Planktonic and Fish Biodiversity, and Fisheries of Reservoir Udaisagar (Udaipur, Rajasthan)

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Thesis

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(Limnology & Fisheries)

By

LAXMI KUNWAR RATHORE

2011

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
RAJASTHAN COLLEGE OF AGRICULTURE, UDAIPUR

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Dated: / /2011

This is to certify that **Mrs. Laxmi Kunwar Rathore** has successfully completed the Preliminary Examination held on 16.10.2007 as required under the regulation for the degree of **Doctor of Philosophy in Agriculture (Limnology & Fisheries).**

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PLANKTONIC AND FISH BIODIVARSITY AND FISHERIES OF RESERVIOR UDAISAGAR, UDAIPUR (RAJ.)

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ABSTRACT

The Present study deals with the **"Planktonic and Fish Biodiversity, and Fisheries of Reservoir Udaisagar (Udaipur, Rajasthan)".** The outcome of the present study from planktonic diversity of Udaisagar reservoir, a total 35 species of phytoplankton and 34 species of zooplankton were noticed. Out of 35 species of phytoplankton, 11 belong to Chlorophyceae, 9 to Bacillariophyceae, 12 to Cyanophyceae and 3 to Desmidiaceae from this reservoir. Out of 34 species of zooplankton noticed in the reservoir, 18 belong to Rotifera, 9 to Cladocera and 7 to Copepoda. In the present study, the observed zooplankton ranking in order of : Rotifers > Cladocerans > Copepods. Further, as regards relative dominance of different algal groups, Cyanophyceae dominated the phytoplankton Chlorophyceae followed by Bacillariophyceae and Desmidiaceae in the present study which could be considered a desirable feature from the fisheries point of view. Qualitative and quantitative analysis of planktonic resources also revealed the moderate productivity of this reservoir.

The study also incorporates the fisheries potential of Udaisagar reservoir in relation to current water quality status. In all, 31 fish species representing nine families have been recorded from this reservoir. Out of which, *Catla catla* and *Labeo rohita* have dominated the catch of this reservoir.

The relationship between length and weight of *Catla catla* and *Labeo rohita* from fish catch was calculated by establishing correlation and regression between the two parameters. The exponent values of total length and weight varied from 0.138 to 0.280 and 0.104 to 0.262 for different length groups of *Catla catla* and *Labeo rohita.* The higher values of 'n' could be attributed to high rate of weight increase with per unit increase in length. The correlation co-efficient 'r' between total length and weight were found to be significant for all the length groups of both the species. The values of condition factor (K) of both the species were also computed and found that

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both the species performed well. The maximum of 'K' value was found 1.917 in *Catla catla* (group A) and 1.63 in *Labeo rohita* (group B).

The mean primary productivity (GPP) of Udaisagar reservoir was found to be 0.48 g $Cm^{-3}h^{-1}$. Water quality parameters viz., air and water temperature, pH, depth of visibility, dissolved oxygen, free carbon dioxide, carbonate and bicarbonate alkalinity, EC, TDS, orthophosphate and nitrate-nitrogen were observed throughout the study period and indicated that the water of this reservoir remained congenial and highly productive from the fisheries point of view. Relationship between all the physico-chemical and biological parameters were analysed statistically for suitable interpretation.

1. INTRODUCTION

India is endowed with great biodiversity in various forms. In the modern era of biotechnological approaches and creation of transgenic species, loss of biodiversity is a serious problem than ever before. The aquatic biodiversity assessment and their conservation is the need of the new millennium. India has an envious spectrum of biodiversity, which is matching with few nations in the world. The fish genetic diversity is no exception to this, our nation is blessed with a vast and varied expanse of open waters displaying enormous diversity in their biotic and abiotic characteristics. This constitutes approximately 11 per cent of the world's total of about 25,000 species of fishes. Out of these 400 species are commercially important which includes wild and culturable species (Das and Kapoor, 1990). The aquatic eco systems have been subjected to various forms of environmental stress, during the past few decades. Most of such environmental problems are man-made and thus increased human activities in the catchment area of various aquatic systems have affected the natural processes of these systems adversely thereby threatening the survival and growth of biotic communities.

For a sustainable agriculture judicious protection of fish and other faunal diversity is gaining prominence in the global political and economic scenario of the new century. Biodiversity conservation is therefore becoming a prime need of the new millennium.

Rapidly reducing per capita availability of land and subsequent pressure on biological production from terrestrial source may attract people towards aquatic resources for harnessing food for their sustenance. Evidently, in such a scenario the land biodiversity would become very critical whereas the aquatic biodiversity may assume greater significance as the main supplier of food for alarmingly growing population.

India has made rapid progress in fisheries sector by increasing its total annual catch of the marine and inland fish from 0.816 million tones in 1950-51 to 7.6 million tones during 2008-09. However the per capita consumption rate of fish in India, with an average of 9 kg per year, remains well behind the world average of 12 kg per year. Projected achievable target of fish production by the end of eleventh five year plan (2007-12) is 10 million tones of which the share of Inland fisheries is to be 5.3 million tones with growth rate of 8 per cent against present growth rate of 6.55 per cent.

Obviously, to achieve the target, the developmental processes in fisheries sector need to go on with a faster modern technological advancement.

Inland water normally has enormous populations of small sized wild trash fishes on which the catfishes thrive. Natarajan (1972) has emphasized that extermination of the undesirable catfishes and trash fishes is an important element in the scientific development of reservoir fisheries in India. The knowledge of fish fauna of a reservoir is therefore gaining vital importance.

Fortunately for meeting the nation's target, the inland fisheries sector offers several opportunities. Out of these, reservoirs alone constitute over three million hectares. Small reservoirs numbering about 19000 accounts for a total water spread area of 14,85,557 hectares and about 180 medium and 56 large reservoir which constitutes 5,24,541 hectares and 11,40,268 hectares, respectively (Sugunan, 1995). However, these vital resources are yet not fully exhibited to their full potential to contribute the expected level of inland fish production.

Rajasthan is the largest state of India with an area of 3,42,239 square kms which is 10.74 per cent area of our country. Rajasthan is situated between northern latitude 23°3' to 30°12' and eastern longitude 69°30' to 78°17'. The Aravali hill ranges diagonally divides the state of Rajasthan geographically into east and the southeast and west, northwest. The major portion of the state i.e. western and northwestern Rajasthan is desert with relatively low rainfall and warm climate, while eastern and southeastern part receives high rainfall with moderate climate. As the major portion of the state is desert, water spread in respect of fishery resources in this part of the state is relatively low. However, with the creation of Indira Gandhi Canal ample water resources have come into existence. A large network of seasonal and perennial rivers, canals, ponds and lakes of the state offer tremendous scope for fisheries as temporary and permanent water resources covering around 3.63 lakh hectares. Out of this total water area, large and medium reservoirs constitute about 1.53 lakh hectares water area, small reservoirs and ponds contribute 1.80 lakh hectares, whereas, 0.30 lakh hectares water area is available in the form of rivers and canals (Anonymous, 2004).

The state of Rajasthan thus offers vast potential for the development of fisheries due to the availability of 3131 water bodies of different sizes (Choudhary and Juyal, 1995). However, only 866 water bodies are used presently for fish production (Anonymous, 2004). Further, bylarge, fisheries in the state is mainly of capture type wherein fisheries exploitation is practiced through open bid system. However, in the recent years, water bodies are auctioned on long lease and therefore, fish seed is also stocked for better returns. Under culture-cum-capture fisheries in Rajasthan state, the water bodies have been categorized into A, B, C and D class waters on the basis of annual revenue. The number of water bodies under different categories and revenue obtained from these categories are shown as under:

Category	**No. of water bodies**	**Revenue**
A	35	≥ 5 lakh rupees
B*	201	< 5 lakh ≥ 50,000
C*	532	< 50,000 ≥ 10,000
D*	15	< 10,000
FFDA*	83	--
Religious	33	--

* All the water bodies except 'A' class water bodies have been transferred to Panchayati Raj Institutions

Source: State Fisheries Department, Udaipur (Raj.)

Udaisagar lake was constructed by Late Maharana Udai Singh Ji in the year 1559-65 A.D. across river Berach. It has a storage capacity of 23.4 milli cubic meter. To manage the overflowing lake during rainy season, one channel has been made connecting to Berach river. It commands a culturable commended area of 4656.7 ha with irrigable area of 1944 ha. The maximum irrigation done was 1947.6 ha in the year 1977-78. Besides providing irrigation facilities, Udaisagar provides 157 McFt (4.4 M.Cum) to M/s Hindustan Zinc Ltd. for its Debari Zinc Smelter plant and other allied industries.

Indian major carps *viz., Catla catla, Labeo rohita* and *Cirrhinus mrigala* dominate the fishery wealth from Indian reservoirs. Though Indian major carps dominate the whole reservoir fishery of North India, during the recent years their population in the total catch is drastically reduced in comparison to their production potential. This is chiefly attributed to the lack of care and improper management practices for the native fish fauna of major carps. Thus, there is a need to adopt proper management practices based on location specific studies on the commercially important fish species.

Inspite of favourable conditions for high fish growth rate in the state of Rajasthan, fish culture has yet not gained required popularity. It is mainly due to inadequate knowledge about growth performance and other related information on Indian major carps in the specific climate of southern Rajasthan in different types of water bodies except few notable studies by Durve (1976), Mahajan *et al.* (1981), Sharma *et al.* (1986), Johal and Tandon (1987), Sinha *et al.* (1991), Sugunan (1995), Kohli *et al.* (1998) Ujjania (2003), Raj kumar (2005) and Vijay kumar (2007).

One of the most useful aspects of fishery biology is to develop mathematical relationship between length and weight of fish for future use. In case of Indian major carps there exist a linear relationship between length and weight of fish (Jhingran, 1952); it is also termed as ‘cube law’ because of three dimensional growth of fish. Hence, from such a relationship, it is possible to determine the weight of fish harvested from water body if their length are known and vice-versa.

The condition factor is an important biological aspect which indicates the well being of a specific fish in a water body. It is an index of species average size and its value depends on the physiological features like maturity, spawning, environmental factors and food availability in a water body. Therefore, the study of condition factor is a mirror for the evaluation of the well being of the fish in relation to its biotic and abiotic environments.

In general, the growth of a fish is influenced by the quality and quantity of food materials available and consumed. Thus, any variation in quality and quantity of food materials will affect the growth rate of the fish. The qualitative and quantitative variations of natural food materials in a water body are under the influence of several abiotic and biotic factors. Moreover, these variations coulde be known by qualitative and quantitative analyses of plankton. A comparative study of plankton and productivity of Udaipur water in comparison to the selected waters of Rajasthan have been carried out by Sharma (1980).

Physico-chemical features such as temperature, transparency, pH, alkalinity, free carbon dioxide, dissolved oxygen, electrical conductance, nitrate-nitrogen, orthophosphate etc. of any water body grossly determine the trophic status of that water body. These parameters influence the primary productivity (phytoplankton and zooplankton productivity) and in turn the growth of the fish. The primary productivity of different water bodies has been widely investigated to assess the fish production potentialities of a water body and to formulate fishery management policies.

Natarajan and Pathak (1983) have also advocate the significance of physico-chemical and primary productivity studies in the management of inland waters.

In view of the above, the present study on the planktonic and fish biodiversity, and fisheries of reservoir Udaisagar, Udaipur (Rajasthan) has been designed and conducted. This study is likely to enrich our knowledge on growth performance of selected fish, biodiversity of fish, plankton and general limnological status of this water body. The outcome of the investigation of the above referred aspects would help in developing suitable management policy for fisheries of this water body.

This study has been conducted with following principal objectives:

1. To make qualitative and quantitative enumeration of phytoplankton and zooplankton.
2. To assess the primary productivity of reservoir Udaisagar in order to establish its link with fish production.
3. To investigate current status of selected water quality parameters of reservoir Udaisagar and establish their relationship with two biotic resources.
4. To assess the biodiversity of ichthyo fauna of reservoir Udaisagar.
5. To study the biology of two major fish species of reservoir Udaisagar.

2. REVIEW OF LITERATURE

Biodiversity may be defined as the variety, and variability of flora, fauna and microbes in an ecosystem. In recent years, the sustainable utilization of available biodiversity has assumed great significance in the face of increasing environmental threats. The overexploitation of biological resources to feed the growing human population, especially in densely populated third world countries, is so vivid that most of the resources, be it terrestrial or aquatic, have developed symptoms of impairment which is a matter of serious concern for all. Biodiversity conservation has, thus become a necessity so as to protect this planet from disintegration. The level of debates on conservation and rational utilization of biological wealth is going on for quite some decades, the same has, however, received an impetus after the earth summit held in Rio de Janeiro in 1992.

Biodiversity has intimate relationship with the progress and development of human civilization, as most of the human needs are linked with biological sources be it food, clothing, shelter, medicine or recreation. It is essential, therefore that the same is carefully nurtured and rationally exploited. The level of information and the perceptions on biodiversity conservation is still poor, especially in developing countries like India, where biomass economy holds the key of development. It is paradox, however, that the understanding an aquatic biodiversity is still in its nascent stage in spite of the fact that the aquatic resources are covering 75% the Earth's crust.

The aquatic biodiversity assessment and their conservation is the need of the new millennium. Several reservoirs were studied by various workers for assessing biodiversity of Ichthyofauna. Desai and Shrivastava (1995) studied the Ichthyofauna of Rihand reservoir (U.P.) and reported 42 species belonging to 11 families and 29 genera. Chari and Abbasi (2003) reported the fish fauna of Ossudu lake situated in Pondicherry.

Fish diversity in various water bodies of Rajasthan were also described by several researchers. Sharma and Johal (1984) investigated fish and fisheries of Kota district in Rajasthan and presented a list of seventy nine fish species. Sinha *et al.* (1991) and Kohli *et al.* (1988) have reported the fisheries resources of southern Rajasthan including Mahi, Kadana, Jaisamand and Jakham. Choudhary (1995) further reported the fisheries status of Mahi Bajaj Sagar. Jain (1998) has described the fisheries resources of Rajasthan and management strategies for promoting the fisheries of Rajasthan. Chouhan (2000) reviewed the fish diversity of North-West Rajasthan. Jain (2000) has also described the biodiversity-of Siliserh reservoir of Alwar District of Rajasthan.

Rajkumar (2005) studied on some aspects of fish biology and fisheries potential in relation to current water quality status of Daya reservoir, Udaipur (Raj.). Vijay Kumar (2007) current fish and planktonic biodiversity in the reservoir Jaisamand, Udaipur (Raj.). Sarang (2007) ecology of macro invertebrates from littoral zone of selected waters of southern Rajasthan.

In fishery biology, the determination of mathematical relationship not only helps in assessing the age and the growth of fish but also indicates the status of particular fish species in its environment. In India, considerable work on the biology of carps is available (Jhingran, 1952, 1957, 1959, 1968; Menon, 1953; Tandon and Johal, 1972; Johal and Chahal, 1988). Zalewski and Hickley (2004) studied ecohydrology and physical habitat modification of as an fish the integrative approach for reversing decline of fish communities and good ecological status of freshwater eco-system. Mahapatra *et al*. (2004) observed fish biodiversity of north eastern India with a note on their sustainable utilization. Kumar *et al.* (2007) studied the diversity of fish fauna in Dudhawa reservoir. Pandey (2006) studied the fisheries and fish catch composition of Kidari Jheel, Mahaba, Uttar Pradesh. Agarwal and Thaphyal (2005) investigated preimpoundment hydro biological status of the Bhilangana river from Tehri reservoir in U.P.

Le Cren (1951) reported that growth in fishes follows “Cube Law”. Length-weight relationship and conditions factor are the two important indices for assessing the suitability of a water body for supporting growth of any fish. Length and weight of Indian major carps in relation to selected growth parameters have been studied by Chakrabarty and Murty (1972), Choudhary *et al.* (1982), Desai and Shrivastava (1990), Johal and Kingra (1992a), Zafar and Mustafa (1992), Ahmed and Saha (1996), Saha *et al.* (1997), Singh *et al.* (1998), Sarkar *et al.* (1998), Basu *et al.* (1998) and Jain (2000). Chatterjee *et al*. (1977) studied the length-weight relationship of Labeo rohita. Chatta and Salam (1993) studied the growth performance of cultured Labeo rohita (Ham.) under semi-intensive farming and assessed the growth performance using log transformed regression method (Rajkumar, 2005; Vijay Kumar, 2007 and Sarang, 2007).

Agarwal and Saxena (1979) described length-weight relationship of *Catla catla*. Johal and Tandon (1983) found a strong linear relationship between total length and weight of Catla catla from Govind Sagar. Kartha and Rao (1990) reported isometric growth pattern in *Catla catla* of Gandhi Sagar (M.P.) Johal and Kingra (1992b) reported the length-weight relationship of three Indian major carps from Jaisamand lake, Udaipur (Rajasthan) and reported that the exponent value 'b' varies from 2.753 to 3.545. Kulshrestha *et al.* (1993) worked on the length-weight relationship of Catla catla from two water bodies of Bhopal. Salam and Mahmood (1993) studied length-weight relationship and condition factor of wild *Catla catla* (Ham.) of a freshwater yearling from Chenab river and presented log transformed regression to test the allometric growth. Sarkar *et al.* (1997) performed investigation on length-weight relationship and relative condition factor of hatchery and bund-bred of *Catla catla*. Rajkumar (2005) worked on length-weight relationship and condition factor of a Catla and Rohu. Similar work done by Vijay Kumar (2007) worked on length-weight relationship and condition factor of a Catla, Rohu and Mrigal.

Rajbanshi *et al.* (1984) reported an isometric growth pattern at juvenile stage of Cirrhinus mrigala from a water body in the southern Rajasthan. Sarkar *et al.* (1998) studied length-weight relationship and relative condition factors during early period of development of Cirrhinus mrigala (Ham.) spawned in bundh and hatchery and reported an allonietric growth of the species from both the environment. Desai and Shrivastava (1990) reported that Cirrhinus mrigala from Rihand reservoir did not follow the cube law exactly because the exponential value (b) was found to be 2.914. Reddy and Rao (1992) studied the length-weight relationship of 750 specimens of Punflus sophore (Hamilton-Buchanan) from lake Hussain Sagar, Hyderabad and reported that length-weight relationship could be expressed by a curvilinear regression with a regression co-efficient (n) of 3.029.

Primary productivity of various water bodies has been studied by several workers in order to predict their fish production potential. Bott *et al.* (2006) studied primary productivity and chlorophyll-a concentrations in 8 reservoirs in New York City. Hargeby *et al.* (2006) reported primary production in two shallow lakes and estimated the total vegetation biomass and net primary production. Ayyappan and Gupta (1980) studied the primary productivity of Ramasmudra Tank situated in Karnataka. Pollingher and Berman (1991) have described that primary productivity in tropical lakes are higher than that of temperate lakes. Das (2000) studied nine reservoirs and three riverine systems of Andhra Pradesh to evaluate their productivity status through physico-chemical determinants and concluded that the nutrient status of waters under study was very poor. Shrivastava *et al.* (2002) studied primary productivity of Tawa reservoir near Hosangabad (Madhya Pradesh) and predicted that the present annual catch was only 33 per cent of the total potential fish yield which was estimated at 84 kg ha^{-1} y^{-1}. Sharma *et al.* (2007) observed primary productivity in relation to fisheries potential and fish landings of the reservoir Daya.

Singh (2003) studied the length-weight relationship of a Cyprinid, Osteobrama belangeri (Val.) and found the exponential value (b) of 2.970. Zacharia and Natarajan (2003) found significant differences in the length-weight relationship between sexes of threadfin bream, *Nemipterus mesoprion* from Mangalore Malpe. Annappaswamy (2004) studied the length-weight relationship of Indian sandwhiting *Silago sihama* in Mulky estuary, Mangalore and obtained the exponent value 'b' of 2.853 and 3.027 for male and female, respectively.

Das (2002) estimated the potential fish production of Yerrakalva, a peninsular reservoir of Andhra Pradesh and reported that large gap exists between fish yield potential and actual harvest.

Katiha *et al.* (2001) concluded the detailed investigations in Govind Sagar and pong reservoir of (Himachal Pradesh), towards their (i) existing level of fish population; (ii) carrying capacity of potential fish population; and (iii) maximum sustainable fish harvest and reported that the fish production potential for both the reservoirs was nearly three times the existing level, offering immense scope for enhancing fish production.

In Rajasthan, the estimation of fish production potential of different water bodies, their physico-chemical and primary productivity have been studied by several workers (Nayer, 1968, Vyas, 1968, Vyas and Kumar, 1968 and Durve, 1976; Rajkumar, 2005; Vijay Kumar, 2007 and Sarang, 2007).

Sultan *et al.* (2003) investigated a small reservoir, Pahunj located at Jhansi in Uttar Pradesh for its physico-chemical features and productivity status and concluded that higher primary productivity indicated congenial environment for biological production. Sengupta *et al.* (2004) used gross primary production for predicting the yield as stocked recovery.

Sharma and Durve (1985) studied the trophic status and fishery potential of various water bodies of Rajasthan and reported that the water bodies of Rajasthan are highly productive as compared to those located in other parts of India. Gupta *et al.*

(1991) studied the primary productivity of a shallow pond of southern Rajasthan and reported higher biological production. Kaushal and Sharma (2007) studied the limnological & production potential of Rajasthan waters and noticed that all the reservoirs of Eastern Rajasthan are very productivity.

As it is well known that quality of water body grossly determines the quality and quantity of aquatic biota. Therefore, this aspect has been studied extensively by Welch (1952), Hutchinson (1957), Needham and Needham (1962), Ruttner (1963), Edmondson (1965), Cole (1975) and Wetzel (1975). Edwards *et al.* (1956) and Murphy and Riley (1962) standardized the method for quantification of phosphorus in aquatic ecosystem. The phosphorus estimation in lake Gardsjon (Sweden) was made by Jansson *et al.* (1986).

In view of the complex nature of interactions between abiotic and biotic factors affects the multi use of water especially in respect of irrigation and fisheries in the aquatic ecosystem and a number of scientists were attracted to the study of limnology.

Balvay (1998) studied zooplankton in lake Geneva as the essential link in the trophic chain. Welseng *et al.* (2006) assessed major contribution from littoral crustaceans (zooplankton) species to the richness in lakes. Quin *et al.* (2006). studied the role of periphytic responses to the different trophic levels and their impact on macrophyte production in a shallow eutorphic lake Taihu, China. Celekli and Kulkoyluoglu (2006) reported net planktonic diatom (Bacillariophyceae) composition of lake Abant (Bolu).wherein reported a total of 123 diatom taxa. Park and Hyun (2007) studied phyto and zooplankton composition and its relation to fish productivity in a west coast fish pond ecosystem. Mathivanam *et al.* (2007) studied plankton population of Cauvery river with reference to pollution and reported the dominance of rotifers on other groups of organisms throughout the study period. Akinyemi and Nwankwoi (2007) studied the effects of seasons on water quality and phytoplankton of the Asejire reservoir in Nigeria. Further, they also observed the abundance of phytoplankton getting influenced by the changes in chemical characteristics of the water. Yinxi *et al.* (2007) studied the phytoplankton development trends in lake Euxian of China and found that both biomass and phytoplanktonic diversity were influenced by the concentrations of nitrate and phosphate. Shazia and Raja (2007) studied two freshwater bodies of Aligarh region to determine the zooplankton diversity.

Studies of plankton and productivity of Udaipur waters in comparison to the selected waters of Rajasthan have been carried out by Sharma (1980). Bhatnagar et al (2007) investigated the plankton and ichthyo-fauna in Jhamri Dam, Udaipur, Rajasthan. Jagetiya *et al.* (2007) conducted an experiment on phytoplankton diversity in Raithalias Dam, near Chandrabliaga river of Bhilwara, Rajasthan. Sharma *et al.* (2007) studied biodiversity of zooplankton in seven different water bodies of southern Rajasthan to find out species composition. Sarang *et al.* (2007) studied the effects of the warm water release to the Rana Pratap Sagar lake and its effect on water quality of the shoreline areas. Kumar *et al.* (2007) investigated planktonic diversity in the reservoir Daya, Udaipur. The study indicated that phytoplankton and zooplankton populations of Daya reservoir were represented by 28 and 20 genera, respectively, indicating a fairly good species diversity. Balai (2007) concluded that the density and quality of phytoplankton and zooplankton indicated the moderate productivity of the Jaisamand reservoir wherein phyto and zooplankton populations were represented by 68 and 44 genera respectively thereby showing a fairly good plankton diversity. Sarang (2007) reported good number of planktonic species in Kishore Sagar (34 nos.), Jawahar Sagar (29 nos.), Kota Barage (27 nos.), Jharjhani Pond (24 nos.), Deep Pura Pond (9 nos.) and Tamlao Pond (20 nos.).

Tarzwell (1957) gave water quality criteria for aquatic life. In south-east Asia. Holsinger (1955) studied the plankton of three Ceylon lakes whereas Roberts (1984) investigated factors controlling primary productivity in hypertrophic lake of south Africa. Correlation between physico-chemical factors and population density of cladocerans in the Tigris and Diyala rivers are reported by Mangalo and Manal (198 8) and dynamics of the zooplankton was studied by Margaritora *et al.* (1988). Plankton, primary productivity and some physico-chemical factors of lake were investigated by Barbieri *et al.* (1989). Such studies were also conducted by Estok and Milinki (1989) and Lampos *et al.* (1990). Effect of concentration of orthophosphate on growth of phytoplankton was reported by Adachi and Tadasi (1990).

Harwood and Kuhn (1970) and Keeney *et al.* (1970) estimated nitrogen and its different forms in various water bodies. Motomizu *et al.* (1986) have determined the nitrate in natural waters.

Gupta *et al.* (1988) reported seasonal variation and correlation of zooplankton with cultivable fishes of Sagar lake. Nakanishi *et al.* (1988) reported studies on some limnological variables in subtropical lakes. Moreover, limnological studies on

Yeshwant Sagar reservoir as regards assessment of its potential for fish culture has been studied by Sharma and Diwan (1989).

Physico-chemical parameters of different water bodies along with various planktonic resources were studied by several workers. Apart from the lakes, small reservoirs, farm ponds and tanks etc. were also studied for different physico-chemical and productivity aspects (Wallen, 1959, Murphy, 196 2, Timms, 1970, Kushlan and Hunt, 1979, Boyd, 1984 and Gupta, 1988).

Lampus *et al.* (1990) worked out the seasonal variations in the primary productivity, phytoplankton and zooplankton abundance in a smaller lake Todas Lossontos (Chile). AfanasEva and Ignatov (1992) determined the changes in zooplankton biomass in lake Baikal. Habib *et al.* (1997) investigated seasonal change in phytoplankton community structure in relation to physico-chemical factors in Loh Comond Scotland. Presing *et al.* (1999) reported nitrogen uptake by summer phytoplankton in lake Belaton.

Gannon and Stemberger (1978) and Papinska and Pijanowska (1980) studied lake biota and especially zooplankton. Nakanishi *et al.* (1988) reported some limnological variables in subtropical lakes whereas relation between zooplankton biomass and grazing were attempted by Lampert (1988). Pathak (197.9) reported water temperature from various reservoirs.

Balsare *et al.* (1992) worked out the numerical and volumetric variations in plankton populations of a polymictic tropical lake of Bhopal (Madhya Pradesh). The Physico-chernical parameters of Doon vally were studied by Rauthan *et al.* (1992).

Chakrabarty and Saha (1993) reported the physico-chemical and hydrobiological features of three stagnant water sources in Darjeeling hills. Whereas, Vaithiyanathan *et al.* (1993) conducted studies on phosphorus distribution in the sediments of the Hooghly estuary.

Vaishya and Adoni (1993) established the relationship between phytopankton, seasonality and physico-chemical properties in a hypereutrophic central Indian lake (Sagar lake). Kolekar *et al.* (1995) studied the plankton abundance of two different pond ecosystems near Guwahati (Assam).

Larson and Mark (1998) observed variability of seechi disc readings in an exceptionally deep Coldera lake. Dissolved oxygen and thermal regimes of a Ugandan crater lake were studied by Chapman *et al.* (1998). Elo *et al.* (1928) reported effect of climate change on the temperature conditions of lakes.

Seasonal variations of dissolved oxygen and deoxygenation in two tropical Australian reservoirs were investigated. by Simon (1999). Physico-chernical fluctuations of lake Tanganyika were studied by Plisnier *et al.* (1999).

Effect of temperature and other factors on phosphorus in the inner bay of Quinte lake, Ontario were investigated by Nicholls (1999). Brown *et al.* (1999) observed evaluation of surface sampling for estimating total phosphorus and total nitrogen concentration in shallow Florida lake.

Bharadwaj (1995) conducted study on certain hydrobiological aspects of two seasonal ponds of Udaipur (Rajasthan). Sharma *et al.* (1994) worked on limnology and prospects of fisheries development in five man-made lakes of Udaipur (Rajasthan).

Dwivedi *et al.* (2000) studied production dynamics and fisheries development in Naktara reservoir situated in Madhya Pradesh and reported that physico-chemical parameters (dissolved oxygen 7.04-12.00 ppm; bicarbonate alkalinity 24-28 ppm; pH 7,15-8.88; nitrate 0.18-0.29 ppm; phosphate 0.20-0.55 pm) and average plankton population which ranged from 86 μ^{-1} to 256 μ^{-1}, periphyton population 2413 to 2724 μcm^{-2} and average macro-benthic population from 396 μm^{-2} to 788 μm^{-2} indicating low to moderate productivity potential of the reservoir. Bandyopadhyay *et al.* (2002) also observed plankton pulses in late monsoon and spring season associated with nutrients. Average primary productivity of Pahunj reservoirs (125.6 mg C m^{-2} hr^{-1}) with two plankton pulses suggested that the water body holds high potential for fish production.

Singh (2003) recorded the length-weight relationship and condition factor of Osteobrama belangeri, cyprinid fish with restricted distribution in China, Myanmar and India (Manipur). The value of the exponent ‘b’ was higher in females (3.21) compared to that of males (2.44). Seasonal variations of the condition and relative condition factors were correlated with breeding cycle of the fish.

Samanta and Das (2002) concluded from their study that water movement made a profound impact on the stability and productivity of the ecosystem. Sultan *et al.* (2003) conducted experiment on hydro-biological parameters of the reservoirs and concluded that transparency of water varied from 18 to 85.5 cm.

Bhaumik et al (2003) investigated on Barnoo reservoir, Madhya Pradesh for augmenting fish production through stocking with carp seed. The study revealed that water and soil quality of the reservoir fluctuated with season and location. The requirements of fingerlings for enhancing fish production of the reservoir was estimated at 500 nos. and were stocked in the reservoir. In the fish catch composition, Indian major carps formed (50-60%), cat fishes (10-30%) and miscellaneous (2030%). It was emphasized that for reservoir fisheries development, adoption of scientific management techniques and provision of necessary infrastructure support are essential.

Sukumaran and Das (2001) studied the composition and distribution of Plankton of selected reservoirs in Karnataka during different seasons.

Shrivastava *et al.* (2003) carried out investigation on phytoplankton and primary production in Tawa reservoir. Both the gross and net productions were more in 1995-96 (1390 and 480) than 1996-97 (900 and 370 mg C m^{-3} d^{-1}); community respiration also varied greatly to the tune of 1092 and 636 mg C m^{-3} d^{-1} respectively. Based on primary production studies, the potential fish yield was estimated at 84 kg ha^{-1} y^{-1} which can be achieved through scientific management practices.

Sarang *et al.* (2002) observed impact of exotic fish *Oreochromis mossambicus* (Peters) on the ecosystem of Jaisamand lake, Udaipur, Rajasthan. Dasgupta *et al.* (2007) made on extensive survey of the fish fauna of the new alluvial zone of West Bengal. Gupta and Sharma (2007) conducted study on depthwise quantitative and qualitative zooplankton at two locations in a perennial water body situated at Amarchand, Udaipur, Rajasthan. Sharan *et al.* (2007) studied the hydrobiology of village pond in the desert region of Rajasthan with special reference to phytoplanktonic community and its relationship with the ionic regime. Prakash *et al.* (2007) reported that 51 species belonging to 33 genera, 17 families and 6 orders in the tributaries Kharun and Jonk of the Mahanadi river system.

Ansari and Raja (2007) studied two freshwater bodies of Aligarh region to determine the zooplankton diversity.

Paulose and Maheshwari (2007) studied the two contrasting aquatic ecosystems Jal Mahal and Ramgarh lake in Jaipur, Rajasthan, and reported that the plankton population in the two lakes showed marked variations in total density because of diverse hydrobiological conditions.

Kumar *et al.* (2007) observed biodiversity of fish fauna in the Dudhawa reservoirs. Kumar *et al.* (2007) investigated physico-chemical parameters at seasonal intervals from two different sites in sewage fed Telibandha pond of Raipur, Chhattisgarh.

Ujjania *et al.* (2007) studied three different water bodies namely Mahi Bajaj Sagar, Survania dam and Aasan pond located in Southern part of Rajasthan (Banswara district) and reported that all the three water bodies were highly productive. Kaushal and Sharma (2007) studied fish production levels and limnochemical features of four selected reservoirs, Mavshi and Guda in Tonk, Mansarovar in Sawai Madhopur and Silisher in Alwar district of the Rajasthan. Ramesh *et al.* (2007) studied the water quality of the Singanallur lake situated in Coimbatore district, and reported that the water was unsuitable for the survival of aquatic organisms. Chouhan and Sharma (2007) reported physico-chemical and biological status of a perennial and important lake the Budha Pushkar lake of Ajmer, Rajasthan. In this investigation pollution status was studied with special emphasis on physicochemical and biological parameters.

RaJkumar *et al.* (2007) investigated qualitative and quantitative zooplankton and phytoplanktonic resources of Daya reservoir, Udaipur, Rajasthan. Jagetiya *et al.* (2007) conducted an experiment on phytoplankton diversity in Raithalias Dam, near Chandrabhaga river of Bhilwara, Rajasthan.

Singh *et al.* (2007) studied the physico-chemical and biological parameters of the Hathaikheda reservoir, and reported that the reservoir constantly received pollutants from its catchment area and faced degradation. Vijayvergia (2007) studied composition and periodicity of cyanophyceae in eutrophic lake Udai Sagar, Udaipur, Rajasthan. Lubana *et al.* (2007) investigated a fresh water reservoir created in 1994 in the Indian Desert for its physico-chemical limnology and planktonic components.

3. MATERIALS AND METHODS

The present study was carried out during Sept. 2008 to Sept. 2009 with a view to investigate the fish diversity and biology of two Indian major carps of Udaisagar reservoir with reference to limnology and productivity. For this purpose, laboratory studies were conducted in the College of Fisheries, Udaipur while field studies were conducted at Udaisagar reservoir.

A. CLIMATE OF SOUTHERN RAJASTHAN:

This zone experience a subtropical climate with the average rainfall ranging from 76-89 cm and relative humidity of 75-95 per cent during the monsoon period. The summers are hot and winters are cool having an average range of maximum temperature between 38-41°C and minimum between 1-5°C. The elevation of study zone is 598 m above mean sea level.

B. STUDY AREA:

The Udaisagar reservoir, under investigation is situated 18 km away from Udaipur (Rajasthan) near the village Bichari. This reservoir originates from Berach river near the village Bichari. River Berach covering a distance of 3 km from Hindustan Zinc Colony, Debari, Udaipur. The catchment area of Udaisagar reservoir is semi-hilly and rocky.

C. MORPHOLOGY OF UDAISAGAR RESERVOIR:

The details of morphometric features of Udaisagar reservoir are given in Table 3.1 and Fig.3.1. The reservoir has water spread area of 4.75 km^2. The maximum depth being 15 meters.

D. SAMPLING STATIONS:

In the present investigation, three sampling stations were selected in reservoir (Fig 3.1) All the three sampling stations namely A, B and C were selected for surface water analysis. These sampling stations were selected on the basis of reservoir topography. Station A was located just opposite side of the entry point of the river water into reservoir. Station B was located at the dam site of Udaisagar reservoir. Sampling stations C was fixed at the north- Eastern shore of the reservoir.

Table 3.1: Morphometric features of Udaisagar reservoir

1.	Location	
	Longitude	73°47'0" E
	Latitude	24°33'0" N
2.	Average rainfall	625 mm
3.	Maximum depth (Zm)	15 m
4.	Maximum length (L)	3.75 km
5.	Maximum width (bx)	2.40 km
6.	Water spread area	4.75 sq.km
7.	Catchment area	76 sq.miles
8.	Live storage capacity	975 Mc Ft
9.	Type of dam	Both side face wall with earthen dam
10.	Tehsil	Girwa
11.	Accesses	3 km from Hindustan Zinc Colony, Debari
12.	Year of construction	1565

Source: Irrigation Department, Udaipur (Rajasthan)

E. SAMPLE COLLECTION:

During the study period, surface water samples from all the three selected sampling stations were collected using a plastic bucket.

F. ANALYTICAL TECHNIQUES:

1. Water Quality Analysis:

Water quality parameters such as temperature of water and air, depth of visibility, pH, alkalinity (carbonates and biocarbonates), dissolved oxygen, free carbon dioxide, electrical conductivity (EC) and primary productivity were determined in the field itself, while for the analysis of nitrate-nitrogen and orthophosphate the samples were brought to the laboratory in plastic bottles of one litre capacity and analyzed as soon as possible using standard methods of APHA (1989). The methods employed for specific parameters are described below:

Physico-chemical parameters:

(i) Air and water temperature:

A centigrade thermometer of 0 to 50°C range and graduated to 0.1°C was used to measure air and water temperature. Air temperature around the sampling station was measured in shade. The water temperature was observed by immersing the thermometer in water samples immediately after collection.

(ii) Depth of visibility:

The transparency of water was determined using a standard Secchi disc of 20 cm diameter. Two readings, one for disappearance and other for reappearance were recorded and then the depth of visibility was calculated as under:

$$Depth\ of\ visibility = \frac{D_1 + D_2}{2}$$

Where,

D_1 = Depth of disappearance in cm

D_2 = Depth of reappearance in cm

(iii) Hydrogen ion concentration (pH):

The pH of water sample was measured using electronic digital pH meter.

(iv) Electrical conductivity (EC):

Electrical conductivity was measured with the help of a pen type electronic conductivity meter and results were expressed as mS/cm.

(v) Total dissolved solids (TDS):

For the estimation of total dissolved solids in every sample, a factor value of 640 is multiplied with the respective value of EC.

(vi) Dissolved oxygen:

The concentration of dissolved oxygen in water was estimated following the modified Winkler's method (Ellis *et al.*, 1949).

In this procedure, oxygen combines with manganous hydroxide to form higher hydroxides which on acidification liberate iodine equivalent to that of oxygen fixed. This iodine is titrated with standard sodium thiosulphide solution using starch as an indicator. Following steps were adopted for oxygen estimation:

(1) Water sample was collected in 250 ml glass bottle without bubbling.

(2) Two ml of each manganous sulphate (Winkler A) and alkaline-iodine solutions (Winkler B) were dispensed one after the other right at the bottom of the bottle with separate pipettes. Then stopper was replaced.

(3) The bottle was shaken upside down at least 6 times and allowed the brown precipitate to settle.

(4) The precipitates were dissolved by adding two ml of concentrated sulphuric acid and the stoppered bottle was again shaken.

(5) 50 ml of aliquot was taken in a flask and then titrated with sodium thiosulphate (0.025 N) till the colour change to pale straw.

(6) After that, two drops of starch indicator were added and titrated further till the blue colour disappeared for the first time.

(7) The total amount of titrant used were noted and then dissolved oxygen content was calculated using following formula:

$$Dissolved\ oxygen\ (mg\ l^{-1}) = \left[\frac{8\ x\ 1000\ x\ N}{V_1}\right]\ x\ V_2$$

Where,

N = Normality of the titrant (0.025 N)

V_1 = Volume of sample (ml)

V_2 = Volume of titrant used (ml)

(vii) Free carbon dioxide:

For the estimation of free CO_2, 100 ml of water sample was taken in a conical flask and a few drops of phenolphthalein indicator were added. In case the colour turned pink, free CO_2 was taken as absent. If sample remained colourless, the same was titrated against NaOH (0.05N) till the appearance of pink colour and free carbon dioxide was calculated using following formula:

$$Free\ CO_2\ (mg\ l^{-1}) = \frac{ml\ of\ NaOH\ x\ N\ x\ 1000\ x\ 44}{ml\ of\ sample}$$

Where,

N = Normality of the titrant NaOH (0.05N)

(viii) Alkalinity:

For determining carbonate alkalinity, 100 ml of water sample was taken in a conical flask and a few drops of phenolphthalein indicator were added. If sample remained colourless, then carbonate alkalinity was taken as absent and if pink colour developed then water sample was titrated to a colourless end point using 0.01 N HCl. The same water sample, after determining carbonate alkalinity, was used for the estimation of bicarbonate alkalinity by continuation of the titration with methyl orange as indicator. Calculation was performed using following formulae:

(i) Carbonate alkalinity (mg l^{-1}) = $\frac{A \times N \times 1000 \times 50}{\text{ml of sample}}$

(ii) Biarbonate alkalinity (mg l^{-1}) = $\frac{B \times N \times 1000 \times 50}{\text{ml of sample}}$

(iii) Total ankalinity (mg l^{-1}) = Carbonate alkalinity + Bicarbonate alkalinity

Where,

A = ml of HCl used only with phenolphthalein
B = ml of HCl used only with methyl orange
N = Normality of HCl

(ix) Orthophosphate:

This was measured following the stannous chloride method of APHA (1989). Orthophosphate (PO_4-P) in an acidic ammonium molybdate solution produces blue colour when stannous chloride is added. This colour is measured with spectrophotometer at 690 nm. The estimation was made using following procedure:

(i) 50 ml of water sample was taken in a Erlenmeyer flask. Distilled water blank was also prepared simultaneously.

(ii) 2 ml of ammonium molybdate solution and 0.25 ml (5-6 drops) of stannous chloride solution were added.

(iii) Blue colour appeared gradually.

(iv) After 10 minutes, colour (Blue) intensity was estimated at 690 nm using spectrophotometer.

(v) Concentration Of HP04'was 'calculated with the help of *standard curve and orthophosphate was expressed as PO_4 – P in mgl^{-1}.

(x) Nitrate-nitrogen:

This was analysed using phenol disulphonic acid (PDA) method. For this purpose, 50 ml of filtered sample was taken in a conical flask. To remove the interferences of chlorides, 5 ml silver sulphate solution was added. This was heated slightly and the precipitate obtained was removed by filtration. The filterate was evaporated in a porcelein dish to dryness. The residue was cooled and dissolved in 2 ml phenoldisulphonic acid. The content was diluted to 50 ml with double distilled water. To this, 6 ml of liquid ammonia was added for developing yellow colour.

The yellow colour developed due to presence of nitrate, was measured using a Systronics 108 UV spectrophotometer at 410 nm. Using standard nitrate solution, a standard curve was plotted to estimate the amount of nitrate in the sample which was expressed as NO_3 - N in mg l^{-1}.

(xi) Primary Productivity:

Primary productivity was measured at all the stations following light and dark bottles method. For this purpose, glass stoppered black and white BOD bottles of 250 ml were used. In case of surface water samples, the bottles were suspended about 15 cm below the water line. The incubation period was kept three hours. Oxygen (O_2) estimation in the BOD bottles were made following usual Winkler's method. The calculation was done as under:

(i) Gross Oxygen Production (GOP) mg l^{-1} LB – DB

(ii) Net Oxygen Production (NOP) mg l^{-1} LB – IB

(iii) Community Respiration (CR) mg l^{-1} IB – DB

The values of gross and net primary productivity were calculated as follows:

(i) Gross Primary Productivity (g C m^{-3} h^{-1}) $= \dfrac{GOP}{1.2 \times h} \times 0.375$

(ii) Net Primary productivity (g C m^{-3} h^{-1}) $= \dfrac{NOP}{1.2 \times h} \times 0.375$

Where,

LB = Dissolved oxygen in light bottle
DB = Dissolved oxygen in dark bottle
IB = Dissolved oxygen in initial bottle
h = Duration of incubation or exposure
1.2 = A constant
0.375 = A factor value (I g of oxygen is equal to 0.375 g carbon)

Plankton Analysis:

The phytoplankton and zooplankton samples were collected alongwith the sampling of water. For the sample collection, an appropriate quantity of water sample (i.e. 50 litres from surface and 5 litres from bottom) was filtered through bolting silk No.16 and plankton (both phytoplankton and zooplankton) thus obtained were preserved in 4% neutralized formaline.

For quantitative analysis of plankton, one ml subsample was taken in Sedgwick Rafter Cell with the help of plankton pipette and counted under CZ inverted microscope. The total number of plankton counted in each sub-sample were multiplied with dilution factor and results were expressed as No. l^{-1} and Cell ml^{-1} respectively for zooplankton and phytoplankton (APHA, 1989).

The qualitative analysis of phytoplankton and zooplankton was done following the standard methods of Edmondson (1965) and Needham and Needham (1978). The identification of phytoplankton was restricted only upto major groups *viz.* cynophyceae, chlorophyceae, bacillariophyceae and desmidiaceae. Similarly, the zooplankton were also identified upto major groups such as cladocerans, rotifers and copepods.

Study of Fish Biodiversity:

The study was carried out during Sept. 2008 to Sept. 2009 As far as possible, fishes were identified in the field itself using standard manuals (Day, 1994; Talwar and Jhingran, 1991). Species that could not be identified in the field were preserved in 5 per cent formalin and brought to the laboratory for identification.

Fishery Biological Study:

In order to study the biology of two commercially important species, samples of fishes namely *Catla catla* and *Labeo rohita* were collected from the commercial catches during fishing year 2008 at landing centre of Udaisagar reservoir.

A. Length-weight relationship:

About 500 specimens, each of *Catla catla* and *Labeo rohita*, were collected during the fishing year 2008 from Udaisagar reservoir for the length-weight relationship. The total length and weight of fish samples were measured in centimetre and gram, respectively. The samples collected for both the species (*Catla catla* and *Labeo rohita*) were divided into four length groups i.e. 40.0-50.0, 50.0-60.0, 60.0-70.0 and 70.0-80.0 cm and named as A, B, C and D, respectively. After grouping, the relationship (correlation and regression) between body weight and total body length for each group was calculated using following formula of Le Cren (1951):

$$W = aL^n$$

Where,

W	=	Weight of the fish in g
L	=	Total length in cm
a & n	=	Constants

B. Condition factor or ponderal index (K):

The condition factor or ponderal index (K) was determined using length and weight data of fish samples. The condition factor was calculated as per the standard method of Le Cren (1951).

$$K = \frac{W \times 100}{L^3}$$

Where,

W	=	Observed weight of fish in g
L	=	Total length of fish in cm

STATISTICAL ANALYSIS:

The data collected during the present investigation were processed for statistical analysis. The analysis of correlation coefficient and regression was done as per the method described by Snedecor and Cochran (1981). The length-weight relationship was established using the linear equation of the form Log W = Log a + b Log L.

4. EXPERIMENTAL RESULTS

Fish Biodiversity:

The fish faunal varieties found in the present investigation have been depicted in Table 4.1. This table clearly indicates that total 31 fish species belonging to 9 families could be located from the Udaisagar reservoir. Thus fish faunal structure appears fairly rich.

Out of the recorded 31 fish species, only 12 species *viz.*, *Catia catta, Labeo rohita Cirrhinus mrigala, Labeo gonius, Labeo calbasu, Ctenopharyngodon idella, Hypophthalmichthys molitrix, Puntius sarana, Puntius sophore, Amblypharyngodon mola, Heteropneustes fossilis, Wallago attu*, *Mystus seenghala* and *Mastacembelus armatus* contributed to the commercial catch of this reservoir (Plates 1 to 12). Indian major carps have dominated the fishery of the reservoir followed by the minor carps and catfishes (Table 4.2). In general, the Indian major carps appear to contribute around 90 per cent to the total landings of the Udaisagar reservoir. While the per cent contributions of minor carps and catfishes in the total catch were only 8.84 and 0.9, respectively. Amongst the Indian major carps, *Catla catla* dominated by (70 %) followed by *Labeo rohita* (25%) and *Cirrhinus mrigala* (5%).

Further, in the case of minor carps, *Labeo gonius* dominated with a contribution of 63% followed by *Puntius* species *viz.*, *P. sarana*, *P. sophore* (26%). Other varieties especially *Labeo calbasu* formed 11% of the total minor carp catch. The catfishes have also made a smaller contribution to the landings of the Udaisagar reservoir, the highest catfish landing being of *Wallago attu* (65%) followed by *Mystus seenghala* (15%) and others i.e., *Mystus aor*, lesser silurids and bagrids. The live fish varieties are represented by *H. fossilis* and three species of *Channa*. The former, however, has been included in the air-breathing fish .

Biological Studies:

Biological studies in fishes encompass a fairly wider aspects of fish body functions and in a research, it is impossible to touch all aspects in details. As such, only the following aspects of the fish biology in the I.M.C. *Catla catla* and *Labeo rohita* have been dealt with below:

(A) Length-weight relationship

(B) Condition factor or ponderal index

For the purpose, the fishes selected for the study were grouped into 4 length groups

i.e., A-40.0 to 50.0 cm, B-50.0 to 60.0 cm, C-60.0 to 70.0 cm and D-70.0 to 80.0 cm as also described in the Chapter-3 (Materials and Methods).

It would be seen from Table 4.3 and Fig.4.1 that *Catla catla* from Udaisagar reservoir was primarily dominated by C length-group (50.46%) while the other length group *viz.*, D, A and B followed in the same sequential order, with percentage of 36.4%, 7.2% and 6.0% respectively.

In the case of *Labeo rohita*, the picture was more or less similar to that of *Catla catla* with C length-group dominating the scene (45%) followed by D (32.0%), B (20.0%) and A (3.0%) as shown in the Table 4.4 and Fig.4.1.

The statistical relationships of body-weight with total body-length in the case of *Catla catla* were highly significant as seen by significant correlation coefficients (r value) indicated in the Table 4.3 for all the length groups. It may be noted here that the highest 'r' value (0.775) was in C length-group followed by length-groups D (0.741), A (0.648) and B (0.557).

Table 4.3 also depicts that *Catla catla* deviated from Cube law at all the length groups. The exponent 'n' values for body-weight and total body-length ranged between 0.138 and 0.280. The above highest and lowest values of 'n' were observed in length groups D and B, respectively. For other length-groups i.e. A and C, the exponent values were 0.197 and 0.228, respectively.

The values of 'a' constant for different length-groups ranged between -3.810 and -14.741 (Table 4.3) This value was the highest in the length-group D (-14.741) followed by length-group C (-10.137), A (-7.271) and B (-3.810). Fig-4.2 shows the graphical representation of relationship between log of total body-weight with log of total body length.

The statistical relationships of body-weight with total body-length of *Labeo rohita* were calculated for different length-groups. A highly significant correlation was observed between body-weight and total body-length for all the length-groups (Table 4.4). The highest 'r' value (0.788) was in 'A' length group followed by D (0.665), C (0.513) and B (0.394) length groups.

The exponent 'n' values for body-weight and total body-length ranged between 0.104 and 0.262. These values show the deviation of *Labeo rohita* in its growth from the Cube law. The highest and lowest exponent values (0.262 and 0.104) were observed in length-groups D and B respectively. On the other hand, for other length-groups *viz.*, A and C, it was 0.147 and 0.113 respectively.

The values of ‘a’ constant was found highest in length-group D (-14.273) followed by length groups A (-5.198), C (-3.701) and B (-2.970). The relationship between log of body weight and log of body length is given in the Fig. 4.3.

(B) Condition factor/Ponderal index (K):

The mean values of condition factor (K) for all the length-groups of *Catla catla and Labeo rohita* are shown in Table 4.5. The ‘K’ values of *Catla catla* ranged between 1.484 and 2.278. The highest being recorded from the length-group B. The highest ‘K’ value of B group was subsequently followed by those of A, C and D groups in the order of 1.917, 1.705 and 1.484 respectively.

The values of condition factor for the different length-groups of *Labeo rohita* ranged between 1.273 and 1.637 the highest values being of 1.637 from the length-group B. In the case of length groups A, C and D, the values of K were 1.575, 1.320 and 1.273 respectively.

Primary Productivity:

The results pertaining to gross and net primary productivities of Udaisagar reservoir during the study period (2008-09) are presented in Tables 4.6 to 4.8 and Fig.. . . In general, the gross primary productivity (GPP) at Station A, B and C ranged from 0.20-0.70, 0.30-0.70 and 0.20-0.70 g C m^{-3} h^{-1}. Further, mean value of GPP in surface water was 0.48 g C m^{-3} h^{-1} (Table 4.13). The statistical relationship of gross primary productivity with water temperatures, pH, depth of visibility, bi-carbonate alkalinity and total alkalinity, NPP, total phytoplankton and total zooplankton was found to be significantly positive. However, in the case of air temperature, dissolved solids, orthophosphate and CR had a negative significant relationship (Table 4.14).

The respective values of net primary productivity (NPP) at stations A, B and C ranged from 0.15-0.65, 0.20-0.55 and 0.15-0.55 g C m^{-3} h^{-1}. The average values of NPP was 0.35 g C m^{-3} h^{-1} (Tables 4.14).

Statistical relationship of net primary productivity with water temperature, pH, depth of visibility, bicarbonate alkalinity, total alkalinity, EC, nitrate-nitrogen and TZP was found to be significantly positive. However, in the case of air temperature, dissolved oxygen and orthophosphate had a negative significant relationship (Table…).

From the Table 4.13, it would be seen that the community respiration (CR) values at three surface sampling stations ranged from 0.03 - 0.24 g C m^{-3} h^{-1} with a mean value of 0.12. The statistical relation of CR with air temperature, water temperature, pH and dissolved oxygen found to be significantly positive. However, in the case of depth of visibility, carbonate alkalinity, bicarbonate alkalinity, EC, TDS, NO_3-N and NPP had a negative significant relationship (Table 4.14).

Physico-chemical Parameters:

The fortnightly fluctuation in selected water quality parameters of Udaisagar reservoir are presented in Tables 4.6 to 4.12 and Figs 4.4 to 4.8. Seasonal impact on water quality of this reservoir is clearly evident from the results of this study.

(i) Air and water temperature:

The seasonal variations in air and water temperature are depicted in Table 4.13. From this table (4.13), it is evident that the highest air temperature (37.33°C) was during June and lowest (22.4°C) in Jan. with a mean of 30.38°C. The surface water temperature fluctuated between 19.70 and 31.00°C (Table 4.13), whereas with mean value of water temperature was 26.14°C.

The correlation of air and water temperatures with other water quality parameters are shown in Tables 4.14. The statistical analysis indicates that during the study period, surface water temperature had positive significant relationship with air temperature, pH, dissolved oxygen, carbonate alkalinity CR and negative significant relationship with depth of visibility, total alkalinity, EC, TDS, NO_3-N, orthophosphate, GPP, NPP and TZP.

(ii) Hydrogen ion concentration (pH):

In general, the water of Udaisagar reservoir remained alkaline throughout the study period. The values of pH oscillated from 8.0 to 8.8, 7.8 to 9.1 and 7.9 to 9.0 at Three stations *viz.* A, B and C, respectively. Further, the respective mean values of pH at stations A, B and C were 8.37, 8.27 and 8.38 (Tables 4.6 to 4.8).

The statistical results shows that pH had positive significant relationship with air and water temperature, dissolved oxygen, carbonate alkalinity and CR and negative significant relationship with depth of visibility, bicarbonate alkalinity, total alkalinity, EC, TDS and orthophosphate content (Tables 4.14).

(iii) Depth of visibility:

The values of depth of visibility also referred to as transparency at station A, B and C fluctuated between 30 to 100, 5 to 92 and 15 to 105, respectively. The mean value of the depth of visibility was highest at station A and lowest at station B. The data on depth of visibility clearly show the seasonal impact as it was highest during summer and lowest during winter. This aspect is discussed in details in the chapter-5 (Discussion). The statistical results show that during the study period, the depth of visibility had a positive significant relationship with carbonate, bicarbonate and total alkalinity, EC, TDS, NO^3-N, HP^o4, GPP, NPP and TPP had a negative significant relationship with both air and water temperature, PH, CR and TZP.

(iv) Dissolved oxygen (DO):

During study period, the concentration of dissolved oxygen, in surface water of Udaisagar reservoir, ranged from 6.8 to 8.8, 7.2 to 9.2 and 6.8 to 8.8 mg l^{-1} at stations A, B and C, respectively. The mean values of DO in surface water was 7.95 mgl^{-1}. Statistical relationship of DO with selected water quality parameters is shown in (Tables 4.14). From this table, it is apparent that the DO had positive significant relationship with air and water temperature, pH, carbonate alkalinity, CR and TZP and negative significant relationship with depth of visibility, bicarbonate alkalinity, total alkalinity, EC, TDS, NO_3-N, GPP, NPP and total phytoplankton.

(v) Free carbon dioxide (Free CO_2):

Over the study period, the free CO_2 as conspicuous by its absence on all three sampling stations.

(vi) Carbonate alkalinity:

The values of carbonate alkalinity ranged from 38 to 70, 40 to 70 and 44 to 70 mg l^{-1} in surface water of station A, B and C, respectively. The mean value of carbonate alkalinity on surface water was 58.52 mg l^{-1} (Table 4.6 to 4.8).

The statistical treatment of carbonate alkalinity had a positive significant correlation with air and water temperature, pH, depth of visibility, dissolved oxygen, Orthophosphate and negative significant correlation with bicarbonate, total alkalinity, EC, TDS, GPP, NPP, TPP and TZP.

(vii) Bicarbonate alkalinity:

The values of bicarbonate alkalinity ranged from 98 to 244, 120 to 258 and 190 to 280 mg 1^{-1} in surface water of stations A, B and C, respectively. The mean value of bicarbonate alkalinity in surface water was 221.25 mg l^{-1} (Table 4.13).

The statistical treatment of bicarbonate alkalinity is shown in Table 4.14 In surface water, the bicarbonate alkalinity had a positive significant correlation with depth of visibility, total alkalinity, EC, TDS, NO_3-N, orthophosphate, GPP, NPP and TPP and significant negative correlation with air and water temperature, pH, dissolved oxygen, carbonate alkalinity, CR and total zooplankton.

(viii) Total alkalinity:

The values of total alkalinity ranged from 248 to 310, 180 to 314 and 222 to 326 mg l^{-1} on surface water of station A, B and C, respectively (Table 4.6 to 4.8). The mean value of total alkalinity on surface water was 381.55 mgl^{-1} (Tables 4.6 to 4.8).

The statistical treatment of total alkalinity is shown in Table 4.14. In surface water, the total alkalinity had a positive significant correlation with depth of visibility, bicarbonate alkalinity, EC, TDS and negative significant correlation with air and water temperature, pH, dissolved oxygen, carbonate alkalinity and CR.

(ix) Electrical conductance (EC):

In the case of surface water, the value of EC fluctuated from 0.20 to 0.36, 0.14 to 0.34 and 0.19 to 0.35 m S cm^{-1} at station A, B and station C respectively (Tables 4.6 to 4.8). The mean value of EC was 0.25 m S cm^{-1} in (Table 4.13).

The statistical relationships of EC with selected water quality parameters is shown in (Table 4.14). Table indicates a positive significant correlation with depth of visibility, carbonate & bicarbonate alkalinity, total alkalinity, TDS, NO_3-N, orthophosphate, GPP and a negative significant relationship with air and water temperature, pH and dissolved oxygen.

(x) Total dissolved solids (TDS):

Values of TDS fluctuated from 128.00 to 230.40, 89.60 to 211.20 and 121.60 to 224.00 mg l^{-1} in surface waters at all the three stations in a respective order. (Table 4.6 to 4.8). The mean value of TDS was 165.27 mg l^{-1} (Table 4.13).

The statistical relationship of TDS with selected water quality parameters is presented in Table 4.14. The TDS exhibited a positive significant, relationship with depth of visibility, carbonate, bicarbonate & total alkalinity, EC, NO_3-N, orthophosphate and GPP. and a negative significant relationship with air and water temperature, pH and dissolved oxygen.

(xi) Nitrate -Nitrogen (NO_3 - N):

The nitrate-nitrogen in surface water of Udaisagar reservoir ranged from 0.05 to 0.36, 0.05 to 0.33 and 0.05 to 0.20 mgl^{-1} at stations A, B and C, respectively (Tables 4.6 to 4.8). The mean value of nitrate - nitrogen in surface water was 0.15 mg l^{-1}. Table 4.13 shows that in the surface water, nitrate-nitrogen had a positive significant relationship with only NPP and TZP.

(xii) Orthophosphate (HPO_4-P):

In the surface water of the reservoir ,the orthophosphate ranged from 0.29 to 0.71, 0.31 to 0.78 and 0.26 to 0.70 mgl^{-1} at the three stations *viz.*, A, B and C respectively.(Tables 4.6 to 4.8). The mean value of orthophosphate in surface water was 0.57 mg l^{-1}.

Statistically, the levels of orthophosphate in surface waters had a positive significant relationship with depth of visibility, dissolved oxygen, carbonate alkalinity, bicarbonate alkalinity, total alkalinity, EC, TDS. However, a significantly negative relationship was shown with air and water temperature, pH, NO_3-N, GPP, NPP, CR and total phytoplankton.

Plankton Biodiversity:

(i) Phytoplankton:

The algal flora of the Udaisagar reservoir was contributed by the four major groups *viz.*, cyanophyceae, chlorophyceae, bacillariophyceae and desmidiaceae and 35 genera were recorded during the present study (Table 4.9). Out of the total 35 genera, 11 were from chlorophyceae, 9 from bacillariophyceae, 12 from cyanophyceae and 3 belonged to desimidiaceae. The station wise distribution of the planktonic, assemblages showed the dominance of phytoplankton over the zooplankton population. The mean phytoplankton density was 408.68 Cell ml^{-1}. In the case of surface water, number of phytoplankton ranged from 266.33 to 599.35 Cell ml^{-1}.

Out of the 4 major groups of phytoplankton stated earlier, the cyanophyceae and bacillariophyceae were dominant, followed by chlorophyceae and desimidiaceae (Fig 4.11).

The surface water density of phytoplankton exhibited a positive significant relationship with pH, depth of visibility, bicarbonate alkalinity, total alkalinity, NO_3-N, GPP, NPP and CR. However, a negative significant relationship with air and water temperature, dissolved oxygen, carbonate alkalinity, EC, TDS, orthophosphate and total zooplankton. It is further seen that there were considerable variations in the density of individual group as well as total phytoplankton population. A closer look into the Tables 4.10a to 4.12b indicate the absence of any regularity or rhythmicity in the density occurrence of the total phytoplankton. However, in general, phytoplankton exhibited higher incidence during summer and post-monsoon months than in winter (Fig.4.10).

Zooplankton:

Among the zooplankton, total 34 genera belonging to three major groups i.e. rotifera, cladocera and copepoda, were recorded during study period in Udaisagar reservoir. These genera are enumerated in the Table 4.9. Out of these 34 genera, 18 were from rotifera, 9 from cladocera and 7 belonged to copepoda group. The mean value of zooplankton was 46.23 No. l^{-1}. The population of zooplankton ranged from 29.66 to 73.66 No. l^{-1} in surface water.

At the surface waters of stations A, B and C, the zooplanktonic population was dominated by rotifers cladocerans (Fig 4.12).

In the case of surface waters, zooplankton had positive significant relationship with water temperature, pH, dissolved oxygen, total alkalinity, NO_3-N, orthophosphate, GPP, NPP and total phytoplankton contrary to negative significant relationship with air temperature, depth of visibility, carbonate and bicarbonate alkalinity, EC, TDS and CR.

FISH AND FISHERIES:

The Udaisagar reservoir has supported a sizeable fishery in spite of indiscriminate exploitation without observing any fisheries regulating measures like mesh-size restriction and fish seed stocking. The details of fishery of the reservoir, as already discussed in earlier pages, is given in Table 4.2.

Fish fauna: The reservoir has a rich fish fauna and so far 31 species representing the important genera have been recorded (Table 4.1). Out of these, 12 species contribute to the commercial fisheries of this reservoir.

Catch and statistics: No systematic data are available on catch statistics for the earlier years. Since late eighties, major carps have dominated the fishery followed by catfishes and minor carps. In general, the major carps contributed around 90.00 per cent to the total landings from this reservoir.

Fishing Gears: The gears used in this reservoir are mainly of two types *viz.*, surface gill net and purse seine (locally called fesi). The gillnets of nylon twine are about 20 meters long and 2.5 meters wide varying in mesh-size from 4 to 9 cm bar; the majority being 6-7 cm. The tarred purse seine are of 200-300 meters long with a central bag. Gill nets are set in the evening and taken out in the next morning, while the purse seine hauls start early morning averaging about 4 hauls per 8 hours per day.

Fishermen: The skilled fishermen engaged in fishing from the Udaisagar reservoir hail from Orrisa and Bihar and are employed by the contractor as per need. About 20 fishermen normally fish in the reservoir every year. The fishermen parties operate their nets from the boats supplied by the contractor.

Fish Trade: The fishing parties land their catches which are weighed at a fixed landing site. The fishes are categorized and packed in plastic crates (Capacity 50 kg) with ice. The packed fishes are sent to Ahamdabad and Delhi by contractor. A small part of the catch is marketed in the fish market of Udaipur.

Seed stocking: In view of poor auto-stocking, this reservoir is stocked with 40-80 mm sized fingerlings of IMC @ 700/ha/year since 2002 AD by the contractor.

Fish catch: As per the record available with contractor, total fish production of 2008-09 was 90,000 kg.

Water holding capacity:

Table 4.15 shows the minimum and maximum levels of gauge and -water holding capacity of Udaisagar reservoir during different years. It would be observed from Table 4.15 that when gauge was at zero level (June, 2005), the water holding capacity of Udaisagar reservoir was Zero million cubic feet (MCFT) and when the gauge was at 24. (September, 2006), water holding capacity was 1100 MCFT.

5. DISCUSSION

Water quality (physico-chemical and biological) characteristics of open waters are environmental conditions, human activities, land use in catchment etc. A quantitative assessment of these factors in the form of nutrient budget, hydrological profile etc., are essential for effective conservation of aquatic biodiversity. Aquatic systems need to be monitored in time series so as to keep a track on the changing face of biodiversity with increased human pressure.

Water quality plays several role in the ecological relation of the fauna and flora. The physico-chemical conditions of the water as a substance and its mechanical action as a medium have their own importance for the living complex. Reid (1961) pointed out that whole of the aquatic life in the river, tank, pond and reservoir is governed by the interaction of a number of physical and chemical conditions. Results of present study (Tables 4.6 to 4.8 and Figs.4.4 to 4.10), is vividly indicate water quality status in relation to fish production of Udaisagar reservoir with particular reference to planktonic and fish biodiversity.

Physio-chemical parameters of Udaisagar reservoir were found to be congenial for fishery development throughout the study period. The relationship between air and water temperature was clearly seen in the present study where a positive significant relationship was established between air and water temperature. Shekhawat (1991) reported close association of air and water temperature in the small sized water body. Similar relationship was reported by Ganapati (1962), Verma (1967), Gupta (1991), Solomon (1994), Sharma and Gupta (1994) and Sarang (2001). However, Michael (1964) and Timms (1970) did not find such a relationship between air and water temperature. The statistical analysis indicates that during the study period, water temperature had positive significant relationship with air temperature, pH, dissolved oxygen, carbonate alkalinity and CR and negative significant relationship with depth of visibility, total alkalinity, EC, TDS, NO_3-N, orthophosphate, GPP, NPP and TZP. Similar results were also reported by Rajkumar (2005) and Vijay Kumar (2007).

During present study air and water temperature were high in summer and low in winter. Moreover, air temperature remained higher than the water temperature in all the seasons. The air temperature ranged between 22.4 to 37.33°C at all the three stations. Similar range of temperature was also recorded by Saran (2000), Sisodiya (2002), Rajkumar (2005) and Vijay Kumar (2007) in different water bodies of arid and semi-arid regions of Rajasthan. In Indian sub-continent temperature in most of the water bodies, ranges between 7.8°C to 38.5°C (Quadri and Yousuf, 1980 and Yalavarthi, 2002). In the typical setting of arid and semi-arid regions, water temperature showed a wide annual fluctuation at all the study sites, this wide range of variations fall in the line of investigations conducted by Bohra (1976), Vyas and Nama (1991) and Rawat (2002). At all the three stations of Udaisagar reservoir, water temperature showed maximum and minimum values in summer and winter, respectively. Similar findings were also reported by Kolekar (2006), Negi *et al.* (2006), Rathore *et al.* (2006) and Upadhyay and Dwivedi (2006).

pH is an important factor of freshwater bodies. Factors like, exposure to air, temperature and disposal of industrial wastes etc. bring about changes in pH. In the present study, the average pH ranged from 8.33 to 8.63 at all the three stations. Further, pH showed slightly lower values during summer and higher values during winter. The annual variations in pH were not large during the study period.

The pH range of 6-9 has been considered as the most suitable for fish culture while pH above 9 is unsuitable (Ellis *et al.*, 1948, Swingle, 1967). According to Jhingran (1977) pH range from 7 to 9 is considered good for fish culture. Thus, the present study indicate that the Udaisagar reservoir having pH from 8.33 to 8.63 offer congenial environment for fish culture. pH of Udaisagar reservoir was found alkaline during the study period as already stated in the results.

The pH of Udaisagar reservoir was found to be moderately alkaline which is suitable for supporting fairly good aquatic productivity. Such alkaline pH has also been reported earlier by Misra *et al.* (1978), Gupta (1991), Gupta and Sharma (1994), Sarang (2001), Rawat and Jakher (2002 a,b). Ujjania (2003) also found alkaline water in the three water bodies of southern Rajasthan. Rajkumar (2005) also found alkaline water in the Daya reservoir of Udaipur (Raj.)

The statistical results shows that pH had positive significant relationship with air and water temperature, dissolved oxygen, carbonate alkalinity and CR and negative significant relationship with depth of visibility, bicarbonate alkalinity, total alkalinity, EC, TDS and orthophosphate content.

The secchi disc still remains one of the valuable tools in the study of limnology. According to Wetzel (1975), the secchi disc transparency is a function of the reflection of light from the water surface. The intensity of light penetration decreases with increasing average depth of water and suspended materials. The average depth of visibility of 56.78 cm in the present investigation points out relatively high levels of nutrients in the Udaisagar reservoir. Shekhawat (1991) reported the transparency values of 39.77 cm in a water body of Udaipur (Rajasthan). Sarang (2001) observed the water transparency of 93.8 to 153.0 cm during the period from April to August and reported that the water body had fairly moderate productivity.

In the present investigation the water clarity varied from 21.66 to 95.35 cm throughout the study period (September 2008 to September 2009). The mean water clarity value was 56.78 cm which as per the classification of Sharma and Durve (1990) indicates the highly eutrophic nature of Udaisagar. The observed value of clarity might be mainly influenced by the suspended particulate matter, plankton and variation in water level during study period.

The statistical results show that during the study period, the depth of visibility had a positive significant relationship with carbonate, bicarbonate and total alkalinity, EC, TDS, NO_3-N, orthophosphate, GPP, NPP and TPP and had a negative significant relationship with both air and water temperature, pH, CR and TZP. Soloman (1994) reported the relationship of total plankton counts with the clarity values for Udaipur lakes. He also observed positive relationship between oxygen and water temperature which was not evident during the present study. Sarang (2001) also did not find any relationship between depth of visibility and water temperature.

The electrical conductance represents total ionic load in water due to dissolved substances and sometimes considered as an index of productivity. As per the Rawson (1960) criteria, the Udaisagar reservoir with electrical conductance values well above 250 µS cm^{-1} could be considered highly 'eutrophic'. Sharma (1980) recorded average electrical conductance of 426.6 from Fateh Sagar lake, whereas for Bhavanisagar, Nagarjuna Sagar and Govind Sagar the recorded electrical conductance value ranged from 212.4 to 338.0. Shekhawat (1991) has reported the electrical conductance values of 391.87 µ mhos cm^{-1} in Rameshwar anicut. Gupta and Sharma (1994) observed EC of 412 to 850 µ mhos cm^{-1} in the Amarchand reservoir, southern Rajasthan. Rao (1984) has observed the electrical conductance of 503.4 µmho cm^{-1} and Sarang (2001) has also observed the electrical conductance values of 765 µmho cm^{-1} from Jaisamand reservoir during April to August.

Kushlan and Hunt (1979) and Rao (1984) recorded higher electrical conductance in summer and comparatively lower values during monsoon. In present study a positive significant correlation of EC was found with depth of visibility, bicarbonate alkalinity, total alkalinity, TDS, NO_3-N, orthophosphate, NPP and a negative significant relationship was found with air and water temperature, pH, dissolved oxygen, carbonate alkalinity.. Meena *et al.* (2007) reported significant correlationship of electrical conductance with primary production, TDS, BOD and total alkalinity of Lake Pichhola, Udaipur (Raj.).

The estimation of total dissolved solids (TDS) is based on EC values and hence this parameter showed same relationship as indicated by EC with other water quality parameters. Thus, high TDS values justified eutrophic nature of water body.

Dissolved oxygen is the most critical water quality variable aquatic ecosystem. It is of primary importance both as regulator of metabolism of plant and animal communities and as an indicator of water condition. According to Hutchinson (1957) dissolved oxygen is most significant chemical abiotic component which is essential for smooth running of metabolic activities for all organisms in the aquatic ecosystem and is one of the best indicators to show the nature of the water body. According to Wetzel (1975) oxygen content is important for direct requirement of many organisms and affects the solubility and availability of many nutrients and therefore the productivity of aquatic ecosystem.

During present study dissolved oxygen concentration ranged from 5.2 to 8.93 mg l^{-1} with average value 7.95 mg 1^{-1}. Similar range and average was also noted by Gupta and Sharma (1994), Wanganeo *et al.* (1997), Bharadwaj and Sharma (1999), Sharma *et al.* (2000), Sarang *et al.* (2002), Nandan and Magar (2007) and Tamot *et al.* (2007) in the different water bodies of India. In the present study, the dissolved oxygen indicated higher concentration during Feb-March and May-June while lower in the months of October-December and July-August.

The significant correlationship of dissolved oxygen with air and water temperature and pH was found during study and similar result was found by Kumar *et al.* (2007). Bhardwaj and Sharma (1999) also found inverse correlationship of dissolved oxygen with water temperature at sewage fertilized seasonal pond of Udaipur (Raj.).

The presence of CO_2 in an aquatic body can be attributed to (i) atmosphere, (ii) respiration, (iii) bacterial decomposition, (iv) in flowing ground water and (v) within the water itself in combination with calcium and magnesium. The free CO_2 is necessary to retain calcium in solution in the form of Ca (HCO_3) which is called the equilibrium of free CO_2. This free CO_2 is contained in half bound state as (HCO_3) and bound state as CO_3. Both CO_3 and HCO_3 are together called combined CO_2. The complex equilibrium reaction of inorganic carbon and the distribution of different forms of total carbon dioxide ($CO_2 = CO_2 + HCO_3^- + CO_3^-$) has been discussed in detail by Wetzel (1975).

As per Dwivedi and Pandey (2002), the main source of free CO_2 is mainly decomposition of organic matter and respiration of plants and animals. In the present investigation however free CO_2 was found absent throughout the study period. Similar results were also reported by Gupta and Sharma (1994), Das (2000), Dasgupta *et al.* (2007), Parihar *et al.* (2007) and Paulose and Maheshwari (2007). Ujjania *et al.* (2007) also found the absence of free CO_2 was in the three water bodies of southern Rajasthan. Negi *et al.* (2006) observed absence of free carbondioxide for most of the time during his studies in Pangdam reservoir in Himachal Pradesh.

Carbonates are bound form of carbondioxide. A change in alkalinity thus indicates either an addition or precipitation of carbonates. Alikunhi (1957) stated that in highly productive waters, the alkalinity ought to be over 100 ppm. According to Swingle (1967) such waters are suitable for fish culture. During present study carbonate alkalinity showed regular presence in the Udaisagar reservoir where the average carbonates was 58.52 mg l^{-1}.

The regular presence of carbonates in the water bodies of arid and semi-arid region was also reported by Khatri (1980), Saxena (1982), Sharma and Gupta (1994) and Sarang *et al.* (2002). Michael (1964) Verma (1964), Vijayaraghavan (1970) and Nandan and Magar (2007) noticed regular presence of carbonate in various water bodies of India.

The statistical relationship of carbonate alkalinity had a positive significant correlation with air and water temperature, pH, depth of visibility, dissolved oxygen and negative significant correlation with bicarbonate, total alkalinity, EC, TDS, GPP, NPP, TPP and TZP.

Bicarbonate form a major source of carbon for aquatic flora, particularly for the phytoplankton in the absence of free CO_2 . Presence of bicarbonates, carbondioxide and hydrogen alkalinity implied that CO_3-HCO_3 and free CO_2 were responsible for alkalinity (Jhingran, 1992). During present study bicarbonate always dominated over carbonate alkalinity which varied from 144.86 to 245.33 mg l^{-1} in Udaisagar reservoir.

Bicarbonate alkalinity remained slightly high in winter and low in summer at all the stations. David *et al.* (1969) found maximum alkalinity in March and minimum in September whereas, Goldman and Wetzel (1963) and Sreenivasan (1966) found maximum alkalinity during summer which declined subsequently in the monsoon. Vijayaraghavan (1970), Sharma and Gupta (1994), Bhardwaj and Sharma (1999), Das (2000), Dwivedi *et al.* (2000), and Nandan and Magar (2007) also found similar trend in the bicarbonate alkalinity.

In present study bicarbonate alkalinity had a positive significant correlation with depth of visibility, total alkalinity, EC, TDS, NO_3-N, orthophosphate, GPP, NPP and TPP and significant negative correlation with air and water temperature, pH, dissolved oxygen, carbonate alkalinity, CR and total zooplankton. Parihar *et al.* (2007) also reported highly significant correlation between bicarbonate and total alkalinity.

Natural bodies of water in the tropics usually show a wide range of fluctuation in total alkalinity values depending upon the location, seasons, plankton population and nature of bottom deposits. Stagnant waters in tropical plains in low rainfall areas during the summer season are likely to have high total alkalinity values. A range of 4 to over 1000 ppm alkalinity has been encountered in natural bodies of water (Jhingran, 1992). In the present study, total alkalinity ranged from 246.66 to 303.33 mg l^{-1} (Table 4.13). Rao (1984), Gupta (1992), Mwachiro (1993) and Solomon (1994) have studied selected lakes of Udaipur and reported the alkalinity above 60 mg 1^{-1} in all the water bodies. Ujjania (2003) observed total alkalinity of 65 to 199 mg 1^{-1} in three water bodies of southern Rajasthan. Rajkumar (2005) and Parihar *et al.* (2007) also reported higher range of alkalinity in the different water bodies of the Udaipur region.

In the present study, total alkalinity had a positive significant correlation with depth of visibility, bicarbonate alkalinity, EC, TDS and negative significant correlation with air and water temperature, pH, dissolved oxygen, carbonate alkalinity and CR.

Total alkalinity values were low in June, July, August and September. In subsequent months (till summer) it remained high which supports the observations (high in summer and low in rainy and winter seasons) of Dwivedi and Pandey (2002).

High alkalinity during summer can be compared with a rise in temperature which also coincides with concentration of nutrients and carbonates and bicarbonates in particular. Results by Hazelwood and Parker (1961) also showed that a decrease in water level due to evaporation can cause a steady increase in alkalinity (Nasar and Sharma, 1980).

The values of total alkalinity above 60 ppm are indication of nutrient rich condition (Spence, 1964). Further, the Udaisagar reservoir is highly ‘eutrophic’.

Phosphorus is generally recognized as a key nutrient in the fertility of a water body. This nutrient frequently limits plant production and ultimately influences fish production. Too much phosphorus is sometimes responsible for excessive production of blue-green algae or other nuisance plant species in an aquatic body. Phosphorus in natural water bodies is mainly contributed from the phosphorus bearing rocks and from the leaching of soils of the catchment area by rain. The other source of phosphorus in water body is from dead plankton by the microbial actions. These plankton are broken down by autolysis. Hence the phosphorus bound protein (nucleoprotein) in the cells gets disseminated in aquatic bodies by the action of phosphates enzyme. According to Cole (1979) phosphorous is very meager in terms of abundance on the earth surface and ecologically it is often considered as the most critical single element in the maintenance of the aquatic productivity.

Phytoplankton absorb phosphorus very rapidly and most of the uptake following fertilization probably occurs within a few hours or even minutes (Coffin *et al.*, 1949).

Indian reservoirs are characterized by low levels of phosphate; phosphate occurs mostly in traces and rarely exceeds 0.1 mg l^{-1}. Low phosphate in waters not necessarily is an indicative of low productivity particularly in Indian reservoirs because of their rapid turn over and quick recycling e.g. 95% of the phosphorus is taken up by phytoplankton within 20 minutes while some algae can convert inorganic phosphate into more stable organic state within one minute (Hayes and Philips, 1958).

Atkins (1913) stated that inorganic phosphate over 0.5 mg l^{-1} is an indicator of organic pollution. Srinath and Pillai (1972) opined that concentration of phosphate in water should be less than 0.05 pprn for the control of algal growth. The results (Tables 4.6 to 4.8) on inorganic phosphate obtained in the present study thus justifies highly polluted status of Udaisagar reservoir.

Here the dissolved phosphate concentrations ranged between 0.29 to 0.71 mg l^{-1} during the study period. Dwivedi *et al.* (2000) recorded phosphate from 0.20 to 0.55 ppm in Naktora reservoir, (M.P.) India. Sultan *et al.* (2003) recorded nutrients in the form of phosphate phosphorus ranging between 0.07 to 0.50 mg l^{-1} at Pahunj reservoir, Uttar Pradesh. Whereas, Chouhan and Sharma (2007) reported appreciably higher concentration of phosphate between 2.58 to 2.66 ppm at lake Budha Pushkar Near Ajmer, Rajasthan.

In determining the productivity status of lakes, phosphate and nitrogen have been considered as the basic nutrients. In the present investigation phosphate showed the dominance over nitrate-nitrogen contents. Gupta (1991) studied orthophosphate and nitrate contents and reported the dominance of phosphate over nitrate. The higher value of orthophosphate as compared to nitrate could be attributed to reduced volume of water during most part of the study period and increased density of biota, which produces metabolic waters. Further, the high value of orthophosphate may also be due to inadequate utilization of this nutrient within the water body.

Statistically, the levels of orthophosphate in surface waters had a negative significant relationship with depth of visibility, dissolved oxygen, carbonate alkalinity, bicarbonate alkalinity, total alkalinity, EC, TDS. However, a significantly negative relationship was shown with air and water temperature, pH, NO_3-N, GPP, NPP, CR and total phytoplankton.

In the lake ecosystem the major input of nitrate-nitrogen is through run off, but this may also be contributed from the decomposition of nitrogenous matter and its further oxidation (Goldman and Horne, 1983). Nitrate generally occurs in the trace quantities which is essential for many photosynthetic autotrophs and in some cases has also been identified as the growth limiting nutrient.

In the present study the value of nitrate-nitrogen varied from 0.053 to 0.240 mg l^{-1} in Udaisagar reservoir. These values of nitrate were comparable to those reported by Sharma (1980), Nasar and Kaur (1982), Kumar and Sharma (1991), Sharma and Gupta (1994), Bharadwaj and Sharma (1999), Das (2000), Dwivedi *et al.* (2000), Sultan *et al.* (2003), and Kumar *et al.* (2007). Ujjania *et al.* (2007) reported nitrate value ranging from 0.11 to 0.27 mg l^{-1} in three different water bodies namely Mahi Bajaj Sagar, Survania Dam and Aasan pond located in southern Rajasthan.

Relatively higher value of nitrate in the present investigation was recorded during December-January. Further, high value of nitrate in winter was found possibly due to its release from decomposition of organic matter. Similar trend of nitrate concentration was found by Dwivedi and Pandey (2002).

The statistical computation indicated a positive correlation of nitrates with only NPP and TZP. Meena *et al.* (2007) also found positive significant correlationship between nitrate-nitrogen and orthophosphate in the lake Pichhola, Udaipur.

Plankton in inland water bodies holds a key position in the metabolism of water bodies, trophic levels, food chains and energy flow. As producers and consumers they play an important role in the transformation of energy from one trophic level to the higher trophic levels ultimately leading to fish production which is the final product of aquatic environment.

The outcome of the present study from planktonic diversity of Udaisagar reservoir, a total 35 species of phytoplankton and 34 species of zooplankton were noticed. Out of 35 species of phytoplankton, 11 belong to Chlorophyceae, 9 to Bacillariophyceae, 12 to Cyanophyceae and 3 to Desmidiaceae from this reservoir. Out of 34 species of zooplankton noticed in the reservoir, 18 belong to Rotifera, 9 to Cladocera and 7 to Copepoda. In the present study, the observed zooplankton ranking in order of : Rotifers > Cladocerans > Copepods. Further, as regards relative dominance of different algal groups, Cyanophyceae dominated the phytoplankton Chlorophyceae followed by Bacillariophyceae and Desmidiaceae in the present study which could be considered a desirable feature from the fisheries point of view.

However, Rao and Durve (1987) have reported 52 genera, out of which 25 belong to Chlorophyceae, 12 to Bacillariophyceae, 2 to Euglenophyceae, 1 to Xanthophyceae and 12 to Myxophyceae from Jaisamand reservoir. Sarang *et al.* (2002) reported only 18 species of phytoplankton and 21 species of zooplankton with dominance of green algae followed by blue green algae and diatoms. They observed zooplankton ranking in order of : Rotifers > Copepods > Cladocerans > Others in Jaisamand reservoir. In Udaipur lakes receiving organic pollutants, Soloman (1994) reported the dominance of blue-green algae. Sarang (2001) reported dominance of green algae followed by blue green algae and diatoms in lake Jaisamand.

The average density of phytoplankton as reported by Sarang *et al.* (2002) were only 20 to 214 No. l^{-1}. While in the present study the mean phytoplankton and zooplankton populations were relatively higher (Tables 4.10a - 4.12b) in Udaisagar water. The phytoplankton were dominated by Cyanophyceae > Chlorophyceae > Bacillariophyceae > Desmidiaceae. The zooplankton were dominated by Rotifers >

Cladocera > Copepoda at all the stations. Such dominance of zooplankton were also reported by Ansari and Raja (2007) in the two freshwater bodies of Aligarh region, Uttar Pradesh, India.

The observed scenario of plankton was more or less comparable at all the three stations, as already given in Chapter 4. The minute variation in the zooplankton may be associated with prevailing water quality conditions of this reservoir.

Gupta (1975) gave a general account of the faunistic survey done in Rajasthan from 1920-1969. This was mainly based on the survey conducted by Zoological Survey of India. Datta and Majumdar (1970) made an extensive survey at 93 collection stations and reported 75 fish species. Other notable contributions on the fish fauna of the Rajasthan are of Mathur (1952), Krishna and Menon (1958), Dattagupta *et al.* (1961) and Moona (1963). Paleographical features of Rajasthan waters with the distribution of fishes were discussed by Hora and Mathur (1952), whereas studies on fish fossils was made by Borooch (1950) and Tiwari (1968). Other intensive studies on fish fauna were conducted in different districts of Rajasthan with a number of new additions to the fauna (Dhawan, 1969; Mathur and Yazdani, 1969, 1973; Yazdani and Bhargava 1969; Mahajan *et al.*, 1981; Johal and Dhillon, 1981; Johal 1982; Sharma and Johal 1982, Johal and Sharma, 1986 and Kumar and Vijayan, 1988). Further, fisheries aspects of one of the biggest reservoir in Rajasthan Rana Pratap Sagar were discussed by Choudhary (1978) and that of Jaisamand reservoir were studied by Durve (1976).

A total of 116 species of fish belonging to 9 orders 23 families and 58 genera were recorded from Rajasthan by Kumar and Asthana (1993).

The outcome of the present study from the biodiversity and fisheries point of view is that in the Udaisagar reservoir in all 31 species, 9 families (Table 4.1) were recorded to contribute to the Ichthyofauna of the reservoir. Out of these, majority are important food fishes but only 12 species form the commercial catch of the Udaisagar reservoir. In the commercial fish catch, Indian major carps viz., *Catla catla, Labeo rohita* and *Cirrhinus mrigala* dominated contributing 90 per cent of the total fish landing followed by minor carps and catfishes which respectively formed only 8.84 per cent and 0.9 per cent of the total fish catch. The relative abundance of different groups of fishes forming the total catch appeared I.M.C. > Minor carp > Catfishes.

Accepting that there is some mini scule level contribution to the recruitment from the natural breeding, the projected picture of fishable stock appears satisfactory.

the relative contribution of major and minor carps are 90 and 8.84 per cent. Further, the fishery is largely contributed by two Indian major carps. viz. *Catla catla, Labeo rohita*. The contributions of catfishes to the total catch was 0.9 per cent. Out of the three Indian major carps, *Catla catla*, and *Labeo rohita* contribute 70.0 and 25 per cent in total fish production.

The relative abundance of IMC species was in the order of *Catla catla* > *Labeo rohita* > *Cirrhinus mrigala*. Present dominance of *Catla catla* and *Labeo rohita* in Udaisagar reservoir is probably attributable to the regular stocking of these two species.

Length weight relationship for any fish species gives its performance and well being in relation to habitat and helps in monitoring the status of fish stock for obtaining optimum yield.

The length-weight relationship of Indian major carps has been discussed by Khan and Husain (1945), Jhingran (1959), Chakrabarty and Singh (1963), Natarajan and Jhingran (1963), Srivastava and Singh (1964), Kamal (1969, 1971), Rao and Rao (1972), Choudhary *et al*. (1982), Johal and Tandon (1987), Johan and Kingra (1988) and Kumar (1988) from different localities of India.

Studies on length-weight relationship have widely attracted the attention of fishery biologists. However, on Rajasthan waters such reservoirs are comparatively meager. In the present study on length-weight relationship and exponent values for the carps, *Catla catla* and *Labeo rohita* from Udaisagar reservoir, Udaipur Rajasthan have been computed.

The observations on *Catla catla* and *Labeo rohita* clearly indicate that in all these fishes morphometric parameters of these species showed the relationship between total body length and body weight were highly significant (Table 4.3-4.5). The results shown in the Tables 4.3-4.5 and Fig 4.1 point out a highly significant relationship between total body length and body weight of the two fish species. Coefficient of correlation (r) in respect of various parameters (Table 4.3-4.5) further indicated that relationship for morphometrical parameters were highly significant.

In the present study, the exponent value 'n' was found to be deviated from ‘cube law’ i.e. the values were 0.228 for *Catla catla* and 0.262 for *Labeo rohita*. Such deviations from ‘cube law’ were also observed by earlier workers. Desai and Shrivastava (1990) observed an exponent value of 2.9143 for Cirrhinus mrigala from Rihand reservoir. Johal and Kingra (1992b) reported exponent values varying between 2.752 to 3.545 in three Indian major carps. Pandey and Sharma (1998) reported exponent values for *Cirrhinus mrigala, Labeo rohita* and *Catla catla* as 1.7932, 2.2502 and 2.5274 respectively, and indicated that these carps did not follow the ‘cube law’ in sodic soil pond conditions in U.P. India.

In Rajasthan, Choudhary *et al.* (1991) reported exponent values varying from 2.416 to 3.287 for *Labeo calbasu* from Rana Pratap Sagar reservoir, Rajasthan. Jain (2000) reported a high variations in ‘cube law’ for *Catla catla, Labeo rohita* and *Cirrhinus mrigala* from Siliserh reservoir, and observed that availability of living space and food could strongly influence the values of exponent. Panicker (2000) also observed the exponent value in several species of fishes from Chulliar reservoir and reported that in the case of *Catla catla* and *Labeo rohita* the values of ‘n’ were 3.353 and 3.113, respectively. It was further stated that the shifting of exponent value to higher than 3 indicates a favourable environment for fish in the reservoir for their good growth and well being.

Ujjania (2003) attempted to workout length weight relationship in three Indian major carps namely, *Catla catla, Labeo rohita* and *Cirrhinus mrigala* and reported a highly positive significant relationship between standard body length and body weight. He also reported the variations in the exponent value (n) of *Catla catla* at different length-weight groups from 3.160 to 3.805, 2.734 to 4.452 and 3.013 to 4.004 from Mahi Bajaj Sagar, Surwania dam and Aasan pond, respectively from southern Rajasthan. Further, the same author reported the exponent value 'n' to vary from 2.770 to 4.574, 2.853 to 4.056 and 2.685 to 4.455 in Three length-groups of rohu from the above stated three reservoirs in respective order.

From above discussion it may be seen that the exponent values obtained in the present study in respect of *Catla catla* and *Labeo rohita* of Udaisagar reservoir are comparable to those reported by Johal and Kingra (1992), Pandey and Sharma (1998), Jain (2000) and UJania (2003).

Condition factor or ponderal index is a physiological indicator of the well being of any fish living in a giving environment. Low values of condition factor or K, as it is normally referred to in a fishery language, is a definite sign of non-allometric fish growth probably owing to the competition for the food and space within the different fish communities in a waterbody. In the present study, the values of K varied between 1.484 and 2.278 for catla and 1.273 and 1.637 for rohu. The nearness of K value to

1.0 in both the species, clearly indicates the environmental suitability of the resvoir Udaisagar for good growth of fish.

Further, the high value of condition factor (K) in the present study is an indicator of higher increase in weight in relation to length. The higher 'K' value for catla in comparison to that of rohu are supportive of the assumption that rohu has a higher length increment than in catla. Conversely, the latter has higher weight increase. Choudhary *et al*. (1991) reported the oscillation of 'K' value in the case of *L. calbasu* between 1.15 and 1.26. In this connection, the observation of Jain (2000) in respect of IMC in Seliserh reservoir are comparable and supportive. Ujjania (2003) observed that the condition factors varying from 2.788-3.225 for catla, 2.053-2.339 for rohu and 1.779-1.965 for mrigal. He also reported that such values of 'K' are indicative of the suitability of the waterbody for good fish growth. All the above studies support the presently made observations in catla and rohu of Udaisagar reservoir.

PRESENT FISH PRODUCTION V/S POTENTIAL:

From the available catch records it was observed that total fish production in the year 2008-09 was 90,000 kg. in Udaisagar reservoir. According to Natarajan (1976) in any water body the fish production potential is affected by certain factors such as lack of understanding of the ecology, paucity of quality seeds, faulty stockings, exploitation policies and presence of predatory and weed fishes. Sugunan and Sinha (2000) emphasized that fish productivity is related to morphometric, hydrological and ecological features of a particular water body because the yield is partly a function of biotic and abiotic factors influencing production process of that ecosystem.

Species wise fish composition in total catch has direct influence on production of economically important fish like carps. It is well known that carps have different types of breeding and feeding patterns and presence of weeds and catfishes may directly affect carp fish production.

Durve (1976) reported that fish production of Jaisamand (Udaipur) increased after heavy stocking of fingerlings of major carps. Durve and Kakkar (1982) recorded about 45 per cent contribution of catfishes in total fish production during 1979-80 while in 1971-72 major carps contributed 39.7 per cent in total catch of Jaisamand reservoir.

During the present study, major carps visibly dominated the catch, particularly due to continuous stocking and partly due to relatively lower population of large predatory fishes.

The total fish production was around 90,000 kg during 2008-09 from this reservoir. Thus, there was large gap between potential fish yield and actual fish harvest. There is an ample scope for increasing fish production which could be achieved through sustainable management practices.

According to Sugunan (1995) the estimated production potential of small (less than 1000 ha), medium (1000-5000 ha) and big reservoirs (above 5000 ha) in India are 200-300, 75-100 and 50-75 kg ha^{-1} y^{-1} respectively. Dwivedi *et al.* (2005) stated that the annual fish production of large reservoirs of India is 20 to 150 kg ha^{-1} y^{-1} while average fish production of small reservoirs is varies from 50 to 200 kg ha^{-1} y^{-1}. Ayyappan (2007) recently computed maximum fish production of 35 kg ha^{-1} y^{-1} from large reservoirs of India.

Jhingran and Tripathy (1969) recorded fish production of 6.2 and 39 kg ha^{-1} y^{-1} in Tungabhadra and Mettur reservoirs respectively and 250 kg ha^{-1} y^{-1} fish production in Keetharn reservoir. On the other hand, Mohan and Singh (1985) recorded only 4 kg ha^{-1} y^{-1} fish production in Kailana-Takhat Sagar. Sultan and Chauhan (2005) recorded 43.57 kg ha^{-1} y^{-1} fish production in Pahunj reservoir of Uttar Pradesh. Whereas, Pandey (2006) recorded 57.89 kg ha^{-1} y^{-1} average fish production in Kidari Jheel in U.P. while Kolekar (2006) estimated fish production of 220.09 kg ha^{-1} y^{-1} in Keetharn lake of Agra.

6. SUMMARY

The present study on **"Planktonic and Fish Biodiversity, and Fisheries of Reservoir Udaisagar (Udaipur, Rajasthan)"** was conducted during Sept. 2008-Sept. 2009. Two commercially important fish species of Udaisagar reservoir *viz.*, *Catla catla and Labeo rohita* were selected for their biological studies. For various physico-chemical studies, the three surface sampling stations were selected.

Several aspects were covered in the present study which include the identification of fish fauna, length-weight relationship, condition factor, primary productivity, physico-chemical and other biological characteristics *viz.*, plankton of Udaisagar reservoir. From this study, following inferences have been made.

- The reservoir has a fairly rich fish fauna and so far 31 species representing 9 families have been recorded in the present investigation, of these, 12 species predominantly contributed to the commercial fisheries of this reservoir.
- During study period, the Indian major crops dominated the catch by contributing 90 per cent the total landings from this reservoir. Besides IMC, minor carps and catfishes were reported to be 8.84 and 0.9 per cent, respectively. In case in Indian major carps, the *Catla catla* (70%) dominated the groups followed by *Labeo rohita* (25%) and *Cirrhinus mrigala* (5%).
- On the basis of exponent value of length-weight relation, it could be concluded that fishes attained more weight per unit of length in the Udaisagar reservoir. Observed condition factor of both the species reported that both the fishes were in well condition during the study period. On the basis of length-weight data, the regression equations of body weight on total body length were calculated.

Catla catla

Length groups (cm)	**Equation**
40-50	y= -7.271 + 0.197x; r = 0.648
50-60	y= -3.810 + 0.138x; r = 0.557
60-70	y= -10.137 + 0.228x; r = 0.775
70-80	y= -14.741 + 0.280x; r = 0.741

Labeo rohita :

Length groups (cm)	**Equation**
40-50	y= -5.198 + .0.147x; r = 0.788

50-60	y= -2.970 + 0.104x; r = 0.394
60-70	y= -3.701 + 0.113x; r = 0.513
70-80	y= -14.273 + 0.262x; r = 0.665

- Gross primary productivity of Udaisagar reservoir computed as 0.25 g C m^{-3} h^{-1}. On this basis, the conversion rate of primary productivity into the fish production was found to be 0.26 per cent which showed vast scope for enhancing the production of Udaisagar reservoir. Further, the production potential of Udaisagar reservoir was estimated to be 90,000 kg. While, the average fish production i.e. 27000 kg was only 30 per cent of the estimated potential. It again indicates the productive nature of water body and considerable scope for enhancing the present production level. The declining trend of fish catch from last ten years indicates the lack of proper management practices.
- During study period, a positive significant relationship was found between air and water temperature. Hydrogen ion concentration (pH) remained alkaline through out the study period. The Average depth of visibility was 56.78 cm which shows that the water body is highly eutrophic.
- Dissolved oxygen content remained congenial throughout the study period. Dissolved oxygen has not showed any significant relationship with temperature and carbon dioxide which are generally observed. Free CO_2 remained absent throughout the study period.
- During the study period the total alkalinity was contributed by carbonate and bicarbonate alkalinity. Total alkalinity was found in the surface water. High values of alkalinity (>100 ppm) indicated that the reservoir has productive hard water. High values of EC and TDS again declared the Udaisagar reservoir as productive water body.
- High orthophosphate level was noticed in the reservoir which was mainly from allochthonous sources added with sewage water from Udaipur city. The level of orthophosphate and nitrate were found congenial for biological production. The dominance of inorganic phosphates over the nitrate was a noteworthy features of this reservoir which needs further study in detail.
- The density and quality of phytoplankton and zooplankton observed during study period indicated the moderate productivity of this reservoir.

Comparatively phytoplankton showed the dominance over zooplankton population. The positive significant correlation of zooplankton with total phytoplankton again suggests the grazing action of former on latter. Phytoplankton and zooplankton populations were represented by 35 and 38 genera, respectively, which shows a fairly good planktonic diversity.

- In general, the results obtained for primary productivity, physico-chemical parameters and planktonic diversity justify the nutrient rich status of reservoir. As per Odm (1971), the ideal fish conversion should be 1.2 per cent. However, in view of the fact that this index is based on the observations o temperate water bodies and as such may not be very appropriate to apply for Rajasthan waters. Thus, considering the gap identified between primary productivity and fish landings, there is scope for enhancing the fish production. The plankton and productivity data also support the view that present production can be increased manifolds. The production was during the study period 2008-09 was 90,000 kg. This speaks of good production potential of this reservoir and suggests the need for maintaining the production upto this level on sustainable basis by adopting following management measures :

    1. Water quality monitoring for important parameters such as physico-chemical parameters, plankton, benthos and other food resources.
    2. For optimum utilization of available fish food resources stocking policy should be formulated. Presently, only Catla and Rohu are being stocked, therefore, leaving vast amount of food resources available in the form of benthic flora and fauna remain underutilized. Thus, Mrigal should also be stocked and the stocking ratio of 2 Catla : 3 Rohu : 2 Mrigal may be adopted.
    3. The fish growth studies should be performed periodically and suitable modifications may be done according to need and performance particular fish.

From the present studies, it could be concluded that the fish catch from Udaisagar reservoir mainly comprises *Catla catla* which is not desirable for the optimum utilization of food resources. Hence, this water body should be scientifically stocked with different species of varying feeding habits. The declining trend of fish catch in the Udaisagar reservoir shows the lack of suitable management practices.

Hence, this problem should be avoided by strictly adopting fisheries conservation and scientific management practices.

Table 4.9: Check list of plankton found in Udaisagar reservoir, Udaipur

Phytoplankton	Zooplankton
CYANOPHYCEAE	**ROTIFERA**
Anabaena sp.	*Filinia longiseta*
Nostoc sp.	*Keratella* sp.
Polycystis sp.	*Keratella cochlearis*
Oscillatoria sp.	*Keratella quadrata*
Aphanizomenon sp.	*Keratella lielmalis*
Coelospharium sp.	*Keratella hiemalis*
Microcystis (Microcystis aeruginosa)	*Keratalla canadensis*
Meriosmopedia sp.	*Keratella tropica*
Spirulina sp.	*Trichocera* sp.
Aphanocapsa sp.	*Testudinella* sp.
Synechocystis sp.	*Hexarthra* sp.
Arthrospira sp.	*Rotaria* sp.
	Polyarthra sp.
	Brachionus plicatilis
	Brachionus havanaensis
	Monostyla sp.
	Platyias sp.
	Notholca sp.
BACILLARIOPHYCEAE	**CLADOCERA**
Synedra sp.	*Daphnia* sp.
Nitzschia sp.	*Moina* sp.
Fragilaria sp.	*Bosmina* sp.
Navicula sp.	*Sida* sp.
Diatoma sp.	*Macrothrix* sp.
Tabellaria sp.	*Diaphanosoma* sp.
Cyclotella sp.	*Simocephalus* sp.
Asterionella sp.	*Chydorus* sp.
Pinnularia sp.	*Alonella* sp.
CHLOROPHYCEAE	**COPEPODA**
Pedistrum sp.	*Diaptomus* sp.
Protococcus sp.	*Cyclops* sp.
Ulothrix sp.	*Canthocampus* sp.
Spirogyra sp.	*Mauplius larvae*
Tetraspora cylindrica	*Mesocyclops* sp.
Ankistrodesmus sp.	*Halicyclops* sp.
Hydrdodictyon reticulatum	*Eucyclops* sp.
Volvox sp.	
Chlorella sp.	
Coelastrum sp.	
Zygnema sp.	
DESMIDIACEAE	
Cosmarium	
Ganatozygon	

Table 4.1: List of fish fauna represented in the catch from Udaisagar reservoir, Udaipur

	Family	Species		
			Scientific name	Local name
A.	Cyprinidae	1.	*Catla catla* (Ham.)	Catla
		2.	*Cirrhinus mrigala* (Ham.)	Mrigal or Narain
		3.	*Labeo rohita* (Ham.)	Rohu
		4.	*Labeo gonius* (Ham.)	Sarsi
		5.	*Labeo kalbasu* (Ham.)	Kalaunt
		6.	*Labeo boggut*	
		7.	*Labeo pengusia*	
		8.	*Amblypharyngodon mola* (Ham.)	Malwa
		9.	*Punitus ticto* (Ham.)	Puthi
		10.	*Punitus sophore* (Ham.)	Puthi
		11.	*Punitis sarana* (Ham.)	Puthi/Kharpata
		12.	*Punitus punctulus* (Ham.)	
		13.	*Punitus amphibius* (Ham.)	
		14.	*Punitus dorsalis* (Ham.)	
		15.	*Tor tor* (Ham.)	Mahseer
		16.	*Rasbora daniconius* (Ham.)	Chal
		17.	*Oxygaster clupeoides* (Ham.)	Silues chal
		18.	*Ctenopharyngodon idella*	Grasp carp
		19.	*Hypophthalmichthys molitrix*	Silver carp
B.	Siluridae	20.	*Heteropneustes fossilis* (Bloch)	Singhi
		21.	*Wallago attu* (Bloch & Schneider)	Lanchi
C.	Notopteridae	22.	*Notopterus notopterus* (Pallas)	Patola
D.	Bagridae	23.	*Mystus seenghala* (Sykes)	Singhara
		24.	*Mystus dor* (Ham.)	Pitar
E.	Mastacembelidae	25.	*Mastacembelus armatus* (Lacepede)	Bam
F.	Channidae	26.	*Channa marulius* (Ham.)	Sawal
		27.	*Channa striatus* (Bloch)	Kabra
		28.	*Channa punctatus* (Ham.)	Girhi
G.	Centropomidae	29.	*Chanda nama* (Ham.)	Chalputhi
H.	Belonidae	30.	*Xenentodon cancilai (Ham.)*	Suhia
I.	Cobitidae	31.	*Nemacheilus botia* (Ham.)	Botia

Table 4.2: Per cent composition of prominent fish species in total landings from Udaisagar reservoir during period 2008-09

S. No.	Fish group	Per cent composition	
		In group	In total fish production
1	**Major Carps**		
	Catla catla	70	63
	Labeo rohita	25	22.5
	Cirrhinus mrigala	5	4.5
2	**Minor Carps**		
	Labeo spp.	63	5.6
	Puntius spp.	26	2.34
	Miscellaneous	11	0.9
3	**Cat Fishes**		
	Wallago attu	65	0.59
	Mystus seenghala	15	0.13
	Miscellaneous	20	0.18

Table 4.15: Water holding capacity and guage of Udaisagar reservoir during period 2005-2010

Year	Minimum		Maximum	
	Guage (Feet)	Capacity (MCFT)*	Guage (Feet)	Capacity (MCFT)*
2005	Zero	Nill	19	700
2006	4.6	182.5	24	1100
2007	7.11	248	12.2	356
2008	4.6	182.5	10.3	302.5
2009	3.9	169.8	8.9	255
2010	1.1	136	20	780

Table 4.3: Correlation of total body length (cm) with body weight (kg) of *Catla catla* at different length groups

S.No.	Length	Group	Total No of Observation	Frequency (%)	Mean L±SD	Mean W ±SD	a' Value	n' value	r' value
1	40-50	A	36	7.2	47.194±3.097	2.015±0.940	-7.271	0.197	0.648**
2	50-60	B	30	6	54.867±3.627	3.363±0.899	-3.81	0.138	0.557**
3	60-70	C	252	50.4	66.259±3.583	4.961±1.053	-10.137	0.228	0.775**
4	70-80	D	182	36.4	75.372±3.240	6.357±1.218	-14.741	0.28	0.741**

** Significant at 1 % Level of significance

Table 4.4 : Correlation of total body length (cm) with body weight (kg) of *Labeo rohita* at different length groups

S. No.	Length	Group	Total No of Observation	Frequency (%)	Mean L±SD	Mean W ±SD	a' Value	n' value	r' value
1	40-50	A	15	3	45.800±3.278	1.513±0.609	-5.198	0.147	0.788**
2	50-60	B	100	20	55.980±3.134	2.872±0.830	-2.97	0.104	0.394**
3	60-70	C	225	45	65.570±3.220	3.723±0.711	-3.701	0.113	0.513**
4	70-80	D	160	32	74.289±3.354	5.220±1.323	-14.273	0.262	0.665**

** Significant at 1 % Level of significance

Table 4.5 : Condition factor of *Catla catla* and *Labeo rohita*

S. No.	Length groups (cm)	Condition Factor (K)	
		Catla catla	***Labeo rohita***
1	40-50	1.9172	1.5752
2	50-60	2.2785	1.6373
3	60-70	1.7055	1.3206
4	70-80	1.4846	1.2731

Table 4.13: Statistical standard deviation, minimum-maximum range and mean value amongst different surface water parameters of Udaisagar reservoir

Para-meters	Air temp. (°C)	Water temp. (°C)	pH	Depth of visibility (cm)	Dissolved O_2 (mg l^{-1})	Free CO_2 (mg l^{-1})	Carbonate alkalinity (mg l^{-1})	Bicarbonate alkalinity (mg l^{-1})	Total alkalinity (mg l^{-1})	EC (Ms cn^{-1})	Total dissolve solid	Nitrate-N (mg l^{-1})	Ortho-phosphate (mg l^{-1})	Gross primary produc-tivity (gcm $3h^{-1}$)	Net primary produc-tivity	Comm-nity respi-ration	Total phyto-plankton	Total zoo-plankton
1	32.16	29.40	8.56	36.66	7.86	--	48.00	245.33	293.33	0.21	136.53	0.14	0.63	0.56	0.45	0.11	495.33	61.00
2	35.83	31.00	8.46	41.66	7.86	--	58.66	234.66	293.33	0.23	147.20	0.05	0.47	0.51	0.40	0.11	476.66	73.66
3	32.66	27.60	8.43	38.00	8.00	--	58.66	244.66	303.33	0.24	153.60	0.13	0.29	0.61	0.46	0.14	468.00	40.33
4	32.16	27.80	8.33	39.00	8.40	--	48.66	245.33	294.00	0.24	157.86	0.16	0.55	0.43	0.31	0.11	455.33	55.33
5	22.43	23.60	8.36	42.33	8.53	--	56.66	240.66	297.33	0.25	162.13	0.17	0.61	0.38	0.26	0.11	551.00	49.66
6	23.56	19.70	8.63	41.66	5.20	--	57.33	242.66	300.00	0.30	196.26	0.24	0.65	0.41	0.28	0.12	484.66	49.33
7	24.30	20.60	8.30	26.00	7.86	--	58.66	244.00	302.66	0.31	198.40	0.13	0.71	0.35	0.25	0.10	437.66	41.33
8	22.40	21.60	8.63	21.66	7.66	--	63.33	238.66	302.00	0.30	194.13	0.23	0.67	0.43	0.35	0.08	368.33	30.66
9	25.40	21.00	8.33	27.33	8.00	--	56.66	235.33	292.00	0.28	181.33	0.24	0.65	0.45	0.30	0.15	344.33	41.66
10	26.50	21.90	8.16	54.33	8.00	--	60.00	144.86	272.66	0.23	151.46	0.19	0.65	0.48	0.33	0.14	297.33	70.66
11	28.30	24.40	8.23	62.66	7.86	--	47.33	226.00	276.00	0.30	194.13	0.21	0.46	0.53	0.38	0.14	404.66	53.66
12	24.66	24.00	8.26	67.33	8.53	--	54.00	227.33	281.33	0.33	211.20	0.20	0.68	0.56	0.48	0.07	360.60	48.33
13	34.50	24.50	8.56	74.66	8.93	--	62.00	232.66	294.66	0.34	221.86	0.23	0.69	0.43	0.35	0.08	393.33	29.66
14	33.23	28.10	8.53	84.00	8.40	--	63.33	225.33	283.66	0.26	168.80	0.17	0.69	0.48	0.35	0.13	282.66	43.00
15	33.83	28.60	8.56	90.66	8.13	--	62.66	220.00	280.66	0.26	170.70	0.17	0.67	0.46	0.31	0.14	383.66	51.33
16	34.50	28.00	8.56	95.66	7.46	--	62.00	228.00	290.00	0.25	153.60	0.15	0.64	0.50	0.38	0.11	352.33	53.33
17	35.83	28.50	8.40	95.00	8.13	--	61.33	219.33	278.66	0.24	157.86	0.17	0.67	0.61	0.36	0.24	337.00	52.00
18	34.50	29.50	8.13	92.33	7.60	--	66.66	223.33	290.00	0.25	164.26	0.19	0.68	0.56	0.33	0.22	363.00	39.66
19	37.33	27.83	8.00	69.66	8.26	--	56.00	193.33	249.33	0.22	142.93	0.08	0.61	0.43	0.31	0.11	363.66	40.00
20	34.83	29.33	8.46	61.33	8.00	--	60.66	220.00	264.00	0.20	129.93	0.07	0.30	0.43	0.30	0.13	599.35	37.33
21	31.36	26.50	8.40	60.33	8.00	--	60.66	210.00	270.66	0.23	146.93	0.07	0.62	0.40	0.23	0.16	527.66	45.00
22	30.50	26.83	8.13	55.00	8.00	--	60.60	186.66	246.66	0.20	130.13	0.17	0.59	0.53	0.45	0.08	468.33	43.66
23	29.50	27.60	8.46	55.00	7.86	--	62.66	216.66	279.33	0.24	138.46	0.10	0.43	0.58	0.40	0.18	465.00	34.66
24	30.50	28.66	8.36	45.00	8.40	--	56.66	190.00	246.66	0.24	155.73	0.13	0.39	0.60	0.41	0.18	271.00	30.33
25	30.16	27.16	8.30	42.33	8.00	--	60.00	196.66	256.66	0.23	166.40	0.18	0.41	0.43	0.40	0.03	266.33	40.33
Total	759.63	653.71	206.53	1419.53	198.94	--	1463.17	5531.44	7038.91	6.38	4131.82	3.97	14.41	12.14	8.900	3.24	10217.2	1155.9
Mean	30.38	26.14	8.26	56.78	7.95	--	58.52	221.25	281.55	0.25	165.27	0.15	0.57	0.48	0.35	0.12	408.68	46.23
Min.	22.40	19.70	5.33	21.66	5.2	--	47.33	144.86	246.66	0.20	129.93	0.05	0.29	0.35	0.23	0.03	266.33	29.66
Max.	37.33	31.00	8.63	95.33	8.93	--	66.66	245.33	303.33	0.34	221.86	0.24	0.71	0.61	0.48	0.24	599.35	73.66
SD	4.54	3.20	0.63	22.30	0.66	--	4.86	23.75	17.59	0.038	25.16	0.054	0.12	0.07	0.067	0.047	89.16	11.25
CV(%)	14.94	12.25	7.66	39.27	8.29	--	8.31	10.73	6.24	15.09	15.22	33.99	22.02	15.58	18.91	36.34	21.81	24.33

Table 4.6: Physico-chemical and biological characteristics at station ‘A’ in Udaisagar reservoir during Sept. 2008 to Sept. 2009

Parameters	Date																								Mean	Min	Max	SD	CV
	Sep.	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept.					
	28	13	28	12	27	12	27	11	26	10	25	12	27	11	26	11	26	10	25	10	25	9	24	8	23					
Air temp. (°C)	31.5	32.0	32.0	35	33.5	22.5	23.5	24.5	22.0	25.5	25.5	29.0	25.5	35.5	34.5	36.5	36.0	36.5	35.5	34.5	30.5	29.5	31.5	30.5	30.5	30.54	22.0	36.5	30.51	99.91
Water temp. (°C)	29.5	30.5	28	26.5	24.5	20	21	22	21.5	23.5	27.5	24.5	27.5	29.5	30.5	30.5	30.0	30.0	29.5	29.5	27.5	26.5	27.6	29.0	27.5	26.94	20.0	30.5	3.23	12.00
pH	8.8	8.7	8.4	8.2	8.0	8.2	8.3	8.2	8.0	8.2	8.8	8.4	8.8	8.5	8.6	8.5	8.4	8.0	8.0	8.6	8.3	8.0	8.6	8.3	8.5	8.4	8.0	8.8	0.26	3.17
Depth of visibility (cm)	30	45	47	49	51	55	43	45	48	58	66	70	79	82	89	90	98	100	59	61	59	58	56	52	45	61.4	30	100	18.49	30.12
Dissolved O_2 (mg l^{-1})	8.0	7.6	7.2	8.4	8.4	7.6	6.8	8.8	8.4	8.2	8.8	8.8	8.8	8.4	8.4	7.6	8.8	7.6	8.4	8.4	8.0	8.4	7.6	8.0	8.0	8.13	6.8	8.8	0.53	6.60
Free CO_2 (mg l^{-1})	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbonate alkalinity (mg l^{-1})	50	70	66	60	64	60	66	64	62	62	58	54	62	64	66	62	56	70	60	64	58	58	64	58	64	60.88	38	70	6.61	10.85
Bicarbonate alkalinity (mg l^{-1})	98	238	244	238	222	232	232	236	244	218	232	234	244	224	216	232	218	230	194	210	190	210	210	210	190	217.84	98	244	29.71	13.64
Total alkalinity (mg l^{-1})	248	308	310	298	286	292	298	300	306	280	290	288	306	288	276	294	274	300	254	274	248	268	274	268	254	283.28	248	310	18.96	6.69
EC (m S cm^{-1})	0.24	0.22	0.25	0.25	0.27	0.32	0.30	0.32	0.3	0.26	0.32	0.33	0.36	0.26	0.28	0.24	0.24	0.24	0.22	0.20	0.24	0.22	0.22	0.23	0.20	0.26	0.20	0.36	0.043	16.77
Total dissolved solids (mg l^{-1})	153.6	140.8	160	160	172.8	204.8	192	204.8	192	166.4	204.8	211.2	230.4	166.4	179.2	153.6	153.6	153.6	140.8	128	153.6	140.8	140.8	147.2	128	167.16	128	230.4	28.03	16.77
Nitrate-N (mg l^{-1})	0.18	0.05	0.17	0.17	0.18	0.36	0.28	0.20	0.30	0.23	0.30	0.19	0.27	0.17	0.16	0.17	0.18	0.20	0.07	0.09	0.09	0.19	0.12	0.12	0.19	018	0.05	0.36	0.075	40.56
Orthophosphate (mg l^{-1})	0.62	0.5	0.31	0.67	0.63	0.68	0.76	0.78	0.67	0.66	0.52	0.65	0.69	0.68	0.69	0.68	0.69	0.68	0.62	0.29	0.62	0.60	0.47	0.40	0.38	0.59	0.29	0.78	0.133	22.33
Gross primary productivity (g C m^{-3} h^{-1})	0.60	0.45	0.55	0.45	0.40	0.55	0.30	0.50	0.55	0.60	0.60	0.65	0.40	0.20	0.30	0.40	0.55	0.60	0.50	0.55	0.35	0.65	0.55	0.70	0.45	0.49	0.20	0.70	0.48	97.97
Net primary productivity (g C m^{-3} h^{-1})	0.45	0.35	0.45	0.25	0.25	0.45	0.25	0.35	0.35	0.45	0.40	0.50	0.35	0.15	0.20	0.25	0.35	0.40	0.35	0.40	0.15	0.45	0.40	0.65	0.35	0.35	0.15	0.65	0.35	97.97
Community respiration	0.15	0.10	0.10	0.20	0.15	0.10	0.05	0.15	0.20	0.15	0.20	0.15	0.05	0.05	0.10	0.15	0.20	0.20	0.15	0.15	0.20	0.20	0.15	0.05	0.10	0.13	0.05	0.20	0.13	97.97

Table 4.7: Physico-chemical and biological characteristics at station 'B' in Udaisagar reservoir during Sept. 2008 to Sept. 2009

Parameters	Date																									Mean	Min	Max	SD	CV
	Sep.	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept.						
	28	13	28	12	27	12	27	11	26	10	25	12	27	11	26	11	26	10	25	10	25	9	24	8	23					
Air temp. (°C)	30.5	38.0	30.6	31.5	32.5	24.0	24.5	23.5	24.2	52.5	26.5	58.5	25.0	32.5	30.2	29.5	31.0	35.5	38.0	35.5	29.5	30.5	31.5	29.5	30.5	32.08	23.5	58.5	8.04	25.08
Water temp. (°C)	29.4	32.0	27.5	29.5	23.0	19.8	20.5	21.5	22.3	21.5	22.5	24.0	22.5	27.5	26.0	23.0	25.5	29.5	26.5	29.0	23.5	27.5	27.5	27.5	27.5	25.46	19.8	32	3.31	13.01
pH	8.4	8.0	8.5	7.8	8.5	8.9	8.2	9.1	8.0	8.2	8.5	8.1	8.5	8.6	8.4	8.7	8.4	8.4	8.0	8.3	8.5	8.4	8.4	8.6	8.0	8.37	7.8	9.1	0.29	
Depth of visibility (cm)	35	30	27	25	27	25	10	5	15	50	62	69	66	81	88	92	89	79	65	64	62	52	50	34	30	49.28	5	92	26.05	52.86
Dissolved O_2 (mg l^{-1})	7.6	7.6	8.4	9.2	9.2	8.0	8.4	8.8	8.4	8.8	8.0	8.4	9.2	8.4	8.0	7.6	8.4	7.6	8.0	7.2	7.6	7.6	8.0	8.4	7.6	8.17	7.2	9.2	0.56	6.93
Free CO_2 (mg l^{-1})	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbonate alkalinity (mg l^{-1})	48	50	52	42	54	58	58	70	58	60	40	58	64	62	58	60	62	60	58	58	60	60	66	62	66	57.76	40	70	6.98	12.09
Bicarbonate alkalinity (mg l^{-1})	258	242	252	246	248	254	256	244	216	214	226	230	238	226	212	224	224	210	192	190	210	120	230	170	210	221.68	120	258	30.68	13.84
Total alkalinity (mg l^{-1})	306	292	304	288	302	312	314	314	274	274	266	288	302	288	270	284	286	270	250	248	270	180	296	232	276	279.44	180	314	29.58	10.58
EC (m S cm^{-1})	0.14	0.23	0.25	0.26	0.25	0.3	0.32	0.29	0.26	0.23	0.29	0.32	0.33	0.28	0.25	0.22	0.26	0.26	0.2	0.19	0.22	0.2	0.19	0.26	0.28	0.25	0.14	0.33	0.046	18.36
Total dissolved solids (mg l^{-1})	89.6	147.2	160	166.4	160	192	204.8	185.6	166.4	147.2	185.6	204.8	211.2	179.2	160	140.8	166.4	166.4	128	121	140	128	121	166.4	179.2	160.68	89.6	211.2	29.61	18.42
Nitrate-N (mg l^{-1})	0.18	0.05	0.15	0.19	0.16	0.29	0.07	0.33	0.23	0.19	0.13	0.22	0.30	0.19	0.18	0.14	0.20	0.18	0.09	0.06	0.06	0.17	0.10	0.15	0.18	0.16	0.05	0.33	0.073	43.68
Orthophosphate (mg l^{-1})	0.62	0.49	0.31	0.64	0.6	0.66	0.7	0.67	0.69	0.63	0.39	0.7	0.71	0.71	0.63	0.59	0.67	0.7	0.59	0.35	0.6	0.59	0.4	0.39	0.42	0.57	0.31	0.71	0.12	21.96
Gross primary productivity (g C m^{-3} h^{-1})	0.50	0.55	0.65	0.45	0.50	0.40	0.45	0.40	0.45	0.35	0.35	0.45	0.35	0.55	0.60	0.70	0.55	0.45	0.50	0.45	0.30	0.60	0.45	0.40	0.65	0.48	0.30	0.70	0.47	97.97
Net primary productivity (g C m^{-3} h^{-1})	0.45	0.50	0.55	0.35	0.40	0.25	0.30	0.35	0.30	0.25	0.30	0.40	0.25	0.35	0.45	0.55	0.30	0.25	0.40	0.35	0.20	0.45	0.35	0.25	0.45	0.36	0.20	0.55	0.35	97.97
Community respiration	0.05	0.05	0.10	0.10	0.10	0.15	0.15	0.05	0.15	0.10	0.05	0.05	0.10	0.20	0.15	0.15	0.25	0.20	0.10	0.10	0.10	0.15	0.10	0.15	0.20	0.12	0.05	0.25	0.11	97.97

Table 4.8: Physico-chemical and biological characteristics at station 'C' in Udaisagar reservoir during Sept. 2008 to Sept. 2009

Parameters	Date																									Mean	Min	Max	SD	CV
	Sep.	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept.						
	28	13	28	12	27	12	27	11	26	10	25	12	27	11	26	11	26	10	25	10	25	9	24	8	23					
Air temp. (°C)	34.5	31.5	34.5	33.5	30.5	20.7	22.7	24.9	21.1	25.2	27.5	29.0	23.5	35.5	35.0	35.5	36.5	35.5	38.5	34.5	31.5	28.5	30.9	31.5	29.5	30.48	20.7	38.5	5.10	16.74
Water temp. (°C)	29.4	30.5	27.5	27.5	23.5	19.5	20.5	21.5	19.2	20.9	23.2	23.5	23.5	27.5	29.5	30.5	30.0	29.0	27.5	29.5	28.5	26.5	27.7	29.5	26.5	26.09	19.2	30.5	3.67	14.07
pH	8.5	8.7	8.4	9.0	8.6	8.8	8.4	8.5	7.9	8.1	8.4	8.3	8.4	8.5	8.7	8.5	8.4	8.0	8.0	8.5	8.4	8.0	8.0	8.2	8.4	8.38	7.9	9.0	0.27	3.27
Depth of visibility (cm)	45	50	40	43	49	45	25	15	19	55	60	69	79	89	95	105	100	98	85	59	60	55	69	49	52	60.4	15	105	24.83	41.12
Dissolved O_2 (mg l^{-1})	8.0	8.4	8.4	7.6	8.0	8.0	7.6	8.8	7.2	8.0	6.8	8.4	8.8	8.4	8.0	7.2	7.2	7.6	8.4	8.4	8.4	8.0	8.0	8.8	8.4	8.03	6.8	8.8	0.54	6.73
Free CO_2 (mg l^{-1})	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Carbonate alkalinity (mg l^{-1})	46	56	58	44	52	54	52	56	50	58	44	50	60	64	64	64	66	70	50	60	64	62	58	50	50	56.08	44	70	7.17	12.79
Bicarbonate alkalinity (mg l^{-1})	280	224	238	252	252	242	244	236	246	206	228	218	216	226	232	228	216	230	194	260	230	230	210	190	190	228.72	190	280	21.50	9.40
Total alkalinity (mg l^{-1})	326	280	296	296	304	296	296	292	296	264	272	268	276	290	296	292	282	300	244	270	294	292	268	240	240	280.8	222	326	24.03	8.55
EC (m S cm^{-1})	0.26	0.24	0.22	0.23	0.24	0.3	0.31	0.30	0.29	0.22	0.30	0.34	0.35	0.25	0.27	0.26	0.24	0.27	0.25	0.22	0.23	0.19	0.24	0.24	0.30	0.262	0.19	0.35	0.039	15.17
Total dissolved solids (mg l^{-1})	166.4	153.6	140.8	147.2	153.6	192	198.4	192	185.6	140.8	192	217.6	224	160.8	172.8	166.4	153.6	172.8	160	140.8	147.2	121.6	153.6	153.6	192	167.96	121.6	224	25.47	15.16
Nitrate-N (mg l^{-1})	0.05	0.06	0.07	0.12	0.18	0.09	0.06	0.16	0.20	0.15	0.20	0.19	0.13	0.17	0.19	0.16	0.14	0.20	0.07	0.07	0.07	0.16	0.09	0.13	0.18	0.13	0.05	0.20	0.05	39.70
Orthophosphate (mg l^{-1})	0.66	0.44	0.26	0.63	0.61	0.62	0.69	0.58	0.59	0.66	0.49	0.69	0.67	0.69	0.70	0.66	0.66	0.68	0.62	0.30	0.66	0.58	0.43	0.4	0.44	0.58	0.26	0.70	0.12	22.25
Gross primary productivity (g C m^{-3} h^{-1})	0.60	0.55	0.65	0.40	0.25	0.20	0.30	0.40	0.35	0.50	0.65	0.60	0.55	0.70	0.50	0.45	0.60	0.55	0.35	0.25	0.40	0.65	0.60	0.65	0.45	0.48	0.20	0.70	0.47	97.97
Net primary productivity (g C m^{-3} h^{-1})	0.45	0.35	0.40	0.35	0.15	0.15	0.20	0.35	0.25	0.30	0.45	0.55	0.45	0.55	0.30	0.35	0.45	0.35	0.20	0.15	0.35	0.45	0.45	0.35	0.40	0.35	0.15	0.55	0.34	97.97
Community respiration	0.15	0.20	0.25	0.05	0.10	0.05	0.10	0.05	0.10	0.20	0.20	0.05	0.10	0.15	0.20	0.10	0.15	0.20	0.15	0.10	0.05	0.20	0.15	0.30	0.05	0.13	0.05	0.30	0.13	100

Table 4.10a: Variations in phytoplankton (cell ml^{-1}) at sampling station 'A' of Udaisagar reservoir during Sept 2008 to 2009

Parameters	Date																									Mean	SD	CV%
	Sep.	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept.				
	28	13	28	12	27	12	27	11	26	10	25	12	27	11	26	11	26	10	25	10	25	9	24	8	23			
Bacillariophycea	190	135	160	118	160	215	180	205	215	160	170	120	125	205	175	118	190	118	215	135	100	95	105	90	35	155.58	47.24	30.36
Chlorophyceae	130	105	95	80	75	105	102	110	105	100	105	125	135	100	195	205	125	130	137	170	125	95	105	170	16	122.71	39.03	31.81
Myxophyceae	205	252	307	250	251	270	305	307	195	205	210	305	420	305	425	468	554	509	468	554	305	509	195	205	75	335.58	130.18	38.79
Desmidiaceae	15	19	10	13	7	8	16	7	9	12	5	9	10	15	17	13	7	5	9	12	16	7	9	11	45	12.75	7.83	61.43
Total	540	511	572	461	493	598	603	629	524	477	490	559	690	625	812	804	876	762	829	871	546	602	414	476	171	626.62	159.19	25.40

Table 4.10b: Variations in zooplankton (No. l^{-1}) at sampling station 'A' of Udaisagar reservoir during Sept 2008 to 2009

Parameters	Date																									Mean	SD	CV%
	Sep.	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept.				
	28	13	28	12	27	12	27	11	26	10	25	12	27	11	26	11	26	10	25	10	25	9	24	8	23			
Rotifers	35	16	9	19	20	24	42	15	2	75	25	45	20	19	12	52	30	22	16	28	16	20	17	10	16	25.20	15.62	61.98
Cladocerans	25	45	15	25	40	10	15	7	10	35	40	17	19	45	65	32	25	19	16	--	7	20	16	--	17	23.54	14.58	61.95
Copepods	45	60	10	35	15	25	9	9	25	19	12	8	--	5	12	--	25	3	9	16	25	30	3	8	12	17.50	14.09	80.52
Other	7	6	0	2	0	3	0	4	0	--	1	2	--	11	3	6	--	1	2	--	1	2	1	3	7	2.58	3.92	113.17
Total	112	127	34	81	75	62	66	35	37	129	78	72	39	80	92	90	80	45	43	44	49	72	37	21	52	66.67	29.59	44.39

Table 4.11a: Variations in phytoplankton (cell ml^{-1}) at sampling station 'B' of Udaisagar reservoir during Sept 2008 to 2009

Parameters	Date																								Mean	SD	CV%
	Sep.	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept.			
	28	13	28	12	27	12	27	11	26	10	25	12	27	11	26	11	26	10	25	10	25	9	24	8	23		
Bacillariophycea	90	103	135	215	175	160	130	175	125	118	175	135	190	105	110	105	130	125	215	205	160	190	118	205	10	150.17	47.67	31.74
Chlorophyceae	95	35	38	55	45	38	90	60	45	55	195	203	190	203	105	105	115	45	55	75	105	23	35	55	9	86.42	58.19	67.33
Myxophyceae	45	55	48	95	138	85	95	105	115	205	85	205	190	170	305	159	405	298	351	298	420	251	105	210	35	186.37	113.79	61.06
Desmidiaceae	5	7	9	10	8	11	13	5	4	7	6	3	5	2	4	3	7	8	5	9	5	10	8	13	25	8.00	4.68	58.49
Total	235	200	230	375	366	324	328	345	289	385	461	546	575	480	524	372	657	476	626	587	690	474	266	688	79	427.67	145.96	34.13

Table 4.11b: Variations in zooplankton (No. l^{-1}) at sampling station 'B' of Udaisagar reservoir during Sept 2008 to 2009

Parameters	Date																								Mean	SD	CV%
	Sep.	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept.			
	28	13	28	12	27	12	27	11	26	10	25	12	27	11	26	11	26	10	25	10	25	9	24	8	23		
Rotifers	10	30	25	16	20	9	7	8	11	17	5	3	1	3	4	2	5	7	2	6	8	11	22	9	9	10.41	7.62	73.16
Cladocerans	7	13	9	6	6	3	2	7	1	3	6	7	2	9	6	3	7	2	10	9	6	3	2	1	7	5.70	3.16	55.42
Copepods	6	3	7	9	11	17	6	1	3	7	9	7	2	6	6	7	5	8	11	3	2	1	7	8	13	6.87	3.83	55.70
Other	2	--	--	1	1	3	--	--	4	1	2	1	--	--	3	1	6	--	--	2	7	3	--	1	8	19.92	2.28	118.78
Total	25	46	41	32	38	32	15	16	19	28	22	18	5	18	19	13	23	17	23	20	23	18	31	19	37	24.92	9.41	37.76

Table 4.12a: Variations in phytoplankton (cell ml^{-1}) at sampling station 'C' of Udaisagar reservoir during Sept 2008 to 2009

Parameters	Date																								Mean	SD	CV%
	Sep.	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept.			
	28	13	28	12	27	12	27	11	26	10	25	12	27	11	26	11	26	10	25	10	25	9	24	8	23			
Bacillariophycea	17	13	10	7	9	38	13	9	7	3	2	1	5	17	3	10	9	7	17	5	13	17	9	11	16	11.17	7.51	67.29
Chlorophyceae	36	30	45	25	45	9	41	13	6	9	19	55	105	195	205	38	18	9	16	21	45	90	38	18	19	47.92	52.15	108.84
Myxophyceae	190	85	38	95	55	48	38	105	95	15	240	105	205	350	105	251	159	200	205	99	108	106	85	100	30	129.67	81.33	62.73
Desmidiaceae	3	2	5	4	3	1	5	4	7	3	2	6	0	0	3	1	4	--	2	1	3	2	1	2	16	3.33	3.24	97.18
Total	246	130	98	131	112	96	97	131	115	30	263	167	315	562	316	300	190	216	240	126	169	215	133	131	81	192.08	117.90	61.38.

Table 4.12b: Variations in zooplankton (No. l^{-1}) at sampling station 'C' of Udaisagar reservoir during Sept 2008 to 2009

Parameters	Date																								Mean	SD	CV%
	Sep.	Oct		Nov		Dec		Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sept.			
	28	13	28	12	27	12	27	11	26	10	25	12	27	11	26	11	26	10	25	10	25	9	24	8	23			
Rotifers	20	22	18	20	16	22	18	18	17	20	18	16	13	10	18	22	21	24	19	17	29	16	17	20	8	19.12	4.24	22.18
Cladocerans	16	18	13	19	11	14	14	15	18	15	23	22	15	18	15	16	20	15	18	16	19	13	11	14	9	16.54	3.34	20.22
Copepods	9	7	13	13	8	13	9	7	15	17	19	15	16	13	8	13	9	18	16	13	14	9	7	16	9	12.75	3.74	29.37
Other	1	1	2	1	1	5	2	1	1	3	1	2	1	1	2	7	3	1	1	2	1	3	1	1	6	2.12	16.67	78.60
Total	46	48	46	53	36	54	43	41	51	55	61	55	45	42	43	58	53	58	54	48	63	41	36	51	32	50.54	8.09	16.00

Table 4.14: Statistical correlation matrix amongst different water parameters of Udaisagar reservoir, Udaipur

Parameters	Air temp.	Water temp.	pH	Depth of visibility	Dissolved O_2	Free CO_2	CO_3	HCO_3	Total Alk.	EC	TDS	NO_3-N	HPO_4	GPP	NPP	CR	TPP	TZP
Air temp.	1.0000																	
Water temp.	0.2167	1.0000																
pH	0.3055	0.8424*	1.0000															
Depth of vis.	-0.2867	-0.0210	-0.1026	1.0000														
Dissolved O_2	0.4526	0.5664*	0.4522*	-0.0593	1.0000													
Free CO_2	-	-	-	-	-	-												
CO_3	0.4538	0.1770	0.0920	0.1625	0.3959*	-	1.0000											
HCO_3	-0.5949*	-0.7055	-0.0726	0.5424**	-0.2110	-	-0.2222	1.0000										
Total Alk.	-0.7897*	-0.2185	-0.3427	0.5270**	-0.2291	-	-0.0256	0.7765**	1.0000									
EC	-0.2807	-0.4422	-0.6440*	0.2380	-0.0444	-	-0.0353	0.4121*	0.5073**	1.0000								
TDS	-0.2685	-0.4358	0.6448*	0.1945	-0.0614	-	-0.0523	0.3652	0.4538*	0.9761**	1.0000							
NO_3-N	-0.3929	0.2030	0.1588	0.1388	-0.1596	-	0.0004	0.1620	0.2421	0.0384	0.0422	1.0000						
HPO_4	-0.1873	-0.2083	-0.4033	0.0263	0.2595	-	0.1594	0.0836	0.3124	0.4427*	0.4413*	-0.0542	1.0000					
GPP	-0.5608*	0.0810	0.2039	0.1839	-0.3901	-	-0.4607	0.4184*	0.3951*	-0.2026	-0.1919	0.1705	-0.0449	1.0000				
NPP	-0.5070	0.1539	0.2656	0.1446	-0.1240	-	-0.3132	0.3181	0.2946	0.0248	-0.0050	0.6554**	-0.0309	0.3748	1.0000			
CR	0.1981	0.0264	0.0456	-0.1000	0.0913	-	-0.1596	-0.0272	-0.1963	-0.1249	-0.1118	-0.4956*	-0.2192	-0.2196	-0.4413*	1.0000		

TPP	-0.3024	0.0812	0.0520	0.2000	-0.2657	-	-0.1954	0.4192*	0.2477	-0.2205	-0.2870	0.0538	-0.2515	0.2566	0.1768	0.0490	1.0000	
TZP	-0.4987*	0.1236	0.1082	-0.0570	-0.0337	-	-0.3642	-0.0826	0.1707	-0.2430	-0.2301	0.5125**	0.1374	0.2952	0.5376**	-0.1474	0.1060	1.000

*** Significant at 5% level of significance**
**** Significant at 1% level of significance**

Fig.3.2: Panoramic view of Udaisagar reservoir showing stations A, B and C

Plate 1. *Catla catla*

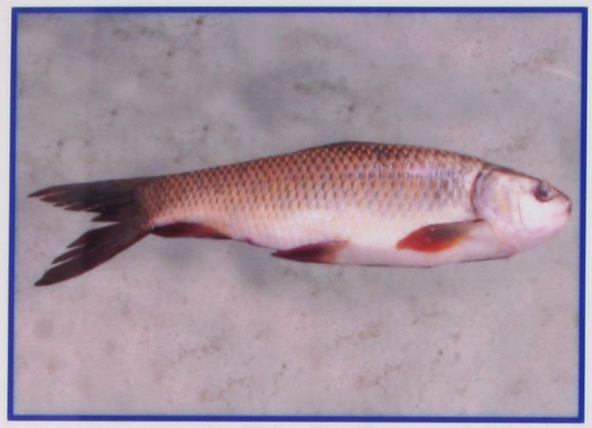

Plate 2. *Labeo rohita*

Plate 3. *Cirrhinus mrigala*

Plates showing prominent fish species of Udaisagar reservoir

Plate 4. *Puntius sarana*

Plate 5. *Puntius sophore*

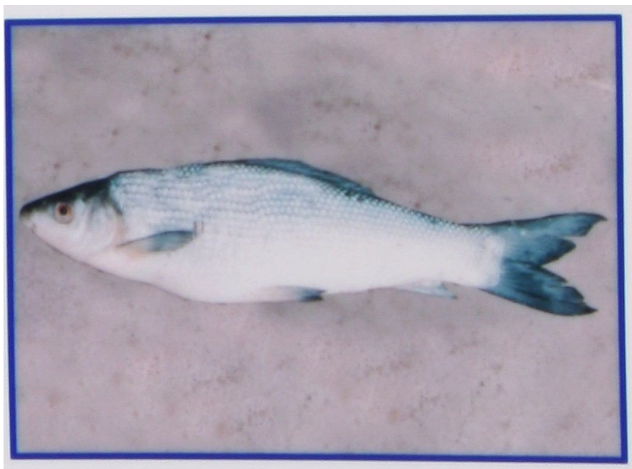

Plate 6. *Labeo gonius*

Plates showing prominent fish species of Udaisagar reservoir

Plate 7. *Labeo calbasu*

Plate 8. *Amblypharyngodon mola*

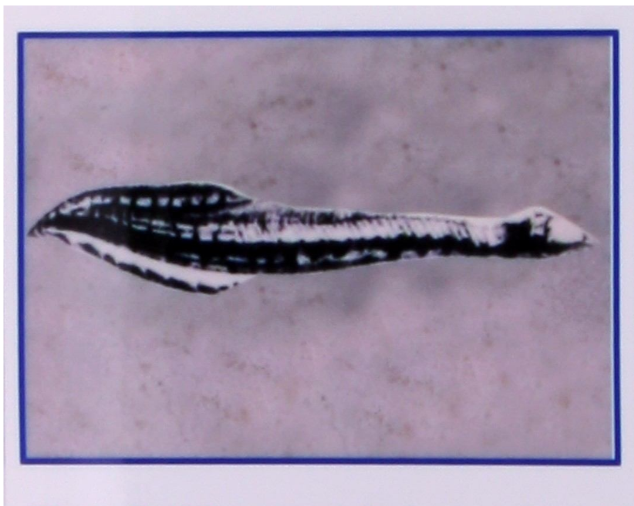

Plate 9. *Mastacembelus armatus*

Plates showing prominent fish species of Udaisagar reservoir

Plate 10. *Wallago attu*

Plate 11. *Heteropneustes fossilis*

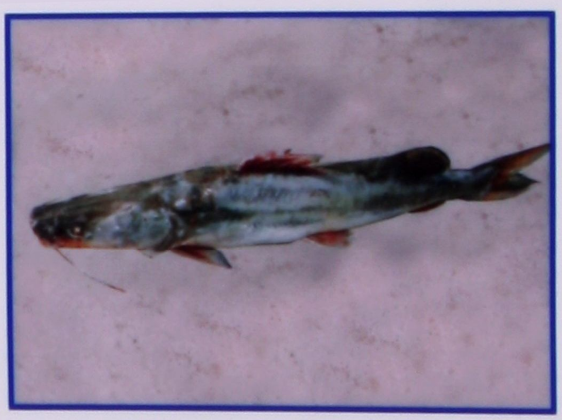

Plate 12. *Mystus seenghala*

Plates showing prominent fish species of Udaisagar reservoir

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