Water quality and the biota of Saraiyaman Lake of Udaipur Wildlife Sanctuary, Bettiah (West Champaran).

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WATER QUALITY AND THE BIOTA OF SARAIYAMAN LAKE OF UDAIPUR WILDLIFE SANCTUARY, BAIRIA, BETTIAH (WEST CHAMPARAN)

Final Report

June, 2015

Submitted to

The Divisional Forest Officer (DFO)

Bettiah Forest Division,

Bettiah, Bihar

Submitted by:

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Place: Patna

Date: 30th June 2015 Dr. Ravindra Kumara Sinha

Contents

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Saraiyaman Lake (Bettiah): A unique wetland of North Bihar

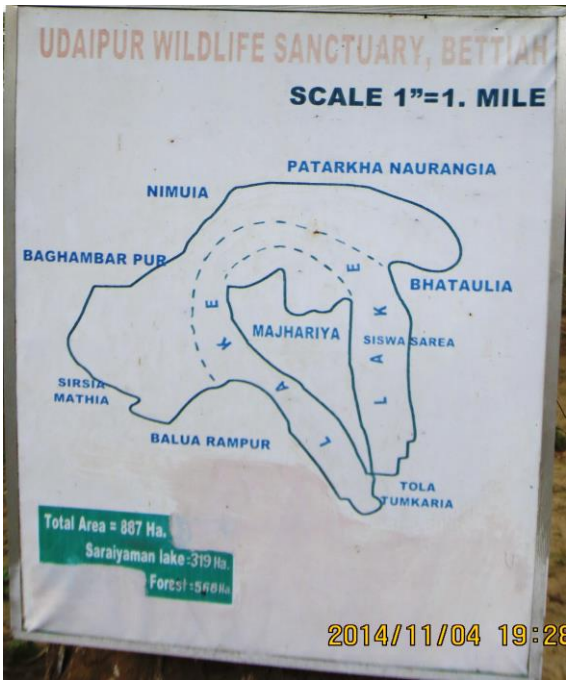
1. Introduction

Wetlands have many distinguishing features, the most notable of which are the presence of standing water for some period during the growing season, unique soil conditions, and organisms, especially vegetation, adapted to or tolerant of saturated soils. the International Union for the Conservation of Nature and Natural Resources (IUCN) at the Convention on Wetlands of International Importance Especially as Waterfowl Habitat, better known as the Ramsar Convention in 1971, adopted the following definition of wetlands:

"area of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt including areas of marine water, the depth of which at low tide does not exceed 6 meters."

1.1. Name, location, constitution and extent; approach and access

The 'Udaipur Wildlife Sanctuary' is situated in the West Champaran district of Bihar, about 15 km South-West of Bettiah town under 'Bairia' Circle, covering an area of 887.35 hectares of forest land. This sanctuary was notified in 1978 vide notification no. 12 / 78 Forest Patna dated 29.4.78 under the Wildlife (Protection) Act 1972 (Sharma, 1996). The Sanctuary is connected with Bettiah through a pitch road. The Geographical Coordinates of the Sanctuary is latitude $26^0$50'N and longitude is $84^0$28'E. Udaipur Forest occurs on a more or less flat ground in the form of a crescent moon bordering a lake of 319 hectares known as 'Saraiyaman Lake', encircling the land of Majharia village more or less in the form of an island.



Site map at Forest Rest House showing Saraiyaman Lake

A small patch of forest exists on the other side of the lake in the village Majharia and along its border. The Saraiyaman is connected with a river, called ‘Haraha’, which forms a part of the western boundary of Udaipur forest. The Haraha is not an aggressive river and as there is not much of undulation on the forest floor, the configuration of this forest land is comparatively stable (Roy Chaudhury, 1960).

Sri H. K. Rai (D.F.O., Bettiah) leading the team near the entrance of Udaipur Wildlife Sanctuary

1.2. Statement of significance/ importance

The area of the sanctuary, though small, has a tremendous value from ecological and tourism point of view. More than one third of the area of sanctuary is occupied by a ‘horse shoe shaped’ freshwater lake, Saraiyaman, constituting an aquatic ecosystem. The small area of the sanctuary has got beautiful cane brakes in the north – west and west of the forests along the *nalas*. Saraiyaman Lake is uniquely surrounded by the Jamun trees, is a horse-shoe shaped natural lake and whole area drains in this lake. The Jamun fruits fall in the lake which may be adding ethno-medicinal value to the lake water.

2. Background information and attributes

2.1 Biogeographic zone and wetland type

As far as biogeography is concerned, the area falls in the *Oriental Region* according to Wallace. The biogeographic classification in relation to this area is ***Indomalayan Realm*** as given by Udvardy (1975) together with Wallace's terminology, *Oriental Region*. Actually in 1975, the Wallace's classification of biogeographical regions was modified. It does not differ much from Wallace's original classification but takes vegetation into account mainly as field experience and faunistic works for this area was lacking.

About this, Udvardy (1975) clarifies that the tropical ecosystems of the Eurasian continent and of the neighboring Southeast Asian (Australasian) Archipelago form a subkingdom of the Palaeotropical Kingdom of Engler; Slater named this area an *Indian Region*, but Wallace's term, *Oriental Region* stuck. This term was perfectly acceptable when the world was looked upon from longitude 0^{o} as center, but is not so expressive today. Therefore, he had shorn it from its Pacific Island world extension, and renamed this area as a biogeographical realm – the *Indomalayan Realm*. It consisted of the mainland of Southeast Asia, south of the temperate-Palaearctic Himalayas chain and the Szechwan Mountains.

Saraiyaman Lake is an ***Ox-bow Lake*** type wetland and seems to be formed after dereliction from the River Gandak probably in early 19^{th} century.

2.2. Boundaries: The boundaries of the sanctuary is as follows –

North: Cultivation land of village Patrakha-Naurangia,

South: Cultivation land of Balua-Rampurva and Tumkuria village,

East: Cultivation of Siswa Saria village, and Bhataulia,

West: Harhi Nala and cultivation land of Baghambarpur and Sirsia-Mathia village.

2.3. Altitude / Terrain types: Udaipur Forest occurs on a more or less flat ground in the form of a crescent moon bordering a lake known as Saraiyaman at an altitude of 65 meter (Sharma, 1996).

2.4. Catchment characteristics: Geology, rock and soil: The area is occupied by old alluvium, no rock is visible. The soil is clayey, sandy loam at places and is grayish in color. Humus is present and soil is deep. The configuration of ground is plain and low-lying (Roy Chaudhury, 1960).

3. Materials and Methods

3.1 Water sampling and analysis

Subsurface water samples were collected following standard procedures. Air and water temperature were measured at the time of sampling. Besides, water temperature, pH, Dissolved Oxygen, Electrical Conductivity, Total alkalinity, carbonate, free Carbon dioxide, bicarbonate were analyzed on the spot. For other parameters, the samples were preserved and transported to the laboratory at Patna where the samples were analyzed within the time frame. Altogether the water samples were analyzed to assess the following physico-chemical and biological parameters.

3.1.1 Physical parameters: Air temperature, water temperature, pH, electrical conductivity, turbidity, total dissolved solids (TDS) and total suspended solids (TSS).

3.1.2 Chemical parameters: Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), total alkalinity, free CO_2, chloride, total hardness, calcium, magnesium, sulphate, phosphate, nitrate, nitrite, sodium, potassium and total iron.

3.1.3 Biological parameters: Primary Productivity, Zooplankton, benthic macro-invertebrates, fish and birds.

3.2 Collection and preservation of samples: Water samples were collected only once in the first week of November 2014 following Standard Methods (APHA, 1998). Grab water samples were collected manually from a depth of about 20-30 cm from the water surface using polyethylene carboy. Samples for general analysis were kept in 1 liter capacity polyethylene bottles and transported to the laboratory in ice-box for further analysis. Separate samples were collected for the parameters that required specific preservation as detailed in the following table:

Table: Type of containers and sample preservation methods.

Parameters	**Container**	**Preservation**
Total dissolved solids, total suspended solids, chloride, phosphate, sulphate, calcium, magnesium and total hardness.	Polyethylene	4^{o} C, dark
Biological Oxygen Demand,	BOD Bottles made of Glass	4^{o} C, dark
Chemical Oxygen Demand and Nitrate Nitrogen	Polyethylene	Acidified with H_2SO_4, pH< 2
Plankton	Glass vials (15 ml)	5% formalin solution
Benthos	Plastic container	5% formalin and 70% alcohol

Fish	Ice-box	5% formalin

Water temperature, pH, electrical conductivity, alkalinity, free CO_2 and dissolved oxygen were measured on the sampling spot.

3.3 Analytical techniques

Water quality parameters were analyzed following the Standard Methods (APHA, 1998); de Zwart and Trivedi (1995); and Trivedy and Goel (1986). A brief outline of the methods used for the laboratory analysis of these parameters is as follow:

3.3.1 Water temperature: Water temperature was measured with the help of a centigrade thermometer (-10 to 40°C) with 0.1°C graduations, by immersing it in water. The value was expressed in °C.

3.3.2 pH: pH is the measure of the intensity of acidity or alkalinity expressed in terms of concentration of hydrogen ions in water. The normal acidity or alkalinity depends upon excess of H^+ and OH^- ions over the others. It is generally measured on a log scale and equals to negative log_{10} of hydrogen ion concentration. pH scale ranges from 0 to 14 with 7 as neutral, below 7 being acidic and above 7 as alkaline. The pH value of water was estimated using a portable pH meter (*Make*: Eutech Instrument, Malaysia; *Model*: pH testr 2).

3.3.3 Electrical conductivity: It is the measure of capacity of a substance or solution to conduct electric current. As most of the salts in the water are present in the ionic form capable of conducting current, therefore, conductivity is a good and rapid measure of the total dissolved solids. The parameter was estimated at the sampling site with the help of portable conductivity meter (*Make*: Eutech Instruments, Malaysia; *Model*: EC testr) and expressed as µS/cm (µSiemens per cm).

3.3.4 Total Dissolved Solids (TDS) and Total Suspended Solids (TSS): A well - mixed sample was filtered through weighed glass fiber filter paper (47 mm diameter) and the filtrate was evaporated to dryness in a weighed dish and dried to constant weight at 180 ± 5^0 C. The increase in dish weight represented the total dissolved solids. The results were expressed in mg/L.

The residue retained on the filter paper was dried to a constant weight at 105^0 C. The increase in weight of the filter paper represented the total suspended solids. The results were expressed in terms of mg/L.

3.3.5 Dissolved Oxygen (DO): Dissolved oxygen reflects the physical and biological processes prevailing in the water. Its presence is essential to maintain the higher forms of biological life in the water. It was determined by the 'Winkler's azide modified method' on the spot at sampling site using manganous sulphate and alkaline iodide – azide as reagent, sodium thiosulphate (0.025 N) as titrant and 1% starch solution as indicator. The results were expressed in mg/L.

3.3.6 Biochemical Oxygen Demand (BOD): Biochemical Oxygen Demand is the amount of oxygen utilized by microorganism in stabilizing the organic matter. The demand for oxygen is proportional to the amount of organic waste to be degraded aerobically.

It was determined by subtracting DO value after five days incubation at 20°C from initial DO, which was estimated on the sampling spot. The results were expressed as mg/L.

3.3.7 Chemical Oxygen Demand (COD): Chemical Oxygen Demand is the oxygen required by the organic substances in water to get oxidized by a strong chemical oxidant.

It was estimated by 'Open Reflux method'. Ferroin and ferrous ammonium sulphate (0.025N) were used as indicator and titrant respectively. Other reagents used in the estimation were Ag_2SO_4, Hg_2SO_4 and $K_2Cr_2O_7$. The COD results were expressed as mg/L.

3.3.8 Total Hardness: It is a property of water that prevents lather formation with soap and increases its boiling point. Hardness of water is due to the presence of carbonate and bicarbonate salts of the cations and sulphates and chlorides of the metals. Principal cations causing hardness are Calcium and Magnesium.

It was determined by 'EDTA Titremetric method' using Ethylenediamine tetra acetic acid (EDTA) 0.01M as titrant and Erichrome black –T as indicator. Results were expressed as mg $CaCO_3$/ L.

3.3.9 Calcium: Calcium is one of the most abundant substances of the natural waters, present in high quantities in the rocks and leach out to contaminate the water.

It was estimated following 'EDTA Titremetric method'. Murexide was used as an indicator and EDTA, 0.01M as titrant. The results were expressed as mg Ca/ L.

3.3.10 Magnesium: It also occurs in all kinds of natural waters with calcium but in lower concentration. Its principal sources in natural waters are various kinds of rocks, sewage and industrial wastes.

It was estimated as the difference between total hardness and calcium hardness expressed as: mg Mg^{++} /L = [total hardness (as mg $CaCO_3$/ L) – calcium hardness (as mg Ca/L)] × 0.243.

3.3.11 Total Alkalinity (TA): Alkalinity of water is its acid neutralizing capacity. It is sum of all titrable bases. Alkalinity of many surface waters is primarily a function of carbonate, bicarbonate and hydroxide content.

It was determined by Titremetric Method using methyl orange as indicator and N/50 H_2SO_4 as titrant. The results were expressed in terms of mg $CaCO_3$/ L. This parameter was also estimated on the spot.

3.3.12 Free Carbon Dioxide (CO_2): Free carbon dioxide was determined by titrating the water sample with N/50 NaOH solution using phenolphthalein indicator (alcoholic). If the color turns pink then the free CO_2 was absent. If the sample remained colorless then it was titrated against N/50 NaOH solution. At the end a pink color appeared. It was calculated using the formula:

$$\text{Free } CO_2, \text{ mg/L} = \frac{(\text{ml.} \times \text{N}) \text{ of NaOH} \times 1000 \times 44}{\text{ml. of sample.}}$$

3.3.13 Chloride: It occurs naturally in all types of water; however, domestic sewage is a major source in sewage fed water body. Man and other animals excrete very high quantities of chlorides together with nitrogenous compound.

It was estimated by Argentometric method using 5% potassium chromate solution as indicator and 0.0141N silver nitrate solution as titrant. Result was expressed as mg Cl^-/ L.

3.3.14 Sulphate: It is a naturally occurring anion in all kinds of natural waters. Biological oxidation of reduced sulphur species to sulphate increases its concentration; rainwater has quite high concentration of sulphate in the areas of high atmospheric pollution. In arid and semi-arid regions, it is found in particularly higher concentration due to the accumulation of soluble salts in solids and shallow aquifers.

It was estimated by 'Turbiditimetric Method'. Concentration of sulphate was measured by taking absorbance by digital spectrophotometer (Systronic-104) at 420 nm wavelength followed by comparison with a standard curve. Results were expressed in terms of mg SO_4^{-2} / L.

3.3.15 Phosphate: In fresh water, phosphorus is present mainly in inorganic forms such as PO_4^{-3} and its major sources are detergents, fertilizers and waste waters. The rocks in which most of the phosphorus is bound are generally insoluble in water and hence the phosphorus content of natural freshwater is low.

The amount of phosphate was determined by 'Stannous chloride method' using ammonium molybdate and stannous chloride solution. The absorbance was recorded with the help of spectrophotometer at 690 nm wavelength. The amount of phosphate (mg/L) was calculated from standard curve prepared for phosphate.

34.3.16 Nitrate: It represents the highest oxidized form of nitrogen. The most important source of nitrate is biological oxidation of organic nitrogenous substances, which comes in sewage and industrial wastes or produced indigenously in the waters.

It was estimated by 'Phenol disulphonic acid method' using silver sulphate, phenol disulphonic acid and ammonia solution as reagents. Absorbance was recorded on spectrophotometer at 410 nm wavelength. The amount of nitrate (mg/L) was calculated from the standard curve prepared for nitrate - nitrogen.

3.3.17 Nitrite: Nitrite is formed in waters as an intermediate form of the oxidation of ammonium compounds or by reduction of nitrates in the nitrogen cycle because there is no mineral source of this ion in natural waters. Nitrite is an unstable compound, gets converted into either ammonia or nitrite depending upon the conditions prevailing in the water and due to its reductive nature, nitrite is highly toxic. Usually the concentration in natural waters are in the order of 100 µg/L but higher amounts may be present in sewage and industrial wastes, especially in biologically purified effluents and in polluted streams. The high concentration of nitrites can also cause 'blue baby syndrome (Methamoglobinemia)' in infants.

Nitrite reacts in strongly acidic medium with sulphanilamide and the resulting diazo compound is coupled with N-(1-naphthyl)-ethylenediamine-dihydrochloride to form a red colored compound. The absorbance was recorded on spectrophotometer at 543 nm wavelength and the

amount was estimated from the standard curve prepared for nitrite-nitrogen and expressed as nitrite (mg/L).

3.3.18 Total Iron: Iron is one of the most abundant elements of the rocks and soil, ranking fourth by weight. All kinds of waters including ground water have appreciable quantities of iron. In water samples, iron may occur in true solution, in a colloidal state that may peptized by organic matter, in inorganic or organic complexes, or in relatively coarse suspended particles. It may be ferrous or ferric, suspended or dissolved. Silt and clay in suspension may contain acid-soluble iron.

It was estimated by 'Phenanthroline method' by converting all the iron into ferrous state by boiling with hydrochloric acid and hydroxylamine solution and treated with sodium acetate solution and phenanthroline solution at pH 3.2 to 3.3. Three molecules of phenanthroline chelate each atom of ferrous iron to form an orange-red complex and absorbance was recorded on spectrophotometer at 510 nm wavelength. The amount of total iron (mg/L) was calculated by using the standard curve prepared for total iron.

3.3.19 Sodium and Potassium: These are important cations occurring naturally in surface waters through weathering of rocks. Domestic sewage also contributes these cations to surface waters. Sodium and Potassium were determined by 'Flame Emission Photometric method' using Digital Flame Photometer – 126 coupled with FPM Compressor – 126 of *Systronics* at 589 nm and 786 nm wavelength respectively. The results were expressed in terms of mg /L.

3.3.20 Aquatic Macrophytes: The aquatic macrophytes consist of vascular flowering plants, but it also includes the aquatic mosses, liverworts, ferns, and the larger macro-algae. Macrophytes studies involve functioning of aquatic plants in nutrient and heavy metal uptake and turnover, use of plants as indicator organisms, and effects of plants on water quality conditions.

Specimens of aquatic macrophytes were collected and brought to the laboratory at Patna. A stereomicroscope was used to identify many of the plants, especially aquatic grasses and sedges. Identification of macrophytes was done with the help of Cook (1996), and other standard literature like Bhattacharya and Sarkar (1998); Haines (1921-23); Ghosh (2005); Nesemann and Sharma (2012); and Sharma and Nesemann (2013).

3.3.21 Plankton: The zooplankton in freshwater comprise principally of protozoans, rotifers, cladocerans, and copepods. Qualitative and quantitative analysis of the zooplankton are important not only to assess the species diversity but for monitoring of the river water quality.

The plankton samples were collected for quantitative and qualitative studies. For quantitative examination, plankton sample was collected by filtering 50 liters of water through plankton net (made up of bolting silk number 21 with 77mesh/cm^2) and for qualitative examination, the plankton net was dragged at 45° angle for few minutes in limnetic zone of the lake. The plankton were preserved in 5% formalin solution at the site and then brought to the laboratory for qualitative and quantitative analysis. Identification was done using Sedgwick-Rafter cell and Trinocular Research Microscope, *Microlux-11* of Kyowa, Tokyo with the help of standard texts like, Alfred *et al.* (1973); Vasisht and Sharma (1976); Tonapi (1980); Michael and Sharma (1988); Sharma (1983, 1986, 1987); and Ward and Whipple (1992).

The quantitative estimation of plankton was made by following formula:

$$\mathbf{n = \frac{a \times 1000 \times c}{L}}$$

Where, n = number of plankton per liter of water

a = Average number of plankton in 1 ml of sub-sample (concentrated)

L = Volume of original water sample in liters.

c = ml of plankton concentrated.

Diversity Indices: Diversity indices are mathematical expressions that combine three components of community structure-richness (number of species present), evenness (the distribution of individuals among species) and abundance (total number of organisms present). It is used to describe the response of a community to the quality of its environment. Shannon-Wiener diversity index (1964), beta diversity of Whittaker (1972) and Evenness index of Jaccard (1942) was calculated as follows and as suggested by Mugurran (2004):

Shannon-Weiner Diversity Index: Shannon-Weiner diversity index (H') was calculated using following formula:

Diversity index (H') = $pi.\log pi.$ or, $\sum_{i-1}^{s}\left(\frac{ni}{N}\right)\ln\left(\frac{ni}{N}\right)$.

Where, H' = Shannon Wiener index of diversity;

ni = Total no of individual of a species;

N = Total no of individuals of all species.

Beta diversity: Beta diversity is a comparison of diversity between sites or communities, usually measured as the amount of species change between the ecosystems. Beta diversity (β) was computed as suggested by Whittaker (1972) to determine the rate of species change across the sites. The expression is given below:

$$\text{Beta diversity } (\beta) = \left(\frac{S_c}{S} \right).$$

Where, Sc = total number of species encountered in all sites

S = average number of species per site

Evenness Index: Evenness was calculated by using Evenness index of Jaccard (1942):

$$\text{Jaccard Evenness } (J') = \left(\frac{H'}{H \max} \right) = \left(\frac{H'}{\ln S} \right).$$

Where, H' = Shannon diversity index;

S = Number of species.

H_{max} is the maximum diversity which could possibly occur in a situation where all species had equal abundance.

3.3.22 Benthos: The benthic macro-invertebrates inhabit the sediments at bottom, or on or in other available bottom substrates. These communities respond to changing habitats and water quality by alterations in community structure (invertebrate abundance and composition). However, many habitats, especially disturbed ones, are dominated by a few species. Macro-invertebrate community responses to environmental changes are useful in assessing the impact of municipal, industrial, and agricultural wastes, and impacts from land uses on surface waters.

The benthic macro-invertebrate samples (grab samples) were collected from a point away from any possible wastewater discharges of concern opposite Forest Rest House for qualitative analyses by Eckman dredge 15.2 × 15.2 cm in size. The dredged material was then sieved through a metallic sieve (mesh size 425 micron). For qualitative study, benthic samples were also collected for as many different organisms as possible by any method that captured representative species. The macro-invertebrates were then transferred from the metallic sieve to a white enamel tray from where they were picked up manually and preserved in 5% formalin. The macro-invertebrates were then sorted out and enumerated group wise, then species wise using appropriate microscope. Identification was done with the help of Alfred *et al*. (1973);

Tonapi (1980); Subba Rao (1989); Ward and Whipple (1992); Subba Rao *et al.* (1995); Nesemann and Sharma (2005a, b); and Nesemann *et al.* 2007.

3.3.23 Primary Productivity: The well known and universally accepted '*Light and Dark bottle method*' of Gaarder and Gran (1927) was adopted for the estimation of primary productivity in this study. This method takes care of mainly phytoplankton productivity. To assess the primary productivity of both macrophytes and phytoplankton, '*Diurnal Method*' should be used. It needs more manpower, time and energy. Nevertheless, *Light and Dark Bottle Method* is universally well recognized method. Water samples were collected from the surface and at the lower level (at the end of transparency) in a large polyethylene bottle of 2.5 liter capacity. Collected water samples were then filled in the two sets of initial, light (transparent) and dark (black painted bottle) bottles from the desired depth. The dissolved oxygen contents of the initial bottles were determined immediately following the Winkler's azide modified method (APHA, 1998) before suspending the light and dark bottles. The bottles were incubated with the help of float and nylon rope at a regular interval of 3 hours during the daytime. After the expiry of incubation periods, the suspended bottles were removed and the dissolved oxygen contents in each bottle were determined. The calculated average hourly values were pooled in an average daily data.

Calculation:

Gross Primary Productivity: Oxygen mg/L/hr = Dl – Dd/h.

Net Primary Productivity: Oxygen mg/L/hr = Dl – Di/h.

Community respiration: Oxygen mg/L/hr = Di – Dd/h.

Where,

Di = dissolved oxygen in the initial bottle in mg/L.

Dl = dissolved oxygen in the light bottle in mg/L.

Dd = dissolved oxygen in the dark bottle in mg/L.

h = duration of incubation in hours.

3.3.24 Fish: Fish samples were collected only once by casting the fish net (length 4.05m, diameter 10.8 m and mesh size 12-14mm) bearing heavy sinkers of solid irons beads (150-250) weighing 5.0 kg attached to the periphery with the help of local fisherman twice near the Forest Rest House in the shallow water zone of the lake. Identification and analysis was done with the help of standard texts of Srivastava (1980); Talwar (1991); Talwar and Jhingaran (1991); Biswas (1993); Khanna (2003); Vishwanath, Lakra and Sarkar(2007); and Pandey and Shukala (2007).

3.3.25 Birds: Avian fauna were recorded following actual sighting methods as well as their calls and identified with the help of standard literature, viz. Ali (1979); Ali and Ripley (1987); Kazmierczak, (2000); and Grimett *et al*. (2007) .

3.3.25 Data Analysis: Parameter wise range, mean and standard deviation were calculated for water quality data and some of the biological data of different sampling sites. The statistics applied (Zar, 1984) in the analysis are as below:

Mean: It is most widely used measure of central tendency.

$$\overline{X} = \frac{\sum Xi}{n}$$

Where $\overline{X}$ is sample mean, $\sum X_i$ is sum of all measurements in the sample and n is number of measurements.

Standard deviation: It is measure of absolute deviation from mean.

$$S = \frac{\sum \left| Xi - \overline{X} \right|}{n}$$

Where, $\sum \left| Xi - \overline{X} \right|$ is sum of all deviations from the mean and *n* is sample size of group.

Range: The difference between the highest and lowest measurements in a group of a data is termed as range.

Range = $X_n - X_1$

Where X_n is lowest value and X_1 is highest value.

3.4 Bathymetry

For depth profile of the Saraiyaman Lake, we measured the depths at four points across the section of the lake at an interval of approximately 500 meters; and at different points, respective geographical coordinates were also recorded with the help of GPS Receiver (Model *GPS-315, Magellan* make). For recording depth, we used SONAR System (Model *X-25A, Lowrance* make). The Forest Rest House was our reference point and we proceeded first towards right hand side and then in the left hand side of the lake as far as it was navigable. For recording depth and GPS locations data, we used an oar driven country boat made available to us by the DFO (Bettiah), Sri Hem Kant Rai, with two boatmen. As the speed of the boat was less than 3km/ hr., the odometer reading (distance travelled) of the GPS Receiver was not working, so we used the eye

estimation method for the distance travelled. Several points of the selected cross-section were heavily infested with submerged macrophytes and it was difficult to record the depth with SONAR so we had to shift a little bit in either side of the selected point for recording the depth. We also recorded a land-mark opposite each segment and presented in Table 8 along with respective GPS locations and depths.

4. Hydrological features and Results

4.1. Sources of water: The main source of water is precipitation and runoff from the catchment area. Earlier the lake was connected with the River Gandak but currently the connection is snapped.

4.2. Physico-chemical characteristics/ water quality of the Lake: Water quality of the lake at four different sites of the Saraiyaman has been depicted in Table No. 1. The water quality of the adjacent River Gandak in the same month (November 2014) has also been presented in the same table. However, the river water samples were collected upstream Hajipur.

It may be observed that the water quality of the lake and the Gandak River is almost comparable except the turbidity and Electrical Conductivity which is due to flowing or lotic nature of the river.

On the basis of one time sampling, the water quality of the lake has been found to be conducive to sustain the aquatic life. pH of the lake water ranged between 7.62 - 9.19 (mean=8.09±0.74), the water temperature varied between 26 - 29 ^{O}C (mean 27.88±4.37 ^{O}C) during day hours (7:00 AM - 4:00 PM). Turbidity was found to be in the range of 1.0 - 4.0 NTU (mean 3.0±1.41 NTU) which indicates that light penetration in the lake is suitable for better primary productivity of the lake. The Secchi Disc transparency was recorded as 1.75 meter in the middle of the lake, opposite Forest Rest House. Electrical conductivity lies between 319 - 402 µS/cm with an average of 379±40.34 µS/cm. Total alkalinity ranged between 162.8 - 200 mg/l (as $CaCO_3$), and the average was 186±16.19 mg/l. The alkaline nature of water is more suitable for the aquatic organisms.

The average Dissolved Oxygen content was found to be 5.89±3.95 mg/l lying within the prescribed limit of 5.0 mg/l for surface water to sustain aquatic life, especially fish.

However, the Dissolved Oxygen in the Lake water near the Forest Rest House was only 2.5 mg/l at 8 AM; and near Majharia village the same was 2.82 mg/l at 11.45 AM. The DO levels were found quite fluctuating as DO in the water sample collected from the bank (littoral zone) close to the Forest Rest House was 10.71 mg/l. These observations indicate eutrophic condition of the lake; however, **based on one time sampling the same cannot be concluded. It needs regular monitoring on long term basis**. The Biological Oxygen Demand (BOD) was also lower than 3.0 mg/l, with an average load of 2.64±0.86 mg/l which meets the bathing water quality as per norms of the Central Pollution Control Board. **It needs regular monitoring along with estimation of the bacterial load also in the lake**. Total hardness ranged from 175 - 180 mg/l and its average value was 177.5±2.08 mg/l while the chloride concentration was found to be in the range of 7.08 - 9.91 (average 9.09±1.35) mg/l. A lower concentration of chloride indicates that it is still free from anthropogenic pressure especially sewage pollution. Calcium, Magnesium, Sodium and Potassium fluctuated between 32.08 - 37.18 (average 34.81±2.41), 20.41 - 23.33 (average 21.99±1.44), 16.0 - 18.1 (average 17.25±0.90) and 12.5 - 13.2 (average 12.80±0.32) mg/l respectively.

Nutrients like nitrate, sulphate, phosphate were found to be ranging between 0.438 - 0.621 (average 0.529±0.077), 5.12 - 7.32 (average 5.89±0.98), 0.041 - 0.062 (average 0.053±0.099) mg/l respectively. The main source of the nutrients appears to be autochthonous, i.e. from the lake itself, from the detritus or dead and decaying organic matters. However, the leaf litters and fruits from the Jamun and other trees surrounding the lake are also adding nutrient load to the lake. Though the nutrient load does not indicate eutrophic condition of the lake, but the large fluctuation of Dissolved Oxygen does. Thus the suitability of lake for aquatic life is questionable as DO content fluctuation and nutrient load are not at par. At the same time **not much can be concluded from one time sampling in any water body**. Total iron concentration was as low as 0.25±0.08 (range 0.19 - 0.36) mg/l. Total dissolved solids were found to be more than 90% of total solids ranging between 209 - 235 (average 221±10.80) mg/l. Values of the total volatile dissolved solids ranged from 18 to 31% of the total dissolved solids. The source of organic matter is mainly the lake ecosystem and surrounding forest as no other source of domestic or industrial discharge could be noticed. The same in the River Gandak in November 2014 was 17%. A total suspended solid in the Gandak was higher due to flowing water (Lotic system) compared to the Saraiyaman Lake, a Lentic System, i.e. stagnant water body.

4.3. Bathymetry: In the first week of November 2014, we recorded maximum depth of 9.45 meter (31 feet) with the SONAR in the middle of the lake opposite Watch Tower near the Forest Rest House and an average depth of 6.12±1.63 meter (Range 3.23 - 9.45 meter, n= 37). And as per the 1995 Management Plan of the Sanctuary (Sharma, 1996), water depth in the 'Saraiyaman Lake' used to be 25- 30m (70-100 feet) in the middle and decreases as we go to sides. Thus the lake has lost more than 2/3rd of its depth within last 20 years, may be due to excess silt load entering into the lake with the run-off from the devegetated catchment area, besides heavy detrital load of infested vegetation/ macrophytes in the lake. We observed that towards both ends, the lake has got silted and the area is being heavily occupied by weed/grasses. The depth profile along with the geographical coordinates of the sections of the lake surveyed by our team in the first week of November 2014 has been shown in Table 8 and the Google map of the lake annexed with this report (Figure 1).

5. General ecological features including flora and fauna

5.1 Terrestrial Vegetation

As per the Management Plan of Udaipur Wildlife Sanctuary (Sharma, 1996) the Udaipur forest along Saraiyaman lake contains a special type of moist miscellaneous forest. Along the border of the lake a gregarious crop of *Eugenia jambolina* (Jamun) occurs with occasional *Ficus tomentosa* (barun). In the lake, patchy growth of *Barringtonia acutangula* (Izzar) was found. On the flat surface towards the south and between the banks of the Saraiyaman and of Haraha river a gregarious crop of *Putranjiva roxburghii* (Patjug) occurs (Roy Chaudhury, 1960). The other species were as follows:-

Adina cardifolia (karama); *Alstonia scholaris* (chatwan); *Streblus asper* (shihora); *Mallotuas philippinansis* (rohini); *Erhetia laevis* (datrang); *Aegle marmelos* (bel); *Ghor karanja*; *Pongamia glabra* (karanj); *Milusa velutina* (domsal); *Placourtia ramonchi* (katahi semal); Khair (*Acacia catechu*) and Sisoo (*Dalbergia sisoo*).

The sanctuary area contains moist miscellaneous forests as well as plantations raised during last two decades. Khair trees are found scattered.

Moist mixed deciduous forests **(3C/C_3**/A): Inferior miscellaneous forests occur mostly in the western portion of this sanctuary and in patches in the southern side. The tract is liable to inundation each year. The main species are as under –

Top canopy: *Syzgium cumini* (Jamun), *Adina cardifolia* (Karma), *Garuga pinnata* (Kankar), *Lannea grandis* (Jhigna), *Salmalia malabarica* (Semal), *Bischefia javanica, Dalbergia sisoo* (Shisham).

Middle story: *Mallotus philippinensis* (Rohina), *Aegle marmelos* (Bel), *Putranjiva roxburghii, Zizyphus jujube* (Ber), *Acacia catechu* (Khair)**,** *Strablus asper, Croton oblongigolius, Pngamis glabre, Ailanthus excelsa.*

Ground cover: *Colebrookie oppositifolia* (Bhaint), *Clerodendron infertunatum, Holarrhena antidysentrica.*

Grasses: *Erianthus munja* (Munj), *Saccharum spontaneum* (Kush) are sparsely found.

Climbers: *Butea parviflora* and Caesalpinae. Dig plantation of Teak, Sisoo, bamboo have been raised in plantation working circle in about 340.679 hectare.

***Cane brakes* (1B/ E1)**: Cane brakes are found in the North-west and west of the forests along nalas. *Calamus tenuis* (cane) occurs under large sized miscellaneous trees and rise to height up to 40 feet or more depending upon support of the trees.

5.2 Aquatic Macrophytes

The lake is highly infested with submerged, floating and emerged macrophytes. We could collect some specimen from the lake near Forest Rest House. Altogether only 14 species were identified, during this brief study, which have been depicted in Table 2. This is a small fragment of the total macrophytes as we could collect samples from one point only. **It needs regular study covering the whole lake in different seasons for at least three years to complete the list of the macrophytes**.

5.3 Primary Productivity of Saraiya Man, Bettiah

Primary Productivity is the productivity by chlorophyll bearing plants. In the lake the plants include macrophytes and phytoplankton. The experiment was conducted for 8 hours at only one site, i.e. FRH site in the middle of the lake at two points, subsurface and at depth of about 6 feet, the depth of Secchi Disc Transparency. The details have been given below.

Basic data:

Geographical coordinates of the sampling site: $26^0$48'48N/ $84^0$26'06E

Depth: 27.5 feet (8.36 mtr.)

Transparency: 5.9 feet (1.75 mtr.)

Water temperature: 26.0 ^{0}C

Wind: Westerly

Weather: Sunny

Initial DO of sub-surface sample at 8:00AM: 2.50 mg/L

Initial DO of euphotic zone's sample at 8:00AM: 1.96 mg/ L

Final DO of sub-surface sample at 4:00PM (Light bottle): 3.99 mg/ L

Final DO of sub-surface sample at 4:00PM (Dark bottle): 1.80 mg/ L

Final DO of euphotic zone's sample at 4:00PM (Light bottle): 1.80 mg/ L

Final DO of euphotic zone's sample at 4:00PM (Dark bottle): 1.25 mg/ L

Calculation:

A. Sub-surface sample:

- Gross primary productivity = $\frac{Dl-Dd}{h} = \frac{3.99-1.80}{8} = 0.274$ O_2 mg/L/hr

  or, $0.274 \times 0.375 = 0.103$ gC/m^3hr. or, $0.103 \times 12 = 1.236$ gC/m^3/day
- Net primary productivity = $\frac{Dl-Di}{h} = \frac{3.99-2.50}{8} = 0.186$ O_2 mg/L/hr

  or, $0.186 \times 0.375 = 0.070$ gC/m^3hr. or, $0.0.070 \times 12 = 0.840$ gC/m^3/day
- Community respiration = $\frac{Di-Dd}{h} = \frac{2.50-1.80}{8} = 0.088$ O_2 mg/L/hr

  or, $0.088 \times 0.375 = 0.033$ gC/m^3hr. or, $0.033 \times 24 = 0.792$ gC/m^3/day

B. Euphotic zones sample:

- Gross primary productivity = $\frac{Dl-Dd}{h} = \frac{1.80-1.25}{8} = 0.069$ O_2 mg/L/hr

  or, $0.069 \times 0.375 = 0.026$ gC/m^3hr. or, $0.026 \times 12 = 0.312$ gC/m^3/day
- Net primary productivity = $\frac{Dl-Di}{h} = \frac{1.80-1.96}{8} = -0.020$ O_2 mg/L/hr

  or, $-0.020 \times 0.375 = -0.0075$ gC/m^3hr. or, $0. 0075 \times 12 = -0.090$ gC/m^3/day
- Community respiration = $\frac{Di-Dd}{h} = \frac{1.96-1.25}{8} = 0.089$ O_2 mg/L/hr

  or, $0.089 \times 0.375 = 0.0334$ gC/m^3hr. or, $0.0334 \times 24 = 0.802$ gC/m^3/day

5.4 Fauna

Knowledge of the fauna has been acquired on the basis of actual sightings by staff and others. However, no estimate of the population of different species has been made on scientific basis. Reportedly common wild animals were as following –

5.4.1 Herbivores: Spotted deer, barking deer, wild bear, Nilgai, porcupines etc. have been reported inside the miscellaneous forests and plantation area of the sanctuary (Sharma, 1996).

5.4.2 Birds: During the brief study, in the first week of November 2014, only 15 species of birds were recorded in the Udaipur Wildlife Sanctuary in and around Saraiyaman Lake. Family Dicruridae, Capitonidae, Psittacdae, Bucerotidae, Alcedinidae, and Picidae were represented by a single species while Anatidae, Ardeidae and Corvidae by two and Rallidae by three species. Out of these 15 species, only two (Gadwall and Mallard) were 'winter visitor' while others were 'breeding resident'. Later in the first week of February 2015, a more diverse avifauna was reported (Table 7) as winter months are the best for bird watching.

As per earlier report (Sharma, 1996), the migratory birds visible during winter months in the lake were Red crested pochard, Common pochard, Garganey teal, Pintail duck, Coots, Common teal and Dabchick. Besides, in the lake side, birds like Bronze winged jacana, Pond heron, Egrets, Purple moorhen and swamp partridge were also reported. In the miscellaneous forests, closed to the lake, common birds were Jungle crow, White crested bulbul, Red whiskered bulbul, Blackbird, Tree pie, Jungle babbler and Common babbler etc.

5.4.3 Reptiles: Banded Karait, Python, Cobra, etc. are common in the sanctuary. Reportedly one Mugger and two Gharials (4 years old) were released in Udaipur (Saraiyaman) Lake in 1984. It was not confirmed if they are surviving.

5.4.4 Fish: To collect fish samples, Fish net was casted reluctantly only two times by a local fisherman in the shallow water close to the Forest Rest House in afternoon. The catch was very poor as only five species were recorded (Table 6). We also interviewed couple of local fishermen to enquire about availability of fishes in the lake. The information gathered from Chandi Sahni and Jamuna Chaudhary of Tumkaria village about the fishes available in previous and the current years has also been shown in Table 6.

Fishes of Saraiyaman Lake are very popular among the locals as they treat it as very tasty and healthy. Katla, Kawai, Naini, Tengra, Rohu, Banguri and several other edible fishes are found in the Udaipur (Saraiyaman) Lake and Harha nala (Sharma, 1996).

5.4.5 Zooplankton: Altogether 41 species (21 Rotifera, 11 Cladocera and 9 Copepoda) were recorded from three locations of the lake (Table 3). Out of total of 41 zooplankton species, 28 were recorded from the sample collected close to the Forest Rest House (FRH), 12 were from Majharia side and 18 from Tumkaria side of the lake. The Shannon diversity Index of Zooplankton was calculated and presented in Table 4. The Shannon Index (H') was found to be 2.189, 1.242 and 1.586 at Forest Rest House site, Majharia side and Tumkaria side, respectively. The index values are between 1 and 3, which indicates that the lake is high mesotrophic at Majharia and Tumkaria side, whereas it is low mesotrophic at FRH site. However, it would not be wise to conclude the trophic status of the lake based on one time sampling. Nevertheless, the zooplankton in the lake was found to be rich and diversified. More studies in different areas of the lake are required in different season to get complete picture of the zooplankton of the lake. It may be noted that zooplankton serves as food for many of the fishes.

5.4.6 Benthic macro-invertebrates: Sample for the benthic macro-invertebrates could be collected from only one site, opposite to the FRH. The site was full of emerged, floating and submerged macrophytes. The bottom materials were mainly partly decomposed detritus of the macrophytes and very low clay and silt which are preferred habitat for the benthos. Altogether 14 genera of benthic macro-invertebrates were recorded, out of which 7 were gastropod molluscs, 2 oligochaete annelids and 5 arthropods (Table 5). Interestingly no bivalves were recorded in the sample. It may be noted that bivalves are very scarce and rare in the River Gandak also. This observation indicates that the lake has direct bearing with the River Gandak. However, it will be too early to conclude anything based on only one sample of benthos. It may be noted that the benthic macro-invertebrates are best tool for biomonitoring of water quality. Therefore, it is suggested that intensive and extensive study of benthic fauna of the lake should be undertaken in future.

6. Major functions and values:

Saraiyaman Lake is strongly influenced by inputs of nutrients from its catchment area. Geological inputs include nutrients dissolved in groundwater and inflowing particulate matter washed into the basin from the surrounding terrestrial watershed. The lake has lost its connectivity with the River Gandak. The lake metabolisms are dominated by the detrital food

chain. Detritus is all dead organic material. It includes particulate and dissolved organic carbon from external and internal sources. Particulate organic carbon comes from three sources: (1) imports, such as leaf litters, fruits etc from the forest trees, in the lake from the out side; (2) the littoral zone (shallow zone); (3) the limnetic zone. Primary production is carried out in the limnetic zone by phytoplankton and in the littoral zone by macrophytes. The phytoplankton production is influenced by nutrient availability in the water column. The phytoplankton productivity of the lake was recorded using 'Light and Dark Bottle method'. Its value was recorded to be 0.840 gC/m^3/day in the sub-surface water, whereas in the euphotic zone (1.75 meter depth; total depth 8.36 meter) the primary productivity was -0.090 gC/m^3/day. This means the phytoplankton population was high at the surface/sub-surface water but poor at the deeper zone, though it was euphotic zone. Also result shows that at the depth of 1.75 meter there was more community respiration compared to the photosynthesis as the lake has high load of detritus. Rooted aquatic plants, the macrophytes, also contribute heavily to the lake production, however, this productivity was not recorded. The zooplankton density was significant but the benthos was poor.

7. Weed infestation

Weed infestation especially reeds and water hyacinth (jalkumbhi), Typha sps. (pater), reed (narkat) are very heavy and needs urgent attention to control the same.

8. Recommendations

This report is based on a very brief study of the lake for two days only. Nevertheless, preliminary baseline information could be generated on different aspects of the lake, viz. bathymetry, physico-chemical characteristics of the lake water, aquatic flora and fauna etc. As no previous limnological and ecological study of the lake is available, comparison with previous data could not be made.

Therefore, it is highly recommended that a detailed ecological study of the lake be undertaken especially on the following points:

- rate of sedimentation in the lake and characterization of soil,
- Physico-chemical characteristics of the water of the lake in different seasons,

- flora and fauna of the lake in different seasons including invertebrates, fishes and avifauna at least for three years to develop baseline data which will help in proper management and conservation of the lake.
- To probe the possibilities of weed reduction, especially water hyacinth, reeds etc. from the Saraiyaman Lake owing to maintain the health of this unique aquatic ecosystem.
- To develop guidelines to promote eco-tourism which will be helpful for the livelihood of local people also.

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Table 1: Physico-chemical parameters of water samples collected in November 2014 from Saraiyaman Lake, Bettiah compared with a reference point on the River Gandak at Hajipur

Sl. No.	Parameter	Site 1: Bank near Forest Rest house	Site 2: Midstream near Forest Rest house	Site 3: Midstream near Majharia village	Site 4: Midstream near Tumkariya village	Reference point: Mid stream of River Gandak at Hajipur
	Date of sampling	4.11.2014	5.11.2014	5.11.2014	5.11.2014	14.11.2014
	Time of sampling	5:40pm	8:00am	11:45am	3:00pm	8:00 am
	Geographical coordinates	$26^0$48'49N $84^0$26'07E	$26^0$48'48N $84^0$26'06E	$26^0$47'59N $84^0$25'28E	$26^0$47'39N $84^0$26'52E	$25^0$41'59N $85^0$11'36E
	Depth (mtr.)	0.45	8.36	5.49	5.87	1.86
	Air temperature	21.0	21.5	30.0	27.0	23.0
1	**Water temperature**	28.5	26.0	28.0	29.0	24.5
2	**pH**	9.19	7.78	7.62	7.76	8.4
3	**Electrical conductivity**	319	402	402	394	280
4	**Turbidity**	4.0	3.0	1.0	4.0	133
5	Phenolphthalein alkalinity	20.8	-	-	-	3.2
6	**Total alkalinity**	162.8	192	200	190	108
7	Free CO_2	-	17.25	14.08	11.97	-
8	Carbonate alkalinity	41.6	-	-	-	6.4
9	Bicarbonate alkalinity	121.2	192	200	190	102
10	**Dissolved Oxygen**	10.71	2.50	2.82	7.51	6.7
11	**Biological Oxygen Demand**	2.19	2.03	2.43	3.91	1.2
12	Chemical Oxygen Demand	29.60	17.76	23.68	14.80	12.5
13	Chloride	7.08	9.44	9.91	9.91	5.66
14	**Total Hardness, as $CaCO_3$**	175	178	177	180	129
15	**Calcium^{++}, as $CaCO_3$**	32.08	36.45	37.18	33.53	33.92
16	**Magnesium^{++}, as $CaCO_3$**	23.09	21.14	20.41	23.33	10.69
17	**Nitrite-Nitrogen**	0.038	0.051	0.025	0.028	0.034
18	Nitrate-Nitrogen	0.549	0.621	0.506	0.438	0.255
19	**Sulphate**	7.32	5.49	5.12	5.61	28.90
20	**Phosphate**	0.041	0.062	0.051	0.056	0.098*****
21	**Sodium$^+$**	16.0	17.3	18.1	17.6	3.6
22	**Potassium$^+$**	13.2	12.6	12.5	12.9	0.4
23	Total Iron	0.36	0.19	0.23	0.21	12.90
24	Total solids	219	240	252	237	393
25	Total volatile solids	70	73	53	55	45
26	Total fixed solids	149	167	199	182	348
27	**Total Dissolved solids**	209	222	235	218	164
28	Total volatile dissolved solids	65	61	43	41	28
29	Total fixed dissolved solids	144	161	192	177	136
30	Total Suspended solids	10	18	17	19	229
31	Total volatile suspended solids	5	12	10	14	17
32	Total fixed suspended solids	5	6	7	5	212

Note: All parameters are in (mg/l) except temperature (^{0}C), pH, electrical conductivity (µS/cm) and turbidity (NTU).

***** = Total Phosphorus (mg/l) while in other samples Orthophosphate (mg/l) were estimated.

Table 2: Aquatic Macrophytes reported from Saraiyaman Lake, Bettiah in November 2014

Species name	Family
1. *Caldesia parnassiifolia* (Bassi ex Linnaeus) Parlatore	[Alismataceae]
2. *Ceratophyllum demersum* Linnaeus	[Ceratophyllaceae]
3. *Eichhornia crassipes* (Martius) Solms-Laubach	[Pontederiaceae]
4. *Hydrilla verticillata* (Linnaeus fil.) Royle	[Hydrocharitaceae]
5. *Limnophila indica* (Linnaeus) Druce	[Scrophulariaceae]
6. *Najas indica* (Willdenow) Chamisso	[Najadaceae]
7. *Nelumbu nucifera* Gaertner	[Nelumbonaceae]
8. *Nymphaea pubescens* Willdenow	[Nymphaeaceae]
9. *Nymphoides indica* (Linnaeus)	[Menyanthaceae]
10. *Nymphoides hydrophylla* (Loureiro)	[Menyanthaceae]
11. *Phragmites karka* (Retzius) Steudel	[Poaceae]
12. *Potamogeton malaianus* Miquel	[Potamogetonaceae]
13. *Utricularia foveolata* Edgeworth	[Lentibulariaceae]
14. *Typha latifolia* Linnaeus	[Typhaceae]

Table 3: Zooplankton diversity at three different locations of Saraiyaman Lake, Bettiah in November 2014

Zooplankton	Sampling site # 1	Sampling site # 2	Sampling site # 3
Rotifera			
Order - Ploimida			
Family - Asplanchnidae			
1. Asplanchna brightwelli	+	-	-
Family - Brachionidae			
2. Anuraeopsis fissa	-	+	+
3. Brachionus angularis	+	-	-
4. B. Caudatus	+	-	-
5. B. diversicornis	+	-	-
6. B. forficula	-	-	+
7. B. fulcatus	+	-	+
8. B. rubens	+	-	-
9. Keratella lenzi	+	+	+
10. K. quadrata	+	-	+
11. K. tropica	+	+	+
Family - Synchaetidae			
12. Polyarthra sp.	-	-	+
Family - Trichotridae			
13. Macrochaetus sericus	+	-	-
Family - Collurellidae			
14. Colurella sulcata	+	-	-
Family - Lecanidae			
15. Lecane curvicornis	+	-	-
16. Lecane sp.	+	-	-
Family - Trichocercidae			
17. Trichocerca cylindrica	+	-	-
18. Trichocerca rattus	-	+	-
19. Trichocerca similis	+	-	-
Order - Gnesiotrocha			
Family - Filiniidae			
20. Filinia longiseta	+	+	+
Family - Testudinellidae			
21. Pompholyx sulcata	-	+	-
Cladocera			
Family - Chydoridae			
22. Chydorus ovalis	-	+	+
Family - Daphniidae			
23. Ceriodaphnia reticulate	+	+	+
24. Daphnia carinata	-	-	+

25. Daphnia lumholtzi	-	-	+
26. Daphnia pulex	-	-	+
27. Daphnia sp.	+	-	-
28. Scapholebris kingi	+	-	-
Family - Moinidae			
29. Moina macrocopa	+	-	-
30. Moina weismani	-	-	+
Family - Macrothricidae			
31. Macrothrix sp.	-	+	-
Family - Sididae			
32. Diaphanosoma sp.	+	-	-
Copepoda			
Family - Cyclopidae			
33. Cyclops magnus	+	-	-
34. Eucyclops prionophorus	+	-	-
35. Mesocyclops hyalinus	+	+	+
36. Mesocyclops leuckarti	+	+	-
37. Mesocyclops sp.	-	-	+
Family - Diaptomidae			
38. Diaptomus sp.	+	-	-
39. Heliodiaptomus sp.	+	-	-
40. Neodiaptomus sp.	-	-	+
41. Nauplii	+	+	+
Number of taxa present	**28**	**12**	**18**
Beta diversity (β)	**1.464**	**3.417**	**2.278**

Note: (+) = Present; (-) = Absent

Table 4: Zooplankton diversity (individual/ litre) at Saraiyaman Lake, Bettiah in November 2014

Zooplankton	Sampling site # 1	Sampling site # 2	Sampling site # 3
Asplanchna brightwelli	0	0	300
Anuraeopsis fissa	0	300	0
Brachionus angularis	300	0	0
B. Caudatus	300	0	0
B. diversicornis	300	0	0
B. fulcatus	300	0	0
B. rubens	300	0	0
Keratella tropica	2400	300	0
K. lenzi	1500	0	0
Polyarthra sp.	0	300	0
Filinia longiseta	600	0	600
Ceriodaphnia reticulate	1200	0	900
Daphnia pulex	0	0	300
Daphnia sp.	600	0	0
Macrothrix sp.	600	0	0
Mesocyclops hyalinus	300	0	0
Mesocyclops leuckarti	2100	0	0
Heliodiaptomus sp.	300	0	0
Neodiaptomus sp.	0	0	300
Nauplii	5400	900	1500
Total number of organism	**16500**	**1800**	**3900**
Total number of taxa	**15**	**4**	**6**
Beta diversity (β)	1.333	5.000	3.333
Shannon diversity index (H')	**2.189**	**1.242**	**1.586**
Shannon Hmax	2.708	1.386	1.792
Shannon Evenness index (J')	**0.808**	**0.896**	**0.885**

Note: Shannon's species diversity index (H') is calculated using log value of natural log.

Table 5: Benthic macro-invertebrates reported from Saraiyaman Lake, Bettiah in November 2014

	Species name	Family	Phylum
1.	*Bellamya bengalensis* (Lamarck 1822)	Viviparidae	Mollusca
2.	*Lymnaea accuminata* (Lamarck, 1822)	Lymnaeidae	Mollusca
3.	*Melanoides tuberculatus* (O. F. Müller, 1774)	Thiaridae	Mollusca
4.	*Indoplanorbis exustus* (Deshayes, 1834)	Planorbidae	Mollusca
5.	*Gyraulus convexiusculus* (Hutton, 1849)	Planorbidae	Mollusca
6.	*Gyraulus labiatus* (Benson, 1850)	Planorbidae	Mollusca
7.	*Segmentina sp.*	Planorbidae	Mollusca
8.	*Aulodrilus sp.*	Tubificidae	Annelida
9.	*Branchilodrilus semperi*	Naididae	Annelida
10.	Stenocypris larvae	Cypridae	Arthropoda
11.	*Cybister sp.*	Dysticidae	Arthropoda
12.	*Dystiscus larva*	Dysticidae	Arthropoda
13.	Gomphus sp.	Gomphidae	Arthropoda
14.	Unidentified insect pupa*****	-	Arthropoda

Table 6: Fishes of Saraiyaman Lake, Bettiah

Local name	Common name	Scientific name	Family†
1. Pottiah [1*]	Spotfin swamp barb	*Puntius sophore* (Hamilton)	Cyprinidae
2. Kotree (Kaoli), Pothia [1]	Ticto barb, Two-spot barb	*Puntius ticto* (Hamilton)	Cyprinidae
3. Rehu [*]	Rohu	*Labeo rohita* (Hamilton)	Cyprinidae
4. Katla [*]	Catla	*Catla catla* (Hamilton)	Cyprinidae
5. Naini [*]	Mrigal	*Cirrhinus mrigala* (Hamilton)	Cyprinidae
6. Reva [*]	Reba carp	*Cirrhinus reba* (Hamilton)	Cyprinidae
7. Chelwa [*]	Gora chela	*Securicula gora* (Hamilton)	Cyprinidae
8. Dendua [*]	Flying barb	*Esomus danricus* (Hamilton)	Cyprinidae
9. Grass carp [*]	Grass carp	*Ctenopharyngodon idella* (Valenciennes)	Cyprinidae
10. Tengra [*]	Tengara mystus	*Mystus tengara* (Hamilton)	Bagridae
11. Tengra [*]	Striped dwarf catfish	*Mystus vittatus* (Bloch)	Bagridae
12. Kanti (Palwa) [*]	Gangetic mystus	*Mystus cavasius* (Hamilton)	Bagridae
13. Kauwamachh [1]	Freshwater garfish	*Xenentodon cancila* (Hamilton-Buchanan)	Belonidae
14. Moi (Patara) [*]	Grey Featherback	*Notopterus notopterus* Lacepede	Notopteridae
15. Chital [*]	Humped Featherback	*Chitala chitala* (Hamilton)	Notopteridae

16. Barari*	Gangetic goonch	*Bagarius bagarius* (Hamilton)	Sisoridae
17. Mangur*	Magur	*Clarias batrachus* (Linnaeus)	Claridae
18. Singhi*	Stinging catfish	*Heteropneustes fossilis* (Bloch)	Heteropneustidae
19. Bami*	Tire-track spiny eel	*Mastacembalus armatus* (Lacepede)	Mastacembelidae
20. Gainchi*	Striped spiny eel	*Macrognathus pancalus* Hamilton	Mastacembelidae
21. Kawai*	Climbing perch	*Anabas testudineus* (Bloch)	Anabantidae
22. Jalkapur*	Indian butter-catfish	*Ompok bimaculatus* (Bloch)	Siluridae
23. Chanari 1*	Himalayan glassy perchlet	*Chanda baculis* (Hamilton)	Chandidae
24. Channe, Gurdi, Sirsa 1	Elongate glass-perchlet	*Chanda nama* Hamilton	Chandidae
25. Basari (Kalbasu)*	Kalbasu, Black rohu	*Labeo calbasu* (Hamilton)	Cyprinidae
26. Garai*	Spotted snakehead	*Channa punctatus* (Bloch)	Channidae
27. Saunri*	Striped or Banded snakehead	*Channa striata* (Bloch)	Channidae
28. Bhaunda*	Giant snakehead	*Channa marulias* (Hamilton)	Channidae
29. Jhinga*	Freshwater shrimp	*Macrobrachium sp.*	

1 Recorded during our survey on November 4-5, 2014 (there is possibility of many more fishes from this lake as sampling could not be done properly due to lack of time and lack of proper fishing gears).

* Reported to be found commonly by Sri Jamuna Chaudhari and Chandi Sahni of Tumkaria village, Saraiya Maan, Bettiah on November 5th, 2014 in their earlier catches.

†Classification of Nelson (1994) has been adopted upto family and valid names of genera given by Eschmeyer (2007) were followed.

Table 7: Birds of Saraiyaman Lake, Bettiah

Common name	Scientific name	Family	Population Status†
1. Black Drongo [1]	*Dicrurus macrocercus*	Dicruridae	Breeding Resident
2. Brown headed Barbet [1]*	*Megalaima zeylanica*	Capitonidae	Breeding Resident
3. Crested serpent Eagle *	*Spilornis cheela*	Accipitridae	Breeding Resident
4. Common Moorhen [1]	*Gallinula chloropus*	Rallidae	Breeding Resident
5. White breasted Waterhen [1]	*Amaurornis phoenicurus*	Rallidae	Breeding Resident
6. Common Coot [1]*	*Fulica atra*	Rallidae	Breeding Resident
7. White-eyed Pochard (Ferruginous Pochard) *	*Aythya nyroca*	Anatidae	Winter Visitor
8. Red crested Pochard *	*Rhodonessa rufina*	Anatidae	Winter Visitor
9. Northern Pintail *	*Anas acuta*	Anatidae	Winter Visitor
10. Common Teal *	*Anas trecca*	Anatidae	Winter Visitor
11. Gadwall [1]	*Anas strepera*	Anatidae	Winter Visitor
12. Mallard [1]	*Anas platyrhynchos*	Anatidae	Winter Visitor
13. Common Stonechat *	*Saxicola torquata*	Muscicapidae	Winter visitor
14. Red wettled Lapwing *	*Vanellus indicus*	Charadriidae	Breeding Resident
15. Little Cormorant *	*Phalacrocorax niger*	Phalacrocoracidae	Breeding Resident
16. Rose ringed Parakeet [1]	*Psittacula krameri*	Psittacidae	Breeding Resident
17. Red vented Bulbul *	*Pycnonotus cafer*	Pycnonotidae	Breeding Resident
18. Pond Heron [1]*	*Ardeola grayii*	Ardeidae	Breeding Resident

19. Purple Heron *	*Ardea purpurea*	Ardeidae	Breeding Resident
20. Intermediate Egret *	*Mesophoyx intermedia*	Ardeidae	Breeding Resident
21. Cattle Egret [1]	*Bubulcus ibis*	Ardeidae	Breeding Resident
22. Asian open billed Stork *	*Anastomus oscitans*	Ciconiidae	Breeding Resident
23. Indian grey Hornbill [1]	*Ocyceros birostris*	Bucerotidae	Breeding Resident
24. Rufous Treepie [1]	*Dendrocitta vagabunda*	Corvidae	Breeding Resident
25. House Crow [1]	*Corvus splendens*	Corvidae	Breeding Resident
26. White-throated Kingfisher [1]*	*Halcyon smyrnensis*	Alcedinidae	Breeding Resident
27. Common Kingfisher *	*Alcedo atthis*	Alcedinidae	Breeding Resident
28. Pied Kingfisher *	*Ceryle rudis*	Alcedinidae	Breeding Resident
29. Indian Roller *	*Coracias benghalensis*	Coraciidae	Breeding Resident
30. Brown fish Owl *	*Ketulpa zeylonensis*	Strigidae	Breeding Resident
31. Great Tit *	*Parus major*	Paridae	Breeding Resident
32. Black-rumped Flameback [1]	*Dinopium benghalense*	Picidae	Breeding Resident
33. Bronze winged Jacana *	*Metopidius indicus*	Jacanidae	Breeding Resident
34. Pheasant-tailed Jacana *	*Hydrophasianus chirurgus*	Jacanidae	Breeding Resident

[1] = Recorded by our team, visited the Saraiyaman Lake on November 4th -5th, 2014

* = Reported by Sri H. K. Roy, DFO, Bettiah on February 5th, 2015

† = Population status is as per Grimmett et al. (2007)

Table 8: Depth profile of Saraiyaman Lake, Bettiah recorded on November 5, 2014

Land–mark	Geographical coordinates	Depth (feet)
A. Opposite Forest Rest House	a. 26º48’47N/ 84º26’06 E	22.0
	b. 26º48’46N/ 84º26’06 E	28.0
	c. 26º48’45 N/ 84º26’06 E	24.2
	d. 26º48’43 N/ 84º26’05 E	19.4
B. Opposite Watch Tower	a. 26º48’48 N/ 84º25’53 E	11.2
	b. 26º48’48 N/ 84º25’51 E	31.0
	c. 26º48’46 N/ 84º25’51 E	28.0
	d. 26º48’46 N/ 84º25’50 E	19.8
C. Opposite Palm Tree	a. 26º48’37 N/ 84º25’32 E	19.0
	b. 26º48’37N/ 84º25’33 E	27.8
	c. 26º48’37 N/ 84º25’36 E	29.0
	d. 26º48’37 N/ 84º25’37 E	16.6
D. Opposite Jamun Tree (Bhangar Yadav’s Hide)	a. 26º48’24 N/ 84º25’25 E	19.0
	b. 26º48’23 N/ 84º25’25 E	29.1
	c. 26º48’23 N/ 84º25’26 E	23.0
	d. 26º48’22 N/ 84º26’27 E	17.2
E. Near Majharia village	a. 26º48’00 N/ 84º25’35 E	12.7
	b. 26º48’00 N/ 84º25’34 E	19.5
	c. 26º47’59 N/ 84º25’33 E	22.6
	d. 26º47’59 N/ 84º25’28 E	18.0
F. Upstream Bangla ghat (Opposite dry tree)	a. 26º48’39 N/ 84º26’25 E	19.5
	b. 26º48’39 N/ 84º26’24 E	25.3
	c. 26º48’38 N/ 84º26’23 E	20.2
	d. 26º48’39 N/ 84º26’23 E	11.6
G. Opposite Mango-tree orchard (Besides Banyan tree)	a. 26º48’25 N/ 84º26’42 E	15.2
	b. 26º48’25 N/ 84º26’41 E	22.0
	c. 26º48’24 N/ 84º26’41 E	21.0
	d. 26º48’23 N/ 84º26’41 E	17.0
H. Opposite Shishwa Sharai temple	a. 26º48’02 N/ 84º26’53 E	18.1
	b. 26º48’02 N/ 84º26’53 E	23.0
	c. 26º48’01 N/ 84º26’53 E	18.9
	d. 26º48’01 N/ 84º26’52 E	12.3
I. Near Tumkariya village (Near enclosed fishing area)	a. 26º47’39 N/ 84º26’54 E	10.7
	b. 26º47’39 N/ 84º26’53 E	21.0
	c. 26º47’39 N/ 84º26’52 E	19.3
	d. 26º47’39 N/ 84º26’51 E	11.2

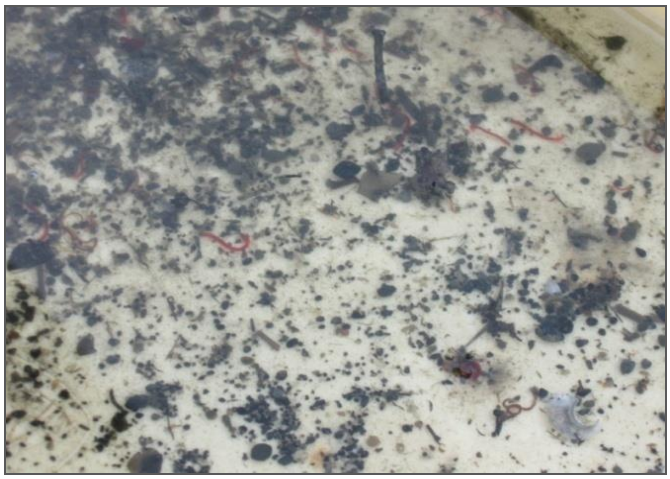
Figure 1: Saraiyaman Lake, Bettiah showing its depth profile as recorded on November 5, 2014

Collection of plankton sample

Concentrated plankton sample

Collecting benthos sample with a dredge

Transferring the dredged sediment



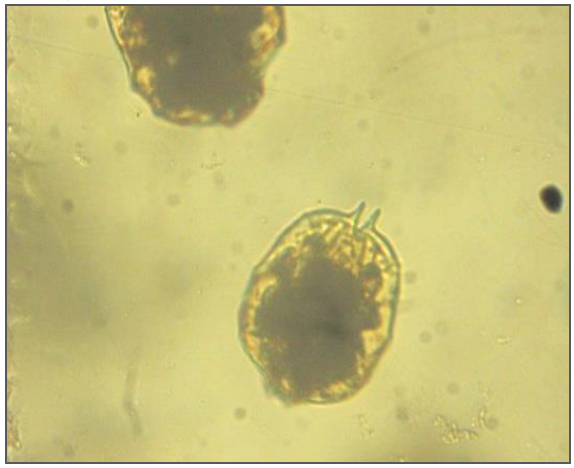
Benthic fauna in a sorting tray

(Photographs by G. P. Purusharti)

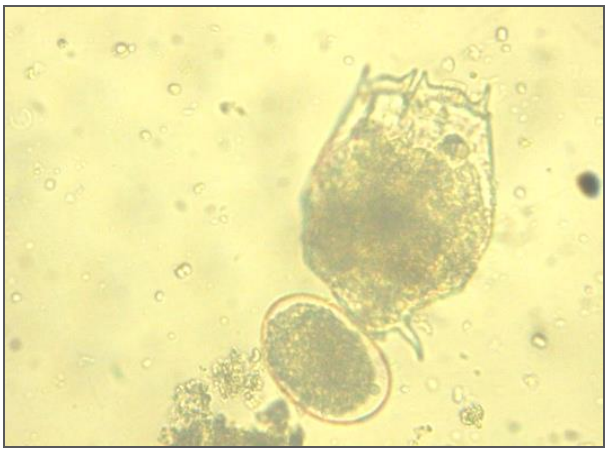
Plate 1: Photographs of plankton and benthos sampling

Plate 2: Some of the identified zooplankton from the Saraiyaman Lake, Bettiah collected in November, 2014

Asplanchna brightwelli

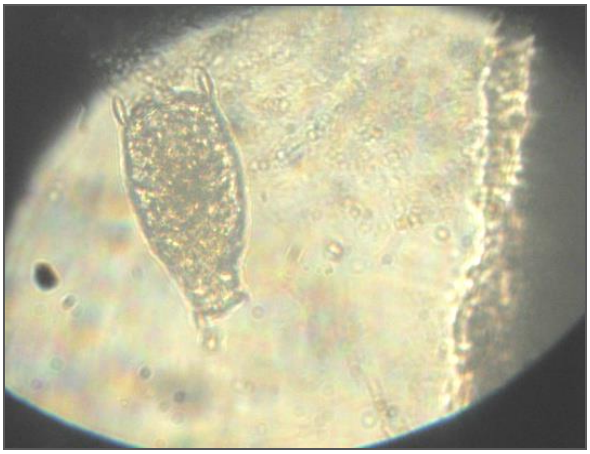


Brachionus angularis



Brachionus caudatus

Brachionus diversicornis



Brachionus forficula

Brachionus rubens

(Photographs by Dr. Neetu)

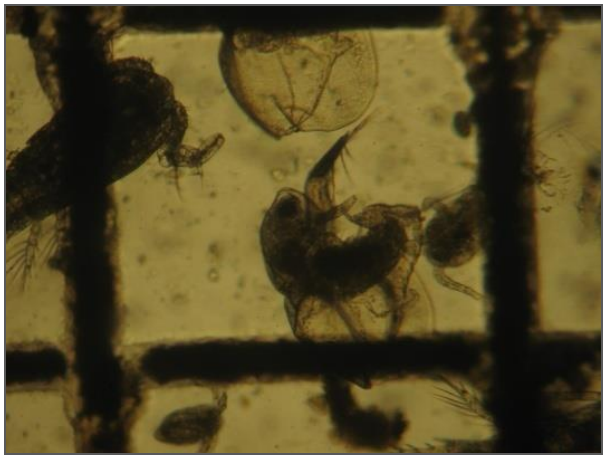
Plate 3: Some other identified zooplankton from the Lake

Filinia longiseta

Keratella tropica

Lecane sp.

Polyarthra sp.



Moina macrocopa and *Mesocyclops leuckarti*

Nauplius larva

(Photographs by Dr. Neetu)

Plate 4: Some of the identified benthic fauna from the Lake collected in November, 2014

Bellamya bengalensis

Melanoides tuberculatus

Lymnaea accuminata

Indoplanorbis exustus

Gyrulus convexiusculus

Gomphus sp.

(Photographs by G. P. Purusharti)

Plate 5: Some identified macrophytes of the Lake in November 2014

Heavy infestation of *Najas indica*

Leaves of *Nymphoides indica* with reeds

Leaves of *Nymphaea pubescens and Caldesia parnassifolia*

***Hydrilla verticillata* plants infestation**

***Eichornia crassipes* plant**

***Nymphoides hydrophylla* plant with flower**

(Photographs by G. P. Purusharti)

Nelumbo nucifera **plants at Saraiyaman Lake**

Nelumbo nucifera **leaf, Herbarium Record, Saraiyaman Lake**

Najas indica **vegetation at Saraiyaman Lake**

Limnophila indica **habitat at Saraiyaman**

Potamogeton malaianus **habitat at Saraiyaman**

Limnophila indica **flowering shoots**

(Photo credit: Nesemann and Sharma, 2012 and Sharma and Nesemann, 2013)

Plate 6: Some other identified macrophytes of the Lake

Plate 7: Fishes collected from Saraiyaman Lake, Bettiah in November, 2014

Puntius sophore (Spotfin swamp barb)

Puntius ticto (Ticto barb)

Xenentodon cancila **(**Freshwater garfish)

Chanda baculis (Himalayan glassy perchlet)

Chanda nama (Elongate glass-perchlet)

(Photographs by G. P. Purusharti)

Plate 8(a): Some other fishes reported from Saraiyaman, Bettiah

Esomus danricus (Flying barb)

Labeo calbasu (Black Rohu, Kalbasu)

Mystus cavasius (Gangetic mystus)

Bagarius bagarius (Gangetic goonch)
(Photo credit: Rajesh Kr. Sinha)

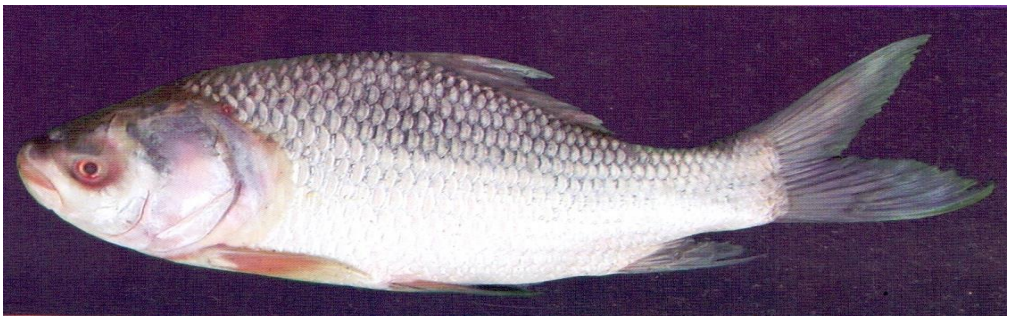
Plate 8(b): Some other fishes reported from Saraiyaman, Bettiah

Mystus tengara (Tengara mystus)

Mystus vittatus (Striped dwarf catfish)

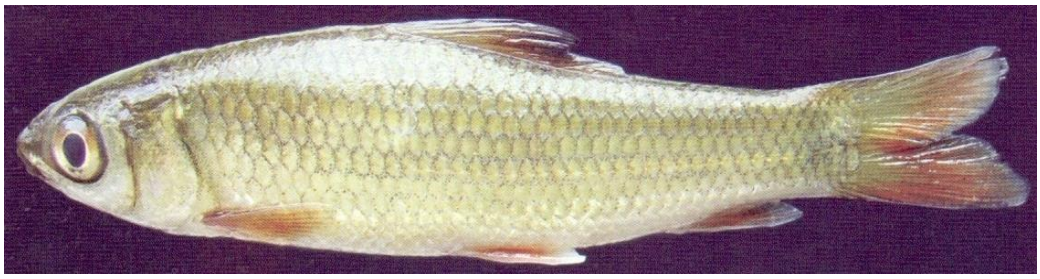
Anabas testudineus (Climbing perch)
(Photo credit: Vishwanath *et al*. 2007)

Plate 8(c): Some other fishes reported from Saraiyaman, Bettiah

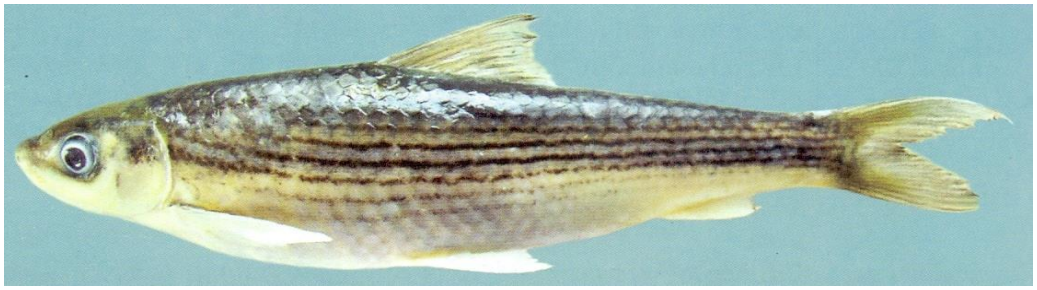


Catla catla (Catla, Indian major carp)

Labeo rohita (Rohu, Indian major carp)



Cirrihinus mrigala (Mrigal, Indian major carp)

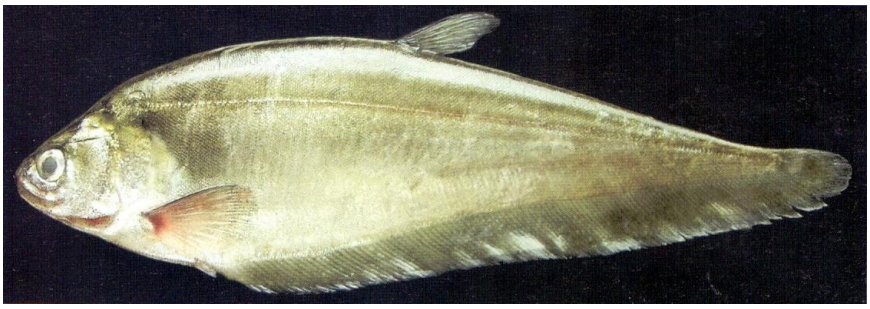


Cirrhinus reba (Reba carp)

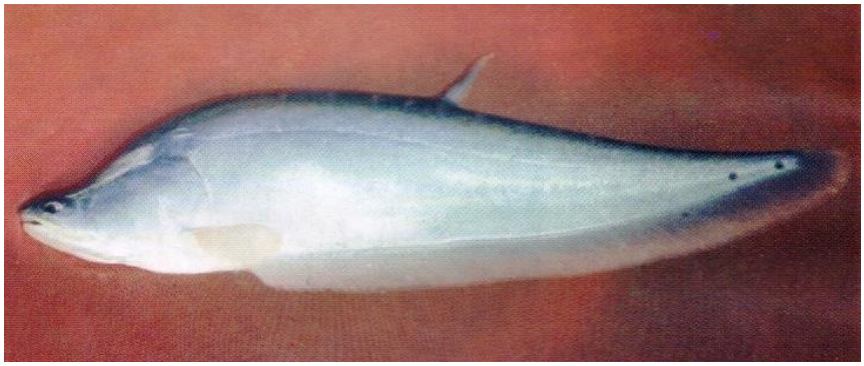
Ctenopharyngodon idella (Grass carp)

(Photo credit: Vishwanath *et al*. 2007)

Plate 8(d): Some other fishes reported from Saraiyaman, Bettiah



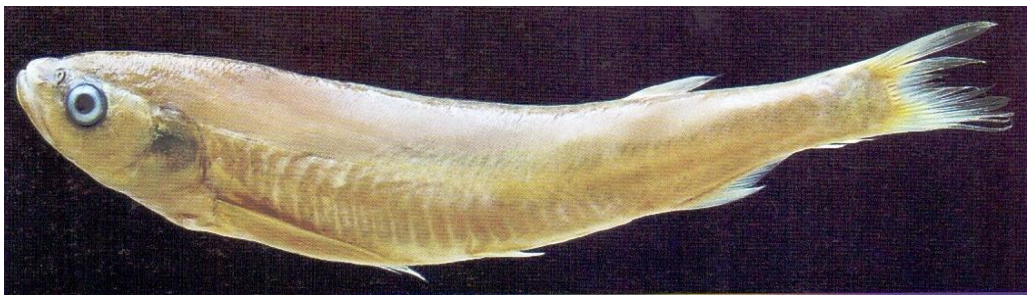
Notopterus notopterus (Grey featherback)



Chitala chitala (Humped featherback)

Macrognathus puncalus (Stiped spiny eel)

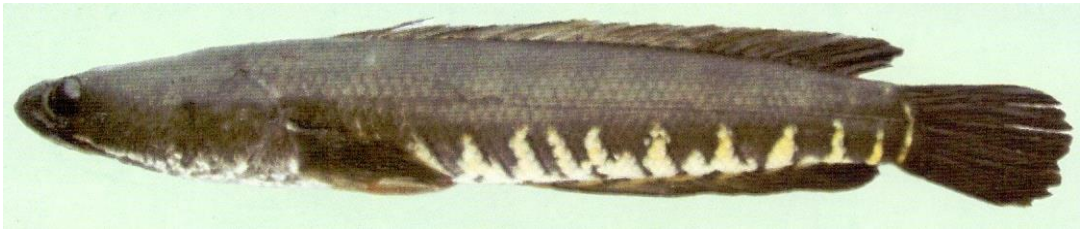
Mastacembalus armatus (Tire-track spiny eel)



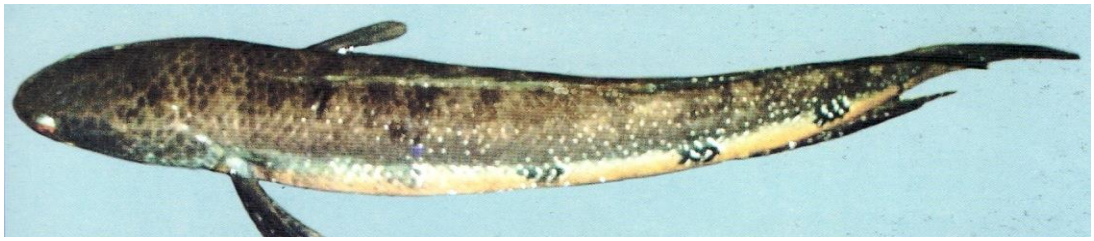
Securicula gora (Gora chela)
(Photo credit: Vishwanath *et al*. 2007)

Plate 8(e): Some other fishes reported from Saraiyaman, Bettiah

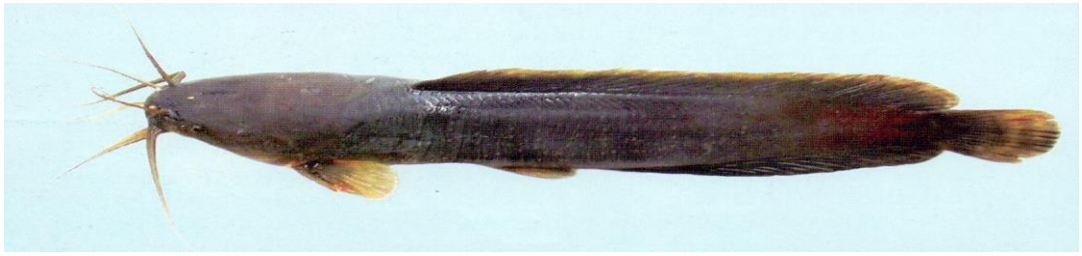
Channa punctatus (Spotted snakehead)



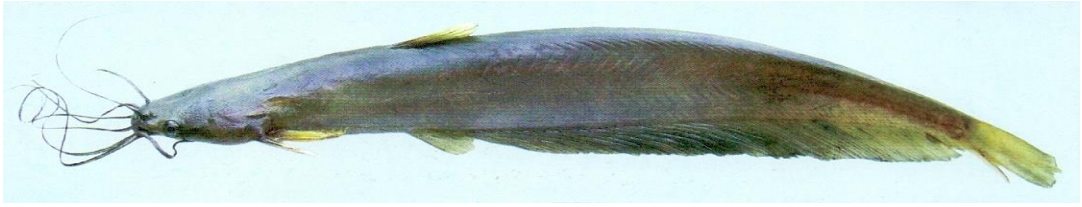
Channa striata (Striped snakehead)



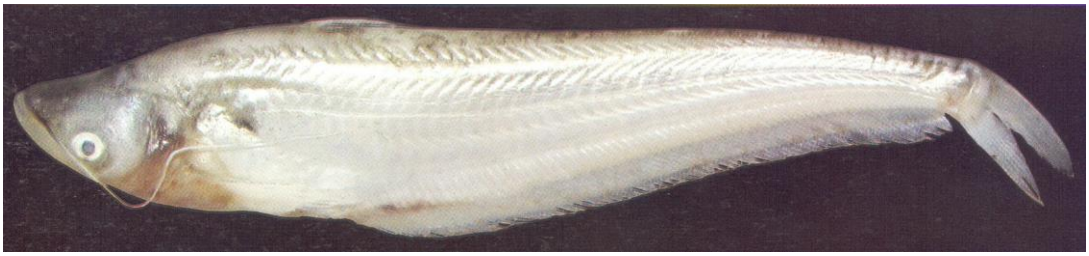
Channa marulias (Giant snakehead)



Clarias batrachus (Magur, Air breathing Catfish)



Heteropneustes fossilis (Stinging catfish)



Ompok bimaculatus (Indian butter-catfish)
(Photo credit: Vishwanath *et al*. 2007)

Plate 8: Photographs of Saraiyaman visit during November 2014

Panoramic view of the Saraiyaman Lake

Sunset at Saraiyaman Lake

Experimental set up for productivity estimation

Discussion with Sri Jamuna Chaudhary of Tumkaria

Prof. R. K. Sinha with Locals of Saraiyaman

DFO, Bettiah discussing management of lake with Prof. R. K. Sinha of Patna University

(Photographs by G. P. Purusharthi)