plays a central role in stream ecology which exerts control over many structural attributes in streams (eg. habitat volume, current velocity, channel geomorphology, and substratum), which is further dependent upon the slope or gradient.

Dissolved oxygen and temperature were found inversely related with each other, and the temperature was a controlling factor for the aquatic organisms. ( Reid and Wood 1976) . They also reported that chloride plays an important role in the distribution and maintenance of many organisms. Further the nitrate intake was influenced by phosphate.

Abiotic factors like quality and quantity of dissolved nutrients, daily and annual temperature ranges, water velocity, pH, oxygen concentrations, physical habitats *etc.* determine the productive capacity of fish community in a river (Zalewski and Naiman, 1985).

Thomas (1986) has shown that specific conductance is linearly correlated with TDS for cold and low ionic strength streams. High correlation was derived in river Ramganga and inverse relation of TDS with flow rate (Pathak and Bhatt, 1993). Total dissolved solids ($Na^+$, $Cl^-$, $K^+$, $SO^{-2}{}_4$) regularly increased due to human interference in the nature from stream order one to river mouth (Meybeck, 1998).

Alkaline nature of water owing to silica, securing in the form of $Si(OH)_4$ or as $SiO_2.2H_2O$ is the result of chemical weathering of silicate minerals and as finely quartz mobilized after erosion of granite (Golteman, 1975). The Silica ($SiO_2$) concentration decreases during spring and summer due to uptake by the aquatic vegetation as diatoms (Thibert, 1994 and Gernier *et al.*, 1995) and inverse correlation between $SiO_2$ and total pigment have been found in Loire river (Meybeck, 1998).

In Yamuna river Chopra *et al.* (1990) observed that abiotic variables *viz.*, water temperature, turbidity, velocity, dissolved oxygen and free $CO_2$ were related to each other and had a direct bearing with primary productivity of the river. The maximum concentration of phytoplankton was observed during winter (February) and minimum during rainy season.

Patterns of diversity of all major lotic assemblage including fish (Minckley and Meffe, 1987), invertebrates (Ward and Standford, 1983), attached algae (Peterson, 1987), and macrophytes (Haslam, 1978; Ladle and Bass, 1981), have been related to patterns of temporal variation in flow. High flow variability can reduce the consistency of biotic interactions (Power *et al.* 1988). Change in flow modifications in rivers/streams by dam construction produces extreme impact on riverine fishes due to the desirability of maintaining natural temperature and flow regimes in streams (Minckley, 1991).

Gill *et al.* (1993) reported that water in river Beas is rich in nutrients like $PO^{2-}{}_4$, $NO_3^{-1}$ with moderate in conductivity and alkalinity and hard in nature. The high concentrations of phytoplankton coupled with the high concentrations of nutrients appeared to have negative correlation with chloride.

Meybeck (1998) studied the particulate chemistry (nutrients), major ions, and heavy metals) in the Seine river basin from stream order one to river mouth. He found that maximum $NO_3^{-1}$ occurs in small agricultural streams but maximum $PO_4^{3-}$ occurs at most downstream streams. Other ions (charges) $SiO_2^{-3}$, $Na^+$, $K^+$, $Mg^{++}$, $Ca^{++}$, $HCO_3^-$, $NH_4^+$, $PO_4^{3-}$ are abundant in urban streams and linked to river eutrophication. According to Leftwich *et al.* (1997) a species is limited by its physiological tolerance to physico-chemical features such as dissolved oxygen, pH and temperature, with suitable habitat like depth, current velocity, substrate type and cover.

Various studies on limnology of freshwater resources of Rajasthan have been made by Vyas (1968), Sharma (1980), Sharma and Durve (1984), Sharma *et* *al.* (1984), Sharma and Durve (1985), Rao (1987), Ranu (2001), Chisty (2002), Sumitra (2002), Sisodia and Chaturbhuj (2006), Sharma (2007), Malara *et al.*(2007), Chandel (2008), Suthar *et al.* (2009), Mudgal *et al.* (2009), Mitharwal *et al.* (2009), Agrawal (2009),Yadav *et al.* (2010), Gaur (2011), Sharma *et al.* (2011), Rathore (2011), Gupta *et al.* (2011), Pandey and Verma (2012), Hussain *et al.* (2012; 2014), Kulshreshtha *et al.* (2013), Gaur *et al.* (2013), Surya (2014), Modi (2015) ,Srinivas *et al.* (2015) and Verma (2015) .

## BIOTIC FACTORS

Fishes mainly feed on plankton and microinvertabrates and their distribution depend upon the physiography, geology, water current and other hydrological factors.

Abundance of phytoplankton and species richness were influenced by the high turbidity, current velocity, fluctuating water levels, water depth and dissolved oxygen in Bhagirathi river (Sharma, 1985) and in Western Ganga canal (Joshi *et al.*, 1995).Badola and Singh (1981) and Nautiyal (1984) referred that in Alakananda river plankton were maximum during winter. This was attributed to low velocity, low temperature, more amount of dissolved oxygen and clearness of water.Singh and Nautiyal (1990) studied the change in macrobenthic insects (Ephemeropterans Dipterans, Coleopterans, Trichopterans, Hemipterans, Plecoptera and Odonata) with altitudinal change (from 3048m and 325m, msl) in the torrent reaches of the river Ganga.

Diatoms and other algae, various zooplankton particularly rotifers and benthic macro invertebrates are being examined for their biomonitoring potential and were studied in several rivers (Venkateswarlu, 1986; Gopal and Shah, 1993; Krishnamurthi *et al.*, 1991 and Pandey *et al.*, 1995).

The periphyton communities are very rich in diatoms, green algae, and blue green algae. Other epiphytic faunal elements include Protozoa and Rotifera (Das *et al.*, 1994; Ticku and Zutshi, 1994; Sarwar, 1996 and Kaur and Mehra, 1997).

Gupta and Michael, 1983; Verma *et al.*, 1984; Arunachalam *et al.*, 1991; Gupta, 1993 and Balasubramanian *et al.*, 1992 studied zoobenthos in different streams

Studies related to Benthos have been done by several workers *viz.* Sinha *et al.* (1992), Singh *et al.* (1994), Singh and Roy (1995), Mishra and Prasad (1997), Singh (1988), Srivastava (1959), Peter (1968), Mitra and Gosh (1992) and Sinha (1995). According to Thienemann (1925), water bodies with less than 1000 /$\mu m^2$ of benthos population are considered poor in productivity.

High variability in the habitats and diverse groups of invertebrates are the hallmark of temporary pool fauna, where larval amphibians abound without competition or predation from fish (Bishop and Forber, 1991; King *et al.*, 1996). These pools had abundant zooplankton like *Arcella* spp., *Gymnodinium* spp., *Keratella* spp., *Lepocinchlis* spp., *Euglena* spp., *Vorticella* spp., *Polyarthra* spp. and *Braechionus* spp. (Bonner *et al.*, 1997).

Riparian vegetation form the interface between aquatic and upland ecosystems which are characterized by distinct vegetations and fauna, high productivity and high density and diversity of wild life species (Armantrout, 1995 and Zalewski *et al.* 2001) and also provide shade necessary for natural temperature regimes, thus preventing excessive summer warming (Barton *et al.*, 1985). By reducing overall flow of water to stream channels, riparian vegetation also regulates sediment transport (Osborne and Kovacic, 1993) and moderates terrestrial inputs of nutrients from agricultural sources (Lowrance *et al.*, 1984).

The influence of riparian vegetation (Ross, 1986; Cummins *et al.*, 1989 and Gregory *et al.*, 1991), benthic organic matter (Cummins, 1975; Naiman and Sedell, 1979 and Newbold *et al.*, 1981 a, b) and large woody debris (Gregory *et al.*, 1991) are important functional organizations in stream community.

Zooplankton in shallow water bodies were dominated by rotifers, cladoceran or copepods (Arunachalam *et al.*, 1982; Sharma and Pant, 1984 ).

In India, notable contribution as regards to phytoplankton is done by Sreenivasan (1971), Moitra and Bhattacharya (1965), Jana (1973), Mathew (1978), Chari (1980), Nandan and Patel (1992), Pandey and Verma (1992), Mahajan and Mandloi (1998), Harikrishnan *et al.* (1999), Verma and Mohanty (2000), Saha *et al.* (2000), Dwivedi and Pandey (2002), Khanna and Singh (2002) and Kiran *et al.* (2002). Apart from aforementioned researchers the following also studied phytoplankton. Ray *et al.* (1966) and Pahwa and Mehrotra (1966) studied the phytoplankton in the river Ganga. The Yamuna at Allahabad was studied by Chakraborty *et al.* (1959) and Ray *et al.* (1966). They reported that diatoms form a dominant group amongst the phytoplankton in the river Yamuna. David (1963) studied phytoplankton in river Gandak and Brahamputra.

The study of phytoplankton in Rajasthan waters is done by Singh (1955), Rao and Choubey (1990), Bohra (1977), Vyas (1968), Vyas and Kumar (1968), Sharma (1980), Billore (1981), Sharma and Durve (1984), Rao (1987), Hussain (1990), Gupta (1992), Sharma and Gupta (1994), Soloman (1994), Shekhawat (1997), Sharma *et al.* (2000), Ranu (2001), Baghela *et al.* (2007) , Sharma *et al.*(2010) and Gaur (2011).

Zooplankton of Indian freshwaters have been studied by Ganpati (1943), Das and Srivastava (1959a), Arora (1966), Bhowmick (1968), Michael (1969), Saha *et al.* (1971), Vasisht and Sharma (1975), Nasar (1977), Rao (1977), Sarkar *et al.* (1977), Govind (1978), Mathew (1978), Ganpati and Pathak (1978), Malhotra *et al.* (1978), Saksena and Sharma (1981), Khan (1983), Rao (1984), Goswami (1985), Yadava *et al.* (1987), Michael and Sharma (1987), Saksena (1987), Bhaskaran *et al.* (1988), Pandey and Verma (1992), Venkatraman and Das (1993), , Kaushik and Saksena (1995), Isaiarasu *et al.* (1995 and 2001), Pandey *et al.* (1995), Sanjer and Sharma (1995), Sarwar and Parveen (1996), Mahajan and Mandloi (1998), Pandit (1999), Sarkar and Choudhary (1999), Kumar *et al.* (2001), Mukhopadhyay and Ghosh (2001), Sharma and Hussain (2001), Khanna and Singh (2002), Prakash *et al.* (2002).

In Rajasthan, notable contribution has been made by Nayar (1968, 70 and 71). Bohra (1976 and 77), Rao (1984), Sharma and Durve (1985), Rao (1987), Hussain (1990), Kumar and Sharma (1991), Gupta (1992), Solomon (1994), Shekhawat (1997), Dadhich and Saxena (1999), Sharma *et al.* (2000), Kumar and Rathore (2001), Ranu (2001), Sarang (2001), Saxena (2001), Chisty (2002), Sumitra (2002), Vijaylaxmi *et al.* (2003), Baghela *et al.* (2007), Sharma *et al.* (2007), Sharma *et al.*(2010), Sharma *et al* ( 2011) , Gaur (2011), Modi (2015) and Verma (2015) .

Studies related to benthos have been done by several workers *viz.* Sinha *et al.* (1992), Singh *et al.* (1994), Singh and Roy (1995), Mishra and Prasad (1997), Singh (1988), Srivastava (1959), Peter (1968), Mitra and Gosh (1992),Sinha (1995) and Gaur (2011).

## POPULATION STUDIES

### (a) MORPHOMETRY AND MERISTIC CHARACTERS

Morphometric measurements and meristic counts are considered as easiest and authentic methods for the identification of specimen which is termed as morphological systematics (Nayman, 1965). Morphometric measurement is measurements of different external body parts of an organism and meristic counts mean anything that can be counted (Talwar and Jhingran, 1991).

Morphometric and meristic characters are helpful in easy and correct identification of fish species in laboratory as well as at natural places (Jayaram, 1999). Morphometric characters are important for identifying fish species and their habitat as well as ecological criteria in any stream, lake or sea. Morphometric study is a powerful tool for characterizing strains / stocks of the same species, which involves detection of subtle variation of shape, independent of size. The complete set of measurements used to describe a form is a morphometric character set (Strauss and Bond, 1990). The studies of morphological and meristic characters of a fish give substantial information with regard to exact identification key of the species (Dhanya *et al*., 2004) and such identification is prerequisite for cytogenetic and molecular investigations.

Morphometric characters of the freshwater fishes have been studied by Godsil (1948), Marr (1955), Krumholz and Cavanah (1968), Pillay(1975b), Berg(1979), Singh (2002), Hossain *et al* (2009), Krishan and Tarana (2010)**,** Hazarika *et al* (2011) , Kanwal and Pathani (2011) , Sedaghat *et al* (2012) and Saroniya *et al* ( 2013).

### (b) FOOD AND FEEDING HABITS

A sound knowledge of food habits of fishes is a prerequisite for an understanding of their general biology, including vital aspects such as growth, breeding and migration (Golikatte and Bhat, 2011). The food and feeding habits of fish vary with the time of the day, season, size of fish, various ecological factors and different food substances present in the water body (Hynes, 1950).

An extensive work on food and feeding habits of fishes have been done by Pathani, and Das ( 1979) , Anthony ( 1985) , Kurain and Inasu (2001), Bahuguna and Badoni ( 2002) ,Ojha, ( 2002) , Rao and Prasad, (2002) , Rao and Rao, (2002),Hatikakoty and Biswas, (2003), Manoj kumar, ( 2003) , Weliange and Amarasinghe ( 2003) ,Jesu *et al* ( 2004) Mamun *et al* ( 2004) , Mondol *et al* ( 2005) , Gandotra, *et al* ( 2007) ,Gregory , *et al* ( 2007) ,Spence, *et al* ( 2007) and Shamsan (2008) in India and abroad.

Recent work on food and feeding habits of fishes have been done by several workers *viz.*, Begum *et al.* (2008), Emmanuel and Ajibola (2010), Parihar and Saksena (2010), Arthi *et al.* (2011), Masdeu *et al.* (2011), Saikia *et al.* (2012), Priyadarsini *et al.* (2012), Kanwal and Pathani (2012), Dutta *et al.* (2013) ,Mushahida-Al-Noor *et al.* (2013), Chaturvedi and Saksena (2013), Singh *et al* (2014) and Chaturvedi and Parihar (2014).

**(c) LENGTH-WEIGHT RELATIONSHIP**

Length-weight relationship in fishes was considered to follow the cube law (Allen, 1938), but Martin (1949) reported that changes occur in the shape and size of fishes as they grow and thus the parabolic relationship was considered to be superior by Le Cren (1951). According to Hile (1936) the value of exponent ‘n’ usually varied between 2.5 and 4 and in a majority of the cases. It differed with sex and locality. Nautiyal (1985c) took the pooled data and found that the calculated value range was 2.3 to 3.1. In the pooled data the value of 2.9 indicated that the length-weight relationship of *Tor putitora* closely follows the cube law and thus may be considered as the ideal fish. The gonado-somatic index too exhibited a similar trend.

The length-weight relationship of cyprinids from India has been studied by several workers (Mohan and Sankaran 1988, Kurup 1990, Reddy and Rao 1992, Biswas 1993, Pandey and Sharma 1997, Sarkar *et al.* 1999 , Sunil 2000 , Geol *et al.* 2011, Shahista Khan *et al.* 2011, Kanwal and Pathani 2011, Dahare 2011 , Dar *et al.*2012, Shafi and Yousuf 2012, Kharat and Khillare 2013, Sarkar *et al.* 2013 , Gogoi and Goswami 2014 and Das *et al.* 2015).

## MORPHOLOGICAL ADAPTATIONS

Hill streams are unique aquatic ecosystem characterised by shallow, narrow channels, low temperature, high altitude, different types of substrata, high current of water, hence the hill stream fishes develop mechanical devices to combat the force of water currents and are successfully adapted to this unique environment. Development of various types of adhesive organs is one of the prerequisites for survival of these fishes.

Fish communities in hill streams are highly adapted to the torrential nature of their habitat; the highly specialized adaptations in turn confine them to these stream; the degree of specialization also make them highly sensitive to any changes in their habitats. These changes are largely caused by anthropogenic activities in the catchment area, which have reached such levels that some of the more specialized species are facing extinction.

An early "descriptive treatment of individual morphological character versus ecology of stream fishes" was given by Hubbs (1941) who related body form to hydrodynamics of the habitat. He noted slimmer bodies (within and between species) of fast flowing habitats and features such as reduction of scale size or size of eyes in fish of swift and turbid habitat.

Hora (1952) summarized much of his earlier work on "organ of attachment" modification of ventral fins to form a suction disc, depressed body form, rugosity or ventral surface of torrent fishes in Himalayas that permit their existence in rapid mountain streams.

Pectoral fins can be used as hydrofoils to hold benthic fish to the substrate (Aleev, 1969; Jones, 1975; Lundberg and Marsh, 1976) or gasping the substrate with fin-ray tips, as in Northern American darters (Matthews, 1985) or Sculpins (Webb *et al.*, 1996). Pelvic fins also can be important structure of benthic attachment in swift waters. Hora (1952) depicted the modified pelvic fins by swift water, benthic fishes in Asia (eg. Hill stream loaches) with the fins serving as suction devices for attachment to rocks. Tandon and Gupta (1975) depicted that in

*Garra lamta* and *Labeo dero* the tail is forked (Caudal fin) and the pectoral fins are spatulated whereas in *Channa punctatus* the caudal fin and pectorals are rounded.

A relationship between oral structures and fin shape with hydrodynamics is established by Aleev (1969), Webb(1975) and Lauder and Wainwright (1992).

Liem (1980) illustrated that a very highly specialized species, presumably adapted morphologically for scrapping attached, algae, had atleast eight distinct feeding modes, each with its detailed neuromuscular repertoire. Analysis of an algae-scrapping Cichlid (Liem, 1980) and neuromuscular canalization in centrachid (Lauder, 1983) suggested that such difference in degree of specialization could account in them for the "radically different patterns of trophic diversification". Many fish species that feed by scrapping attached algae stones or other hard surface have a lower jaw modified by a ridge of cartilage (e.g. the North American Campostoma) (Matthews *et al.* 1986).

Welcomme (1985) depicted adaptations of African fishes for swift streams, including oral suckers, stiffened barbels, stout pectoral spines, and elongated body form.

Sense organs are dependent on ecology of species, and on its feeding strategy as well as on the specific stages or acts of feeding behaviour and set of abiotic and biotic factors against the background of which feeding behaviour takes place (Pavlov and Kosumyan, 1990).

SEM study of adhesive apparatus of *Garra gotyla gotyla* by Singh *et al.* (1994) and Das and Nag (2006) revealed that protrusions bearing spines present on both lips and disc and mucous pores on callous pad function based on the suction principle.

The functional morphology of the anchorage system and food scrapers of *Garra lamta* is described using SEM by Ojha and Singh (1992). Again, a detailed report on lips and associated structures of the same fish *G. lamta* is made by Pinky *et al.(*2002). Also a brief report on the presence of unculi on the upper jaw epithelium of *Cirrhinus mrigala* by Yashpal *et al.* (2009) and More recently, a detailed report on lips and associated structures of the fish *Puntius sophore* by

Tripathi and Mittal (2010). Joshi *et al.* (2011) studied SEM structure in *Glyptothorax pectinopterus.*

In the recent years, the surface ultrastructure of the adhesive apparatus of *Garra* species using SEM was studied by Teimori *et al*. (2011) and Gaur *et al*. (2013).

## CAUSES OF DECLINE AND CONSERVATION :-

Globally, rivers and streams are among the most threatened ecosystems, suffering from declines in biodiversity that are far greater than those in even the most severely affected terrestrial ecosystems (Dudgeon *et al.* 2006). In particular, climate change could be one of the main threats faced by aquatic ecosystems and freshwater biodiversity (Sala *et al.* 2000, Heino *et al.* 2009). Like many terrestrial species, the distribution of aquatic organisms could be significantly modified by climate change, as temperature has critical effects on ectotherms through its combined impacts on dissolved oxygen levels and metabolism (Portner and Knust 2007). Changes in stream flows due to increase in temperature can also be expected to further reduce the suitable habitat available for stream fish, even if total precipitation goes unchanged (Carpenter *et al.* 1992, Leith and Whitfield 1998). Recent findings have confirmed that changes in water temperatures could have significant effects, leading to alterations of fish growth and recruitment success (Schindler 2005, Daufresne 2009, Clews 2010, Nunn 2010). Furthermore, in contrast to their terrestrial counterparts, stream fish distributions are determined by biotic and abiotic factors that vary along the upstream– downstream gradient (i.e. downstream distance, stream order) (Matthews 1998, Buisson 2008). Their ability to move in response to environmental change is thus constrained by the dendritic structure of drainage basins (Fausch 2002, Brown and Swan 2010, Lise and Gael 2013).

A number of scientists worked on decline and conservation of fishes in several countries in last few decades *viz.* Maitland (1974, 1979, 1990 and 1995), Paepke (1981), Johnson and Rinne (1982), Almaca (1983), McDowall (1983), Goulding *et al.* (1988) , Skelton (1990), Williams and Miller (1990), Pollard *et al.* (1990), Moyle and Williams (1990), Reinthel and Stiassny (1990), Minckley and

Deacon (1991), Moyle and Leidy (1992), Maitland and Morgan (1997), Cowx and Welcomme (1998), Karr and Chu (1999), and Yusuf (2000).

Freshwater ecosystems and particularly rivers are among the most intensively human-influenced habitats on Earth (Dudgeon *et al.* 2006), and there is no doubt that the recent documented regional and global extinctions of freshwater fauna are due to human activities. For fish, a well-studied and high-interest taxon, habitat degradation and fragmentation, overexploitation, eutrophication and introduction of non-native species are believed to be among the greatest actual diversity threats world-wide (Dudgeon *et al.* 2006).

# CHAPTER– III

# MATERIALS AND METHODS

Before starting collections, protocols were prepared for the collection of field data. The following methodology was used to record the observations from the different streams.

1. Longitude, latitude and altitude (msl) were determined with the help of Magellan Trailblazer XL GPS system.

2. The stream gradient (both in percentage and degree) was determined between two points in the linear fashion with the help of Suunto Clinometer.

3. The stream width (mts.) was measured with Bushnell Laser Range Finder Yardage Pro 400. It is a horizontal distance (average of 5-6 points having different widths) along the stream perpendicular to the stream flow from wetland to wetland to the nearest 0.1 mt.

4. Water current ($m^3$/sec) was calculated with the help of EMCON Current Meter. Readings were recorded from 3-4 points, having different depths by placing the propeller of the EMCON Current Meter at the desired spot. Average of all these values was considered as the mean water current ($m^3$/sec) of the entire stream.

5. The stream depth was calculated with the help of a graduated iron bar. It is the vertical distance from the bottom to the upper surface layer of water. Depth was recorded from at least 7-8 points having different depths and the average of all these points was considered as the mean depth.

6. For the study of plankton, 50 litre of was filtered through 24 $mm^2$ mesh size cloth on a ring net in case of each stream. A few drops of 10% formaldehyde solution were added to preserve the plankton. This water sample was brought to the laboratory for further analysis.

7. Fishes were collected using cast nets made up of nylon webbing having the mesh size 1.0 × 0.5cm having height of 6' and proportionate round of 30'. Hand nets have been also used in shallow water. Fish samples were also collected by hooks and other traditional methods.

8. For the identification of phytoplankton, zooplankton, benthos and fishes the following references were consulted: Day (1878), Smith (1950), Jayaram (1981a, 1999), Talwar and Jhingran (1991),and Edmondson (1992).

## STREAM MORPHOLOGY

Macrohabitat structures were observed in 500m in stretches from down stream to upstream at a fixed point. Percentage of habitat types was quantified based on the visual estimation.

In order to classify the streams the methods described by Rosgen (1996) were followed.

The definitions of the habitats according to Armantrout (1998) are as follows:

- **Pool :** A segment of the stream with reduced current velocity, with depths exceeding other surrounding habitats, usable by fish for resting and cover.
- **Riffle :** A relatively shallow area with gradient less than four percent with swifter flowing water completely or nearly covering obstruction and substrates of smaller rock, gravel or bedrock, having surface and subsurface agitation but without standing waves.
- **Rapid :** A relatively deep stream section with swift current and gradients exceeding four percent resulting in a series of short drops, considerable surface agitation, standing waves, pocket pools and rocks and boulders exposed at all but high flows.
- **Run :** An area of swiftly flowing water with a gradient over four percent with minor surface agitation or waves, which approximates uniform flow and in which the slope of the water surface is roughly parallel to the overall gradient of the stream reach.

- **Cascade :** A Swift current, exposed rock and boulders, steep gradient, pocket pools, localized standing waves and considerable turbulence and surface agitation within a stopped series of drops characterize cascade.

Substrate composition of the streambed was visually or tactically estimated along each transect using the following categories as described by Armontrout (1998).

| **Substratum** | **Particle Size (mm)** |
|---|---|
| Clay | 0.004 |
| Silt | 0.004 – 0.062 |
| Sand | 0.062 – 2.00 |
| Gravel | 2.00 – 15.00 |
| Pebble | 15.00 – 63.50 |
| Cobble | 63.50 – 254.0 |
| Boulder | 254.0 – 1524.0 |
| Bedrock | > 1524.0 |

## COLLECTION AND IDENTIFICATION

A stretch of 500m of the stream was selected for sampling. The samples were chosen to represent a wide range of habitat conditions throughout the selected stream. Samples were collected from different stream habitats such as pools, riffles, runs, rapids and cascades etc. Different type of gears e.g. cast net (10 mm mesh size), dipnet, scoopnet, handnet ,angling rods and other traditional methods depending upon the depth and current were employed for the collection of fish. Most of the fishes were examined at site, counted and were released back into the streams after preserving the representative specimens for further analysis. These were preserved in 10% formalin and transported to the laboratory. Fishes were identified with the help of the keys given by Day (1875, 1878), Johal and Tandon (1979, 1980), Talwar and Jhingran (1991) and Jayaram (1999).

## POPULATION SIZE

Fish population size was estimated on the basis of fish catch and visual observations in each stream. In order to obtain total population it is of course necessary to add the catch to the number tallied in the streams. Estimation of population size was calculated using area density method.

Density of fishes = Number or counts/Area ($m^2$)

In order to determine the racial structure of the fishes, their morphometric and meristic counts were considered according to the definition given by Jayaram (1999). To find out their relationship Karl Pearson's correlation coefficient method was applied ($r=xy/\sqrt{x^2y^2}$) and regression equations were calculated ($y=a+bX$).

On the basis of meristic counts, their formulae have been described. The percentage and the proportion of body parts, in relation to total length and head length were computed.

The various morphometric characters were then classified on the basis of ranges into genetically (>10%), intermediate (10-15%), and environmentally (<15%) controlled characters (Johal *et al.* 1994). The morphometric variables are shown diagrammatically in Fig 3.1

## FOOD AND FEEDING

The juveniles and adults of hill stream fishes were collected at monthly intervals from the selected streams. After the collection, specimens were brought to the laboratory, dissected and digestive tracts were carefully removed from the body cavity and preserved in 5% formalin. The stomach contents were collected in a glass vial making up the volume to 1 ml to determine different food items eaten by the fish both qualitatively and quantitatively. Frequency of occurrence method was employed to express the percentage of each item in the gut and was determined by the formula given by Hynes (1950).

$$\text{Percentage occurrence of food items} = \frac{\text{Volume of food item}}{\text{Volume of whole gut content}} \times 100$$

The distension of the stomach is judged and classified as 'gorged or distended', 'full', '3/4full', '1/2full',1/4 full, trace etc. by eye estimation.

Feeding intensity (GSI): The feeding intensity or gastro-somatic index (GSI) was calculated using the following formula by Desai (1970).

$$GSI = \frac{\text{Weight of the gut}}{\text{Total weight of the fish}} \times 100$$

## PARASITES

Gut contents of the dissected fish were examined in a separate dish containing 5% formalin. Identification of parasites often requires microscopic examination of gut contents. For identification of parasites, Yamaguti (1959) has been consulted.

## LENGTH - WEIGHT RELATIONSHIP

The weight of fishes may be considered a function of the length and since weight is a measure of volume while length is a linear measure. The weight of fishes is said to increase approximately as the cube of the length and can be expressed by the formula $W=aL^3$ (Le Cren, 1951). The cubes law is based on the assumption that the form and specific gravity remain constant throughout the life history of the fish. But in general practice, the fish has to pass through many stages, such as hatchling, fry,fingerlings, yearlings etc. which are responsible for the deviation from the cube law. Thus the length-weight relationship of most fishes can be expressed by the general equation.

$$W = aL^n$$

Where;

W = weight in grams

L = total length in mm

a = constant

n = an exponent expressing relationship between L and W.

The value of 'n' generally lies between 2.0 - 4.0 (Hile, 1936, Martin, 1949). For an ideal fish which maintains isometric growth the value of 'n' should be 3 but this has not been observed so far (Allen, 1938).

The relationship ($W=aL^n$) when converted into logarithmic form, gives a straight line relationship graphically. Logarithmic transformation of this may be written as:

$$\text{Log } W = \log a + n\log L$$

Where, log W, the dependent variable (Y), log L the independent variable (X), n the regression coefficient or slope (b); and log a the Y - intercept. It is further stated that the formula $W=aL^n$ besides providing a means for calculating weight from length, and a direct way of converting logarithmic growth-rates calculated on length into growth-rates for weight, may also give indications of taxonomic differences and events in the life history, such as metamorphosis and the onset of maturity.

## STATUS

The status of fishes in this region was determined by the distribution of threatened species. The conservation status of the species was based on the criteria given by CAMP (1998), IUCN (2001) and IUCN (2015).

During present study the IUCN criteria were adopted with some modifications. The conservation status of fishes were made based on (i) Restricted distribution of the species and (ii) The number of species recorded.

The fishes were classified into following categories :-

**Threatened categories :**

- **Critically Endangered (CR) :** A taxon is critically endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.
- **Endangered (EN) :** A taxon is endangered when it was not critically endangered but is facing a very high risk of extinction in the wild in the near future.

- **Vulnerable (VU) :** A taxon is vulnerable when it is not CR or EN but is facing a high risk of extinction in the wild in the medium term future.

**Non-threatened categories :**

- **Low Risk – Near Threatened (LRnt ) :** A taxon is low risk when it has been evaluated and does not qualify for any of the threatened categories now but is close to qualifying for or is likely to qualify for a threatened category in the near future.
- **Low Risk- Least Concern (LRlc) :** A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

## FISH DIVERSITY

For each sampling sites species diversity was calculated by using Shannon-Weaver diversity index. (Shannon -Weaver, 1949).

**Shannon -Weaver index**

$$H = -\Sigma \text{ Pi In Pi}$$

Where,

H = Shannon Weaver index.

i = an index number for each species present in a sample.

Pi = ni/N = the number of individuals of a species (ni) divided by the total number of individuals (N) present in the entire sample.

In = Natural log

## LIMNOLOGICAL ANALYSIS

### (A) ABIOTIC FACTORS

Fish assemblage depends on the physico-chemical environment, hence changes in the composition of a fish community often indicate a variation in pH, salinity, temperature regime, solutes, flow, clarity, DO, substrate composition or pollution level. Therefore, abiotic factors play an important role in determing fish communities.

For the assessment of water quality, the samples were collected in 2 liter PVC bottles from each site and brought to the laboratory for further analysis. All water quality parameters were estimated by using the standard methods following APHA (1998) and Pandey and Sharma (2003).

**(i)** **Air and Water Temperature:** Water temperature was measured by using LCD portable digital multistem thermometer of –50°C to 150°C range . The water temperature was observed by immersing the probe of the thermometer into the surface water after taking into the beaker. The air temperature was measured with help of streamline thermometer.

**(ii)** **Conductivity:** Conductivity was measured by 'Systronics' direct reading conductivity meter and results are expressed in µS/cm.

**(iii)** **Depth of Visibility:** A standard Secchi disc of 20 cm diameter was used to determine the transparency of water. Two readings, one for disappearance and another for reappearance were recorded and the average of two was taken as depth of visibility.

$$\text{Depth of visibility (cm)} = \frac{D_1 + D_2}{2}$$

Where,

$D_1$ = Depth of disappearance in cm.

$D_2$ = Depth of reappearance in cm.

**(iv)** **Total Dissolved Solids (TDS):** Digital (Hold) TDS meter was used for estimation of total dissolved solids and results are expressed in mg/l.

**(v)** **pH:** A digital pH meter was used for measuring hydrogen ion concentration (pH) by dipping the electrode into experimental water in clean beaker at the sampling station. This pH meter was previously calibrated in the laboratory using different buffers.

**(vi)** **Chlorides:** Argentometric method was applied for estimating chloride, 1 ml of potassium chromate ($K_2CrO_4$) indicator solution was added to 100 ml of sample. This was titrated with standard silver nitrate (0.0141N) to a brick red end point. Samples with high chlorides were diluted to decrease the usage of $AgNO_3$.

Standard sodium chloride (0.0141N) solution was used for the standardization of the silver nitrate titrant. Chloride was calculated using the following formula:

$$\text{Cl (ppm)} = \frac{(A - B) \times N \times 35.450}{\text{ml. sample}}$$

Where, A = ml. titrant for sample.

B = ml. titrant for blank.

N = Normality of $AgNO_3$.

**(vii)** **Total Alkalinity:** For the estimation of alkalinity acid titrant method was followed. For this purpose 50 ml of water sample was treated with a few drops of phenolphthalein indicator. The appearance of pink colour indicates presence of carbonate alkalinity. This was titrated against 0.02 N $H_2SO_4$ until the colour disappeared. For estimating bicarbonate alkalinity a few drops of methyl orange indicator were added to the same sample and titrated with 0.02 N $H_2SO_4$ until the yellow colour changed to faint orange (yellowish pink). Total alkalinity was calculated using the formula:

$$\text{Total alkalinity (mg/l)} = \frac{A \times 1000}{\text{ml. of sample}}$$

Where,

A = Volume of standard sulphuric acid used in ml.

**(viii)** **Total Hardness:** The total hardness was calculated by taking 100 ml of sample water, which was added with few drops of 0.01 N HCl and boiled. Later 0.5 ml of buffer solution was added and titrated with standard sodium versenate with Eriochrome black T as an indicator until a green colour end point was observed. The total hardness was calculated using the following formula:

$$\text{Total hardness (ppm)} = \frac{T \times 1000}{V}$$

Where,

T = Titre value in ml.

V = Volume of sample used in ml.

**(ix)** **Dissolved Oxygen (DO):** The basic unmodified method as given by Ellis *et al.* (1948) was applied for the determination of dissolved oxygen. For this purpose water samples were collected in amber coloured oxygen sampling bottles of 125 ml capacity disallowing any air bubble to come inside the bottle. The water sample so collected was added with 1ml of manganese sulphate solution i.e., Winkler 'A' and 1ml alkaline potassium iodide solution i.e., Winkler 'B'. The contents were mixed by shaking the bottle up and down. The precipitate so formed was allowed to settle down and acidified using 2 ml concentrated sulphuric acid to dissolve the precipitate. Acidified samples were titrated against 0.025 N Sodium thiosulphate (Hypo) to a colourless end point with starch as an indicator.

Dissolved oxygen was calculated using the following formula:

$$\text{Dissolved oxygen (mg/l)} = \frac{1000 \times B \times F}{A}$$

Where,

A = Volume of sample titrated in ml.

B = Volume of hypo used.

F = Factor value (For calculation of factor value another titration was done).

**(x)** **Nitrate - Nitrogen:** For the colorimetric estimation of nitrate Brucine method was followed. The reaction between nitrate and brucine-sulfanilic acid produces a yellow color.

10 ml of water sample was taken and 2 ml NaCl solution was added to it. After adding 10 ml concentrated $H_2SO_4$ solution, it was mixed thoroughly and allowed to cool. Further 0.5 ml of Brucine – sulfanilic acid reagent was

added and again mixed completely. The rack of tubes was placed in a boiling water bath. After 20 minutes, samples were removed and immersed in a cold-water bath. After attaining thermal equilibrium, reading for standards and sample with reagent blank were taken at 410 nm on a Systronics 108 UV-visible spectrophotometer. The concentrations of $NO_3$–N were computed from the standard curve to have values of nitrate-nitrogen in mg/l.

$$\text{Nitrate (mg/l)} = \frac{\text{Concentration of standard solution}}{\text{Absorbance of standard solution}} \times \frac{\text{Absorbance of sample}}{\text{Volume of sample}} \times 1000$$

**(xi)** **Phosphate:** For the estimation of phosphate, 50 ml of filtered sample was taken in a conical flask and 2-3 drops of phenolphthalein solution were added. On appearance of pink colour, standard sulphuric acid (0.02 N) was added drop by drop until the colour disappeared. The 2 ml of acidified ammonium molybdate solution and 5 drops of stannous chloride solution were added. The blue colour developed by the presence of phosphate was measured at 690 nm on a digital Spectrophotometer using reagent blank as the reference solution. Phosphate concentration of the water sample was calculated with the help of standard curve.

$$\text{Phosphate (mg/l)} = \frac{\text{Concentration of standard solution}}{\text{Absorbance of standard solution}} \times \frac{\text{Absorbance of sample}}{\text{Volume of sample}} \times 1000$$

Inorganic phosphates (mg/l) and nitrates (mg/l) were determined by taking optical density on Systronics 108 UV-visible spectrophotometer and were based on the methodology described in APHA (1998).

**(xii)** **Silicates:** Silicates in water were determined by colorimetric method using artificial standards following Jhingran *et al.* (1982). For this 50 ml of water sample was taken in a beaker then 2 ml of 5% Ammonium molybdate solution and 0.5 ml of 25% $H_2SO_4$ were added, stirred and allowed to stand for 10 minutes. After development of color, reading for standards and samples with reagent blank were taken at 410 nm on a Systronics 108 UV-Visible Spectrophotometer. The concentration of silicates was computed from the standard curve to have values of silicates in mg/l.

$$\text{Silicates (mg/l)} = \frac{\text{Conc. of standard solution}}{\text{Absorbance of standard solution}} \times \frac{\text{Absorbance of sample}}{\text{Volume of sample}} \times 1000$$

## (B) BIOTIC FACTORS:

For the collection of plankton Henson standard plankton net with bolting silk No.25 was kept in the flowing water for an hour to enable the water flow through it. For quantitative estimation ,100 liters of stream water was filtered for plankton collection. The samples collected were preserved in 5% formaldehyde solution on the spot for counting of plankton. For living study and identification of the biota, separate water samples were collected in similar manner. Counting of plankton was done with the help of 'Sedgwick Rafter counting cell' as per the procedure described by Welch (1948).

The aquatic insects and other benthic life were collected enclosing one square meter of stream bottom with square-meshed cloth. The bottom stones, gravel and sand were upturned to dislodge the aquatic life. Each animal was then brush-picked and preserved in 5% formalin.

The standard references of Edmondson (1992), Pennack (1978), Kudo (1986) and APHA (1998) were consulted for the study of plankton and benthos.

**Primary Production:** The light and dark bottle method (Gaarder and Gran, 1927) was followed for assessment of primary production. A pair of light and dark bottles were filled with water and hanged at 6 cm below the surface water for time period of 6 hrs. The initial $O_2$ content (I.B.) of the sample was determined by Winkler method stated earlier. From the values of dissolved oxygen obtained for light and dark bottles in comparison to initial dissolved oxygen, gross primary production and net primary production were measured with following formulae:

$$\text{Gross primary production (mgc/m}^2\text{/hr)} = \frac{\text{L.B.} - \text{D.B.}}{\text{T (hrs.)}} \times \frac{0.375}{\text{PQ}} \times 1000$$

$$\text{Net primary production (mgc/m}^2\text{/hr)} = \frac{\text{L.B.} - \text{I.B.}}{\text{T (hrs.)}} \times \frac{0.375}{\text{PQ}} \times 1000$$

Where

PQ = Photosynthetic coefficient (1.2)

$$\text{Respiration}\ (\text{mgc}/\text{m}^2/\text{hr}) = \frac{\text{I.B.} - \text{D.B.}}{\text{T (hrs.)}} \times 0.375 \times 1000$$

## SEM STUDY

To study the details of the morphological adaptations in some fishes, SEM was done. The following procedure was adopted for the preparation of specimen for SEM.

Sections were cut of the adhesive apparatus with the help of a sharp blade and were fixed in 2.5% glutaraldehyde in 0.1 M Sodium Cacodylate buffer at pH 7.2–7.4 for 24 hours. After several washings in the rinsing buffer 0.1M sodium cacodylate buffer containing 7% sucrose was added and further dehydration was carried out in various grades of acetone. The specimens after acetone treatment were transferred into Emylacetate solution. Then the specimens were dried in a Polaram Critical Point Dryer (CPP) and mounted on metal stubs with double adhesive tape. The specimens were coated with 100A$^{o}$ thick layer of Gold/Palladium in JEOL sputter ion coater. The specimens were examined with JEOL TSM 6100 SEM at 20KV and the images were observed on the screen. Negatives were prepared for photographs.

The Scanning Electron microscopic study was done at Regional Sophisticated Instrumentation Centre (RSIC),Punjab University, Chandigarh .

**ABBREVIATIONS USED IN MORPHOMETRIC STUDIES**

| | | |
|---|---|---|
| TL | : | Total Length |
| FL | : | Fork Length |
| SL | : | Standard Length |
| DPVF | : | Distance between Pectoral fin & Ventral fin |
| DVAF | : | Distance between Ventral fin & Anal fin |
| DDF | : | Depth of dorsal fin |
| ED | : | Eye diameter |
| HL | : | Head length |
| HD | : | Head depth |
| IOD | : | Interorbital distance |
| LAF | : | Length of Anal fin |
| LCF | : | Length of Caudal fin |
| LCP | : | Length of Caudal peduncle |
| LDF | : | Length of Dorsal fin |
| LPF | : | Length of Pectoral fin |
| LAF | : | Length of Anal fin |
| MBD | : | Maximum body depth |
| MiBD | : | Minimum body depth |
| PrDD | : | Predorsal distance |
| PsDD | : | Postdorsal distance |
| PrAD | : | Preanal distance |
| PrOD | : | Preorbital distance |
| PsOD | : | Postorbital distance |

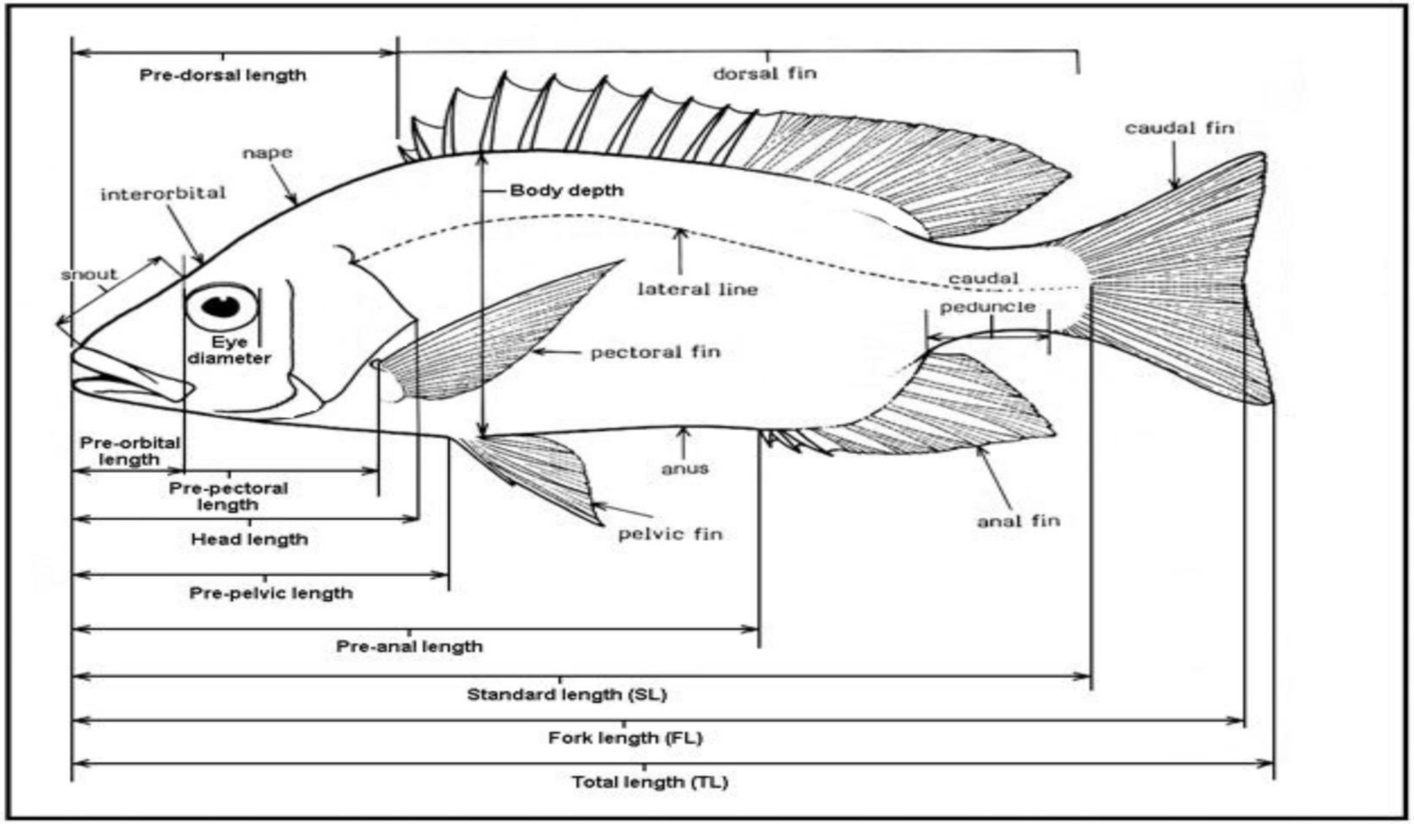


FIG 3.1 MORPHOMETRIC CHARACTERS OF A FISH

# CHAPTER – IV

# MORPHOMETRIC FEATURES OF SELECTED ARAVALLI HILL STREAMS UNDERTAKEN FOR THE STUDY

## (A) INTRODUCTION :

Rajasthan is the largest state of India ,covering an area of about 3,42274 sq. kms. It is located between 23$^{o}$ 03' to 30$^{o}$ 12' North latitude and 69$^{o}$ 70' to 78$^{o}$ 18' East longitude. The Aravalli hill range is conspicuous physiographic feature. It divides the Rajasthan into two parts - Eastern and Western Rajasthan. Various rivers and streams arise from Aravalli hills. The rivers are monsoon fed and mostly are dry during off monsoon. Although a few rivers are perennial.

In Rajasthan, the Aravalli is geographically divided into four parts :–

(a) The North Eastern hill tracts of the Alwar region.

(b) The central Aravalli region of Sambhar, Shekhawati and Marwar hills.

(c) The Mewar rocky region and Bhorrat region.

(d) The Abu block region.

## (B) GENERAL FEATURES OF STREAM

Streams in the hills appear like arteries in the body . The water flow is always very fast .They carry dissolved and suspended materials; supporting a community of plants and animals also within the riparian zone.

Streams are lifelines of hills. They not only provide drinking water to the villagers but are also spawning grounds of fishes.

The streambed mainly consists of boulders, cobbles, pebbles, gravel, silt and sand in different proportion in different reaches.

The flow of water in a stream is generally turbulent due to uneven bed. It exerts a shearing force that causes particles to move along the bed by pushing, rolling and skipping is called as bed load, whereas in rainy season the finer particles like sand and silt moves in suspension referred to as suspension load.

In the upper reaches streams are with stony bed, heavy boulders, steep gradient and bounded by hills on either side whereas finer and soft substrates like sand and silt are found in the flatter gradient/low velocity regions. It was observed during present study that where the banks are unstable, width is greater. Here stream bed is generally dominated by cobbles, gravel, sand, silt and mud. In these conditions the stream loses its energy in form of riffles and pools. The stream adopt meandering geometry pattern along with riffles and pools to dissipate kinetic energy of the moving water for the better transportation of sediments.

Habitat diversity is an important factor to determine the fish diversity. Habitat variability includes factors such as food, spawning areas, water quality, substrates and flow patterns. Macrohabitat and microhabitat combine to form total space available for organisms. Macrohabitat controls the general pattern of species distribution and abundance. These govern the flow of energy through the system and also control the distribution and abundance of microhabitat.

## (C) STREAM CLASSIFICATION

Rosgen (1996) classified the hill streams into senven broad categories namely A, B, C, D, E, F and G types based on gradient and width depth ratio.

To classify the stream , it is not desirable to employ only one character. In the present study the gradient is more reliable followed by substrate, soil features and land form. On the basis of these characters and following the criteria given by Rosgen ( 1996) , the geomorphology of the selected streams along with stream types is given in Table 4.1

The streams under report belong to two categories *viz.*, ‘C’ and ‘F’. The characteristic features of these two types of streams are as under:-

**(i) ‘C’ type streams:**

This type has an altitude between 400 – 754 m, msl. Their bed is dominated by silt and sand with occasional cobbles and gravel. The habitat includes runs, rapids and riffles. The stream gradient is < 2%.

The shapes of this type of streams are indicated by cross-sectional width /depth ratios generally greater than 12. The C type stream exhibits a sequencing of steps (riffles) and flats (pools). The primary morphological features of the C stream types are sinuous, low relief channel and well developed flood plains.

Sisarma river , Jhadol stream , Ubeshwar stream, Banas river and Thur ki pal falls into **‘C’** type streams.

**(ii) ‘F’ type streams**:

They have an altitude between 390 – 400 m, msl. Runs, pools and riffles are the main habitats of the ‘F’ type streams. The gradient is < 0.5%. The ‘F’ type streams are gravel dominated followed by sand and cobbles. Width /depth ratio is > 12.

Nandeshwar stream , Barapal stream and Jhameshwar stream belong to **‘F’** type streams

## D. STREAMS UNDER INVESTIGATION

Although the complete South Rajasthan is covered and fish samples represent wider area but the selected research sites are given in table 4.1 ( Fig - 4.1 -4.2, Plates – 4.1- 4.10)

### River Sisarma:

River Kotra and Amonjok meet near village Sisarma and after this meeting point up to Pichhola lake ,this river is known as Sisarma. The river seems to be named after village Sisarma . It is the main feeding source of Pichhola lake.**(Plate 4.1)**

**Jhadol Stream:**

It is located 10 Km south east of Jhadol Village in Jhadol Tehsil of Udaipur district. It is situated on a tributary of river Wakal. It has a good catchment area. In future the water of Jhadol tank will be brought to the Pichhola lake and will be used as Potable water for the people of Udaipur city. **(Plate 4.2)**

**Ubeshwar Stream:**

The Origin of this Stream is from Ubeshwar plateau near Shankar khera Village. It meets in lake Bari. It is also known as Morwania Ki Nadi. It meets in Bari Tank near village Morwania. **(Plate 4.3)**

**Nandeshwar Stream:**

It is near village Nai in Girwa tehsil of Udaipur district. A dam is built on River Kotra and used as water tank for the city of Udaipur . Water from Dewas and Wakal accumulates in nandeshwar dam and then release for Pichhola lake. **(Plate 4.4)**

**Banas River :**

It originates in the Khamnor hills of the Aravalli range (about 5 km from Kumbhalgarh) and flows generally in a southwest-northeast direction. Entire length of the river is about 512 km, which lies in Rajasthan State. It is a major tributary of the River Chambal, to which it meets near village Rameshwar in the Khandar Block in Sawai Madhopur District. **(Plate 4.5)**

**Barapal Stream:**

A dam is constracted on River Tidi near village Barapal on N.H. No 8 . It is mainly for iirigation purpose .It is also being planned to brought water from this reservoir to Udaipur city as potable water. It is about 30 K.M. from Udaipur on Udaipur Ahmedabad N.H. No.8. **(Plate 4.6)**

**Thur ki Pal:**

It is about 15 Km North Udaipur city on Udaipur –Gogunda road near Thur village. It is one of the oldest dam which was initially built for the cultivation of sugarcane in this region. It is built on Ahar River which originated from east of Gogunda Town. At present it is in damaged condition . **(Plate 4.7)**

**Jhameshwar stream:**

It originates from south of Udai Sagar .It was one of the perennial stream of this region. It meets Gomti River and Gomti River meets in Jaisamand Lake. **(Plate 4.8)**

**Lake Fateh Sagar:**

It is situated in the city of Udaipur . It is an artificial lake named after Maharana Fateh Singh ,constructed to the north-west of Udaipur, located to the north of Lake Pichhola .The runoff emerging from surrounding hills drains into this lake. The lake is pear-shaped and is encircled by the Aravalli hills on three sides with a straight gravity stone masonry dam on the eastern side which has a spillway to discharge flood flows during the monsoon season.Three causeways, one from Pichhola Lake, the other from Madar Lake and the third one from Badi Lake lead to the Fateh Sagar Lake. There are three inlet channels, which feed the lake and an overflow section on the eastern side in the Masonry dam of 800 m length. **(Plate 4.9)**

**Lake Pichhola :-**

It is situated in Udaipur city , is an artificial fresh water lake.The Sisarma stream, a tributary of the Kotra River, drains a catchment of 55 $km^2$ from the Aravalli Mountains and contributes to the flows in the lake. The average annual rainfall in the lake basin is 635 millimetres (25.0 in). The lake has a surface area of about 696 ha. It is 4 kilometres long and 3 kilometres wide, and has depth varying from a minimum of 4.32 metres (14.2 ft) to a maximum of 8.5 metres (28 ft). **(Plate 4.10)**

Lake Fateh Sagar and Lake Pichhola were included for study as during monsoon season these used to be over flow and these reservoirs maintaining continuous flow within this chain of Lakes and Rivers.

## RIVER SISARMA

| | | |
|---|---|---|
| Nearest village | : | Sisarma |
| Origin of River/ Stream | : | Meeting Point of River Kotra and Amonjok near village Sisarma |
| River Basin | : | Kotra |

**Geographical Location**

| | | |
|---|---|---|
| Longitude | : | 73°39'15"E |
| Latitude | : | 24°34'15"N |
| Altitude (m,msl) | : | 540 |
| Bed Features | : | The bed is mainly composed of small boulders in addition to the cobbles, gravels and sand . |
| Stream gradient | : | < 2 % |
| Width/Depth Ratio | : | >12 |
| Stream type | : | C |
| General description | : | The water current is fast in rainy season but moderate in winter. The banks are stable with riparian vegetation. The flood plain area is moderate. |
| Pollution/ Human impact | : | Domestic and agricultural waste. |

## JHADOL STREAM

| | | |
|---|---|---|
| Nearest village | : | Jhadol |
| Origin of River/ Stream | : | Near village Jhadol |
| River Basin | : | Wakal |

**Geographical Location**

| | | |
|---|---|---|
| Longitude | : | 73°29'15"E |
| Latitude | : | 24°24'15"N |
| Altitude (m,msl) | : | 605 |
| Bed Features | : | The bed is mainly composed of small and large boulders in addition to the cobbles and gravels . |
| Stream gradient | : | < 2% |
| Width/Depth Ratio | : | >12 |
| Stream type | : | C |
| General description | : | The water current is fast in rainy season but moderate in winter. The banks are stable with riparian vegetation. The flood plain area is moderate. |
| Pollution/ Human impact | : | Domestic and agricultural waste. |

## UBESHWAR STREAM

| | | |
|---|---|---|
| Nearest village | : | Morvania |
| Origin of River/ Stream: | | Ubeshwar plateau near Shankar khera village |
| River Basin | : | Morvani |

**Geographical Location**

| | | |
|---|---|---|
| Longitude | : | 73°36'30"E |
| Latitude | : | 24°37'0"N |
| Altitude (m, msl) | : | 700 |
| Bed Features | : | The bed is characterised by Small boulders, cobbles, pebbles, gravels and sand . |
| Stream gradient | : | < 2 % |
| Width/Depth Ratio | : | >12 |
| Stream type | : | C |
| General description | : | The water current is fast in rainy season but moderate in winter. The banks are unstable with riparian vegetation. |
| Pollution/ Human impact: | | Domestic and agricultural waste |

**NANDESHWAR STREAM**

| | | |
|---|---|---|
| Nearest village | : | Nai |
| Origin of River/ Stream: | | Nandeshwar dam |
| River Basin | : | Kotra |

**Geographical Location**

| | | |
|---|---|---|
| Longitude | : | 73°37'20"E |
| Latitude | : | 24°32'0"N |
| Altitude (m,msl) | : | 660 |
| Bed Features | : | The dominant bed features are cobbles, pebbles and gravel followed by small boulders. |
| Stream gradient | : | < 0.5 % |
| Width/Depth Ratio | : | >12 |
| Stream type | : | F |
| General description | : | It is seasonal stream having fast water current in rainy season but moderate in winter. The banks are unstable . |
| Pollution/ Human impact: | | Domestic and agricultural waste. |

## RIVER BANAS

| | | |
|---|---|---|
| Nearest village | : | Nandeshma |
| Origin of River/ Stream | : | Originates in the Khamnor Hills of the Aravalli range |
| River Basin | : | Banas |

**Geographical Location**

| | | |
|---|---|---|
| Longitude | : | 73°29'45"E |
| Latitude | : | 24°52'30"N |
| Altitude (m,msl) | : | 750 |
| Bed Features | : | The bed is mainly composed of rocks, large and small boulders in addition to the cobbles , gravels ,sand and silt. |
| Stream gradient | : | > 2% |
| Width/Depth Ratio | : | >12 |
| Stream type | : | C |
| General description | : | The water current is fast in rainy season but moderate in winter. The banks are stable with riparian vegetation. The flood plain area is moderate. |
| Pollution/ Human impact | : | Domestic and agricultural waste. |

## BARAPAL STREAM

Nearest village : Barapal

Origin of River/ Stream : Barapal Dam

River Basin : Tidi

**Geographical Location**

Longitude : 73°38'12"E

Latitude : 24°23'30"N

Altitude (m,msl) : 540

Bed Features : The bed is dominated by silt and sand with cobbles and gravel .

Stream gradient : < 0.5%

Width/Depth Ratio : >12

Stream type : F

General description : It is Monsoon Stream. The water current is moderate. The banks are unstable with riparian vegetation.

Pollution/ Human impact: Agricultural waste.

## THUR KI PAL

| | | |
|---|---|---|
| Nearest village | : | Thur |
| Origin of River/ Stream | : | Dam |
| River Basin | : | Berach |

**Geographical Location**

| | | |
|---|---|---|
| Longitude | : | 73°38'15"E |
| Latitude | : | 24°40'30"N |
| Altitude (m,msl) | : | 620 |
| Bed Features | : | The bed is mainly composed of small boulders in addition to the cobbles, gravels and sand . |
| Stream gradient | : | < 2% |
| Width/Depth Ratio | : | >12 |
| Stream type | : | C |
| General description | : | The water current is fast in rainy season but moderate in winter. The banks are stable as well unstable with riparian vegetation. The flood plain area is moderate. |
| Pollution/ Human impact | : | Domestic and agricultural waste. |

## JHAMESHWAR STREAM

Nearest village : Jamer Kotra

Origin of River/ Stream: Udai Sagar

River Basin : Kotra

**Geographical Location**

Longitude : 73°52'0''E

Latitude : 24°28'30''N

Altitude (m,msl) : 520

Bed Features : The dominant bed features are cobbles , pebbles and gravel followed by small boulders.

Stream gradient : < 0.5%

Width/Depth Ratio : >12

Stream type : F

General description : The water current is fast in rainy season but moderate in winter. The banks are stable as well unstable.

Pollution/ Human impact: Minning and agricultural waste.

## LAKE FATEH SAGAR

| | | |
|---|---|---|
| Nearest village | : | Udaipur City |
| Origin of River/ Stream | : | Dam |
| River Basin | : | Morvania ki nadi |

**Geographical Location**

| | | |
|---|---|---|
| Longitude | : | 73°40'31"E |
| Latitude | : | 24°36'07"N |
| Altitude (m,msl) | : | 587 |
| Bed Features | : | The bed is mainly composed of small boulders in addition to the cobbles, gravels, sand and mud. |
| General description | : | It is an artificial lake constructed to the north-west of Udaipur.The runoff emerging from surrounding hills drains into this lake. The lake is pear-shaped and is encircled by the Aravalli hills on three sides with a stone masonry dam on the eastern side which has a spillway to discharge flood flows during the monsoon season. |
| Pollution/ Human impact | : | Domestic and agricultural waste. |

## LAKE PICHHOLA

Nearest village : Udaipur City

Origin of River/ Stream : Dam

River Basin : Sisarma

**Geographical Location**

Longitude : 73°40'0"E

Latitude : 24°34'0"N

Altitude (m,msl) : 582

Bed Features : The bed is mainly composed of small boulders in addition to the cobbles, gravels , sand and mud.

General description : It is an artificial fresh water lake. The Sisarma stream, a tributary of the Kotra River, drains a catchment of 55 $km^2$ from the Aravalli Mountains and contributes to the flows in the lake.

Pollution/ Human impact: Domestic and agricultural waste.

**Table 4.1: Location and physiography of study area**

| Name of Streams/ Rivers | Latitude | Longitude | Altitude (m, msl) | Location by collection point and near town | River basin | Stream Type |
|---|---|---|---|---|---|---|
| Sisarma river | 24°34'15"N | 73°39'15"E | 540 | 6 Km. from Udaipur<br>Udaipur-Jhadol Road | Kotra | C |
| Jhadol stream | 24°24'15"N | 73°29'15"E | 605 | 25 Km. from Udaipur<br>Udaipur-Jhadol Road | Wakal | C |
| Ubeshwar stream | 24°37'0"N | 73°36'30"E | 700 | 14 Km. from Udaipur<br>Udaipur-Ubeshwar Road Near Morvania | Morvani | C |
| Nandeshwar stream | 24°32'0"N | 73°37'20"E | 660 | 13 Km. from Udaipur<br>Udaipur-Jhadol Road | Kotra | F |
| Banas river | 24°52'30"N | 73°29'45"E | 750 | 55 Km. from Udaipur<br>Udaipur-Gogunda Road Near Nandeshma | Banas | C |
| Barapal Stream | 24°23'30"N | 73°38'12"E | 540 | 22 Km. from Udaipur<br>Udaipur-Ahmedabad Road Near Tidi | Tidi | F |
| Thur ki Pal stream | 24°40'30"N | 73°38'15"E | 620 | 18 Km. from Udaipur<br>Udaipur-Iswal Road | Berach | C |
| Jhameshwar stream | 24°28'30"N | 73°52'0"E | 520 | 25 Km. from Udaipur<br>Udaipur-Jamer kotra Road | Jameri | F |
| Fateh Sagar lake | 24°36'07"N | 73°40'31"E | 587 | Udaipur city | Morwania ki nadi | - |
| Pichhola lake | 24°34'0"N | 73°40'0"E | 582 | Udaipur city | Berach | - |

# CHAPTER – V

# HILL STREAM ICHTHYOFAUNA OF ARAVALLI REGION BELONGING TO SOUTH RAJASTHAN

## INTRODUCTION

Rajasthan state (formerly called Rajputana) is the largest and the Western most state of India. It is situated between latitudes 23$^{o}$ 10' and 30$^{o}$ 30' North and longitudes 69$^{o}$ 50' and 78$^{o}$ 25' East. Rajasthan is cut into two unequal halves by the Aravalli hills. 25$^{o}$ 0' N and 73$^{o}$ 18' E (highest peak Guru Shikhar near Mount Abu 6500 ft. above mean sea level) into South West and North East. The smaller Southern part was undertaken for the study which is rocky and served by rivers like Banas, Mahi, Chambal, Berach, and Sisarma.

The state of Rajasthan has great potentialities for the growth of inland fisheries. There are a large number of rivers, streams, lakes, tanks and seasonal ponds. However, very little is known about the hill stream fish fauna of Rajasthan, but the important work has been done by Hora and Mathur (1952), Mathur (1952), Krishna and Menon (1958), Datta Gupta *et al.* (1961), Dhawan (1968),Roonwal (1969), Datta and Majumdar (1970), , Mathur and Yazdani (1971), Choudhary (1978), Johal and Dhillon (1981), Sharma and Kulshreshta (1981),Johal (1982), Sharma and Johal (1982 and 1984), Johal and Sharma (1986), Kumar and Asthana (1993), Chauhan (2001), Sharma and Chaudhary(2007), Gaur (2011) and Banyal and Kumar (2014).

The collections of fish were made throughout the year during 2013-14 and 2014-15 from short stretches of selected water bodies of Aravalli region.

To study the fish diversity in these streams in relation to abiotic and biotic factors and stream morphology, fish samples, water samples and plankton were collected seasonally. Different type of gears e.g. castnet (10 mm mesh size), dipnet, handnet sometimes baited hooks and other traditional methods were used to catch the specimens. Most of the fishes were examined at the site, counted and were released back into the streams and representative specimens were preserved in 5% formalin. Fishes were identified with the help of the keys given by Day (1875, 1878), Talwar and Jhingran (1991) and Jayaram (1999).

## (A) FISH FAUNA

### Observations

A list of fishes with their local and scientific names have been presented in the table 5.1. Besides these information; the maximum size observed , IUCN status and economic value have also been mentioned.

### Result and Discussion :

During present study total 32 ichthyospecies have been recorded from the selected waterbodies belonging to 23 genera and 10 families.The members of family Cyprinidae were represented by 17 species (53%), followed by Channidae and Bagridae with three species each(10%), Balitoridae and Siluridae was expressed by two species each(6%), Notopteridae, Saccobranchidae, Centropomidae, Belonidae and Mastacembelidae were represented by one species only(3%) (Fig 5.1). Family Cyprinidae was represented by the *Chela bacaila, Rasbora daniconius, Puntius ticto, Systomus sarana, Puntius sophore, Garra gotyla, Tor tor, Amblypharyngodon mola, Danio rerio, Osteobrama cotio, Catla catla, Cirrhinus mrigala, Labeo rohita, Labeo bata, Labeo boggut, Labeo gonius* and *Labeo calbasu.* Family Notopteridae by *Notopterus notopterus.* Family Balitoridae by *Noemachielus botia* and *Noemacheilus denisonii.* Bagridae by *Sperata seenghala, Mystus cavasius* and *Mystus oar,* Siluridae by *Wallogo attu* and *Callichrous pabda,* Saccobranchidae by *Heteropneustes fossilis* .Channidae by *Channa punctatus,Channa marulius* and *Channa striatus.* Centropomidae by *Chanda nama.* Belonidae by *Xenentodon cancila* and Mastacembelidae by *Mastacembelus armatus* covering all the sites.

As per previous study, Datta and Majumdar (1970) recorded 75 fish species belonging to 36 genera and 16 families from Rajasthan, as per records of Zoological Survey of India. Johal *et al.* (1993) discovered 95 fish species belonging to 52 genera, 7 orders and 5 super orders. Gaur (2011) recorded 30 species belonging to 20 genera and 8 families from some tributaries of river Chambal of South-eastern Rajasthan.

## (B) SHANNON -WEAVER DIVERSITY INDEX :

The concept of the "species diversity" involves two components: the number of species or species richness and the distribution of individuals among species. During present study Shannon-Weaver diversity was calculated for the selected sites (Tables 5.2, 5.3 and fig- 5.2 ).The highest Shannon- Weaver diversity index was found in lake Fateh Sagar (**3.20659)** where lowest was observed in Ubeshwar stream (**1.66378**).

**Results and Discussion:**

- During present study the Shannon-Weaver diversity index ranged between 1.66378 to 3.20659 indicating a moderate diversity in the selected waterbodies .
- The Sisarma river is a C- type stream holds 13 species with abundance of 58. The Shannon Weavers diversity index of this stream is 2.12765.
- Jhadol which is also a C-type stream, supports 12 species with abundance of 27 and its diversity index is 2.40276.
- Ubeshwar too a C type stream, harbours just 8 species with abundance of 68. Its Shannon- Weavers diversity index is 1.66378.
- Nandeshwar, an F-type stream sustains 8 species; abundance of 28. Its Shannon -Weavers diversity index is 1.87835.
- Banas river is a C-type stream holds 16 species and abundance of 40. The Shannon- Weavers diversity index of this stream is 2.57917.
- Barapal is an F-type stream supports 8 species and an abundance of 25. Its Shannon- Weavers diversity index is 1.91129.

- Thur ki Pal is a C-type stream upholding 8 species with abundance of 26. The Shannon- Weavers diversity index of this stream is 1.97138.
- Jhameshwar is an F-type stream harbours 9 species with abundance of 26. Its Shannon- Weavers diversity index is 2.02093.

Besides these eight lotic water bodies , two lentic water bodies were also selected during present study *i.e.* Lake Fateh Sagar and Lake Pichhola.

- Lake Fateh Sagar supports 28 species with abundance of 78. Its Shannon- Weavers diversity index is 3.20659.
- Lake Pichhola holds 29 species with abundance of 83. Its Shannon- Weavers diversity index is 3.17443.

As far as lotic water bodies concern, the maximum species richness was observed in river Banas. Its dominating fishes are *Rasbora daniconius, Puntius ticto, Chela bacaila, Garra gotyla, Channa punctatus* and *Amblypharyngodon mola* whereas the supporting fish fauna includes *Systomus sarana, Puntius sophore, Noemacheilus botia, Noemacheilus denisonii, Xenentodon cancila, Danio rerio, Osteobrama cotio, Labeo gonius, Mystus cavasius* and *Heteropneustes fossilis*. Its species richness is fair.

This is followed by Jhadol stream. Its dominant fishes are *Puntius sophore, Amblypharyngodon mola, Noemacheilus botia, N. denisonii, Cirrhinus mrigala, Labeo rohita* and *Channa punctatus*. The supporting fish fauna includes *Heteropneustes fossilis, Channa marulius, C. striatus ,Mystus cavasius and Xenentodon cancila.*

River Sisarma dominanted by *Puntius ticto, P.sophore ,Chela bacaila, Rasbora daniconius, and Chanda nama* and supported by *Heteropneustes fossilis, Danio rerio, Osteobrama cotio, Channa marulius, C. striatus, Garra gotyla, Noemacheilus botia and N. denisonii.*

Jhameshwar stream is dominated by *Chela bacaila, Rasbora daniconius, Puntius ticto* and *Noemacheilus botia* but supported by *Garra gotyla, Channa punctatus, C. striatus, Noemacheilus denisonii* and *Chanda nama.*

Thur ki Pal stream is dominated *by Rasbora daniconius, Puntius ticto, Chela bacaila, Noemacheilus botia, N. denisonii* and *Channa punctatus and* *supported by Osteobrama cotio* and *Garra gotyla* .

Stream Barapal is dominated by *Rasbora daniconius, Puntius ticto, Garra gotyla, Noemacheilus botia* and *N. denisonii* and supported by *Chela bacaila, Channa punctatus* and *Mastacembelus armatus.*

Nandeshwar stream is dominated by *Rasbora daniconius, Chela bacaila, Noemacheilus botia, N. denisonii* and *Chanda nama* and supported by *Puntius ticto ,Channa striatus and Garra gotyla.*

Ubeshwar stream is dominated by *Rasbora daniconius, Chela bacaila Garra gotyla, Noemacheilus botia, N. denisonii* and *Puntius ticto* and supported by *Heteropneustes fossilis* and *Channa marulius.* Thus its diversity is poor . This is due to construction of road on its bed and also construction of the weirs.

Lake Fateh Sagar is dominated by *Rasbora daniconius, Chela bacaila ,Puntius ticto, Systomus sarana Catla catla, Labeo rohita , Notopterus notopterus, Sperata seenghala, Mystus oar ,Channa punctatus, C. marulius , Callichrous pabda* and *Chanda nama* and supported by *Puntius sophore, Amblypharyngodon mola,Cirrhinus mrigala, Labeo bata, L. boggut, L.gonius, L. calbasu Noemacheilus botia, N. denisonii, Mystus cavasius, Wallago attu, Heteropneustes fossilis,Channa striatus, Xenentodon cancila* and *Mastacembelus armatus.*

Lake Pichhola is dominated by *Chela bacaila, Puntius ticto, Rasbora daniconius Catla catla, Labeo rohita , Noemacheilus botia, N. denisonii, Notopterus notopterus, Sperata seenghala, Mystus oar ,Channa punctatus, C. marulius , Callichrous pabda* and *Chanda nama* and supported by *Puntius sophore, Systomus sarana Amblypharyngodon mola,Cirrhinus mrigala, Labeo bata, L. boggut, L.gonius, L. calbasu Mystus cavasius, Wallago attu Heteropneustes fossilis,Channa striatus, Tor tor ,Xenentodon cancila* and *Mastacembelus armatus.*

Both Lake Fateh Sagar and Lake Pichhola have the maximum species richness, abundance and high Shannon-Weaver diversity.

The species richness also depends upon factors like alkalinity, conductivity, water current and hardness. The same was gauged by Sehgal (1988, 1990) and Johal *et al.* (2001). It is worthy to conclude that pool habitat has maximum species richness.

**Table 5.1: Ichthyofauna of selected waterbodies of South Rajasthan**

| S.No. | Species | Local name | Max. size observed | Status | Economic value | Plate |
|---|---|---|---|---|---|---|
| **Family – Cyprinidae** | | | | | | |
| 1. | *Chela bacaila* (Ham.) | Chilwa | 16 cm | LRlc | LV | **Plate-5.1A** |
| 2. | *Rasbora daniconius* (Ham.) | Zebra | 18 cm | LRlc | LV | **Plate-5.1B** |
| 3. | *Puntius ticto* (Ham.) | Putti | 12 cm | LRlc | BT,LV,WF | **Plate-5.1C** |
| 4. | *Systomus sarana* (Ham.) | Putti | 22 cm | VU | BT,LV,WF | **Plate-5.2A** |
| 5. | *Puntius sophore* (Ham.) | Putti | 10 cm | LRlc | BT,LV,WF | **Plate-5.2B** |
| 6. | *Garra gotyla* (Gray) | Patthar chata | 16 cm | VU | MD | **Plate-5.2C** |
| 7. | *Tor tor* (Ham-Buch) | Mahseer | 35 cm | CR | FD | **Plate-5.3A** |
| 8. | *Amblypharyngodon mola* (Ham.) | Mola | 14cm | LRlc | LV | **Plate-5.3B** |
| 9. | *Danio rerio (* Ham.) | - | 11 cm | VU | MD | **Plate-5.3C** |
| 10. | *Osteobrama cotio* (Ham.) | Rohtee | 5 cm | LRnt | LV | **Plate-5.4A** |
| 11. | *Catla catla* (Ham.) | Catla | 25 cm | LRlc | FD | **Plate-5.4B** |
| 12. | *Cirrhinus mrigala* (Ham.) | Mrigal | 22cm | LRnt | FD | **Plate-5.4C** |
| 13. | *Labeo rohita (Ham.)* | *Rohu* | 24 cm | LRlc | FD | **Plate-5.5A** |
| 14. | *Labeo bata* (Ham.) | Bata | 18 cm | LRnt | FD | **Plate-5.5B** |
| 15. | *Labeo boggut* (Sykes ) | Dudhiya | 16 cm | LRlc | FD | **Plate-5.5C** |

| S.No. | Species | Local name | Max. size observed | Status | Economic value | Plate |
|---|---|---|---|---|---|---|
| 16. | *Labeo gonius* (Ham.) | Sarsi | 15 cm | VU | FD | **Plate-5.6A** |
| 17. | *Labeo calbasu* ((Ham.) | Kalaut | 17 cm | LRnt | FD | **Plate-5.6B** |
| **Family – Notopteridae** | | | | | | |
| 18. | *Notopterus notopterus* (Pallas) | Patola | 22 cm | EN | PF, FD | **Plate-5.6C** |
| **Family – Balitoridae** | | | | | | |
| 19. | *Noemacheilus botia* (Ham.) | Bamna | 10 cm | LRlc | MD | **Plate-5.7A** |
| 20. | *Noemacheilus denisonii* (Ham.) | Bamna | 7.5 cm | LRlc | MD | **Plate-5.7B** |
| **Family- Bagridae** | | | | | | |
| 21. | *Sperata seenghala* (Sykes) | Singhara | 32 cm | LRlc | PF,FD | **Plate-5.7C** |
| 22. | *Mystus cavasius* (Ham.) | Katava | 18 cm | VU | PF, FD | **Plate-5.8A** |
| 23. | *Mystus oar* (Ham.) | | 19 cm | LRlc | PF, FD | **Plate-5.8B** |
| **Family – Siluridae** | | | | | | |
| 24. | *Wallago attu* (Bloch) | Lachi | 32 cm | VU | PF, FD | **Plate-5.8C** |
| 25. | *Callichrous pabda* (Bloch) | Pabda | 18 cm | VU | FD | **Plate-5.9A** |
| **Family-Saccobranchidae** | | | | | | |
| 26. | *Heteropneustes fossilis* (Ham.) | Singhi | 11cm | VU | FD | **Plate-5.9B** |
| **Family – Channidae** | | | | | | |

| S.No. | Species | Local name | Max. size observed | Status | Economic value | Plate |
|---|---|---|---|---|---|---|
| 27. | *Channa punctatus* (Bloch) | Girhi | 12 cm | LRlc | FD ,MD | **Plate-5.9C** |
| 28. | *Channa marulius* (Ham.) | Saval | 10 cm | VU | FD,MD | **Plate-5.10A** |
| 29. | *Channa striatus* (Bloch) | Kabra | 8 cm | LRlc | FD | **Plate-5.10B** |
| **Family – Centropomidae** | | | | | | |
| 30. | *Chanda nama* (Ham.) | Sisa | 11cm | LRlc | LV, PF | **Plate-5.10C** |
| **Family – Belonidae** | | | | | | |
| 31. | *Xenentodon cancila* (Ham.) | Suhia | 28 cm | VU | WF | **Plate-5.11A** |
| **Family – *Mastacembelidae*** | | | | | | |
| 32. | *Mastacembelus armatus* (Lacepede) | Bam | 40 cm | LRnt | PF | **Plate-5.11B** |

LV – Larvivorous fish , BT- Bait, PF- Predatory Food Fish, WF- Weed Fish, MD- Medicinal Value, FD- Food Fish .

CR-Critically endangered, EN-Endangered,VU- Vulnerable, LRnt- Low risk near threatened, LRlc - Low risk least concern

**Table 5.2: Abundance of Hill Stream Fishes in selected waterbodies of South Rajasthan**

| S.No. | Fish species | Sisarma | Jhadol | Ubeshwar | Nandeshwar | Banas | Barapal | Thur ki Pal | Jhameshwar | Fatehsagar | Pichhola | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | *Chela bacaila* (Ham.) | 6 | - | 16 | 3 | 4 | 2 | 2 | 4 | 5 | 7 | 49 |
| 2. | *Rasbora daniconius* (Ham.) | 15 | - | 25 | 8 | 2 | 4 | 4 | 3 | 9 | 4 | 78 |
| 3. | *Puntius ticto* (Ham.) | 13 | - | 4 | 2 | 9 | 4 | 6 | 7 | 4 | 10 | 58 |
| 4. | *Systomus sarana* (Ham.) | - | - | - | - | 2 | - | - | - | 3 | 2 | 7 |
| 5. | *Puntius sophore* (Ham.) | 3 | 4 | – | – | 2 | – | – | – | 2 | 4 | 15 |
| 6. | *Garra gotyla* (Gray) | 2 | - | 12 | 1 | 3 | 7 | 2 | 1 | - | - | 28 |
| 7. | *Tor tor* (Ham-Buch) | – | - | – | – | - | – | – | – | - | 1 | 1 |
| 8. | *Amblypharyngodon mola* (Ham.) | – | 2 | – | – | 2 | – | – | – | 2 | 3 | 9 |
| 9. | *Danio rerio*(Ham.) | 1 | - | - | - | 2 | - | - | - | - | - | 4 |
| 10. | *Osteobrama cotio* (Ham.) | 1 | - | - | - | 1 | - | 1 | - | - | - | 3 |
| 11. | *Catla catla* (Ham.) | – | - | – | – | – | – | – | – | 3 | 4 | 7 |
| 12. | *Cirrhinus mrigala* (Ham.) | – | 2 | – | – | – | – | – | – | 2 | 2 | 6 |
| 13. | *Labeo rohita* (Ham.) | – | 2 | – | – | – | – | – | – | 4 | 2 | 8 |
| 14. | *Labeo bata* (Ham.) | – | - | – | – | – | – | – | – | 2 | 1 | 3 |

| S.No. | Fish species | Sisarma | Jhadol | Ubeshwar | Nandeshwar | Banas | Barapal | Thur ki Pal | Jhameshwar | Fatehsagar | Pichhola | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15. | *Labeo boggut* (Sykes ) | – | - | – | – | – | – | – | – | 1 | 1 | 2 |
| 16. | *Labeo gonius* (Ham.) | - | - | - | - | 1 | - | - | - | 1 | 2 | 4 |
| 17. | *Labeo calbasu* ((Ham.) | - | - | - | - | - | - | - | - | 2 | 1 | 3 |
| 18. | *Notopterus notopterus* (Pallas) | – | - | – | – | - | – | – | – | 3 | 2 | 5 |
| 19. | *Noemacheilus botia* (Ham.) | 3 | 2 | 4 | 5 | 2 | 3 | 4 | 4 | 2 | 5 | 34 |
| 20. | *Noemacheilus denisonii* (Ham.) | 2 | 3 | 5 | 5 | 2 | 3 | 3 | 1 | 2 | 3 | 29 |
| 21. | *Sperata seenghala* (Sykes) | – | - | – | – | – | – | – | – | 4 | 2 | 6 |
| 22. | *Mystus cavasius* (Sykes) | – | 1 | – | – | 2 | – | – | – | 2 | 3 | 8 |
| 23. | *Mystus oar* (Ham.) | - | - | - | - | - | - | - | - | 3 | 2 | 5 |
| 24. | *Wallago attu*(Bloch) | - | - | - | - | - | - | - | - | 2 | 3 | 5 |
| 25. | *Callichrous pabda*(Bloch) | - | - | - | - | - | - | - | - | 3 | 4 | 7 |
| 26. | *Heteropneustes fossilis* (Ham.) | 2 | 2 | 1 | – | 3 | – | – | – | 2 | 1 | 11 |
| 27. | *Channa punctatus* (Bloch) | - | 4 | - | - | 2 | 1 | 4 | 2 | 4 | 3 | 20 |
| 28. | *Channa marulius* (Ham.) | 1 | 1 | 1 | - | - | - | - | - | 3 | 2 | 8 |
| 29. | *Channa striatus* (Bloch) | 1 | 2 | - | 1 | - | - | - | 2 | 1 | 1 | 8 |

| S.No. | Fish species | Sisarma | Jhadol | Ubeshwar | Nandeshwar | Banas | Barapal | Thur ki Pal | Jhameshwar | Fatehsagar | Pichhola | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30. | *Chanda nama* (Ham.) | 8 | - | - | 3 | - | - | - | 2 | 3 | 4 | 20 |
| 31. | *Xenentodon cancila* (Ham.) | - | 2 | - | - | 1 | - | - | - | 2 | 3 | 8 |
| 32. | *Mastacembelus armatus* (Lacepede) | - | - | - | - | - | 1 | - | - | 2 | 1 | 4 |
| | Total | 58 | 27 | 68 | 28 | 40 | 25 | 26 | 26 | 78 | 83 | 463 |

**Table 5.3: Fish diversity in selected water bodies of Aravalli region based on values of Shannon- Weaver diversity index.**

| Streams | Species richness (S) | Abundance (N) | Fish Diversity (H’) | Altitude |
|---|---|---|---|---|
| Sisarma river | 13 | 58 | 2.12765 | 540 |
| Jhadol stream | 12 | 27 | 2.40276 | 605 |
| Ubeshwar stream | 8 | 68 | 1.66378 | 700 |
| Nandeshwar stream | 8 | 28 | 1.87835 | 660 |
| Banas river | 16 | 40 | 2.57917 | 750 |
| Barapal stream | 8 | 25 | 1.91129 | 540 |
| Thur ki Pal stream | 8 | 26 | 1.97138 | 620 |
| Jhameshwar Stream | 9 | 26 | 2.02093 | 520 |
| Fatehsagar Lake | 28 | 78 | 3.20659 | 587 |
| Pichhola Lake | 29 | 83 | 3.17443 | 582 |

## (C) ETHNOZOOLOGICAL STUDIES

Ethnozoology deals with the study of interrelationship between primitive human societies and the animal resources around them . Many fish species have been proved to be vital source of tribal medicine.

Although ethnozoological studies related to fishes is scanty yet Alves and Rosa (2007) studied zootherapeutic practices among fishing communities in Brazil. Ruddle (1994) and Stoffle *et al.* (1994) worked on folk management of fisheries. Sharma (1998) studied ethnozoology of fishes of Rajasthan, Joshi (1986) studied fish stupefying plants employed by tribals of South Rajasthan whereas Gaur (2011) studied ethnozoological importance of hill stream fishes South-Eastern Rajasthan.

During present study ,therapeutic importance of hill stream fishes was discovered ( Table 5.4 ). Tribals use various parts of hill stream fishes to cure many ailments, *viz.*, tuberculosis, joint pains, respiratory disorders, pneumonia, asthma, sexual impotency, paralysis, skin diseases, psoriasis, high B. P. and kidney ailments, etc.

It also came to know by the conversation with tribals that consumption of certain hill stream fishes like *Noemacheilus botia, Noemacheilus denisonii ,Garra gotyla* etc. help them to tolerate hard winters without wearing warm cloths .

**Table 5.4: Therapeutic uses of hill stream fishes by Tribals**

| S.N. | Fish species | Local name | Family | Therapeutic use |
|---|---|---|---|---|
| 1. | *Garra gotyla* | Patthar chata | Cyprinidae | Asthma & other Rsepiratory diseases |
| 2. | *Danio rerio* | Danio | Cyprinidae | Respiratory & Skin diseases |
| 3. | *Noemacheilus botia* | Bamna | Balitoridae | Paralysis,Respiratory disorders & Skin diseases especially Eczema |
| 4. | *Noemacheilus denisonii* | Bamna | Balitoridae | Paralysis,Respiratory disorders & Skin diseases |
| 5. | *Channa punctatus* | Girhi | Channidae | Respiratory disorders |
| 6. | *Channa marulius* | Saval | Channidae | Kidney ailments ( Otoliths) |

# CHAPTER – VI

# LIMNOLOGY OF SELECTED LENTIC AND LOTIC WATERBODIES OF ARAVALLI REGION

## A. ABIOTIC FACTORS

### Introduction

Aquatic ecosystems consist of physico-chemical and biotic components. Physico-chemical parameters directly affect the biodiversity of water bodies. Seasonal study for two annual cycles was under taken to assess different physico-chemical parameters, primary production and zooplanktonic fauna of selected lentic and lotic water bodies of Southern Rajasthan .

Biological production in any aquatic body gives direct correlation with its physico-chemical status which can be used as trophic status and fisheries resources potential (Jhingran *et al*., 1965). Life in aquatic environment is largely governed by physico-chemical characteristics and their stability. These characteristics have enabled biota to develop many adaptations that improve sustained productivity and regulate lake metabolism.

The physico-chemical parameters are essential and fundamental to know the trophic status of an aquatic ecosystem. Therefore, in the present investigation the limnological parameters and their relationship along with phytoplankton and zooplankton status in the selected water bodies have been studied during the study period.

The life processes depends directly or indirectly upon various physical and chemical factors. The physico-chemical and biological factors important from limnological point of view have been studied and season wise samples were collected in the years 2013-14 and 2014-15 from eight lotic water bodies *viz.*

Sisarma , Jhadol , Ubeshwar , Nandeshwar, Banas , Barapal, Thur ki Pal and Jhameshwar and two lentic water bodies *viz.* the Lake Fateh Sagar and Lake Pichhola in the present investigation.

The season wise physico-chemical characteristics of these water bodies are given in the **tables 6.1 to 6.10**. Season wise graphic representation of various physico-chemical characteristics are shown by **Figures 6.1-6.17** and the correlations are given in the **appendices**.

Various studies on limnology of freshwater resources of Rajasthan have been made by Vyas (1968), Sharma (1980), Sharma and Durve (1984), Sharma *et al.* (1984), Sharma and Durve (1985), Rao (1987), Ranu (2001), Chisty (2002) , Sumitra (2002), Sisodia and Chaturbhuj (2006), Sharma (2007), Malara *et al.*(2007), Chandel (2008), Suthar *et al.* (2009), Mudgal *et al.* (2009), Mitharwal *et al.* (2009), Agrawal (2009),Yadav *et al.* (2010), Sharma (2006, 2011), Sharma *et al.* (2011), Rathore (2011), Gupta *et al.* (2011), Pandey and Verma (2012), Hussain *et al.* (2012; 2014), Kulshreshtha *et al.* (2013), Gaur *et al.* (2013), Surya (2014), Modi (2015) , Srinivas *et al.* (2015) and Verma (2015).

Important studies have been done in relation to stream water chemistry versus nutrients, agricultural land adjoining the stream banks, seasons, hydrology, geology and topology (Osborne and Wiley, 1988; Omernik *et al.* 1981; Close and Davies-Colley, 1990; Lawrence *et al.*, 1985 and Gregory *et al.*, 1991).Johnson *et al.* (1997) studied sixty two sub-catchments within Saginan Bay catchment of Central Michigan and found that stream water chemistry was strongly related to land use and geomorphology.

Johal *et al.* (2000) studied 13 water parameters of 23 hill streams and observed that water temperature, alkalinity, TDS, conductivity, total hardness and pH have direct influence on the fish species richness where as chlorides, turbidity, altitude, water current have been found to be negatively correlated with the fish species richness.

## RESULTS AND DISCUSSIONS

### 1. Air and water temperature

Temperature plays an important role in chemical reactions and biological processes in a water body. Both air and water temperatures are important factors influencing aquatic flora ,fauna and chemical solutes (Thapa and Saund, 2012; Raina *et al.*, 2013).In general, gradually increased temperature had positive influence on the growth and survival of aquatic organisms (Aldridge *et al.* 1995).Therefore, each species survive at an optimum temperature (Gaur *et al.*, 2014).

Furthermore, this key factor has been used to classify lakes, as gradation of water temperature causes thermal stratification and determines circulation patterns in water bodies (Sharma, 2007).

Temperature directly impacts growth, oxygen demand, food requirements and food conversion in aquatic life forms. Moderate fluctuation in temperatures was recorded spatially and no significant variation was observed with increase in altitude.

The minimum air temperature( 19.2$^{o}$C) was recorded at the stream Jhadol whereas the maximum (39.4°C ) was recorded at the lake Fateh Sagar.

It was observed that water temperature is strongly influenced by air temperature.The minimum water temperature 15.2°C was recorded at the stream Nandeshwar and maximum of 33.8°C recorded at the lake Fateh Sagar.

Water temperature showed maximum and minimum values in summer and winter respectively. Similar findings were reported by Khare (2002), Pawar and Pulle (2005), Kolekar (2006), Upadhyay and Dwivedi (2006), Negi *et al.* (2006), Rathore *et al.* (2006) Sharma *et al.* (2007) and Gaur (2011) .

A significant inverse relationship was observed between temperature and dissolved oxygen at all the water bodies under investigation. Such an inverse relationship was also observed by Reid (1961), Sharma (1980), Rao (1984), Karki (1988), Sharma and Gupta (1994), Ranu (2001), Chisty (2002), Sharma *et al.* (2007) ,Sharma *et al.* (2010) and Gaur (2011).

## 2. pH

The negative logarithm of the hydrogen ion ($H^+$) concentration in the solution is known as pH. It is an important chemical factor that influences biological activities and trophic status of a water body.

During present study the pH values varied from a minimum of 6.9 to a maximum of 8.8 .The pH range such as 5 to 9 is not directly lethal to fishes (Lloyd, 1960). According to Umavathi *et al*. (2007) pH range of 5 to 8.5 is suitable for plankton growth. However, according to Jhingran (1988) the pH values ranging from 6.5 - 9.0 were most suitable for maximum fish production.

During the study period values of pH fluctuated between 7.0 to 7.8 at river Sisarma, 7.1 to 8.4 at the stream Jhadol, 7.1 to 7.8 at the Ubeshwar stream , 7.2 to 7.8 at Nandeshwar stream, 7.5 to 8.3 at the river Banas, 7.4 to 7.9 at Barapal stream, 7.4 to 7.8 at Thur ki Pal, 7.1 to 7.8 at Jhameshwar, 7.6 to 8.8 at the lake Fateh Sagar and 6.9 to 8.3 at the lake Pichhola.

Seasonal variation revealed that during monsoon and winter, pH was low, whereas during summer it was high.The minimum values of pH were recorded during monsoon season in all the water bodies which was mainly attributed to addition of rain water.

Sharma (1980) noted pH range of 7.7 to 8.7 and 7.4 to 9.2 in Lake Pichhola and Fatehsagar respectively.The pH of Berach river system was observed from 7.2 to 10.07 by Sharma *et al*.(2000). Gaur (2011) and Modi (2015) reported pH values between 7.1 to 8.4 and 6.4 to 9.1, respectively from different water bodies of the Rajasthan.

pH was found to have positive correlation with alkalinity, hardness, chloride, nitrate, phosphate, silicate and productivity.

## 3. Water current

Water current is the important characteristic of lotic water bodies *viz*. rivers and streams. It significantly affects the distribution of fishes and plankton in lotic waters..

Maximum water current was observed during monsoon, it slows down in winters and disappears in summers in most of the water bodies due to drought conditions .

The maximum water current of 178 cm/sec was recorded at the stream Barapal. River Sisarma had a maximum water current of 117 cm/sec during monsoon period whereas during winter and summer flow gets depleted . Maximum water flow rate at Jhadol stream, Ubeshwar stream, Nandeshwar stream, River Banas, Thur ki pal stream,. and the stream Jhameshwar were 121 cm/sec, 120 cm/sec, 102 cm/sec, 142 cm/sec, 149 cm/sec, 95 cm/sec respectively . All had shown maximum water current during monsoon.

Change in flow modifications in river/streams by dam construction produces extreme impact on riverine fishes due to the desirability of maintaining natural temperature and flow regimes in streams (Minkley, 1991).

### 4. Electrical Conductivity

Conductivity is a better index to measure trophic status of a water body. Conductivity of water depends upon the presence of salts in the form of anions and cations. It is a quick method to measure total solids in water as it is directly related with total dissolved solids (Mishra and Saksena, 1993). In turn, conductivity provides a rapid mean of obtaining approximate knowledge of total dissolved solids concentration and salinity of water sample (Odum, 1971).

The highest value of 463.2 µS/cm of conductance was recorded at the lake Pichhola and the lowest value of 122.6 µS/cm was observed in Nandeshwar stream . Maximum values of the electric conductivity at Sisarma (380.6 µS/cm), at Jhadol (379.0 µS/cm), at Ubeshwar (369.0 µS/cm), at Nandeshwar (359.6 µS/cm) , at Banas (433.4 µS/cm), at Barapal ( 313.7 µS/cm ), at Thur ki Pal (366.0 µS/cm ), at Jhameshwar (391.5 µS/cm ) and at Fateh Sagar ( 393.2 µS/cm )were recorded during present study.

Conductivity show positive correlation with TDS and total hardness while negative correlation with water temperature, pH, total alkalinity and dissolved oxygen. Pandey and Sharma (1998) recorded conductivity in the range of 136-851 µ mhos during limnological study of the Ramganga river at Moradabad. Sharma *et* *al.* (2000) found conductivity in the range of 0.36 m mhos to 3.04 m mhos during their study of Berach river system.Ranu (2001) also recorded a wide range of conductivity in water bodies of the Bandi river system with minimum and maximum values of 0.285 m mhos and 8.85 m mhos, respectively. Thomas (1986) has shown that specific conductance is linearly correlated with TDS for cold and low ionic strength streams.

**5. Depth of visibility**

Depth of visibility of any water body gives a clear picture of the water quality (Sharma *et al.* 2011) The visibility of water is directly related to the turbidity and therefore turbidity determines the extent of light penetration in water and depth of euphotic zone in the water body. Transparency is considered as a function of suspended organic matter and wind action. Edmondson (1992), Ganpati (1943), Subbarao and Govind (1964), Sreenivasan (1972), Green (1974), Sharma (1980), Rao (1987), Gupta (1992) and Sharma *et al.* (2000).

In the present study, the depth of visibility varied between a minimum of 42.9 cm to a maximum of 53.4 cm at Sisarma river, 39.7 cm to 49.8 cm at the Jhadol stream, 30.5 cm to 37.2 cm at the Ubeshwar stream, 32.9 cm to 50.5 cm at the Nandeshwar stream, 21.7 cm to 63.0 cm at Banas river, 22.2 cm to 40.5 cm at Barapal, 22.8 cm to 50.6 cm at Thur ki Pal, 42.1 cm to 50.2 cm Jhameshwar stream , 78.5 cm to 140.5 cm at lake Fateh Sagar and 82.1 cm to 150.3 cm at lake Pichhola .

The majority of the streams, were dried during summer seasons hence the depth of visibility was not measured .

The depth of visibility was considerably low during the monsoon season as compared to the summer and winter . This may be attributed to presence of silt and dense phytoplankton population. Reduction in water clearity during monsoon season has also been recorded by Sharma (1980), Ranu (2001), Chisty (2002), Sumitra *et al.* (2007), Sharma *et al.* (2007), Sharma *et al.* (2010), Gaur (2011) and Modi (2015).

The depth of visibility showed a positive correlation with conductivity and TDS and negative correlation with chlorides, nitrates and phosphates. Similar findings were recorded by Sharma *et al.* (2007) . However, the data observed by Gaur (2011) were opposite to the present investigation.

**6. Total dissolved solids**

TDS in a water body is a sum of dissolved salts *viz.*, sulphates, phosphates, carbonates, bicarbonates, chlorides, nitrates of calcium, magnesium, sodium, potassium, iron, magnesium, etc. A high content of dissolved solids elevates the density of water and influences osmoregulation of freshwater organisms (Mishra and Saksena, 1993).

In the present study, total dissolved solids ranged between 184 mg/l to 231 mg/l at Sisarma, 149 mg/l to 242 mg/l at Jhadol, 162 mg/l to 241 mg/l at Ubeshwar , 54 mg/l to 178 mg/l at Nandeshwar, 98 mg/l to 142 mg/l at Banas , 154 mg/l to 190 mg/l at Barapal, 175 mg/l to 240 mg/l at Thur ki Pal , 181 mg/l to 240 mg/l at Jhameshwar,78.5 mg/l to 140.5 mg /l at the lake Fateh Sagar and 210 mg/l to 282 mg/l at the lake Pichhola.

Ranu (2001) recorded a wide range in TDS between 126.5 mg/l to 1595.0 mg/l in the Bandi river system. Sharma *et al.* (2010) showed higher TDS content (237.5 mg/l) in the lake Pichhola as compared to the lake Fatehsagar (156.7 mg/l) and the lake Swaroopsagar (146.45 mg/l) during 2005-07.Jindal and Sharma (2011) studied water quality of Sutlej River around Ludhiana. They found TDS fluctuations between 161.07 mg/l to 290.5 mg/l at station 1, 156.10 mg/l to 300.34 mg/l at station 2 and 265.31 mg/l to 582.00 mg/l at station 3 respectively during the November, 2006 to October, 2007. Sharma *et al.* (2011) observed TDS values ranging 178 mg/l to 728 mg/l in Madar tank, Udaipur. Modi (2015) reported value of TDS ranging from 153 to 603 mg/l from the selected water bodies of South Rajasthan.

Pathak and Bhatt (1993) derived inverse relation of TDS with flow rate. Total dissolved solids ($Na^+$, $Cl^-$, $K^+$, $SO_4^{2-}$) regularly increased due to human interference in nature from stream order one to river mouth (Meybeck, 1998).

## 7. Chlorides

Chloride concentration in water indicates the presence of organic waste (Thresh *et al.*1949 , Goel *et al.*1980, Palaria and Rana 1985 and Sinha 1988). They opined that chloride content indicates domestic as well as industrial pollution. Chlorides present in both fresh and salt water is an important element of life (Hunt *et al.* 2013).Chlorides occur in freshwaters as a result of dissolution of salts deposited in the soil (Michael, 1986).

During present investigation, the chloride concentration varied between 0.01200 mg/l to 0.04401mg/l at Sisarma , 0.01178 mg/l to 0.06921 mg/l at the stream Jhadol, 0.01078 mg/l to 0.04417 mg/l at the stream Ubeshwar, 0.0315 mg/l to 0.05320 mg/l at Nandeshwar stream , 0.00911 mg/l to 0.0832 mg/l at Banas river, 0.01346 mg/l to 0.04451 mg/l at Barapal stream , 0.02730 mg/l to 0.05351 mg/l at Thur ki Pal , 0.01181 mg/l to 0.0430 mg/l at Jhameshwar.

Very high values of chloride content 38.82 mg/l to 74.84 mg/l at lake Fateh Sagar and 132.20 mg/l to 220.80 mg/l at the Pichhola lake were recorded during present findings.

The chloride concentration of lake water depends upon the degree of pollution resulting from the waste materials poured into the lakes. As streams are comparatively less pollutant so Chloride concentration was very low.

Chloride content of the river Ramganga fluctuated between 10 mg/l and 42 mg/l (Pandey and Sharma, 1998). Limnological studies reported by Doctor *et al.* (1989) revealed that in river Bhadar, Chloride values varied in the range of 452.00 mg/l to 582 mg/l. Studies on pollution of river Noyyal revealed that the chloride values ranged between 1218 mg/l to 4490 mg/l (Jacob *et al.*, 1999). Ranu (2001) reported low to very high values of chloride content 23.03 mg/l to 2671.15 mg/l in Bandi river system.

Gaur (2011) observed very low chloride concentration (0.00921 mg/l to 0.0228 mg/l ) in river Chambal.

Verma *et al.* (1984) reported that chloride ion concentration is minimum during winter and maximum during summer months depending on the precipitations and evaporation.

During the present study, chlorides showed positive correlation with pH, alkalinity, total hardness, nitrate, phosphate and productivity. Whereas, it had negative correlation with dissolved oxygen, TDS, electrical conductance and depth of visibility. These observations were similar to the findings of Gaur (2011) .According to Sharma, *et al.*(2010) chlorides content showed positive correlation with depth of visibility, pH, alkalinity, total hardness, TDS, electrical conductance, nitrate, phosphate and silicate, whereas it has negative relation with dissolved oxygen, fluoride and productivity in water bodies of south Rajasthan.

**8. Total alkalinity**

Alkalinity is a measure of the capacity to absorb hydrogen ions and neutralize a strong acid which combine with hydrogen ions. Carbonates, bicarbonates and hydroxides are considered to be prominent bases affecting total alkalinity. The minimum values of total alkalinity were observed during monsoon months, the values increased during summer.

The total alkalinity ranged between a minimum of 74.0 mg/l recorded at the stream Nandeshwar and a maximum of 256 mg/l recorded at the lake Pichhola.

Ranu,(2001) observed high total alkalinity values in the range of 87.5 mg/l to 548.45 mg/l in the Bandi river system, which are polluted with industrial pollutants Total alkalinity of two dry bundhs fluctuated between 43.2 ppm to 177.6 ppm (Vijaylaxmi *et al.*, 2003). Jain and Singh (2013) found a high range of alkalinity from 1400-1600 mg/l during October- 2012 to August- 2013 in lake Anasagar, Ajmer. Sharma *et al.(*2010) also reported total alkalinity variation between 154 mg/l and 254 mg/l in the lake Pichhola, between 157 mg/l and 240 mg/l in the lake Fateh Sagar and between 190 mg/l and 250 mg/l in the lake Swaroopsagar, respectively of Rajasthan waters. Gaur *et al*. (2014) recorded total alkalinity ranging between 80.1 mg/l to 117 mg/l in some lentic and lotic water bodies of south-eastern Rajasthan during the years of 2008-2009.

Total alkalinity showed a positive relationship with pH, total hardness, chloride, nitrate, phosphate, silicate and respiration and a negative correlation with conductivity and TDS.

## 9. Total hardness

Cations of calcium, magnesium together with anions like carbonate, bicarbonate give rise to the temporary hardness and while with sulphates, chloride and other anions constitute the permanent hardness (Wetzel, 2001; Roy and Kumar, 2002). Alkalinity and water hardness are closely interrelated. Alkalinity and hardness both are vital in providing sufficient natural food and in maintaining a healthy fish population (Lock, 1993). Waters with hardness up to 75 mg/l are termed soft waters while the waters with hardness of more than 300 mg/l are considered hard.

During present study ,total hardness ranged between 98 mg/l to 128 mg/l at Sisarma,90 mg/l to 189 mg/l at Jhadol, 89 mg/l to 119 mg/l at Ubeshwar, 88 mg/l to 123 mg/l at Nandeshwar, 102 mg/l to 190 mg/l at Banas, 98.5 mg/l to 124 mg/l at Barapal, 110 mg/l to 159 mg/l at Thur ki Pal, 98 mg/l to 134 mg/l at Jhameshwar, 149 mg/l to 215 mg/l at Fateh Sagar and 142 mg/l to 232 mg/l at Pichhola. The total hardness was high during summer, which gradually decreased in winter, the minimum values were found during monsoon season . The increase in total hardness in summer season can be attributed to higher photosynthetic activity, free carbon dioxide is utilized and bicarbonates are converted into carbonates and precipitates as calcium salts thus increasing hardness (Reid and Wood, 1976).

Sharma (1980) noted average total hardness of 83.36 mg/l and 79.18 mg/l in the lake Pichhola and lake Fatehsagar during 1974-75 while his later studies conducted during 1994 showed a range of 129-317 mg/l in the Lake Pichhola.Pandey and Sharma (1998) found hardness values fluctuating between 129 mg/l to 1465 mg/l in the polluted Ramganga river at Moradabad; Jacob *et al.* (1999) observed hardness of water to vary from 114 mg/l to 434 mg/l in the river Noyyal of Tripura. Thorat and Sultana (2000) reported variation in values of hardness between 51.75 mg/l and 73.62 mg/l in Morana river, Ankola. Ranu (2001) observed a minimum of 137.5 mg/l and maximum of 800.00 mg/l values of hardness in water bodies of the Bandi river system.

Total hardness showed a positive correlation with pH, alkalinity, chloride, nitrate, phosphate and silicate. But a negative relation with temperature .

## 10. Dissolved oxygen

Dissolved oxygen is an important limnological parameter indicating level of water quality and organic production in the lake (Wetzel, 1983). It is essential and becomes limiting factor in some cases for maintaining aquatic life (Srivastava *et al.* 2009). Stagnant water has moderate capacity to hold oxygen as compared to flowing water (Gaur, 2011). Further, a unique correlation of dissolved oxygen with temperature, carbon dioxide and total alkalinity makes it a more important limnological parameter.

The solubility of atmospheric oxygen in freshwater ranges from 14.0 mg/l at 0°C to about 7 mg/l at 35°C under one atmospheric pressure. The cold water has a greater capacity to hold dissolved oxygen (Hutchinson, 1957) whereas fresh sterile water at 0°C can contain up to 14.0 mg/l oxygen but at 20°C it can hold a maximum of only 9.2 mg oxygen per liter in estuarine waters. The dissolved oxygen has inverse correlation with total alkalinity (Pillai *et al.*, 1999).

During present study, all the streams were characterised by high levels of dissolved oxygen as running water has good capacity of aeration. The maximum value of Dissolved oxygen of 8.8mg/l was observed in winter season of 2013-14 at Nandeshwar stream whereas, the lowest oxygen value of 4.9 mg/l was observed in summer 2014-15 at the lake Pichhola .

During limnological study of the river Ramganga at Moradabad, Pandey and Sharma (1998) observed dissolved oxygen of water in the range of 3.0 mg/l to 9.6 mg/l. Sharma and Agarwal (1999) found that dissolved oxygen fluctuated between 2.5 mg/l to 9.5 mg/l in the river Yamuna. Rath (2000) reported dissolved oxygen values of Nondisa and Brahmani rivers in the range of 6.30 mg/l to 10.2 mg/l and 2.29 mg/l to 6.78 mg/l respectively. Ranu (2001) observed range of 1.8 mg/l to 9.1 mg/l of dissolved oxygen in the Bandi river system. Gaur (2011) observed dissolved oxygen value of 8.7 mg/l in winter season of 2008 at Bhamboo Khal and Paharajhar streams, whereas, lowest oxygen value of 6.6 mg/l in summer 2009 at RPS dam.

Modi (2015) reported value of dissolved oxygen between 3.4 to 8.0 mg/l from the selected water bodies such as Lodha dam, Dialav pond, Tripura sundari pond, Udaisagar lake, Goverdhan sagar lake, Fatah sagar lake, Madar pond, Patela pond, Surpur pond Patela pond and Sabela pond of South Rajasthan.

Dissolved oxygen showed a positive correlation with alkalinity,hardness, chlorides ,nitrate, phosphates and silicate while negative correlation was noted with temperature and electric conductivity. Reid and Wood (1976) described that dissolved oxygen and temperature were inversely related to each other, and the temperature was a controlling factor for the aquatic organism.

### 11. Nitrates

Nitrate plays an important role in the process of eutrophication and its concentration in excess of 0.3 ppm is sufficient to stimulate algal bloom (Raina *et al.*, 1984). It generally occurs in little quantities. High concentration of nitrate beyond 40 ppm is toxic (Gilli *et al.*, 1984). On the other hand, nitrate is essential for many photosynthetic autotrophs and in some cases has also been identified as the growth limiting nutrient (Bharti and Krishnamurthy, 1992).

During present observation, the nitrate content varied from 0.0537mg/l at Ubeshwar stream to 4.8541 mg/l at lake Fateh Sagar .

High nitrate content was recorded during summer, declines in winter and monsoon seasons. This may be due to pouring in of the fertilisers from the catchment area.(Gaur 2011).

Ranu (2001) observed fluctuations of nitrates between 0.101 mg/l to 0.909 mg/l in the Bandi river system. Chisty (2002) observed the values of nitrate in selected water bodies of the Berach river system between 0.121 mg/l 1.02 mg/l. Modi (2015) observed nitrate contents between 2.125 to 10.0 mg/l in the selected water bodies of South Rajasthan.

Nitrate showed positive correlation with pH, alkalinity, total hardness, dissolved oxygen, chloride, phosphate and silicate and negative relation with temperature, TDS and conductivity.

### 12. Orthophosphate

Phosphorus occurs naturally in rocks and other mineral deposits. During the natural process of weathering, the rocks gradually release the phosphorus as phosphate ions which are soluble in water. Moderate amount of phosphorus makes the water bodies suitable for growth of plankton and other freshwater communities. Ambient phosphorus concentration is used as criteria in lake eutrophication models (Vollenweider, 1968). The increased phosphate contents also indicate high degree of pollution (Williams *et al.* 1969). Too much phosphate is responsible for excessive production of blue-green algae or other nuisance plants in water bodies (Boyd, 1971). Domestic, industrial effluents and agricultural runoff are the major sources of phosphorus (Bharti and Krishnamurthy, 1992).

During present study maximum orthophosphate content of 4.5821 mg/l was observed during summer of 2014-15 at Fateh Sagar lake and minimum of 0.0225mg/l during monsoon of 2014-15 at the Barapal stream. The high values of phosphates in summer may be due to evaporation resulting reduced volume of water. The increased density of biota, which produces metabolic wastes, high water temperature and higher biodegradation releasing this nutrient from the sediment.

Higher values of phosphate during summer months were also reported (Solomon, 1994; Shekhawat, 1997; Sarang, 2001; Sharma, 2007 ; Gaur 2011 and Sharma *et. al* 2011 )

Chattopadhyay *et al.* (1984) observed rich phosphates with a range of 0.4 mg/l – 7 mg/l in the river Ganga at Kanpur. Arvinda *et al.* (1998) noticed the presence of phosphates in the range of 0.04 mg/l to 0.18 mg/l in the river Tungabhadra. Water bodies of Berach river system contained phosphates in the range of 0.002 mg/l to 0.005 mg/l (Sharma *et al.*, 2000). Ranu (2001) reported rich phosphates upto a level of 1.28 mg/l in polluted ponds of Bandi river system. Chisty (2002) observed the range of phosphate between 0.05 mg/l to 1.24 mg/l in water bodies of the Berach river system.

### 13. Silicates

Silicate plays a significant role as a nutrient in aquatic ecosystems. It does not occur in nature as a free element. Natural waters commonly contain silicon dioxide and in some form of soluble silicate. A lower amount of silicates may be important to phytoplankton for diatom's growth which further contribute to lake productivity and also through the food web, support commercially important fish species (Tuncq *et al.*, 2012).

The silica ($SiO_2$) concentration decreases during spring and summer due to uptake by the aquatic vegetation as diatoms (Thibert, 1994 and Gernier *et al.*, 1995).

During present investigation the value of silicates ranged between 0.0332 mg/l at lake Fateh Sagar to 6.6399 mg/l at Thur ki Pal. All the water bodies did not show increase in silicate values in summer as seen by Nair *et al.* (1988). Vijay Laxmi (2003) reported the range of silicate to oscillate between 0.002 to 0.009 and 0.01 to 0.04 in two dry Bundhs of Udaipur district. Kaushal and Sharma (2007).observed silicates to range between 2.2 to 3.8 mg/l in selected reservoirs of Eastern Rajasthan. Gaur (2011) investigated the value of silicates ranged between 3.0744 mg/l to 6.6400 mg/l respectively in water bodies of South-Eastern Rajasthan.

**15. Productivity :**

The trophic status of an ecosystem depends on rate of energy flow which may be assessed by estimating primary production. Basically, Primary productivity is the rate at which the sun's radiant energy is accumulated or created by photosynthetic and chemosynthetic activities of producers (like phytoplankton, algae and macrophytes of the water) in the form of organic substances (Odum, 1971).

The water bodies are classified on the basis of their productivity as Oligotrophic, Mesotrophic, Eutrophic and Dystrophic.

The main factors which influence primary production are temperature, alkalinity, pH, dissolved oxygen, phosphate sulphate and nitrates (Pandey *et al.*, 2010). These factors act as a limiting factor for the primary production of aquatic ecosystem.

During present study the GPP varied between 127.5 mgc/$m^2$/hr to 362.7 mgc/$m^2$/hr at Sisarma, 117.5 mgc/$m^2$/hr to 328.8 mgc/$m^2$/hr at Jhadol, 137.5 mgc/$m^2$/hr to332.8 mgc/$m^2$/hr at Ubeshwar, 95.9 mgc/$m^2$/hr to 169.5 mgc/$m^2$/hr at

Nandeshwar, 141.6 mgc/$m^2$/hr to 248.4 mgc/$m^2$/hr at Banas, 152.0 mgc/$m^2$/hr to 240.7 mgc/$m^2$/hr at Barapal, 135.6 mgc/$m^2$/hr to 281.5 mgc/$m^2$/hr at Thur ki Pal, 125.0 mgc/$m^2$/hr to 359.3 mgc/$m^2$/hr at Jhameshwar stream, 184.4 mgc/$m^2$/hr to 348.2 mgc/$m^2$/hr at Fateh Sagar and 189.5 mgc/$m^2$/hr to 378.2 mgc/$m^2$/hr at Pichhola.

The NPP varied between 69.5 mgc/$m^2$/hr to 209.5 mgc/$m^2$/hr at Sisarma, 49.5 mgc/$m^2$/hr to 205.6 mgc/$m^2$/hr at Jhadol, 62.8 mgc/$m^2$/hr to 181.2 mgc/$m^2$/hr at Ubeshwar, 52.5 mgc/$m^2$/hr to 72.5 mgc/$m^2$/hr at Nandeshwar, 62.5 mgc/$m^2$/hr to 156.2 mgc/$m^2$/hr at Banas, 61.5 mgc/$m^2$/hr to 128.0 mgc/$m^2$/hr at Barapal, 67.6 mgc/$m^2$/hr to 156.5 mgc/$m^2$/hr at Thur ki Pal, 62.5 mgc/$m^2$/hr to 218.5 mgc/$m^2$/hr at Jhameshwar stream, 62.1 mgc/$m^2$/hr to 182.4 mgc/$m^2$/hr at Fateh Sagar and 62.5 mgc/$m^2$/hr to 252.2 mgc/$m^2$/hr at Pichhola.

During present study high primary productivity were recorded in winter months at all the water bodies except river Banas . Tripathy (1988), Naz *et al.* (2006), Sharma *et al.* (2007) and Malara (2008) observed high primary productivity in winters, whereas, Kannan and Job (1980), Khan and Siddiqui (1971), Vijayraghvan (1971), Arvola (1983), Sharma and Gupta (1994) have reported a direct relationship between temperature and primary production in some water bodies. Gaur (2011) observed high primary productivity in winters as well as in summers in different water bodies of South-Eastern Rajasthan.

In the current study GPP was found to have positive correlationship with dissolved oxygen, total hardness, total alkalinity, chlorides, nitrates phosphates, silicates , NPP and respiration and negative relationship with temperature and TDS. Similar findings were observed by Gaur (2011) and Sharma *et al* (2011).

## B. BIOTIC FACTORS

Biotic components refer to the living world of an ecosystem which include single cell as well as multicellular organisms and decomposing plant and animal materials. The biotic factors are categorised into phytoplanton, zooplanton and bentos.

### (i) Phytoplankton

Phytoplanton are the base of aquatic ecosystem. They are primary producers and direct and indirect food of fishes. The quality and quantity of phytoplankton depends on limnological characteristics and geographical features. The phytoplantonic community of selected water bodies during present study was represented by six groups *viz.* Cyanophyceae, Chlophyceae, Bacillariophyceae, Xanthophyceae, Chrysophyaceae and Dinophyceae. Cyanophyceae comprises of prokaryotic organisms popolarly known as blue-green algae, occur in unicellular, filamentous and colonial forms.The Chlorophyceae( green algae )constitutes one of the major groups of algae mostly occurs in fresh water . The Xanthophyceae (yellow-green algae) are unicellular, colonial or filamentous algae characterised by fair amount of carotenoids that results in their predominantly yellow-green coloration. The diatoms or Bacillariophyceae is having characterised siliceous cell wall. This group is divided into the centric diatoms (centrales) which have radial symmetry and the pennate diatoms (Pennales) which exhibit bilateral symmetry. Chrysophyceae (golden algae) are a large group of algae found mostly in freshwater.The Dinoflagellates or Dinophyceae are unicelluar flagellated algae having horny projections ( armoured dianoflagellates) or thecal plates ( unarmoured dinoflagellates ) .

In India, notable contribution as regards to phytoplankton is done by Sreenivasan (1971), Moitra and Bhattacharya (1965), Jana (1973), Mathew (1978), Chari (1980), Nandan and Patel (1992), Pandey and Verma (1992), Verma and Mohanty (2000), Mahajan and Mandloi (1998), Harikrishnan *et al.* (1999), Saha *et al.* (2000), Dwivedi and Pandey (2002), Khanna and Singh (2002) and Kiran *et al.* (2002). Apart from aforementioned researchers the following also studied phytoplankton: Ray *et al.* (1966) and Pahwa and Mehrotra (1966) studied the Ganges. The Yamuna at Allahabad was studied by Chakraborty *et al.* (1959) and Ray *et al.* (1966), they reported that diatoms form a dominant group amongst the phytoplankton in the river Yamuna. David (1963) studied river Gandak and Brahamputra.

The study of phytoplankton in Rajasthan waters is done by Singh (1955), Rao and Choubey (1990), Bohra (1977), Vyas (1968), Vyas and Kumar (1968), Sharma (1980), Billore (1981), Sharma and Durve (1984), Rao (1987), Hussain (1990), Gupta (1992), Sharma and Gupta (1994), Soloman (1994), Shekhawat (1997), Sharma *et al.* (2000), Ranu (2001), Baghela *et al.* (2007) , Sharma *et al.* (2010) and Gaur (2011).

**Results and Discussion**

A list of phytoplankton with their occurrence is given in the form of Table 6.11

The phytoplanktonic community of the selected lotic and lentic water bodies was represented by six groups *viz.* Myxophyceae, Chlorophyceae, Xanthophyceae, Bacillariophyceae, Chrysophyceae and Dinophyceae. Total 44 forms were identified, out of these 8 belonged to Myxophyceae, 15 to Chlorophyceae, 4 to Xanthophyceae, 12 to Bacillariophyceae, 1 to Chrysophyceae and 4 to Dinophyceae .

*Oscillatoria sp., Phormidium sp., Spirulina sp.,Merismopedia sp., Coccochlaris sp,.Microcystis sp., Nostoc sp.* and *Anabaena sp.belonged* to Myxophyceae . Chlorophyceae was represented by *Pediastrum sp., Scenedesmus sp., Hydrodictyon sp., Zygnema sp., Cosmarium sp., Desmidium sp., Panium sp., Ulothrix sp., Actinastrum sp., Volvox sp., Oedogonium sp., Closteriopsis sp.,Cladophora sp.,Microspora sp.* and *Spirogyra sp.*

*Trobonema sp.,Botrydiopsis sp.,Chlorobotrys sp.and Botryococcus sp*.represented Xanthophyceae. Bacillariophyceae was represented by *Melosira sp., Pinnularia sp.,Tabellaria sp.,Fragillaria sp., Bacillaria sp., Gomphonema sp., Nitzschia sp., Ophephora sp., Cymbella sp., Cyclotella sp., Synedra sp.* and *Navicula sp.* Chrysophyceae represented by *Chromulina sp.*and Dinophyceae by *Glenidium sp., Peridinium sp.,Ceratium sp. and Gymnodium sp.*

The most prominent phytoplankton during the study were *Microcystis sp., Anabaena sp. Nostoc sp. Spirulina sp.* and *Phormidium sp.* from group Cyanophyceae. While *Volvox sp. Spirogyra sp. Chlorella sp. Ulothrix sp.* and *Pediastrum sp.* from group Chlorophyceae. As evident from the study, Chlorophyceae dominated over Cyanophyceae. Baghela (2006) observed the dominance of Chlorophyceae in oligotrophic lake Jawai Dam. Sharma *et al.* (2011)

also observed dominance of Chlorophyceae over Cyanophyceae in Lake Pichhola. On the contrary, Sharma (1980), Solomon (1994) and Shekhawat (1997) observed dominance of blue green algae in Udaipur waters.

The phytoplankton are generally found in lentic water or large rivers of low water current Wetzel (1983). During present study, the selected streams also exhibit similar condition harbouring a good planktonic flora. Abundance of phytoplankton and species richness were influenced by the high turbidity, current velocity, fluctuating water levels, water depth and dissolved oxygen in Bhagirathi river (Sharma, 1985) and in Western Ganga canal (Joshi *et al.*, 1995).Badola and Singh (1981) and Nautiyal (1984) referred that in Alakananda river plankton were maximum during winter. This was attributed to low velocity, low temperature, more amount of dissolved oxygen and clearness of water.

**(ii) Zooplankton**

Zooplankton are small animals that flaot freely in surface water or column of water bodies .Their distribution isprimaly determined by water current and waves. Zooplankton are the intermediate link between phytoplankton and fish. The zooplankton diversity is one of the most important ecological parameters in water quality and biodiversity assessment because they are strongly affected by environmental conditions and respond quickly to changes in water quality.

Owing to their sensitivity in terms of water quality, zooplankton are considered as important bioindicators. Zooplankton are choice food of commercially important fishes and their juveniles, their study provides necessary information regarding fishery potential of water bodies.

Main components of freshwater zooplankton are Protozoans, Rotifers and Crustaceans. Knowledge of quality as well as quantity of freshwater zooplankton is considered essential to understand trophic nature and energy transfer in wetlands (Kulshreshta *et al.*, 1992).

Among limnological parameters temperature, pH, dissolved oxygen and nutrients are known to control the production, composition and distribution of zooplankton. Planktonic flora, littoral vegetation and fish fauna also influence the qualitative and quantitative composition of zooplankton.

Zooplankton of Indian freshwaters have been studied by Ganpati (1943), Das and Srivastava (1959a), Arora (1966), Bhowmick (1968), Michael (1969), Saha *et al.* (1971), Vasisht and Sharma (1975), , Nasar (1977), Rao (1977), Sarkar *et al.* (1977), Govind (1978), Mathew (1978), Ganpati and Pathak (1978), Malhotra *et al.* (1978), Saksena and Sharma (1981), Khan (1983), Rao (1984), Goswami (1985), Yadava *et al.* (1987), Michael and Sharma (1987), Saksena (1987), Bhaskaran *et al.* (1988), Pandey and Verma (1992), Venkatraman and Das (1993), , Kaushik and Saksena (1995), Isaiarasu *et al.* (1995 and 2001), Pandey *et al.* (1995), Sanjer and Sharma (1995), Sarwar and Parveen (1996), Mahahan and Mandloi (1998), Pandit (1999), Sarkar and Choudhary (1999), Kumar *et al.* (2001), Mukhopadhyay and Ghosh (2001), Sharma and Hussain (2001), Khanna and Singh (2002), Prakash *et al.* (2002).

In Rajasthan, notable contribution has been done by Nayar (1968, 70 and 71). Bohra (1976 and 77), Rao (1984), Sharma and Durve (1985), Rao (1987), Hussain (1990), Kumar and Sharma (1991), Gupta (1992), Solomon (1994), Shekhawat (1997), Dadhich and Saxena (1999), Sharma *et al.* (2000), Kumar and Rathore (2001), Ranu (2001), Sarang (2001), Saxena (2001), Chisty (2002), Sumitra (2002), Vijaylaxmi *et al.* (2003), Baghela *et al.* (2007), Sharma *et al.* (2007), Sharma *et al* ( 2010) ,Gaur (2011) , Modi (2015) and Verma (2015) .

**Results and Discussion**

During present study,Total 34 forms of zooplankton comprising of five groups, namely Protozoa , Rotifera , Cladocera , Copepoda and Ostracoda were identified in the selected lotic and lentic water bodies. Out of these 8 belonged to Protozoa, 9 belonged to Rotifera, 4 to Ostracoda, 8 to Cladocera and 5 to Copepoda.

A list of zooplankton with their occurrence is given in the form of Table 6.12 . Zooplankton *Arcella sp.*, *Euglena sp.*, *Difflugia sp.*, *Phacus sp.*, *Vorticella sp.*, *Stentor sp* , *Amoeba sp.* and *Paramecium sp.* belonging to phylum Protozoa. Rotifera was represented by *Brachionus sp.*, *Lepadella sp.*, *Keratella sp.*, *Horella sp.*,*Tricocerca sp.*, *Filinia sp.*,*Lecane sp.*, *Monostyla sp.* and *Asplanchna sp.*

Among Cladocera the represented forms were *Daphnia sp., Moina sp., Ceriodaphnia sp., Bosmina sp., Diaphanosoma sp., Pleurocus sp., Alona sp.* and *Macrothrix sp.* Ostracoda represented by *Cypris sp. Heterocypris sp., Stenocypris sp.* and *Centrocypris sp.* Copepodes included *Cyclops sp.,Mesocyclops sp.,Rhinodiaptomus sp.,Heliodiaptomus sp.* and *Eucyclops sp.*

During present study Rotifers showed dominance over Cladocerans followed by Protozoans, Copepods, and Ostracods in the selected water bodies. These findings are supported by Sharma *et al.(*2011) in Lake Pichhola.

Anthropogenic factors like discharge of industrial, domestic and agricultural wastes are adversely affecting diversity and density of these zooplanktonic groups. The relationship between biodiversity and ecosystem functioning has recently emerged as a focused area of ecological research (Sharma *et al.* 2000).

**(iii) Benthos**

The term benthos includes all bottom dwelling organisms. They are often considered to be best indicators of organic pollution because of their constant presence, relatively long life span, sedentary habits, and different tolerance to stress habitat. These benthic invertebrates become food for the other aquatic invertebrates and vertebrates, hence play a critical role in the natural flow of energy and nutrients in the ecosystem. The factors affect benthic community in reservoirs are rock bottom, frequent water level fluctuations and loss of substrate due to deposition of silt and other suspended particles. As far as streams are concerned, their ephemerality adversely impacts the benthos.

Studies related to benthos have been done by several workers *viz.* Sinha *et al.* (1992), Singh *et al.* (1994), Singh and Roy (1995), Mishra and Prasad (1997), Singh (1988), Srivastava (1959), Peter (1968), Mitra and Gosh (1992),Sinha (1995) and Gaur (2011). According to Thienemann (1925), water bodies with less than 1000/ $\mu m^2$ of benthos population are considered poor in productivity.

## RESULTS AND DISCUSSION

During present study,the benthic fauna of selected water bodies is given in the table 6.13 .It comprises a diversity of species belonging to phylum Annelida (Class Oligochaeta and Hirudinea), Arthropoda (Class Insecta) and Mollusca (Class Gastropoda and Bivalvia) .

The phylum Annelida was represented by 4 Oligochaetes namely *Chaetogaster sp .,Tubifex sp., Nais sp.*and *Limnodrilus sp.* and 1 Hirudinian *Hirudinaria sp.*

During the present study insects were represented by adult as well as larval forms.The insect fauna belonged to order Diptera by *Chironomous sp., Simulium sp.*, *Tabanus sp.*, *Pentaneura sp.* and *Culex larva sp.*, Coleoptera *by Ectopria sp.;* Odonata by *Anas sp.* and Ephemeroptera by *Cinygmula sp., Heptagenia sp., Leptophlebia sp., Centroptilum sp., Ephemerella sp.* and *Baetis sp.*

The Molluscans *Pila sp., Lymnaea sp., Planorbis sp., Limax sp., Vivipara sp.* and *Gyraulus sp.* represented the class Gastropoda and *Unio sp.* and *Lamellidens sp.* belonged to class Bivalvia.

During present study, the most prominent benthos were *Chironomous larvae sp.*, *Culex larvae sp.*and *Tabanus sp.* from order Diptera. While *Pila sp.*, *Unio sp.*, *Lymnaea sp.* and *Limax sp.* from phylum Mollusca.

The benthic fauna is dominated by various Arthropods (chiefly insects), followed by Gastropods, Oligochaetes and Bivalves in the selected water bodies. Similar findings were observed by Burton and Sivaramkrishanan(1993) and Sivaramkrishanan *et al.*(1995) in South Indian streams.

**Table 6.1: Physico-Chemical Parameters of River Sisarma**

| S.N. | Parameters | 2013-14 | | | 2014-15 | | |
|---|---|---|---|---|---|---|---|
| | | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** | **Summer** |
| 1. | Air Temperature (°C) | 30.5 | 21.0 | 36.0 | 31.5 | 20.9 | 37.2 |
| 2. | Water Temp. (°C) | 22.0 | 18.1 | – | 24.5 | 18.0 | - |
| 3. | pH | 7.0 | 7.7 | - | 7.2 | 7.8 | - |
| 4. | Conductivity (µS/cm) | 380.6 | 316.6 | - | 329.1 | 312.4 | - |
| 5. | Depth of Visibility (cm) | 42.9 | - | - | 53.4 | - | - |
| 6. | Total Dissolved Solids (mg/l) | 231 | 191 | - | 195 | 184 | - |
| 7. | Water Current (cm/sec) | 112 | – | - | 117 | – | – |
| 8. | Total Alkalinity (mg/l) | 128 | 169 | - | 132 | 173 | - |
| 9. | Total Hardness (mg/l) | 98 | 128 | - | 100 | 123 | - |
| 10. | Dissolved Oxygen (mg/l) | 7.5 | 8.4 | - | 7.6 | 8.3 | - |
| 11. | Chlorides (mg/l) | 0.01200 | 0.03971 | - | 0.02251 | 0.04401 | - |
| 12. | Nitrates (mg/l) | 0.0559 | 0.0902 | - | 0.0715 | 0.0929 | - |
| 13. | Phosphates (mg/l) | 0.0601 | 0.1240 | - | 0.0589 | 0.1327 | - |
| 14. | Silicates (mg/l) | 3.7025 | 3.5871 | - | 4.0342 | 4.7419 | - |
| 15. | GPP (mgc/$m^2$/hr) | 127.5 | 330.5 | - | 149.9 | 362.7 | - |
| 16. | NPP (mgc/$m^2$/hr) | 69.5 | 201.5 | - | 70.5 | 209.5 | - |
| 17. | Respiration (mgc/$m^2$/hr) | 51.5 | 116.5 | - | 62.5 | 119.2 | - |

**Table 6.2: Physico-Chemical Parameters of Jhadol Stream**

| S. N. | Parameters | 2013-14 | | | 2014-15 | | |
|---|---|---|---|---|---|---|---|
| | | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** | **Summer** |
| 1. | Air Temperature (°C) | 31.4 | 19.2 | 34.0 | 30.7 | 20.1 | 33.3 |
| 2. | Water Temp. (°C) | 21.9 | 17.2 | 25.3 | 22.6 | 16.4 | 23.4 |
| 3. | pH | 7.1 | 7.8 | 8.2 | 7.1 | 7.7 | 8.4 |
| 4. | Conductivity (µS/cm) | 379.0 | 301.2 | 268.4 | 335.4 | 302.9 | 281.9 |
| 5. | Depth of Visibility (cm) | 39.7 | - | - | 49.8 | - | - |
| 6. | Total Dissolved Solids (mg/l) | 242 | 201 | 149 | 201 | 179 | 168 |
| 7. | Water Current (cm/sec) | 121 | – | – | 105 | – | – |
| 8. | Total Alkalinity (mg/l) | 115 | 162 | 202 | 123 | 169 | 214 |
| 9. | Total Hardness (mg/l) | 90 | 121 | 171 | 97 | 123 | 189 |
| 10. | Dissolved Oxygen (mg/l) | 7.4 | 8.3 | 8.0 | 7.3 | 8.4 | 7.9 |
| 11. | Chlorides (mg/l) | 0.01178 | 0.03785 | 0.06632 | 0.02352 | 0.04511 | 0.06921 |
| 12. | Nitrates (mg/l) | 0.0540 | 0.0906 | 0.3175 | 0.0715 | 0.0929 | 0.3472 |
| 13. | Phosphates (mg/l) | 0.0578 | 0.1240 | 0.4250 | 0.0780 | 0.1322 | 0.3712 |
| 14. | Silicates (mg/l) | 3.7128 | 3.2876 | 5.2011 | 4.0449 | 4.6410 | 5.4214 |
| 15. | GPP (mgc/m$^2$/hr)qQ | 117.5 | 298.2 | 318.9 | 149.9 | 302.1 | 328.8 |
| 16. | NPP (mgc/m$^2$/hr) | 49.5 | 171.2 | 178.7 | 62.2 | 189.5 | 205.6 |
| 17. | Respiration (mgc/m$^2$/hr) | 41.5 | 107.5 | 148.5 | 58.2 | 107.6 | 158.4 |

**Table 6.3: Physico-Chemical Parameters of Ubeshwar Stream**

| S. N. | Parameters | 2013-14 | | | 2014-15 | | |
|---|---|---|---|---|---|---|---|
| | | Monsoon | Winter | Summer | Monsoon | Winter | Summer |
| 1. | Air Temperature (°C) | 31.3 | 20.7 | 34.0 | 30.9 | 19.5 | 35.2 |
| 2. | Water Temp. (°C) | 21.1 | 16.9 | - | 22.8 | 17.5 | - |
| 3. | pH | 7.3 | 7.8 | - | 7.1 | 7.7 | - |
| 4. | Conductivity (µS/cm) | 369.0 | 318.9 | - | 325.4 | 298.5 | - |
| 5. | Depth of Visibility (cm) | 30.5 | - | - | 37.2 | - | - |
| 6. | Total Dissolved Solids (mg/l) | 241 | 162 | - | 221 | 231 | - |
| 7. | Water Current (cm/sec) | 120 | 24 | - | 115 | 29 | - |
| 8. | Total Alkalinity (mg/l) | 125 | 172 | - | 129 | 169 | - |
| 9. | Total Hardness (mg/l) | 92 | 119 | - | 89 | 111 | - |
| 10. | Dissolved Oxygen (mg/l) | 7.3 | 8.2 | - | 7.4 | 8.1 | - |
| 11. | Chlorides (mg/l) | 0.01078 | 0.04417 | - | 0.02450 | 0.03792 | - |
| 12. | Nitrates (mg/l) | 0.0537 | 0.0934 | - | 0.0719 | 0.0818 | - |
| 13. | Phosphates (mg/l) | 0.0559 | 0.1420 | - | 0.0689 | 0.1234 | - |
| 14. | Silicates (mg/l) | 3.6148 | 4.5211 | - | 4.1429 | 3.4888 | - |
| 15. | GPP (mgc/m2/hr) | 137.5 | 332.8 | - | 162.4 | 321.8 | - |
| 16. | NPP (mgc/m2/hr) | 62.8 | 178.4 | - | 77.2 | 181.2 | - |
| 17. | Respiration (mgc/m2/hr) | 51.5 | 127.9 | - | 65.2 | 124.6 | - |

**Table 6.4: Physico-Chemical Parameters of Nandeshwar Stream**

| S. N. | Parameters | 2013-14 | | | 2014-15 | | |
|---|---|---|---|---|---|---|---|
| | | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** | **Summer** |
| 1. | Air Temperature (°C) | 29.2 | 21.0 | 34.2 | 30.0 | 22.5 | 37 |
| 2. | Water Temp. (°C) | 23.0 | 15.2 | - | 23.9 | 16.8 | - |
| 3. | pH | 7.4 | 7.7 | - | 7.2 | 7.8 | - |
| 4. | Conductivity (µS/cm) | 359.6 | 122.6 | - | 329.8 | 242.4 | - |
| 5. | Depth of Visibility (cm) | 32.9 | - | - | 50.5 | - | - |
| 6. | Total Dissolved Solids (mg/l) | 68 | 178 | - | 165 | 54 | - |
| 7. | Water Current (cm/sec) | 102 | – | – | 99 | – | – |
| 8. | Total Alkalinity (mg/l) | 74 | 88 | - | 77 | 92 | - |
| 9. | Total Hardness (mg/l) | 88 | 121 | - | 95 | 123 | - |
| 10. | Dissolved Oxygen (mg/l) | 7.7 | 8.8 | - | 7.6 | 8.6 | - |
| 11. | Chlorides (mg/l) | 0.0315 | 0.0448 | - | 0.03635 | 0.0532 | - |
| 12. | Nitrates (mg/l) | 0.0621 | 0.0902 | - | 0.05952 | 0.0929 | - |
| 13. | Phosphates (mg/l) | 0.0554 | 0.1240 | - | 0.0581 | 0.1305 | - |
| 14. | Silicates (mg/l) | 3.9823 | 5.0759 | - | 4.1842 | 5.7852 | - |
| 15. | GPP (mgc/$m^2$/hr) | 110.5 | 169.5 | - | 95.9 | 162.7 | - |
| 16. | NPP (mgc/$m^2$/hr) | 52.5 | 72.5 | - | 54.5 | 69.5 | - |
| 17. | Respiration (mgc/$m^2$/hr) | 41.7 | 66.5 | - | 38.5 | 79.2 | - |

**Table 6.5: Physico-Chemical Parameters of River Banas**

| S. N. | Parameters | 2013-14 | | | 2014-15 | | |
|---|---|---|---|---|---|---|---|
| | | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** | **Summer** |
| 1. | Air Temperature (°C) | 31.2 | 24.1 | 35.4 | 29.7 | 25.2 | 34.5 |
| 2. | Water Temp. (°C) | 25.7 | 20.1 | 28.7 | 23.2 | 20.1 | 28.4 |
| 3. | pH | 7.5 | 7.9 | 8.2 | 7.6 | 7.8 | 8.3 |
| 4. | Conductivity (µS/cm) | 186.0 | 173.8 | 433.4 | 211.7 | 184.3 | 340.1 |
| 5. | Depth of Visibility (cm) | 63.0 | 34.0 | 28.0 | 61.0 | 40.8 | 21.7 |
| 6. | Total Dissolved Solids (mg/l) | 142 | 114 | 98 | 135 | 112 | 101 |
| 7. | Water Current (cm/sec) | 142 | 78 | – | 128 | 79 | – |
| 8. | Total Alkalinity (mg/l) | 97 | 122 | 150 | 93 | 129 | 150 |
| 9. | Total Hardness (mg/l) | 112 | 141 | 179 | 102 | 123 | 190 |
| 10. | Dissolved Oxygen (mg/l) | 8.1 | 8.3 | 7.5 | 7.8 | 8.5 | 7.4 |
| 11. | Chlorides (mg/l) | 0.009117 | 0.04199 | 0.08012 | 0.01156 | 0.0448 | 0.0832 |
| 12. | Nitrates (mg/l) | 0.3771 | 0.3121 | 0.3975 | 0.3325 | 0.2942 | 0.4015 |
| 13. | Phosphates (mg/l) | 0.4071 | 0.2988 | 0.5633 | 0.4264 | 0.3107 | 0.6020 |
| 14. | Silicates (mg/l) | 5.1174 | 5.2931 | 5.5701 | 5.0127 | 5.3221 | 5.8665 |
| 15. | GPP (mgc/$m^2$/hr) | 158 | 141.6 | 222.5 | 149 | 171.5 | 248.4 |
| 16. | NPP (mgc/$m^2$/hr) | 77.7 | 83.3 | 125 | 62.5 | 93.7 | 156.2 |
| 17. | Respiration (mgc/$m^2$/hr) | 50.1 | 46.8 | 91.5 | 61.7 | 78.2 | 87.5 |

**Table 6.6: Physico-Chemical Parameters of Barapal Stream**

| S. N. | Parameters | 2013-14 | | | 2014-15 | | |
|---|---|---|---|---|---|---|---|
| | | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** | **Summer** |
| 1. | Air Temperature (°C) | 29.7 | 22.6 | 37.5 | 28.9 | 24.7 | 36.8 |
| 2. | Water Temp. (°C) | 23.8 | 18.0 | – | 22.8 | 18.9 | – |
| 3. | pH | 7.6 | 7.8 | – | 7.4 | 7.9 | – |
| 4. | Conductivity (µS/cm) | 266.4 | 313.7 | – | 240.2 | 281.3 | – |
| 5. | Depth of Visibility (cm) | 22.2 | 40.5 | – | 22.2 | 33.5 | – |
| 6. | Total Dissolved Solids (mg/l) | 159 | 190 | – | 154 | 177 | – |
| 7. | Water Current (cm/sec) | 165 | – | – | 178 | – | – |
| 8. | Total Alkalinity (mg/l) | 148.0 | 160.0 | – | 129.0 | 171.0 | – |
| 9. | Total Hardness (mg/l) | 124 | 118 | – | 98.5 | 123 | – |
| 10. | Dissolved Oxygen (mg/l) | 7.5 | 8.0 | – | 7.5 | 8.1 | – |
| 11. | Chlorides (mg/l) | 0.02272 | 0.04451 | – | 0.01346 | 0.0340 | – |
| 12. | Nitrates (mg/l) | 0.0539 | 0.1174 | – | 0.0670 | 0.0970 | – |
| 13. | Phosphates (mg/l) | 0.03140 | 0.1890 | – | 0.02255 | 0.1951 | – |
| 14. | Silicates (mg/l) | 6.0113 | 4.3180 | – | 5.298 | 4.203 | – |
| 15. | GPP (mgc/$m^2$/hr) | 158 | 234.5 | – | 152 | 240.7 | – |
| 16. | NPP (mgc/$m^2$/hr) | 61.5 | 125 | – | 76.8 | 128 | – |
| 17. | Respiration (mgc/$m^2$/hr) | 42.5 | 105.4 | – | 52.5 | 110.2 | – |

**Table 6.7: Physico-Chemical Parameters of Stream Thur ki Pal**

| S. N. | Parameters | 2013-14 | | | 2014-15 | | |
|---|---|---|---|---|---|---|---|
| | | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** | **Summer** |
| 1. | Air Temperature (°C) | 28.3 | 22.5 | 37.5 | 29.6 | 21.0 | 36.8 |
| 2. | Water Temp. (°C) | 21.4 | 18.0 | – | 20.0 | 18.4 | – |
| 3. | pH | 7.4 | 7.8 | – | 7.4 | 7.7 | – |
| 4. | Conductivity (µS/cm) | 356.0 | 311.8 | – | 366.0 | 301.4 | – |
| 5. | Depth of Visibility (cm) | 50.6 | 32.8 | – | 48.1 | 22.8 | – |
| 6. | Total Dissolved Solids (mg/l) | 240 | 189 | – | 232 | 175 | – |
| 7. | Water Current (cm/sec) | 138 | – | – | 149 | – | – |
| 8. | Total Alkalinity (mg/l) | 128 | 168 | – | 130 | 142 | – |
| 9. | Total Hardness (mg/l) | 117 | 159 | – | 110 | 131 | – |
| 10. | Dissolved Oxygen (mg/l) | 7.5 | 8.1 | – | 7.6 | 8.5 | – |
| 11. | Chlorides (mg/l) | 0.02730 | 0.05351 | – | 0.03071 | 0.04813 | – |
| 12. | Nitrates (mg/l) | 0.06940 | 0.365 | – | 0.07142 | 0.2033 | – |
| 13. | Phosphates (mg/l) | 0.05481 | 0.2789 | – | 0.03661 | 0.2271 | – |
| 14. | Silicates (mg/l) | 5.7348 | 4.9821 | – | 6.6399 | 4.760 | – |
| 15. | GPP (mgc/$m^2$/hr) | 135.6 | 281.5 | – | 156.5 | 270.3 | – |
| 16. | NPP (mgc/$m^2$/hr) | 67.6 | 156.5 | – | 78.5 | 150.3 | – |
| 17. | Respiration (mgc/$m^2$/hr) | 67.6 | 125.5 | – | 83.5 | 101.3 | – |

**Table 6.8: Physico-Chemical Parameters of Jhameshwar Stream**

| S. N. | Parameters | 2013-14 | | | 2014-15 | | |
|---|---|---|---|---|---|---|---|
| | | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** | **Summer** |
| 1. | Air Temperature (°C) | 32.5 | 21.9 | 37.7 | 31.0 | 20.2 | 36.4 |
| 2. | Water Temp. (°C) | 24.1 | 18.0 | – | 22.5 | 17.8 | – |
| 3. | pH | 7.2 | 7.7 | – | 7.1 | 7.8 | – |
| 4. | Conductivity (µS/cm) | 333.2 | 301.0 | – | 391.5 | 316.0 | – |
| 5. | Depth of Visibility (cm) | 50.2 | - | – | 42.1 | - | – |
| 6. | Total Dissolved Solids (mg/l) | 210 | 181 | – | 240 | 202 | – |
| 7. | Water Current (cm/sec) | 95 | – | – | 81 | – | – |
| 8. | Total Alkalinity (mg/l) | 127 | 150 | – | 133 | 170 | – |
| 9. | Total Hardness (mg/l) | 98 | 132 | – | 102 | 134 | – |
| 10. | Dissolved Oxygen (mg/l) | 7.6 | 8.2 | – | 7.7 | 8.7 | – |
| 11. | Chlorides (mg/l) | 0.02151 | 0.04304 | – | 0.01181 | 0.03982 | – |
| 12. | Nitrates (mg/l) | 0.0611 | 0.0974 | – | 0.0545 | 0.0880 | – |
| 13. | Phosphates (mg/l) | 0.0560 | 0.1302 | – | 0.0596 | 0.0942 | – |
| 14. | Silicates (mg/l) | 5.1391 | 3.7413 | – | 4.85 | 3.587 | – |
| 15. | GPP ($mgc/m^2/hr$) | 160 | 359.3 | – | 125 | 312.5 | – |
| 16. | NPP ($mgc/m^2/hr$) | 62.5 | 218.5 | – | 62.5 | 183.1 | – |
| 17. | Respiration ($mgc/m^2/hr$) | 60.5 | 142.5 | – | 42.5 | 120.2 | – |

**Table 6.9: Physico-Chemical Parameters of Lake Fateh Sagar**

| S. No. | Parameters | 2013-14 | | | 2014-15 | | |
|---|---|---|---|---|---|---|---|
| | | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** | **Summer** |
| 1. | Air Temperature (°C) | 30.2 | 24.9 | 37.1 | 34.0 | 22.2 | 39.4 |
| 2. | Water Temp. (°C) | 29.8 | 19.7 | 30 | 30.5 | 20.8 | 33.8 |
| 3. | pH | 7.6 | 8.1 | 8.5 | 8 | 8.4 | 8.8 |
| 4. | Conductivity (µS/cm) | 275.2 | 312.0 | 393.2 | 211.5 | 286.0 | 345.5 |
| 5. | Depth of Visibility (cm) | 78.5 | 104.2 | 89.5 | 97.5 | 140.5 | 113.2 |
| 6. | Total Dissolved Solids (mg/l) | 133.6 | 154.8 | 198.8 | 132.5 | 160.2 | 172.5 |
| 7. | Water Current (cm/sec) | - | – | – | - | – | – |
| 8. | Total Alkalinity (mg/l) | 167 | 180 | 198 | 183 | 158 | 242 |
| 9. | Total Hardness (mg/l) | 152 | 174 | 195 | 149 | 192 | 215 |
| 10. | Dissolved Oxygen (mg/l) | 7.2 | 7.7 | 6.2 | 7.8 | 8.0 | 5.8 |
| 11. | Chlorides (mg/l) | 38.82 | 57.45 | 39.25 | 46.25 | 61.25 | 74.84 |
| 12. | Nitrates (mg/l) | 2.6104 | 3.7075 | 4.4054 | 2.7980 | 3.5671 | 4.8541 |
| 13. | Phosphates (mg/l) | 1.7871 | 2.2054 | 3.9231 | 1.8545 | 2.4801 | 4.5821 |
| 14. | Silicates (mg/l) | 0.0332 | 0.0478 | 0.1552 | 0.0458 | 0.0575 | 0.0854 |
| 15. | GPP (mgc/$m^2$/hr) | 184.4 | 269.2 | 312.9 | 189.4 | 348.2 | 325.8 |
| 16. | NPP (mgc/$m^2$/hr) | 92.4 | 182.4 | 145 | 62.1 | 162.4 | 102.2 |
| 17. | Respiration (mgc/$m^2$/hr) | 89.4 | 75.5 | 116.2 | 84.8 | 154.2 | 198.5 |

**Table 6.10: Physico-Chemical Parameters of Lake Pichhola**

| S. N. | Parameters | 2013-14 | | | 2014-15 | | |
|---|---|---|---|---|---|---|---|
| | | **Monsoon** | **Winter** | **Summer** | **Monsoon** | **Winter** | **Summer** |
| 1. | Air Temperature (°C) | 30.2 | 21.9 | 37.7 | 34.0 | 21.2 | 38.4 |
| 2. | Water Temp. (°C) | 29.1 | 18.0 | 30 | 28.5 | 18.8 | 31.8 |
| 3. | pH | 6.9 | 7.2 | 8 | 7.1 | 7.5 | 8.3 |
| 4. | Conductivity (µS/cm) | 375.2 | 342.0 | 463.2 | 351.5 | 386.0 | 445.5 |
| 5. | Depth of Visibility (cm) | 98.5 | 141.2 | 150.3 | 82.1 | 131.3 | 138 |
| 6. | Total Dissolved Solids (mg/l) | 230 | 210 | 282 | 210 | 232 | 270 |
| 7. | Water Current (cm/sec) | - | – | – | - | – | – |
| 8. | Total Alkalinity (mg/l) | 197 | 150 | 256 | 193 | 204 | 248 |
| 9. | Total Hardness (mg/l) | 163 | 150 | 194 | 142 | 174 | 232 |
| 10. | Dissolved Oxygen (mg/l) | 5.9 | 7.2 | 5.3 | 5.7 | 6.0 | 4.9 |
| 11. | Chlorides (mg/l) | 132.20 | 165.23 | 220.8 | 173.5 | 153.2 | 216.8 |
| 12. | Nitrates (mg/l) | 2.6544 | 3.6475 | 4.3954 | 2.9985 | 3.8675 | 4.4521 |
| 13. | Phosphates (mg/l) | 1.9875 | 2.8654 | 3.4235 | 2.0453 | 2.7854 | 3.5421 |
| 14. | Silicates (mg/l) | 0.0890 | 0.1240 | 0.1485 | 0.0623 | 0.0956 | 0.1245 |
| 15. | GPP (mgc/$m^2$/hr) | 251 | 374.2 | 312.9 | 189.5 | 378.2 | 314.8 |
| 16. | NPP (mgc/$m^2$/hr) | 126 | 252 | 191.2 | 62.5 | 252.2 | 112.2 |
| 17. | Respiration (mgc/$m^2$/hr) | 150.2 | 125.5 | 176.2 | 74.2 | 124.2 | 198.5 |

**Table 6.11: List of Phytoplankton inhabiting selected water bodies of Aravalli Region**

| S. N. | Name of Phytoplankton | Sisarma | Jhadol | Ubeshwar | Nandeshwar | Banas | Barapal | Thur ki Pal | Jhameshwar | Fateh Sagar | Pichhola |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Myxophyceae** | | | | | | | | | | | |
| 1 | *Oscillatoria sp.* | + | + | + | - | + | - | - | - | - | + |
| 2 | *Phormidium sp.* | + | + | + | + | + | - | + | + | + | - |
| 3 | *Spirulina sp.* | + | + | + | + | + | + | + | + | - | + |
| 4 | *Merismopedia sp.* | - | + | + | - | + | - | - | + | + | - |
| 5 | *Coccochlaris sp.* | + | - | + | - | - | + | + | - | - | - |
| 6 | *Microcystis sp.* | + | + | + | - | + | + | + | + | + | - |
| 7 | *Nostoc sp.* | + | + | + | + | + | + | + | - | + | + |
| 8 | *Anabaena sp.* | + | + | + | + | + | + | + | + | + | - |
| **Chlorophyceae** | | | | | | | | | | | |
| 1 | *Pediastrum sp*. | + | + | - | + | + | + | + | + | - | - |
| 2 | *Scenedesmus* sp. | - | + | - | - | - | + | - | - | - | + |
| 3 | *Hydrodictyon sp.* | - | - | - | + | + | - | - | + | - | + |
| 4 | *Zygnema sp.* | - | - | - | - | - | + | + | - | + | - |
| 5 | *Cosmarium sp.* | + | - | - | + | + | - | + | - | - | - |
| 6 | *Desmidium sp.* | - | - | + | + | - | + | - | + | - | + |
| 7 | *Panium sp.* | - | + | + | - | - | - | - | + | - | + |
| 8 | *Ulothrix sp.* | + | + | + | + | + | + | - | + | - | + |
| 9 | *Actinastrum sp.* | - | - | - | + | - | + | - | - | + | - |
| 10 | *Volvox sp.* | + | + | + | + | + | + | - | + | + | + |
| 11 | *Oedogonium sp.* | - | - | - | - | + | - | + | + | + | - |
| 12 | *Closteriopsis sp.* | + | + | + | - | + | - | + | - | + | + |
| 13 | *Cladophora sp.* | - | - | + | - | + | + | + | - | + | + |
| 14 | *Microspora sp.* | + | - | + | - | - | + | + | + | + | + |

| S. N. | Name of Phytoplankton | Sisarma | Jhadol | Ubeshwar | Nandeshwar | Banas | Barapal | Thur ki Pal | Jhameshwar | Fateh Sagar | Pichhola |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | *Spirogyra sp.* | + | + | + | + | + | + | + | + | + | + |
| | **Xanthophyceae** | | | | | | | | | | |
| 1 | *Trobonema sp.* | + | + | - | + | - | + | + | - | + | + |
| 2 | *Botrydiopsis sp.* | + | - | + | - | - | - | + | + | - | - |
| 3 | *Chlorobotrys sp.* | + | + | - | - | + | + | - | + | - | + |
| 4 | *Botryococcus sp.* | + | + | - | - | + | - | + | - | + | - |
| | **Bacillariophyceae** | | | | | | | | | | |
| 1 | *Melosira sp.* | + | + | - | + | + | + | + | + | + | + |
| 2 | *Pinnularia sp.* | - | + | + | - | + | + | + | - | - | - |
| 3 | *Tabellaria sp.* | + | - | + | + | + | + | + | + | - | + |
| 4 | *Fragillaria sp.* | - | + | + | - | + | - | + | - | - | - |
| 5 | *Bacillaria sp.* | + | + | - | - | + | + | + | + | + | - |
| 6 | *Gomphonema sp.* | - | - | + | + | - | + | - | - | - | + |
| 7 | *Nitzschia sp.* | - | + | - | - | + | - | + | + | - | - |
| 8 | *Ophephora sp.* | - | + | + | - | + | - | + | - | + | - |
| 9 | *Cymbella sp.* | - | + | + | + | + | + | + | + | - | + |
| 10 | *Cyclotella sp.* | + | - | + | - | + | - | + | - | - | + |
| 11 | *Synedra sp.* | - | - | - | + | - | - | - | + | + | + |
| 12 | *Navicula sp.* | - | - | + | - | + | - | + | + | - | + |
| | **Chrysophyceae** | | | | | | | | | | |
| 1 | *Chromulina sp.* | + | + | + | - | + | - | + | + | + | - |
| | **Dinophyceae** | | | | | | | | | | |
| 1 | *Glenidium sp.* | + | + | + | - | + | - | + | + | + | + |
| 2 | *Peridinium sp.* | - | - | + | + | - | + | - | + | + | - |
| 3 | *Ceratium sp.* | - | + | - | + | - | - | + | - | - | + |
| 4 | *Gymnodium sp.* | - | + | + | - | + | - | + | + | + | + |

**Table 6.12: List of Zooplankton inhabiting selected water bodies of Aravalli Region**

| S N | Name of Zooplankton | Sisarma | Jhadol | Ubeshwar | Nandeshwar | Banas | Barapal | Thur ki Pal | Jhameshwar | Fateh Sagar | Picchola |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Protozoa** | | | | | | | | | | | |
| 1 | *Arcella sp.* | + | + | + | + | - | + | - | - | + | + |
| 2 | *Euglena sp.* | - | + | | + | + | + | - | + | + | + |
| 3 | *Difflugia sp.* | - | + | + | - | + | - | _ | + | + | + |
| 4 | *Phacus sp.* | + | _ | + | + | + | - | + | - | + | + |
| 5 | *Vorticella sp.* | + | - | + | - | - | + | - | + | + | + |
| 6 | *Stentor sp.* | - | - | + | - | + | + | - | - | + | - |
| 7 | *Amoeba sp.* | - | - | + | + | - | - | - | + | + | + |
| 8 | *Paramecium sp.* | - | - | + | + | + | - | + | + | + | + |
| **Rotifera** | | | | | | | | | | | |
| 1 | *Brachionus sp.* | - | _ | - | + | - | + | - | - | + | + |
| 2 | *Lepadella sp.* | - | + | - | - | - | + | - | - | + | + |
| 3 | *Keratella sp.* | - | - | + | + | - | - | - | + | + | + |
| 4 | *Horella sp.* | - | - | - | - | - | + | + | - | + | + |
| 5 | *Tricocerca sp.* | + | + | - | + | - | + | - | + | + | + |
| 6 | *Filinia sp.* | - | - | + | + | - | + | - | + | - | + |
| 7 | *Lecane sp.* | - | - | - | - | - | - | - | + | - | + |
| 8 | *Monostyla sp.* | - | + | + | + | - | - | + | - | + | - |
| 9 | *Asplanchna sp.* | - | - | - | + | - | + | - | - | + | + |
| **Ostracoda** | | | | | | | | | | | |
| 1 | *Cypris sp.* | + | - | - | - | + | + | - | - | + | + |
| 2 | *Centrocypris sp.* | + | - | - | - | + | + | + | + | + | + |
| 3 | *Heterocypris sp.* | - | - | - | + | - | - | - | + | + | + |
| 4 | *Stenocypris sp.* | + | - | - | - | - | + | - | - | + | + |

| SN | Name of Zooplankton | Sisarma | Jhadol | Ubeshwar | Nandeshwar | Banas | Barapal | Thur ki Pal | Jhameshwar | Fateh Sagar | Picchola |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cladocera** | | | | | | | | | | | |
| 1 | *Daphnia sp.* | + | + | + | - | + | + | + | + | + | + |
| 2 | *Moina sp.* | - | + | + | - | + | + | + | - | + | + |
| 3 | *Ceriodaphnia sp.* | + | - | + | + | + | + | + | + | + | + |
| 4 | *Bosmina sp.* | - | + | + | + | + | + | + | + | + | + |
| 5 | *Diaphanosoma sp.* | + | - | - | - | + | + | + | + | + | + |
| 6 | *Pleurocus sp.* | - | - | - | + | - | - | - | + | + | + |
| 7 | *Alona sp.* | - | - | - | - | + | - | + | + | + | + |
| 8 | *Macrothrix sp.* | + | + | + | - | + | - | + | - | + | + |
| **Copepoda** | | | | | | | | | | | |
| 1 | *Cyclops sp.* | + | + | + | - | + | + | + | + | + | + |
| 2 | *Mesocyclops sp.* | - | - | + | + | - | - | - | + | + | + |
| 3 | *Rhinodiaptomus sp.* | - | + | - | - | - | - | + | + | + | + |
| 4 | *Heliodiaptomus sp.* | - | + | + | - | - | - | + | + | + | + |
| 5 | *Eucyclops sp.* | - | - | + | - | - | - | + | + | + | + |

**Table 6.13: List of Benthos inhabiting selected waterbodies of Aravalli region**

| S. N | Name of Benthos | Sisarma | Jhadol | Ubeshwar | Nandeshwar | Banas | Barapal | Thur ki Pal | Jhameshwar | Fateh Sagar | Pichhola |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **PHYLUM - ANNELIDA** | | | | | | | | | | | |
| **Class - Oligochaeta** | | | | | | | | | | | |
| 1 | *Chaetogaster sp.* | - | - | + | + | - | + | - | + | + | + |
| 2 | *Tubifex sp.* | + | - | - | + | - | + | - | - | + | + |
| 3 | *Nais sp.* | - | + | + | - | - | - | + | - | + | + |
| 4 | *Limnodrilus sp.* | - | + | + | + | - | - | - | - | + | + |
| **Class- Hirudinea** | | | | | | | | | | | |
| 1 | *Hirudinaria* | + | + | + | + | - | - | + | + | + | + |
| **PHYLUM - ARTHOPODA** | | | | | | | | | | | |
| **Class- Insecta** | | | | | | | | | | | |
| **Order - Diptera** | | | | | | | | | | | |
| 1 | *Chironomous sp.* | - | - | + | + | - | + | - | + | + | + |
| 2 | *Simulium sp.* | + | - | - | - | - | - | + | - | - | + |
| 3 | *Tabanus sp.* | - | + | - | - | + | - | + | + | - | - |
| 4 | *Pentaneura sp.* | - | + | - | + | - | - | - | - | + | - |
| 5 | *Culex sp. (Larva)* | - | - | + | + | + | + | + | + | + | + |
| **Order- Coleoptera** | | | | | | | | | | | |
| 1 | *Ectopria sp.* | + | + | - | + | + | - | - | - | + | - |
| **Order - Odonata** | | | | | | | | | | | |
| 1 | *Anas sp.* | - | + | - | + | - | - | + | - | - | - |
| **Order- Ephemeroptera** | | | | | | | | | | | |
| 1 | *Cinygmula sp.* | - | + | - | + | - | - | + | - | + | + |
| 2 | *Heptagenia sp.* | - | + | - | + | - | - | - | - | + | - |

| S.N | Name of Benthos | Sisarma | Jhadol | Ubeshwar | Nandeshwar | Banas | Barapal | Thur ki Pal | Jhameshwar | Fateh Sagar | Pichhola |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | *Leptophlebia sp.* | - | + | - | + | + | + | - | + | + | - |
| 4 | *Centroptilum sp.* | - | + | - | + | + | + | + | - | + | + |
| 5 | *Ephemerella sp.* | - | + | - | + | - | + | - | - | - | + |
| 6 | *Baetis sp.* | - | + | - | + | - | + | - | - | + | - |
| **PHYLUM - MOLLUSCA** | | | | | | | | | | | |
| **Class- Gastropoda** | | | | | | | | | | | |
| 1 | *Pila sp.* | - | + | - | + | - | - | + | - | + | + |
| 2 | *Lymnaea sp.* | + | - | - | - | + | + | + | - | - | + |
| 3 | *Planorbis sp.* | - | + | - | - | - | + | - | + | - | - |
| 4 | *Limax sp.* | - | - | - | - | + | - | - | + | + | + |
| 5 | *Vivipara sp.* | + | + | - | + | - | - | + | - | + | + |
| 6 | *Gyraulus sp.* | - | + | - | + | - | - | - | - | + | - |
| **Class- Bivalvia** | | | | | | | | | | | |
| 1 | *Unio sp.* | + | - | + | - | + | - | + | + | + | + |
| 2 | *Lamellidens sp.* | + | + | - | + | - | - | - | + | + | + |

**Appendix – 1 Statical Correlation Matrix among different Physico- chemical parameters of River Sisarma**

| Parameters | AT | WT | pH | Cond | Dept | TDS | WC | TA | TH | DO | CHL | NIT | PHT | SIT | GP | NP | RES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 1 | .964** | -.690 | -.489 | .133 | -.293 | .028 | -.898* | -.836* | -.813* | -.851* | -.301 | -.823* | -.548 | -.663 | -.824* | -.879* |
| Water Temp. (°C) | .964** | 1 | -.481 | -.702 | -.016 | -.529 | -.004 | -.762 | -.674 | -.633 | -.700 | -.216 | -.655 | -.456 | -.449 | -.653 | -.721 |
| pH | -.690 | -.481 | 1 | -.279 | -.434 | -.480 | -.150 | .930** | .940** | .946** | .926** | .358 | .961** | .646 | .984** | .960** | .947** |
| Conductivity (µS/cm) | -.489 | -.702 | -.279 | 1 | .423 | .955** | .075 | .087 | -.031 | -.098 | .024 | -.050 | -.066 | .026 | -.313 | -.073 | .014 |
| Depth of Visibility (cm) | .133 | -.016 | -.434 | .423 | 1 | .338 | -.739 | -.292 | -.325 | -.454 | -.164 | .278 | -.480 | -.117 | -.575 | -.479 | -.373 |
| Total Dissolved Solids (mg/l) | -.293 | -.529 | -.480 | .955** | .338 | 1 | .237 | -.132 | -.220 | -.265 | -.225 | -.251 | -.246 | -.225 | -.473 | -.250 | -.189 |
| Water Current (cm/sec) | .028 | -.004 | -.150 | .075 | -.739 | .237 | 1 | -.138 | -.192 | -.065 | -.286 | -.443 | -.009 | -.048 | -.008 | -.020 | -.085 |
| Total Alkalinity (mg/l) | -.898* | -.762 | .930** | .087 | -.292 | -.132 | -.138 | 1 | .974** | .949** | .960** | .308 | .976** | .637 | .906* | .973** | .986** |
| Total Hardness (mg/l) | -.836* | -.674 | .940** | -.031 | -.325 | -.220 | -.192 | .974** | 1 | .980** | .935** | .269 | .973** | .485 | .928** | .979** | .977** |
| Dissolved Oxygen (mg/l) | -.813* | -.633 | .946** | -.098 | -.454 | -.265 | -.065 | .949** | .980** | 1 | .923** | .317 | .974** | .499 | .951** | .985** | .982** |
| Chlorides (mg/l) | -.851* | -.700 | .926** | .024 | -.164 | -.225 | -.286 | .960** | .935** | .923** | 1 | .556 | .914* | .717 | .865* | .918** | .965** |
| Nitrates (mg/l) | -.301 | -.216 | .358 | -.050 | .278 | -.251 | -.443 | .308 | .269 | .317 | .556 | 1 | .214 | .611 | .231 | .234 | .370 |
| Phosphates (mg/l) | -.823* | -.655 | .961** | -.066 | -.480 | -.246 | -.009 | .976** | .973** | .974** | .914* | .214 | 1 | .581 | .968** | .998** | .981** |
| Silicates (mg/l) | -.548 | -.456 | .646 | .026 | -.117 | -.225 | -.048 | .637 | .485 | .499 | .717 | .611 | .581 | 1 | .564 | .558 | .623 |
| GPP (mgc/m$^2$/hr) | -.663 | -.449 | .984** | -.313 | -.575 | -.473 | -.008 | .906* | .928** | .951** | .865* | .231 | .968** | .564 | 1 | .968** | .932** |
| NPP (mgc/m$^2$/hr) | -.824* | -.653 | .960** | -.073 | -.479 | -.250 | -.020 | .973** | .979** | .985** | .918** | .234 | .998** | .558 | .968** | 1 | .986** |
| Respiration (mgc/m$^2$/hr) | -.879* | -.721 | .947** | .014 | -.373 | -.189 | -.085 | .986** | .977** | .982** | .965** | .370 | .981** | .623 | .932** | .986** | 1 |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

## Appendix – 2 Statical Correlation Matrix among different Physico- chemical parameters of Jhadol Stream

| Parameters | AT | WT | pH | Cond | Dept | TDS | WC | TA | TH | DO | CHL | NIT | PHT | SIT | GP | NP | RES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 1 | .975** | .119 | .028 | .103 | -.154 | .199 | .145 | .351 | -.673 | .196 | .559 | .502 | .525 | -.234 | -.265 | .102 |
| Water Temp. (°C) | .975** | 1 | .201 | -.110 | .047 | -.271 | .087 | .222 | .415 | -.594 | .282 | .619 | .589 | .522 | -.132 | -.190 | .196 |
| pH | .119 | .201 | 1 | -.903* | -.934** | -.828* | -.931** | .991** | .967** | .612 | .968** | .887* | .894* | .712 | .925** | .912* | .991** |
| Conductivity (μS/cm) | .028 | -.110 | -.903* | 1 | .828* | .952** | .956** | -.923** | -.856* | -.669 | -.942** | -.762 | -.816* | -.650 | -.940** | -.898* | -.949** |
| Depth of Visibility (cm) | .103 | .047 | -.934** | .828* | 1 | .747 | .935** | -.929** | -.847* | -.793 | -.886* | -.726 | -.762 | -.633 | -.940** | -.952** | -.920** |
| Total Dissolved Solids (mg/l) | -.154 | -.271 | -.828* | .952** | .747 | 1 | .856* | -.883* | -.844* | -.515 | -.933** | -.795 | -.852* | -.803 | -.834* | -.794 | -.895* |
| Water Current (cm/sec) | .199 | .087 | -.931** | .956** | .935** | .856* | 1 | -.931** | -.831* | -.827* | -.914* | -.694 | -.744 | -.570 | -.998** | -.981** | -.950** |
| Total Alkalinity (mg/l) | .145 | .222 | .991** | -.923** | -.929** | -.883* | -.931** | 1 | .974** | .600 | .991** | .899* | .909* | .785 | .925** | .914* | .996** |
| Total Hardness (mg/l) | .351 | .415 | .967** | -.856* | -.847* | -.844* | -.831* | .974** | 1 | .409 | .972** | .971** | .957** | .834* | .819* | .805 | .962** |
| Dissolved Oxygen (mg/l) | -.673 | -.594 | .612 | -.669 | -.793 | -.515 | -.827* | .600 | .409 | 1 | .551 | .202 | .285 | .162 | .845* | .859* | .625 |
| Chlorides (mg/l) | .196 | .282 | .968** | -.942** | -.886* | -.933** | -.914* | .991** | .972** | .551 | 1 | .912* | .928** | .827* | .903* | .884* | .989** |
| Nitrates (mg/l) | .559 | .619 | .887* | -.762 | -.726 | -.795 | -.694 | .899* | .971** | .202 | .912* | 1 | .981** | .860* | .672 | .645 | .881* |
| Phosphates (mg/l) | .502 | .589 | .894* | -.816* | -.762 | -.852* | -.744 | .909* | .957** | .285 | .928** | .981** | 1 | .842* | .716 | .675 | .898* |
| Silicates (mg/l) | .525 | .522 | .712 | -.650 | -.633 | -.803 | -.570 | .785 | .834* | .162 | .827* | .860* | .842* | 1 | .561 | .571 | .744 |
| GPP (mgc/m²/hr) | -.234 | -.132 | .925** | -.940** | -.940** | -.834* | -.998** | .925** | .819* | .845* | .903* | .672 | .716 | .561 | 1 | .991** | .942** |
| NPP (mgc/m²/hr) | -.265 | -.190 | .912* | -.898* | -.952** | -.794 | -.981** | .914* | .805 | .859* | .884* | .645 | .675 | .571 | .991** | 1 | .924** |
| Respiration (mgc/m²/hr) | .102 | .196 | .991** | -.949** | -.920** | -.895* | -.950** | .996** | .962** | .625 | .989** | .881* | .898* | .744 | .942** | .924** | 1 |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

## Appendix -3: Statical Correlation Matrix among different Physico- chemical parameters of Ubeshwar Stream

| Parameters | AT | WT | pH | Cond | Dept | TDS | WC | TA | TH | DO | CHL | NIT | PHT | SIT | GP | NP | RES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 1 | .974** | -.952** | .047 | .278 | -.197 | .176 | -.978** | -.959** | -.974** | -.944** | -.916* | -.965** | -.430 | -.979** | -.987** | -.983** |
| Water Temp. (°C) | .974** | 1 | -.982** | -.077 | .374 | -.197 | .122 | -.958** | -.976** | -.945** | -.888* | -.877* | -.942** | -.451 | -.944** | -.948** | -.944** |
| pH | -.952** | -.982** | 1 | .107 | -.529 | .087 | -.249 | .908* | .987** | .928** | .866* | .846* | .951** | .429 | .943** | .939** | .921** |
| Conductivity (µS/cm) | .047 | -.077 | .107 | 1 | -.185 | .472 | .565 | -.127 | .113 | -.210 | -.139 | .045 | -.066 | .191 | -.169 | -.172 | -.190 |
| Depth of Visibility (cm) | .278 | .374 | -.529 | -.185 | 1 | .546 | .646 | -.176 | -.484 | -.327 | -.231 | -.183 | -.432 | -.154 | -.376 | -.332 | -.275 |
| Total Dissolved Solids (mg/l) | -.197 | -.197 | .087 | .472 | .546 | 1 | .732 | .176 | .069 | -.003 | .022 | .137 | -.031 | -.176 | -.002 | .050 | .056 |
| Water Current (cm/sec) | .176 | .122 | -.249 | .565 | .646 | .732 | 1 | -.101 | -.202 | -.302 | -.188 | -.008 | -.302 | .202 | -.340 | -.311 | -.257 |
| Total Alkalinity (mg/l) | -.978** | -.958** | .908* | -.127 | -.176 | .176 | -.101 | 1 | .926** | .977** | .950** | .923** | .942** | .507 | .960** | .968** | .983** |
| Total Hardness (mg/l) | -.959** | -.976** | .987** | .113 | -.484 | .069 | -.202 | .926** | 1 | .942** | .920** | .914* | .978** | .551 | .955** | .948** | .940** |
| Dissolved Oxygen (mg/l) | -.974** | -.945** | .928** | -.210 | -.327 | -.003 | -.302 | .977** | .942** | 1 | .962** | .906* | .978** | .487 | .994** | .993** | .997** |
| Chlorides (mg/l) | -.944** | -.888* | .866* | -.139 | -.231 | .022 | -.188 | .950** | .920** | .962** | 1 | .977** | .971** | .642 | .961** | .958** | .972** |
| Nitrates (mg/l) | -.916* | -.877* | .846* | .045 | -.183 | .137 | -.008 | .923** | .914* | .906* | .977** | 1 | .938** | .727 | .906* | .903* | .924** |
| Phosphates (mg/l) | -.965** | -.942** | .951** | -.066 | -.432 | -.031 | -.302 | .942** | .978** | .978** | .971** | .938** | 1 | .566 | .988** | .980** | .976** |
| Silicates (mg/l) | -.430 | -.451 | .429 | .191 | -.154 | -.176 | .202 | .507 | .551 | .487 | .642 | .727 | .566 | 1 | .462 | .432 | .487 |
| GPP ($mgc/m^2/hr$) | -.979** | -.944** | .943** | -.169 | -.376 | -.002 | -.340 | .960** | .955** | .994** | .961** | .906* | .988** | .462 | 1 | .998** | .993** |
| NPP ($mgc/m^2/hr$) | -.987** | -.948** | .939** | -.172 | -.332 | .050 | -.311 | .968** | .948** | .993** | .958** | .903* | .980** | .432 | .998** | 1 | .995** |
| Respiration ($mgc/m^2/hr$) | -.983** | -.944** | .921** | -.190 | -.275 | .056 | -.257 | .983** | .940** | .997** | .972** | .924** | .976** | .487 | .993** | .995** | 1 |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

## Appendix 4: Statical Correlation Matrix among different Physico- chemical parameters of Nandeshwar Stream

| Parameters | AT | WT | pH | Cond | Dept | TDS | WC | TA | TH | DO | CHL | NIT | PHT | SIT | GP | NP | RES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 1 | .989** | -.865* | .347 | -.120 | -.229 | -.192 | -.393 | -.947** | -.936** | -.921** | -.945** | -.941** | -.794 | -.856* | -.610 | -.853* |
| Water Temp. (°C) | .989** | 1 | -.912* | .474 | .019 | -.220 | -.052 | -.418 | -.965** | -.973** | -.916* | -.974** | -.972** | -.807 | -.922** | -.593 | -.899* |
| pH | -.865* | -.912* | 1 | -.515 | -.265 | -.090 | -.166 | .321 | .915* | .951** | .857* | .968** | .948** | .874* | .967** | .640 | .970** |
| Conductivity (µS/cm) | .347 | .474 | -.515 | 1 | .685 | -.372 | .721 | -.315 | -.493 | -.594 | -.305 | -.518 | -.538 | -.247 | -.700 | -.039 | -.525 |
| Depth of Visibility (cm) | -.120 | .019 | -.265 | .685 | 1 | .322 | .919** | -.350 | .005 | -.135 | .086 | -.116 | -.124 | -.158 | -.367 | .187 | -.254 |
| Total Dissolved Solids (mg/l) | -.229 | -.220 | -.090 | -.372 | .322 | 1 | .184 | -.110 | .224 | .217 | .062 | .105 | .128 | -.208 | .085 | -.176 | -.079 |
| Water Current (cm/sec) | -.192 | -.052 | -.166 | .721 | .919** | .184 | 1 | -.385 | -.009 | -.080 | .047 | -.076 | -.110 | .110 | -.296 | .031 | -.238 |
| Total Alkalinity (mg/l) | -.393 | -.418 | .321 | -.315 | -.350 | -.110 | -.385 | 1 | .352 | .311 | .498 | .384 | .457 | .177 | .401 | .324 | .454 |
| Total Hardness (mg/l) | -.947** | -.965** | .915* | -.493 | .005 | .224 | -.009 | .352 | 1 | .973** | .954** | .985** | .987** | .705 | .917* | .737 | .938** |
| Dissolved Oxygen (mg/l) | -.936** | -.973** | .951** | -.594 | -.135 | .217 | -.080 | .311 | .973** | 1 | .879* | .987** | .977** | .796 | .970** | .590 | .930** |
| Chlorides (mg/l) | -.921** | -.916* | .857* | -.305 | .086 | .062 | .047 | .498 | .954** | .879* | 1 | .936** | .952** | .649 | .823* | .857* | .924** |
| Nitrates (mg/l) | -.945** | -.974** | .968** | -.518 | -.116 | .105 | -.076 | .384 | .985** | .987** | .936** | 1 | .995** | .798 | .961** | .694 | .970** |
| Phosphates (mg/l) | -.941** | -.972** | .948** | -.538 | -.124 | .128 | -.110 | .457 | .987** | .977** | .952** | .995** | 1 | .750 | .955** | .713 | .971** |
| Silicates (mg/l) | -.794 | -.807 | .874* | -.247 | -.158 | -.208 | .110 | .177 | .705 | .796 | .649 | .798 | .750 | 1 | .795 | .349 | .751 |
| GPP (mgc/m²/hr) | -.856* | -.922** | .967** | -.700 | -.367 | .085 | -.296 | .401 | .917* | .970** | .823* | .961** | .955** | .795 | 1 | .539 | .950** |
| NPP (mgc/m²/hr) | -.610 | -.593 | .640 | -.039 | .187 | -.176 | .031 | .324 | .737 | .590 | .857* | .694 | .713 | .349 | .539 | 1 | .765 |
| Respiration (mgc/m²/hr) | -.853* | -.899* | .970** | -.525 | -.254 | -.079 | -.238 | .454 | .938** | .930** | .924** | .970** | .971** | .751 | .950** | .765 | 1 |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

## Appendix – 5 Statical Correlation Matrix among different Physico- chemical parameters of River Banas

| Parameters | AT | WT | pH | Cond | Dept | TDS | WC | TA | TH | DO | CHL | NIT | PHT | SIT | GP | NP | RES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 1 | .989** | .476 | .845* | -.240 | -.266 | -.433 | .390 | .583 | -.911* | .471 | .952** | .958** | .523 | .777 | .620 | .610 |
| Water Temp. (°C) | .989** | 1 | .513 | .833* | -.294 | -.291 | -.463 | .428 | .639 | -.896* | .504 | .985** | .952** | .578 | .794 | .668 | .570 |
| pH | .476 | .513 | 1 | .792 | -.963** | -.947** | -.990** | .956** | .974** | -.607 | .986** | .481 | .655 | .948** | .854* | .919** | .753 |
| Conductivity (µS/cm) | .845* | .833* | .792 | 1 | -.628 | -.696 | -.787 | .744 | .823* | -.839* | .801 | .766 | .879* | .722 | .859* | .766 | .816* |
| Depth of Visibility (cm) | -.240 | -.294 | -.963** | -.628 | 1 | .969** | .969** | -.959** | -.920** | .376 | -.959** | -.279 | -.435 | -.909* | -.726 | -.851* | -.644 |
| Total Dissolved Solids (mg/l) | -.266 | -.291 | -.947** | -.696 | .969** | 1 | .978** | -.976** | -.879* | .370 | -.968** | -.237 | -.438 | -.861* | -.733 | -.815* | -.762 |
| Water Current (cm/sec) | -.433 | -.463 | -.990** | -.787 | .969** | .978** | 1 | -.983** | -.953** | .534 | -.997** | -.419 | -.601 | -.933** | -.841* | -.903* | -.795 |
| Total Alkalinity (mg/l) | .390 | .428 | .956** | .744 | -.959** | -.976** | -.983** | 1 | .930** | -.428 | .989** | .386 | .535 | .930** | .831* | .903* | .798 |
| Total Hardness (mg/l) | .583 | .639 | .974** | .823* | -.920** | -.879* | -.953** | .930** | 1 | -.658 | .962** | .632 | .723 | .960** | .886* | .946** | .701 |
| Dissolved Oxygen (mg/l) | -.911* | -.896* | -.607 | -.839* | .376 | .370 | .534 | -.428 | -.658 | 1 | -.544 | -.859* | -.967** | -.583 | -.764 | -.644 | -.585 |
| Chlorides (mg/l) | .471 | .504 | .986** | .801 | -.959** | -.968** | -.997** | .989** | .962** | -.544 | 1 | .461 | .627 | .948** | .870* | .926** | .811 |
| Nitrates (mg/l) | .952** | .985** | .481 | .766 | -.279 | -.237 | -.419 | .386 | .632 | -.859* | .461 | 1 | .910* | .563 | .743 | .646 | .447 |
| Phosphates (mg/l) | .958** | .952** | .655 | .879* | -.435 | -.438 | -.601 | .535 | .723 | -.967** | .627 | .910* | 1 | .689 | .879* | .761 | .700 |
| Silicates (mg/l) | .523 | .578 | .948** | .722 | -.909* | -.861* | -.933** | .930** | .960** | -.583 | .948** | .563 | .689 | 1 | .922** | .991** | .748 |
| GPP (mgc/m2/hr) | .777 | .794 | .854* | .859* | -.726 | -.733 | -.841* | .831* | .886* | -.764 | .870* | .743 | .879* | .922** | 1 | .963** | .872* |
| NPP (mgc/m2/hr) | .620 | .668 | .919** | .766 | -.851* | -.815* | -.903* | .903* | .946** | -.644 | .926** | .646 | .761 | .991** | .963** | 1 | .786 |
| Respiration (mgc/m2/hr) | .610 | .570 | .753 | .816* | -.644 | -.762 | -.795 | .798 | .701 | -.585 | .811 | .447 | .700 | .748 | .872* | .786 | 1 |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

## Appendix 6: Statical Correlation Matrix among different Physico- chemical parameters of Barapal Stream

| Parameters | AT | WT | pH | Cond | Dept | TDS | WC | TA | TH | DO | CHL | NIT | PHT | SIT | GP | NP | RES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 1 | .967** | .604 | -.839* | -.924** | .499 | -.340 | .356 | .278 | -.966** | .257 | .176 | .121 | .975** | .236 | .173 | .133 |
| Water Temp. (°C) | .967** | 1 | .402 | -.866* | -.974** | .290 | -.100 | .145 | .173 | -.975** | .043 | -.060 | -.127 | .973** | -.009 | -.080 | -.120 |
| pH | .604 | .402 | 1 | -.271 | -.279 | .952** | -.941** | .898* | .733 | -.469 | .878* | .756 | .848* | .555 | .905* | .835* | .830* |
| Conductivity (µS/cm) | -.839* | -.866* | -.271 | 1 | .893* | -.158 | .006 | .061 | .048 | .855* | .172 | .190 | .184 | -.795 | .063 | .074 | .127 |
| Depth of Visibility (cm) | -.924** | -.974** | -.279 | .893* | 1 | -.131 | -.014 | -.062 | -.036 | .914* | .118 | .161 | .234 | -.898* | .124 | .173 | .213 |
| Total Dissolved Solids (mg/l) | .499 | .290 | .952** | -.158 | -.131 | 1 | -.942** | .814* | .626 | -.416 | .939** | .848* | .875* | .474 | .921** | .878* | .864* |
| Water Current (cm/sec) | -.340 | -.100 | .941** | .006 | -.014 | .942** | 1 | .924** | -.641 | .189 | .943** | .903* | .974** | -.266 | .991** | .964** | .966** |
| Total Alkalinity (mg/l) | .356 | .145 | .898* | .061 | -.062 | .814* | -.924** | 1 | .748 | -.156 | .878* | .797 | .884* | .283 | .893* | .824* | .845* |
| Total Hardness (mg/l) | .278 | .173 | .733 | .048 | -.036 | .626 | -.641 | .748 | 1 | -.162 | .678 | .340 | .599 | .332 | .635 | .467 | .504 |
| Dissolved Oxygen (mg/l) | -.966** | -.975** | -.469 | .855* | .914* | -.416 | .189 | -.156 | -.162 | 1 | -.154 | -.061 | .030 | -.981** | -.090 | -.033 | .016 |
| Chlorides (mg/l) | .257 | .043 | .878* | .172 | .118 | .939** | -.943** | .878* | .678 | -.154 | 1 | .907* | .929** | .244 | .934** | .884* | .892* |
| Nitrates (mg/l) | .176 | -.060 | .756 | .190 | .161 | .848* | -.903* | .797 | .340 | -.061 | .907* | 1 | .912* | .094 | .893* | .926** | .921** |
| Phosphates (mg/l) | .121 | -.127 | .848* | .184 | .234 | .875* | -.974** | .884* | .599 | .030 | .929** | .912* | 1 | .045 | .991** | .981** | .991** |
| Silicates (mg/l) | .975** | .973** | .555 | -.795 | -.898* | .474 | -.266 | .283 | .332 | -.981** | .244 | .094 | .045 | 1 | .164 | .075 | .037 |
| GPP (mgc/m²/hr) | .236 | -.009 | .905* | .063 | .124 | .921** | -.991** | .893* | .635 | -.090 | .934** | .893* | .991** | .164 | 1 | .979** | .984** |
| NPP (mgc/m²/hr) | .173 | -.080 | .835* | .074 | .173 | .878* | -.964** | .824* | .467 | -.033 | .884* | .926** | .981** | .075 | .979** | 1 | .997** |
| Respiration (mgc/m²/hr) | .133 | -.120 | .830* | .127 | .213 | .864* | -.966** | .845* | .504 | .016 | .892* | .921** | .991** | .037 | .984** | .997** | 1 |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

**Appendix – 7 Statical Correlation Matrix among different Physico- chemical parameters of Thur ki Pal Stream**

| Parameters | AT | WT | pH | Cond | Dept | TDS | WC | TA | TH | DO | CHL | NIT | PHT | SIT | GP | NP | RES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | | .964** | .566 | -.578 | -.369 | .377 | -.329 | .459 | .443 | -.937** | -.084 | -.634 | -.184 | .964** | .225 | -.201 | .122 |
| Water Temp. (°C) | .964** | 1 | .682 | -.716 | -.524 | .226 | -.497 | .543 | .555 | -.868* | .046 | -.570 | -.026 | .872* | .363 | -.057 | .195 |
| pH | .566 | .682 | 1 | -.963** | -.934** | -.506 | -.950** | .953** | .943** | -.342 | .742 | .153 | .691 | .434 | .916* | .678 | .802 |
| Conductivity (µS/cm) | -.578 | -.716 | -.963** | 1 | .944** | .441 | .951** | -.858* | -.908* | .372 | -.712 | -.053 | -.652 | -.462 | -.897* | -.643 | -.752 |
| Depth of Visibility (cm) | -.369 | -.524 | -.934** | .944** | 1 | .688 | .981** | -.827* | -.836* | .090 | -.805 | -.190 | -.756 | -.254 | -.950** | -.787 | -.779 |
| Total Dissolved Solids (mg/l) | .377 | .226 | -.506 | .441 | .688 | 1 | .691 | -.518 | -.474 | -.634 | -.834* | -.689 | -.864* | .469 | -.752 | -.915* | -.673 |
| Water Current (cm/sec) | -.329 | -.497 | -.950** | .951** | .981** | .691 | 1 | -.882* | -.908* | .087 | -.860* | -.303 | -.832* | -.192 | -.975** | -.830* | -.837* |
| Total Alkalinity (mg/l) | .459 | .543 | .953** | -.858* | -.827* | -.518 | -.882* | 1 | .968** | -.281 | .789 | .358 | .752 | .332 | .895* | .715 | .877* |
| Total Hardness (mg/l) | .443 | .555 | .943** | -.908* | -.836* | -.474 | -.908* | .968** | 1 | -.304 | .818* | .359 | .784 | .318 | .911* | .730 | .891* |
| Dissolved Oxygen (mg/l) | -.937** | -.868* | -.342 | .372 | .090 | -.634 | .087 | -.281 | -.304 | 1 | .268 | .650 | .351 | -.924** | .010 | .408 | .036 |
| Chlorides (mg/l) | -.084 | .046 | .742 | -.712 | -.805 | -.834* | -.860* | .789 | .818* | .268 | 1 | .715 | .981** | -.157 | .940** | .985** | .955** |
| Nitrates (mg/l) | -.634 | -.570 | .153 | -.053 | -.190 | -.689 | -.303 | .358 | .359 | .650 | .715 | 1 | .776 | -.671 | .453 | .742 | .629 |
| Phosphates (mg/l) | -.184 | -.026 | .691 | -.652 | -.756 | -.864* | -.832* | .752 | .784 | .351 | .981** | .776 | 1 | -.294 | .898* | .982** | .899* |
| Silicates (mg/l) | .964** | .872* | .434 | -.462 | -.254 | .469 | -.192 | .332 | .318 | -.924** | -.157 | -.671 | -.294 | 1 | .125 | -.281 | .077 |
| GPP (mgc/m²/hr) | .225 | .363 | .916* | -.897* | -.950** | -.752 | -.975** | .895* | .911* | .010 | .940** | .453 | .898* | .125 | 1 | .908* | .931** |
| NPP (mgc/m²/hr) | -.201 | -.057 | .678 | -.643 | -.787 | -.915* | -.830* | .715 | .730 | .408 | .985** | .742 | .982** | -.281 | .908* | 1 | .896* |
| Respiration (mgc/m²/hr) | .122 | .195 | .802 | -.752 | -.779 | -.673 | -.837* | .877* | .891* | .036 | .955** | .629 | .899* | .077 | .931** | .896* | 1 |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

## Appendix – 8 Statical Correlation Matrix among different Physico- chemical parameters of Jhameshwar Stream

| Parameters | AT | WT | pH | Cond | Dept | TDS | WC | TA | TH | DO | CHL | NIT | PHT | SIT | GP | NP | RES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 1 | .992** | .207 | -.430 | -.186 | -.108 | -.142 | .194 | .251 | -.967** | .035 | .197 | .468 | .956** | -.057 | -.283 | .016 |
| Water Temp. (°C) | .992** | 1 | .219 | -.440 | -.184 | -.060 | -.116 | .198 | .248 | -.961** | .051 | .193 | .457 | .969** | -.069 | -.294 | .014 |
| pH | .207 | .219 | 1 | -.934** | -.959** | -.588 | -.941** | .965** | .990** | -.226 | .964** | .979** | .932** | .000 | .919** | .843* | .950** |
| Conductivity (µS/cm) | -.430 | -.440 | -.934** | 1 | .828* | .692 | .860* | -.852* | -.919** | .446 | -.908* | -.946** | -.943** | -.233 | -.852* | -.706 | -.891* |
| Depth of Visibility (cm) | -.186 | -.184 | -.959** | .828* | 1 | .508 | .924** | -.994** | -.973** | .168 | -.870* | -.912* | -.883* | .037 | -.851* | -.797 | -.869* |
| Total Dissolved Solids (mg/l) | -.108 | -.060 | -.588 | .692 | .508 | 1 | .650 | -.548 | -.592 | .051 | -.635 | -.685 | -.576 | .144 | -.756 | -.649 | -.689 |
| Water Current (cm/sec) | -.142 | -.116 | -.941** | .860* | .924** | .650 | 1 | -.904* | -.968** | .191 | -.921** | -.972** | -.931** | .097 | -.945** | -.895* | -.955** |
| Total Alkalinity (mg/l) | .194 | .198 | .965** | -.852* | -.994** | -.548 | -.904* | 1 | .968** | -.160 | .880* | .913* | .871* | -.030 | .854* | .789 | .870* |
| Total Hardness (mg/l) | .251 | .248 | .990** | -.919** | -.973** | -.592 | -.968** | .968** | 1 | -.271 | .935** | .978** | .957** | .029 | .909* | .832* | .937** |
| Dissolved Oxygen (mg/l) | -.967** | -.961** | -.226 | .446 | .168 | .051 | .191 | -.160 | -.271 | 1 | -.089 | -.240 | -.516 | -.945** | .017 | .225 | -.074 |
| Chlorides (mg/l) | .035 | .051 | .964** | -.908* | -.870* | -.635 | -.921** | .880* | .935** | -.089 | 1 | .974** | .868* | -.156 | .967** | .919** | .990** |
| Nitrates (mg/l) | .197 | .193 | .979** | -.946** | -.912* | -.685 | -.972** | .913* | .978** | -.240 | .974** | 1 | .949** | -.025 | .960** | .881* | .981** |
| Phosphates (mg/l) | .468 | .457 | .932** | -.943** | -.883* | -.576 | -.931** | .871* | .957** | -.516 | .868* | .949** | 1 | .262 | .828* | .705 | .876* |
| Silicates (mg/l) | .956** | .969** | .000 | -.233 | .037 | .144 | .097 | -.030 | .029 | -.945** | -.156 | -.025 | .262 | 1 | -.287 | -.491 | -.196 |
| GPP (mgc/m²/hr) | -.057 | -.069 | .919** | -.852* | -.851* | -.756 | -.945** | .854* | .909* | .017 | .967** | .960** | .828* | -.287 | 1 | .969** | .990** |
| NPP (mgc/m²/hr) | -.283 | -.294 | .843* | -.706 | -.797 | -.649 | -.895* | .789 | .832* | .225 | .919** | .881* | .705 | -.491 | .969** | 1 | .948** |
| Respiration (mgc/m²/hr) | .016 | .014 | .950** | -.891* | -.869* | -.689 | -.955** | .870* | .937** | -.074 | .990** | .981** | .876* | -.196 | .990** | .948** | 1 |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

## Appendix – 9 Statical Correlation Matrix among different Physico- chemical parameters of Lake Fateh Sagar

| Parameters | AT | WT | pH | Cond | Dept | TDS | WC | TA | TH | DO | CHL | NIT | PHT | SIT | GP | NP | RES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 1 | .929** | .385 | .352 | -.454 | .367 | | .817* | .279 | -.837* | -.019 | .448 | .660 | .556 | -.054 | -.580 | .322 |
| Water Temp. (°C) | .929** | 1 | .165 | .111 | -.488 | .099 | | .658 | .089 | -.715 | -.097 | .184 | .466 | .317 | -.245 | -.795 | .309 |
| pH | .385 | .165 | 1 | .630 | .551 | .781 | | .695 | .940** | -.587 | .671 | .929** | .891* | .646 | .867* | .270 | .816* |
| Conductivity (µS/cm) | .352 | .111 | .630 | 1 | -.034 | .927** | | .503 | .765 | -.749 | .136 | .835* | .801 | .827* | .666 | .513 | .407 |
| Depth of Visibility (cm) | -.454 | -.488 | .551 | -.034 | 1 | .152 | | -.055 | .521 | .274 | .727 | .309 | .161 | -.095 | .718 | .426 | .586 |
| Total Dissolved Solids (mg/l) | .367 | .099 | .781 | .927** | .152 | 1 | | .480 | .812* | -.664 | .157 | .866* | .833* | .935** | .778 | .483 | .474 |
| Water Current (cm/sec) | | | | | | | | | | | | | | | | | |
| Total Alkalinity (mg/l) | .817* | .658 | .695 | .503 | -.055 | .480 | | 1 | .638 | -.857* | .517 | .771 | .849* | .468 | .314 | -.235 | .608 |
| Total Hardness (mg/l) | .279 | .089 | .940** | .765 | .521 | .812* | | .638 | 1 | -.643 | .673 | .946** | .901* | .614 | .921** | .412 | .853* |
| Dissolved Oxygen (mg/l) | -.837* | -.715 | -.587 | -.749 | .274 | -.664 | | -.857* | -.643 | 1 | -.187 | -.747 | -.889* | -.693 | -.330 | .154 | -.558 |
| Chlorides (mg/l) | -.019 | -.097 | .671 | .136 | .727 | .157 | | .517 | .673 | -.187 | 1 | .581 | .472 | -.111 | .607 | .208 | .744 |
| Nitrates (mg/l) | .448 | .184 | .929** | .835* | .309 | .866* | | .771 | .946** | -.747 | .581 | 1 | .948** | .719 | .811 | .373 | .705 |
| Phosphates (mg/l) | .660 | .466 | .891* | .801 | .161 | .833* | | .849* | .901* | -.889* | .472 | .948** | 1 | .765 | .695 | .105 | .770 |
| Silicates (mg/l) | .556 | .317 | .646 | .827* | -.095 | .935** | | .468 | .614 | -.693 | -.111 | .719 | .765 | 1 | .546 | .226 | .318 |
| GPP (mgc/m²/hr) | -.054 | -.245 | .867* | .666 | .718 | .778 | | .314 | .921** | -.330 | .607 | .811 | .695 | .546 | 1 | .635 | .732 |
| NPP (mgc/m²/hr) | -.580 | -.795 | .270 | .513 | .426 | .483 | | -.235 | .412 | .154 | .208 | .373 | .105 | .226 | .635 | 1 | .006 |
| Respiration (mgc/m²/hr) | .322 | .309 | .816* | .407 | .586 | .474 | | .608 | .853* | -.558 | .744 | .705 | .770 | .318 | .732 | .006 | 1 |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

## Appendix – 10 Statical Correlation Matrix among different Physico- chemical parameters of Lake Pichchola

| Parameters | AT | WT | pH | Cond | Dept | TDS | WC | TA | TH | DO | CHL | NIT | PHT | SIT | GP | NP | RES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature (°C) | 1 | .956** | .544 | .681 | -.053 | .669 | | .776 | .558 | -.842* | .713 | .279 | .302 | .210 | -.554 | -.720 | .458 |
| Water Temp. (°C) | .956** | 1 | .375 | .591 | -.231 | .583 | | .719 | .496 | -.839* | .493 | .062 | .100 | .049 | -.660 | -.807 | .440 |
| pH | .544 | .375 | 1 | .879* | .693 | .865* | | .804 | .917* | -.657 | .885* | .938** | .929** | .690 | .349 | .043 | .745 |
| Conductivity (μS/cm) | .681 | .591 | .879* | 1 | .573 | .997** | | .955** | .874* | -.785 | .783 | .759 | .766 | .679 | .154 | -.053 | .826* |
| Depth of Visibility (cm) | -.053 | -.231 | .693 | .573 | 1 | .600 | | .323 | .572 | .014 | .551 | .865* | .901* | .931** | .842* | .698 | .660 |
| Total Dissolved Solids (mg/l) | .669 | .583 | .865* | .997** | .600 | 1 | | .934** | .872* | -.750 | .770 | .751 | .771 | .718 | .177 | -.027 | .858* |
| Water Current (cm/sec) | | | | | | | | | | | | | | | | | |
| Total Alkalinity (mg/l) | .776 | .719 | .804 | .955** | .323 | .934** | | 1 | .817* | -.925** | .728 | .617 | .592 | .434 | -.085 | -.280 | .684 |
| Total Hardness (mg/l) | .558 | .496 | .917* | .874* | .572 | .872* | | .817* | 1 | -.726 | .698 | .772 | .802 | .600 | .280 | -.072 | .889* |
| Dissolved Oxygen (mg/l) | -.842* | -.839* | -.657 | -.785 | .014 | -.750 | | -.925** | -.726 | 1 | -.601 | -.382 | -.345 | -.102 | .368 | .586 | -.506 |
| Chlorides (mg/l) | .713 | .493 | .885* | .783 | .551 | .770 | | .728 | .698 | -.601 | 1 | .826* | .821* | .651 | .078 | -.141 | .547 |
| Nitrates (mg/l) | .279 | .062 | .938** | .759 | .865* | .751 | | .617 | .772 | -.382 | .826* | 1 | .982** | .794 | .597 | .355 | .644 |
| Phosphates (mg/l) | .302 | .100 | .929** | .766 | .901* | .771 | | .592 | .802 | -.345 | .821* | .982** | 1 | .870* | .610 | .352 | .740 |
| Silicates (mg/l) | .210 | .049 | .690 | .679 | .931** | .718 | | .434 | .600 | -.102 | .651 | .794 | .870* | 1 | .620 | .490 | .770 |
| GPP (mgc/m²/hr) | -.554 | -.660 | .349 | .154 | .842* | .177 | | -.085 | .280 | .368 | .078 | .597 | .610 | .620 | 1 | .913* | .361 |
| NPP (mgc/m²/hr) | -.720 | -.807 | .043 | -.053 | .698 | -.027 | | -.280 | -.072 | .586 | -.141 | .355 | .352 | .490 | .913* | 1 | .091 |
| Respiration (mgc/m²/hr) | .458 | .440 | .745 | .826* | .660 | .858* | | .684 | .889* | -.506 | .547 | .644 | .740 | .770 | .361 | .091 | 1 |

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed)

# CHAPTER- VII

# POPULATION STUDIES AND ASSOCIATION OF HILL STREAM FISHES

## A. POPULATION STUDIES

### (a) Meristic Characters

The meristics characters along with some general information of the selected hillstream fishes mentioned below . These were found similar to those described by Day (1873,1875 and 1878) , Talwar and Jhingran (1991) , Jayaram (1999) , Johal and Tandon (1979, 1980 and 1981).

**1. *Chela bacaila* (Ham.)**

**Family – Cyprinidae**

- B. iii, D. 9(2/7), P. 13, V. 9, A. 13-15 , C-19, L l 86-110, L. tr. 17-19/6-10.
- **Fins –** first anal ray is below the middle of the dorsal fin : pectoral nearly reaches the ventral, whilst the latter does not quite extend to the anal.
- **Geographical distribution–** Throughout India except Malabar, Mysore and Madras and parts of the Deccan.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982) , in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984). Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).

- **(b) Present record :** Sisarma river , Ubeshwar stream , Nandeshwar sream, Banas river , Jhameshar stream , Thur ki pal stream, Barapal stream , lake Fateh Sagar and lake Pichhola.

**2.** ***Rasbora daniconius* (Ham.)**

**Family – Cyprinidae**

- B. iii, D 9 (2/7), P.15, V 9, A.7 (2/5), C.19, L. l. 31-34, Ltr 4½ 15, Vert. 18/14.
- **Fins –** dorsal 2/3, the height of the body it commences nearer the base of the caudal than the front edge of the snout and rather nearer origin of ventral than that of anal in some examples.
- **Lateral line –** descends very gradually for the depth of 2 rows of scales : 2 rows of scales between it and ventral fin : 14 rows in front of base of dorsal fin.
- **Geographical distribution –** Continents of India, Ceylon, Burma, Malay in ponds, tanks and streams.
- **Distribution in Rajasthan –** (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982) , in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984). Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Sisarma river , Ubeshwar stream , Nandeshwar sream, Banas river , Jhameshar stream , Thur ki pal stream, Barapal stream , lake Fateh Sagar and lake Pichhola.

**3.** ***Puntius ticto* (Ham- Buch)**

**Family – Cyprinidae**

- B. iii, D 11 (3/8), p. 15, V. 9, A 7 (2/5), C. 19, L l 23-26, L. tr. 5-6/6.
- **Body** - strongly compressed and elevated.

- **Fins –** osseous dorsal ray strong, three-quarters as long as the head, fin half as high as the body caudal forked.
- **Colours –** silvery, sometimes stained with red, a black spot on the side of the tail before the base of the caudal fin .
- **Geographical distribution–** Sind, throughout India and Ceylon.
- **Distribution in Rajasthan –** (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982) , in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984). Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Sisarma river , Ubeshwar stream , Nandeshwar sream, Banas river , Jhameshar stream , Thur ki pal stream, Barapal stream , lake Fateh Sagar and lake Pichhola.

**4.** ***Systomus sarana* (Ham. )**

**(Olive Barb)**

- Family – Cyprinidae
- B. iii, D 11 (3/8), P. 15, V. 9, A 8 (3/5), C. 19, L. 1 32-34, L. tr. 5½ - 6/6.
- **Body**- Profile of the back elevated.
- **Barbels –** the rostral pair about as long as the orbit, the maxillary pair longer, sometimes equaling 1½ diameters of the orbit.
- **Fins –** dorsal commences slightly nearer the snout than the base of the caudal fin and opposite the insertion of the ventral.
- **Colours –** silvery, darkest superiorly opercles shot with gold, mostly some dark spots behind the opercle.
- **Geographical distribution –** Sind and the Punjab throughout India, Assam and Burma. Inhabiting streams, rivers, ponds, lakes and tanks.
- **Distribution in Rajasthan –** (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982) , in Jaisamand

lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984). Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).

- **(b) Present record :** Banas river , lake Fateh Sagar and lake Pichhola.

**5.** ***Puntius sophore* (Ham.)**

**Family – Cyprinidae**

- B. iii, D. 12 (3/9), P. 15, V. 9, A. 7 (2/5), L. l. 25, L. tr. 3½ / 4½.
- Upper jaw longer.
- **Barbels –** Maxillary pair half longer than the eye, the rostral pair slightly shorter.
- **Fins –** dorsal ray weak, osseous, the fin arises slightly before ventral, and midway between the end of snout and the root of the caudal.
- **Colour –** silvery.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982) , in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984). Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Sisarma river , Banas river , Jhadol stream ,lake Fateh Sagar and lake Pichhola.

**6.** ***Garra gotyla* (Gray)**

**(Stone sucker)**

**Family – Cyprinidae**

- B. iii, D. 11 $\left(\frac{\mathbf{3-2}}{\mathbf{8-9}}\right)$, P. 15, V. 9, A. 7 (2/5), C. 17, L. l. 32-36, L. tr. 4-4½/5.

- **Fins –** the dorsal arises midway between the end of snout and the base of caudal. The pectoral shorter than the head, caudal slightly lobed.
- It bears well developed adhesive disc on its ventral surface.
- The mouth is inferior. Both lips are thick and have prominent tubercles. Upper lip is highly fringed. Behind the lower jaw, lower lip continues and its labial fold has free margin forming the circular disc. The space between the lower lip and postero-lateral free margin of disc becomes thickened and forms the callous pad.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982) , in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984). Recently in rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Sisarma river , Ubeshwar stream , Nandeshwar sream, Banas river , Jhameshar stream , Thur ki pal stream, Barapal stream

**7. *Tor tor* (Ham-Buch.)**

**(Mahseer)**

**Family – Cyprinidae**

- B. iii, D. 12 (3/9), P. 19, V. 9, A. 7-8 (2-3/5) L. l 25-27, L. tr. 4/4.
- Snout pointed jaws of about the same length, lips thick, with an uninterrupted fold across the lower jaw.
- **Barbles** – the maxillary pair longer than the rostral ones, and extend to below the last third of the eye.
- **Colours –** Silvery or greenish along the upper half of the body, becoming silvery shot with gold on the sides and beneath.
- **Geographical distribution** – Generally throughout India but in the largest size and greatest abundance in mountain streams or those which are rocky.

- **Distribution in Rajasthan** – (a) Earlier records : in Jhalawar district (Gupta and Kulshreshtha 1985), in Swai-Madhopur district (Johal and Sharma1986) , in Chambal river by Gaur (2011).
- **(b) Present record :** only in lake Pichhola.

**8.** ***Amblypharyngodon mola* (Ham.)**

**Family –Cyprinidae**

- B.iii, D.9(2/7), P.15, V.9 , A.7 (2/5),C.19 ,L.l.65-75, L. tr.12/12 .
- **Body** - elongated with small scales.
- **Fins**- dorsal, anal and caudal fins with dark markings.
- **Lateral line** - incomplete with 65-91 scales, 9-10 scale rows between lateral line and pelvic fin base .
- **Colours**- A broad silvery lateral band on body.
- **Geographical distribution** – Throughout India except Malabar coast , Pakisthan Bangladesh and Myanmar.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982) , in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984). Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Jhadol stream , Banas river , lake Fateh Sagar and lake Pichhola.

**9.** ***Danio rerio* (Ham.)**

**Family – Cyprinidae**

- B. iii, 9 (2/7), P. 13, V. 8, A: 15-16 $\left(\frac{\mathbf{2-3}}{\mathbf{12-13}}\right)$. C. 19, L. l. 26-28, L. tr. 6.
- **Barbels –** rostral short, maxillary ones reaching the end of opercle.

- **Lateral line –** absent.
- **Colour –** four metallic blue lines along the sides. Dorsal with a blue edging. Anal with three longitudinal blue bands.
- **Distribution in Rajasthan –** (a) Earlier records : in Kota district (Sharma and Johal 1984) and in Chambal river by Gaur (2011).
- (b) Present record : Sisarma river and Banas river .

**10.** ***Osteobrama cotio* ( Ham.)**

**Family – Cyprinidae**

- B. iii, D. 11-12, P. 13, V. 10, A. 29-36 ,C. 19, L. l. 55-70, L. tr. $\frac{\mathbf{9-15}}{\mathbf{14-21}}$.
- **Profile –** a great rise to the base of dorsal fin.
- **Fins –** dorsal commences nearer the snout than the base of caudal fin, its osseous ray is weak and serrated. Pectoral reaches over the ventral and the latter to the anal.
- **Geographical distribution –** Throughout India except Malabar coast , Pakisthan Bangladesh and Myanmar.
- **Distribution in Rajasthan –**(a) Earliar records : in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) .Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Jhadol stream , Banas river , lake Fateh Sagar and lake Pichhola.

**11.** ***Catla catla* ( Ham.)**

**Family – Cyprinidae**

- B.iii D. 18, P. 21,V.9 , A. 8(3/5), C.19, L.l. 40-43, L.tr. $7^{1/2}$/9.
- **Mouth -** wide, lower jaw prominent.

- **Fins-** dorsal commences in advance of the ventrals.Pectoral extends to the ventral.
- **Colours –** grayish above , silvery on the sides.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Lake Fateh Sagar and lake Pichhola.

**12.** ***Cirrhinus mrigala*** **(Ham.)**

**(Mrigal)**

**Family – Cyprinidae**

- B.iii, D.15-16$\left(\frac{\mathbf{3}}{\mathbf{12\text{-}13}}\right)$, P.15, V.9, A.8, C.15, L.1.40-45, L.tr.6½- 7/8 ½.
- **Fins –** dorsal nearly as high as the body. Pectoral as long as the head. Caudal with deeply forked lobes.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Jhadol stream , lake Fateh Sagar and lake Pichhola.

13. *Labeo rohita* **(Ham.)**

**(Rohu)**

**Family – Cyprinidae**

- B. iii, D. 15-16 $\left(\frac{\mathbf{3}}{\mathbf{12\text{-}13}}\right)$, P. 17, V. 9. A. 7 , C. 19, L. l. 40-42, L. tr. 6½/9.
- **Barbels –** a short and thin maxillary pair.
- **Fins –** the dorsal arises about midway between the snout and the base of caudal fin. Caudal deeply forked.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Jhadol stream, lake Fateh Sagar and lake Pichhola.

14. *Labeo bata* **(Ham.)**

**Family – Cyprinidae**

- B. iii, D. 11-12 $\left(\frac{\mathbf{2\text{-}3}}{\mathbf{9\text{-}10}}\right)$, P. 18, V. 9, A. 7, C. 19, L. 1. 37-40, L. tr. 7/6-7.
- **Barbels –** a pair of short maxillary ones.
- **Fins –** dorsal as high as the head. Pectoral as long as head. Caudal deeply forked.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and

Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).

- **(b) Present record :** Lake Fateh Sagar and lake Pichhola.

**15.** ***Labeo boggut* (Sykes)**

**Family – Cyprinidae**

- B. iii, D. 11-12 $\left(\frac{\mathbf{3}}{\mathbf{8-9}}\right)$, P. 17, V. 9, A. 7 , C. 19, L l. 60-65, L. tr. 11-12/14.
- **Barbels –** a short maxillary, but no rostral pair.
- **Fins –** the dorsal commences nearer to the snout than the root of the caudal, pectoral as long as head, ventral does not extent to anal, caudal deeply forked.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Lake Fateh Sagar and lake Pichhola.

**16.** ***Labeo gonius* (Ham.)**

**Family – Cyprinidae**

- B. ii, D. 16-18 $\left(\frac{\mathbf{2-3}}{\mathbf{13-14}}\right)$, P. 17, 9, A. 7 (2/5), C. 19, L. 1. 74-84, L. tr. 16/17.
- Dorsal profile more convex that of the abdomen.

- **Barbels –** 4, short maxillary and rostral ones.
- **Fins –** the dorsal commences much nearer the snout than the base of caudal fin. Pectoral as long as head. Caudal deeply forked.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** River Banas , lake Fateh Sagar and lake Pichhola.

**17.** ***Labeo calbasu*** **(Ham.)**

**Family – Cyprinidae**

- B. iii, D. 16-18 $\left(\frac{\mathbf{3}}{\mathbf{13-15}}\right)$, P. 19, V. 9, A. 7 , C. 19, L. l. 40-44. L. tr. 7½/8.
- **Fins –** dorsal commences in advance of ventrals. Ventral commences below 4 or 5 dorsal ray (Branched). Caudal deeply forked.
- **Lateral line –** 5½ to 6 rows of scales between it and the base of ventral fin. Scales 40 – 44.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Lake Fateh Sagar and lake Pichhola.

**18.** *Notopterus notopterus* **(Pallas)**

**Family – Notopteriadae**

- D. 8 (1/7), P. 17, V. 6, A. 100, C. 19, L. l. 225, Vert 30/60.
- Anal with 100-110 rays.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Lake Fateh Sagar and lake Pichhola.

**19.** *Noemacheilus botia* **(Ham. Buch.)**

**(Striped Loach)**

**Family – Cobitidae**

- B. iii, D 12-14 (2/10-12) P. 11, V. 8, A. 7 (2/5), C. 17.
- **Barbels –** long, the maxillary pair reaching to below the posterior edge of the eye.
- **Fins –** dorsal commences rather nearer the snout than to the base of the caudal fin, whilst the length of its base equals that of the head, its upper edge nearly straight. Pectoral as long as the head ventral inserted under the middle of the dorsal, caudal slightly notched.
- **Colours –** grayish, with form 10-14 short bars on the lateral line and a number of irregular blotches above it. Dorsal fin orange and with rows of black spots. Caudal with about seven irregular bars of a > shape and a black ocellus on the upper portion of the base of the fin.
- **Geographical distribution** – Generally throughout India.

- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** All the selected waterbodies.

**20.** *Noemacheilus denisonii* **(Ham.)**

**Family – Cobitidae**

- B. iii, D. 10-11 (2-3/8), P. 10, V. 7, A. 7 (2/5), C. 18.
- **Barbels –** long, the rostral and maxillary ones reach the eye.
- **Fins** – dorsal with its upper edge rather convex, Pectoral extends two-thirds of the distance to the ventral, which last scarcely reaches half way to the anal. Caudal very slightly emarginate, its lobes being rounded.
- **Lateral line –** incomplete.
- **Colours –** purplish, becoming lighter on the abdomen, having from ten to twelve very narrow vertical white bands, not above 1/8 or 1/6 as wide as the ground colour, a black band at the root of the caudal fin; a black blotch at the base of the first few dorsal rays, on to which the white body bands are continued. Caudal with narrow bands of dark spots .Two bands also on the ventral and anal fins.
- **Geographical distribution –** Bengal and N.W. Provinces.
- **Distribution in Rajasthan –** (a) Earlier records : Mathur (1952), Datta and Majumdar (1970).
- **(b) Present record :** in all the selected waterbodies.

**21.** *Sperata seenghala* **(Sykes)**

**Family – Bagridae**

- B. xii, D. 1/2 | 0, P. 1/9, V. 6, A. 11-12 (13/8-9), C. 19-21.
- **Barbels –** the maxillary ones extend to the middle or just beyond the hind margin of the dorsal fin.
- **Fins –** dorsal one-third to one-half higher than the body, length of the base of the adipose dorsal equals or exceeds that of the rayed fin. Pectoral extends rather above half way to the ventral, Ventral arises behind the vertical from the last dorsal ray and reaches 2/3 of the distance to the anal. Caudal deeply forked, upper lobe the longer.
- **Colours –** brownish along the back, silvery on the sides and beneath, a round black spot at the posterior end of the base of the adipose dorsal fin.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan –** (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Lake Fateh Sagar and lake Pichhola.

**22.** *Mystus cavasius* **(Sykes)**

**Family – Bagridae**

- B. vi, D. 1/7 / 0, P. 1/8, V. 6, A. 11-13 (4/7-9), C. 16.
- **Barbels –** the maxillary extend to beyond the base of the caudal fin, the external mandibular almost to the base of the ventral, whilst the internal are as long as the head.
- **Fins –** the adipose dorsal commences just behind the rayed one, and the length of its base in three times as long. Pectoral spine as long as, but

stronger than the dorsal, smooth externally, denticulated internally. Ventral arises just posterior to the vertical from the last dorsal ray. Caudal pointed, upper lobe the longer.

- **Colours –** leaden superiorly, becoming yellowish along the abdomen and cheeks. There is usually a black spot covering the basal bone of the dorsal fin.
- **Geographical distribution –** Generally throughout India.
- **Distribution in Rajasthan –** (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Jhadol stream, river Banas ,Lake Fateh Sagar and lake Pichhola.

**23. *Mystus aor* (Ham.)**

**Family – Bagridae**

- B. xii, D. 1/7 | 0, P. 1/9-10 V. 6, A. 12-13 (3-4/9), C. 17.
- **Barbels –** the maxillary extend to, or even beyond, the base of the caudal fin : the nasal half-way to the orbit : the outer mandibular ones to the base of the pectoral, and the inner two-thirds of that distance.
- **Fins –** dorsal spine rather weak, nearly or quite as long as the head. Pectoral as long as the head excluding the snout and its spine is stronger than that of the dorsal but shorter. Ventral arises below the last dorsal rays and does not reach the anal. Caudal with deeply pointed lobes, the three outer rays in the upper lobe being produced.
- **Colours –** bluish-leaden superiorly, becoming white beneath : fins yellowish, stained with dark externally in both the dorsal and caudal. A

black spot about equal to the diameter of the eye on the soft dorsal on its posterior and inferior portion.

- **Geographical distribution**– Throughout Sind and India to Burma.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Lake Fateh Sagar and lake Pichhola.

**24.** ***Wallago attu* (Bloch)**

**Family – Siluridae**

- B. xix-xxi, D. 5, P. 1/13-15, V. 8.10, A. 86-93 $\left(\frac{\mathbf{4}}{\mathbf{82-89}}\right)$, C. 17, Vert. 13/56.
- **Barbels –** the maxillary twice as long as the head, mandibular ones as long as snout.
- **Fins –** dorsal as long as the pectoral. Pectoral serrated anal not confluent with the caudal.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Lake Fateh Sagar and lake Pichhola.

**25.** ***Callichrous pabda* ( Bloch)**

**Family –Siluridae**

- B. xii-xiv, D. 4-5, P. 1/11-13, V. 8, A. 54-60 (2/52–58), C. 18.
- The width of the gape of the mouth equals half the length of the head. Lower jaw very prominent.
- **Barbels** – the maxillary reach the middle or end of the pectoral fin, the mandibular to the hind edge of the orbit.
- **Fins –** pectoral spine as long as the postorbital portion of the head, or the head behind the middle of the eyes, Anal not confluent with the caudal.
- **Colours** – usually silvery glossed with gold, having a dark shoulder spot above the middle of the pectoral fin, and usually another close to the base of the tail.
- **Geographical distribution**– Throughout India, Assam and Burma.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Lake Fateh Sagar and lake Pichhola.

**26.** ***Heteropneustes fossilis* (Ham.)**

**Family – Heteropneustidae**

- B.vii, D. 6-7, P. 1/7, V. 6, A. 60-79, C. 19
- **Eyes –** from 2 to 3 diameters from end of snout.
- **Barbels –** Four pairs.
- **Fins –** the dorsal commences rather before the anterior third of the body, the ventrals reach to the third or fourth anal ray or just to the origin of that

fin. Pectoral spine serrated internally. Anal and caudal separated by a more or less distinct notch.

- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Sisarma river, Jhadol stream, Ubeshwar stream, Banas river, lake Fateh Sagar and lake Pichhola.

**27.** ***Channa punctatus* (Bloch)**

**Family – Channidae**

- D. 29-32, P. 17, V. 6, A. 21-23, C. 12, L. l 37-40, L. tr. 4-5/9 9/6.
- **Eyes –** diameter 7 to 8½ in length of head.
- **Fins –** pectoral equals half the length of head; ventral ¾ as long as pectoral, dorsal a little longer than the anal.
- **Lateral line –** slightly curved above fourth anal ray.
- **Colour –** Vary with water they reside in.
- **Geographical distribution**– Throughout India, Assam and Burma.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Jhadol stream , Banas river, Barapal stream, Thur ki Pal stream, Jhameshwar stream, lake Fateh Sagar and lake Pichhola.

**28.** *Channa marulius* **(Ham.)**

**Family – Channidae**

- B. V, D. 45-55, P. 18, V. 6, A. 28-36, C. 14, L. l 60-70, L. tr. 4½/13 – 6½/11.
- **Eyes –** diameter 1/7 of length of head.
- **Fins –** dorsal and anal somewhat lowest anteriorly. Pectoral rather more than ½ as long as the head; ventral 2/3 as long as pectoral.
- **Lateral line –** first passes along 16 or 18 rows of scales, descends for two rows and subsequently passes direct to the centre of caudal.
- **Geographical distribution**– fresh waters of Sind, India and Ceylon.
- **Distribution in Rajasthan** – (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Sisarma river, Jhadol stream, Ubeshwar stream, Lake Fateh Sagar and lake Pichhola.

**29.** *Channa striatus* **(Bloch)**

**Family – Channidae**

- B. V, D. 37-45, P. 17, V. 6, A. 23-26, C. 13, L. l 50-57 L. tr. 4½-7/9-7.
- **Eyes –** diameter 1/6 to 1/7 of length of head.
- **Fins –** pectoral does not reach above the origin of the anal.
- **Geographical distribution**– fresh waters of Sind, India and Ceylon.
- **Distribution in Rajasthan –** (a) Earlier records : in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and

Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).

- (b) Present record : Sisarma river , Jhadol stream ,Nandeshwar stream, Jhameshwar stream ,lake Fateh Sagar and lake Pichhola.

**30.** ***Chanda nama*** **(Ham.)**

**Family – Centropomidae**

- B. VI, D.7/1/18-17, P.13, V.1/5, A. 3/14-17, C.17.
- Body compressed; the dorsal and abdominal profiles equally envex.
- Lower jaw much longer than the upper.
- **Fins –** dorsal spines of moderate strength a recumbent one anterior to the fin. The second spine the longest and equal in length to the head behind the anterior edge or middle of the eye. The caudal deeply forked, the lobes of equal length.
- **Scales –** minute, in young specimens captured form stagnant pieces of water, the mucous often causes the scales to be overlooked.
- **Lateral line –** is always indistinct, in some specimens it is entire, in others it ceases after proceeding a short way or it may even be absent.
- **Geographical distribution –**Throughout India, Assam and Burma.
- **Distribution in Rajasthan –** (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Sisarma river, Nandeshwar stream, Jhameshwar stream,lake Fateh Sagar and lake Pichhola.

31. *Xenentodon cancila* **(Hamiton- Buchanan)**

**Family – Belonidae**

- B. X, D. 15-18 (2/13 – 3/15), P. 11. V. 6, A. 16-18 (2/14 – 3/15), C. 15.
- A deep longitudinal groove along the upper surface of the head.
- **Lower jaw the longer**. Supra orbital margin smooth.
- **Fins –** dorsal commences opposite the anal, and is rather more than, or else twice as far from the anterior extremity of the orbit as it is from the posterior extremity of the tail. Pectoral equals half the distance of the head behind the front edge of the eye. Ventral is inserted rather nearer the base of the caudal .Caudal slightly emarginate.
- **Scales –** Small over the body and in irregular rows, some over front end of groove on head, also on sides of head except opercles.
- **Geographical distribution –** fresh waters of Sind, India and Ceylon.
- **Distribution in Rajasthan –** (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).
- **(b) Present record :** Jhadol, Banas, lake Fateh Sagar and lake Pichhola.

32. *Mastacembelus armatus* **(Lacepede)**

**Family – Mastacembelidae**

- B. VI, D-32-39, 74-90, P. 23, A. 3/ 75-88.
- Snout trilobed at its anterior extremity.
- **Fins** – the dorsal spines commences over posterior being the longest. Vertical fins confluent.

- **Geographical distribution–** This fish extends from Sind, throughout the fresh and brackish waters of the plains and hills of India, Ceylon.
- **Geographical distribution** – Generally throughout India.
- **Distribution in Rajasthan –** (a) Earlier records : in Udaipur lakes ( Dhawan 1969), in Ganganagar district (Johal 1982), in Jaisamand lake(Durve 1976 ,Sharma and Johal 1982 ,),in Kota district (Sharma and Johal 1984), in Jhalawar district ( Gupta and Kulshreshtha 1985) Recently in Rajasthan waters by Sharma and Choudhary (2007) and in Chambal river by Gaur (2011).

  (b) Present record : Barapal stream, lake Fateh Sagar and lake Pichhola.

## (b) Morphometric characters of selected hillstream fishes

Morphometric analysis was done of selected hillstream fishes. A total of 22 characters were taken for morphometric measurements and the value of maximum, minimum, mean, standard deviations, correlation coefficient and regression equations are given in tables -7.1 - 7.5

Some characters in percentage of total length (TL) and a few in percentage of head length (HL) were calculated. The significance of morphometric studies is that, if one character is known other can be extrapolated by using regression equation; the variability of characters and relationship between characters can also be estimated.

The range difference (difference between maximum and minimum) is used to determine genetically controlled, intermediate and environmentally controlled characters. Vladykov (1934) based on the range difference expressed in percentage of various characters, divided the characters into two categories. The characters having the range difference less than 10% are considered as genetically controlled whereas those having range difference more than 15% are regarded as environmentally controlled characters. However, Johal *et al.* (1994) categorised variables which fall in between the range difference of 10-15% as intermediate characters *i.e.* partly genetically and partly environmentally controlled characters. This criteria has been followed in this study also.

During present study morphometric characters of *Chela bacaila* (n = 15), *Rasbora daniconius* (n= 17) , *Noemacheilus botia*( n= 13) *and Puntius sophore* (n= 12) were calculated.

***Chela bacaila* :**

A total of fifteen specimens were collected for the morphometric analysis and the data are given in the **table-7.1**. On the basis of range difference the following characters *viz.* Standard Length(SL), Head Length(HL), Pre-Dorsal Distance(PrDD), Post Dorsal Distance (PsDD), Length of Dorsal Fin (LDF), Depth of Dorsal Fin(DDF), Length of Anal Fin(LAF), Depth of Dorsal Fin(DAF), Pre-Anal Distance (PrAD), Length of Pectoral Fin (LPF), Length of Anal Fin (LVF), Minimum Body Depth(MiBD), Maximum Body Depth(MBD), Distance between Pectoral and Ventral Fin (DPVF), Distance between Ventral and Anal Fin (DVAF), Length of Caudal Fin (LCF), Length of Caudal Peduncle(LCP) and Fork Length(FL) in percentage of Total Length(TL) have been considered as genetically controlled characters. The characters like head depth(HD), preorbital distance(PrOD),Eye diameter(ED) and Inter Orbital Distance (IOD) in percentage of head length were found to be intermediate characters whereas post orbital distance(PsOD) in percentage of head length was genetically controlled character.

The value of correlation coefficient was fairly high in almost all the characters so it can be concluded that all the dependent characters increase in direct proportion to each other.

***Rasbora daniconius* :**

A total of seventeen specimens were collected for the study of their morphometric characters and the data are given in the **table -7.2**. On the basis of high value of correlation coefficient in all the characters , it can be concluded that all the dependent characters increase in direct proportion to each other.

On the basis of range difference, the characters like SL, HL, PrDD, PsDD, LDF, DDF, LAF, ,DAF,Pr AD, LPF, LVF, Mi BD, MBD, DPVF, DVAF, LCF, LCP and FL in percentage of total length and ED in percentage of HL have been considered as genetically controlled characters whereas the characters like HD ,PrOD, PsOD and IOD in percentage of HL were intermediate characters .

***Noemacheilus botia* :-**

A total 13 specimens were subjected to the morphometry and the data are given in **table -7.3**.On the basis of range difference the characters *viz.* SL, HL, PrDD, PsDD, LDF, DDF, LAF, ,DAF, PrAD, LPF, LVF, MiBD, MBD, DPVF, DVAF, LCF, LCP and FL in percentage of total length and PrOD, PsOD, and ED in percentage of HL have been considered as genetically controlled characters, the character IOD in percentage of HL were intermediate character and HD in percentage of HL were found to be environment controlled character.

***Puntius sophore :***

A total 12 specimens were collected for the study of their morphometric characters and the data are given in the **table -7.4**. On the basis of range difference, the characters like SL, HL, PrDD, PsDD, LDF, DDF, LAF, ,DAF, Pr AD, LPF, LVF, Mi BD, MBD, DPVF, DVAF, LCF, LCP and FL in percentage of total length and ED in percentage of HL have been considered as genetically controlled characters whereas the characters like HD ,PrOD, PsOD and IOD in percentage of HL were intermediate characters .

On the basis of high value of correlation coefficient in all the characters except LDF, DDF, MiBD and LCP it can be concluded that all the dependent characters increase in direct proportion to each other.

## Table 7.1 Morphometric Characters of *Chela bacaila*

| N= 15 | Min. | Max. | Mean | SD | Correlation | Intercept (a) | Slope (b) | Regression Equation |
|---|---|---|---|---|---|---|---|---|
| In % of TL | | | | | | | | |
| SL | 76.667 | 84.138 | 79.6409 | 2.275289 | 0.996** | -0.551 | 0.862 | Y= -0.551 + 0.862X |
| HL | 18.367 | 22.917 | 20.2761 | 1.394968 | 0.967** | 0.010 | 0.201 | Y= 0.010 + 0.201X |
| PrDD | 38.235 | 44.828 | 40.9948 | 1.926681 | 0.996** | -0.680 | 0.492 | Y= -0.680 + 0.492X |
| PsDD | 14.400 | 22.989 | 18.1700 | 2.041148 | 0.893** | -0.044 | 0.187 | Y= -0.044 + 0.187X |
| LDF | 5.814 | 10.417 | 7.9783 | 1.428194 | 0.717** | 0.243 | 0.050 | Y= 0243 + 0.050X |
| DDF | 5.600 | 11.667 | 9.3652 | 1.945284 | 0.639* | 0.206 | 0.068 | Y= 0.206 + 0.068X |
| LAF | 9.524 | 14.286 | 11.9282 | 1.459922 | 0.859** | 0.224 | 0.092 | Y= 0224 + 0.092X |
| DAF | 8.333 | 13.265 | 9.93272 | 1.371746 | 0.886** | -0.042 | 0.104 | Y= -0.42 + 0.104X |
| Pr AD | 58.974 | 66.897 | 62.9696 | 2.927960 | 0.984** | -0.232 | 0.656 | Y= -0.232 + 0.656X |
| LPF | 17.442 | 22.069 | 19.6011 | 1.246014 | 0.988** | -0.378 | 0.241 | Y= -0.378 + 0.241X |
| LVF | 8.974 | 11.628 | 10.6617 | .770801 | 0.966** | 0.013 | 0.105 | Y= 0.013 + 0.105X |
| MiBD | 7.292 | 11.594 | 9.84127 | 1.319080 | 0.865** | 0.152 | 0.079 | Y= 0.152 + 0.079X |
| MBD | 15.000 | 23.077 | 18.2900 | 2.014686 | 0.918** | 0.223 | 0.156 | Y= 0.223 + 0.156X |
| DPVF | 28.333 | 33.793 | 30.3395 | 1.411965 | 0.989** | -0.391 | 0.350 | Y= -0.391 + 0.350X |
| DVAF | 13.333 | 18.605 | 15.7399 | 1.836391 | 0.960** | -0.379 | 0.203 | Y= -0.379 + 0.203X |
| LCF | 17.241 | 23.810 | 20.7111 | 1.802132 | 0.922** | 0.323 | 0.168 | Y= 0.323 + 0.168X |
| LCP | 8.333 | 15.000 | 11.8794 | 1.952669 | 0.924** | -0.296 | 0.154 | Y= -0.296 + 0.154X |
| FL | 86.047 | 92.800 | 89.3770 | 1.926266 | 0.996** | -0.091 | 0.904 | Y= -0.091 + 0.904X |
| In % of HL | | | | | | | | |
| HD | 53.333 | 66.667 | 60.9634 | 3.730909 | 0.976** | -0.001 | 0.610 | Y= -0.001 + 0.610X |
| PrOD | 30.769 | 35.714 | 32.5647 | 1.516612 | 0.984** | 0.003 | 0.324 | Y= 0.003 + 0.324X |
| PsOD | 43.750 | 55.172 | 47.4983 | 3.578756 | 0.983** | -0.230 | 0.612 | Y= -0.230 + 0.612X |
| ED | 16.667 | 28.571 | 24.0717 | 3.697704 | 0.805** | 0.071 | 0.198 | Y= 0.071 + 0.198X |
| IOD | 26.667 | 38.889 | 31.917 | 3.840100 | 0.892** | 0.069 | 0.278 | Y= 0.069 + 0.278X |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

## Table 7.2: Morphometric Characters of *Rasbora daniconius*

| N= 17 | Min. | Max. | Mean | SD | Correlation | Intercept (a) | Slope (b) | Regression Equation |
|---|---|---|---|---|---|---|---|---|
| In % of TL | | | | | | | | |
| SL | 76.000 | 85.714 | 80.634 | 3.085565 | 0.988** | 0.541 | 0.741 | Y= 0.541 + 0.741X |
| HL | 21.905 | 29.825 | 24.961 | 2.551322 | 0.985** | 0.848 | 0.148 | Y= 0.848 + 0.148X |
| PrDD | 44.000 | 53.448 | 48.841 | 3.542321 | 0.967** | 0.994 | 0.369 | Y= 0.994 + 0.369X |
| PsDD | 27.678 | 34.482 | 31.009 | 2.052101 | 0.973** | 0.625 | 0.235 | Y= 0.625 + 0.235X |
| LDF | 4.706 | 5.882 | 5.406 | .353643 | 0.963** | -0.015 | 0.055 | Y= -0.015 + 0.055X |
| DDF | 8.824 | 12.000 | 9.983 | .880865 | 0.937** | -0.063 | 0.107 | Y= -0.063 + 0.107X |
| LAF | 6.522 | 10.526 | 8.179 | 1.306324 | 0.806** | 0.365 | 0.038 | Y= 0.365 + 0.038X |
| DAF | 6.250 | 10.526 | 8.148 | 1.411312 | 0.760** | 0.442 | 0.028 | Y= 0.442 + 0.028X |
| Pr AD | 68.750 | 76.000 | 72.591 | 2.16364 | 0.993** | 0.478 | 0.669 | Y= 0.478 + 0.669X |
| LPF | 10.476 | 14.286 | 11.962 | 1.391118 | 0.956** | 0.452 | 0.065 | Y= 0.452 + 0.065X |
| LVF | 9.524 | 14.035 | 11.187 | 1.529826 | 0.947** | 0.487 | 0.053 | Y= 0.487 + 0.053X |
| MiBD | 17.143 | 24.561 | 20.340 | 2.813058 | 0.926** | 0.956 | 0.089 | Y= 0.956 + 0.089X |
| MBD | 38.235 | 46.551 | 41.565 | 2.091974 | 0.984** | 0.207 | 0.390 | Y= 0.207 + 0.390X |
| DPVF | 34.545 | 42.857 | 38.895 | 2.878376 | 0.957** | 0.782 | 0.295 | Y= 0.782 + 0.295X |
| DVAF | 18.033 | 24.561 | 21.112 | 2.066948 | 0.964** | 0.695 | 0.128 | Y= 0.695 + 0.128X |
| LCF | 19.000 | 28.070 | 23.583 | 2.767496 | 0.880** | 0.444 | 0.182 | Y= 0.444 + 0.182X |
| LCP | 18.000 | 25.000 | 20.223 | 2.087169 | 0.931** | 0.492 | 0.143 | Y= 0.492 + 0.143X |
| FL | 82.786 | 91.176 | 86.208 | 2.210387 | 0.995** | 0.414 | 0.812 | Y= 0.414 + 0.812X |
| In % of HL | | | | | | | | |
| HD | 63.158 | 77.778 | 70.250 | 4.078767 | 0.963** | -0.260 | 0.825 | Y= -0.260 + 0.825X |
| PrOD | 27.777 | 40.740 | 33.991 | 3.346205 | 0.879** | -0.215 | 0.441 | Y= -0.215 + 0.441X |
| PsOD | 41.176 | 55.555 | 47.519 | 3.402564 | 0.961** | 0.353 | 0.642 | Y= 0.353 + 0.642X |
| ED | 18.181 | 23.529 | 20.833 | 1.584307 | 0.865** | 0.057 | 0.181 | Y= 0.057 + 0.181X |
| IOD | 30.000 | 44.444 | 34.732 | 3.831043 | 0.890** | -0.340 | 0.507 | Y= -0.340 + 0.507X |

**. Correlation is significant at the 0.01 level.

*. Correlation is significant at the 0.05 level (2-tailed).

## Table 7.3: Morphometric Characters of *Noemacheilus botia*

| N=13 | Min. | Max. | Mean | SD | Correlation | Intercept (a) | Slope (b) | Regression Equation |
|---|---|---|---|---|---|---|---|---|
| In % of TL | | | | | | | | |
| SL | 80.165 | 85.227 | 82.373 | 1.751322 | 0.992** | 0.621 | 0.7650 | Y= 0.621 + 0.7650X |
| HL | 17.857 | 22.989 | 20.238 | 1.800037 | 0.869** | 1.143 | 0.0943 | Y= 1.143 + 0.0943X |
| PrDD | 30.681 | 39.370 | 34.930 | 2.845297 | 0.991** | -1.987 | 0.5360 | Y= -1.987 +0.5360X |
| PsDD | 23.232 | 27.083 | 24.650 | 1.278706 | 0.964** | 0.728 | 0.1777 | Y= 0.728 + 0.1777X |
| LDF | 7.865 | 10.000 | 8.94262 | 0.720504 | 0.976** | -0.401 | 0.1274 | Y= -0.401 +0.1274X |
| DDF | 7.143 | 9.195 | 8.06207 | 0.749949 | 0.806** | 0.424 | 0.0405 | Y= 0.424 + 0.0405X |
| LAF | 10.656 | 12.644 | 11.346 | 0.771813 | 0.940** | 0.457 | 0.0703 | Y= 0.457 + 0.0703X |
| DAF | 6.364 | 8.081 | 71.885 | 0.615089 | 0.832** | 0.328 | 0.0409 | Y= 0.328 + 0.0409X |
| Pr AD | 56.565 | 60.919 | 58.893 | 1.532028 | 0.985** | 0.507 | 0.5410 | Y= 0.507 + 0.5410X |
| LPF | 12.121 | 15.686 | 14.583 | 0.877446 | 0.946** | -0.173 | 0.162 | Y= -0.173 + 0.162X |
| LVF | 10.101 | 13.793 | 11.908 | 1.085195 | 0.830** | 0.377 | 0.083 | Y= 0.377 + 0.083X |
| MiBD | 17.172 | 24.138 | 20.097 | 2.243518 | 0.725** | 1.109 | 0.096 | Y= 1.109 + 0.096X |
| MBD | 22.222 | 29.885 | 25.085 | 2.697836 | 0.754** | 1.504 | 0.108 | Y= 1.504 + 0.108X |
| DPVF | 32.031 | 38.636 | 35.056 | 2.224000 | 0.917** | 1.123 | 0.244 | Y= 1.123 + 0.244X |
| DVAF | 21.590 | 30.392 | 27.448 | 3.111300 | 0.914** | -1.000 | 0.369 | Y= -1.000 + 0.369X |
| LCF | 14.606 | 21.569 | 17.665 | 2.126511 | 0.848** | -0.363 | 0.211 | Y= -0.363 + 0.211X |
| LCP | 11.111 | 13.725 | 12.813 | 0.698958 | 0.947** | -0.081 | 0.1358 | Y= -0.081 + 0.135X |
| FL | 89.772 | 93.700 | 91.484 | 1.290001 | 0.996** | -0.568 | 0.968 | Y= -0.568 + 0.968X |
| In % of HL | | | | | | | | |
| HD | 71.429 | 86.957 | 81.894 | 4.041775 | 0.822** | 0.171 | 0.739 | Y= 0.171+ 0.739X |
| PrOD | 38.095 | 45.000 | 40.5947 | 1.987187 | 0.820** | 0.103 | 0.358 | Y=0 .103+ 0.358X |
| PsOD | 40.909 | 50.000 | 44.529 | 2.308967 | 0.789** | 0.172 | 0.365 | Y= 0.172+0 .365X |
| ED | 14.286 | 19.048 | 16.313 | 1.539731 | 0.841** | -0.214 | 0.262 | Y= -0.214 + 0.262X |
| IOD | 20.000 | 32.000 | 23.591 | 3.66229 | 0.982** | -1.037 | 0.718 | Y= -1.037 + 0.718X |

*. Correlation is significant at the 0.05 level .

**. Correlation is significant at the 0.01 level (2-tailed).

**Table 7.4: Morphometric Characters of *Puntius sophore***

| N= 12 | Min. | Max. | Mean | SD | Correlation | Intercept (a) | Slope (b) | Regression Equation |
|---|---|---|---|---|---|---|---|---|
| In % of TL | | | | | | | | |
| SL | 76.667 | 83.824 | 79.011 | 2.039085 | 0.984** | 0.456 | 0.730 | Y= 0.456 + 0.730X |
| HL | 17.391 | 21.875 | 18.502 | 1.248242 | 0.959** | -0.627 | 0.266 | Y= -0.627 + 0.266X |
| PrDD | 38.235 | 43.210 | 40.354 | 1.434157 | 0.974** | -0.413 | 0.457 | Y= -0.413 + 0.457X |
| PsDD | 16.667 | 22.989 | 18.342 | 1.827338 | 0.813** | -0.215 | 0.211 | Y= -0.215 + 0.211X |
| LDF | 5.814 | 10.417 | 8.269 | 1.451595 | 0.510 | 0.088 | 0.071 | Y= 0.088 + 0.071X |
| DDF | 6.977 | 11.667 | 9.867 | 1.486222 | 0.588* | 0.073 | 0.089 | Y= 0.073 + 0.089X |
| LAF | 9.524 | 13.750 | 11.991 | 1.327728 | 0.740** | 0.025 | 0.116 | Y= 0.025 + 0.116X |
| DAF | 8.333 | 11.628 | 9.705 | 1.145433 | 0.792** | -0.181 | 0.120 | Y= -0.181 + 0.120X |
| Pr AD | 58.974 | 66.667 | 62.835 | 3.030360 | 0.922** | 0.847 | 0.518 | Y= 0.847 + 0.518X |
| LPF | 17.442 | 20.290 | 19.143 | .871403 | 0.937** | -0.001 | 0.191 | Y= -0.001 + 0.191X |
| LVF | 8.974 | 11.628 | 10.663 | .843814 | 0.899** | -0.184 | 0.130 | Y= -0.184 + 0.130X |
| MiBD | 7.292 | 11.594 | 9.998 | 1.430582 | 0.437 | 0.356 | 0.053 | Y= 0.356 + 0.053X |
| MBD | 15.000 | 23.077 | 18.495 | 2.194924 | 0.717** | 0.090 | 0.173 | Y= 0.090 + 0.173X |
| DPVF | 28.333 | 32.184 | 30.109 | 1.159291 | 0.967** | -0.220 | 0.329 | Y= -0.220 + 0.329X |
| DVAF | 13.333 | 18.605 | 15.259 | 1.719574 | 0.778** | -0.127 | 0.169 | Y= -0.127 + 0.169X |
| LCF | 18.750 | 23.810 | 20.933 | 1.713982 | 0.875** | -0.210 | 0.236 | Y= -0.210 + 0.236X |
| LCP | 8.333 | 15.000 | 11.621 | 2.006906 | 0.666* | -0.129 | 0.133 | Y= -0.129 + 0.133X |
| FL | 84.884 | 92.308 | 88.783 | 2.164242 | 0.982** | 0.652 | 0.802 | Y= 0.652 + 0.802X |
| In % of HL | | | | | | | | |
| HD | 61.538 | 72.727 | 66.893 | 3.728308 | 0.960** | 0.093 | 0.602 | Y= 0.093 + 0.602X |
| PrOD | 33.333 | 43.750 | 37.400 | 3.456523 | 0.870** | 0.044 | 0.343 | Y= 0.044 + 0.343X |
| PsOD | 43.750 | 58.333 | 50.962 | 3.966582 | 0.917** | 0.174 | 0.385 | Y= 0.174 + 0.385X |
| ED | 23.809 | 30.769 | 27.153 | 2.43556 | 0.866** | 0.085 | 0.210 | Y= 0.085 + 0.210X |
| IOD | 26.666 | 38.461 | 33.060 | 3.465985 | 0.812** | 0.151 | 0.222 | Y= 0.151 + 0.222X |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

## (B) ASSOCIATION OF DIFFERENT HILL STREAM FISHES :

The association and assemblage of hill stream fishes is determined and regulated by various factors like topography, substratum, season, altitude, degree of human intervention, water current, riparian vegetation, biotic and abiotic factors etc. The coexistence of fish species also depends upon their mutual interaction, competition for food and space etc.

Fish habitats are classified into a number of types according to the location within channels, patterns of water flow (cascades, riffles, rapids or pools) and nature of flow (Bisson *et al.*, 1981), which mainly depend upon the bed materials (Leopold *et al.*, 1964) and gradient (Rosgen, 1996). Habitat for fish includes physical, chemical, and biological factors to sustain life which comprises suitable water quality, migration routes, spawning grounds, feeding and resting sites, shelter from predators and adverse environmental conditions (Orth and White, 1993). Thus the local physical phenomena which directly have an impact on fish population and composition include size of habitat, pool development, permanency of water and habitat structure as well as microhabitat phenomenon such as flow pattern, oxygen concentration, temperature, depth, substrate type, cover and gradient (Wellborn *et al.*, 1996).

Lohr and Fausch (1997) stated that fish assemblages undergo drastic changes due to drought, which eliminated small pools and limited opportunities for colonization in the stream

Martin-Smith (1998b) found that riffle habitat had the lowest species diversity, but high abundance, whereas the pool assemblages had the highest species diversity and cyprinid had the maximum representation. Run assemblages were intermediate in assemblage characteristics between riffle and pool assemblages.

Gido and Propst (1999) observed that native juvenile fishes exhibited greater interspecific association with non-native fishes, whereas adult and sub adult native fishes showed the least in the San Juan river New Mexico and Utah. Mirza and Alam (2000) found that freshwater fish assemblages in the Indus river are affected by various ecosystem functions and the way in which these functions respond to various spatial and temporal changes. It is also influenced by hydrophysiographic/geomorphic factors including width, velocities, discharge, channel slope, roughness of channel material and sediment load into its stream and fish assemblages.

Hill and Grossman (1987) and Scalet (1973) stated that some stream fishes may remain within very short segments of streams for most of their lives and even completing the life cycle within a single riffle.

The fish diversity, community structure and species assemblages in the streams depend on many abiotic and biotic factors. These factors determine the success or failure of fish species assemblages in the streams within the range of spatial distribution limits (Minns, 1989). The altitude plays an important role in the change of fish diversity and stream morphology because weather, climate and precipitation depend on temperature which in turn on altitude. Hence, altitude and stream morphology are deciding parameters for the fish diversity and abundance.

**RESULTS AND DISCUSSION :**

During present observation, 24 fish species were found in more than one stream having similar geomorphological and ecological conditions. The maximum assemblage was seen by *Chela bacaila, Rasbora daniconius, Noemacheilus botia,* and *Puntius ticto.* The maximum frequency of occurrence has been shown by *Rasbora daniconius, Noemacheilus botia, Puntius ticto* and *Channa punctatus*. 10 species *viz. Catla catla*, *Labeo boggut, Labeo bata*, *Labeo calbasu*, *Tor tor, Notopterus notopterus*, *Sperata seenghala*, *Mystus aor*, *Wallago attu*, and *Callichrous pabda* have been reported to inhabit only lentic water bodies *viz*. lake Fateh Sagar and Lake Pichhola .

The maximum diversity was seen in river Banas and the minimum number of species was found in Ubeshwar stream .

The dominant species like *Garra gotyla* and *Noemacheilus botia* having adhesive organs were always found in streams with bedrocks and boulders. Another dominant species *Channa punctatus* preferred shallow water areas or under the small boulders where moist sand or mud existed. *Puntius* sp. found in shoals in shallow pools at the stream banks having sandy and gravel substratum.

*Chela bacaila* and *Callichrous pabda* prefers rocky pool whereas *Danio rerio, Chanda nama* and *Osteobrama cotio* prefers shallow muddy pools.

*Catla catla, Cirrhinus mrigala, Labeo rohita, Labeo bata, Labeo gonius, Labeo calbasu, Tor tor, Sperata seenghala, Mystus aor, Mystus cavasius Belone cancila, Mastacembelus armatus, Heteropneustes fossilis, Notopterus notopterus, Wallago attu* and *Channa marulius* were found in deeper pools.

During the study most preferred sites were pools, which are comparatively deeper areas of stream, offering constancy of environment. Johal *et al.* (2002) on detailed investigation on nine streams of the river Ghaggar, Yamuna and Sutlej found that pool habitat supports maximum fish diversity followed by run, riffles and rapids.

## (C) FOOD AND FEEDING

### Introduction :

The basic functions of organisms like growth, development, reproduction take place at the expense of energy, which enters the organisms in the form of food. A sound knowledge of food habits of fishes is a prerequisite for an understanding of their general biology, including vital aspects such as growth, breeding and migration (Golikatte and Bhat, 2011). The food and feeding habits of fish vary with the time of the day, season, size of fish, various ecological factors and different food substances present in the water body (Hynes, 1950).

Fish feed on a wide range of food material and obtain their nourishment from plant as well as animals. Schaperclaus(1933) has classified the natural food of fishes under four groups i.e.; (a) main food or natural food which the fishes prefer under favorable condition and on which they thrive best, (b) secondary food is consumed by the fish when available, (c) incidental food enters the gut of fishes by chance with other items, and is rarely seen in the gut, (d) emergency and obligatory food is ingested by fishes in order to survive under unfavorable conditions when the natural or basic food is not available. Natural fish food may be broadly divided into four categories viz., (a) plankton (b) nekton, (c) benthos (d) Periphyton and (e) detritus. Depending upon the variety of food items, consumed by fish, Nikolsky (1963) has classified them as (1) euryphagic (feeding on a wide range of food items) or (2) stenophagic (feeding on a few different types of food items), and (3) monophagic (feeding on only a single food item). Thus, most of the fishes fall under the category of euryphagic fishes.

Recent work on food and feeding habits of different fishes has done by several workers (Begum *et al.* 2008, Emmanuel & Ajibola 2010, Parihar & Saksena 2010, Arthi *et al.* 2011, Masdeu *et al.* 2011, Saikia *et al.* 2012, Priyadarsini *et al.* 2012, Dutta *et al.* 2013, Mushahida-Al-Noor *et al.*2013, Chaturvedi & Saksena 2013, Singh *et al* 2014 and Chaturvedi & Parihar 2014).

During present investigation specimens were collected from selected streams of Aravalli region. Just after collection, the live fishes were killed and 10% formalin solution was injected into the guts of the fishes in order to inhibit further digestion and rotting of the food items. The fish specimen was dissected out and the stomachs were detached from the gut and weight of stomach was recorded and it was preserved in 4 % formalin. The stomach contents were collected in a glass vial making up the volume to 1 ml to determine different food items eaten by the fish both qualitatively and quantitatively. The stomach contents were analyzed by following the methods viz., percent numerical count and percent frequency occurrence methods reviewed by Hynes ,(1950).

$$\text{Percentage occurrence of food items} = \frac{\text{Volume of food item}}{\text{Volume of whole gut content}} \times 100$$

An important fact assessed by the examination of the stomach is the state or the intensity of feeding. This is judged by the degree of distension of the stomach or by the quantity of food that is contained in it. The distension of the stomach is judged and classified as ‘gorged or distended’, ‘full’, ‘3/4full’, ‘1/2full’,1/4 full, trace etc by eye estimation.

Feeding intensity (GSI): The feeding intensity or gastro-somatic index (GSI) was calculated using the following formula by Desai (1970).

$$\text{GSI} = \frac{\text{Weight of the gut}}{\text{Total weight of the fish}} \times 100$$

The present study deals with food and feeding of two hill stream fishes i.e. *Rasbora daniconius* and *Noemacheilus botia* .

## RESULTS AND DISCUSSION:

### 1. *Rasbora daniconius*

Total 35 specimens having a standard length ranges between 4.5 to 12.0 cm and weight 1.2 to 10.0 gms were collected during present study.

The gut content analysis revealed the presence of the following food items (Table 7.5 & Fig: 7.1).

- **Insect Larvae** : Formed 15.5 % of the food item.
- **Insects :-** Constituted 13.5 % of the total food item consumed.
- **Microcrustaceans** : Formed 31.3 % of the food composition . It included Copepods and Cladocerans .
- **Rotifers** :- Formed 4.2% .
- **Green algae** : 12.5 % of the consumed food was algal matter.
- **Diatomes:** - Constituted 9.8 % .
- **Plant matter** : Formed 11.2 % of the total food items. It comprised of parts of leaves, stems and roots of aquatic plants and semi digested vegetable matter.
- **Miscellaneous items**: Formed 2.0% .It included all other items in the gut like shell matter, crustacean and insect appendages,and unidentified materials.

The highest value of numerical percent was shown by microcrustaceans (31.3%) followed by insect larvae (15.5%), insects (13.5%) and the lowest value was for miscellaneous items (2%). Observations on the food and feeding habits of *Rasbora daniconius* revealed that it is a surface or sub surface feeder and omnivorous that mainly feeds on insects, insect larvae and microcrustaceans. The food items found in the examined stomachs were categorized into (i) animal food and (ii) plant food . Animal food consists of, insects , insect larvae, micro crustaceans & rotifers formed 64.5% and plant food includes green algae, diatoms and plant parts constituted 33.5 % of total food item.

The overall feeding intensity aws revealed by percentage data *i.e.* 31.94 % stomachs were found full, 17.78 % were 3/4 full, 19.44 % were ½ full , 18.61% were ¼ full and 12.22% contained only trace amounts during the study period. None of the guts were gorged or empty. Fishes with full, 3/4 full and ½ full stomachs were considered to feed actively and fishes with ¼ full and trace amount stomachs were considered to feed inactively. The overall percentage occurrence revealed that 69.16% fish showed active feeding during the study period (Fig. 7.2).

The gastrosomatic index of different months was observed. The Table 7.7 deplicts intensity of feeding ( in % ) in various months showing that *R. daniconius* does not feed at the same rate.

The pronounced high feeding intensity during post monsoon months (September –October) was observed when the gastrosomatic index were 5.15 and and 4.75 respectively, 88.71% specimens showed active feeding, most of stomachs were full and contained good amount of food, while the feeding intensity was generally low during July and August (GSI 1.98 and 2.10 respectively ) when stomachs contained poor amount of food. The feeding intensity was improved in January & February as the gastrosomatic indices were recorded as 3.45 and 3.65 respectively .Maximum number of stomachs were observed with poor food in the month of July which happens to be peak maturity period of the gonads of the fish during monsoon period of breeding.

The result also agreed with the findings of Mustafa and Ahmed (1979) in *Notopterus notopterus*, Hossain and Nargis (1987) in *Anabas testudineus*, Bhuiyan and Islam (1988) in *Xenentodon cancila*, Bhuiyan *et al.* (1992) in *Aspidoparia morar,* Hossain *et al*. (1992) in *Nandus nandus,* Bhuiyan *et al*. (1994) in *Rhinomugil corsula,* Santic *et al.* (2005) in *Trachurrus trachurus,* and Xue *et al.* (2005) in *Pseudosciaena polyactis*.

The occurrence of low feeding in other fishes coincide with their peak breeding has been reported by several workers such as Jhingaran, (1961), Desai (1970), Bhatnagar and Karamchandani (1970), Fatima and Khan, (1991) and

Serajuddin *et al*. (1998). The low feeding rate during the months of March and April was due to some factors other than breeding, it may be due to non availability of food or due to abiotic factors such as temperature and turbidity.

## CONCLUSION

Gut content analysis showed the *Rasbora daniconius* is an opportunistic omnivore, feeding on various plankton and insect larvae .

### 2. ***Noemacheilus botia***

Total 38 specimens having a standard length ranges between 4.0 to 5.5 cm and weight 1.0 to 2.5 gms were collected during present study.

The gut content analysis revealed the presence of the following food items (Table 7.6 & Fig: 7.3).

- **Benthic microinvertebrates** : formed 29.5 % of the food consumed. It comprised of cladocerans and copepods.
- **Insect larvae & nymphs** : 41.8 % of total consumed food materials. It constituted ephemeropteran larvae & nymphs and Chironomous larvae.
- **Algal matter** : formed 12.3% of the gut content .
- **Detritus** : was 6.5 % of consumed food .
- **Plant parts** : 8.6 % of consumed food . It comprised of parts of leaves, stems and roots of aquatic plants and semi digested vegetable matter.
- **Miscellaneous items**: Formed 1.3 % .It included all other items in the gut like shell matter, crustacean and insect appendages,and unidentified materials.

The observation revealed that the highest numerical percentage was shown by insect larvae and nymphs (41.8%) followed by microcrustaceans (29.5%), algal matter (12.3%) and the lowest value was for miscellaneous items (1.3%).

Observations on the food and feeding habits of ***Noemacheilus botia*** revealed that it is a bottom feeder and carniomnivorous that mainly feeds on insect larvae and microcrustaceans. The animal food formed 71.3% and plant food constituted 27.4 % of total food item.

The overall feeding intensity revealed that 34.55 % stomachs were found full, 22.25 % were 3/4 full, 22.77 % were ½ full , 11.51% were ¼ full and 8.9 % contained only trace amounts during the study period. None of the guts were gorged or empty. Fishes with full, 3/4 full and ½ full stomachs were considered to feed actively and fishes with ¼ full and trace amount stomachs were considered to feed inactively. The overall percentage occurrence revealed that 79.58% fish showed active feeding during the study period (Fig. 7.4).

he gastrosomatic index of different months was observed. The Table 7.8 deplicts intensity of feeding ( in % ) in various months shows that *Noemacheilus botia* does not feed at the same rate.

## CONCLUSION

Gut content analysis showed that the fish *Noemacheilus botia* is carniomnivorous that mainly feeds on insect larvae and benthic microinvertebrates.

**Table 7.5. Mean contribution of different food items of *Rasbora daniconius* on the basis of percentage numerical count and percentage frequency occurrence method ( Total 35 specimens)**

| S.N. | Food item | | Average % Numerical Count | Average % frequency occurrence |
|---|---|---|---|---|
| A. | Animal Food | | | |
| | 1. | Insects | 13.5 | 71.42 |
| | 2. | Insect larvae | 15.5 | 91.42 |
| | 3. | Cladocerans | 18.8 | 62.85 |
| | 4. | Copepods | 12.5 | 74.28 |
| | 5. | Rotifers | 4.2 | 34.28 |
| B. | Plant Food | | | |
| | 1. | Green algae | 12.5 | 51.42 |
| | 2. | Diatoms | 9.8 | 45.71 |
| | 3. | Plant matter | 11.2 | 40.0 |
| C. | Miscellaneous(unidentified matter) | | 2.0 | 48.57 |

**Table 7.6. Mean contribution of different food items of *Noemacheilus botia* on the basis of percentage numerical count and percentage frequency occurrence method (Total 38 specimens)**

| S.N. | Food item | | Average % Numerical Count | Average % frequency occurrence |
|---|---|---|---|---|
| A. | Animal Food | | | |
| | 1. | Benthic microinvertebrates | 29.5 | 65.78 |
| | 2. | Insect larvae & nymphs | 41.8 | 84.21 |
| B. | Plant Food | | | |
| | 1. | Algal matter | 12.3 | 42.10 |
| | 2. | Plant matter | 8.6 | 21.05 |
| | 3. | Detritus | 6.5 | 31.57 |
| C. | Miscellaneous(unidentified matter) | | 1.3 | 15.78 |

**Table 7.7. Feeding intensity and gastro-somatic indices of *Rasbora daniconius* in different months :-**

| **Months** | **No.of stomachs examined** | **Average GSI** | **Full %** | **¾ Full %** | **½ Full %** | **¼ Full %** | **Trace amount %** |
|---|---|---|---|---|---|---|---|
| May-14 | 32 | 3.15 | 25% | 12.5% | 31.25% | 21.87% | 9.38 % |
| June | 28 | 2.85 | 32.14% | 21.43% | 21.43% | 17.86% | 7.14% |
| July | 31 | 1.98 | 9.67% | 12.90% | 16.12% | 3.22% | 29.03% |
| Aug. | 34 | 2.10 | 11.76% | 14.70% | 20.58% | 32.35% | 20.58% |
| Sep. | 30 | 5.15 | 53.33% | 20% | 13.33% | 6.67% | 6.67% |
| Oct. | 32 | 4.75 | 43.75% | 25% | 21.87% | 6.25% | 3.12% |
| Nov. | 31 | 3.85 | 35.48% | 25.81% | 16.12% | 12.90% | 9.67% |
| Dec. | 34 | 2.65 | 2.94% | 14.70% | 23.52% | 20.59% | 11.76% |
| Jan.-15 | 28 | 3.45 | 39.28% | 17.86% | 14.28% | 10.71% | 17.86% |
| Feb. | 24 | 3.65 | 50.0% | 20.83% | 16.67% | 8.33% | 4.17% |
| Mar. | 26 | 2.95 | 30.77% | 15.38% | 19.23% | 23.07% | 11.53% |
| Apr. | 30 | 2.6 | 30% | 13.33% | 16.67% | 26.67% | 13.33% |

**Table 7.8.** **Feeding intensity and gastro-somatic indices of *Noemacheilus botia* in different months :-**

| Months | No.of stomachs examined | Average GSI | Full % | ¾ Full % | ½ Full % | ¼ Full % | Trace amount % |
|---|---|---|---|---|---|---|---|
| May-14 | 30 | 3.2 | 36.67 | 26.67 | 20 | 10 | 6.67 |
| June | 32 | 2.8 | 21.87 | 12.5 | 31.25 | 18.75 | 15.62 |
| July | 31 | 3.9 | 32.25 | 12.9 | 32.25 | 16.13 | 6.45 |
| Aug. | 34 | 4.1 | 41.17 | 26.47 | 17.65 | 8.82 | 5.88 |
| Sep. | 28 | 1.4 | 3.57 | 7.14 | 28.57 | 28.57 | 32.14 |
| Oct. | 35 | 3.1 | 31.43 | 22.85 | 25.71 | 14.28 | 5.71 |
| Nov. | 28 | 3.8 | 35.71 | 28.57 | 21.43 | 7.14 | 7.14 |
| Dec. | 32 | 2.7 | 25 | 34.37 | 25 | 6.25 | 9.37 |
| Jan.-15 | 30 | 3.2 | 26.67 | 33.34 | 23.34 | 10 | 6.67 |
| Feb. | 34 | 3.1 | 35.29 | 23.53 | 26.47 | 8.82 | 5.88 |
| Mar. | 32 | 3.5 | 56.25 | 21.87 | 9.37 | 6.25 | 6.25 |
| Apr. | 36 | 5.6 | 61.11 | 16.67 | 13.89 | 5.55 | 2.78 |

## (D) LENGTH-WEIGHT RELATIONSHIP

### Introduction

The Study of length- weight relationship of fishes has considerable importance in fishery because it shows relevance to fish population dynamics and pattern of growth on fish stocks. Knowledge of length weight relationship is of paramount importance in fishery biology as it serves several practical purposes. The general length-weight relation equation provides a mathematical relationship between the two variables, length and weight, so that the unknown variable can be easily calculated from the known variable. This expression had extensively been used in the study of fish population dynamics for estimating population strength (Beverton & Holt, 1957).It also yields information on growth, gonadal development and general condition of fish (Le Cren, 1951) and therefore, useful for comparison of body forms of different groups of fishes. The length-weight relationship has a biological basis also as it depicts the pattern of growth of fishes. According to the general cube law governing length-weight relationship, the weight of the fish would vary as the cube of length. A true relationship exists between the length and weight of fishes . These two categories of growth are highly correlated. However , changes in weight without any change in length and vice versa may also occur in fishes .

The fish species namely *Chela bacaila* , *Puntius sophore* and *Chanda nama* were taken into account to find out the length-weight relationship. The length-weight relationship of the selected species was established using Le Cren (1951) parabolic equation. $\mathbf{W = a\,L^b}$ where ,W = weight of the fish in gms , L = Total length of fish in cms and 'a' is the initial growth index and 'b' is the equilibrium constant.

The general equation $W = a\,L^b$ can be written as Log W = Log a + b Log L i.e. Y = a + bX Where 'b' represents the slope of the line and 'log a' is a constant.The length-weight relationship of cyprinids from India has been studied by several workers (Mohan & Sankaran 1988, Kurup 1990, Reddy & Rao 1992, Biswas 1993, Pandey & Sharma 1997, Sarkar *et. al.* 1999 , Sunil 2000 , Geol *et. al.* 2011, Shahista Khan *et al* 2011, Kharat & Khillare 2013 and Gogoi & Goswami 2014 and Das *et. al.* 2015).

## RESULTS AND DISCUSSION :

During present investigation three fish species namely *Chela bacaila* , *Puntius sophore* and, *Chanda nama* were selected for the study of length-weight relationship. The samples were collected at monthly intervals from the specific streams of Aravalli hills. Soon after collection, the specimens were wiped out with a blotting paper and weighted in an electric balance.The sexes were differentiated by surgical observation of the gonads. The observed lengths and weights were transformed into logarithmic values and equations were calculated by least square method. The length- weight relationship (LWR) of selected species are given below :-

### 1. *Chela bacaila* ( Hamilton )

182 fishes comprising 98 males and 84 females ranging from 5.8cm. to 11.4cm. and weight 1.6 to 7.9 gm. were utilized. The data of length –weight relationship of *Chela bacaila* was categorized in three groups *i.e.* male, female and common(sex combined).

The data of statistical analysis of length -weight relationship of *Chela bacaila* are presented in Table 7.9

Values of correlation coefficient (r) in table-7.9 indicate a high degree of correlation between length and weight. The observed length and weight were delineated in scatter diagrams of Fig.7.5- 7.7 for female ,male and combined sex respectively. The values of regression coefficient (b) computed were 2.743 (female), 2.950 (male), and 2.887 (sexes combined). During present investigation the ‘b’ values were found to be lower than the isometric value 3 which indicates that the *Chela bacaila* becomes more slender as the length increases. The ‘b’ value of males was slightly higher than females in this case .Similar findings were observed by Dahare (2011) in case of *Chela bacaila* .

### 2. *Puntius sophore* (Hamilton)

The regression equation computed from data for females, males and combined ones is presented in Table 7.10

The logarithmic values for lengths and weights when plotted gave straight-line relationship. ( Fig. 7.8-7.10)

The values of regression coefficient (b) computed were 3.289 (female), 3.350 (male), and 3.315 (sexes combined).

The regression equations clearly indicated that the two sexes (male and female) exhibited slight difference in the value of exponent ‘b’. In *P. sophore* males recorded higher exponential value than the females. It indicates that the weight gain is slightly more in case of males than females. The logarithmic values for lengths and weights were plotted shows a straight-line relationship as shown in Fig 7.8 for female, Fig 7.9 for male and Fig 7.10 for sexes combined.

***Chanda nama* (Hora):-**

The data on regression equations, correlation coefficient (r) , coefficient of determination ($R^2$) for female ,male and sexes combined are given in Table 7.11 .The logarithmic values for lengths and weights were plotted shows a straight-line relationship as shown in Fig 7.11 for female, Fig 7.12 for male and Fig 7.13 for sexes combined .

The values of regression coefficient (b) computed were 3.546 (female), 3.417 (male), and 3.493 (sexes combined).

The value of ‘b’ generally lies between 2.5-4.0 (Hile, 1936 and Martin, 1949) or 3 (Allen, 1938). For an ideal fish, which maintains isometric growth, the value of ‘b’ should be 3. In majority of cases where length-weight relationship has been calculated, it has been observed that the cube law is not obeyed. Further, most fishes do change their shapes as they grow (Martin, 1949), hence a cube relationship between length-weight relationship could hardly be expected. Le Cren (1951) pointed out that the variation in “b” value is due to environmental factors, season, food availability, sex, life stage and other physiological factors.

The present work intends to find out some baseline information (LWR) regarding these three fish species from the Aravalli hill streams of Southern Rajasthan and will add to understand their growth, well being and stock assessments for the betterment of fisheries management .

**Table 7.9: Statistical analysis of length-weight relationship of *Chela bacaila***

| Sex | No. of fishes | intercept (a) | Regression coefficient (b) | Regression equation | Corl. Coeft. (r) | Coeft. of det. (R2) |
|---|---|---|---|---|---|---|
| Female | 84 | -1.858 | 2.743 | Log W= - 1.858+ 2.743 Log L | 0.902 | 0.814 |
| Male | 98 | - 2.079 | 2.950 | Log W = - 2.079 + 2.950 Log L | 0.904 | 0.818 |
| Sexes combined | 182 | - 2.017 | 2.887 | Log W = - 2.017+ 2.887 Log L | 0.900 | 0.810 |

**Table 7.10 Statistical analysis of length-weight relationship of *Puntius sophore***

| Sex | No. of fishes | intercept (a) | Regression coefficient (b) | Regression equation | Corl. Coeft. (r) | Coeft. of det. (R2) |
|---|---|---|---|---|---|---|
| Female | 124 | -2.221 | 3.289 | Log W = - 2.221+ 3.289 Log L | 0.966 | 0.938 |
| Male | 94 | - 2.273 | 3.350 | Log W = - 2.273 + 3.350 Log L | 0.950 | 0.903 |
| Sexes combined | 218 | - 2.241 | 3.315 | Log W = - 2.241+ 3.315 Log L | 0.943 | 0.890 |

**Table 7.11: Statistical analysis of length-weight relationship of *Chanda nama***

| Sex | No. of fishes | intercept (a) | Regression coefficient (b) | Regression equation | Corl. Coeft. (r) | Coeft. of det. (R2) |
|---|---|---|---|---|---|---|
| Female | 162 | - 2.631 | 3.546 | Log W = -2.631+3.546 Log L | 0.950 | 0.904 |
| Male | 92 | - 2.298 | 3.417 | Log W = -2.298+3.417 Log L | 0.962 | 0.926 |
| Sexes combined | 254 | - 2.579 | 3.493 | Log W = -2.579+3.493 Log L | 0.953 | 0.908 |

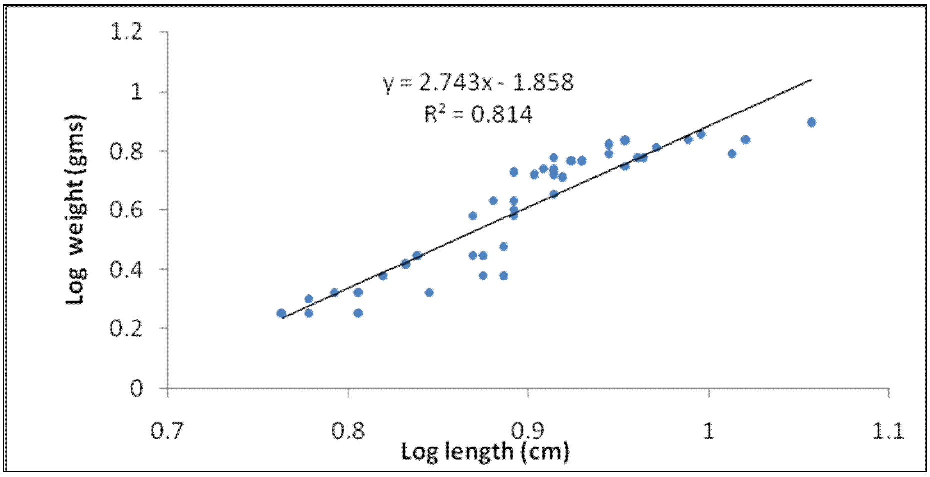


**Fig 7.5: Length-weight relationship of female *Chela bacaila***

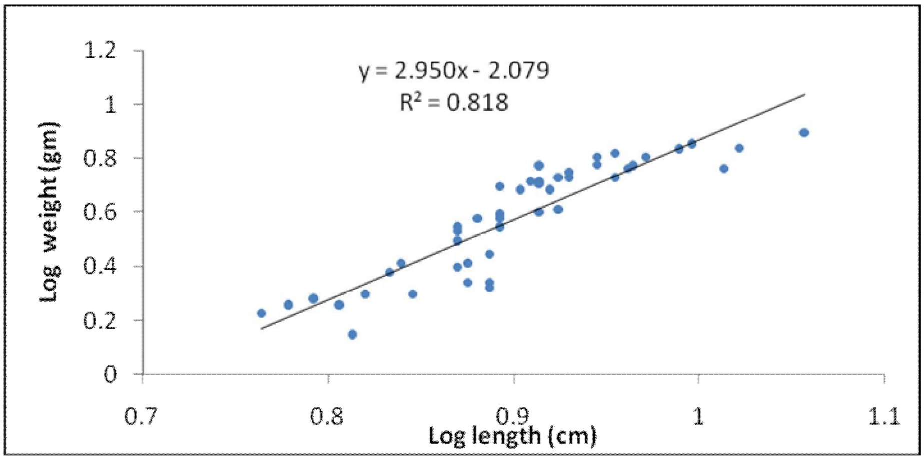


**Fig 7.6: Length-weight relationship of male *Chela bacaila***

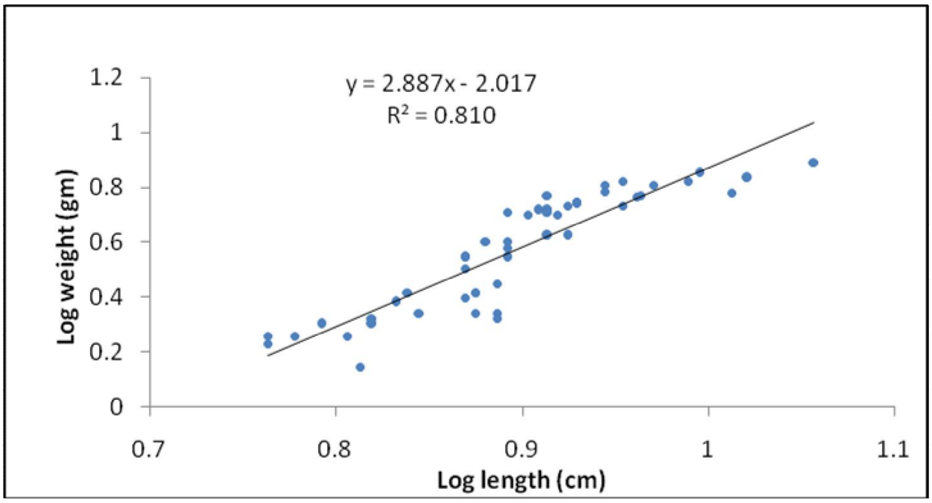


**Fig 7.7: Length-weight relationship of combined sex *Chela bacaila***

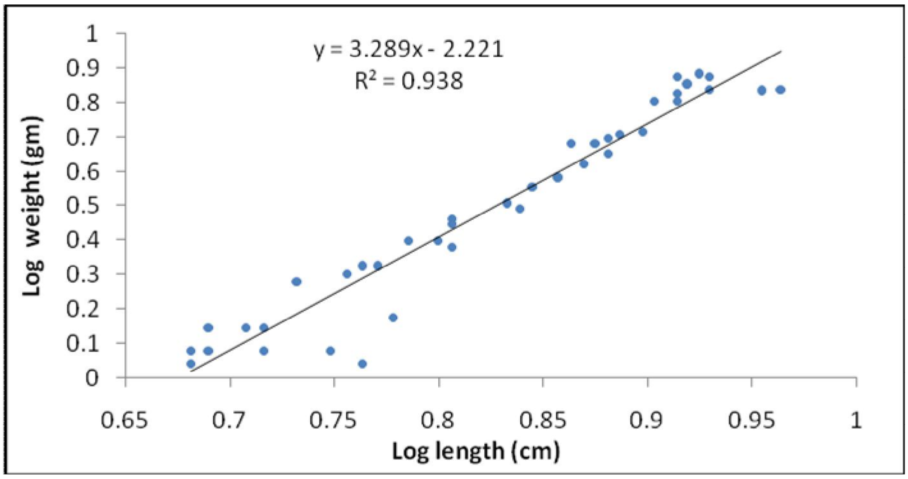


**Fig 7.8: Length-weight relationship of female *Puntius sophore***

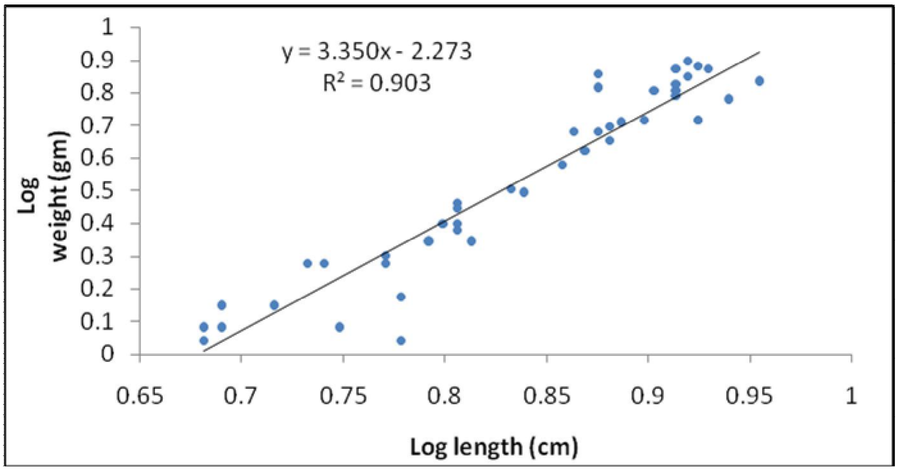


**Fig 7.9: Length-weight relationship of male *Puntius sophore***

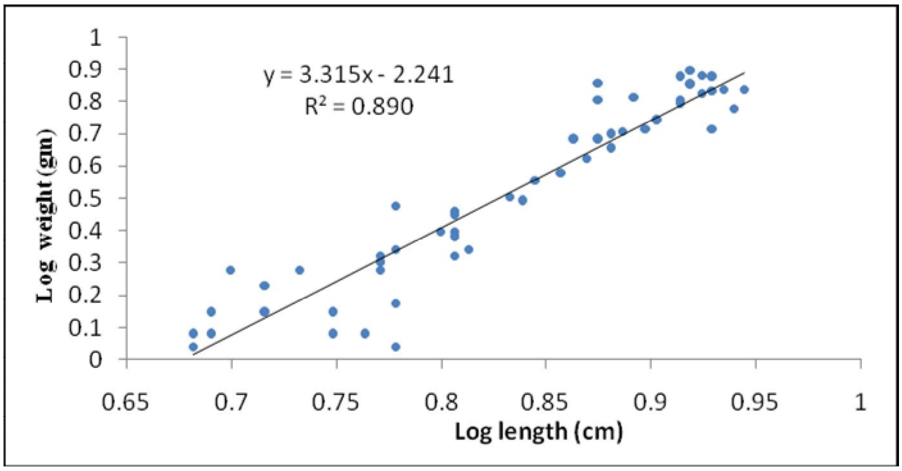


**Fig 7.10: Length-weight relationship of combined sex *Puntius sophore***

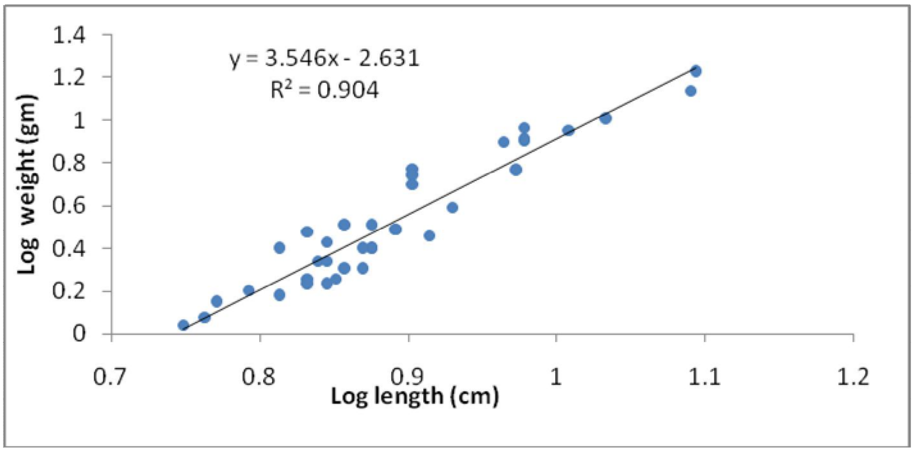


**Fig 7.11: Length-weight relationship of female *Chanda nama***

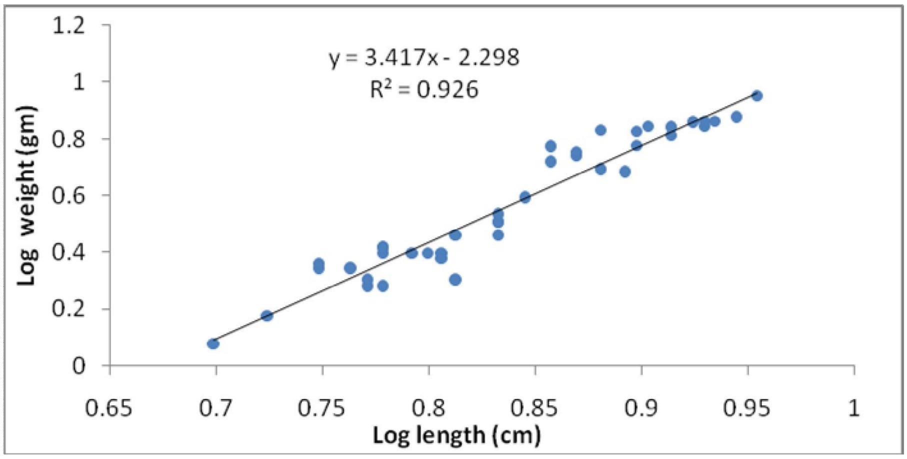


**Fig 7.12: Length-weight relationship of male *Chanda nama***

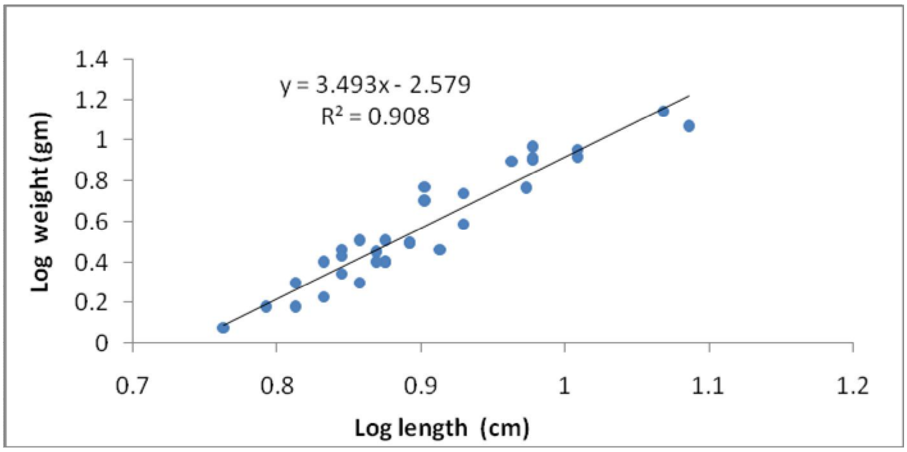


**Fig 7.13: Length-weight relationship of combined sex *Chanda nama***

# CHAPTER- VIII

# HILL STREAM FISHERY, CAUSES OF DECLINE AND CONSERVATION MEASURES

## INTRODUCTION :

The hill streams have great importance in the fishery of hilly areas as they provide congenial conditions for development and growth of all the fishes that form the fishery of the rivers and reservoirs. These are breeding grounds for the fishes of reservoirs. The hill stream fishes are important from ecological point of view. The presence or absence of fishes indicates the water quality of the streams. Also they are excellent food for the predatory fishes and piscivorous birds.

The evidences of declining fish diversity have been collected throughout the world. According to Warren and Burr (1994) about 33% of the North American native fresh water fishes are endangered. Dehadrai and Poniah (1997) accounted that 79 fish species of India are threatened.

A number of scientists worked on decline and conservation of fishes in several countries in last few decades: Maitland (1974, 1979, 1990 and 1995), Paepke (1981), Johnson and Rinne (1982), Almaca (1983), McDowall (1983), Goulding *et al.* (1988) , Skelton (1990), Williams and Miller (1990), Pollard *et al.* (1990), Moyle and Williams (1990), Reinthel and Stiassny (1990), Minckley and Deacon (1991), Moyle and Leidy (1992), Maitland and Morgan (1997), Cowx and Welcomme (1998), Karr and Chu (1999), and Yusuf (2000).

According to Maitland and Lyle (1990), there are five major reasons for decline of fishes *viz.* pollution, acidification, land use, habitat loss and introduction of alien species. Hynes (1970), opined that the anthropogenic activities have adversely and irreversibly affected almost all the streams of the world, especially the freshwater aquatic habitats of the developing countries greatly stressed. CAMP (1998) documented 397 species of fishes, out of these 227 freshwater fishes are threatened, 98 of them are presently regarded endangered, 82 vulnerable, 66 near threatened, 16 least concern and the accurate data of 26 fish species are unavailable.

Loss in fish diversity is affected when changes in environment occur beyond its endurance limits. The major contributors in decline of ichthyodiversity are pollution, habitat deterioration and deforestation. The deterioration of streams is caused by removal of channel materials (Cobbles, gravel and sand), riparian vegetation, dumping of effluents and human waste, operation of destructive fishing methods, overgrazing, habitat fragmentation, soil erosion, impoundments (Dams, Check dams and Weirs) and habitat fragmentation.

The present investigation is aimed to provide information on the anthropogenic pressure on the rivers, streams and lakes and useful baseline data for ichthyofaunal conservation, management and fishery policy formulation.

The Fish faunal varieties found in the present investigation have been depicted in Table 5.1. The table clearly indicates that total 32 fish species belonging to 10 families were located from the selected lentic and lotic water bodies of Aravalli region of South Rajasthan in the present study. This fish fauna appears fairly rich.

**Fishing Gears**

Information on fishing methods and gears were collected through intensive field survey and interaction with local fishermen of this region during the period of 2013-14 and 2014-15. Diversion of river channel, netting, angling, spearing, rock striking and hammering, dynamiting, river poisoning, and some other traditional methods are some of the fishing methods used in this area.

**Causes of decline:-**

The hill stream fish fauna of Aravalli region in South Rajasthan is comparatively poor than the fish fauna of Himachal Pradesh . This is due to following reasons -

- The average rain fall is very low.
- Irregular monsoon condition .
- Most of the rivers in this region are seasonal and water flow remains only for monsoon months.
- The annual storage of water in reservoirs is only up to 30 – 50 % of the total storage capacity.
- Among the main priorities of water use are the irrigation, drinking and domestic needs. The fisheries development is at the last priority.

Besides these reasons, various factors affecting the fish faunal diversity in this region are as follows:-

**Habitat alternation :-**

Decreasing rainfall trends, embanking of water courses and increasing utilization trends of stored surface water have adversely reduced the water storage of reservoirs. The flow in rivers & streams is insufficient for effective fish migration. Due to these reasons the natural habitats for the fishes have been modified .

**Environmental degradation :-**

Conversion of forest land into agriculture land, bed cultivation and mining activities in upper reaches have resulted in heavy soil erosion during monsoon which resulted in destruction of valuable spawning grounds as well as silting of the water bodies.

**Aquatic pollution :-**

Water pollution is an undesirable change caused directly or indirectly by anthropogenic activities. The result of unprecedented increase in human population and industrialization has caused water pollution through excessive discharge of waste material , domestic wastes ,sewage into the rivers , streams or lakes without any pre-treatment ,has polluted the water to such an extent that some rivers (like River Ahar) have become drains of wastes material .This has been further increased by the huge amount of pesticides and insecticides that are washed in to the rivers & streams from agricultural lands. This has been harmful to fishes and various organisms living in water.

Besides this, there are acid drainage waters from mining operations, resulting from sulphides in ores being converted to sulphuric acid. The acid water then dissolves metals like copper, iron , zinc,adding to the pollution problem as copper is especially toxic to fish. Mineral deposits cause serious problem in Aravalli region .

During recent years a few instances of mass mortality of fishes have been reported in various rivers & lakes due to release of untreated industrial effluents , mineral ores and sewage waters in streams and adjoining water bodies.

**Effects of pollutants on Fish :-**

Various pollutants effect the fish life directly or indirectly, and the extent of damage depends on the quality and quantity of the pollutants and the species of fish.

Pollution susceptibility in freshwater animals and fish may vary from species to species . Among fish there are no pollution tolerant ( e.g. some minor carps ) to little and more pollution tolerant species like catfishes (*Heteropneustius* ,etc.)

Among the many physio-chemical and biological effects of pollution, some are mentioned as follows :-

- Increase in salinity and osmotic pressure and turbidity of water.
- Increase in acidity , TDS , nitrate and phosphate of water.
- Depletion of dissolved of oxygen content of water and increase in BOD.
- Damage to the gills due to suspended matter in the water.
- Spawning grounds of fish are destroyed .
- Population of zooplankton and phytoplankton is reduced , effecting availability of natural food to fish.

- Pathogenic effects caused by micro organisms.

**Introduction of exotic species :-**

Rajasthan needs over 400 million fish seed for stocking the water bodies. Due to inadequacy of seed within the state, seed is procured from other states such as West Bengal, M.P. , U.P. , and Gujarat . Many a times seed is contaminated with invasive and objectionable fish varieties. Such fishes like Tilapia ( *Oreochromis mossambica*) and Thai Magur ( *Clarias gariepinus* ) have got entry in a few waters of state and already got established there.

**Wanton destruction :-**

The practices of destruction of brood fish and juveniles by way of illegal fishing methods like use of dynamites, pesticides , small meshed nets and cloths are increasing to cause failure of natural recruitment of the fisheries resources. **( Plate 8.1, 8.2)**

**Conservation of hill stream fishes**

During recent years decrease in the diversity and abundance of fishes have been reported an all aquatic environments. Therefore fisheries as a renewable resource should be properly managed and conserved in order to have sustainable yield. Principles of fish conservation include the following aspects :-

**Conservation of genetic diversity :-**

Genetic diversity means genetic variability among the individuals of the same species ( intraspecific genetic variability ) and between individuals of many different species ( interspecific genetic variability).

**Conservation of Ecological diversity :-**

Ecological diversity means species richness in different environments, i.e. the number of fish species available in a particular region ( or a particular water body ) .Ecological diversity also includes diversity of habitats and their flora and fauna, which are important as fish food organisms.

**Conservation measures –**

The necessity for fisheries protection by legislation was felt as early as 1897 when the fisheries Act IV was passed. The state Fisheries Departments were also authorized to formulate guidelines for controlling fishing operations and conservation and management of natural fish resources.

For the protection of aquatic resources , flora & fauna particular in the State, there is need to remove various stresses on the aquatic resources. Some of the suggestive measures are :-

**Habitat restoration :-**

The protection and care of breeding grounds and prevention of environmental degradation are essential .

**Fish ranching and enhancement :-**

The stocking of indigenous fish yearlings for ranching year after year in rivers and perennial reservoirs on a large scale will be helpful for restoration of threatened and disappeared fish species.

**Declaration of fish sanctuaries and protected aquatic reserves.**

**(*In-situ* conservation):-**

For the conservation of biodiversity of the aquatic resources it is essential to identify some suitable segments of the rivers for declaring as Aquatic Reserves, so that the population of native fish fauna may be conserved.

**Improvement of human resource and capacity in fish systematic :-**

For detailed identification of available local biodiversity and implementing the required conservation measures, it is essential to improve the human resource and capacity in fish systematics and establish proper facilities for species verification.

**Suitable infrastructure development for restoration programme :-**

For restoration of disappeared / endangered species back in existing water bodies it is essential to develop infrastructure like suitable hatchery, seed rearing areas, brood stock pond etc. at suitable sites.

**(VI) Sports Fisheries : -**

Many palces in this area are tourist attraction and thousands of tourists are coming from different states of India and number of other counteries. Mahseer and some other fish species may be encouraged to strengthen economy of the region.

**(VII) Cryopreservation :-**

In Cryopreservation, the biological material is preserved and stored at very low temperatures, usually at -196 $^0$C, the temperature of liquid nitrogen. Cryopreservation of fish gametes and embryos of threatened fish species is an important aspect of conservation of germ plasm resources.

In India , the NBFGR has developed and standardised the technique for cryopreservation of fish milt and a mini gene bank with milt of *Labeo rohita* , *Catla catla* , *Cirrhinus mrigala* , *Cyprinus carpio* , *Tor putitora* ,*T. khudree* has been developed.

# CHAPTER- IX

# SCANNING ELECTRON MICROSCOPIC STUDY OF ADHESIVE ORGAN OF *GARRA SP.*

## INTRODUCTION :

Hill streams are unique aquatic ecosystem characterised by shallow, narrow channels, low temperature. high altitude, different types of substratum, high current of water, hence the hill stream fishes develop mechanical devices to combat the force of water currents and are successfully adapted to this unique environment. According to Hora (1922a, 1927 and 1952), Saxena (1966) and Jayaram (1983), Sinha *et al* (1990) and Ojha and Singh (1992), development of various types of adhesive organs is one of the prerequisites for survival of these fishes. Till now the exact mechanisms of adhering or anchoring or sticking themselves to the substratum is not well understood. Moreover, there is no information on the relationship between the degree of development of these adaptations, type of substratum and water current etc.

However, Hora (1952) reports on “organ of attachment” modification of ventral fins to form a suction disc, depressed body form, rugosity or ventral surface of torrent fishes in Himalayas that permit its existence in rapid mountain streams. According to Tandon and Gupta (1975),in *Garra lamta* and *Labeo dero* the tail is forked (Caudal fin) and the pectoral fins are spatulated whereas in *Channa punctatus* athe caudal fin and pectorals are rounded.Aleev(1969),Webb(1975)and Wainwright and Lauder(1992) found a relationship between oral stimulation and fin shape with hydrodynamics**.**

Singh *et al* (1994) and Das and Nag (2006) studied SEM structure of adhesive apparatus of *Garra gotyla gotyla* and revealed that protrusions bearing spines present on both lips and disc and mucous pores on callous pad function based on the suction principle.

The functional morphology of the anchorage system and food scrapers of *G. lamta* is described using SEM by Ojha and Singh (1992). Again, a detailed report on lips and associated structures of the same fish *G. lamta* is made by Pinky *et al.(*2002).Also a brief report on the presence of unculi on the upper jaw epithelium of *Cirrhinus mrigala* by Yashpal *et al* (2009) and More recently, a detailed report on lips and associated structures of the fish *Puntius sophore* by Tripathi and Mittal (2010).Joshi *et al* (2011) studied SEM structure in *Glyptothorax pectinopterus.*

In the recent years, the surface ultrastructure of the adhesive apparatus of *Garra* species using SEM was studied by Teimori *et al*. (2011) and Gaur *et al*. (2013).

The fishes were collected from altitude between 520m–750m. As the elevation rises stream morphology changes because of the rise in gradient. Rise in slope is directly related to the fast water current where fishes face many adverse conditions not only from fast water current but also roughness of the substratum (cobbles, gravels, boulders and rocks). To study the exact mechanism or adhesion to the substratum, a typical hill stream fish *i.e. Garra gotyla* with excellent adhesive mechanism have been selected. An attempt to study their adhesive apparatus has been made using SEM.

***Garra gotyla***

*Garra gotyla* is commonly known as "*stone sucker*" or "*Patthar chatta*". and bears well developed adhesive disc on its ventral surface**(Fig 9.1)**. It is an inhabitant of fast flowing streams and a bottom dweller fish. The mouth is inferior. Both lips are thick and have prominent tubercles. Upper lip is highly fringed. Behind the lower jaw, lower lip continues and its labial fold has free margin forming the circular disc. The space between the lower lip and postero-lateral free margin of disc becomes thickened and forms the callous pad. Thus, morphologically the disc comprises four components *viz.* the fringed anterior labial fold or upper lip the posterior free labial fold of lower lip the central callous portion of the disc or callous pad and the poster lateral free margin of disc. The spines **(S**, **Fig.9.2)** attached to the stub-shaped tubercles **(ST, Fig. 9.2)** were very well marked on the upper fringed lip and lower free labial fold of the disc. It was evident that stub-shaped structures are covered with the squamous epithelium **(SE**, **Fig.9.3)**. The spines on the circular margin of stub-shaped tubercles were small in size and their size increases from margin to the centre. Likewise, the lower lip beared elongated stub-shaped tubercles with longer spines on its surface. Posterior part of the lower lip is callous pad which was thick and hard.

The spines and tubercles of the upper fringed lip and free border of the disc were shorter in length as compared to those on lower lip. Each spine was attached to its base, which was much broader. Base of spine had penta/hexagonal epithelial cells indicating that these spines or dentations are the modification of squamous epithelium. The teeth-shaped spines indicated that they can be used for firm attachment to the substratum and for scrapping the food present on the substratum. The inter space between the tubercles and its surface shows almost hexagonal epithelial covering. The callous pad beared numerous mucous openings **(MO**, **Fig.9.2)** on its surface. The epithelial layer present on the callous pad showed irregular formation of micro ridge with varying shape and size having elevations and depressions. The depressions may provide canal system for the distribution of mucous.

**Discussion**

It appeared that stub-shaped tubercles bearing spines of upper fringed lip, lower lip and lower free labial fold of disc come in contact with the substratum first which not only anchor to the substratum but also act as mechano-sensory organs. This process is followed by the secretion of mucous of callous pad, enabling the fish to make firm hold. The sudden spread of mucous of callous pad is facilitated by numerous canaliculi formed by epidermal micro ridges. Hence, cumulative action of spines and mucous enables the fish to make firm hold on the substratum. The present findings do not support the findings of Hora (1952), Singh *et al.* (1994) who opined that mucous secretion is primary function and anchorage of spine (S) of tubercles (ST) is secondary. Thus main function of teeth-like spines (S) is the anchorage to the substratum whereas free ends act as neuromuscular organs (Liem, 1980) because of the absence of special kind of mechano-receptors in pits. Secondary present findings do not support the principle of suction feeding because the presence of cartilaginous jaw just below the lower-labial fold or lower lip is used to scrap the algal matter from stones or pebbles (Mathews *et al.*, 1986).

The interspaces between the tubercles provide continuous flow of water for aeration. Squamous epithelium is very much clear, in the interspace, on the muscular tubercles and as well as on the base of spines indicating that they are the epithelial modification. The micro ridges provide structural integrity to squamous epithelium of callous pad and increase the surface area and also prevent mechanical abrasions (Oslon, 1995). The mucous, which quickly spreads on micro ridges is immunological in nature and prevents any type of injury to the exposed parts (Ourth, 1980).

In this fish it is evident that the stubbed tubercles act like neuromuscular repertoire. The mechano-receptors or sensory cilia on ventral part of mouth are absent. The attachment of spines is more clear in where basal cells are also clearly visible. These spines may also be acting as sensory organ (Liem, 1980).

The anchoring devices include true suckers of *Garra* species. *Noemacheilus* does not possess such adhesive devices so it escapes from the fast hill stream current by moving into side of the stream where the current is always slow.

True suckers are the characteristics of *Garra* species. The anchorage system of *Garra* is in the form of a ventrally placed, cup-shaped adhesive disc (0.031 $cm^2$) just behind the arched lower lip and separated from it by a crescent-shaped groove. The adhesive disc is capable of generating formidable sticking force if applied against the substratum and pressed carefully to create a vacuum by draining the underlying water. The intensity of this force is directly proportional to the vacuum created. The total sticking force under absolute vacuum is about 34914.9 dyne (Pa = 101298 $dyne/cm^2$ + Ph = 9800 $dyne/cm^2$) X 0.031 $cm^2$ (A), where Pa = atmospheric pressure, Ph = hydrostatic pressure of 100 cm of water column on fish body and A = area of the anchorage (adhesive) disc. Great muscular effort with higher energy expenditure is required to achieve a vacuum nearer to the absolute value. Under such circumstances the fish regulates muscular effort to achieve an adequate sticking force with a minimum energy expenditure. The crescent furrow above the adhesive disc, and the specialized globular structure on the crescent's margin, can be used to regulate the pressure gradient during the anchorage of fish to the substratum. The surface ultra structure of the adhesive disc of *Garra* reveals the presence of hexagonal epithelial cells with elevated cell boundaries. Scantly mucous gland openings are also discernible in the adhesive disc.

Thus, there is no doubt that this fish possesses a perfect adhesive apparatus. Due to its adaptive features it has become a key-stone species in the hill streams.

Present findings were compared with SEM observation of adhesive organ of Himalayan *Garra gotyla* . It was revealed that ultrastructure was same but size of each structure was considerably smaller as compared to Himalayan fish.

Looking to challenge of fast current faced by Himalayan fish , size of organ and its respective structures were bigger and strong as compared to Aravallian *Garra gotyla* which was investigated during present study.

# SUMMARY

Biodiversity is part of our daily lives and livelihood and constitutes the resources upon which families, communities, nations and future generations depend. Biological diversity includes three hierarchical levels:(i) Genetic diversity, (ii) Species diversity, and (iii) Community and Ecosystem diversity .The diversity of fish species comprises total number of species in a defined area (species richness), relative number of species(species abundance) and relationships between different groups of species(polygenetic diversity).

The hill streams are small bodies of water in mountain regions, flowing in a channel or water course. It is also commonly referred as brook. These streams ultimately enter the rivers. The hill streams, which constitute an integral part of any river system, have been observed to serve as nursery grounds for most of the fish species that abode in the rivers. The hill streams have well defined habitats like runs, riffles, pools and rapids.

Rajasthan is cut into two unequal halves by the Aravalli hills. $25^o$ 0' N and $73^o$ 18' E (highest peak Guru Shikhar near Mount Abu 6500 ft. above mean sea level) into South West and North East. The smaller Southern part is rocky served by rivers like Banas, Mahi, Chambal, Berach, and Sisarma which was undertaken for the study.

Total 32 ichthyospecies have been recorded from the selected waterbodies during present study belonging to 23 genera and 10 families(Table ).The members of family Cyprinidae were represented by 17 species, followed by Channidae and Bagridae with three species each, Balitoridae and Siluridae was expressed by two species each, Notopteridae, Saccobranchidae, Centropomidae, Belonidae and Mastacembelidae were represented by one species only (Fig 5.1) . Family Cyprinidae was represented by the *Chela bacaila, Rasbora daniconius, Puntius ticto, Systomus sarana, Puntius sophore, Garra gotyla, Tor tor, Amblypharyngodon mola, Danio rerio, Osteobrama cotio, Catla catla, Cirrhinus mrigala, Labeo rohita, Labeo bata, Labeo boggut, Labeo gonius* and *Labeo* *calbasu*. Family Notopteridae by *Notopterus notopterus*. Family Balitoridae by *Noemacheilus botia* and *Noemacheilus denisonii*. Bagridae by *Sperata seenghala, Mystus cavasius* and *Mystus oar,* Siluridae by *Wallogo attu* and *Callichrous pabda,* Saccobranchidae by *Heteropneustes fossilis* .Channidae by *Channa punctatus,Channa marulius* and *Channa striatus.* Centropomidae by *Chanda nama*. Belonidae by *Xenentodon cancila* and Mastacembelidae by *Mastacembelus armatus* covering all the sites.

Morphometric analysis was done of selected hillstream fishes. A total of 22 characters were taken for morphometric measurements

The range difference (difference between maximum and minimum) was used to determine genetically controlled, intermediate and environmentally controlled characters.

During present study morphometric characters of *Chela bacaila* (n = 15), *Rasbora daniconius* (n= 17) , *Noemacheilus botia*( n= 13) and *Puntius sophore* (n= 12) were calculated.

***Chela bacaila*** : On the basis of range difference most of the characters in percentage of Total Length(TL) have been considered as genetically controlled characters. The characters like head depth(HD), preorbital distance(PrOD),Eye diameter(ED) and Inter Orbital Distance (IOD) in percentage of head length were found to be intermediate characters whereas post orbital distance(PsOD) in percentage of head length was genetically controlled character.

***Rasbora daniconius*** :On the basis of range difference, the characters like SL, HL, PrDD, PsDD, LDF, DDF, LAF, ,DAF,Pr AD, LPF, LVF, Mi BD, MBD, DPVF, DVAF, LCF, LCP and FL in percentage of total length and ED in percentage of HL have been considered as genetically controlled characters whereas the characters like HD ,PrOD, PsOD and IOD in percentage of HL were intermediate characters .

***Noemacheilus botia*** :On the basis of range difference the characters *viz.* SL, HL, PrDD, PsDD, LDF, DDF, LAF, ,DAF, PrAD, LPF, LVF, MiBD, MBD, DPVF, DVAF, LCF, LCP and FL in percentage of total length and PrOD, PsOD, and ED in percentage of HL have been considered as genetically controlled characters, the character IOD in percentage of HL were intermediate character and HD in percentage of HL were found to be environment controlled character.

***Puntius sophore :*** On the basis of range difference, the characters like SL, HL, PrDD, PsDD, LDF, DDF, LAF, ,DAF, Pr AD, LPF, LVF, Mi BD, MBD, DPVF, DVAF, LCF, LCP and FL in percentage of total length and ED in percentage of HL have been considered as genetically controlled characters whereas the characters like HD ,PrOD, PsOD and IOD in percentage of HL were intermediate characters.

Two hill stream fishes i.e. *Rasbora daniconius* and *Noemacheilus botia* were selected to know the food and feeding habits of hill stream fishes .

***Rasbora daniconius* :** Observations on the food and feeding habits of *Rasbora daniconius* revealed that it is a surface or sub surface feeder and omnivorous that mainly feeds on insects, insect larvae and microcrustaceans. The pronounced high feeding intensity during post monsoon months ( September – October) was observed .

***Noemacheilus botia :*** The observation revealed that the highest numerical percentage was shown by insect larvae and nymphs (41.8%) followed by microcrustaceans (29.5%), algal matter (12.3%) and the lowest value was for miscellaneous items (1.3%). Observations on the food and feeding habits of *Noemacheilus botia* revealed that it is a bottom feeder and carniomnivorous that mainly feeds on insect larvae and microcrustaceans.

During present investigation three fish species namely *Chela bacaila* , *Puntius sophore* and, *Chanda nama* were selected for the study of length-weight relationship.

The values of regression coefficient (b) computed were 2.743 (female), 2.950 (male), and 2.887 (sexes combined) in case of *Chela bacaila*.

In *Puntius sophore* males recorded higher exponential value than the females. It indicates that the weight gain is slightly more in case of males than females. In case of *Chanda nama* The values of regression coefficient (b) were 3.546 (female), 3.417 (male), and 3.493 (sexes combined).

During present study Shannon -Weaver diversity was calculated for the selected sites .The highest Shannon- Weaver diversity index was found in lake Fateh Sagar (3.20659) whereas lowest was observed in Ubeshwar stream (1.66378) .

During present observation , 24 fish species found in more than one stream having similar geomorphological and ecological conditions. The maximum assemblage was seen by *Chela bacaila, Rasbora daniconius, Noemachielus botia,* and *Puntius ticto.* The maximum frequency of occurrence has been shown by *Rasbora daniconius, Noemachielus botia, Puntius ticto* and *Channa punctatus*.

The maximum diversity was seen in the C type streams like river Banas and the minimum number of species was found in Ubeshwar stream.

Seasonwise various physico-chemical characteristics were observed during 2013-14 and 2014-15 .

Air temperature varied between a minimum of 19.2°C at Jhadol to maximum of 39.4°C at Fateh Sagar. Moderate fluctuation in temperatures was recorded spatially and no significant variation was observed with increase in altitude.

The minimum water temperature 15.2°C was recorded at the stream Nandeshwar and maximum of 33.8°C recorded at the lake Fateh Sagar.

During the study period values of pH fluctuated between 7.0 to 7.8 at river Sisarma, 7.1 to 8.4 at the stream Jhadol, 7.1 to 7.8 at the Ubeshwar stream , 7.2 to 7.8 at Nandeshwar stream, 7.5 to 8.3 at the river Banas, 7.4 to 7.9 at Barapal stream, 7.4 to 7.8 at Thur ki Pal, 7.1 to 7.8 at Jhameshwar, 7.6 to 8.8 at the lake Fateh Sagar and 6.9 to 8.3 at the lake Pichhola.

The maximum water current of 178 cm/sec was recorded at the stream Barapal.

The highest value of 463.2 μS/cm of electrical conductance was recorded at the lake Pichhola and the lowest value of 122.6 μS/cm was observed in Nandeshwar stream. In the present study, the depth of visibility varied between a minimum of 42.9 cm to a maximum of 53.4 cm at Sisarma river, 39.7 cm to 49.8

cm at the Jhadol stream, 30.5 cm to 37.2 cm at the Ubeshwar stream, 32.9 cm to 50.5 cm at the Nandeshwar stream, 21.7 cm to 63.0 cm at Banas river, 22.2 cm to 40.5 cm at Barapal, 22.8 cm to 50.6 cm at Thur ki Pal, 42.1 cm to 50.2 cm Jhameshwar stream , 78.5 cm to 140.5 cm at lake Fateh Sagar and 82.1 cm to 150.3 cm at lake Pichhola. The majority of the streams, were dried during summer seasons hence the depth of visibility was not measured .

In the present study, total dissolved solids ranged between 184 mg/l to 231 mg/l at Sisarma, 149 mg/l to 242 mg/l at Jhadol, 162 mg/l to 241 mg/l at Ubeshwar , 54 mg/l to 178 mg/l at Nandeshwar, 98 mg/l to 142 mg/l at Banas , 154 mg/l to 190 mg/l at Barapal, 175 mg/l to 240 mg/l at Thur ki Pal , 181 mg/l to 240 mg/l at Jhameshwar,78.5 mg/l to 140.5 mg /l at the lake Fateh Sagar and 210 mg/l to 282 mg/l at the lake Pichhola **.**

During present investigation, the chloride concentration varied between 0.01200 mg/l to 0.04401mg/l at Sisarma , 0.01178 mg/l to 0.06921 mg/l at the stream Jhadol, 0.01078 mg/l to 0.04417 mg/l at the stream Ubeshwar, 0.0315 mg/l to 0.05320 mg/l at Nandeshwar stream , 0.00911 mg/l to 0.0832 mg/l at Banas river, 0.01346 mg/l to 0.04451 mg/l at Barapal stream , 0.02730 mg/l to 0.05351 mg/l at Thur ki Pal , 0.01181 mg/l to 0.0430 mg/l at Jhameshwar.

Very high values of chloride content 38.82 mg/l to 74.84 mg/l at lake Fateh Sagar and 132.20 mg/l to 220.80 mg/l at the Pichhola lake were recorded during present study.

The total alkalinity ranged between a minimum of 74.0 mg/l recorded at the stream Nandeshwar and a maximum of 256 mg/l at the lake Pichhola **.**

During present study ,total hardness ranged between 98 mg/l to 128 mg/l at Sisarma,90 mg/l to 189 mg/l at Jhadol, 89 mg/l to 119 mg/l at Ubeshwar, 88 mg/l to 123 mg/l at Nandeshwar, 102 mg/l to 190 mg/l at Banas, 98.5 mg/l to 124 mg/l at Barapal, 110 mg/l to 159 mg/l at Thur ki Pal, 98 mg/l to 134 mg/l at Jhameshwar, 149 mg/l to 215 mg/l at Fateh Sagar and 142 mg/l to 232 mg/l at Pichhola. The total hardness was high during summer, which gradually decreased in winter, the minimum values were found during monsoon season .

During present study, all the streams were characterized by high levels of dissolved oxygen as running water has good capacity of aeration. The maximum value of dissolved oxygen of 8.8mg/l was observed in winter season at Nandeshwar stream whereas, the lowest oxygen value of 4.9 mg/l was observed in summer at the lake Pichhola .

During present observation, the nitrate content varied from 0.0537mg/l at Ubeshwar stream to 4.8541 mg/l at lake Fateh Sagar .

During present study maximum orthophosphate content of 4.5821 mg/l was at Fateh Sagar lake and minimum of 0.0225mg/l at the Barapal stream .

During present investigation the value of silicates ranged between 0.0332 mg/l at lake Fateh Sagar to 6.6399 mg/l at Thur ki Pal.

The phytoplanktonic community of the selected lotic and lentic water bodies was represented by six groups *viz.* Myxophyceae, Chlorophyceae, Xanthophyceae, Bacillariophyceae, Chrysophyceae and Dinophyceae. Total 44 forms were identified, out of these 8 belonged to Myxophyceae, 15 to Chlorophyceae, 4 to Xanthophyceae, 12 to Bacillariophyceae, 1 to Chrysophyceae and 4 to Dinophyceae .

During present study, total 34 forms of zooplankton comprising of five groups, namely Protozoa , Rotifera , Cladocera , Copepoda and Ostracoda were identified in the selected lotic and lentic water bodies . Out of these 8 belonged to Protozoa, 9 belonged to Rotifera, 4 to Ostracoda, 8 to Cladocera and to 5 Copepoda.

The benthic fauna comprises a diversity of species belonging to phylum Annelida (Class Oligochaeta and Hirudinea), Arthropoda (Class Insecta) and Mollusca (Class Gastropoda and Bivalvia) .

To study the exact mechanism of adhesion to the substratum, a typical hill stream fish *i.e. Garra gotyla* with excellent adhesive mechanism was selected using SEM. The spines and tubercles of the upper fringed lip and free border of the disc are shorter in length as compared to those on lower lip. Each spine is attached to its base, which is much broader. Base of spine has penta/hexagonal epithelial cells indicating that these spines or dentations are the modification of squamous epithelium.

Present findings were compared with SEM observation of adhesive organ of Himalayan *Garra gotyla* . It was revealed that ultrastructure was same but size of each structure was considerably smaller as compared to Himalayan fish.

The present investigation provided information on the anthropogenic pressure on the rivers, streams and lakes and useful baseline data for ichthyofaunal conservation, management and fishery policy formulation. Loss in fish diversity is affected when changes in environment occur beyond its endurance limits. The major contributors in decline of ichthyodiversity are pollution, habitat deterioration and deforestation.

The hill stream fish fauna of Aravalli region in South Rajasthan is comparatively poor than the fish fauna of Himachal Pradesh .

Various factors affecting the fish faunal diversity in this region are as follows:- Habitat alternation , Environmental degradation , Aquatic pollution , Introduction of exotic species and Wanton destruction.

For the protection of aquatic resources and fauna particular in the State, there is need to remove various stresses on the aquatic resources. Some of the suggestive measures are :-Habitat restoration ,fish ranching and enhancement ,declaration of fish sanctuaries and protected aquatic reserves, improvement of human resource and capacity in fish systematic ,suitable infrastructure development for restoration programme and Cryopreservation of fish gametes and embryos of threatened fish species is an important aspect of conservation of germ plasm resources.

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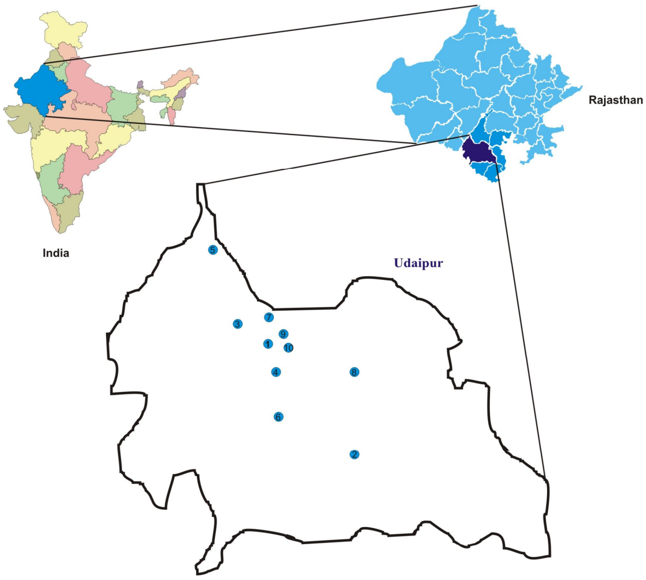



| | |
|---|---|
| 1 | Sisarma |
| 2 | Jhadol |
| 3 | Ubeshwar |
| 4 | Nandeshwar |
| 5 | Banas |
| 6 | Barapal |
| 7 | Thur ki Pal |
| 8 | Jhameshwar |
| 9 | Fateh Sagar |
| 10 | Pichhola |

**Fig. 4.1: Map showing water bodies of the study area**

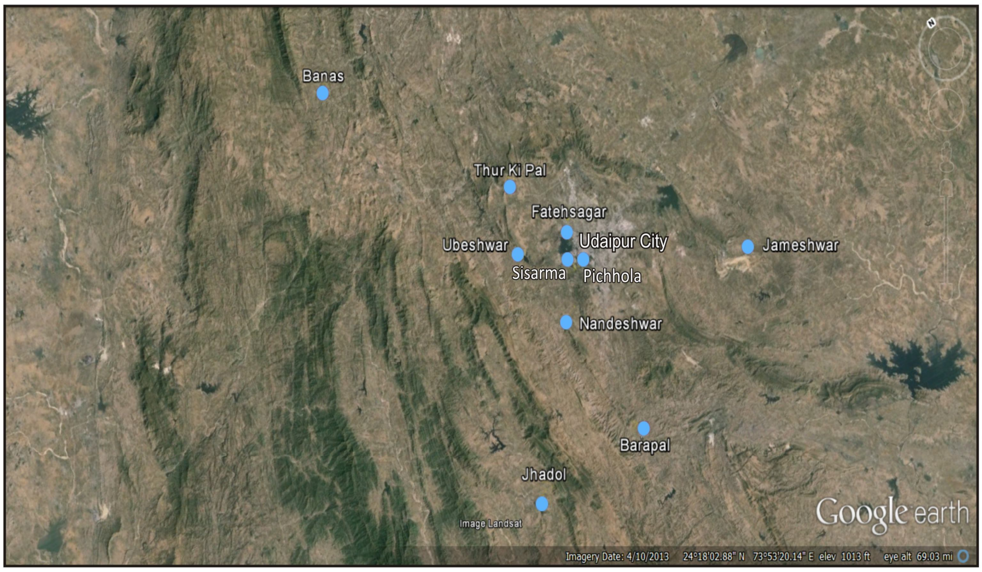
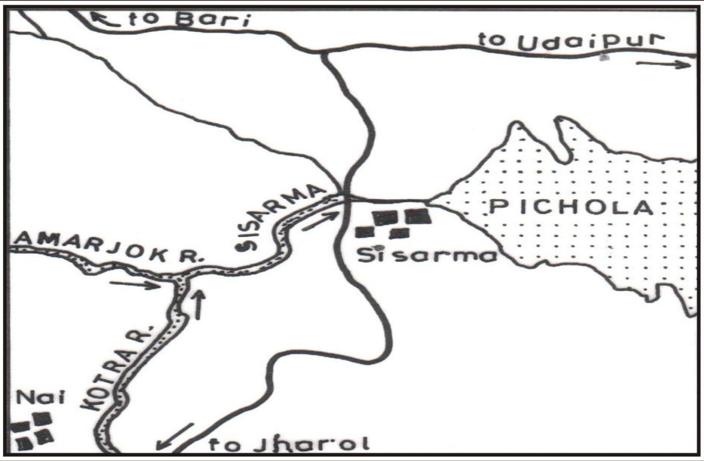


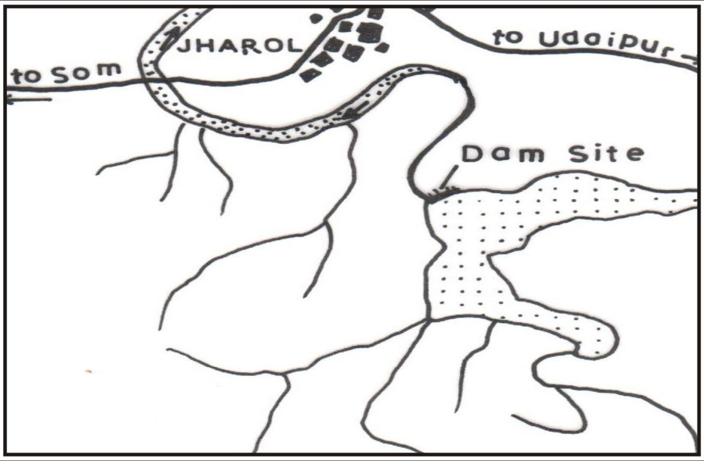

**Fig-.4.2 : Map showing selected water bodies of South Rajasthan under taken for the study**

# PLATE-4.1



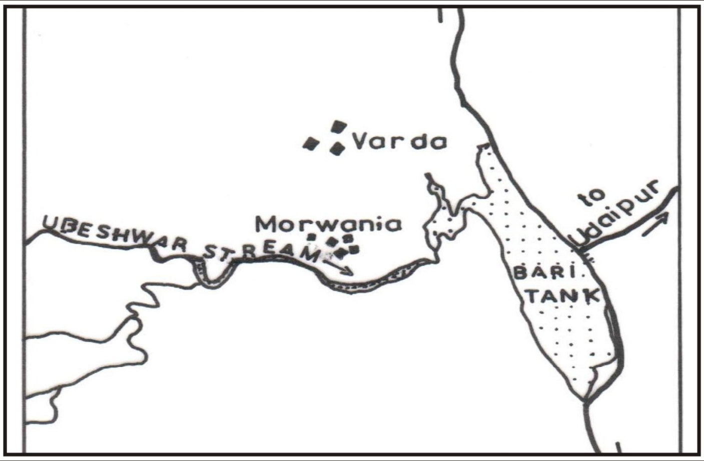

Sisarma River

**PLATE-4.2**



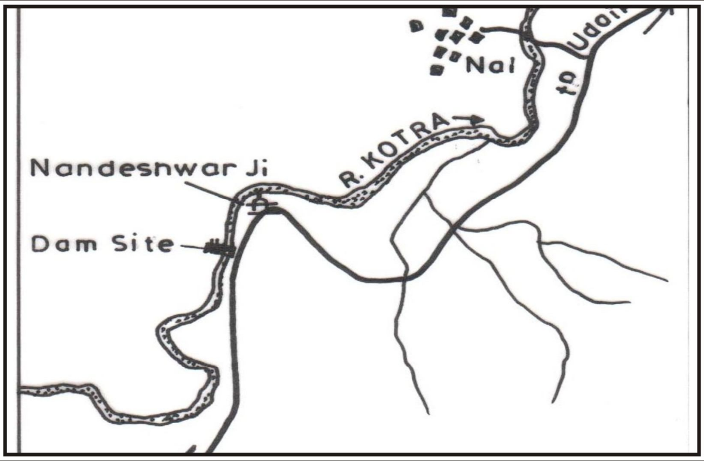

Jhadol Stream

## PLATE-4.3



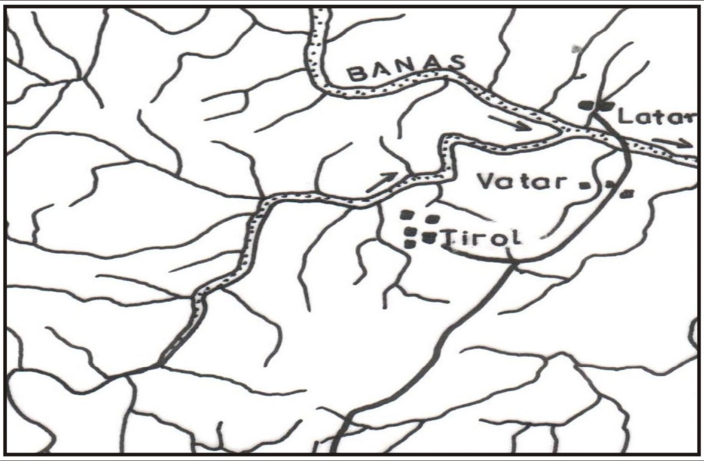

Ubeshwar Stream

# PLATE-4.4



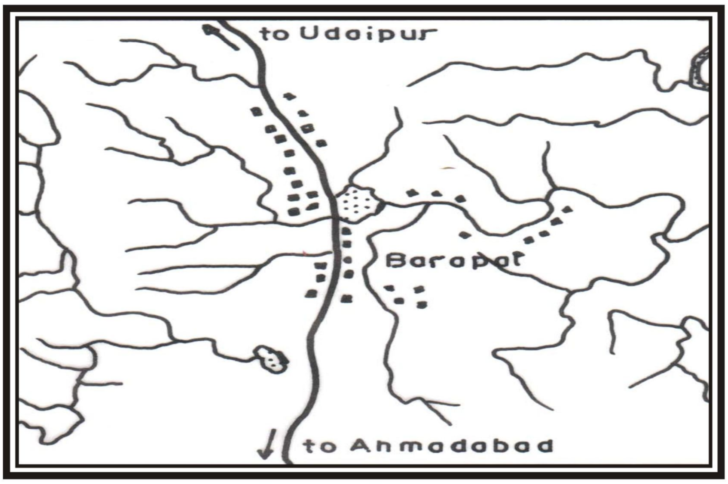

Nandeshwar Stream

## PLATE-4.5



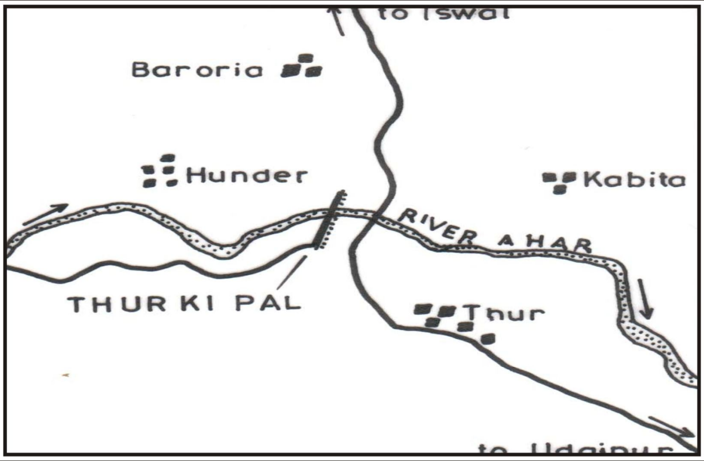

Banas River

## PLATE-4.6



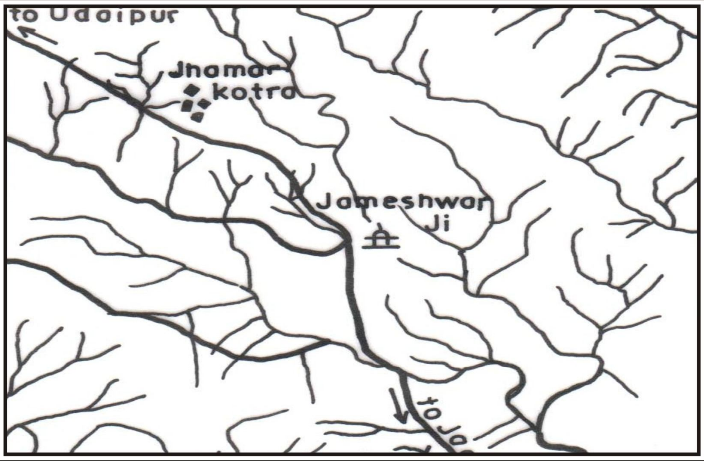

Barapal Stream

## PLATE-4.7



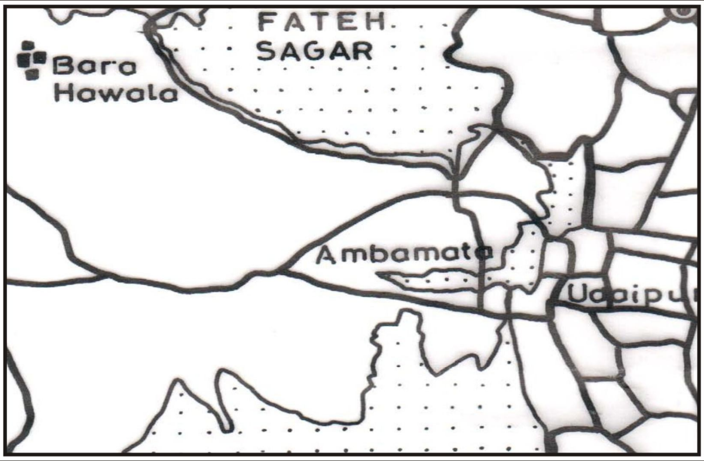

Thur Ki Pal Stream

# PLATE-4.8



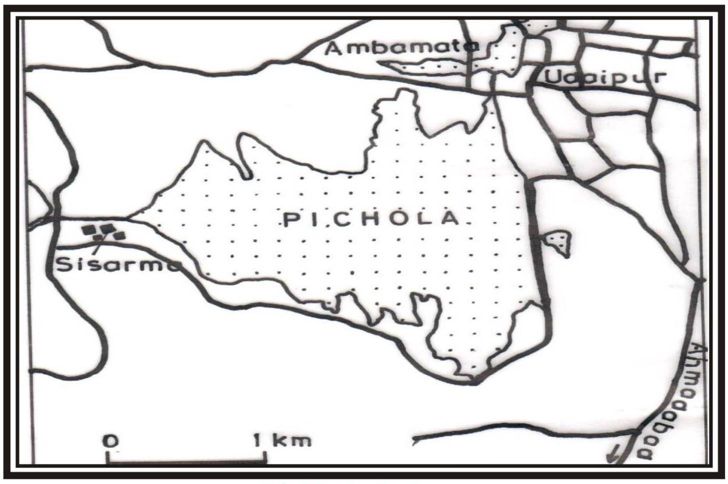

Jhameshwar Stream

## PLATE-4.9



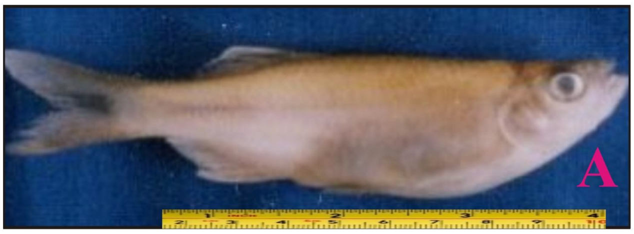

Fateh Sagar Lake

## PLATE-4.10

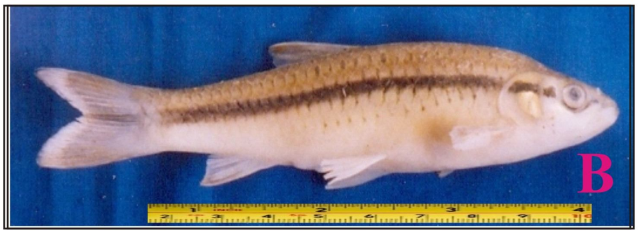



Pichhola Lake

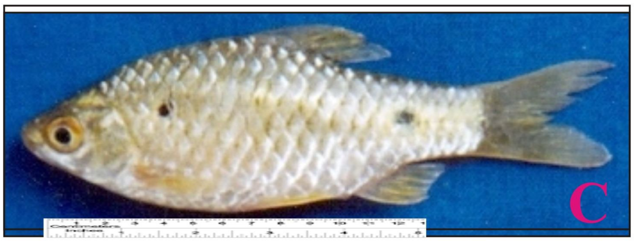
**FISH FAUNA**




*Chela bacaila*




*Rasbora daniconius*



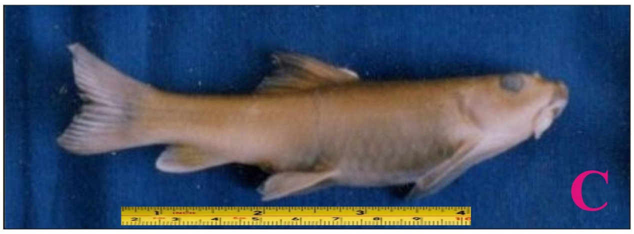

*Puntius ticto*

**PLATE-5.1**

**FISH FAUNA**


*Systomus sarana*


*Puntius sophore*

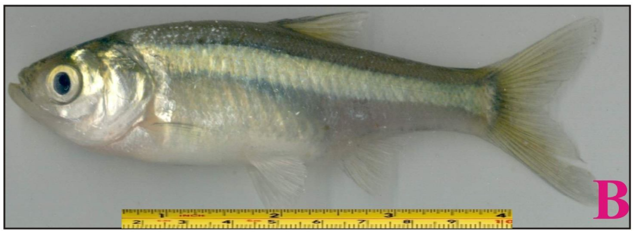



*Garra gotyla*

## PLATE-5.2

**FISH FAUNA**

*Tor tor*

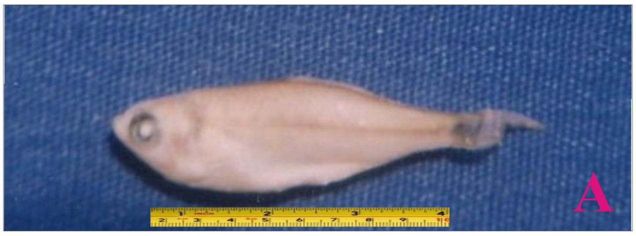


*Amblypharyngodon mola*

*Danio rerio*

# PLATE-5.3

**FISH FAUNA**




***Osteobrama cotio***


***Catla catla***


***Cirrinus mrigala***

## PLATE-5.4

**FISH FAUNA**

*Labeo rohita*

*Labeo bata*

*Labeo boggut*

## PLATE-5.5

**FISH FAUNA**


***Labeo gonius***


***Labeo calbasu***


***Notopterus notopterus***

## PLATE-5.6

**FISH FAUNA**


***Noemacheilus botia***


***Noemacheilus denisonii***


***Sperata seenghala***

## PLATE-5.7

## FISH FAUNA


*Mystus cavasius*

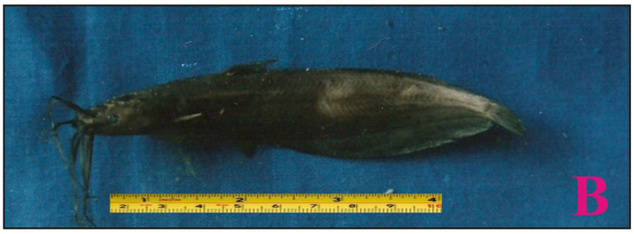

*Mystus oar*


*Wallago attu*

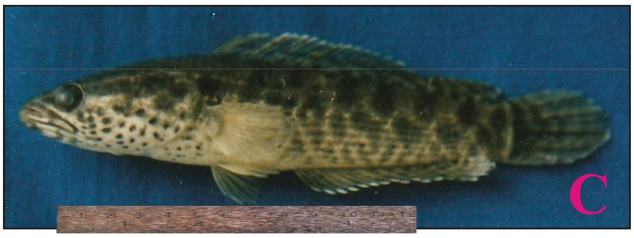
# PLATE-5.8

**FISH FAUNA**


*Callichrous pabda*




*Heteropneustes fossilis*



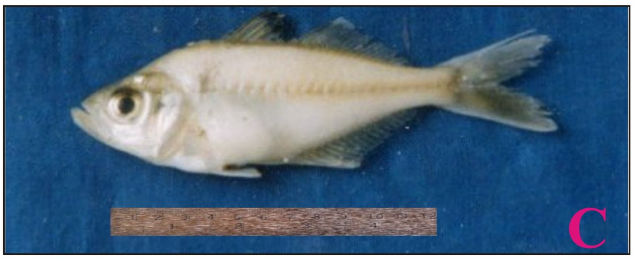

*Channa puntatus*

## PLATE-5.9

**FISH FAUNA**


*Channa marulius*


*Channa stratus*




*Chanda nama*

## PLATE-5.10

**FISH FAUNA**


*Xenentodon cancila*


*Mastacembelus armatus*

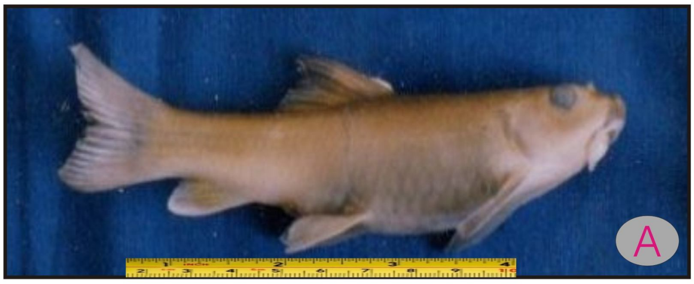
## PLATE-5.11

**Fishing by Tribes**

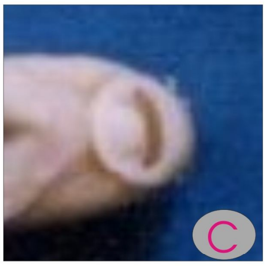
## PLATE-8.1

**Fishing by Tribes**

**PLATE-8.2**







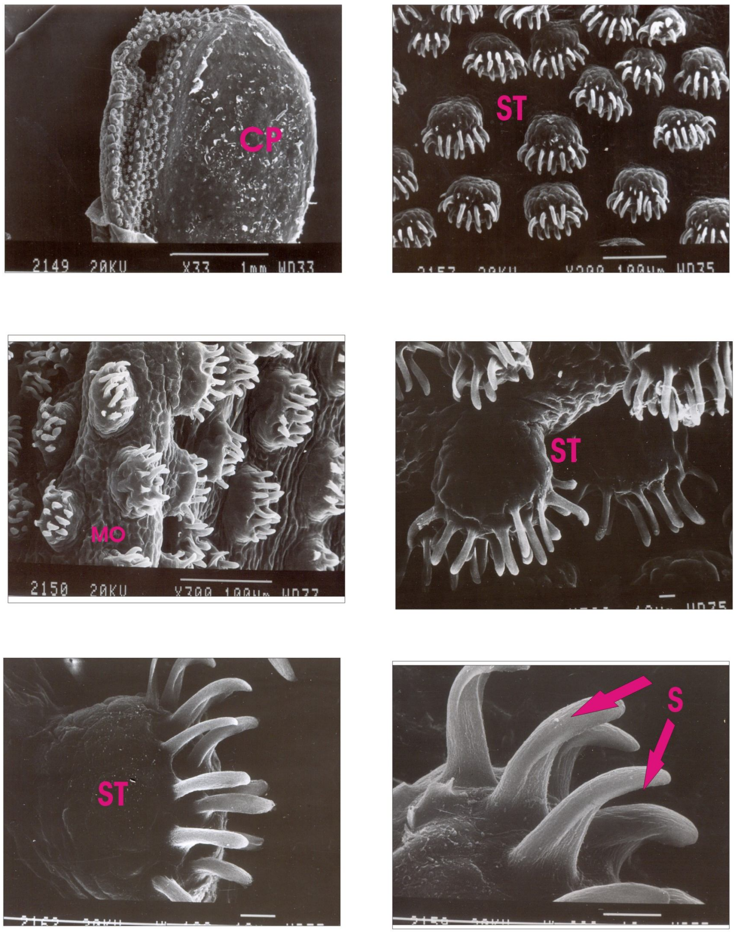

( A ) **Lateral Veiw**

( B ) **Ventral View**

( C ) **Adhesive Disc**

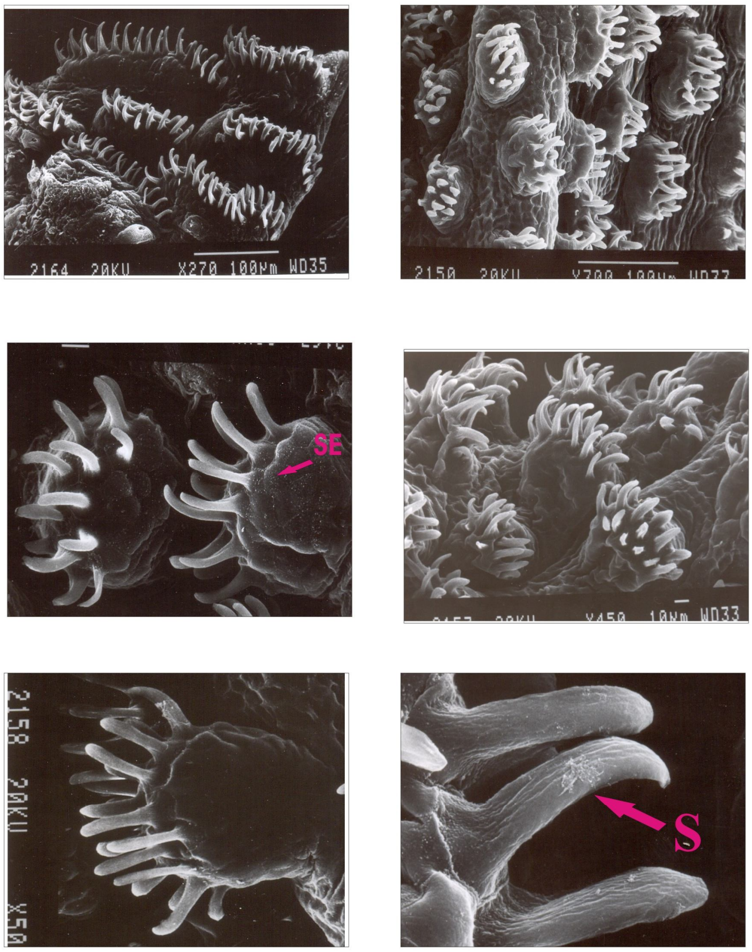
**A Typical Hill Stream Fish: *Garra gotyla***

**PLATE-9.1**




**S.E.M.Micrograph of adhesive organ of *Garra gotyla***

# PLATE-9.2




S.E.M.Micrograph of adhesive organ of *Garra gotyla*

## PLATE-9.3

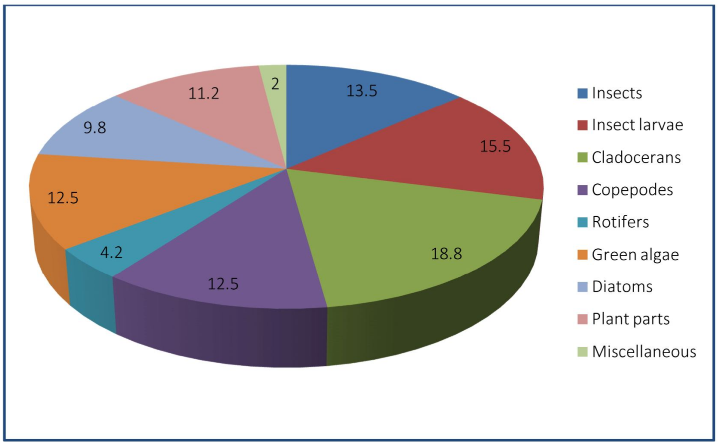



**Fig -7.1 Average annual food items of *Rasbora daniconius***

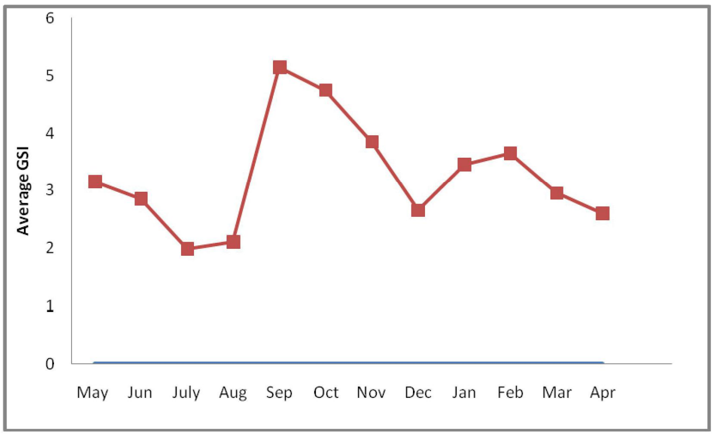



**Fig -7.2 Average GSI of different months of *Rasbora daniconius***

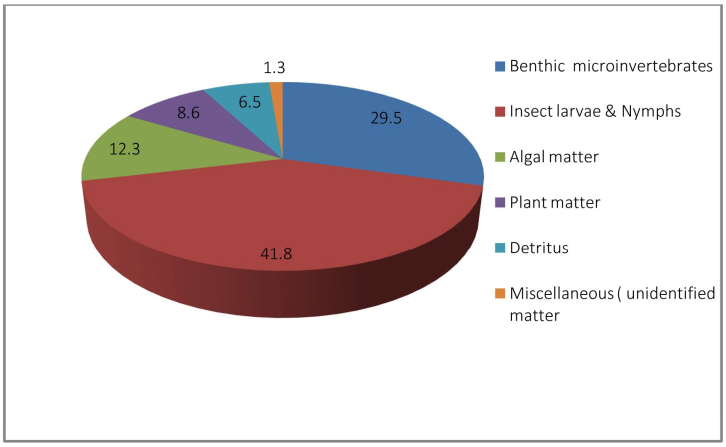



**Fig -7.3 Average annual food items of *Noemacheilus botia***

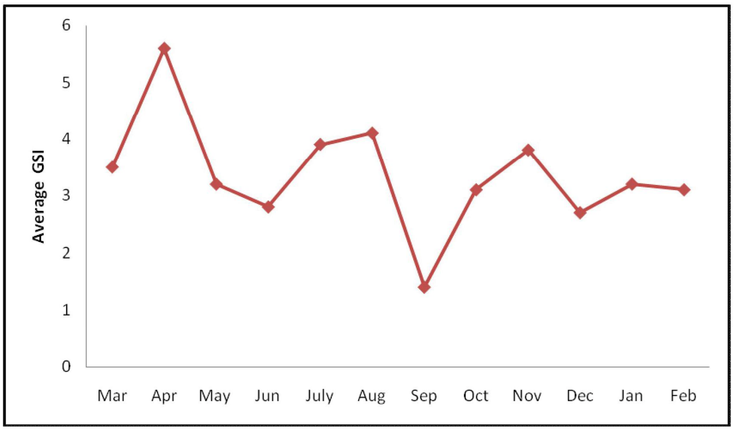
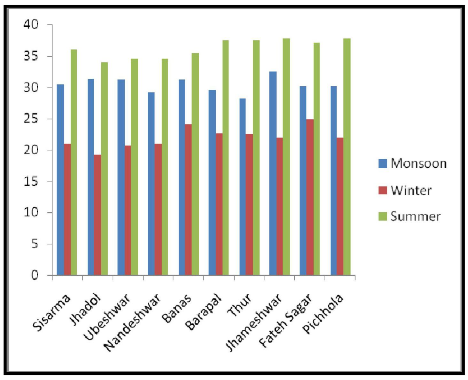
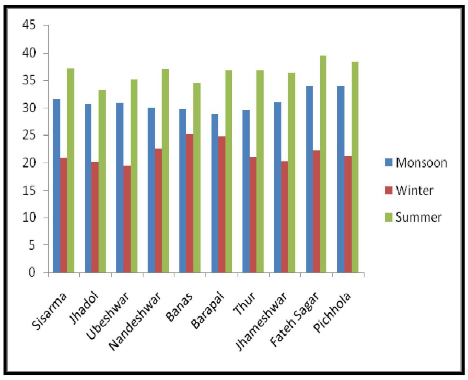



**Fig -7.4 Average GSI of different months of *Noemacheilus botia***

**AIR TEMPERATURE**

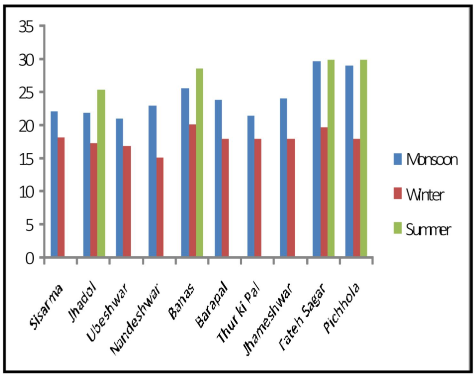


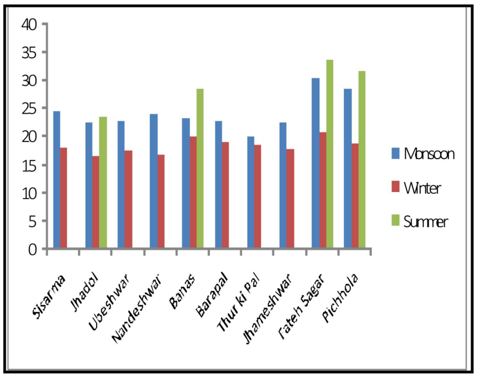




Year 2013-14 Year 2014-15

Fig- 6.1 Season-wise air temperature of selected water bodies under taken for the study

**WATER TEMPERATURE**

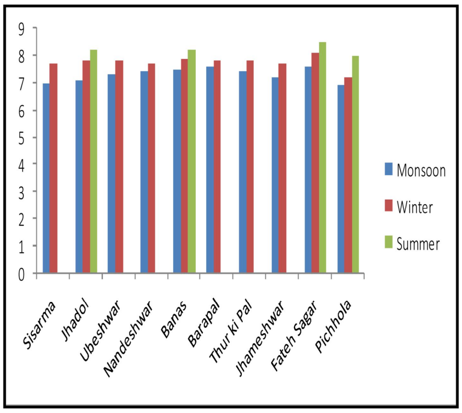


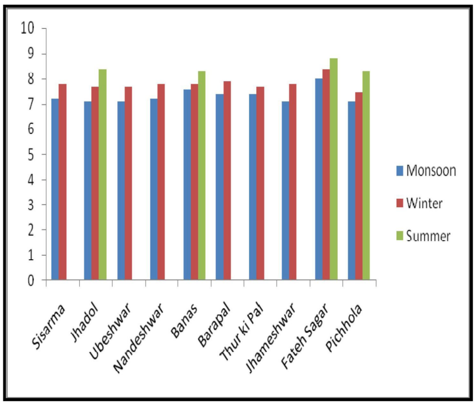

Year 2013-14 Year 2014-15

Fig- 6.2 Season-wise water temperature of selected water bodies under taken for the study

**pH**



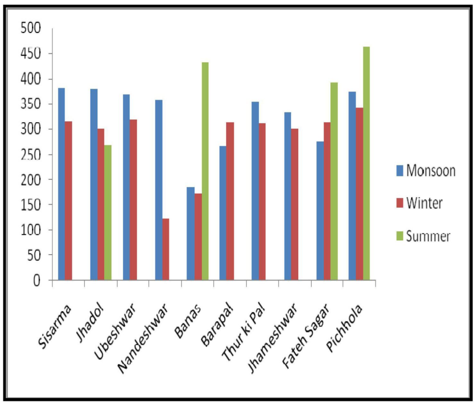

Year 2013-14



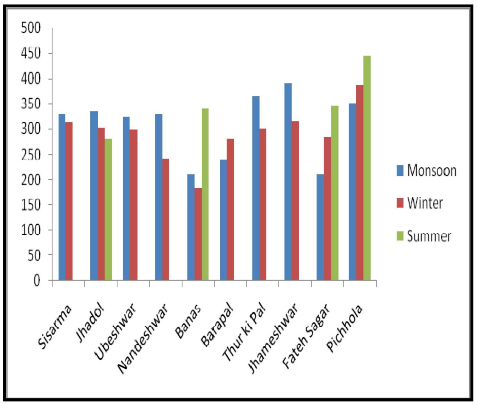

Year 2014-15

Fig- 6.3 Season-wise hydrogen ion concentration of selected water bodies under taken for the study

**ELECTRICAL CONDUCTIVITY**



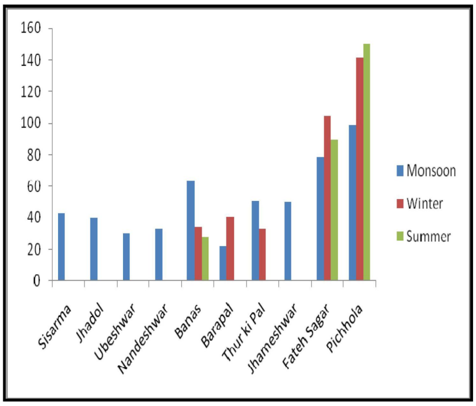

Year 2013-14




Year 2014-15

Fig- 6.4 Season-wise Electrical conductivity of selected water bodies under taken for the study

**DEPTH OF VISIBILITY**



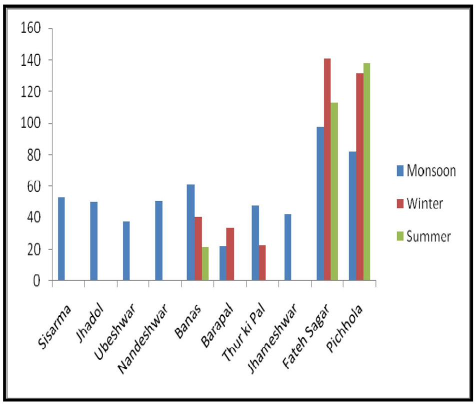




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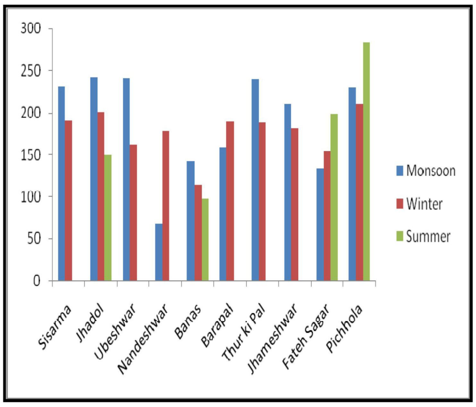
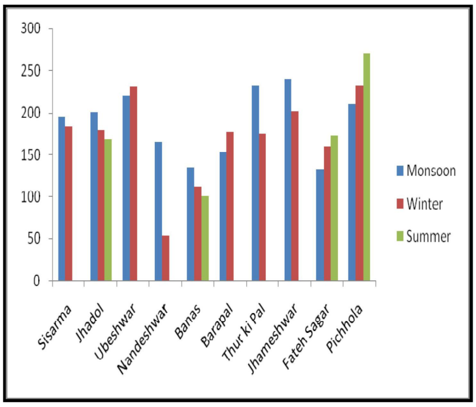
Fig- 6.5 Season-wise depth of visibility of selected water bodies under taken for the study

**TDS**

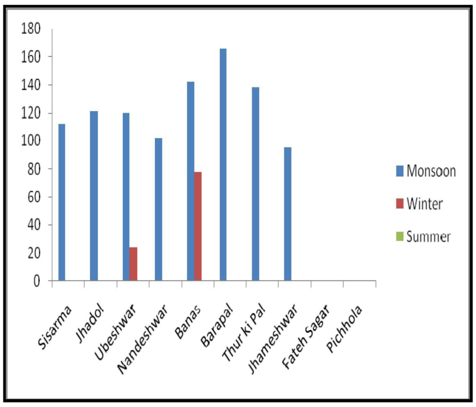


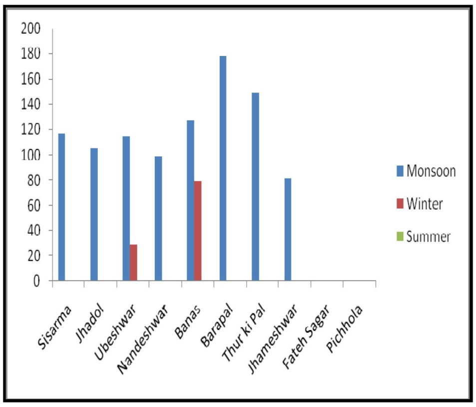

Year 2013-14 Year 2014-15

Fig- 6.6 Season-wise Total dissolved solids of selected water bodies under taken for the study

**WATER CURRENT**



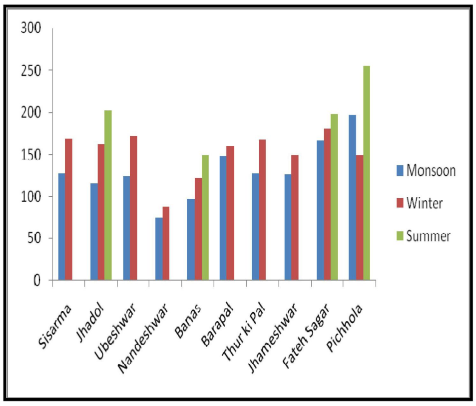

Year 2013-14



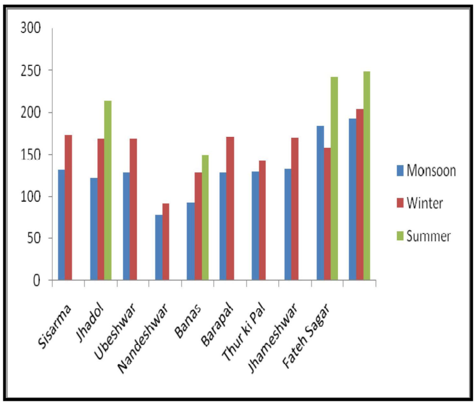

Year 2014-15

Fig- 6.7 Season-wise water current of selected water bodies under taken for the study

**TOTAL ALKALINITY**




Year 2013-14




Year 2014-15

Fig- 6.8 Season-wise total alkalinity of selected water bodies under taken for the study

**TOTAL HARDNESS**

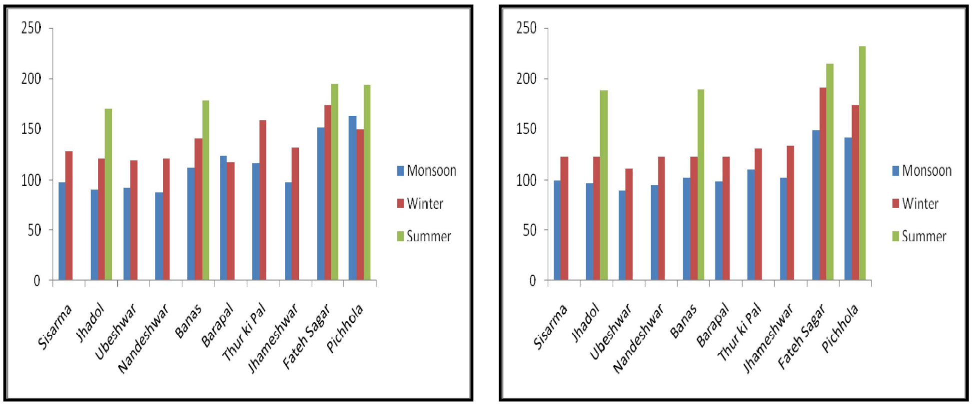



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Fig- 6.9 Season-wise Total Hardness of selected water bodies under taken for the study

**DO**

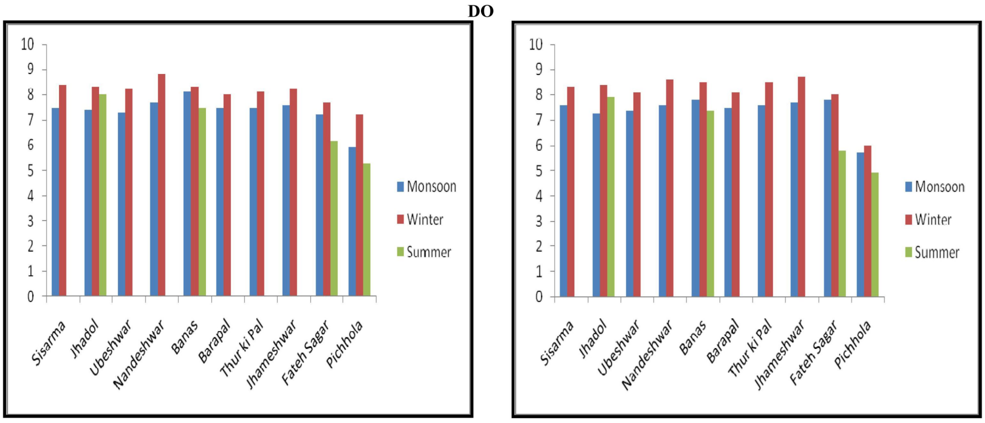


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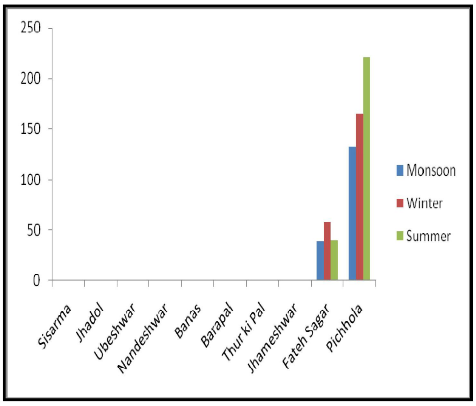
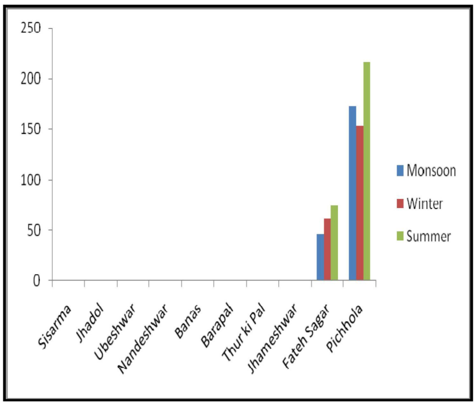
Fig- 6.10 Season-wise dissolved oxygen of selected water bodies under taken for the study

**CHOLRIDE**

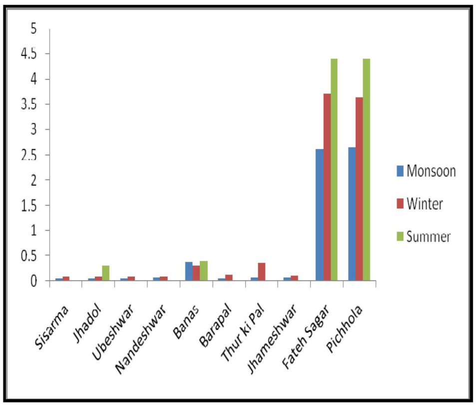



Year 2013-14 Year 2014-15

Fig- 6.11 Season-wise Chloride ion concentration of selected water bodies under taken for the study

**NITRATES**



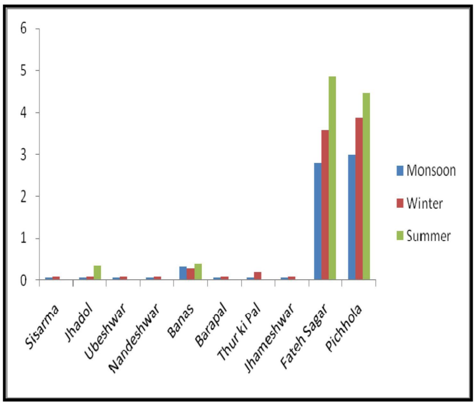




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Fig-6.12 Season-wise Nitrate ion concentration of selected water bodies under taken for the study

**PHOSPHATES**

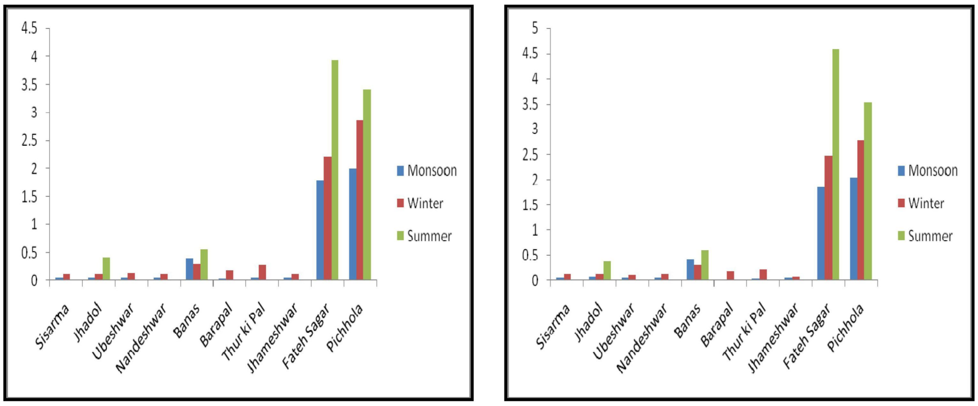


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Fig- 6.13 Season-wise Phosphate ion concentration of selected water bodies under taken for the study

**SILICATES**

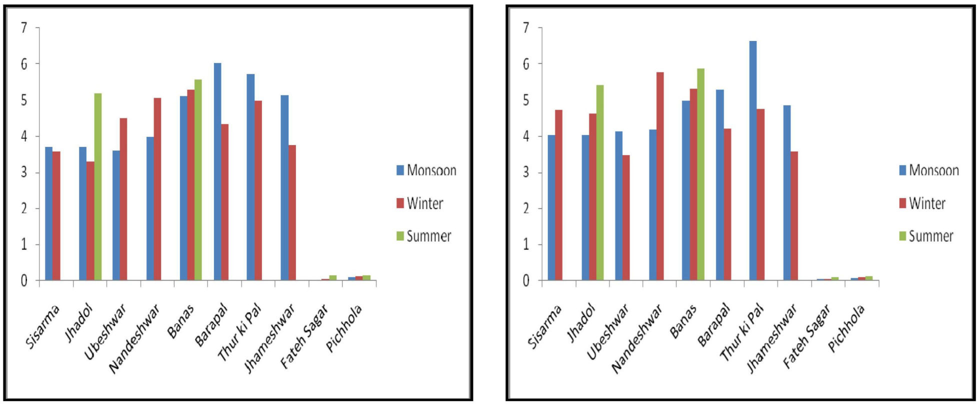


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Fig-6.14 Season-wise silicate ion concentration of selected water bodies under taken for the study

**GPP**

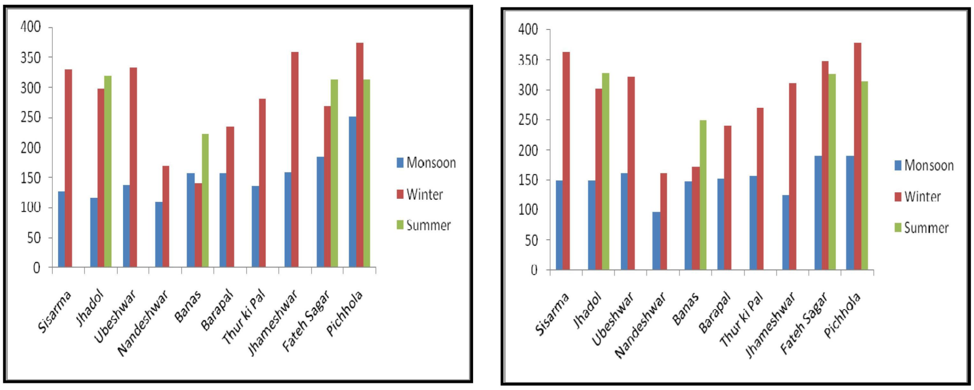


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Fig-6.15 Season-wise Gross Primary Production of selected water bodies under taken for the study

**NPP**

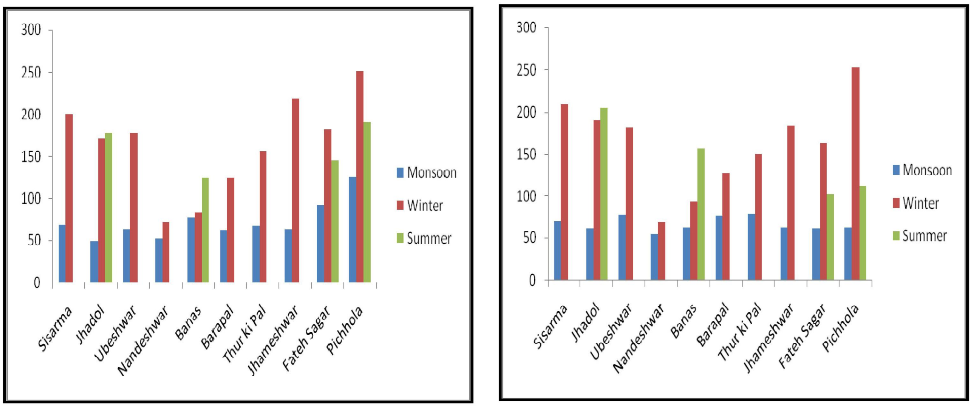


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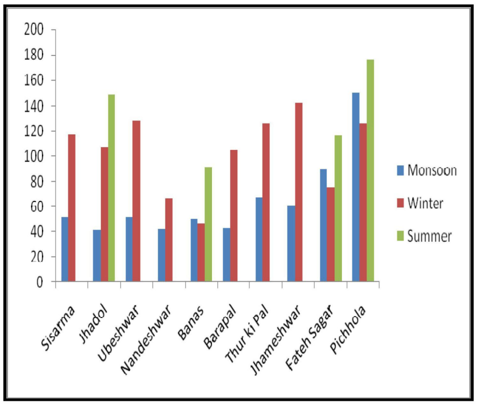
Fig- 6.16 Season-wise Net Primary Production of selected water bodies under taken for the study

**RESPIRATION**



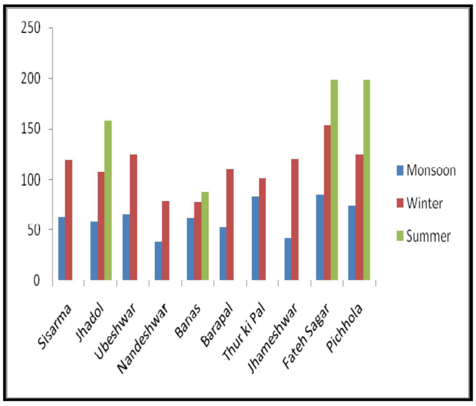




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Fig-6.17 Season-wise Respiration rate of selected water bodies under taken for the study

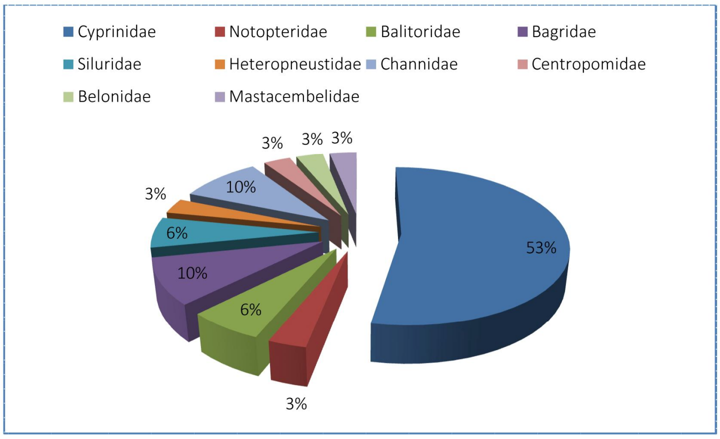


**Fig 5.1:** **Family wise percentage of hill stream fishes in selected water bodies of South Rajasthan**

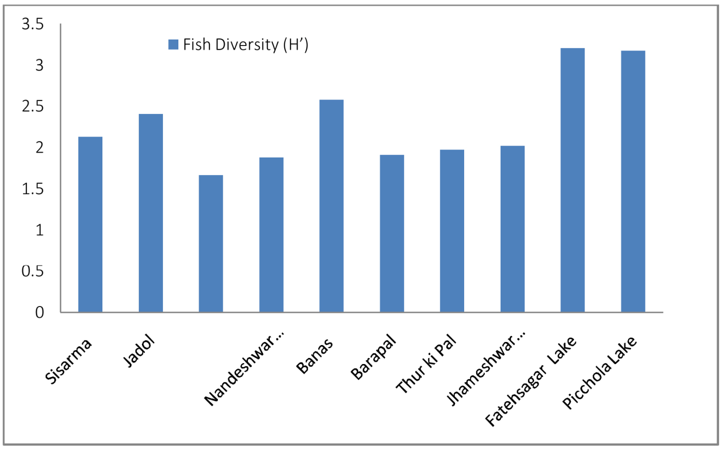


**Fig. 5.2:** **Diversity of Hill stream fishes in selected waterbodies of South Rajasthan using Shannon – Weaver diversity index**