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Impact of Water Pollution on The Ecology And Biology of Utricularia L. in Rajshahi

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IMPACT OF WATER POLLUTION ON THE ECOLOGY AND BIOLOGY OF *UTRICULARIA* L. IN RAJSHAHI

A thesis

submitted to the Faculty of Life and Earth Science, University of Rajshahi, in fulfilment of the requirements for the degree of Doctor of Philosophy

IN

BOTANY

Submitted By

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N.S.T. Fellow

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PHYCOLOGY AND LIMNOLOGY LABORATORY
DEPARTMENT OF BOTANY
UNIVERSITY OF RAJSHAHI
BANGLADESH

DEDICATED TO

MY PARENTS
WHO ALLWAYS TRY TO CONSERVE
THE BEAUTY OF
NATURE

DECLARATION

I do hereby declare that the entire work submitted as a thesis towards the fulfilment for the degree of Doctor of Philosophy in Botany at the University of Rajshahi, is the result of my own investigation.

Abdullah Harun Chowdhury
18-8-2002

Abdullah Harun Chowdhury
Candidate

CERTIFICATE

This is to certify that the research work presented in this Ph.D. thesis entitled **"IMPACT OF WATER POLLUTION ON THE ECOLOGY AND BIOLOGY OF *UTRICULARIA* L. IN RAJSHAHI"** was carried out by the **N.S.T. Fellow Mr. Abdullah Harun Chowdhury**, under my supervision. It is approved as to the style and contents.

M. Zaman.
14. 8. 2002

Dr. M. Zaman
Professor of Botany
Supervisor

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The Author

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LIST OF ABBREVIATIONS

WT	=	Water temperature
Tr	=	Transparency
TSS	=	Total suspended solids
TDS	=	Total dissolved solids
pH	=	Hydrogen ion concentration
DO	=	Dissolve oxygen
% of sat.	=	Percentage of saturation of oxygen
Eh	=	Oxidation reduction potential
rH_2	=	Oxidation reduction index
BOD_5	=	Biochemical oxygen demand
COD	=	Chemical oxygen demand
EC	=	Electric conductivity
Cl	=	Chloride
S.salt	=	Soluble salt
CO_2	=	Carbon dioxide
CO_3	=	Carbonate
HCO_3	=	Bicarbonate
TH	=	Total hardness
Ca.H	=	Calcium hardness
Mg.H	=	Magnesium hardness
PO_4	=	Phosphate
$NH_4.N$	=	Ammonium nitrogen
TS	=	Total sulphide
alk.	=	Alkalinity
mg/ l	=	Milligram per liter
°C	=	Centigrade
cm	=	Centimeter
M mol l^{-1}	=	Mole per liter
μ ohms	=	Micro ohms
mv	=	Milli volt
μ	=	Micron
mg g^{-1}dry wt.	=	Milligram per dry weight
mg dm^{-2}	=	Milligram per square decameter
WBWU	=	Water Bodies With *Utricularia* sp.
WBWTU	=	Water Bodies Without *Utricularia* sp.

ABSTRACT

The impact of water pollution on the ecology and biology of *Utricularia* L. have been studied in Rajshahi from July 1999 to June 2001. During the period of study 24 physico-chemical parameter of water and measurements of chemical nature of bottom soil of seven *Utricularia* habitats and those of seven without *Utricularia* were studied. All sampling spots are located in greater Rajshahi and sampling was performed at weekly intervals. The impact of water pollution was studied by the help of *Utricularia* culture in 5 earthen aquaria. Statistical analysis has been made to establish the interrelationship between the physico-chemical conditions of water and biological conditions of *Utricularia*. *Utricularia aurea* (With float), *Utricularia aurea* (Without float), *Utricularia stellaris* and *Utricularia exoleata* were found in Rajshahi and these species were used in this study.

During the period of study the impacts of different physico-chemical conditions of water on *Utricularia* spp. were observed. The normal biological processes and prey capturing ability of *Utricularia* spp. are affected by water temperature and higher values of TSS. From this study, it was recorded that the *Utricularia* spp. are unable to survive for more than one month in the polluted water having high organic load.

During the period of study, it was observed that when transparency of *Utricularia* habitats decreased from 25 cm, the chlorophyll content of *Utricularia* spp. also started to decrease. When TDS value crossed 200 mg/l level, *Utricularia* spp. started to die rapidly; chlorophyll and protein content have started to decrease with increase of the TDS values. *Utricularia* spp. exhibited high growth rates when the pH value ranged from 7.1 to 7.5. A level of DO content congenial for the normal growth and function is always above 3 mg/l in case of *Utricularia* spp. When Eh value decreases from 0.755 mv, the flowering and fruit setting of *Utricularia* spp. get gradually inhibited; prey capturing activity was also found to decrease and the protein content was also started to decrease.

From this study, it was recorded that when BOD_5 value started to increase from 1.8 mg/l, the *Utricularia* spp. started showing a decrease in their growth. *Utricularia* spp. could not be grown in the water when COD value was higher than 7 mg/l and also started to die within seven days after releasing *Utricularia* spp. in the culture waters with high COD values. *Utricularia* spp. could not grow when conductivity value was increased from 220 μ-ohms/cm; chlorophyll and protein content of *Utricularia* spp. were started to decrease when the electric conductivity started to increase from 180 μ-ohm/cm. When

chloride value started to increase from 50 mg/l upwards, *Utricularia* spp. begins to show reduction in their growth and started to decompose within 15-20 days when chloride value goes above 60 mg/l.

During the period of study, it was observed that *Utricularia* spp. can not grow in hard water (>150 mg/l hardness). When total hardness level started to increase from 150 mg/l, the growth of *Utricularia* spp. started to decrease; chlorophyll and protein content also started to decrease; in this situation after one month *Utricularia* spp. started to die and decompose eventually. Attempt was made to grow *Utricularia* spp. in vary hard water (>180 mg/l hardness) but could not succeed and within 10-13 days *Utricularia* spp. started to die. It was also observed that immature flower and fruit could not mature in hard water and flower could not open. When calcium hardness content reached to 165 mg/l, the *Utricularia* plants started to die and get decomposed eventually. During the period of study, it was recorded that, the *Utricularia* spp. could not carryout its normal biological activities, such as flowering, fruit setting, photosynthesis, trapping of prey and growth, when phosphate content of water was started to rise above 0.112 mg/l and within 10-12 days, the leaf colour is changed into radish brown, immature fruits turned black, chlorophyll and protein content are reduced to half and immature flower failed to open and its colour turned black; within 18-20 days the whole plant starts to die and decomposed eventually.

From this study, it was observed that the growth and biological activities of *Utricularia* spp. were affected by the ammonium nitrogen. When ammonium nitrogen values started to increase from 0.05 mg/l, the biological activities of *Utricularia* spp. also started to decrease. When ammonium nitrogen begins to go above 0.10 mg/l, then within 5-7 days all parts of *Utricularia* spp. start to die and get decomposed. During the period of study, it was observed that the growth and biological activity of *Utricularia* spp. were affected by higher total sulphide content. The biological activities of *Utricularia* spp. have started to retard gradually when total sulphide content begins to rise from 0.50 M mol l^{-1}. All parts of *Utricularia* plants start to die and get decomposed within 7 days when total sulphide content rises above 0.80 M mol l^{-1}.

The present investigation reveals that the species of *Utricularia* fail to perform their normal biological activities in polluted water and showed some threshold limits of inactivation under certain physico-chemical changes of the habitat water. Death and decomposition of the study plants ensue at certain values of such physico-chemical conditions.

CHAPTER - ONE

INTRODUCTION

INTRODUCTION

Water pollution means such contamination of water or such alternation of the physical, chemical and biological properties of water which occurs directly or indirectly by the discharge of any sewage, trade effluent, any other liquid, gaseous, solid substances into the water as may, create a nuisance or render such water, harmful and injurious to public health and safety, to domestic, commercial, industrial, agricultural and other legitimate uses, and the life and health of animals, aquatic plants and organisms. According to Moore *et al.* (1960), water pollution is the alteration of any body of water having losses of any of its value as a natural resource. Water pollution is becoming a growing problem throughout the world. The toxic substance like metals, detergents, dyes, agricultural pesticides, chemical fertilizers, industrial wastes and effluents, sewerage and municipal wastes may pollute the water sources by surface flow, and bring about changes in physical, chemical and biological characteristic in water. Percolation through soil also may interfere with the self purification capacity of water in the water body (Vollenweider 1979). Physico-chemical and biological characteristics of open water bodies depend upon a number of factors, including the location of water bodies, type of sewerage, municipal wastes and industrial effluents.

The total area of inland open fresh water of Bangladesh is about 35663 km^2 (Ameen 1987, Duijvendijk 1987, Rahman 1988, Khondker 1994 and 1995) including rivers, canals, *beels*, *jheels*, haors, lakes, ponds, swamps, ditches etc. Due to the unexpected increasing population pressure in Bangladesh, all types of fresh water lentic and lotic ecosystems are under utilization for intensive pisciculture, cultivation, irrigation, and various types of domestic and industrial uses. The natural water bodies, thus, undergo drastic structural changes to meet their purpose. The shallower or low-lying water bodies are being filled up for the construction of their homestead and other infrastructure. The aquatic scenario thus being totally altered for human comforts. Recently Bangladesh has been on the progress in the field of rapid industrialization. These industries are dumping or discharge their wastes and effluents onto the land or into the nearby water courses, usually small streams and rivers, practically without pretreatment. Everyday chemical fertilizer factories, tanneries, pharmaceutical and chemical complexes, paper and pulp mills, dyeing mills, jute and textile mills, sugar mills, cement industries, soap factories, food processing industries etc. discharge large quantities of their partially treated or untreated solid and liquid waste effluent, directly or indirectly through discharge channels, to the natural water systems and rivers, as a result the ecosystem balance of dumping places are being adversely affected (Chowdhury *et al.* 1998 and 2000). In the rainy season all effluent dumping sites are over flooded and effluent mixed water is mixed with unpolluted water bodies. Chemical fertilizers and pesticides are used indiscriminately for higher crop yields in the agricultural lands. These fertilizers and pesticides are washed by rain water and flow into water bodies. As a result of which the aquatic flora and fauna are affected. Some pollutants and contaminants produce temporary effect on water whereas others have a long standing effect. So the aquatic plants and animals tolerant to different levels of pollution may survive while others may be destroyed or disappear in the polluted area (Chowdhury *et al.* 1996, 1998 and 2000). Biodiversity is then seriously affected.

The natural distribution and abundance of aquatic biota manifest modifications due to human interventions. All aquatic plants have an important role in the ecosystem of water bodies. Some aquatic plants are used by the people as a vegetable (*Ipomoea aquatica, Enhydra fluctuants* etc.). Some are used for medicinal purposes (Rhizome of water lilies). *Nelumbo* and water lilies are used as ornamental plants. *Eichhornia crassipes* and duck weeds are used for biological water purification. Duck weeds and *Azolla* sp. are also used as a fish feed. *Azolla* sp. is used as a biofertilizer. Some villagers also use *Eichhornia crassipes* as animal feed. All aquatic animals depend on the aquatic plants for their food and nutrients. But *Utricularia* sp. and *Aldrovandra* sp. are carnivorous, which are thought to be able to supplement nutrients from animals. It is supposed that *Aldrovandra* has already disappeared from Bangladesh. *Utricularia* sp. is going to be an endangered plant. About four species of *Utricularia* which occur in the subcontinent including Bangladesh have been listed in the Red data category as globally endangered. The list of world threatened plant database has also included *Utricularia* in their list which is compiled by World Conservation Monitoring Center (WCMC). It is a fact that only 8 -10 years ago *Aldrovanda vesiculosa* and *Euryale ferox* were available in Rajshahi region, but presently they are no where available in the region. During the last few years water bodies which were rich in *Utricularia* sp. are now almost devoid of this plant probably due to the changes in water qualities and other environmental stresses caused by anthropogenic activities. Only a small number of *Utricularia* are genuine aquatic, some rooting and some floating or immersed in the water. These carnivorous or insectivorous plants that capture and digest insects and other tiny animalcules have been subject of scientific curiosity for quite a long time. The conspicuous trapping mechanism, which is a leaf modification, draws special attention to this interesting group of plants (Lloyd 1942 and Shetler and Montgomery 1965).

Under the changed circumstances it has become essential to work on the causes of the disappearance of some plants from the natural habitats and install impact assessment studies for the conservation of endangered aquatic plants. It is a prerequisite to know the ecology and biology of the endangered aquatic plants for their protection and conservation.

There are numerous studies on the effect of water pollution on various phyto-zooplankton, macro-invertebrates and fishes. But impacts of pollution on higher aquatic vegetation have received little attention (Chowdhury and Zaman 2000a). Studies on the growth and distribution of aquatic plants in relation to pollution are also negligible (Wiegleb 1978, 1984, Best 1982 and Kohler and Labus 1983). The aquatic macrophytes can also be used as biological indicators for monitoring water pollution as suggested by Kohler (1977) and Melzer (1976 and 1981).

AIM AND OBJECTIVE OF THE WORK

The present research work was carried out to achieve the following objectives:

1. The study of general external morphology and taxonomy of the species of *Utricularia* L.
2. Estimation of the ecological conditions of *Utricularia* L.
    - (a) Physico-chemical conditions of water of *Utricularia* habitats.
    - (b) Physico-chemical conditions of bottom soil of *Utricularia* habitats.
    - (c) To know the association of *Utricularia* L. with other plants in its habitats.
3. Study to know the reproductive biology of *Utricularia* L.
4. Study to know the bladder activity and anatomical structure of the plant parts.
5. Cytological studies to know the plastids and chromosomes.
6. Estimation of the protein and chlorophyll content of *Utricularia* L.
7. Estimation of the impact of water pollution on the *Utricularia* L.

REVIEW OF LITERATURE

In Bangladesh Khan and Halim (1987) described the external morphology of 4 aquatic species of *Utricularia* L. Many workers in India and other countries including Basak (1975), Santapau (1950), Subramanyam (1981), Arber (1972), DeWit (1964), Fasset (1960), Lloyd (1942), Abraham and Subramanyam (1965), Biswas and Calder (1954), Ahmedullah and Nayar (1986), Taylor (1964), Thanikaimoni (1966), Subramanyam (1962), Shetler (1968) and Subramanyam and Kamble (1968) also described the general morphology, biology, seed, pollen, anatomical structure, trapping habit etc. Virtually no detailed work has been done on the ecology and type of plankton prey of aquatic *Utricularia* L. in Bangladesh and abroad. A number of investigation on the impact of water pollution on the aquatic ecosystem, aquatic biota and water quality have been done in Bangladesh by Bhouyain (1979 and 1983), Begum and Hossain (1993), Amin *et al.* (1979), Chowdhury *et al.* (1996, 1998 and 2000), Rahman (1992), Paul (1981), Talukder *et al.* (1994), Anonymous (1975), EPC (1980) and Chowdhury (1999) but no work have been done on the impact of water pollution on the aquatic plants except Chowdhury and Zaman (2000a). Best (1982) worked on the effects of water pollution on fresh water submerged macrophytes in India. Athie and Cerri (1986), Reddy and Smith (1987), Tourbier and Pierson (1976), Godfrey *et al.* (1985) used macrophytes (water hyacinth, lemnids and cattails) for water pollution control. Kohler (1977) and Melzer (1976 and 1981) used macrophytes as a bioindicator of water pollution. Jha *et al.* (1978) worked on the distribution of certain aquatic species of *Utricularia* in relation to their habitat in and around Jamshedpur, India. Ellis (1955) recorded preliminary notes on the correlation between alkalinity and the distribution of some free-floating and submerged aquatic plants. A number of investigations on the ecology of different macrophytes (*Potamogeton* sp., *Ceratophyllum* sp., *Myriophyllum* sp., *Hydrilla* sp., *Salvinia* sp., *Azolla* sp. and *Charophytes*) in different countries have been done by Pip (1984 and 1987), Purohit and Singh (1985), Kulshreshtha (1982), Kulshreshtha and Gopal (1981), Chamanlal (1989), Vaidya (1967), Sahai and Srivastava (1976) and Wiegleb (1984) and they also worked on the effect of different level of water pollution on the growth and ecophysico-chemical conditions of these macrophytes. No published information is available about the impact of water pollution on the ecology and biology of aquatic *Utricularia* in Bangladesh as yet.

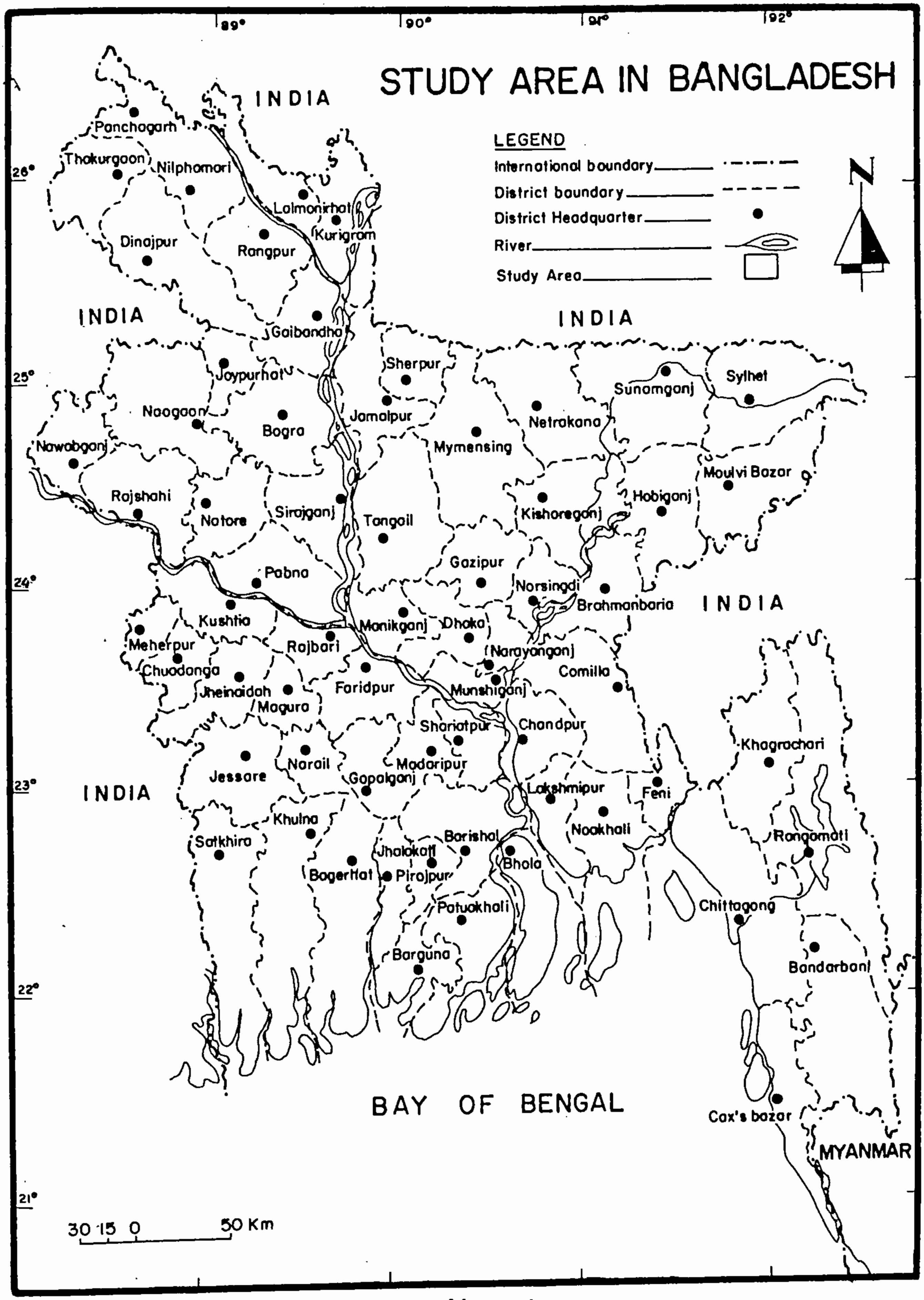
GEOGRAPHICAL LOCATION AND CLIMATE OF RAJSHAHI

Rajshahi is situated in the northern part of the Bangladesh flanked by the fringe of the greater Barind tract on the North and Bhar (VOR) basin on the south and east. It lies between 24.6° to 25.2° north latitude and 88.2° to 89.2° east longitude and is elevated above the sea level by 8-10 meters.

The climate of Rajshahi district where the study site under observations are situated, is characterized by great heat, cold and moderate rainfall owing to its geographical situation, which ensures it against the direct action of disturbing influences such as sea in the south, strong monsoon current in East and Himalayas to the north.

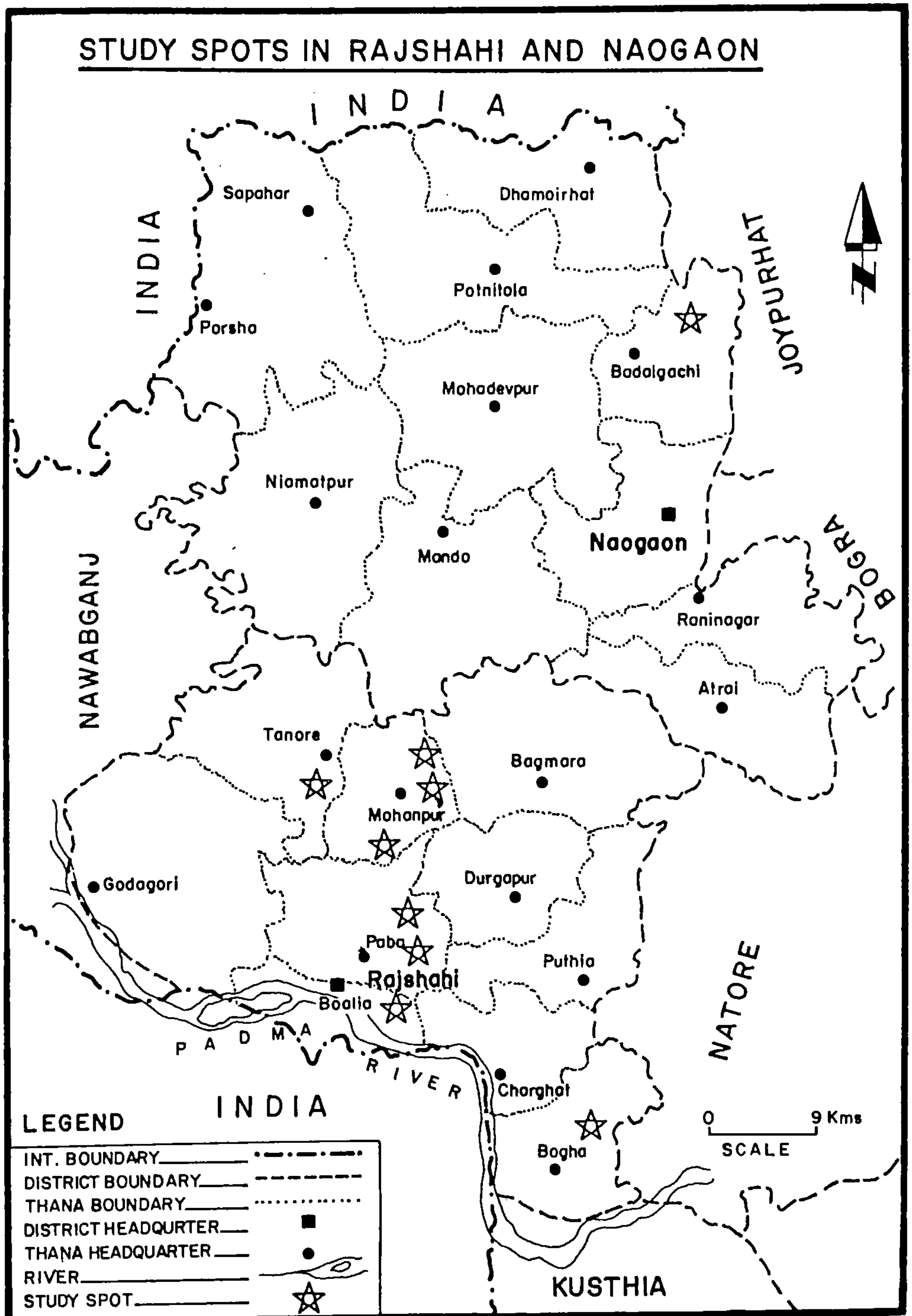
The hot season commences early in the March with the cessation of the northerly wind. Southwesterly wind prevails during the closing days of March and whole of April when moderate to gusty storms are of frequent occurrence with the rise of atmospheric temperature. Southerly wind prevails in May and south-easterly wind in the monsoon from June to the middle of October when cool nights begins to give indications of the approach of winter.

Seasonal range of atmospheric temperature of Rajshahi has been recorded as a maximum of 42°C and a minimum of 4°C round the year. The relative humidity varies from 76 to 81% throughout the year in and around Rajshahi. Usually the monsoon season commences from the mid May and persists up to September. The frequency and amount of rainfall increases as the months proceeds, till the end of the monsoon period. Heavy rainfall (200-300 mm) is recorded in this season. Other seasons are marked by scanty or no rainfall.



Source: BBS, 1991

Map- 1



Source: BBS, 1991

Map- 2

CHAPTER - TWO

MATERIALS AND METHODS

MATERIALS AND METHODS

MATERIALS

Weekly sampling was carried out from July 1999 to June 2001. *Utricularia* L. samples were collected from seven spots. Water and soil samples were collected from 14 sampling spots (7 spots were with *Utricularia* and 7 spots were without *Utricularia*). An average of the collected data of water and soil samples of the study spots were made and presented in tables.

DESCRIPTION OF SAMPLING SITES

COLLECTION SPOTS OF *UTRICULARIA* L.

All the sampling spots are perennial water bodies and rectangular in shape. All the spots were rich in different aquatic plants. Spot-1 and 2 are situated 500 meters away from the Mohonpur *upozila* headquarters under Rajshahi district. These water bodies are known as Mohonpur *beel*. Spot-1 and 2 are divided by a *kacha* road and covered an area of 1.4 km^2 and 1.2 km^2 with average depth varying from 2.6 to 3.4 m round the year. Spot-3 (Tanor *beel*) is located at the Tanor *upozila* under Rajshahi district and covered an area of 1.7 km^2 with an average depth varying from 2.5 to 3.2 m. Spot-4 (Goyespur *beel*) is located in the Badalgachi *upozila* under Naogaon district covering an area 1.6 km^2 with an average depth of 1.8 to 3.2 m. Spot-5 and 6 are ponds located at the Namovadra and Seroil area in the Boalia *thana* under Rajshahi city corporation which covered an area of 4136 m^2 and 5984 m^2 with an average depth of 1.4 to 1.7 m and 1.5 to 1.8 m respectively. Spot-7 is situated at the Bagha *upozila* under Rajshahi district, covered an area 1.5 km^2 with an average depth of 1.4 - 3.2 m. Tanor, Mohonpur and Bagha *upozila* are situated within a radius of 40 km from Rajshahi while Badalgachi *upozila* is situated at a distance of 105 km from Rajshahi.

SPOTS WITHOUT *UTRICULARIA* L.

All the sampling spots are perennial water bodies and rectangular in shape. Spot - 1, 2 and 3 are lake like water bodies which are located in the Mohonpur *upozila* under Rajshahi district, covering an area of 14564 m^2, 9786 m^2 and 12142 m^2 with an average depth of 1.4 to 2.4 m, 1.7 to 2.6 m and 1.5 to 2.3 m respectively. These water bodies are always used for domestic purposes. Spot-4 is a roadside canal, which is situated in the Paba *upozila* under Rajshahi district. This canal is 5.4 to 6.7 m wide and 2.3 km long with an average depth of 1.8 to 2.7 m, which receives the water from the adjacent paddy fields. Spot-5 and 6 are located in the Rajshahi University campus and cover an area are 6458 m^2 and 5672 m^2 with an average depth of 1.3 to 2.4 m and 1.2 to 2.1 m respectively. Both the spots receive wastewater from the nearly students halls of residence. Study spots-7 (Kukhundi *beel*) is situated in the Paba *upozila* under Rajshahi district, which covers an area of 1.2 km^2 and with an average depth of 1.7 to 2.9 m. The effluent of the Rajshahi Sugar Mills mixes with the water of this study spot which is often over flooded during the monsoon. It may be mentioned that about 5-6 years ago *Utricularia* sp. was found to grow profusely at the study spot-3, 4, 6 and 7 but now they have almost disappeared from these spots.

COLLECTION OF SAMPLES

COLLECTION OF PLANT SAMPLES

The plant samples were collected manually. Some times bamboo sticks were used for sample collection. Country boats were also used to collect the plant samples from deep areas. Before collection of plant samples hand globs were used to protect hands from the effect of plant mucilage. Both young and mature plants with flowers, and fruits were collected. During the period of collection – plastic buckets were used to carry the plant samples. After collection, the samples were brought to the laboratory for study and preservation. Fresh materials were placed in earthen aquaria allowing them to grow there for further necessary observations. The earthen aquaria were filled with water of *Utricularia* habitats and that from without *Utricularia* habitats as well. One earthen aquarium was filled with sugar mill effluent mixed polluted water from Spot - 7. Fresh *Utricularia* plants were cultured in these aquaria for observations.

COLLECTION OF WATER SAMPLES

From each study spot, water samples were collected from a depth of 10-25 cm below the surface using a 250ml glass stoppered bottle with scale (Trivedy 1993) for physico-chemical studies. Some of the physico-chemical studies were done on the spot, while others were done in laboratory.

COLLECTION OF SOIL SAMPLES

For the study of the physico-chemical properties of the bottom soils of the study spots, soil samples were manually collected. Sometimes shovels and large ladle were used to collect the bottom soil from all the study spots. The soil samples were kept in plastic bags with care. Some of the physico-chemical characteristics were performed at the spots. Samples were transferred to the laboratory for detailed studies.

METHODS

IDENTIFICATION

The species of *Utricularia* L. samples were identified by following relevant literature and confirmed by the "Bangladesh National Herbarium, Dhaka.

UTRICULARIA CULTURE IN AQUARIUM

Utricularia spp. were cultured in 5 earthen aquaria for different experiment purpose. The diameter and depth of these earthen aquaria were 0.95m and 0.66 m.

ECOLOGICAL STUDY OF *UTRICULARIA* L.

PHYSICAL CONDITIONS OF WATER

AIR AND WATER TEMPERATURE

A centigrade mercury thermometer with a range of 0°C to 120°C and a digital thermometer (model no. 950, range -10 to +110°C) were used to note the air and water temperature simultaneously at the time of sample collection at different study spots.

TRANSPARENCY

To obtain the transparency value of water of the study spots, a secchi disc was slowly lowered into the water, under a shade until it has just disappeared and the depth was noted. Then the disc was slowly raised until it has just reappeared. This depth was also noted. The average of the two depths gave the transparency value expressed in centimeter (cm).

TOTAL SUSPENDED SOLIDS (TSS)

At first a filter paper was dried at 105°C oven temperature and weighted. Then a thoroughly mixed 250ml water sample was filtered through the weighted filter paper. The filter paper was allowed to dry completely in the oven at the same temperature and reweighed. The change in the weight gave the TSS value for 250 ml of water sample, which was duly calculated for one liter. This obtained data is the total suspended solids (Expressed as mg/l) (Ambasht 1990).

TOTAL DISSOLVED SOLIDS (TDS)

A glass beaker was dried at 105°C oven temperature and weighted, and then 250 ml of the filtrate from TSS experiment was taken in this beaker and placed it into the oven at the same temperature. After the complete evaporation of the filtrate the dry weight of the beaker was taken and calculated for a value of weight in one liter of water sample. This result is the total dissolved solids expressed as mg/l (Ambasht 1990)

CHEMICAL CONDITIONS OF WATER

HYDROGEN-ION CONCENTRATION (pH)

The value of pH of water of the study spots was determined by a digital pH meter (Model - pHep HANNA instruments CE EN/50081-1).

DISSOLVED OXYGEN (DO)

Winkler's method (unmodified) was followed for the estimation of dissolved oxygen (APHA 1989). The water samples collected for dissolved oxygen estimation were treated with manganese sulfate solution, alkaline iodide solution and acidified with concentrated sulfuric acid on the spot. The treated sample was transferred to the laboratory and the remaining steps of analysis were done. No noticeable change occurred in the treated samples within 24 hours. The quantity of dissolved oxygen, thus estimated, was expressed in milligram of oxygen per liter of water (mg/l). DO content of sample water was also determined by DO Meter (Model - JENWAY - 9015 DO Meter).

PERCENTAGE OF SATURATION OF OXYGEN

It was calculated by following Welch (1948)

OXIDATION REDUCTION POTENTIAL (Eh)

It was estimated by a Digital pH Redox Meter- CORNING MODEL-3 and HANNA INSTRUMENT. It was also estimated by following deduction methods (Gautam 1990). The result was expressed in milli volt (mv).

OXIDATION REDUCTION INDEX (rH_2)

Oxidation Reduction Index (rH_2) was estimated by deduction of data of Eh by following Gautam (1990).

BIOCHEMICAL OXYGEN DEMAND (BOD_5)

The sample of BOD bottles were filled with water and immediately transported to the laboratory and left for incubation in 20°C for five days. Dissolved oxygen (DO) content of BOD bottle water sample was determined after five days by following the Winkler's method (unmodified). The value of BOD_5 was obtained by subtracting the final dissolve oxygen (FDO) from initial dissolve oxygen (IDO).

When the DO content was almost negligible or showing a condition of total anoxia, the BOD_5 was determined by dilution method (APHA 1989).

CHEMICAL OXYGEN DEMAND (COD)

It was determined by ferrous ammonium sulfate method (APHA 1989). 50ml sample was placed in a 500 ml refluxing flask and 1 g of $HgSO_4$ crystals and 5 ml H_2SO_4 (cons.) were added with several boiling chips. After some times 25 ml of 0.25N $K_2Cr_2O_7$ solution was again mixed with it. Then the refluxing flask was attached to a condenser through which (condenser) 70 ml sulfuric acid was added to it again. After through mixing of the reagents in the flask, heat was applied to it for half an hour. The sample was cooled in room temperature and was titrated (the sample) against ferrous ammonium sulfate with ferroin indicator. A blank was run (double distilled water) following the same procedure. The result was expressed in mg/l.

ELECTRIC CONDUCTIVITY

Electric conductivity was noted by using a portable conductivity meter (Model CM-TK) of range 0-10,000 µ- ohms / cm.

CHLORIDE

The most common method is known as Argentometric method ($AgNO_3$ method). Chloride ion reacts with $AgNO_3$ to produce white ppt of silver chloride and at the end point the free silver ion reacts with chromate ion to give reddish-brown colour of silver chromate. To 50 ml of sample water was mixed 2 ml of $K_2Cr_2O_7$ solution and titrated with 0.2N $AgNO_3$ solution (APHA 1989). End point of titration is a red tinge of colour (persistent). The result was expressed in mg/l.

SOLUBLE SALTS

Soluble salts were determined by following APHA (1989) and FAO (1984).

FREE CARBON DIOXIDE (CO_2)

Free carbon dioxide (CO_2) was determined by titration of water samples with N/44 sodium hydroxide solution (NaOH) using phenolphthalein as an indicator (Welch 1948). The results were expressed in mg of CO_2 per liter (mg/l) of water.

CARBONATE (CO_3) AND BICARBONATE (HCO_3) ALKALINITIES

Carbonate alkalinity or phenolphthalein alkalinity was determined by titration of 100 ml of water sample with N/50 sulfuric acid using phenolphthalein as indicator (Welch 1948). The resultant data were expressed in mg/l of $CaCO_3$, as carbonate alkalinity. Bicarbonate alkalinity or methyl orange alkalinity was determined by titration of 100 ml of water sample with N/50 sulfuric acid using methyl orange as an indicator (Welch 1948). The results were expressed in mg/l of $CaCO_3$, as bicarbonate alkalinity.

TOTAL HARDNESS

50 ml sample of water pretreated with 1 ml ammonia buffer solution was titrated against EDTA using Eriochrome Black - T as an indicator (Mishra *et al.*1992). The result was expressed in mg/l.

CALCIUM HARDNESS

50 ml of sample pretreated with 1 ml of 8% sodium hydroxide solution was titrated against EDTA solution (0.01M) using Murexide indicator (Mishra *et al.*1992). The result was expressed in mg/l.

MAGNESIUM HARDNESS

Magnesium hardness was estimated by following Mishra *et al.* (1992) method. The resultant data were expressed in mg/l.

TOTAL PHOSPHATE (PO_4)

50 mg of sample was treated by 2ml acid ammonium molybdate solution and added 4-5 drops of stenus chloride solution. A blue colour appeared. The same procedure was run with a blank sample for comparison. Both the flasks were then kept on white paper for clear view, followed by the addition of standard phosphate solution to the blank drop by drop with the help of a graduated pipette until the colour of blank exactly matched with the sample (Gautam 1990). The result was expressed in mg/l.

SILICATE

50 ml of sample was treated by 2 ml of ammonium molybdate solution and added 0.5 ml of 5% H_2SO_4. A yellow colour appeared. A blank was run following the same procedure. Then the colour was compared with colour of the sample, by adding drop by drop of K_2CrO_4 solution (Gautam 1990). The resultant data were expressed in mg/l.

AMMONIUM NITROGEN (NH_4.N)

For qualitative determination in the field, to 20 ml of the water sample was added 10 drops of the sodium potassium tartrate solution plus 2-3 drops of Nesslers reagent and mixed vigorously. If no clearly detectable yellow coloration appears, less than 0.1 mg/l of ammonium ion is present; when more than this quantity of ammonia is present; a more or less yellow coloration is seen (0.1-5 mg/l). When more than 5 mg/l is present, yellowish to reddish-brown precipitate forms. For quantitative determination, 2 ml each of the sodium potassium tartrate solution and Nessler's reagent with 100 ml of the water sample was taken into an Erlenmeyer flask and shaken vigorously and left for 5 minutes. Ammonia free 100 ml of distilled water was filled in a second flask and mixed it with the same reagents. Then with a burette graduated in 0.1 ml scales, standard ammonia solution was added drop by drop and was compared the resulting yellowish colour with the colour of the water sample. When the colors were matched the amount of standard ammonium solution added can be read off and the ammonia content can be calculated. The values are given to an accuracy of a decimal point in mg/l (APHA 1989).

TOTAL SULPHIDE

It was determined by titrimetric method (Mishra *et al.* 1992). 110 ml of the water sample was taken in a glass stoppered bottle and added 1 ml $CdCl_2$ solution (2%). This sample was allowed to stand for 24 to 48 hours. The supernatant was decanted and dissolved the precipitate in an exactly known small volume of iodine solution and 5 ml HCl. The excess iodine was titrated with standardized $Na_2S_2O_2$ solution using starch indicator. A change from dark blue colour to colourless solution is the end point. A blank was run with distilled water in similar manner.

BOTTOM SOIL OF WATER BODIES

Chemical nature of bottom soil was determined in the laboratory of Soil Resource Development Institute (SRDI) of Rajshahi by following standard methods of SRDI.

POPULATION STUDY IN FIELD

The population of *Utricularia* L. and associated plants in field were measured by following quadrate method (Ambasht 1974).

BIOLOGICAL STUDY OF *UTRICULARIA* L.

Fresh materials of *Utricularia* L. were used for all morphological studies but preserved materials were used for anatomical and cytological studies.

MEASUREMENT OF PLANT PARTS

Length, width and diameter of all vegetative and floral parts of *Utricularia* L. were measured by meter scale and Vernier Calipers. Some necessary relevant parts of the study plants were also measured by a calibrated microscope.

MEASUREMENT OF WEIGHT

Weight of different parts of *Utricularia* spp. were taken with the help of Electronic Balance (Model no. HF-200h, Max-210g, d=0.001 g, Japan).

CELL, STOMATA AND PLASTID

A fresh leaf of *Utricularia* L. plant was taken on a clear slide with the help of fine forceps and niddle. A clean cover slip was placed upon it and a gentle pressure was applied by finger tip. A drop of 5-10% glycerin was used as a mounting fluid. 1% acito cermin solution was also used for contrast. Paraffin wax and some times sealing wax dissolved in absolute alcohol were used to seal off the edges of the cover slips to prevent the material in the slide from drying. The slide was then ready for microscopic examination and photomicrography.

STUDY OF POLLEN

A mature anther was separated from the flower by fine forceps and placed it on a clean slide containing 5% glycerin. With a fine niddle the anther was crushed carefully and the pollen grains were spread over the slide. A cover slip was placed upon the pollen grain carefully. Then the slide was ready for microscopic examination and photomicrography. The slides of cover slips were plugged by paraffin wax to prevent the slide from drying. Acito cermin were also used to colour the pollen grains and for clear contrast for photomicrography.

STUDY OF CHROMOSOME

Collection, Pre-Treatment, Fixation and Preservation of Root Tips

Root tips of *Utricularia* L. were collected from the plants grown in the earthen aquarium. The young and healthy root tips were collected and pretreated in a saturated aqueous solution of paradi-chloro-benzene (P.D.B.) at 8 -10 °C for 5 -6 hours. The root tips were then transferred and fixed in aceto-alcohol (1:3, one part of acetic acid and three parts of ethyl alcohol) for 48 hours. After fixation the root tips were preserved in 70% ethyl-alcohol and stored in the refrigerator for cytological studies in future.

Staining of Root Tips

For karyotype study, temporary slides were prepared by squash method following the methods of Haque *et al.* (1976) which is described below:

(i) Root tips were washed 4/5 times with distilled water. (ii) Root tips were treated with 50% HCl at room temperature for 8 - 10 minutes. (iii) Root tips were again washed with distilled water for

5/6 minutes to remove the acid completely. (iv) Root tips were then treated with 2% aqueous solution of iron alum (ferric-ammonium-sulphate) for 4/5 minutes (v) Root tips were then washed with distilled water for 5 minutes with a frequent change of water. (vi) Root tips were treated with 0.5% *Hematoxylin* for 10 minutes. (vii) Finally the root tips were washed with distilled water for 10 minutes.

Preparation of Slides

One stained root tip was taken on a clean slide and the tip was cut with a sharp blade and a drop of 0.5% acetocermine was added to it. The root tip tissues were then crushed with a plastic tapper and were covered with clean cover glass. The slide was then heated and cooled very gently over an alcoholic flame for a few seconds and a gentle pressure was applied on the cover slip by fingertip. Additional heating and cooling was applied as needed until the cells and chromosomes were uniformly spread. Slides were then observed under light microscope and photomicrographs were taken.

CHLOROPHYLL CONTENT OF *UTRICULARIA*

Chlorophyll content of the *Utricularia* spp. leaves was estimated. Three times each of $4cm^2$ area were taken from the different positions of the leaves. Chlorophyll was extracted with 80% aqueous acetone using a mortar and pestle by grinding the tissues. The suspension was decanted into centrifuge tubes and centrifuged for 3 minutes. After centrifugation, the upper clear green solution was decanted from the colorless residue and then made up to 10 ml with 80% acetone. The optical density (O.D.) of this solution was determined against 80% acetone as blank using a spectrophotometer at wavelengths of 645 and 663 nm. The chlorophyll a and b were determined according to the formulae given by Mackinney (1941) and later used by Arnon (1949) as follows:

Chlorophyll a = $12.717\ A_2 - 2.84\ A_1$ = mg chlorophyll a per liter

Chlorophyll b = $22.869A_1 - 4.670\ A_2$ = mg chlorophyll b per liter

Where A_1 and A_2 are O.D at wavelengths of 645 and 663 nm respectively. Amount of chlorophyll per unit leaf area was calculated by the following way: 1000 × leaf area

$$\frac{\text{mg chlorophyll a or b per liter}}{1000 \times \text{leaf area}} \times 10$$

PROTEIN CONTENT OF *UTRICULARIA*

Protein content of *Utricularia* spp. was determined by the micro-Kjeldahl method according to Jayaraman (1981). The required reagents for this purpose were (1) conc. H_2SO_4, (2) 5% $CuSO_4$ in H_2O; (3) Solid K_2SO_4; (4) 0.01 N H_2SO_4 solution (accurately standardized against 0.01N Na_2CO_3 solution); (5) 40% (w/v) NaOH solution; (6) 2% boric acid solution containing bromocresol green and methyl red [10 g of boric acid was dissolved in 480 ml of distilled water. Then 20 ml of 0.1% bromocresol green (in 95% ethanol) and 4 ml of 0.1% methyl red solution were added to the boric acid solution]; (7) Few quartz chips and (8) Nitrogen determination apparatus(micro model).

4 ml Conc. H_2SO_4, 0.5g K_2SO_4, 1-2 drops of 5% $CuSO_4$ solution (catalyst) and some quartz chips (to avoid bumping) were added to 0.5g of plant powder in a Kjeldahl flask. The mixture was heated till it had become light green (2-3 hours). The digested mixture from each of the Kjeldahl flask was then separately transferred to 100 ml volumetric flask and made up to the mark with distilled water.

The collection of ammonia was carried out in the steam distillation chamber of the nitrogen determination apparatus. The chamber was designated to act as a micro-Kjeldahl flask. The steam distillation chamber containing the digested mixture (10 ml from each of 100 ml sample) was fitted back to the nitrogen determination apparatus. Boric acid solution (15 ml) in a small flask was so placed that the tip of the condenser outlet dipped below the surface of the boric acid solution. Sufficient amount of concentrated sodium hydroxide solution (30 ml) was added to the digestive in the chamber to neutralize the amount of acid present. Steam was generated from the steam-generating flask and the sample in the chamber was steam distilled until the volume of the boric acid solution became double. The condenser outlet was then rinsed with distilled water and the receiving flask was removed.

The ammonia in the boric acid solution was titrated with 0.01N H_2SO_4 until the solution had been brought back to its original yellow-green color. The titration was repeated with a control containing only 15 ml of boric acid solution diluted to approximately the final volume of the titrated sample. The volume of acid required was noted.

The total nitrogen was calculated using the formula given below:

(i) 1000 ml of 1N acid = 14g of nitrogen

(ii) Amount of protein = 6.25 × Amount of N_2 obtained.

Percentage of protein content (g/100 g of plant powder)

$$\frac{\textit{Amount of protein obtained}}{\textit{Weight of plant powder}} \times 100$$

ANATOMICAL STUDIES

Permanent anatomical slides are needed for anatomical studies of stem. Permanent slides have been made by following microtome technique using paraffin method (Johansen 1940). This method is divided in the following steps. (1) Stems of *Utricularia* were collected and cut into small pieces by sharp scalpel and blade. The small pieces were fixed in F.A.A solution (50-70% ethyl alcohol 90cc + Glacial acetic acid 5cc + Formalin 5cc). (2) Fixed stems were washed by distilled water to remove the excess fixative and were dehydrated by using alcohol. For dehydration, the parts of stem were placed at 24 hours interval in a grade series of ethyl alcohol 50%, 60%, 70%, 80%, 90% and 100%), absolute alcohol with chloroform (2:1, 1:1, 1:2) and pure chloroform. Then the samples were ready for infiltration. (3) A vial was filled with melted paraffin wax and allowed to stand until the paraffin wax solidified but not cooled completely. The samples were placed on the top of the solidified paraffin wax and transferred in the oven at once. The samples passed through the melting paraffin wax and settled on the bottom of the vial. Infiltration was thus a gradual process. The entire mixture of paraffin wax was poured off after the samples have sunk to the bottom of the vial. Oil and traces of chloroform remained, and replaced with pure melted paraffin wax. The samples were kept inside an oven (60°C) for 3-4 days from complete infiltration. (4) The paraffin wax was melted at a temperature of 58 - 60°C in the incubator. Melted wax was poured into a paper tray made earlier. The paper tray was floated on cold water to allow the wax to cool rapidly and uniformly. The wax was stirred with heated niddle to remove all the bubbles from it. When the block became cool, the process of trimming was followed and the block was prepared in suitable size (preferably rectangular). (5) The block was fixed to the block holder of the microtome machine (The Cambridge Rocker) and the microtome razor was placed at an angle of about 45°. Serial sections were cut at 8-10µ thickness and the sections were transferred to clean slides. The slides were slightly smeared by a little drop of Haupt's adhesive. The slide was flooded with 4% formalin and a portion of the ribbon containing the sections was transferred on to the slide by scalpel. Then the slides were kept up on a slide warmer. As soon as the slides dried thoroughly, they are ready for staining.

(6) The sections were stained by the following procedure (Johansen 1940):

At first the slide was taken in xylene for 20 minutes and secondly it was transferred to the following series: (i) 1:1 absolute alcohol and xylene, (ii) 2 times 100% absolute alcohol, (iii) 90% alcohol, (iv) 70% alcohol, (v) 50% alcohol, (vi) thoroughly washed with distilled water to remove the remaining fluids, (vii) 2% zinc chloride for one minute, (viii) washed in distilled water for 10 seconds, (ix) distilled water + 4 drops safranin for 10 minutes, (x) washed in distilled water for 10 seconds, (xi) treated with orange G Tanic acid- for 1 minutes , (xii) washed in distilled water for 10 seconds, (xiii) 1% iron alum for 2 minutes , (xiv) washed in distilled water for 10 seconds, (xv) 50% alcohol for 5 seconds, (xvi) 70% alcohol for 5 seconds, (xvii) 90% alcohol for 5 seconds, (xviii) 2 times xylene for 5 seconds. The slide was ready for mounting.

(7) For mounting the slides were dehydrated through different grades of alcohol (50%, 60%, 70%, 80%, 90% and absolute) and were also passed through xylene. Finally, the sections were mounted in Canada balsam. Then a permanent anatomical slide of *Utricularia* stems was prepared. The permanent slides were studied under microscope and photographs were taken by using photomicrographic techniques.

HYBRIDIZATION

Hybridization was made in six steps by following Singh (1994). The steps were- (1) Selection of plants: healthy plants and inflorescence were selected for hybridization. (2) Emasculation: *Utricularia* sp. is a bisexual plant; emasculation is necessary to prevent self-pollination. Emasculation was done before the anthers are mature and the stigma has become receptive to minimize accidental self-pollination. Emasculation was generally done in the evening, between 4-6 pm, one day before the anthers were expected to mature and the stigma was likely to become fully receptive. Therefore, the flowers selected for emasculation were likely to open the next morning. The corolla of the selected flower was opened and the anthers were carefully removed with the help of fine forceps. (3) Bagging: immediately after emasculation, the flowers were enclosed in suitable "butter paper bags" of appropriate size to prevent random cross pollination. (4) Tagging: the emasculated flowers were tagged just after bagging. Tags sizes were 2 × 3 cm. Date of emasculation and date of pollination were recorded on the tags with a carbon pencil. (5) Pollination: mature anthers were collected from the unemasculated flowers, which were also bagged earlier. Pollen grains were collected in a bag, and were used for dusting on the stigmas of emasculated flowers. The pollen was liberated and applied to the stigmas with the help of a camel hair brush and forceps. (6) Harvesting and storing the F_1 seeds: the mature crossed fruits were harvested, weighted and threshed. The number of seeds was counted, dried and properly stored.

STUDY OF THE TYPE OF PREY OF *UTRICULARIA*

The growing part of study plants were grown separately in zooplankton (prey) free aquarium for three days, to complete the digestion of previously captured zooplankton. It may be mentioned that a bladder can capture preys only once, and it turns black in about three days following the digestion of captured individuals in it. The used bladder is persistent. After three days enough zooplankton were released in these aquaria. Zooplankton was secured form ponds by a plankton net of No. 20 silk bolting cloth (mesh size 0.076 mm). After three hours following the release of zooplankton, half meter long *Utricularia* sp. plants have been collected from the aquarium and immediately preserved in 5% formaldehyde to prevent digestion of the prey captured in the mean time. Simultaneously similar sized growing parts of *Utricularia* L. also have been collected from natural water bodies. These plants were also preserved in 5% formaldehyde. The study was repeated at three months interval during the period from July 1999 to June 2001. 100 bladders of each *Utricularia* L. species of every collection were opened separately and the type of the zooplankton captured was noted and their number was counted. One bladder was opened on a slide and covered with cover slip for microscopic examination. 800 bladders were opened for each species but an average of data of 100 bladders collected from both the aquarium and natural water bodies were made, and presented in a table, as variations of data in 4 samplings throughout the study period were negligible. The data collected from the aquarium samples and that from the natural water bodies had negligible variations. Zooplankton number was counted by using a Sedgewick-Rafter counting chamber (Welch 1948) and identification was made by following Edmondson (1966) and other relevant standard literature.

PREPARATION OF HERBARIUM SHEETS

To make a herbarium sheet – at first an art paper was placed in water under a plant sample in a plastic tray which had both young and flowering stages with fruits. Then the art paper was removed with samples from the water and the water was slowly removed by lowering the side of the art paper. The plant sample was properly arranged on the art paper by a niddle or forceps and the entire sample was covered with a thin and soft cotton cloth. The covered plant sample was transferred inside newspaper folder and dried under sun. The cloth was removed carefully and the dried plant was fixed upon the art paper by transparent scotch tapes.

CHAPTER - THREE

GENERAL MORPHOLOGY AND TAXONOMY OF UTRICULARIA L.

GENERAL MORPHOLOGY AND TAXONOMY OF *UTRICULARIA*

Family: Lentibulariaceae

The genus *Utricularia* L. belongs to the family Lentibulariaceae. The Lentibulariaceae is a small family of annual or perennial herbs, almost root less, found in water and moist habitats, all of which are variously adapted for the capture and digestion of small aquatic animals, preferably the crustaceans and rotifers.

The family is cosmopolitan in distribution and includes 4 genera with about 333 species (Taylor 1977). The largest and widely distributed cosmopolitan genus *Utricularia* L. has about 275 species, almost half of which are known to occur in the new worlds and the rest being distributed in tropical Africa, Asia and Australia. *Pinguicula* L with about 50 species occurs in the central Mediterranean region and South America. The genus *Genlisea* St. Hill. has about 16 species and occurs in the tropics of South America and Africa. But *Polypompholyx* Lehm. has only 2 species and occurs in Australia. Of the 4 genera, only *Utricularia* L. occurs in the Indian subcontinent with about 29 species in India (Basak 1975) and 4 species in Bangladesh (Khan and Halim 1987).

Utricularia and *Polypompholyx* species bear bladders (Bladderwort) but the other two genera do not bear bladders (Bladderworts). The Lentibulariaceae is allied to the Scrophulariaceae in general floral characteristics, but differ by the placentation and carnivorous habit. Lentibulariaceae bears similarity in placentation and mode of dehiscence with Primulaceae, but the two families have little else in common with respect to other characteristics (Taylor 1977).

Genus: *Utricularia* L.

Linne, Gen. Pt. eds (1954) 11; Species P. (1953) 18: Clarke in Hooker, F. Brit. Ind. 4: 329 (1884); Prain, Bengal plants, 2. 581 (1903); Taylor, Kew Bull. 18. 168 (1964); Taylor (1977), Subramanyam (1962), Arbar (1972), DeWit (1964), Basak (1975), Khan and Halim (1987), Santapau (1950), Lubbock (1989), Biswas and Calder (1954).

The species of the genus *Utricularia* L. are carnivorous or insectivorous annual or perennial aquatic terrestrial or epiphytic herbs always of damp places, having no true roots or leaves, but with steam modified in various ways to function as rhizoid, stolon and foliar organs (DeWit 1964, Arber 1972, Taylor 1977, Subramanyam 1962, Basak 1975 and Khan and Halim 1987). All species bear small complex bladder or traps for the capture and digestion of aquatic insects or other tiny animalcules. The bladder (traps) may be compared to bags usually occurring on the leaves or stems. The bladders are closed by a movable valve flap, which guards the apical orifice at the ventral side. Around this entrance there are some projecting bristles, so arranged that an insect or a copepod passing the bladder will tend to be guided toward the mouth. The valve also bears a number of sensitive hairs.

The inflorescence is racemose, peduncled, usually simple, bracteates; sterile bracts often present (Known as scales) on the peduncle and sometimes in the base of the inflorescence axis; two bracteoles often present, always at the base of the pedicel, usually free or connate with the bract.

Calyx 2-lobed, usually accresscent, the lobes are variously dissimilar, usually free, sometimes connate at the base, corolla bilabiate, yellow, various shades of violet or purple, white or rarely blue or red; the upper lip is entire, or 2 or more lobed, lower lip with an entire or 2 to 5 lobed limb; more or less spurred. Stamens 2, inserted at the base of the upper lip, filaments usually short, linear, often curved or flattened and dialated above; anthers dorsifixed, more or less ellipsoid, thecae more or less confluent. Ovary is superior, globose or avoid, ovules 2-many on a free central fleshy placenta; styles usually short, stigma bilabiate, the lower lip is usually larger. Capsule or the fruit is globose or avoid which is indehiscent or open by 2 or 4 longitudinal values or slits, seeds 1 to many, variously shaped and sculptured. The seeds lack endosperm (Taylor 1977).

Utricularia L. is pollinated by insects. The insect first touches the stigma, and afterward comes in contact with the stamens. In *Utricularia* the stigma is irritable and retracts at once on being touched, so that the proboscis after dusting itself with pollen does not again come in contact with it, which supposed to ensure cross fertilization (Lubbock 1989).

1. ***Utricularia aurea* Lour (With float)**

Syn. *U. flexuosa* Vahl. (Huq 1986)

Clarke in Hook. F.H. Brid. nd. 4: 329 (1884); Prain, Beng. Pl. 2: 582 (1903) repr.; Basak (1975); Santapau (1950); Taylor (1977); Khan and Halim (1987)

It is aquatic; peduncle has a whorl of narrowly fusiform floats at the base. Bladders usually numerous. Rhizoids present; stem filiform. Branching style is dichotomous. Inflorescence a raceme on stout peduncle with rather long, recurved pedicles and calyx segments ovate, margins strongly incurved, rather fleshly, somewhat enlarged in fruit and hardly as long as the capsule. Corolla yellow and spur nearly as long as the lower lip. Ovary globose and glandular. Capsule globose, thick and fleshy. Seeds ellipsoid or obovoid, 5-angles and very narrowly winged on all the angles. (Plate 1- Photograph 1).

Habitat : *Beels*, ponds and in low land.

Ecology : Floating submerged below the surface.

2. ***Utricularia aurea* Lour. (Without float)**

Syn. *U. flexuosa* Vahl. (Huq 1986).

Clarke in Hook. Fl. Brit. Ind. 4: 329 (1884); Prain, Beng. P. 2: 582 (1903) repr. Basak (1975); Santapau (1950); Taylor (1977); Klan & Halim (1987).

This is an aquatic floating herb; peduncle has no whorl of narrowly fusiform floats at the base. Bladders usually numerous. Rhizoids present; stem filiform. Branching style is dichotomous. Inflorescence a raceme on stout peduncle with rather long, recurved pedicles and calyx segments ovate, margins strongly incurved, rather fleshly, somewhat enlarged in fruit and hardly as long as the capsule. Corolla yellow and spur nearly as long as the lower lip. Ovary globose and glandular. Capsule globose, thick and fleshy. Seeds ellipsoid or obovoid, 5-angles and very narrowly winged on all the angles. (Plate 1- Photograph 3).

Habitat : *Beels*, ponds and in low land pools.

Ecology : Floating submerged below the surface.

3. ***Utricularia stellaris* L.**

Roxb. Fl. Ind. 1: 143, 1820 & 1: 143; 1932;

Clarke in Hook. Fl. Brit. Ind. 4: 328, Prain, Beng. Fl. 2: 581 (1903); Basak (1975); Khan and Halim (1987).

It is an aquatic floating herb and the plant body is covered with mucilage. Plant color is always bright green. Peduncle stout and without scales and bearing a whorl of oblong floats about the middle. Float sessile without foliar segments at the base. Leaves multifid, interspread with bladders and floating leaves ellipsoid or avoid. Corolla yellow and spur shorter than the lower lip. Anther 1. Stigma unequally 2-labled. Fruit always shorter than the calyx. Seeds thickly discoid. (Plate 1- Photograph 2)

Habitat : Ponds, lakes and in low land pools.

Ecology : Floating submerged below the surface

4. ***Utricularia* exoleata L.**

Clarke in Hook. Fl. Brit. Ind. 4: 29 (1884); Prain, Beng. Fl. 2: 581 (1903) repr.; Taylor (1977); Basak (1975); Santapau (1950); Biswas and Calder (1954); Khan and Halim (1987).

This is aquatic, free floating, fragile stem, much branched and often mat-forming. Leaves alternate and very small, bearing bladders, multipinnate, segments capillary. Peduncle filiform, terete, glabrous; scales usually one near the middle of the peduncle, similar to the bracts. Inflorescence a raceme and 1-3 flowered. Calyx segments ovate. Corolla yellow and spur slightly exceeding the lower lip. Ovary thin and globose. Fruit laterally bivalved. Seeds with discoid margin, thin and patent. (Plate 1- Photograph 4)

Habitat : Ponds, ditches, *beels* and in shallow pools.

Ecology : Floating submerged below the surface.

Details description and measurements of different parts of study plants are given in the following pages of "observations and results" chapter.

Plate 1

Photographs: 1. *U. aurea* (new and old part); 2. *U. stellaris* (new and old part); 3. *U. aurea* (without float); 4. *U. exoleata.*

Plate 2

Photographs: 1. A large single plant of *U. aurea*; 2. A single plant of *U. stellaris* (with float); 3. Branching pattern of *U. aurea*, held by Professor M. Zaman; 4. Dense growth of *U. exoleata*; 5. A longest single plant of *U. aurea* (with float), held by Professor M. Zaman.

CHAPTER - FOUR

OBSERVATIONS AND RESULTS

OBSERVATIONS AND RESULTS

ECOLOGICAL CONDITIONS OF *UTRICULARIA* L

PHYSICAL CONDITIONS OF WATER

AIR TEMPERATURE

Water bodies with *Utricularia*

During the period of study air temperature was found to vary from 25.8-32.6°C, 23.2-30.4°C,16.3-22.8°C and 28.2-35°C in monsoon, post monsoon, winter and summer period respectively. Highest temperature was recorded in the month of May in summer period and lowest in the month of January in winter period. Yearly mean value was 26.6±5.4°C, temperature increased and decreased gradually.

Water bodies without *Utricularia*

The range of air temperature varied from 25.9-32.8°C, 23.4-30.7°C, 16.3-22.8°C and 28.2-35°C in monsoon, post monsoon, winter and summer period respectively. The highest temperature was recorded in the month of May in summer period and the lowest in the month of January in winter period. During the period of study temperature increased and decreased gradually and yearly mean value was 26.7±5.5°C.

The data were presented in Table 1 & 2.

WATER TEMPERATURE

Water bodies with *Utricularia*

The water temperature range varied from 21-29.8°C, 20.5-28.6°C, 14.9-20.2°C and 25.3-30.7°C in the period of monsoon, post monsoon, winter and summer respectively. Highest temperature 30.7°C was recorded in the month of May in summer period and the lowest (14.9°C) was in the month of January in the winter period. During the period of study water temperature increased and decreased gradually and yearly mean value was found to be 23.4±5.2°C.

Water bodies without *Utricularia*

During the study period water temperature varied from 24.2-31.5°C, 22.6-29.8°C, 15.7-21.4°C and 26.9-32.3 °C in monsoon, post monsoon, winter and summer period respectively. The highest temperature (32.3°C) was recorded in the month of May in summer period and the lowest in the month of January in winter season. Yearly mean value was 25.4±5°C and temperature gradually increased and decreased.

The data were presented in Table 1 & 2.

TRANSPARENCY

Water bodies with *Utricularia*

It these water bodies, the range of transparency was found to vary from 29-41cm, 36-49cm, 24-35cm and 19-25cm in monsoon, post monsoon, winter and summer period respectively. The highest transparency range was recorded in the post monsoon period and the lowest in summer period. The yearly mean value was 32±10cm. During the study period transparency increased and decreased gradually, and recorded an uphill and down hill manifestation.

Water bodies without *Utricularia*

The transparency range was found to vary from 20-27cm, 24-30cm, 16-23cm and 11-15 cm in monsoon, post monsoon, winter and summer season respectively. During the period of study the highest range was recorded in the post monsoon period and the lowest in the summer season. The yearly mean value was 20±5cm. Transparency increased and decreased gradually.

The data were presented in Table 1 & 2.

TOTAL SUSPENDED SOLIDS (TSS)

Water bodies with *Utricularia*

During the period of study total suspended solids of water bodies of *Utricularia* varied from 16-22 mg/l, 12-19 mg/l, 24-30 mg/l, 38-54 mg/l in monsoon, post monsoon, winter and summer period. The highest range was recorded in the period of summer and the lowest in the post monsoon. TSS values increased and decreased gradually and yearly mean value was 26±13 mg/l.

Water bodies without *Utricularia*

The range of total suspended solids of water bodies without *Utricularia* was found to vary from 60-110 mg/l, 45-90 mg/l, 78-164 mg/l and 105-220 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest range was recorded in the period of summer and the lowest in the post monsoon period. During the study period TSS values increased and decreased gradually and yearly mean value was 111± 53 mg/l.

The data were presented in Table 1 & 2.

TOTAL DISSOLVED SOLIDS (TDS)

Water bodies with *Utricularia*

During the period of study the range of total dissolved solids in water bodies of *Utricularia* was found to vary from 35-74 mg/l, 52-104 mg/l, 76-138 mg/l and 110-180 mg/l during the monsoon, post monsoon, winter and summer respectively. The highest value of TDS was recorded in the month of May in summer period and the lowest in August in monsoon period. The yearly mean value was 96±44 mg/l. The increase and decrease of TDS values showed an uphill and down hill pattern.

Water bodies without *Utricularia*

The range of total dissolved solids of water bodies without *Utricularia* varied from 190-215 mg/l, 208-230 mg/l, 254-290 mg/l and 282-367 mg/l in the monsoon, post monsoon, winter and summer period. During the period of study the highest TDS value was recorded in the month of May in summer and the lowest in August in monsoon. The pattern of rise and fall of TDS values were almost regular and yearly mean value was 253±52 mg/l.

The data were presented in Table 1 & 2.

Table 1. Physico-chemical conditions of water of *Utricularia* habitats.

Parameter		Monsoon July–Aug.	Post Monsoon Sept.–Nov.	Winter Dec.–Feb.	Summer Mar.–June	Yearly mean
Air temp.	°C	25.8–32.6	23.2–30.4	16.3–22.8	28.2–35	26.6±5.4
Water temp.	°C	21–29.8	20.5–28.6	14.9–20.2	25.3–30.7	23.4±5.2
Transparency	cm	29–41	36–49	24–35	19–25	32±10
TSS	mg/l	16–22	12–19	24–30	38–54	26±13
TDS	mg/l	35–74	52–104	76–138	110–180	96±44
pH		7.2–7.6	7.1–7.4	7.1–7.3	6.9–7.2	7.2±0.2
DO	mg/l	4.9–5.3	5–5.7	4.2–4.5	3.3–3.5	4.6±0.8
% of saturation of O_2		61–64	65–66	46–48	39–44	54±11
Eh	mv	0.953–0.957	0.948–0.955	0.923–0.931	0.884–0.892	0.931±0.028
rH_2		33.86–35	33.69–33.93	31.83–32	30.48–30.76	32.71±1.6
BOD_5	mg/l	0.8–0.9	0.9–1.1	1.1–1.3	1.6–1.8	1.2±0.4
COD	mg/l	3.9–4.2	4.1–4.6	4.6–4.9	5.6–6.2	4.8±0.8
Conductivity	µohms/cm	110–124	119–138	141–157	169–183	142±25
Chloride	mg/l	38–41	39–42	42–44	45–47	42±3
Soluble salts	g/l	0.08–0.09	0.08–0.10	0.10–0.11	0.12–0.13	0.10±0.017
CO_2	mg/l	0–7	0–9	7–10	11–13	8±3
CO_3 alk.	mg/l	0–8	0–7	Nil	Nil	2±3
HCO_3 alk.	mg/l	86–90	108–141	88–99	74–83	96±19
Total hardness	mg/l	56–64	75–82	94–108	116–134	91±26
Ca. hardness	mg/l	41–59	63–75	78–96	99–115	77±22
Mg. hardness	mg/l	1.22–3.66	1.71–2.93	2.93–3.91	4–4.64	3.06±1.11
PO_4	mg/l	Nil	Nil	Nil	Nil	Nil
Silicate	mg/l	Nil	Nil	Nil	Nil	Nil
$NH_4.N$	mg/l	Nil	Nil	Nil	0–0.036	0.003±0.03
Total sulphide	$M\ mol\ l^{-1}$	Nil	Nil	Nil	Nil	Nil

Table 2. Physico-chemical conditions of water bodies without *Utricularia* spp.

Parameter	Monsoon July–Aug.	Post Monsoon Sept.–Nov.	Winter Dec.–Feb.	Summer Mar.–June	Yearly mean
Air temp. °C	25.9–32.8	23.4–30.7	16.3–22.8	28.2–35	26.7±5.5
Water temp. °C	24.2–31.5	22.6–29.8	15.7–21.4	26.9–32.3	25.4±5
Transparency cm	20–27	24–30	16–23	11–15	20±5
TSS mg/l	60–110	45–90	78–164	105–220	111±53
TDS mg/l	190–215	208–230	254–290	282–367	253±52
pH	7.7–8.3	7.6–8.4	6.6–6.9	6.3–6.7	7.6±0.8
DO mg/l	1.9–2.6	2.2–2.8	1.2–1.8	0.7–1.2	1.8±0.7
% of saturation of O_2	26–32	29–33	14–19	10–15	22±8
Eh mv	0.527–0.538	0.516–0.524	0.497–0.506	0.484–0.491	0.511±0.018
rH_2	25.57–25.71	25.41–25.68	24.63–24.82	23.89–24.28	24.99±0.687
BOD_5 mg/l	1.8–2.1	1.9–2.3	2.3–2.6	2.8–3.2	2.4±0.5
COD mg/l	7.9–8.4	9.1–9.9	10.8–11.4	12.8–18.4	13±0.9
Conductivity µohms/cm	204–230	268–283	299–312	363–487	309±89
Chloride mg/l	60–62	66–68	69–74	89–90	72±11
Soluble salts g/l	0.14–0.16	0.19–0.20	0.21–0.22	0.26–0.34	0.22±0.06
CO_2 mg/l	6–8	9–11	12–17	19–25	11±9
CO_3 alk. mg/l	Nil	Nil	Nil	Nil	Nil
HCO_3 alk. mg/l	157–192	173–210	189–206	145–178	184±20
Total hardness mg/l	184–210	237–261	288–304	343–378	277±65
Ca. hardness mg/l	161–183	203–225	244–266	298–330	239±56
Mg. hardness mg/l	6–7	8–9	9–11	11–12	9±2
PO_4 mg/l	0.09–0.16	0.24–0.35	0.37–0.49	0.51–0.64	0.36±0.18
Silicate mg/l	0.018–0.024	0.016–0.021	0.019–0.028	0.021–0.032	0.023±0.005
NH_4.N mg/l	0–0.07	0.09–0.12	0.16–0.41	0.48–0.59	0.324±0.203
Total sulphide M mol l^{-1}	0.64–0.92	1.26–2.55	2.89–3.38	3.85–4.49	2.49±1.15

CHEMICAL CONDITIONS OF WATER

HYDROGEN ION CONCENTRATION (pH)

Water bodies with *Utricularia*

The pH value of water bodies of *Utricularia* varied from 7.2-7.6, 7.1-7.4, 7.1-7.3 and 6.9-7.2 in monsoon, post monsoon, winter and summer period respectively. During the period of study the highest pH value was recorded in the month of August in monsoon and the lowest in May in summer. A slightly acidic value was recorded only in the month of May. Yearly mean value was found to be 7.2±0.2. The pattern of increase and decrease of pH values of these water bodies were almost regular throughout the period of study.

Water bodies without *Utricularia*

During the period of study the pH value was found to vary from 7.7-8.3, 7.6-8.4, 6.6-6.9 and 6.3-6.7 in the monsoon, post monsoon, winter and summer period respectively. The highest pH was recorded in the month of September in post monsoon and the lowest in May in summer period. Acidic values were always recorded in the winter and summer period. In the study period the pattern of increase and decrease of pH values were slightly irregular and the yearly mean value was found to be 7.6±0.8.

The data were presented in Table 1 & 2.

DISSOLVED OXYGEN (DO)

Water bodies with *Utricularia*

During the period of study the dissolved oxygen content of water was found to vary from 4.9-5.3 mg/l, 5-5.7 mg/l, 4.2-4.5 mg/l and 3.3-3.5 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest DO value was recorded in the month of October in post monsoon and lowest in May in summer period. The yearly mean value was 4.6±0.8 mg/l. The rise and fall of DO values were regular.

Water bodies without *Utricularia*

In these water bodies the dissolved oxygen content varied from 1.9-2.6 mg/l, 2.2-2.8 mg/l, 1.2-1.8 mg/l and 0.7-1.2 mg/l in the monsoon, post monsoon, winter and summer period respectively. During the period of study the highest DO content was recorded in the month of October in the post monsoon and the lowest in May in summer period. The pattern of increase and decrease of DO content were almost regular and the yearly mean value was 1.8±0.7 mg/l.

The data were presented in Table 1 & 2.

PERCENTAGE OF SATURATION OF OXYGEN

Water bodies with *Utricularia*

The range of percentage of saturation of oxygen varied from 61-64, 65-66, 46-48 and 39-44 in monsoon, post monsoon, winter and summer period respectively. The highest range was recorded in the post monsoon and the lowest in summer. The yearly mean value was 54±11.

Water bodies without *Utricularia*

During the period of study the range of percentage of saturation of oxygen varied from 26-32, 29-33, 14-19 and 10-15 in monsoon, post monsoon, winter and summer period respectively. The highest range was recorded in the post monsoon period and the lowest in summer. The percentage saturation of oxygen decreased gradually and the yearly mean value was 22±8.

The data were presented in Table 1 & 2.

OXIDATION REDUCTION POTENTIAL (Eh)

Water bodies with *Utricularia*

The range of oxidation reduction potential (Eh) of these water bodies were found to vary from 0.953-0.957 mv, 0.948-0.955 mv, 0.923-0.931 mv and 0.884-0.892 mv in monsoon, post monsoon, winter and summer period. The highest range was recorded in the period of monsoon and the lowest in summer. The values decreased gradually and yearly mean value was found to be 0.931±0.028 mv.

Water bodies without *Utricularia*

Oxidation reduction potential (Eh) values of these water bodies were found to vary from 0.527-0.538 mv, 0.516-0.524 mv, 0.497-0.506 mv and 0.484-0.491 mv in monsoon, post monsoon, winter and summer period. During the period of study the highest range was recorded in monsoon and the lowest in summer period. The yearly mean value was 0.511±0.018 mv and the pattern of fall of values was gradual.

The data were presented in Table 1 & 2.

OXIDATION REDUCTION INDEX (rH_2)

Water bodies with *Utricularia*

During the period of study oxidation reduction index (rH_2) range of these water bodies varied from 33.86-35, 33.69-33.93, 31.83-32 and 30.48-30.76 in monsoon, post monsoon, winter and summer period respectively. The highest range was recorded in the period of monsoon and the lowest in summer. Oxidation reduction index decreased gradually and the yearly mean value was 32.71±1.6.

Water bodies without *Utricularia*

At these water bodies oxygen reduction index (rH_2) varied from 25.57-25.71, 25.41-25.68, 24.63-24.82 and 23.89-24.28 in monsoon, post monsoon, winter and summer period respectively. The highest range was recorded in the period of monsoon and the lowest in summer. Yearly mean value was 24.99 ± 0.687 and the pattern of fall of oxidation reduction index values was gradual.

The data were presented in Table 1 & 2.

BIOLOGICAL OXYGEN DEMAND (BOD_5)

Water bodies with *Utricularia*

Biological oxygen demand (BOD_5) of at these water bodies varied from 0.8-0.9 mg/l, 0.9-1.1 mg/l, 1.1-1.3 mg/l and 1.6-1.8 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest value was recorded in the month of May in summer and the lowest in August in monsoon. During the study period the BOD_5 value increased gradually and the yearly mean value was 1.2±0.4 mg/l.

Water bodies without *Utricularia*

The range of biological oxygen demand (BOD_5) was found to vary from 1.8-2.1 mg/l, 1.9-2.3 mg/l, 2.3-2.6 mg/l and 2.8-3.2 mg/l in monsoon, post monsoon, winter and summer period respectively. During the period of study the highest BOD_5 value was recorded in the month of May in summer period and the lowest in August in monsoon. The yearly mean value of BOD_5 was 2.4±0.5 mg/l and increased gradually from its lowest.

The data were presented in Table 1 & 2.

CHEMICAL OXYGEN DEMAND (COD)

Water bodies with *Utricularia*

At these water bodies chemical oxygen demand (COD) values varied from 3.9-4.2 mg/l, 4.1-4.6 mg/l, 4.6-4.9 mg/l and 5.6-6.2 mg/l in monsoon, post monsoon, winter and summer period respectively. During the period of study the highest value was recorded in the month of May in summer period and the lowest in August in monsoon period. The yearly mean value was 4.8±0.8 mg/l and the pattern of rise and fall were gradual.

Water bodies without *Utricularia*

During the period of study the chemical oxygen demand (COD) of these water bodies were found to vary from 7.9-8.4 mg/l, 9.1-9.9 mg/l, 10.8-11.4 mg/l and 12.8-18.4 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest value was recorded in the month of May in summer period and the lowest in August in monsoon period. The COD values increased gradually and the yearly mean value was 13±0.9 mg/l.

The data were presented in Table 1 & 2.

ELECTRIC CONDUCTIVITY

Water bodies with *Utricularia*

The range of electric conductivity of these water bodies were found the vary from 110-124 μ-ohms/cm, 119-138 μ-ohms/cm, 141-157 μ-ohms/cm and 169-183 μ-ohms/cm in monsoon, post monsoon, winter and summer period respectively. The highest electric conductivity value was recorded in the month of May in summer and the lowest in August in monsoon period. The yearly mean value was 142±25 μ-ohms/cm and pattern of rise of electric conductivity was gradual.

Water bodies without *Utricularia*

The range of electric conductivity values of these water bodies varied from 204-230 μ-ohms/cm, 268-283 μ-ohms/cm, 299-312 μ-ohms/cm and 363-487 μ-ohms/cm in monsoon, post monsoon, winter and summer period respectively. During the period of study the highest electric conductivity value was recorded in the month of May in summer and the lowest in August in monsoon. The yearly mean value was 309±89 μ-ohms/cm.

The data were presented in Table 1 & 2.

CHLORIDE

Water bodies with *Utricularia*

During the period of study the chloride value varied from 38-41 mg/l, 39-42 mg/l, 42-44 mg/l and 45-47 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest value was recorded in the month of May in summer period and the lowest in August in monsoon. Chloride values increased gradually and the yearly mean value was 42±3 mg/l.

Water bodies without *Utricularia*

In these water bodies chloride values varied from 60-62 mg/l, 66-68 mg/l, 69-74 mg/l and 89-90 mg/l in monsoon, post monsoon, winter and summer period respectively. During the study period the highest chloride value was recorded in the month of May in summer period and the lowest in August in monsoon. The yearly mean value was 72±11 mg/l and chloride values increased gradually.

The data were presented in Table 1 & 2.

SOLUBLE SALTS

Water bodies with *Utricularia*

During the period of study the soluble salts varied from 0.08-0.09 g/l, 0.08-0.10 g/l, 0.10-0.11 g/l and 0.12-0.13 g/l in monsoon, post monsoon, winter and summer period respectively. The highest range was recorded in the period of summer and the lowest in monsoon. The rise and fall of soluble salts values were found to be regular round the year. The yearly mean value was 0.10±0.017 g/l.

Water bodies without *Utricularia*

The range of soluble salts of these water bodies varied from 0.14-0.16 g/l, 0.19-0.20 g/l, 0.21-0.22 g/l and 0.26-0.34 g/l in monsoon, post monsoon, winter and summer period respectively. The highest value was recorded in the period of summer and the lowest in monsoon. During the study period the soluble salts increased and decreased gradually round the year. The yearly mean value was found to be 0.22±0.06 g/l.

The data were presented in Table 1 & 2.

CARBON DIOXIDE (CO_2)

Water bodies with *Utricularia*

During the period of study the free carbon dioxide content varied from 0-7 mg/l, 0-9 mg/l, 7-10 mg/l and 11-13 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest value was recorded in the month of May in summer period and no CO_2 was recorded in the month of August and September. Free CO_2 values increased gradually and the yearly mean was found to be 8±3 mg/l.

Water bodies without *Utricularia*

In these water bodies free carbon dioxide values were found to vary from 6-8 mg/l, 9-11 mg/l, 12-17 mg/l and 19-25 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest content of free CO_2 was recorded in the month of May in summer period and the lowest in August in monsoon period. During the period of study the free CO_2 values increased and decreased gradually round the year. The yearly mean value was 11±9 mg/l.

The data were presented in Table 1 & 2.

CARBONATE ALKALINITY (CO_3)

Water bodies with *Utricularia*

During the period of study the carbonate alkalinity (CO_3) value was recorded nil except in the month of August and September.

Water bodies without *Utricularia*

At these water bodies the carbonate alkalinity value was found to be nil during the study period.

The data were presented in Table 1 & 2.

BICARBONATE ALKALINITY (HCO_3)

Water bodies with *Utricularia*

Bicarbonate alkalinity value of these water bodies varied from 86-90 mg/l, 108-141 mg/l, 88-99 mg/l and 74-83 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest range of HCO_3 value was recorded in the post monsoon and the lowest in summer. During the study period the HCO_3 values increased and decreased almost gradually. The yearly mean value of these water bodies was 96±19 mg/l.

Water bodies without *Utricularia*

The range of bicarbonate alkalinity values of these water bodies varied from 157-192 mg/l, 173-210 mg/l, 189-206 mg/l and 145-178 mg/l in monsoon, post monsoon winter and summer period respectively. The highest value was recorded in the month of September in post monsoon period and the lowest in May in summer. Yearly mean value was 184±20 mg/l.

The data were presented in Table 1 & 2.

TOTAL HARDNESS

Water bodies with *Utricularia*

During the period of study the total hardness values of these water bodies varied from 56-64 mg/l, 75-82 mg/l, 94-108 mg/l and 116-134 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest total hardness value was recorded in the month of May in summer period and the lowest in August in monsoon. Total hardness values increased and decreased gradually round the year and the yearly mean value was 91±26 mg/l.

Water bodies without *Utricularia*

The range of total hardness values of these water bodies varied from 184-210 mg/l, 237-261 mg/l, 288-304 mg/l and 343-378 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest value of total hardness was recorded in the period of summer and the lowest in August in monsoon period. During the study period total hardness increased gradually and the yearly mean value was 277±65 mg/l.

The data were presented in Table 1 & 2.

CALCIUM HARDNESS

Water bodies with *Utricularia*

In these water bodies calcium hardness values were found to vary from 41-59 mg/l, 63-75 mg/l, 78-96 mg/l and 99-115 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest value of calcium hardness was recorded in the month of May in summer period and the lowest was in August in monsoon period. The yearly mean value was 77±22 mg/l. During the period of study, the calcium hardness values increased gradually from a lower value to a higher value.

Water bodies without *Utricularia*

Calcium hardness values of these water bodies varied from 161-183 mg/l, 203-225 mg/l, 244-266 mg/l and 298-330 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest calcium value was recorded in the month of May in summer period and the lowest in August in post monsoon. Calcium hardness values showed almost a gradual pattern of rise and the yearly mean value was 239±56 mg/l.

The data were presented in Table 1 & 2.

MAGNESIUM HARDNESS

Water bodies with *Utricularia*

The range of magnesium hardness values of these water bodies varied from 1.22-3.66 mg/l, 1.71-2.93 mg/l, 2.93-3.91 mg/l and 4-4.64 mg/l in monsoon, post monsoon, winter and summer period respectively. The magnesium hardness value was recorded in the month of May in summer and the lowest in August in monsoon. Magnesium hardness values increased and decreased gradually and the yearly mean value was 3.06±1.11 mg/l.

Water bodies without *Utricularia*

Magnesium hardness values of these water bodies varied from 6-7 mg/l, 8-9 mg/l, 9-11 mg/l and 11-12 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest value was recorded in the month of May and the lowest in August. The yearly mean value was 9±2 mg/l during the period of study.

The data were presented in Table 1 & 2.

TOTAL PHOSPHATE (PO_4)

Water bodies with *Utricularia*

During the period of study the total phosphate values of these water bodies were found to be nil.

Water bodies without *Utricularia*

The range of total phosphate value varied from 0.09-0.16 mg/l, 0.24-0.35 mg/l, 0.37-0.49 mg/l and 0.51-0.64 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest PO_4 value was recorded in the period of summer and the lowest in monsoon. The yearly mean value was 0.36±0.18 mg/l. Total phosphate values showed gradual pattern of rise and fall during the period of study.

The data were presented in Table 1 & 2.

SILICATE

Water bodies with *Utricularia*

During the period of study the silicate values of these water bodies were found to be always nil.

Water bodies without *Utricularia*

The silicate values of these water bodies were found to vary from 0.018-0.024 mg/l, 0.016-0.021 mg/l, 0.019-0.028 mg/l and 0.021-0.032 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest value was recorded in the month of May in summer period and the lowest in September in post monsoon period. The fluctuation of silicate values was noticed during the study period. The yearly mean value was 0.023±0.005 mg/l.

The data were presented in Table 1 & 2.

AMMONIUM NITROGEN (NH_4.N)

Water bodies with *Utricularia*

The ammonium nitrogen values of these water bodies were always recorded nil except in the month of April and May in summer period.

Water bodies without *Utricularia*

During the study period the ammonium nitrogen values of these water bodies were found to vary from 0-0.07 mg/l, 0.09-0.12 mg/l, 0.16-0.41 mg/l and 0.48-0.59 mg/l in monsoon, post monsoon, winter and summer period respectively. The highest value was recorded in the summer. No ammonium nitrogen was recorded in the month of August in the monsoon period. Ammonium nitrogen values showed gradual pattern of rise and fall. The yearly mean value was 0.324±0.203 mg/l.

The data were presented in Table 1 & 2.

TOTAL SULPHIDE

Water bodies with *Utricularia*

During the period of study any total sulphide value was not recorded in these water bodies.

Water bodies without *Utricularia*

During the period of study the total sulphide value was recorded only in the study spot-7, which varied from 0.64-0.92, 1.26-2.55, 2.89-3.38 and 3.85-4.49 M mol l^{-1} in monsoon, post monsoon, winter and summer period respectively. The maximum total sulphide content was recorded in the month of May, while the minimum in August. The yearly mean value of total sulphide was 2.49±1.15 M mol l^{-1}.

The data were presented in Table 1 & 2.

SOIL CONDITIONS

Water bodies with *Utricularia*

During the period of study the organic matter and total nitrogen content of soil of *Utricularia* habitats were found to vary from 1.26-1.29 and 0.06-0.08%. pH varied from 7.8-8.1; calcium, magnesium and potassium content varied from 30.70-31.00, 2.42-2.47 and 0.10-0.12 milli equivalent/100g soil respectively. The content of phosphorus, sulpher, boron, copper, iron, manganese and zinc were found to vary from 2.40-2.60, 23.50-23.70, 0.15-0.17, 3.68-3.73, 24.40-24.50, 7.80-8.00 and 0.96-0.97 micro-gram/g soil respectively. The variations of all elements of soil were negligible in the winter, monsoon, post monsoon and summer period.

Water bodies without *Utricularia*

The pH of soil of water bodies without *Utricularia* were found to vary from 6.8-7.6. The organic matter and total nitrogen content varied from 4.23-4.28 and 0.16-0.22%. During the study period the calcium, magnesium and potassium content varied from 38.90-38.93, 4.56-4.58 and 0.31-0.34 milli equivalent/100g soil respectively. The content of phosphorus, sulpher, boron, copper, iron, manganese and zinc of soil were found to vary from 11.50-11.60, 49.60-49.90, 0.48-0.51, 19.60-19.64, 67.20-67.80, 12.50-12.65 and 11.44-11.48 micro-gram/g soil. These values had negligible variations during winter, monsoon, post monsoon and summer periods.

The data were presented in Table 3.

Table 3. Chemical conditions of bottom soil of water bodies with and without *Utricularia* spp.

Soil elements	Water bodies with *Utricularia* spp.	Water bodies without *Utricularia* spp.
pH	7.8–8.1	6.8–7.6
% of organic matter	1.26–1.29	4.23–4.28
Calcium milli equivalent/100 g soil	30.70–31.00	38.90–38.93
Magnesium milli equivalent/100 g soil	2.42–2.47	4.56–4.58
Potassium milli equivalent/100 g soil	0.10–0.12	0.31–0.34
% of total nitrogen	0.06–0.08	0.16–0.22
Phosphorus micro–gram/g soil	2.40–2.60	11.50–11.60
Sulpher micro–gram/g soil	23.50–23.70	49.60–49.90
Boron micro–gram/g soil	0.15–0.17	0.48–0.51
Copper micro–gram/g soil	3.68–3.73	19.60–19.64
Iron micro–gram/g soil	24.40–24.50	67.20–67.80
Manganese micro–gram/g soil	7.80–8.00	12.50–12.65
Zinc micro–gram/g soil	0.96–0.97	11.44–11.48

Table 4. List of algal plants growing upon or associated with *Utricularia* spp.

PHYTOPLANKTON	Inside bladder	On leaf surface	On stem surface
CYANOPHYCEAE			
Oscillatoria (3 spp.)	+	+	+
Lyngbya (2 spp.)	–	+	+
Spirulina major	+	+	+
Arthrospira sp.	–	+	–
Phormidium sp.	–	+	–
Nostoc sp.	–	–	+
Anabaena sp.	–	–	+
Chroococcus sp.	–	+	+
Gloeocapsa sp.	–	+	+
CHLOROPHYCEAE			
Chlorococcum (2 spp.)	+	–	+
Coelastrum (2 spp.)	–	+	+
Chlorella (3 spp.)	+	+	+
Closterium sp.	–	+	+
Scenedesmus (3 spp.)	–	+	+
Pediastrum (3 spp.)	+	–	+
Netrium (2 spp.)	–	+	+
Spirogyra (3 spp.)	–	+	+
Oedogonium (2 spp.)	–	+	+
Cosmarium (2 spp.)	+	–	+
BACILLARIOPHYCEAE			
Fragilaria (3 spp.)	+	+	+
Synedra (2 spp.)	+	+	–
Cocconeis (2 spp.)	+	+	–
Hantzchia (2 spp.)	+	+	+
Surirella (2 spp.)	+	–	+
Rhopalodia (2 spp.)	–	+	+
Gyrosigma sp.	+	–	+
Pinnularia (3 spp.)	+	+	+
Navicula (4 spp.)	+	+	+
Gomphonema sp.	–	+	+
Cymbella (2 spp.)	+	+	–
Melosira (2 spp.)	–	+	+
Stephanodiscus (2 spp.)	+	–	+

+ = Present

– = Not detected

Table 5. **Relative density and importance value index of other hydrophytes occurring in the *Utricularia* habitats.**

Associated plants	Relative density	Importance value index
Utricularia sp.	1.86–2.76%	49.28–55.75
Ceratophyllum submersum	7.34–8.58%	61.14–99.02
Cyperus platystylis	6.92–7.46	74.21–96.09
Cyperus tegetiformis	8.68–10.32%	86.53–97.62
Eichhornia crassipes	5.17–7.27%	83.22–107.84
Enhydra fluctuans	6.11–8.53%	77.69–86.42
Hydrilla verticillata	8.96–18.89%	85.27–120.16
Ipomoea aquatica	3.28–4.65%	71.92–82.12
Lemna minor	10.86–19.48%	105.49–107.39
Limnophylla heterophylla	6.05–7.48%	93.54–104.58
Ludwigia adscendens	7.43–7.70%	88.34–119.54
Marsilea quadrifolia	5.67–8.16%	74.66–114.47
Nymphaea stellata	4.77–5.52%	66.86–84.45
Ottelia alismoides	2.42–3.98%	71.45–88.27
Pistia stratiotes	5.49–7.56%	69.94–86.38
Potamogeton crispus	2.73–4.24%	59.78–67.47
Salvinia rotundifolia	4.12–9.30%	69.21–105.50
Scirpus articulatus	7.53–18.27%	65.85–112.18
Spirodela polyrhiza	11.08–15.41%	89.78–111.23

PHYTOPLANKTON OF *UTRICULARIA* HABITATS

During the period of study, a total 32 genera of phytoplankton were recorded which were associated with *Utricularia* L. amongst which 9 genera belong to Cyanophyceae, 10 to Chlorophyceae and 13 to Bacillariophyceae. The Cyanophytes were *Oscillatoria* sp., *Lyngbya* sp. *Spirulina major*, *Arthrospira* sp., *Phormidium* sp., *Nostoc* sp., *Anabaena* sp. *Chroococcus* sp. and *Gloeocapsa* sp. The Chlorophycean members were *Chlorococcum* sp., *Coelastrum* sp., *Chlorella* sp., *Closterium* sp., *Scenedesmus* sp., *Pediastrum* sp., *Netrium* sp., *Spirogyra* sp., *Oedogonium* sp. and *Cosmarium* sp. The Bacillariophycean members were *Fragilaria* sp., *Synedra* sp., *Cocconeis* sp., *Hantzchia* sp., *Surirella* sp., *Rhopalodia* sp., Gyrosigma sp., *Pinnularia* sp., *Navicula* sp., *Gomphonema* sp., *Cymbella* sp., *Melosira* sp. and *Stephanodiscus* sp. Phytoplankton genera were recorded from inside the bladder, on leaf and stem surface of *Utricularia* spp.. The maximum number of associated phytoplankton genera of *Utricularia* were recorded from the Bacillariophyceae group while the Cyanophytes were minimum.

The data were presented in Table 4.

HYDROPHYTES OF *UTRICULARIA* HABITATS

During the period of study the recorded associated plants of *Utricularia* habitats were *Ceratophyllum submersum, Cyperus platystylis, Cyperus tegetiformis, Eichhornia crassipes, Enhydra fluctuans, Hydrilla verticillata, Ipomoea aquatica, Lemna minor, Limnophylla heterophylla, Ludwigia adscendens, Marsilea quadrifolia, Nymphaea stellata, Ottelia alismoides, Pistia stratiotes, Potamogeton crispus, Salvinia rotundifolia, Scirpus articulatus* and *Spirodela polyrhiza* and their relative density were 7.34-8.58, 6.92-7.46, 8.68-10.32, 5.17-7.27, 6.11-8.53, 8.96-18.89, 3.28-4.65, 10.86-19.48, 6.05-7.48, 7.43-7.70, 5.67-8.16, 4.77-5.52, 2.42-3.98, 5.49-7.56, 2.73-4.24, 4.12-9.30, 7.53-18.27 and 11.08-15.41% respectively. The importance value index of *Ceratophyllum submersum, Cyperus platystylis, Cyperus tegetiformis, Eichhornia crassipes, Enhydra fluctuans, Hydrilla verticillata, Ipomoea aquatica, Lemna minor, Limnophylla heterophylla, Ludwigia adscendens, Marsilea quadrifolia, Nymphaea stellata, Ottelia alismoides, Pistia stratiotes, Potamogeton crispus, Salvinia rotundifolia, Scirpus articulatus* and *Spirodela polyrhiza* were found to vary from 61.14-99.02, 74.21-96.09, 86.53-97.62, 83.22-107.84, 77.69-86.42, 85.27-120.16, 71.92-82.12, 105.49-107.39, 93.54-104.58, 88.34-119.54, 74.66-114.47, 66.86-84.45, 71.45-88.27, 69.94-86.38, 59.78-67.47, 69.21-105.50, 65.85-112.18 and 89.78-111.23 respectively. Whereas the relative density and importance value index of *Utricularia* sp. varied from 1.86-2.76% and 49.28-55.75. The high densities were showed by the *Hydrilla verticillata, Lemna minor, Scirpus articulatus* and *Spirodela polyrhiza* where the lower densities by the *Ottelia alismoides* and *Potamogeton crispus*. During the period of study, *Eichhornia crassipes, Hydrilla verticillata, Lemna minor, Limnophylla heterophylla, Ludwigia adscendens, Marsilea quadrifolia, Salvinia rotundifolia, Scirpus articulatus* and *Spirodela polyrhiza* showed high importance value index while the low was showed by *Potamogeton crispus*.

The data were presented in Table 5.

BIOLOGICAL STUDY OF *UTRICULARIA* L.

MEASUREMENT OF DIFFERENT PARTS OF *UTRICULARIA*

PLANT SIZE

During the period of study the length of whole plant of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found vary from 80–158, 74–190, 50–106 and 12–25 cm respectively. The diameter range of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 5-7, 5-8, 3-6 and 0.3-0.5 cm respectively. The highest length and diameter of *U. aurea* (with float and without float) were recorded in the month of August and September, while the lowest were recorded in the month of April and May. The highest length and diameter of *U. stellaris* were recorded in the month of July and August, while the lowest were recorded in March, April and May. The highest length and diameter of *U. exoleata* were recorded in the month of October and the lowest in May. The length of plant body and diameter of stem of *U. aurea* (with float and without float) and *U. exoleata* decreased gradually from November, whereas *U. stellaris* decreased gradually from September. But the length and diameter of whole plant of all species of *Utricularia* started to increase from June.

The data were presented in Table 6.

Table 6. Measurement of different parts of *Utricularia* spp.

Plant parts			*U. aurea* (with float)	*U. aurea* (without float)	*U. stellaris*	*U. exoleata*
Plant size (Whole plant)	cm	Length	80–158	74–190	50–106	12–25
		Diameter	5–7	5–8	3–6	0.30–0.50
Root	cm	Length	6–12	7–13	5–10	3.40–4.60
		Diameter	0.08–0.12	0.08–0.12	0.07–0.11	0.10–0.14
Stem	cm	Length	–	–	–	–
		Diameter	0.20–0.40	0.20–0.40	0.20–0.40	0.14–0.20
Leaf	cm	Length	1.50–1.90	1.60–2.00	1.30–1.60	1.10–1.50
		Width	0.30–0.50	0.30–0.50	0.30–0.50	0.10–0.14
Float	cm	Length	4–6	No float	2.10–3.60	No float
		Diameter	0.70–0.80	–	0.80–1.10	–
Bladder	cm	Length	0.18–0.45	0.18–0.48	0.22–0.40	0.20–0.25
		Width	0.12–0.38	0.12–0.39	0.12–0.20	0.11–0.17
Peduncle	cm	Length	7.80–11.50	8–11.80	6.70–8.80	4.50–5.20
		Diameter	0.20–0.28	0.20–0.30	0.19–0.26	0.13–0.19
Flower	cm	Length	1.00–1.40	1.10–1.50	0.90–1.20	0.50–0.70
		Width	0.70–1.00	0.80–1.10	0.70–0.90	0.40–0.60
Sepal	cm	Length	0.50–0.60	0.52–0.61	0.70–0.84	0.24–0.30
		Width	0.28–0.34	0.28–0.35	0.52–0.62	0.18–0.22
Largest petal	cm	Length	0.58–0.65	0.59–0.66	0.52–0.71	0.31–0.33
		Width	0.75–0.85	0.76–0.86	0.56–0.73	0.32–0.34
Smallest petal	cm	Length	0.52–0.56	0.53–0.58	0.47–0.67	0.28–0.30
		Width	0.55–0.60	0.56–0.61	0.54–0.70	0.29–0.31
Anther	µm	Length	189–198	192–199	184–192	152–159
		Width	115–127	117–130	109–116	83–88
Ovary	cm	Length	0.35–0.39	0.37–0.41	0.29–0.33	0.21–0.23
		Width	0.19–0.22	0.21–0.22	0.18–0.20	0.11–0.14
Pollen grain	µm	Length	121–157	123–158	118–155	55–63
		Diameter	114–149	115–152	112–143	49–53
Fruit	cm	Length	0.68–0.82	0.68–0.85	0.65–0.78	0.31– 0.45
		Width	0.49–0.56	0.49–0.56	0.38–0.44	0.24–0.36
Seed	cm	Length	0.09–0.11	0.09–0.11	0.06–0.08	–
		Width	0.08–0.09	0.08–0.09	0.06–0.07	–
Stomata	µm	Length	7.3–7.9	7.3–7.9	7.1–7.6	6.9–7.2
		Width	6.6–6.9	6.6–6.9	6.5–6.8	6.2–6.6
Large cell	µm	Length	142–156	144–158	140–152	66–74
		Width	72–88	74–90	68–84	42–49
Small cell	µm	Length	93–114	94–118	88–112	47–58
		Width	71–86	73–88	67–82	34–43
Meristematic cell	µm	Length	35–44	38–48	32–40	25–29
		Width	31–36	33–39	29–35	23–26
Plastid	µm	Length	4–4.6	4–4.6	3.9–4.4	3.6–4.1
		Width	3.6–4	3.6–4	3.6–3.9	3.3–3.7

– = Not detected

Plate 3

Photographs : 1. Inflorescence of *U,aurea* (without float); 2. Fruit of *U.aurea* (with and without float); 3. Fruit axis of *U.aurea* (a) and *U.stellaris* (b); 4. Fruit set by artificial cross (thread mark) in *U.aurea* (without float); 5. Fruits of *U.aurea* (with and without float); 6. Fruits of *U.stellaris*.

ROOT

Roots in all species of *Utricularia* were absent from June to December. Roots were formed in January and were found to be present up to May when water levels have decreased in the study spots. The root length of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 6-12, 7-13, 5-10 and 3.4-6.4 cm respectively. The root diameter of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 0.08-0.12, 0.08-0.12, 0.07-0.11 and 0.1-0.14 cm respectively. The maximum root length and diameter of *U. aurea* (with float and without float) *U. exoleata* were recorded in the month of April and the minimum in January. The maximum root length and diameter of *U. stellaris* were recorded in the month of March and April while the minimum were in January and May. It may be mentioned that roots were found in a small number of *Utricularia* plants.

The data were presented in Table 6.

STEM

During the study period the stems diameter of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 0.2-0.4, 0.2-0.4, 0.2-0.4 and 0.14-0.2 cm respectively. The maximum diameter of all species of *Utricularia* was recorded in the month of August and September, while the minimum in March to May.

The data were presented in Table 6.

LEAF

The length of leaves of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 1.5-1.9, 1.6-2.0, 1.3-1.6 and 1.1-1.5 cm respectively during the period of study. The leaves of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris and U. exoleata* were found to vary from 0.3-0.5, 0.3-0.5, 0.3-0.5 and 0.10-0.14 cm respectively. The maximum leaf length and width of *U. aurea* (with float), *U. aurea* (with float) and *U. stellaris* were recorded in the month of August and September, while the minimum in April and May. But the highest length and width of *U. exoleata* leaves were recorded in the month of September while the lowest in April. The leaves of *Utricularia* were light or dark green in color. *U. exoleata* leaves were slightly flat and leaves of other species were almost circular. The leaves of the all species of *Utricularia* had many microscopic spines (Plate-8) at the upper end.

The data were presented in Table 6.

FLOAT

Floats are spongy structures at the base of inflorescences, which keeps it afloat. During the period of study the length of floats of *U. aurea* (with float) and *U. stellaris* varied from 4-6 and 2.1-3.6 cm. The diameter of *U. aurea* and *U. stellaris* floats were found to vary from 0.7-0.8 and 0.8-1.1 cm. *U. exoleata* has no float. The highest length and diameter of floats of *U. aurea* were recorded in the month of August, September and October, but the highest length of float of *U. stellaris* was recorded in the month of August. The lowest length and diameter of floats of *U. aurea* and *U. stellaris* were recorded in the month of April and May.

The data were presented in Table 6.

BLADDER

The length of bladders of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 0.18-0.45, 0.18-0.48, 0.22-0.40 and 0.20-.0.25 cm respectively during the period of study. The diameter of bladders of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 0.12-0.38, 0.12-0.39, 0.12-0.20 and 0.11-0.17 cm respectively. The highest length and width of bladders of *U. aurea* (with float and without float) and *U. exoleata* were recorded in the month of April and May, while the lowest in September. But the highest length and width of bladders of *U. stellaris* were recorded in the month of August and the lowest in March. The size of bladder of *U. aurea* (with float) and *U. aurea* (without float) were almost similar.

The data were presented in Table 6.

PEDUNCLE

Peduncles of all species of *Utricularia* were mostly cylindrical. During the period of study the length of peduncle of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 7.8-11.5, 8-11.8, 6.7-8.8 and 4.5-5.2 cm respectively. The diameter of peduncle of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 0.2-0.28, 0.2-0.3, 0.19-0.26 and 0.13-0.19 cm respectively. The maximum length and diameter of peduncle of all species of *Utricularia* were recorded in the month of September and October while the minimum was in the month of May and June.

The data were presented in Table 6.

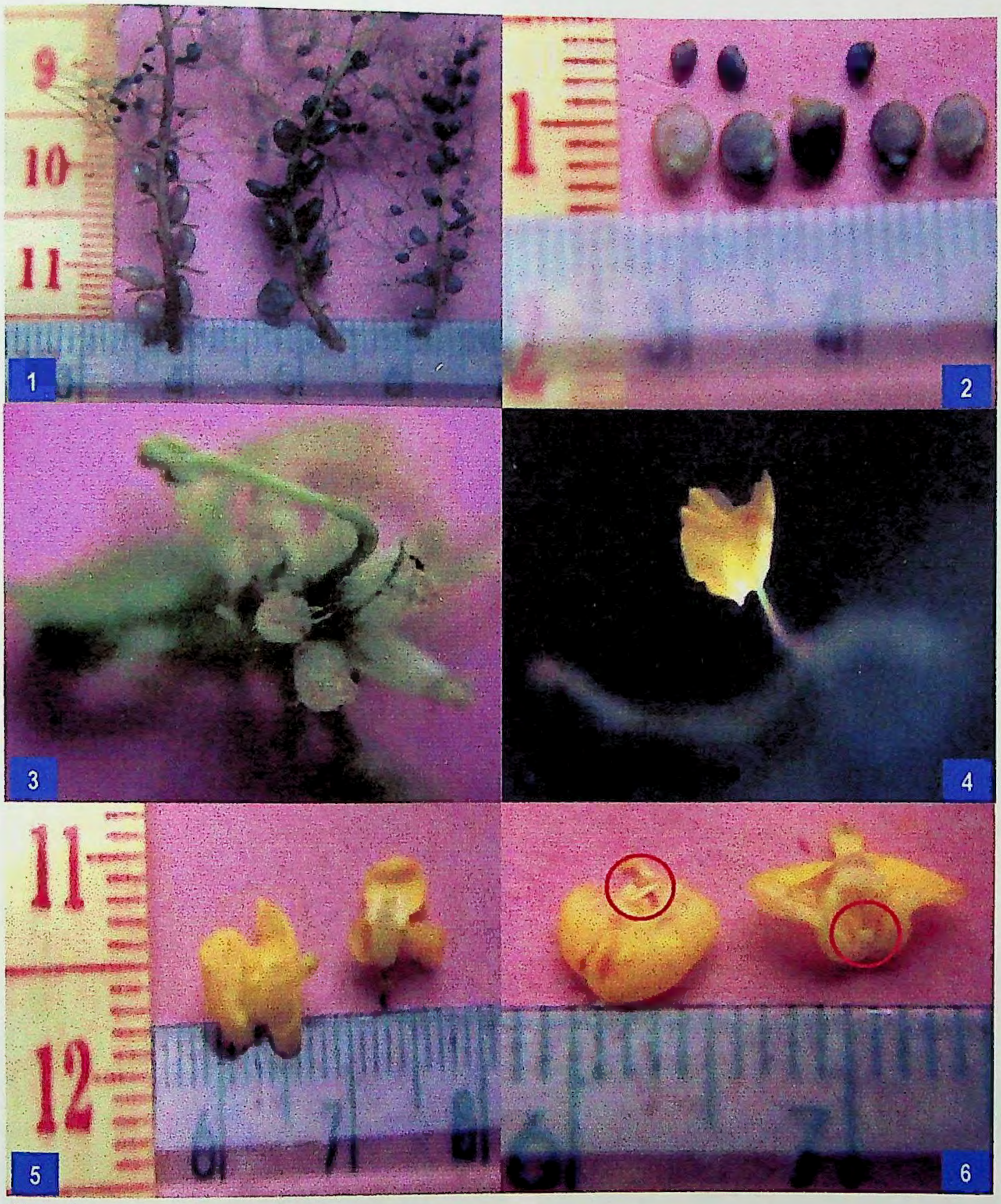


Plate 4

Photographs: 1. Different sizes of bladder of *Utricularia* spp.; 2. Bladders with prey (black) and without prey (clear); 3. Float of *U.stellaris;* 4. Flower of *U.exoleata;* 5. Flower of *U.aurea* and *U. stellaris;* 6.Corolla with anther(red circle) of *Utricularia* spp.

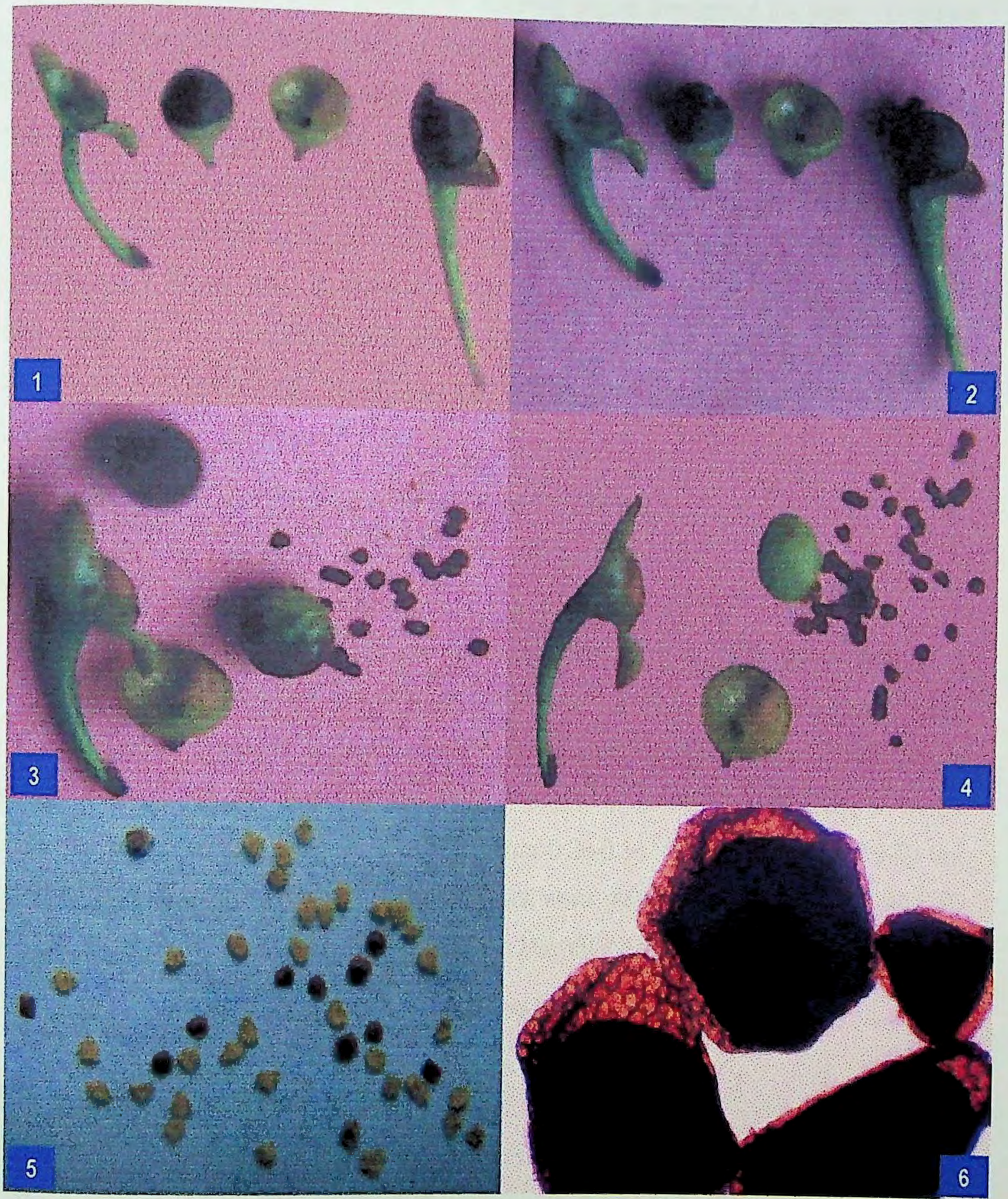


Plate 5

Photographs: 1-2. Dehisced fruits of *Utricularia* spp. showed internal structure; 3-4. Fruit capsule, testa and seeds; 5. Mature (black) and immature (yellow) seeds; 6. Seeds under microscope (X100).

FLOWER

Utricularia spp. are perennial plants and flowering occurs throughout the year. *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* has more than one flower in an inflorescence, whereas in *U. exoleata* the flower is solitary. The flower color is yellow in all species. The flower-length of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* were found to vary from 1.0-1.4, 1.1-1.5 and 0.9-1.2 cm respectively. The width of flower of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* varied from 0.7-1.0, 0.8-1.1 and 0.7-0.9 cm respectively. The highest length and width of flowers of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* were recorded in the month of August, September and October while the lowest in April and May. The flowers of *U. exoleata* were found to appear only in the month of April and May during the study years.

The data were presented in Table 6.

SEPAL

The flowers of *Utricularia* species had two sepals. The length and diameter of the sepals were correlated with flowers length and diameter. The length of sepal of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* varied from 0.50-0.60, 0.52-0.61 and 0.70-0.84 cm respectively during the period of study. The width of sepals of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* were found to vary from 0.28-0.34, 0.28-0.35 and 0.52-0.62 cm respectively. The maximum length and width of sepals were recorded in the month of August, September and October while the minimum in April and May during the period of study.

The data were presented in Table 6.

LARGEST PETAL AND SMALLEST PETAL

All the study species of *Utricularia* the flowers had two petals. One was smaller than the other. The length of the largest petals of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* were found to vary from 0.58-0.65, 0.59-0.66 and 0.52-0.71 cm respectively. The width of largest petals of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* varied from 0.75-0.85, 0.76-0.86 and 0.56-0.73 cm respectively. During the period of study the length of smallest petals of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* varied from

0.52-0.56, 0.53-0.58 and 0.47-0.67 cm respectively. The width of smallest petals of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* varied from 0.55-0.60, 0.56-0.61 and 0.54-0.70 cm respectively. The highest length and width of the largest petals were recorded in the same month of August, September and October while the lowest were recorded in the months April and May. The flowers of *U. exoleata* were found in the month of April and May. The length and width of petals of *U. exoleata* in the month of April were higher than that in May.

The data were presented in Table 6.

ANTHER

During the period of study the length of anther of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* varied from 189-198, 192-199 and 184-192 micron respectively. The width of anther of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* were found to vary from 115-127, 117-130 and 109-116 micron respectively. The maximum length and width of anther of these *Utricularia* were recorded in the month of August, September and October, while the minimum in April and May. The anthers of *U. exoleata* were found only in the month of April and May.

The data were presented in Table 6.

OVARY

The ovary of all species of *Utricularia* appeared like a conical flask. During the period of study the length of ovary of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* were found to vary from 0.35-0.39, 0.37-0.41 and 0.29-0.33 cm respectively. The width of ovary of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* varied from 0.19-0.22, 0.21-0.22 and 0.18-0.20 cm respectively. The maximum length and width of ovary of all study species of *Utricularia* except *U. exoleata* were recorded in the month of August, September and October while minimum in April and May.

The data were presented in Table 6.

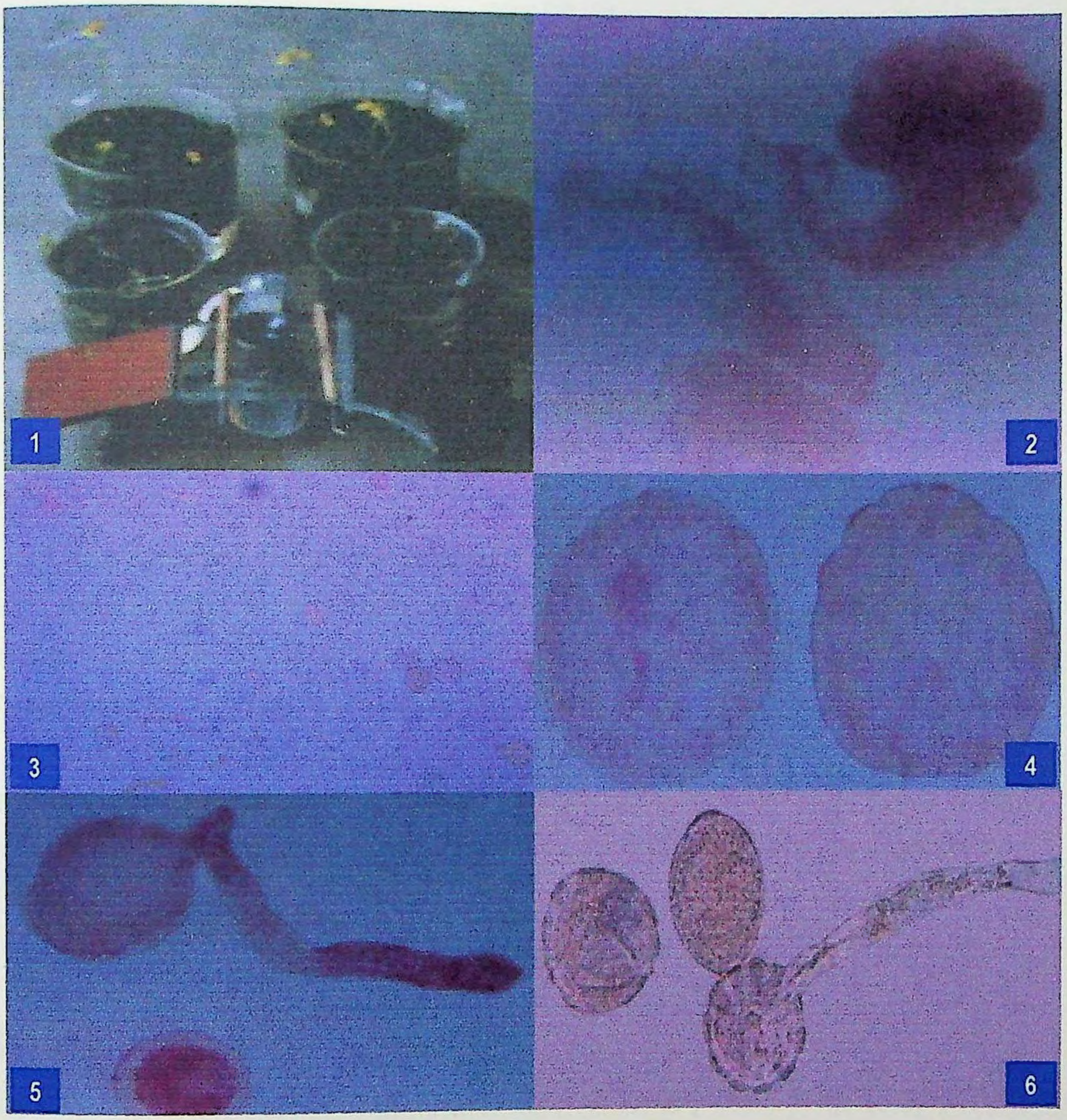


Plate 6

Photographs: 1. Preparation for artificial cross; 2. Anther under microscope; 3. Pollen (X 100); 4. Pollen, without germination tube (X 400); 5. Pollen, with and without germination tube (X 400); 6. Pollen, with and without germination tube (X 400).

POLLEN GRAIN

During the period of study the pollen grain of study species of *Utricularia* were more or less different in size and shape at different times and varied from species to species. Some pollen grains were circular and some were semicircular. The length of pollen grain of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 121-157, 123-158, 118-155 and 55-63 micron respectively. The diameter or width of pollen grain of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 114-149, 115-152, 112-143 and 49-53 micron respectively. During the period of study it was observed that almost all the study species of *Utricularia* had some germinated pollen grains inside the anther before being liberated (Plate-6).

The data were presented in Table 6.

FRUIT

During the period of study the length of fruit of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 0.68-0.82, 0.68-0.85, 0.65-0.78 and 0.31-0.45 cm respectively. The width of fruit of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 0.49-0.56, 0.49-0.56, 0.38-0.44 and 0.24-0.36 cm respectively. The maximum length and width of fruits of *U. aurea* (with float and without float) and *U. stellaris* were recorded in the month of September and October, while the minimum in April and May. During the period of study the fruits of *U. exoleata* were observed only in the month of April and May.

The data were presented in Table 6.

STOMATA

The length of stomata of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 7.3-7.9, 7.3-7.9, 7.1-7.6 and 6.9-7.2 micron respectively. The width of stomata of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 6.6-6.9, 6.6-6.9, 6.5-6.8 and 6.2-6.6 micron respectively. The maximum length and width of stomata and the minimum length and width of stomata were found in the same plants of *U. aurea* (float and without float), *U. stellaris* and *U. exoleata*. It was observed that the size of stomata were not dependant upon the seasonal changes.

The data were presented in Table 6.

SEED

The shape of seeds of *Utricularia* spp. was semicircular. The length of seeds of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* were found to vary from 0.09-0.11, 0.09-0.11 and 0.06-0.08 cm respectively. The width of seeds of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* varied from 0.08-0.09, 0.08-0.09 and 0.06-0.07 cm respectively. The highest and lowest lengths of seeds were found in the same fruit of *U. aurea* (with float and without float) and *U. stellaris*. During the period of study the length and width of *U. exoleata* seeds could not detect.

The data were presented in Table 6.

CELL

The permanent tissue consisting of the xylem, phloem and ring of mechanical tissue surrounding the central vascular region are clearly differentiated from the meristematic tissue. The cortical regions being parenchymatous have peripheral cells with chloroplast. The length and breadth of individual cells irrespective of whether they are meristematic, vascular, mechanical or else, have been measured here as they varied considerably with respect to their size and shape.

During the period of study the meristematic cells were found in the growing part of *Utricularia*. Permanent cells were clearly of two sizes – one was smaller than other. Small and large cells were clearly found in the leaves and stems of *Utricularia*.

Meristematic cell: The length of meristematic cells of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 35-44, 38-48, 32-40 and 25-29 micron respectively. The width of meristematic cells of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 31-36, 33-39, 29-35 and 23-26 micron respectively. The highest and lowest length and width of meristematic cells of *Utricularia* spp. were recorded at the same time and same parts of those species.

Permanent cell:

Large cell: During the period of study the length of large vegetative cells of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 142-156, 144-158, 140-152 and 66-74 micron respectively. The width of large cells of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 72-88, 74-90, 68-84 and 42-49 micron respectively. The maximum and minimum length and width of large vegetative cells of all study species of *Utricularia* were recorded at the same leaves of those species.

Small cell : During the period of study the length of small cell of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 93-114, 94-118, 88-112 and 47-58 micron respectively. The width of small vegetative cells of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 71-86, 73-88, 67-82 and 34-43 micron respectively. The maximum and minimum length and width of small vegetative cells of study species of *Utricularia* were found at the same leaves of those species.

The data were presented in Table 6.

PLASTID

The size and shape of plastids in the study plants were investigated during the period of study. The length of plastid of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 4.0-4.6, 4.0-4.6, 3.9-4.4 and 3.6-4.1 micron respectively. The width of plastid of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 3.6-4.0, 3.6-4.0, 3.6-3.9 and 3.3-3.7 micron respectively. The maximum length and width of plastid and the minimum length and width of plastid were recorded in the same plants of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata*. Plastid size was not dependant upon the season changes.

The data were presented in Table 6.

ANATOMICAL CONDITION OF *UTRICULARIA*

The aquatic species of *Utricularia* are almost rootless and the leaf and shoot can not be easily distinguished. The most characteristic vegetative organ is the well known, small, variously sized traps or bladders for capturing and digesting small animals. The overall anatomical feature of the relevant parts of the plant have been studied in the present investigation and summarized below :

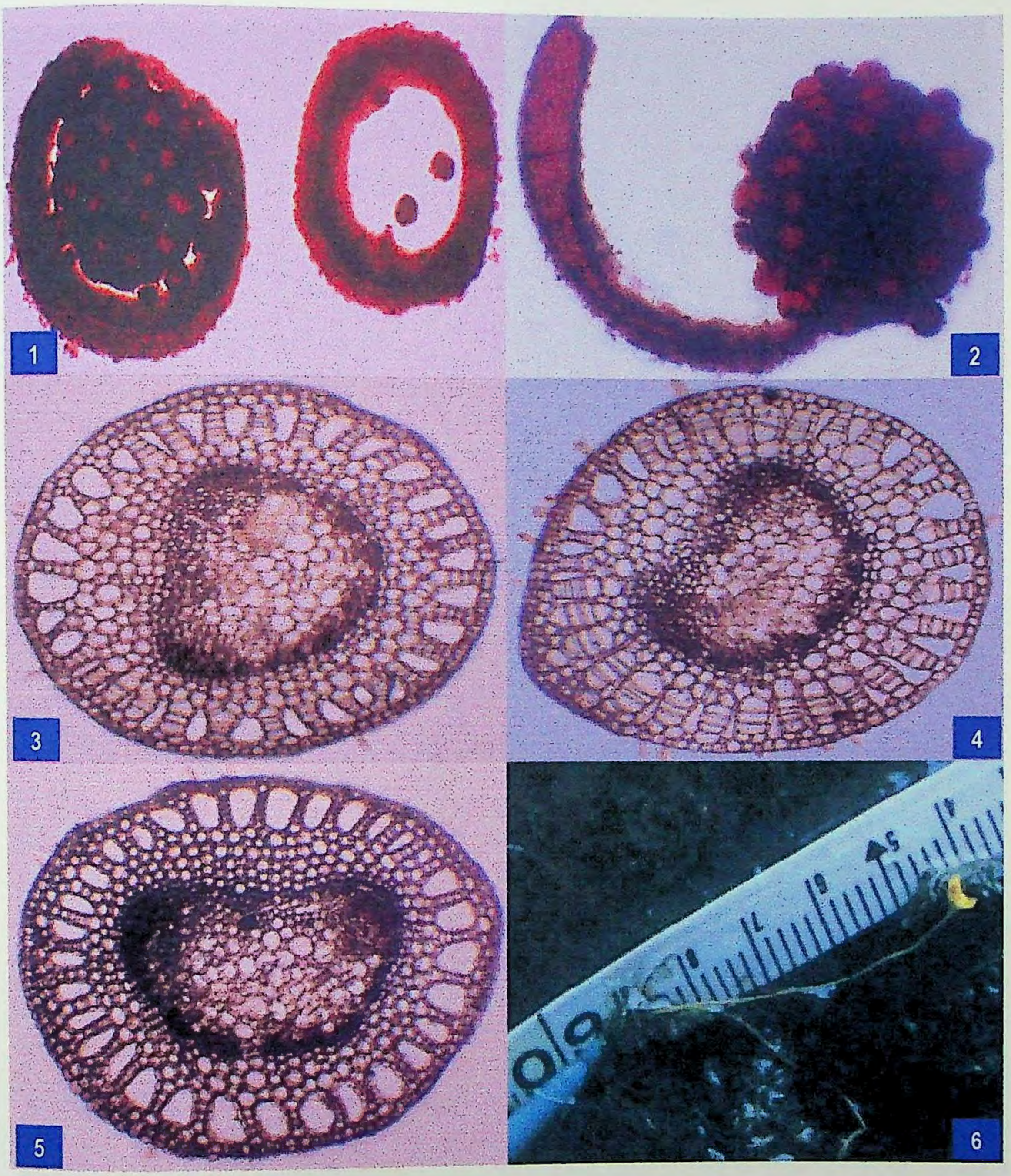


Plate 7

Photographs: 1-2. T.S. of ovary (X100); 3. T.S. of stem of *U.stellaris* (X 50); 4. T.S. of stem of *U.exoleata* (X 50); 5. T.S. of stem of *U.aurea* (X 50); 6. Length of inflorescence axis of *U.exoleata*.

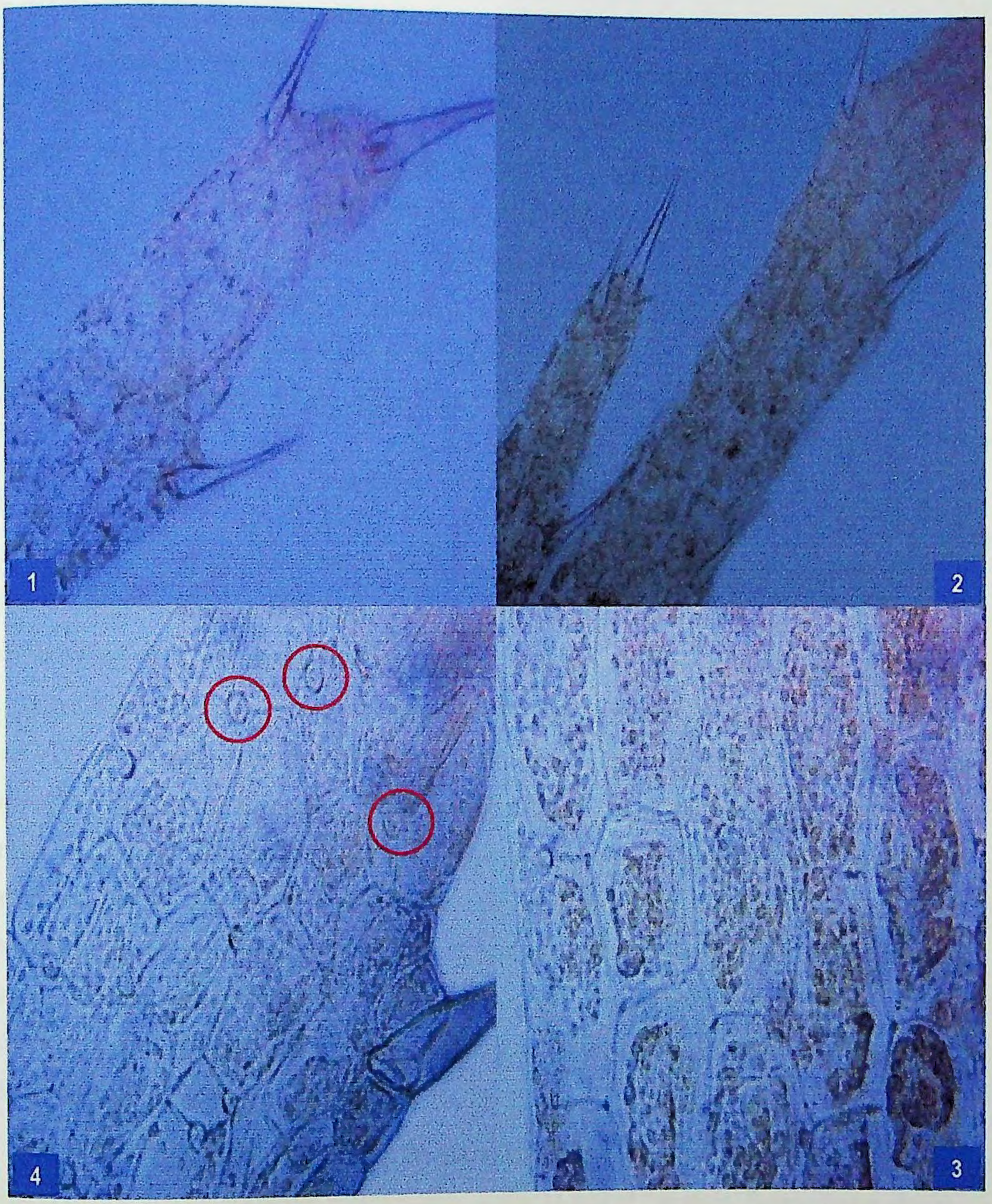


Plate 8

Photographs : 1-2. Structure of leaf with spines under microscope (X 100); 3. Vegetative cells of leaf with reduced stomata (X 400); 4. Plastid in vegetative cells (X 400).

ROOT

In the floating stage the species of *Utricularia* root are absent; but when the water level falls considerably and the plants almost come in contact with the bottom soil, roots were found to develop in a very small number. Anatomically the roots of *Utricularia* spp. present a similar internal tissue differentiation as in other floating submerged hydrophytes. In the studied species of *Utricularia*, the roots had no cuticle and the epidermis in single layered, made up of thin walled parenchymatous cells. The cortex is well developed with thin walled parenchymatous cells. A large number of air chambers or cavities appear just below the epidermis. The endodermis surrounds a thin ring of mechanical tissue. The vascular tissue is poorly developed and the phloem and xylem are separated from each other. The phloem elements occur in the mechanical ring while the xylem elements occur on the inside of the mechanical ring.

STEM

Transverse section of stem of *Utricularia stellaris, U. exoleata* and *U. aurea* (Plate-7, Photos.3-5) exhibit almost similar internal tissue differentiation. Cuticle being absent, the epidermis is distinguished by small isodiametric cells below which the cortex appears and ends in the endodermal layer. The endodermal layer separates the cortical zone from the central vascular area having a prominent pith made up of thin walled, loose, parenchymatous cells. A large number of air chambers or lacunae, characteristic of hydrophytes, occur below the epidermal layer. The air chamber are not of uniform size and are separated from each other by a narrow strip of parenchyma, while the main cortex below consists of small, thin walled isodiametric parenchymatous tissue. The cortex is internally bounded by the endodermal layer which surrounds a ring of mechanical elements of ununiform thickness. The phloem elements occur in the mechanical ring in a scattered manner. The xylem elements, fewer in number, always occur on the inside of the mechanical ring.

A transverse section of the axis of the inflorescence of the three studied species of *Utricularia* exhibit an internal tissue differentiation similar to that of the stem. Cuticle being absent, a single layered epidermis, parenchymatous in nature, is well marked below which the lacunar cortex appears ending in the endodermis layer. A thin layer of mechanical elements is present below the endodermis. The vascular bundle is poorly developed and the position of phloem and xylem is similar to that in the stem. A thin walled parenchymatous pith is present.

THE FOLIAGE LEAVE

The minute cylindrical leaves of *Utricularia* spp. consists of lacular tissue of elongated parenchyma (Plate- 8) cells surrounded by a very reduced axile vascular bundle. Mesophylls of the leaves are homogeneous and composed of more or less isodiametric cells, stomata, in small numbers, are present near the margin and on the lower and upper surfaces. The leaves have small capitate glands and large spiny surface cells (Plate-8), characteristics of aquatic submerged plants. The mesophylls of the leaves contain large number of chloroplasts.

PHYSIOLOGICAL CONDITIONS OF *UTRICULARIA*

CHLOROPHYLL CONTENT OF *UTRICULAIRA*

During the period of study the content of chlorophyll-a of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 1.25-1.27, 1.25-1.27, 1.26-1.30 and 1.16-1.19 mg dm^{-2} respectively. The highest content of chlorophyll-a of all species of *Utricularia* were recorded in the month of August. Whereas, the minimum were recorded in the month of April and May. Chlorophyll-a content increased and decreased showing an uphill and down hill pattern gradually.

Chlorophyll-b content of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 1.86-1.89, 1.86-1.89, 1.89-1.93 and 1.69-1.73 mg dm^{-2} respectively. The highest content of chlorophyll-b of all species of *Utricularia* were recorded in August but the lowest were in April and May. In all the study plants, the chlorophyll-b content showed regular fluctuations.

During the period of study it was found that the chlorophyll-b content was always higher than that of chlorophyll-a in all the species of *Utricularia*.

The data were presented in Table 7.

PROTEIN CONTENT OF *UTRICULARIA*

The protein content of growing parts of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 3.46-3.49, 3.44-3.48, 3.08-3.13 and 1.81-1.84 mg g^{-1}dry weight respectively during the period of study. The highest content of protein of growing part of all species of *Utricularia* were recorded in the month of September, whereas the lowest protein content were recorded in the month of April and May. The increase and decrease pattern of protein content were almost regular.

The protein content of old part of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 3.77-3.81, 3.76-3.80, 3.24-3.29 and 1.81-1.84 mg g^{-1}dry weight respectively. The highest protein content of old part of all species of *Utricularia* were recorded in the month of September, while the minimum were in April and May. Protein content of all species were found to increase and decrease almost in a regular pattern.

During the period of study the protein content of old part of all species of *Utricularia* were always found to be higher than that of the growing parts.

The data were presented in Table 7.

NUMBER AND WEIGHT OF DIFFERENT PARTS OF *UTRICULARIA*

NUMBER OF ANTHER

U. aurea (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* had only 2 anthers in each flower. The anthers were found to be always persistence.

The data were presented in Table 8.

NUMBER OF POLLEN GRAIN

Number of pollen grain of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 33-39, 29-41, 31-43 and 23-34 respectively during the period of study. It is observed that the pollen grain numbers depends upon the anther size, and irrespective of season. The bigger the anther size, the larger the pollen grain numbers.

The data were presented in Table 8.

Table 7. Chlorophyll and protein content of *Utricularia* spp.

Plants name	Chlorophyll (mg dm^{-2})		Protein (mg g^{-1}dry wt.)	
	a	b	New part	Old part
U. aurea (with float)	1.25–1.27	1.86–1.89	3.46–3.49	3.77–3.81
U. aurea (without float)	1.25–1.27	1.86–1.89	3.44–3.48	3.76–3.80
U. stellaris	1.26–1.30	1.89–1.93	3.08–3.13	3.24–3.29
U. exoleata	1.16–1.19	1.69–1.73	1.81–1.84	1.81–1.84

Table 8. Number and weight of different relevant parts of *Utricularia* spp.

Plants name	No. of		Weight (mg) of		Seed no./ Fruit	Bladder no./ 100 cm	Chromosome no.	Plastid no. in	
	Anther	Pollen grain	Ovary	Fruit				Largest cell	Smallest cell
U. aurea (with float)	2	33–39	12–14	21–29	64–76	23616–23993	16	50–70	16–25
U. aurea (without float)	2	29–41	12–14	21–29	62–75	23245–23694	24	52–71	15–25
U. stellaris	2	31–43	11–13	20–27	78–95	5140–5254	–	54–76	19–28
U. exoleata	2	23–44	7–8	12–15	38–52	260–280	–	31–49	12–21

– = Not detected

WEIGHT OF OVARY

During the period of study the weight of ovary of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 12-14, 12-14, 11-13 and 7-8 mg respectively. The variations in the weight of ovary were found to be almost negligible in a particular species.

The data were presented in Table 8.

WEIGHT OF FRUIT

The weight of fruits of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 21-29, 21-29, 20-27 and 12-15 mg respectively. During the period of study the fruits of *U. exoleata* were observed only in the month of April and May. The variations of fruits weight of *U. aurea* with float and without float were similar. The maximum weight of fruits was recorded in the month of September while the minimum were in April and May.

The data were presented in Table 8.

NUMBER OF SEEDS PER FRUITS

During the period of study the number of seeds of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 64-76, 62-75, 78-95 and 38-52 per fruit respectively. The maximum number of seeds of study species was recorded in the month of August and September, whereas the minimum were in April and May.

The data were presented in Table 8.

NUMBER OF BLADDERS

During the period of study the number of bladders per 100cm length of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* varied from 23616-23993, 23245-23694, 5140-5254 and 260-280 respectively. The maximum number of bladders of study species was recorded in the month of August and September, while the minimum in April and May.

The data were presented in Table 8.

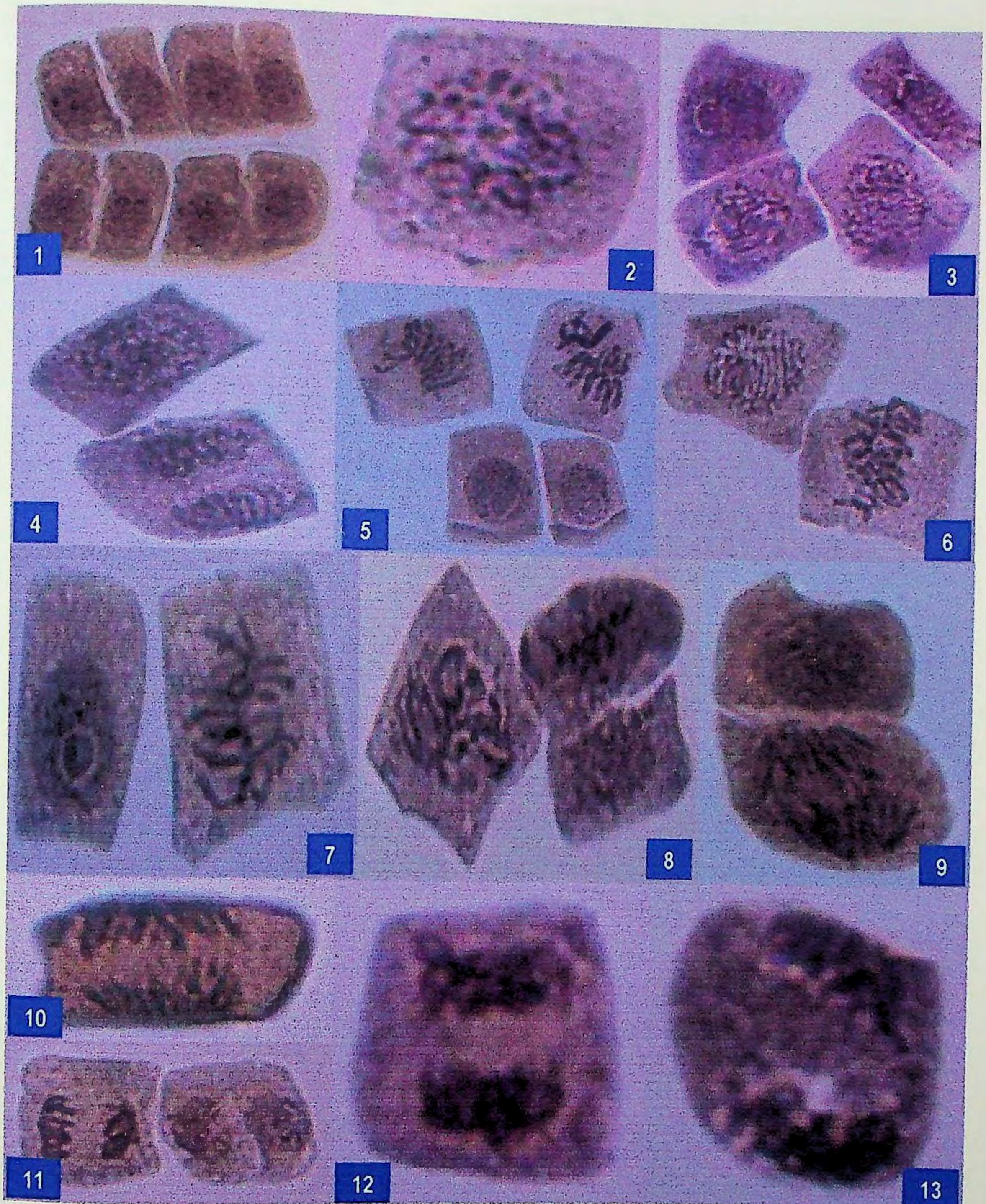


Plate 9

Photographs : 1. Vegetative cells of growing root tips; 2-3. Early metaphase; 4. Early metaphase and telophase; 5, 7-8. Metaphase and vegetative cells; 6. Metaphase; 9-10. Anaphase; 11-13. Telophase. (all magnifications X 600).

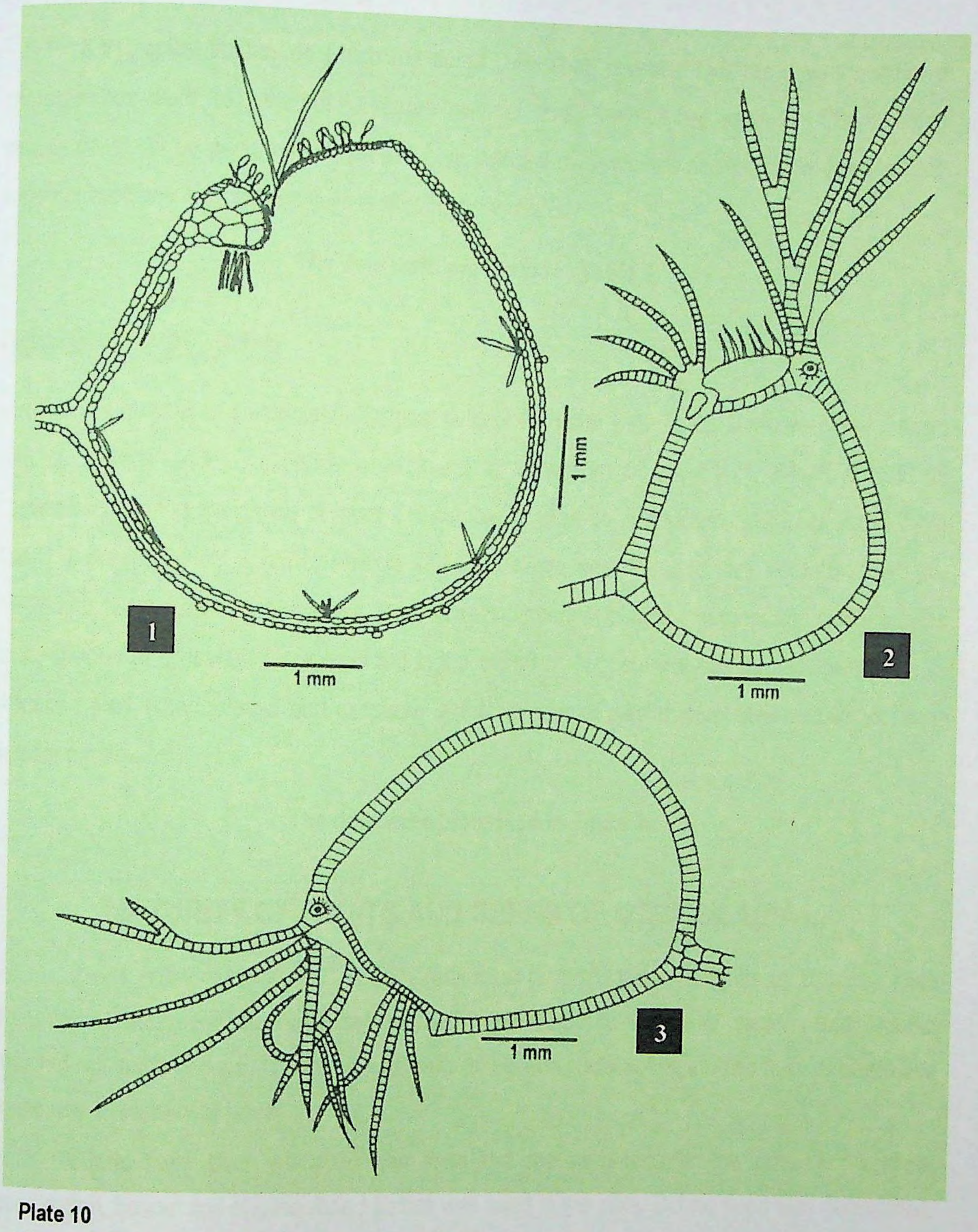


Plate 10

Figures: **Bladder structure of *Utricularia* L.** 1. L. S. of the bladder of *Utricularia aurea* (with and without float); 2. L. S. of the bladder of *U. exoleata*; 3. L. S. of the bladder of *U. stellaris*.

NUMBER OF CHROMOSOME

Karyological studies on *Utricularia aurea* (with float) revealed that the diploid number of chromosomes were 16, whereas *U. aurea* (without float) the number were 24. Chromosomal studies could not be performed in the other two species of *Utricularia* as the fragile growing roots were not available with dividing cells during the time of study.

The data were presented in Table 8.

NUMBER OF PLASTID

The number of chloroplast of largest cells of *U. aurea* (with float), *U. aurea* (without float) and *U. stellaris* and *U. exoleata* were found to vary from 50-70, 51-71, 54-76 and 31-49 respectively. During the period of study the number of plastids of smallest cells of *U. aurea* (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleata* were found to vary from 16-25, 15-25, 19-28 and 12-21 plastids respectively. The highest numbers of plastid of largest and smallest cells of all species of *Utricularia* were recorded in the month of August, whereas the minimum were in April and May. The increase and decrease in the number of plastid were observed almost in a regular pattern.

The data were presented in Table 8.

MATURITY OF FRUITS AND SEEDS OF *UTRICULARIA* L.

It was observed that after artificial pollination (Hybridization) the fruits of *U. aurea* (with float) and *U. aurea* (without float) had matured within 40-50 days. The *U. stellaris* had become matured within 35-49 days. The maturity of fruits and seeds could not be studied in *U. exoleata* due to the non-availability of flower.

Efforts have been made to germinate the mature seeds in the pots. For artificial germination, bottom soil of *Utricularia* habitats was used in the pots. But no seed was germinated. Such repeated efforts totally failed to secure any germination. Probably the seed germination in the bottom soil of *Utricularia* habitats is influenced by some unknown factors.

Table 9a. Number of captured zooplankton per 100 bladders of different species of *Utricularia* in natural water bodies.

ZOOPLANKTON	*U. aurea* (With float)	*U. aurea* (Without float)	*U. stellaris*	*U. exoleata*
ROTIFERA				
Notholca (3spp.)	19	24	21	16
Keratella (2spp.)	11	9	4	3
Brachionus (3spp.)	24	21	16	29
Filinia sp.	–	7	–	–
Philodina sp.	9	4	–	–
Trichocerca sp.	6	10	3	–
Rotaria sp.	15	7	–	3
Harringia sp.	10	2	–	–
CLADOCERA				
Daphnia (3spp.)	64	59	52	21
Moina (2spp.)	21	18	12	9
Bosmina (2spp.)	19	22	28	14
Alona sp.	14	9	–	5
Ceriodaphnia sp.	13	15	6	–
Dadaya sp.	–	–	14	8
Diaphanosoma sp.	6	10	–	–
Sida sp.	8	12	–	2
Macrothrix sp.	–	–	9	–
COPEPODA				
Cyclops (2 spp.)	28	31	17	21
Mesocyclops	7	16	12	5
Macrocyclops sp.	16	11	8	–
Diaptomus sp.	13	9	–	2
* Naupilus	25	26	31	16
Total	328	322	233	154

*Baby Copepods – = Not detected

Table 9b. Percentage (%) of the total food ingested by different stage/species of *Utricularia* from different groups of zooplankton.

Species	Rotifera	Cladocera	Copepoda
U. aurea (with float)	28.6	44.2	27.1
U. aurea (without float)	26.1	45.0	28.8
U. stellaris	18.9	51.93	29.1
U. exoleata	33.1	38.3	28.6
Mean %	26.7	44.9	28.4

COMMON ZOOPLANKTON AS PREY OF *UTRICULARIA* L.

Utricularia aurea (with float), captured 328 individuals of 19 genera in 100 traps which consisted of 94 Rotifers (*Notholca* sp., *Keratella* sp., *Brachionus* sp., *Philodina* sp., *Trichocerca* sp., *Rotaria* sp. and *Harringia* sp.), 145 Cladocerans (*Daphnia* sp., *Moina* sp., *Bosmina* sp., *Alona* sp., *Ceriodaphnia* sp., *Diaphanosoma* sp. and *Sida* sp.) and 89 Copepods (*Cyclops* sp., *Mesocyclops* sp., *Macrocyclops* sp., *Diaptomus* sp. and Naupilus).

Utricularia aurea (without float) secured 322 individuals of 20 genera in 100 traps which consisted of 84 Rotifers (*Notholca* sp., *Keratella* sp., *Brachionus* sp., *Filinia* sp., *Philodina* sp., *Trichocerca* sp., *Rotaria* sp. and *Harringia* sp.), 145 Cladocerans (*Daphnia* sp., *Moina* sp., *Bosmina* sp., *Alona* sp., *Ceriodaphnia* sp., *Diaphanosoma* sp. and *Sida* sp.) and 93 Copepods (*Cyclops* sp., *Mesocyclops* sp., *Macrocyclops* sp., *Diaptomus* sp. and Naupilus).

U. stellaris preyed upon 233 individuals of 14 genera in 100 bladders which consisted of 44 Rotifers (*Notholca* sp., *Keratella* sp., *Brachionus* sp. and *Trichocerca* sp.), 121 Cladocerans (*Daphnia* sp., *Moina* sp., *Bosmina* sp., *Ceriodaphnia* sp., *Dadaya* sp. and *Macrothrix* sp.) and 68 Copepods (*Cyclops* sp., *Mesocyclops* sp., *Macrocyclops* sp., and Naupilus).

Utricularia exoleata trapped 154 zooplankton individuals of 14 genera in 100 bladders in which there were 51 Rotifers (*Notholca* sp., *Keratella* sp., *Brachionus* sp. and *Rotaria* sp.), 54 Cladocerans (*Daphnia* sp., *Moina* sp., *Bosmina* sp., *Alona* sp., *Dadaya* sp. and *Sida* sp.) and 44 Copepods (*Cyclops* sp., *Mesocyclops* sp., *Diaptomus* sp. and Naupilus).

The data were presented in Table 9.

IMPACT OF PHYSICO-CHEMICAL CONDITIONS ON *UTRICULARIA* SP.

During the period of study, it was observed that, when the values of certain physico-chemical conditions of water increased or decreased, the *Utricularia* spp. were affected in different ways. The effects were observed in natural field and aquarium culture. The lethal level of different physico-chemical conditions at which the *Utricularia* spp. were affected, included water temperature 24-25°C, transparency <25 cm, TSS>60 mg/l, TDS>150 mg/l, DO<3 mg/l, Eh <0.755 mg/l, rH_2 <26, BOD>1.8 mg/l, COD>7 mg/l, electric conductivity >220 micro-ohms/cm, chloride>50 mg/l, total hardness >150 mg/l, calcium hardness>140 mg/l, PO_4 >0.112 mg/l, NH_4.N>0.05 mg/l and total sulphide>0.50 M mol l^{-1}(Table 10). Any effect of pH, soluble salts, CO_2, CO_3, HCO_3, magnesium hardness and silicate on the *Utricularia* spp. could not be detected during the period of study. The fatal level of different physico-chemical conditions of *Utricularia* spp. were water temperature >25°C, TSS>75 mg/l, TDS>200 mg/l, BOD>2 mg/l, COD>10 mg/l, electric conductivity>300 micro-ohms/cm, chloride>60 mg/l, total hardness >180 mg/l, calcium hardness>165 mg/l, PO_4 >0.150 mg/l, NH_4.N >0.10 mg/l and total sulphide>0.80 M mol l^{-1} (Table 10). During the period of study the fatal level of transparency, DO content, Eh and rH_2 could not be detected.

It was also observed that when the physico-chemical conditions of water of *Utricularia* habitats reached the values of such danger or lethal level, the growth of *Utricularia* spp. start to be impaired gradually and when the physico-chemical conditions reached the fatal level, *Utricularia* spp. started to die and decompose within specific time.

During the period of study it was also observed that the affected *Utricularia* plants could easily survive and show signs of growth within one month when they were transferred to unpolluted water bodies.

The data were presented in Table 10.

PHYSIOLOGICAL STUDY OF *UTRICULARIA* SPP. TREATED WITH KNO_3

CHLOROPHYLL

In *U. aurea*, the chlorophyll a and chlorophyll b content were found to vary from 1.21 to 4.15 and 1.78 to 4.71 mg dm^{-2} in the different study level of KNO_3 sol^n. The highest chlorophyll a and chlorophyll b were recorded in the 600 mg/l KNO_3 level, whereas the lowest were recorded at the 1000 mg/l KNO_3 level. Initially (in 0 mg/l KNO_3) the chlorophyll a and b were recorded 1.26 and 1.86 mg dm^{-2}. During the period of study, chlorophyll-a and b have both started to increase from 100 mg/l KNO_3 level and reacted to its maximum content. Eventually they started to decrease from 700 mg/l KNO_3 and reached to its minimum content at 1000mg/l KNO_3 level.

Table 10. **Values of physico-chemical parameters of water indicating the levels affecting *Utricularia* spp.**

Parameter		Lethal level	Death level	Death time
Water temperature	°C	24–25	> 25	20–25 days
Transparency	cm	< 25	–	–
TSS	mg/l	> 60	> 75	15–20 days
TDS	mg/l	> 150	> 200	24–30 days
pH		–	–	–
DO	mg/l	< 3	–	–
Eh	mv	< 0.755	–	–
rH_2		< 26	–	–
BOD_5	mg/l	> 1.8	> 2	within one month
COD	mg/l	> 7	> 10	7 days
E. con.	µohms/cm	> 220	> 300	within one month
Chloride	mg/l	> 50	> 60	15–20 days
Soluble salts	g/l	–	–	–
CO_2	mg/l	–	–	–
CO_3	mg/l	–	–	–
HCO_3	mg/l	–	–	–
Total hardness	mg/l	> 150	> 180	10–13 days
Ca hardness	mg/l	> 140	> 165	10–15 days
Mg. hardness	mg/l	–	–	–
PO_4	mg/l	> 0.112	> 0.150	18–20 days
Silicate	mg/l	–	–	–
$NH_4.N$	mg/l	> 0.05	> 0.10	5–7 days
Total sulphide	M mol l^{-1}	> 0.50	> 0.80	7–10 days

– = Not detected

Table 11. Effect of KNO_3 on the chlorophyll and protein content of *Utricularia aurea* and *U. stellaris*.

KNO_3 mg/l	*U. aurea*			*U. stellaris*		
	Chlorophyll mg dm^{-2}		Protein mg g^{-1}dry wt.	Chlorophyll mg dm^{-2}		Protein mg g^{-1}dry wt.
	a	b		a	b	
0	1.26	1.86	3.79	1.28	1.91	3.28
100	1.63	2.34	3.84	1.67	2.41	3.35
200	2.04	2.76	3.91	2.19	2.83	3.49
300	2.93	2.82	3.99	2.98	2.87	3.57
400	3.43	3.10	4.12	3.46	3.15	3.71
500	3.68	3.75	4.23	3.74	3.83	3.89
600	4.15	4.71	4.26	4.21	4.80	3.94
700	3.73	3.90	4.16	3.79	3.99	3.86
800	2.92	3.71	4.05	3.05	3.83	3.71
900	2.11	2.66	3.93	2.23	2.72	3.53
1000	1.21	1.78	3.81	1.24	1.83	3.39

In *U. stellaris*, the chlorophyll-a and chlorophyll b content were found to vary from 1.24 to 4.21 and 1.83 to 4.80 mg dm^{-2} in different study level of KNO_3 sol^n. The highest chlorophyll a and chlorophyll b were recorded in 600 mg/l KNO_3 level. But the lowest were recorded in the 1000 mg/l KNO_3 level. The initial (in 0 mg/l KNO_3) chlorophyll a and b content were recorded 1.28 and 1.91 mg dm^{-2}. The pattern of increase and decrease of the content of chlorophyll-a and b of *U. stellaris* in KNO_3 sol^n were similar to that of *U. aurea*.

PROTEIN CONTENT

Protein content of *U. aurea* varied from 3.81 to 4.26 mg g^{-1}dry wt. in different study level of KNO_3. The maximum protein content was recorded in the 600 mg/l KNO_3 level, whereas the minimum in 1000 mg/l level. In initial stage (0 mg/l KNO_3 level), protein content was found to be 3.79 mg g^{-1}dry wt. During the period of study, protein content was started to rise from 100 mg/l KNO_3 level and reached to its maximum. The protein content started to decrease from 700 mg/l KNO_3 level and reached to its minimum at 1000 mg/l KNO_3 level.

In *U. stellaris*, the protein content was found to vary from 3.35 to 3.94 mg g^{-1}dry wt. in different level of KNO_3 sol^n. The maximum protein content was recorded at 600 mg/l KNO_3 level and the minimum was at 100 mg/l KNO_3 level. The initial protein content was 3.28 mg g^{-1}dry wt. The pattern of increase and decrease of protein content of *U. stellaris* in KNO_3 solution were similar to that of *U. aurea*.

The data were presented in Table 11.

Table 12. **Correlation co-efficient (r) between different physico-chemical factors in water bodies with *Utricularia* spp.**

Parameter	Significant (5% level) positive correlation with	Significant (5% level) negative correlation with
Air temperature	WT, BOD_5	DO
Water temperature	TSS, BOD_5, COD, EC	DO, % of sat., Eh, rH_2
Transparency	DO, Eh, rH_2	TSS, TDS, EC, BOD_5
TSS	TDS, EC, BOD_5, Cl, S. salt	DO, % of sat., Eh, rH_2
TDS	EC, Cl, COD, TH, Ca.H, Mg.H	DO, Eh, rH_2
pH	DO, Eh, rH_2, CO_3, HCO_3	CO_2, BOD_5
DO	% of sat., Eh, rH_2	BOD_5, EC
Eh	rH_2	BOD_5, EC, TH, Ca.H, Mg.H
rH_2		BOD_5, COD, EC, TH, Ca.H., Mg.H
BOD_5	COD, CO_2, EC, TH, Ca.H, Mg.H	
COD	EC, Ca.H	
Electric conductivity	Cl, S. salt	
Chloride	S. salt, Ca.H, Mg.H	
CO_2	TH	CO_3
Total hardness	Ca.H, Mg.H	
Ca. hardness		Mg.H

Table 13. Correlation co-efficient (r) between different physico-chemical factors in water bodies without *Utricularia* spp.

Parameter	Significant (5% level) positive correlation with	Significant (5% level) negative correlation with
Air temperature	WT, BOD_5, TS	DO
Water temperature	BOD_5, NH_4.N, EC, TS	DO, % of sat., Eh, rH_2
Transparency	DO, % of sat., Eh, rH_2	TSS, TDS, EC, BOD_5, PO_4
TSS	TDS, EC, BOD_5, Cl, S. salt, NH_4.N	DO, % of sat., Eh, rH_2
TDS	EC, Cl, S. salt, COD, TH, Ca.H, Mg.H, NH_4.N, TS	DO, Eh, rH_2
pH	DO, Eh, rH_2, % of sat.	CO_2, BOD_5, TS
DO	% of sat., Eh, rH_2	BOD_5, EC, TH, Ca.H, PO_4, NH_4.N, TS
Eh	rH_2	BOD_5, COD, CO_2, EC, TH, Ca.H, Mg.H, PO_4, NH_4.N, TS
rH_2		BOD_5, COD, EC, TH, Ca.H, Mg.H, PO_4, NH_4.N, TS
BOD_5	COD, CO_2, EC, TH, Ca.H, Mg.H, PO_4, NH_4.N, TS	
COD	EC, TH, Ca.H, Mg.H, PO_4, NH_4.N, TS	
Electric conductivity	Cl, S. salt, TH, Ca.H, Mg.H, PO_4, NH_4.N, TS	
Chloride	S. Salt, Ca.H, Mg.H, TS	
CO_2	TH, Ca.H, PO_4, NH_4.N	CO_3
HCO_3		TH, Ca.H
Total hardness	Ca.H, Mg.H, PO_4, NH_4.N, TS	
Ca. hardness	PO_4, NH_4.N, TS	Mg.H
Mg. hardness	PO_4, TS	
NH_4.N	TS	

Table 14. **Showing the effectiveness of Catla and Silver carp fingerlings and *Utricularia* spp. as agents of biological control.**

Pond no.	Agent organism	Target organism	Remarks
Pond-1 130 m²	Catla- 500 fingerlings Silver carp- 2500 fingerlings	All Copepods and Cladocerans absent. Rotifers present after 7 Days	Agents effective against target organism
Pond-2 130 m²	Catla- 1000 fingerlings Silver carp- 2000 fingerlings	All Copepods and Cladocerans gone. Only Rotifers present after 7 Days	Agents effective against target organism
Pond-3 130 m²	Catla- 1500 fingerlings Silver carp- 1500 fingerlings	Similar Results after 7 days	Agents effective against target organism
Pond-4 130 m²	Rui- 2000 fingerlings Mrigal- 2000 fingerlings Common carp- 100 fingerlings	All Copepods, Cladocerans and Rotifers present but their number reduced slightly after 7 days	Agent fishes are less or not effective against targets
Pond-5 130 m²	Rui- 2000 fingerlings Mrigal- 2000 fingerlings Common carp- 100 fingerlings and 500 *Utricularia* plants	The number of the above zooplankton have been reduced considerably after 7 days	*Utricularia* is effective agent against the target to a considerable extent

CHAPTER - FIVE

DISCUSSION

DISCUSSION

All sources of surface fresh water such as ponds, lakes, *beels*, *jheels* and rivers have been used for different human purposes such as bathing and all kinds of washing etc. The people of villages, towns and cities also discharge all trash, domestic refuges and wastes in to these water bodies. These water bodies have a self regulatory mechanism of recycling these wastes quickly if the amount of wastes is small. But when the contamination level increases to such an extent that water becomes less useful or harmful, the water is regarded as polluted. There are different kinds of pollutants such as sewage, organic chemicals like detergents (washing powders) and pesticides, inorganic chemicals, harmful microorganisms and sediments. Different types of pesticides used for the control of pests in agriculture, have become the most serious pollutant of water and soil. Many of such pesticides are non-biodegradable chemicals, which do not decompose or do so very slowly. As a result the reproductive cycle and other biological activities of organisms become affected (Ambasht 1990). Many other inorganic chemicals and fertilizers washed down to water bodies from crop field in watershed areas and reduces the utility of water bodies and natural aquatic ecosystem break down within a small period of time. During the last few years some aquatic plants were available in the Rajshahi region but today, they are not often seen and many of them have disappeared, which may be attributed to the rigorous changes in the water qualities. An aquatic ecosystem is dependent on the physical and chemical qualities of water (Bhatt *et al.* 1999). Some major parameters of the chemical, physical and soil conditions of polluted and unpolluted water are studied and also the impact of polluted water on ecology and biology of carnivorous plant *Utricularia* spp. have been studied. In the proceeding pages, the facts, consequences revealed during the study period are discussed in details.

PHYSICAL CONDITIONS OF WATER

AIR TEMPERATURE

Air temperature is always governed by the sunlight, rainfall, wind flow and humidity. The temperature of the study spots depended upon the weather of greater Rajshahi district characterized by great extreme of heat, cold and moderate rainfall owing to its geographical situation.

In the **WBWU** (water bodies with *Utricularia* sp.), the highest air temperature (35°C) was recorded in summer season in the month of May. From rainy season in the month of July, air temperature started to decrease, till it reached to minimum value (16.3°C), recorded in the month of January. From February air temperature started to increase till the summer (Table 1). Yearly mean value was recorded 26.6±5.4°C. It was found to have a statistically significant positive correlation with water temperature (r=0.911) and BOD_5 (r=0.688) values. It also had a statistically significant negative correlation with DO (r=-0.897) content.

In the **WBWTU** (water bodies without *Utricularia* sp.), the maximum temperature (35°C) was recorded in summer in the month of May. From rainy season in the month of July, air temperature started to decrease gradually, till it reached the minimum value (16.3°C), recorded in winter period in the month of January. From winter, the air temperature started to rise till the summer (Table 2). Yearly mean value was recorded 26.7±5.5°C. It was found to have a statistically significant positive correlation with water temperature (r=0.865), BOD (r=0.691) and total sulphide (r=0.698) values. It also had a statistically significant negative correlation with DO (r=-0.723) content.

It appeared that the changes in air temperature of the study spots were mainly governed by climatological factors.

WATER TEMPERATURE

Water temperature is directly related with the chemical reactions in the water and biochemical reactions in the living organisms of a water body (Shivanikar *et al.* 1999). Temperature is also an important factor influencing self-purification of water. Temperature alone plays significant role in determining the quality of water of an aquatic body because all the physical, biochemical and biological properties are governed by it. As the temperature of water increases, its viscosity decreases, the vapor pressure increases and solubility of gases in water decreases. Other biological and biochemical activities i.e. DO, BOD_5, electric conductivity, photosynthesis, growth and death of micro and macro organisms are all dependent on water temperature (Gautam 1990). Rapid temperature changes produce thermal shocks and the effects of temperature differ in different organisms (Mackenthun 1969).

In the **WBWU**, the water temperature was always lower than the air temperature (Table 1). Yearly mean value was 23.4±5.2°C, which is lower than the water quality standard (25°C) value. It is observed that water temperature of these water bodies are increased and decreased gradually as affected by the increase and decrease pattern of air temperature. The yearly mean value of water temperature of these study area indicates that the water of *Utricularia* habitats were free from thermal pollution. The maximum water temperature (30.7°C) was recorded in the month of May due to the highest air temperature (35°C) of summer period. At that time it was observed that the freshness and chlorophyll content of *Utricularia* spp. slightly decreased from that in other months. Water temperature was found to have a statistically significant positive correlation with TSS (r=0.892), BOD_5 (r=0.835), COD (r=0.835) and electric conductivity (r=0.867) values. It had also statistically significant negative correlation with DO(r=-0.812), % of saturation of oxygen(r=-0.805), Eh (r=-0.798) and rH_2 (r=-0.802) values.

In the **WBWTU**, the recorded water temperature was always lower than the air temperature but always higher than the water temperature of *Utricularia* habitats. Yearly mean value was recorded 25.4±5°C which is higher than accepted limit of water quality standard. Except the winter period, water temperature of these study water bodies were recorded high from the accepted limit of water quality standard. So the water qualities of water bodies without *Utricularia* spp. were thermally polluted. At higher temperature, solubility of oxygen decreases and becomes thermally polluted while the metabolic activities of organism increase (Shivanikar *et al.* 1999). As a result BOD_5, NH_4.N and electric conductivity value have increased and Eh and rH_2 values have decreased. These parameters are the essential indicator factors to evaluate the water pollution levels (Gautam 1990). Increases in the temperature of water of these water bodies might have resulted in decrease of dissolved oxygen. Similar observations were made by Mackenthun (1969). Water temperature of these water bodies were found to have a statistically significant positive correlation with BOD_5 (r=0.794), $NH_4.N$ (r=0.819), Electric Conductivity (r=0.788) and total sulphide (r=0.711) and also have a statistically significant negative correlation with DO (r=-0.791), % of saturation of oxygen (r=-0.802), Eh (r=-0.856) and rH_2 (r=-0.832) values.

From aquarium culture it was observed that when water temperature increased from 25°C and continued for 24 hours then within 7-10 days the growth and prey capturing activity of *Utricularia* spp. ceases, plant colour turned radish brown, chlorophyll and protein content decreased and flowers failed to open. Parts of *Utricularia* spp. plant died within 20-25 days and eventually decomposed. **So it may be mentioned, the normal biological processes of *Utricularia* spp. are sensitive to water temperature of its habitat.** Trivedi and Raj (1992) and Patrick (1953) studied that the life cycle and natural processes of some aquatic plants have been delicately affected due to water temperature.

TRANSPARENCY

Transparency i.e. amount of light penetration in a water body depends upon various factors such as, water colour, abundance of plankton, total suspended and dissolved solids, electric conductivity, detergent, colloidal particles etc. When the content of the above mentioned factors increase then transparency will be decreased (Chowdhury *et al.* 2000 and Mackenthun 1969). It is a unique characteristic feature of any aquatic body. In an aquatic ecosystem such as ponds, marsh, *beels*, *Jheels*, river, etc. the food and energy production for the aquatic lives depend upon the transparency or the extent of light penetration, as the primary productive zone extends up to this depth.

In the **WBWU**, transparency values were always high. The yearly mean of transparency was 32±10 cm. The maximum transparency was recorded in the post monsoon period. The lowest transparency (19 cm) was recorded in the summer period, in the month of May, when water temperature was highest. Higher evaporation rate caused by higher temperature resulted into decrease in its density, viscosity and transparency. The recorded transparency values indicate that these water bodies are fee from high suspended and dissolved solids and water colour was always clear. The transparency was found to have a statistically significant positive correlation with DO (r=0.776), Eh (r=0.822) and rH_2 (r=0.799) values. It was also found to have a statistically significant negative correlation with TSS (r=-0.883), TDS (r=-0.859), electric conductivity (r=-0.843) and BOD_5 (r=-0.898) values.

In the **WBWTU**, the recorded transparency value was always lower than that of water bodies with *Utricularia* spp. The highest transparency was recorded in post monsoon. Whereas the lowest (11 cm) was recorded in summer period in the month of May. The yearly average of transparency was 20±5 cm for which these water bodies were rich in TSS, TDS and other particulate matters. Similar observations were made by Trivedy (1993), Gautam (1990) and Chowdhury *et al.* (2000). The transparency value of these water bodies were found to have a statistically significant positive correlation with DO (r=0.698), % of saturation of oxygen (r=0.705), Eh (r=0.738) and rH_2 (r=0.744) values and also found to have a statistically significant negative correlation with TSS (r=-0.902), TDS (r=-0.886), electric conductivity (r=-0.735), BOD_5 (r=-0.807) and PO_4 (r=-0.769) values.

It was observed that **when transparency of artificial culture spots of *Utricularia* spp. decreased from 25 cm, the chlorophyll content of *Utricularia* spp. started to decrease.**

TOTAL SUSPENDED SOLIDS (TSS)

To evaluate the quality of water, TSS value is a very important factor. In a water body TDS, pH, BOD_5, COD, electric conductivity, chloride, DO, alkalinity, Eh, rH_2 are directly or indirectly influenced by TSS value in that water body (Chowdhury 1999). TSS value also depends upon various types of suspended solids such as debris, silt, alluvium, dead parts of organisms, wastes, PO_4 and oil-grease contents, etc. (Trivedi and Raj 1992, Andrews *et al.* 1972 and Chowdhury *et al.* 2000).

In the **WBWU**, the maximum TSS value (54 mg/l) was recorded in the summer period in the month of May. In this month the, depth of water was the lowest. The minimum TSS value (12 mg/l) was recorded in the post monsoon period in September. Due to monsoonal rainfall, the depth of water increased which eventually resulted into a lower value of TSS. The yearly mean value of TSS of these water bodies was 26±13 mg/l. The recorded TSS values were always lower than the desirable level of TSS (Trivedi and Raj 1992). So the WBWU were free from higher suspended particles and it also may be mentioned that these water bodies were free from pollution. The recorded TSS value was found to have a statistically significant positive correlation with TDS (r=0.826), electric conductivity (r=0.785), BOD_5 (r=0.874), chloride (r=0.842) and soluble salts (r=0.815). It had also statistically significant negative correlation with DO (r=-0.801), % of saturation of oxygen (r=-0.727), Eh (r=-0.756) and rH_2 (r=-0.714) values.

In the **WBWTU**, the TSS values were always higher than that of the WBWU. The yearly mean value was recorded 111±53 mg/l, which was higher than the WBWU mean value (26±13 mg/l). Low TSS value was recorded in post monsoon period, in the month of September. Due to monsoonal rainfall, water depth increased; as a result suspended particles have undergone dilution. According to Trivedi and Raj (1992), Gautam (1990) and Chowdhury *et al.* (2000), the acceptable level of TSS value of any fresh water body is 80 mg/l. They also observed that where fresh water is polluted by different wastes, debris and organic substances, the TSS increases beyond the acceptable level. The recorded TSS values indicate that the WBWTU were polluted by different suspended matter including organic substances. TSS values of these water bodies were found to a have statistically significant positive correlation with TDS (r=0.916), electric conductivity (r=0.887), BOD_5 (r=0.837), chloride (r=0.829), soluble salts (r=0.782) and NH_4.N (r=0.682) values. It was also found to have a statistically significant negative correlation with DO (r=-0.775), % of saturation of oxygen (r=-0.693), Eh (r=-0.874) and rH_2 (r=-0.859) values.

From aquarium culture it was observed that when TSS value rises above 60 mg/l, *Utricularia* failed to survive in that water. Under such condition of higher TSS value, deposition of mucus substances occurs on the surface of the plant parts of *Utricularia* leading to the retardation of biological activity and preying capacity. The *Utricularia* spp. then die within 15-20 days and fully decompose in about a month time. **It is, therefore, clear that this plant is highly sensitive to the higher values of TSS in relation to its biological activities and normal prey capturing ability, and the lethal level is above 60 mg/l.**

TOTAL DISSOLVED SOLIDS (TDS)

Total dissolved solids consists of various kinds of minerals present in water. In natural water TDS is composed mainly of carbonates, bicarbonates, Cl^-, SO_4-S, PO_4-P and NO_3-N, calcium and magnesium hardness, Na^+, K^+, F^{++}, some acids, electric conductivity, ammonia etc. (Andrews *et al.* 1972, Trivedy and Goel 1984 and Gautam 1990).TDS of natural water (rain and snow) range is always less than 10 mg/l (Jacob *et al.* 1999).

In the **WBWU**, the highest TDS value (180 mg/l) was recorded in summer period in the month of May, due to decrease in the water level. The lowest (35 mg/l) TDS value was recorded in monsoon period in the month of August, when the water level increased due to rainfall and dissolved solids were more diluted. The yearly mean value of TDS was recorded 96±44 mg/l. TDS value was found to have a statistically significant positive correlation with electric conductivity (r=0.882), chloride (r=0.891), COD (r=0.906), total hardness (r=0.836), calcium hardness (r=0.819) and magnesium hardness (r=0.837) values. It was also found to have a statistically significant negative correlation with DO (r=-0.766), Eh (r=-0.778) and rH_2 (r=-0.765) values.

In the **WBWTU**, the TDS value was always higher (more than double) than that of WBWU. The yearly mean value was 253±52 mg/l, which indicates that these water bodies were rich in dissolved solids. The highest and lowest value of TDS directly depend upon the rate of dilution of dissolved solids by rise or fall of water level, when the rate of dilution was high, the TDS value was low and vice versa. TDS value was found to have a statistically significant positive correlation with electric conductivity (r=0.924), chloride (r=0.907), soluble salts (r=0.885), COD (r=0.927), total hardness (r=0.835), calcium hardness (r=0.789), magnesium hardness (r=0.754), NH_4.N (r=0.861) and total sulphide (r=0.779) values. It was also found to have a statistically significant negative correlation with DO (r=-0.757), Eh (r=-0.821) and rH_2 (r=-0.803) values.

During the period of study, it was observed that, when TDS value rose above 150 mg/l the normal growth of *Utricularia* spp. started to fall. **When TDS value crossed 200 mg/l level, the *Utricularia* spp. started to die rapidly. It was also observed that chlorophyll and protein content have started to decrease with the increase of TDS values.** Sahai and Srivastava (1976), Kulshreshtha and Gopal (1981) and Chamanlal (1989) also observed that the high concentration of TDS is detrimental to *Utricularia* spp.

CHEMICAL CONDITIONS OF WATER

HYDROGEN ION CONCENTRATION (pH)

The hydrogen ion concentration (pH) is an important factor as a measure of water quality. The wastes can alter the pH of natural waters (Motwant *et al.* 1956, APHA 1989). The optimum range of pH for aquatic life is 6.8 to 9.0 (Gautam 1990 and Palhareya *et al.* 1993).

In the **WBWU**, the pH value was found to be always alkaline except in May. pH value was slightly acidic in May probably due to the high temperature, decomposition, BOD_5 and CO_2 values. As is know earlier that usually the pH value of lentic and lotic water system of Rajshahi have a pH ranging from 7.0 to 8.5 (Naz 1999, Islam *et al.* 1998, Chowdhury and Zaman 2000b). The yearly average of the pH value was recorded 7.2±0.2. The pH value was found to have a statistically significant positive correlation with DO (r=0.716), Eh (r=0.839), rH_2 (r=0.841), CO_3 (r=0.867) and HCO_3 (r=0.794) values. It was also found to have a statistically significant negative correlation with CO_2 (r=-0.911) and BOD_5 (r=-0.742) values.

In the **WBWTU**, the yearly mean of pH value was recorded 7.6±0.8. But in winter and summer period the pH values were always acidic (6.3-6.9), when the content of the biodegradable organic matter and free CO_2 values were high. At this period DO content was also low, BOD_5 value was high and water levels have fallen considerably. Similar findings were made by Trivedi and Raj (1992), Gautam (1990) and Chowdhury and Zaman (2000a). pH value was found to have a statistically significant positive correlation with DO (r=0.725), Eh (r=0.871), rH_2 (r=0.865) and % of saturation of oxygen (r=0.731). It was also found to have a statistically significant negative correlation with CO_2 (r=-0.934), BOD_5 (r=-0.803) and total sulphide (r=-0.741) values.

During the period of study it was observed that ***Utricularia* spp. exhibited high growth rates when the pH value ranged from 7.1 to 7.5.**

DISSOLVED OXYGEN (DO)

The dissolved oxygen is one of the important parameters for water quality assessment (Shivanikar *et al.* 1999). Its presence is essential in an aquatic ecosystem for bringing about various biochemical changes and its effects on metabolic activities of organisms. Dissolved oxygen is regulated primarily by three factors: free diffusion of oxygen from air to water; production through photosynthesis and consumption by plants, animals and decomposers. Dissolved oxygen is a fundamental requirement of life for the plant and animal population in a water body (Trivedi and Raj 1992, Chowdhury 1999 and Thomas 1948).

In the **WBWU**, the highest DO value (5.7 mg/l) was recorded in post monsoon period in the month of September. The lowest value (3.3 mg/l) was recorded in summer period in the month of May, which may be due to high water temperature, TSS, TDS, CO_2 and BOD_5 values. Mathur *et al.* (1991) studied that the dissolved oxygen gradually decrease with the increase of temperature. The yearly mean of DO value was recorded 4.6±0.8 mg/l, which is not less than the accepted value of water quality standard (4.5±0.5 mg/l). The yearly mean value indicates that the water of WBWU were in good conditions. DO value was found to have a statistically significant positive correlation with % of saturation (r=0.853), Eh (r=0.872) and rH_2 (r=0.867) values. It was also found to have a statistically significant negative correlation with BOD_5 (r=-0.824) and electric conductivity (r=-0.696) values.

In the **WBWTU**, the dissolved oxygen content was always much lower than that of WBWU. The highest DO content was recorded to be only 2.8 mg/l in the post monsoon period, in September; when water level was high due to rainfall. The yearly mean of DO content was 1.8±0.7 mg/l. A low content of dissolved oxygen is a sign of organic pollution (Bhatt *et al.*1999). According to Badge and Verma (1985), decomposition of organic matter is an important factor, which is accomplished by the consumption of dissolved oxygen and found to be more vigorous during warm weather. The low DO content indicates that these water bodies were polluted by organic matter, which is also supported by low Eh and rH_2 and high BOD_5 and CO_2 values (Chowdhury 1999, Trivedi and Raj 1992). The DO content was found to have a statistically significant positive correlation with % of saturation of oxygen (r=0.849), Eh (r=0.881) and rH_2 (r=0.878) values. It was also found to have a statistically significant negative correlation with BOD_5 (r=-0.827), electric conductivity(r=-0.719), total hardness(r=-0.687), calcium hardness (r=-0.703), PO_4 (r=-0.686), $NH_4.N$ (r=-0.716) and total sulphide (r=-0.683) values.

During the period of study, it was observed that the growth and prey capturing activity of *Utricularia* spp. show sign of retardation when DO content was below 3 mg/l. At that time chlorophyll and protein content have also started to fall. Kulshreshtha and Gopal (1981) and Chamanlal (1989) expressed that in *Utricularia* spp. and *Salvinia molesta*, growth may be affected in conditions of low DO content. The present study establishes the fact that **a level of DO content congenial for the normal growth and function is always above 3 mg/l in case of** ***Utricularia*** **spp.**

PERCENTAGE OF SATURATION OF OXYGEN

Percentage of saturation of oxygen is positively correlated with dissolve oxygen. Natural water generally contains higher percentage of saturation of oxygen (Mathur *et al.* (1991).

In the **WBWU**, the highest percentage of saturation of oxygen was recorded in post monsoon period in the month of September. The lowest percentage of saturation of oxygen was recorded in summer period in the month of May; which may be due to high water temperature, TSS, TDS, CO_2 and BOD_5 values. Mathur *et al.* (1991) studied that the percentage of saturation of oxygen gradually decreased with the increase of temperature. None of the calculated correlation values regarding percentage of saturation of oxygen were found to be statistically significant.

In the **WBWTU**, the percentage of saturation of oxygen was always much lower than that of *Utricularia* spp. water bodies. The highest percentage of saturation of oxygen was recorded in the post monsoon period, in the month of September; when water level was increased due to rainfall. The yearly mean of the percentage of saturation of oxygen was 22±8. A low content of dissolved oxygen is a sign of organic pollution (Bhatt *et al.*1999). According to Badge and Verma (1985), decomposition of organic matter is an important factor, which takes place by the consumption of dissolved oxygen and found to be more vigorous during warm weather. The low percentage of saturation of oxygen indicates that these water bodies were polluted by organic matter, which is also supported by low Eh and rH_2 and high BOD_5 and CO_2 values (Chowdhury 1999 and Trivedi and Raj 1992). All the calculated correlation values regarding percentage of saturation of oxygen were statistically non-significant.

Lower percentage of saturation of oxygen is indicative of oxygen deficient condition which not favorable for the biota, including *Utricularia* spp.

OXIDATION REDUCTION POTENTIAL (Eh)

The oxidation reduction potential of any solution of water is the net of all reactions and known as Redox Potential of that solution. The redox potential is an indication of the energy state of water system governed by the presence of oxidized and reduced chemical substances or their biological activities (Gautam 1990). As the oxidation and reduction reactions are accompanied by the transferences of electron, the redox potential is a valuable index to measure the conditions of water body. In any aquatic ecosystem undergoing biological metabolism, there is a continual change in the ratio between the materials in reduced form and the materials in oxidized form. If the ecosystem is rich in organic material, the concentration of reduced form is higher which results in lower Eh value. But after a short time when the materials degrade the system starts to attain its original form which means Eh value starts increasing. But when a continuous addition of organic material takes place, a continuous decrease in Eh will occur. The low Eh value indicates the presence of higher amount of organic matter in a habitat (Gautam 1990).

In the **WBWU**, the lowest Eh value (0.884 mv) was recorded in summer period, in the month of May. When the water level have decreased considerably. The yearly mean value of Eh was 0.931±0.028 mv, which indicates that the WBWU had very negligible amount of organic matter. Eh value was found to have a statistically significant positive correlation with rH_2 (r=0.917) value. It was also found to have a statistically significant negative correlation with BOD_5 (r=-0.783), electric conductivity (r=-0.836), total hardness (r=-0.747), calcium hardness (r=-0.693) and magnesium hardness (r=-0.704).

In the **WBWTU**, the Eh value was always lower than that of the WBWU. The yearly mean value of Eh was 0.511±0.018 mv, which was much lesser than 1 (unit) and indicates that the WBWTU were rich in organic substances. Similar observations were made by Gautam (1990), Chowdhury and Zaman (2000a) and Chowdhury *et al.* (2000). Eh value was found to have a statistically significant positive correlation with rH_2(r=0.895) values. It was also found to have a statistically significant negative correlation with BOD_5 (r=-0.753), COD (r=-0.728), CO_2 (r=-0.698), electric conductivity (r=-0.847), total hardness (r=-0.715), calcium hardness (r=-0.708), magnesium hardness (r=-0.721), PO_4 (r=-0.753), NH_4.N (r=-0.833) and total sulphide (r=-0.814) values.

It was observed, that **when Eh value falls below 0.755 mv, the flowering and fruit setting of *Utricularia* spp. get gradually inhibited. Prey capturing activity was also found to retard and the protein content started to decrease.**

OXIDATION REDUCTION INDEX (rH_2)

The oxidation reduction index (rH_2) is a quick and efficient measurement for the oxidation reduction conditions of fresh water is open water bodies (Voznaya 1981). It also shows the trend of Eh variations. An increase and decrease in the value of rH_2 is dependent upon the degradation and addition of organic material respectively similar to the Eh behaviour. According to Voznaya (1981), rH_2 has its neutral point at 28. The lower rH_2 value from 28 indicates the organic pollution in water body (Gautam 1990).

In the **WBWU**, the rH_2 values were always higher than the neutral point (28) of rH_2 value. Yearly mean value was recorded 32.71±1.6, which indicates that inorganic substances of these water bodies were always higher than organic substances. It also mentioned that the WBWU were not polluted by organic substances. Similar observations were made by Gautam (1990) and Voznaya (1981). The rH_2 value was found to have a statistically significant negative correlation with BOD_5 (r=-0.729), COD (r=-0.762), electric conductivity (r=-0.791), total hardness (r=-0.716), calcium hardness (r=-0.819) and magnesium hardness (r=-0.694) values.

In the **WBWTU**, the rH_2 value was always lower than that of the WBWU. The recorded rH_2 value was also always lower than the neutral point (28). The yearly mean value was 24.99±0.687, which indicates that the WBWTU have enough organic loads. Similar observations were also made by Gautam (1990), Chowdhury and Zaman (2000a) and Chowdhury *et al.* (2000). The rH_2 value was found to have a statistically significant negative correlation with BOD_5 (r=-0.746), COD (r=-0.769), electric conductivity (r=-0.802), total hardness (r=-0.728), calcium hardness (r=-0.809), magnesium hardness (r=-0.688), PO_4 (r=-0.822), $NH_4.N$ (r=-0.835) and total sulphide (r=-0.719) values.

During the period of study, it was observed that **the *Utricularia* spp. are unable to survive for more than one month in this type of polluted water having high organic load, as indicated by rH_2 values below the neutral point.**

BIOCHEMICAL OXYGEN DEMAND (BOD_5)

The BOD_5 is an important measure to determine the amount of biodegradable organic material in water. It is defined as the rate of dissolved oxygen used by the micro-organisms in aerobic decomposing of the dissolved or even particulate organic matter in water. BOD_5 in general provides a quantitative index of the organic matter, which is easily degradable in a short span of time. So it is to be mentioned that the more oxidizable organic matter present in water, the more amount of oxygen required to degrade it biologically, hence more BOD_5 value as a consequent is achieved (Gautam 1990, Palhareya *et al.* 1993, Ramjeawon and Baguant 1995 and Khanna 1993).

In the **WBWU**, the highest BOD_5 value (1.8 mg/l) was recorded in the summer period, in the month of May and lowest value (0.8 mg/l) was recorded in the monsoon period, in the month of August. Highest value of BOD_5 in summer may be due to higher rate of organic decomposition. During the monsoon, the water level increased as a result of which organic substances were diluted and decomposition rate came down considerably. Similar observations were also made by Bhatt *et al.* (1999). The yearly mean BOD_5 value was 1.2±0.4 mg/l, which is lower than the eutrophic level of the water bodies. BOD_5 value was found to have a statistically significant positive correlation with COD(r=0.846), CO_2 (r=0.817), electric conductivity (r=0.791) and all hardness (r=0.676) values.

In the **WBWTU**, the BOD_5 value was always higher than that of the WBWU. The highest value of BOD_5 (3.2 mg/l) was recorded in summer, which may due to the higher rate of organic decomposition. According to Ramjeawon and Baguant (1995) and Khanna (1993) the BOD_5 value of unpolluted fresh water is always less than 1.8 mg/l. The yearly mean of BOD_5 value of these water bodies was 2.4±0.5 mg/l, which was higher than the values of eutrophic water. It also indicates that the WBWTU were polluted by biodegradable organic matter. Similar observations were made by Chowdhury *et al.* (2000), Palhareya *et al.* (1993) and Gautam (1990). BOD_5 value was found to have a statistically significant positive correlation with COD (r=0.854), CO_2 (r=0.828), electric conductivity (r=0.812), all hardness (r=0.744), PO_4 (r=0.853), NH_4.N (r=0.822) and total sulphide (r=-0.699) values.

During the period of study, it was observed that **when BOD_5 value started to go above 1.8 mg/l, *Utricularia* spp. started showing a decrease in their normal growth. When BOD_5 value went above 2 mg/l, *Utricularia* spp. started to die and within a month all *Utricularia* spp. were dead and decomposed.** Sahai and Srivastava (1976), Kulshreshtha and Gopal (1981) and Chamanlal (1989) observed in their studies that *Utricularia* spp., *Ceratophyllum* sp., *Hydrilla verticillata* and *Salvinia molesta* could not grow when BOD_5 value got increased from 2 mg/l.

CHEMICAL OXYGEN DEMAND (COD)

The chemical oxygen demand (COD) is a major experiment to measure the pollution of water. The biochemical oxygen demand (BOD_5) is only a measure of biodegradable organic matter but the chemical oxygen demand (COD) is an indication of total organic matter (biodegradable + non-biodegradable) present in water. COD test is designed to measure the oxygen required for the oxidation of organic matter in the sample by using a strong oxidant ($K_2Cr_2O_7$, strong acid and high temperature), where BOD_5 test fails, COD succeeds (Mishra *et al.*1992, APHA 1989 and Gautam 1990). COD value is always influenced by TSS, TDS, electric conductivity, BOD_5, Eh, rH_2, total hardness, calcium hardness, NH_4, NH_3, NH_4.N, total phosphate, total sulphide and heavy metals content (Trivedi and Raj 1992 and Chowdhury *et al.* 2000).

In the **WBWU**, the highest COD value (6.2 mg/l) was recorded in summer, in the month of May, due to the decrease of water level in the habitats. At that time TSS, TDS, BOD_5, electric conductivity and total hardness values were high. According to Sahai and Srivastava (1976), the COD value of the unpolluted fresh water bodies should not exceed a level of 7 mg/l. The yearly mean of COD value of these water bodies was 4.8±0.8 mg/l, which indicates that the habitats of *Utricularia* spp. were not loaded with a high content of biodegradable and non-biodegradable matter. The COD value was found to have a statistically significant positive correlation with electric conductivity (r=0.854) and calcium hardness (r=0.809).

In the **WBWTU**, the COD values were always higher than that of *Utricularia* spp. containing water bodies (WBWTU). The highest COD value (18.4 mg/l) was recorded in summer period in the month of May, which may be due to the decreased water level consequently bringing about a higher concentration of biodegradable and non-biodegradable organic matter in water. Bhatt *et al.* (1999) and Gautam (1990) also recorded high COD in the month of May, in their studies. The yearly mean COD value was recorded 13±0.9 mg/l, which indicates that the WBWTU were polluted by biodegradable and non-biodegradable organic load. The COD value was found to have a statistically significant positive correlation with electric conductivity (r=0.868), total hardness (r=0.837), calcium hardness (r=0.821), magnesium hardness (r=0.792), PO_4 (r=0.824), NH_4.N (r=0.866) and total sulphide (r=-0.826) values.

The value of COD was positively correlated with those of ammonia, nitrite, nitrate, total suspended and dissolved solids; higher amount of suspended-dissolved solids with higher organic and inorganic load consume more dissolved oxygen from the water body and ammonia and nitrite also take up a huge amount of dissolved oxygen for their chemical process (Ramjeawon and Baguant 1995, Pearson and Penridge 1987, Chowdhury 1999 and Gautam 1990). The present findings at this site fit well with the above correlation.

During the period of study it was observed that ***Utricularia* spp. could not be grown in the water, whose COD value was higher than 7 mg/l. *Utricularia* spp. have started to die within seven days after releasing *Utricularia* spp. in the culture waters with high COD values**. Shahai and Srivastava (1976) and Chamanlal (1989) observed that higher COD value (>7 mg/l) was detrimental to *Utricularia* sp., *Salvinia molesta* and *Ricciocarpus natuns*. The present findings fit with the observations of the above workers.

ELECTRIC CONDUCTIVITY (EC)

The capacity of water to conduct electric current is known as electric conductivity. This is a good measure of ionic concentration and dissolved inorganic substances (Ambasht 1990, Gautam 1990 and Jacob *et al.* 1999). Dissolved salts are ionized in the aqueous medium. The ability of conductance is dependent upon the concentration, mobility and valence of ions. Temperature of the medium also regulates this inorganic substances showing better conductance, while organic compounds are poor current conductors, as they do not disassociate. Electric conductivity is normally influenced by TSS, TDS, chloride, NH_4, NH_3, NH_4.N and total hardness values (Chowdhury 1999, Paul 1981 and Jacob *et al.* 1999).

In the **WBWU**, the highest electric conductivity value (183 μ-ohms/cm) was recorded in summer period, in the month of May, when water level was at the lowest. The lowest electric conductivity value (110 μ-ohms/cm) was recorded in monsoon period, in the month of August, when the water level was maximum high due to rainfall and dissolved salts were more diluted. Similar observations were also made by Jacob *et al.* (1999). The yearly mean electric conductivity value was 142±25 μ-ohms/cm. Gautam (1990), Palhareya *et al.* (1993), Bhatt *et al.* (1999) and Andrews *et al.* (1972) mentioned that the electric conductivity of unpolluted fresh water is always less than 200 μ-ohms/cm. Jacob *et al.* (1999) expressed that the presence of salts contamination with wastes increases the conductivity of the water. Hence the *Utricularia* containing water bodies were considerably free from contamination by wastes. The electric conductivity value was found to have a statistically significant positive correlation with chloride (r=0.894) and soluble salts (r=0.886).

In the **WBWTU**, the electric conductivity value was always higher than that of unpolluted fresh water bodies level (200 µ-ohms/cm). The highest value (487 µ-ohms/cm) was recorded in summer, in the month of May and the lowest (204 µ-ohms/cm) was recorded in monsoon in the month of August. The yearly mean electric conductivity value was 309±89 µ-ohms/cm, which indicates the presence of salts contamination with waste that increased the electric conductivity of WBWTU. Chowdhury *et al.* (1996, 2000), Chowdhury and Zaman (2000a), Jacob *et al.* (1999), Gautam (1990) and Palhareya *et al.* (1993) also observed that the waste contamination increases the electric conductivity of water. Electric conductivity value was found to have a statistically significant positive correlation with chloride (r=0.909), soluble salts (r=0.866), total hardness (r=0.792), calcium hardness (r=0.773), magnesium hardness (r=0.739), PO_4 (r=0.675), NH_4.N (r=0.788) and total sulphide (r=0.682) values.

During the period of study, from aquarium culture, it was observed that the ***Utricularia* spp. could not grow when conductivity value rises above 220 µ-ohms/cm. Chlorophyll and protein content of *Utricularia* spp. start to decrease when the electric conductivity started to rise from 180 µ-ohm/cm**. Sahai and Srivastava (1976) and Chamanlal (1989) observed in their studies that *Hydrilla verticillata*, *Salvinia molesta* and *Utricularia* sp. can grow only in fresh water, in which the conductivity value is less than 90 µ-ohms/cm. The present findings also corroborates with the above scientist.

CHLORIDE

Chloride and salinity are positively correlated with each other. Natural water generally contains low concentration of chloride. Jacob *et al.* (1999) observed in continental rain and snow, the chloride value varying from 1.0 to 3.0 mg/l. A high concentration of chloride is harmful and produces salty taste in water (Gautam 1990). The sudden increase in the concentration of chloride in surface water bodies to an abnormally high concentration was previously used as index of pollution through contamination by fecal matters. Since chloride ions are non-biodegradable, these are not removed from the waste even after subjecting it to the secondary treatment process (Trivedi and Raj 1992). In natural waters when chlorine appeared to be free, it reacts with nitrogenous organic material and forms chloramines which are harmful to pregnant mothers and aquatic lives (Venkateswarlu and Jayanti 1969, Trivedi and Raj 1992, Gautam 1990 and Tsai 1973). Total hardness, calcium hardness, soluble salts and electric conductivity values are influenced by chloride (Chowdhury 1999). According to Trivedi and Raj (1992) and Gautam (1990), the chloride value of natural waters should not exceed 50 mg/l.

In the **WBWU**, the maximum chloride value (47 mg/l) was recorded in summer period, in the month of May, when the water level was low. The minimum value (38 mg/l) was recorded in the monsoon, in August, when water level was high due to rainfall. Similar observations were also made by Fakruzzaman and Zaman (1996) and Zaman (1991) in Rajshahi. The yearly mean of chloride value was 42±3 mg/l indicating a lower content of chloride in these water bodies. Chloride value was found to have a statistically significant positive correlation with soluble salts (r=0.907), calcium hardness (r=0.855) and magnesium hardness (r=0.797) values.

In the **WBWTU,** the chloride values were always higher than that of water bodies containing *Utricularia* spp. (WBWU). Highest chloride value (90 mg/l) was recorded in summer, in the month of May and the minimum (60 mg/l) in monsoon in the month of August. The yearly mean chloride value was recorded 72±11 mg/l. Which indicates that this high value may be due to mixing of wastes carrying high chloride contents, consequently raising the chloride value of the study water. Andrews *et al.* (1972), Palhareya *et al.* (1993), Trivedi and Raj (1992) and Chowdhury and Zaman (2000a) observed that, whenever the effluent of industries and domestic sewage contained high chloride, the chloride load of study water also increases considerably.

The WBWTU are always used for domestic purposes and often domestic refuges are dumped there. This is another reason for raising the chloride value there. Human and domestic animal excreta contain chloride equal to the chloride consumed with food and water (Gautam 1990, Venkateswarlu and Jayanti 1969 and Chowdhury 1999). Normal human body discharges from 8 to 15 g (average 9 g) of chloride a day (Trivedi and Raj 1992). Chloride value was found to have a statistically significant positive correlation with soluble salts (r=0.919), calcium hardness (r=0.861), magnesium hardness (r=0.805) and total sulphide (r=0.689).

During the period of study it was recorded that **when chloride value started to increase from 50 mg/l upwards, *Utricularia* spp. begins to show reduction in their growth. *Utricularia* spp. started to die and decompose within 15-20 days when chloride value goes above 60 mg/l.**

SOLUBLE SALTS

Soluble salts is positively correlated with electric conductivity and chloride values. Natural water generally contains low concentration of chloride (Jacob *et al.* 1999).

In the **WBWU**, the maximum soluble salts was recorded in summer period, in the month of May, when the water level was low. The minimum value was recorded in monsoon, in the month of August when water level was high due to rainfall. Similar observations were also made by (Jacob *et al.* 1999). Soluble salts values increased gradually and the yearly mean value was 0.10±0.017 g/l. All the calculated correlation values regarding soluble salts were statistically non-significant.

In the **WBWTU**, the soluble salts values were always higher than that of water bodies containing *Utricularia* spp. The highest value was recorded in summer, in the month of May and the lowest in monsoon in the month of August. During the study period the soluble salts content increased gradually and the yearly mean value was found to be 0.22±0.06 g/l. None of the calculated correlation values regarding soluble salts were found to be statistically significant.

Any effect of soluble salts on the *Utricularia* spp. could not be observed during the period of study.

CARBON DIOXIDE (CO_2)

Carbon dioxide plays a major role in the production biology of aquatic bodies. It is essential for photosynthesis for the aquatic green plants. As a water quality constituent it may be derived from different sources, such as the atmosphere, inflowing ground water, decomposed organic matter and respiration of animals and plants. When it is dissolved in water body, causes increase in acidity (Ellis 1937).

In the **WBWU**, the highest CO_2 value (13 mg/l) was obtained in summer period, in the month of May. No CO_2 were recorded in the month of August and September, when water level reached to its maximum due to rainfall. Similar findings were also made by Fakruzzaman and Zaman (1996) and Zaman (1991). The yearly mean of CO_2 value was 8±3 mg/l. CO_2 value was found to have a statistically significant positive correlation with total hardness (r=0.712). It was also found to have a statistically significant negative correlation with CO_3 (r=-0.881) value.

In the **WBWTU**, the CO_2 values were always higher than that of WBWU. The yearly mean value was recorded 11±9 mg/l. Highest CO_2 value (25 mg/l) was recorded in summer, in the month of May, when pH value was recorded 6.3. Lower value of free CO_2 (6 mg/l) was recorded in rainy season in the month of August, when the water level was high due to rainfall and then high pH (8.3), low BOD_5 and TSS and high DO values were recorded in an industrially polluted spot. The present findings also corroborates with the observations of Chowdhury (1999). Ellis (1937) considered that the concentration of free CO_2 should not exceed 6 mg/l and that any higher value usually indicates a state of pollution. CO_2 value was found to have a statistically significant positive correlation with total hardness (r=0.734), calcium hardness (r=0.721), PO_4 (r=0.682) and NH_4.N (r=0.701) values. It was also found to have a statistically significant negative correlation with CO_3 (r=-0.903) value during the period of study.

Any perceptible effect of CO_2 on the *Utricularia* spp. could not detect.

CARBONATE ALKALINITY (CO_3)

Carbonate alkalinity (CO_3) is a fundamental requirement to know the nature of water. It is positively correlated with pH and DO values and negatively correlated with CO_2.

In the **WBWU**, the CO_3 value were recorded only in the month of August and September, when the water level was high due to rain water and CO_2 was not traced. Similar observations were also made by Fakruzzaman and Zaman (1996) in Rajshahi. All the calculated correlation values regarding CO_3 alkalinity value were statistically non-significant.

In the **WBWTU**, the CO_3 alkalinity value was found to be nil (Table 1) during the period of study. At this time carbon dioxide values were recorded wherever the pH value was less than 8.0 except in August and September. Similar observations were made by Hutchinson (1957), Palhareya *et al.* (1993) and Chowdhury *et al.* (2000) in their studies.

BICARBONATE ALKALINITY (HCO_3)

Alkalinity is a measure of the capacity of water to absorb hydrogen ion, i.e. the capacity of water to neutralize a strong acid is know as alkalinity. This is an ionic phenomenon. All anions such as CO_3^{-2} (carbonate), HCO_3 (bicarbonate), OH^- (hydroxyl) PO_4^{-3} (Phosphate), SiO_4^- (silicate) etc.

contributed to alkalinity of water (Andrews 1972 and Jacob *et al.* 1999). Here the bicarbonate alkalinity is considered.

In the **WBWU**, the maximum bicarbonate value (141 mg/l) was recorded in monsoon period, in the month of September, when the water level was the maximum due to rainfall. Rain water washed down different steps of surface wastes to the water bodies which may be the cause of rise of HCO_3 value there. Shivanikar *et al.* (1999) also recorded maximum HCO_3 value in monsoon period. The yearly mean of HCO_3 value was recorded to be 96±19 mg/l. Similar HCO_3 values were recorded by Fakruzzaman and Zaman (1996) and Zaman (1991) in unpolluted water bodies in Rajshahi. All the calculated correlation values regarding HCO_3 alkalinity were statistically non-significant.

In the **WBWTU**, the HCO_3 alkalinity value was always higher than that of *Utricularia* spp. containing water bodies. Highest HCO_3 alkalinity value (210 mg/l) was recorded in post monsoon period, in the month of September, when water level was high due to rainfall. Higher concentration of bicarbonate value during post monsoon period may be due to the mixing of rainfall and washings from the catchment zone. Welch (1952) and Yaron (1964) held that the alkalinity of aquatic habitat partly depends on the amount of water present in it. The minimum HCO_3 alkalinity value (145 mg/l) was recorded in summer period in monsoon. Andrews (1972), Hutchinson (1957) and Welch (1952) held that a decrease in the alkalinity may be caused by the breakdown of bicarbonate due to the photosynthetic activity of plants. The yearly mean value of HCO_3 alkalinity was 184±20 mg/l. Total alkalinity of the water increases with an increase in pH and calcium (Wetzel 1972). HCO_3 alkalinity value was found to have a statistically significant negative correlation with total hardness ($r=-0.707$) and calcium hardness ($r=-0.679$) values.

Any adverse effect of HCO_3 alkalinity value on the *Utricularia* spp. could not be observed during the period of study. It can be assumed that a HCO_3 alkalinity content below a level of 141 mg/l may be suitable for *Utricularia*.

TOTAL HARDNESS

According to Gautam (1990), the total hardness of the natural water is mainly caused by the bi-valent cations such as Ca^{++}, Mg^{++} etc. May other cations and anions, which can cause it are iron, stronium, chloride, manganese, sulphate etc. (Jacob *et al.* 1999). Higher cations also contribute to hardness to lesser degree but monovalent cations never produce hardness (Trivedi and Raj 1992). The higher hardness value occurs due to the presence of different types of salts in the industrial effluent which is loaded with high concentration of chlorides and sulphates. Its ecological significance is enormous and as such the hardness tests are among the most commonly performed to test the quality of water (Gautam 1990, Mishra *et al.* 1992, Andrews *et al.* 1972 and Jacob *et al.* 1999).

In the **WBWU**, the maximum total hardness value (134 mg/l) was recorded in summer period, in the month of May, when the water level dropped to its minimum due to the high evaporation. The lowest total hardness (56 mg/l) was recorded in the monsoon period, in the month of August, when the water level was high due to rainfall. Bhatt *et al.* (1999) also recorded highest total hardness values in summer and lowest in monsoon. The yearly mean value of total hardness was recorded 91±26 mg/l, which indicates that the water of *Utricularia* containing water bodies were medium hard (WHO 1982). Fakruzzaman and Zaman (1996) and Naz (1999) also recorded similar total hardness in different water bodies in Rajshahi. Total hardness value was found to have a statistically significant positive correlation with calcium (r=0.877) and magnesium hardness (r=0.849) values.

In the **WBWTU**, the total hardness value was always higher than that of the water bodies with *Utricularia* spp. The highest total hardness value (378 mg/l) was recorded in summer, in the month of May, which may be due to the decrease of water level by evaporation. Rainfall in the month of August decreases the value of total hardness. Similar observations were also made by Bhatt *et al.* (1999) and Chowdhury (1999). The yearly mean value of total hardness was 277±65 mg/l, which indicates that the water of WBWTU were very hard (>180 mg/l) as per by WHO (1982) standard. High hardness also indicates that this water bodies may be polluted by industrial effluents, domestic wastes and different chemicals. Ramjeawon and Baguant (1995), Chowdhury *et al.* (2000), Chowdhury (1999), Palhareya *et al.* (1993), Paul (1981), Andrews *et al.* (1972) and Vincent (1993) recorded a high total hardness content in different water bodies, which were polluted by different industrial effluents, domestic wastes, chemical fertilizer and pesticides. The present findings also corroborate with the above works. Total hardness value was found to have a statistically significant positive correlation with calcium hardness (r=0.894), magnesium hardness (r=0.855), PO_4 (r=0.789), NH_4.N (r=0.804) and total sulphide (r=0.833) values.

During the study period, it was observed that **the *Utricularia* spp. can not grow in hard water (>150 mg/l hardness). When total hardness level started to increase from 150 mg/l, the growth of *Utricularia* spp. started to decrease, chlorophyll and protein content also started to decrease. In this situation *Utricularia* spp. started to die and decompose eventually in about a month. Attempt was made to grow *Utricularia* spp. in vary hard water (>180 mg/l hardness) but failed to succeed and within 10-13 days *Utricularia* spp. started to die.** It was also observed that **immature flower and fruit could not mature in hard water and flower could not open**. Sahai and Srivastava (1976) and Chamanlal (1989) observed that the *Utricularia* spp. and *Hydrilla verticillata* and *Salvinia molesta* could not grow in hard water. The present findings are also supported by the above mentioned works.

CALCIUM HARDNESS

The value of calcium hardness of any water depends on the amount of various calcium salts such as $CaCO_3$, $CaHCO_3$, $CaSO_4$, $Ca(PO_4)_3$ dissolved in it (Andrews 1972 and APHA 1989). The temporary hardness is caused by the calcium carbonate and bicarbonate salts, which can be removed by simple boiling and the chloride and sulphate salts of the calcium cause the permanent hardness. Andrews *et al.* (1972), Trivedy (1993), Chowdhury *et al.* (2000), Paul (1981), Vincent (1993) and Gautam (1990) recorded that many industrial and domestic effluents were also responsible for increasing the calcium hardness of the water body where the effluents are discharged, thus changing the quality of natural water. The calcium hardness always superseded magnesium hardness in the degree of volumetric presence.

In the **WBWU**, the maximum calcium hardness value (115 mg/l) was recorded in summer, in the month of May, when water level decreased by evaporation. Minimum calcium hardness value (41 mg/l) was recorded in monsoon in the month of August, when water level was high due to rainfall. The yearly mean of calcium hardness was recorded 77±22 mg/l, which indicates that the water quality of *Utricularia* containing water bodies can be termed as medium hard. Similar observations were made my Fakruzzaman and Zaman (1996) at fresh water bodies in Rajshahi. Calcium hardness value was found to have a statistically significant negative correlation with magnesium hardness (r=-0.861) value.

In the **WBWTU**, the calcium hardness value was always higher than that of *Utricularia* containing water bodies. The highest calcium hardness value (330 mg/l) was recorded in the month of May, when water level was minimum due to hot summer. Minimum calcium hardness value (161 mg/l) was recorded in the rainy month of August, when water level was maximum due to rain water leading to the dilution of the chemicals responsible for calcium hardness. Chowdhury (1999), Jacob *et al.* (1999) and Chowdhury *et al.* (2000) also recorded maximum and minimum calcium hardness contents in summer and monsoon period respectively. The yearly mean of calcium hardness value was recorded to be 239±56 mg/l, which indicates that the water quality of these habitats were very hard. In the present investigation, the high value of chloride (72±11 mg/l) indicates that, the chloride salts always tend to make permanent hardness in these water bodies. The present findings are supported by Chowdhury *et al.* (2000), Trivedi and Raj (1992) and Ramjeawon and Baguant (1995). Pearson and Penridge (1987) studied that the continuous mixing of industrial and domestic effluents and different chemicals such as, dyes, bleaching powder, fertilizers, pesticides etc. are the major factors, which gradually increase the calcium concentration in the water, as a result permanent hardness level is increased. The high calcium hardness value of these study spots indicate that WBWTU were polluted due to the addition of different wastes materials. Similar observations were also made by Chowdhury (1999), Gautam (1990) and Palhareya *et al.* (1993). Calcium hardness value was found to have a statistically significant positive correlation with PO_4 (r=0.816), NH_4.N (r=0.782) and total sulphide (r=0.697) values. It was also found to have a statistically significant negative correlation with magnesium hardness (r=-0.822).

During the period of study it was observed that the flowering, fruit setting, chlorophyll and protein content, budding and growth of *Utricularia* spp. were affected by high calcium hardness (>140 mg/l calcium hardness). When calcium hardness values started to increase from 140 mg/l the flowering and fruit setting are adversely affected; chlorophyll and protein content started to decrease and budding and growth of *Utricularia* spp. started to stop. When **calcium hardness content reached to 165 mg/l the *Utricularia* plants started to die and get decomposed eventually**. Similar observations were also recorded by Sahai and Srivastava (1976) and Chamanlal (1989).

MAGNESIUM HARDNESS

Magnesium hardness makes temporary and permanent hardness. It is caused by the carbonates, bicarbonates, chlorides and sulphates, salts of magnesium. The magnesium and calcium hardness shows an inverse relationship (Gautam 1990, APHA 1989 and Chowdhury 1999) but the calcium always dominated over magnesium quantitatively.

In the **WBWU**, the highest magnesium hardness value (4.64 mg/l) was recorded in summer period, in the month of May and the lowest value (1.22 mg/l) was recorded in post monsoon, in the month of August. The yearly mean value was recorded 3.06±1.11 mg/l. Similar magnesium hardness values were also recorded by Fakruzzaman and Zaman (1996) and Rahman (1997) in different fresh water bodies in Rajshahi. None of the calculated correlation values regarding calcium hardness were found to be statistically significant.

In the **WBWTU**, the magnesium hardness value was always higher than that of *Utricularia* spp. water bodies. Maximum magnesium hardness value (12 mg/l) was recorded in the month of May, may be due to the decrease of water depth in the hot summer period. Minimum magnesium hardness value (6 mg/l) was recorded in the month of August, when water level was high due to the rainfall. The yearly mean value of magnesium hardness was recorded 9±2 mg/l. According to Gautam (1990) and Jacob *et al.* (1999), the magnesium hardness value of a water body is increased due to the mixing of high Mg^+ content wastes. High magnesium can make permanent hardness when chloride salts mix with magnesium. Palhareya *et al.* (1993), Gautam (1990) and Jacob *et al.* (1999) expressed that the magnesium hardness should not exceed more than 6-7 mg/l. Magnesium hardness value was found to have a statistically significant positive correlation with PO_4 (r=0.787) and total sulphide (r=0.709) values.

During the period of study, any effect of magnesium hardness on the *Utricularia* spp. could not be perceived, although a lower value below 4.64 mg/l may probably be congenial for the normal life of *Utricularia* spp. as evident from the values obtained from WBWU.

TOTAL PHOSPHATE (PO_4)

Phosphorus occurs in natural waters almost solely as phosphates, as phosphates rich detritus falls in water and is decomposed by bacteria. In natural water phosphorus is present in the form of phosphate (i.e. $H_2PO_4^-$, HPO_4^- and PO_4^{3-}). All forms of phosphorus such as orthophosphates, condensed phosphates and organically bound phosphates are converted into inorganic phosphate after digestion (Bandela *et al.* 1999). The prominent sources of phosphorus in natural water are industrial effluent, sewage, agricultural runoff, detergents etc. (Gautam 1990, Bandela *et al* 1999, APHA 1989 and Chowdhury 1999). The higher concentration of phosphate causes eutrophication in natural water, which indicates the pollution of water. It also often implicates algal blooms in water ways.

In the **WBWU**, the phosphate content was always found to be nil during the period of investigation. Similar observations were also made by Chowdhury and Zaman (2000b) and Rahman (1997), who worked on the different ponds and river in Rajshahi. Verma and Dalela (1975) and Bandela *et al.* (1999) held that the natural fresh water should always be free from PO_4 content.

In the **WBWTU**, the highest phosphate value (0.64 mg/l) was recorded in summer period, in the month of May, when water level was minimum. Bandela *et al.* (1999) recorded the maximum amount of phosphate in summer period. The minimum phosphate content (0.09 mg/l) was recorded in the month of August, when water level was high due to rainfall resulting in dilution of the chemicals. The yearly mean of phosphate value was recorded 0.36±0.18 mg/l, which is higher than that of the findings of Chowdhury and Zaman (2000a) (0.011±0.0018 mg/l and 0.019±0.02 mg/l). The presence of phosphates in large quantities in fresh water indicates pollution through sewage and industrial wastes (Bandela *et al.* 1999 and Godfrey *et al.* 1985). This is evidently due to the surface runoff from the surrounding crop fields fertilized with phosphate and the increased phosphate content in the water bodies receiving the runoff (Bhatt *et al.* 1999). Excess amount of phosphate can lead to eutrophication (Godfrey *et al.* 1985 and Wetzel 1983). The dominant and regular presence of *Microcystis* sp. is an indicator of pollution and eutrophication of water body showing visual blooms (Vasisht and Sra 1979). Similar to the findings of Godfrey *et al.* 1985, Bandela *et al.* (1999), Vasisht and Sra (1979), Wetzel (1983) and Bhatt *et al.* (1999) the present study also indicates that the WBWTU were polluted by different ways including anthropogenic activity. Study Spots-1, 2 and 3 are always used for domestic purposes; paddy field washes are always found to mix with water of Spot-4 and Spot-5; Spot-6 is always found to receive the waste water from Rajshahi University students hall drainage, while the effluent of Rajshahi Sugar Mills always mixes with the water of study Spot-7. It was also observed that the study Spots 1,2,3,5 and 6 had visual bloom almost round the year, causal by BGA. All the calculated correlation values regarding the total phosphates were found to be statistically non-significant.

During the period of study, it was recorded that, the ***Utricularia*** **spp. could not function its biological activities, such as flowering, fruit setting, photosynthesis, trapping of prey and growth, when phosphate content of water was started to rise above 0.112 mg/l. Within 10-12 days leaf colour is changed into radish brown, immature fruits turned black, chlorophyll and protein content are reduced to half and immature flower failed to open and its colour is changed into black. Within 18-20 days the whole plant starts to die and become decomposed eventually.** Kulshreshtha (1982), Kulshreshtha and Gopal (1981), Sahai and Srivastava (1976) and Chamanlal (1989) also observed that *Ceratophyllum demersum*, *Hydrilla verticillala, Utricularia* sp. and *Salvinia molesta* did not grow in polluted water rich in phosphates.

SILICATE

Silicate is a less soluble constituent of river water (Chowdhury and Zaman 2000b and Gautam 1990), but in natural water, lower concentration of silicates is always present. Excess silicate in natural water some times increases total hardness (Jacob *et al.* 1999).

In the **WBWU**, the silicate content was always found to be nil during the period of study. The low abundance (1768 units/l) of diatoms also supported the present findings, because the silicate is a most important constituent of cell wall of diatoms and an increase in its concentration enhances the growth of diatoms. Similar observations were made by Chowdhury (1999) and Saha *et al.* (1971).

In the **WBWTU**, the highest silicate (0.032 mg/l) was recorded in summer period in the month of May, when the water level was minimum due to the evaporation. The lowest silicate content (0.016 mg/l) was recorded in post monsoon period, in the month of September. The yearly mean value of silicate was 0.023±0.005 mg/l, which is much less than that recorded by Chowdhury and Zaman (2000b). Sufficient information is not available in Bangladesh about the silicate content of water bodies. None of the calculated correlation values regarding silicate were found to be statistically significant.

Any effect of silicate on the *Utricularia* spp. could not be observed.

AMMONIUM NITROGEN ($NH_4.N$)

Ammonium is a source of nitrogen. Its takes up a huge amount of dissolve oxygen for chemical processes as in nature through microbial activities, thereby liberating ammonia (NH_3) (Vincent 1993, Trivedi and Raj 1992, Trivedy and Goel 1984 and Chowdhury 1999). Ammonium nitrogen ($NH_4.N$) is a state of ammonia. Its concentration is depended upon the concentration of ammonia. Ammonium nitrogen has similar kind of effect like ammonia in the aquatic environment (Trivedy and Goel 1984). Ammonia is naturally present in surface and ground water and in industrial and other waste water (Bandela *et al.* 1999, Bhatt *et al.* 1999 and Chowdhury 1999). High value of free ammonia is a sign of pollution (Bruce 1958). The desirable limit of ammonia is less than 0.10 mg/l (WHO 1988). According to Ghose and Sharma (1989), the tolerance level of $NH_4.N$ is 0.05 mg/l for existing biota. BOD_5, COD, TDS, electric conductivity and hardness are influenced by ammonia content (Andrews *et al.* 1972 and Chowdhury *et al.* 1998).

In the **WBWU**, the ammonium nitrogen content was found to be nil during the period of study except in the month of April and May in summer period, when the water level was at its lowest due to evaporation. At that time COD, BOD_5, TDS, electric conductivity and hardness values were high. The highest ammonium nitrogen content was 0.036 mg/l, which is much less than the desirable level.

In the **WBWTU**, the highest ammonium nitrogen (0.59 mg/l) was recorded in the month of May, in summer period, probably due to the anaerobic decomposition of bottom organic matter. Similar observations were also made by Bandela *et al.* (1999) and Bhatt *et al.* (1999). No ammonium nitrogen was recorded in the month of August, in the monsoon period, when the water level was maximum due to rainfall leading to dilution of materials. The yearly mean of ammonium nitrogen was recorded 0.324±0.203 mg/l which was higher than the desirable level and it also indicates that the WBWTU were polluted by different wastes, such as industrial and domestic sewage, pesticides and chemicals fertilizers. Similar observations were also made by Toetz (1971), Bruce (1958), Sharma *et al.* (1981), Singh *et al.* (1969), Rana *et al.* (1991), Prasad *et al.* (1993) and Chowdhury (1999). A higher concentration of ammonia is toxic to aquatic lives. Nitrogen, which is an essential factor for the growth of phytoplankton was observed in its oxidized form i.e. nitrate, but sometimes excess nitrate create toxic water bloom (Bandela *et al.* 1999, Bhatt *et al.* 1999 and Saha *et al.* 1971) and form chloramines which are also toxic to aquatic lives, such as

Cladocera, Copepods, fishes and mollusces (Tsai 1973). NH_4.N was found to have a statistically significant positive correlation with total sulphide (r=0.766).

During the period of study, it was observed that **the growth and biological activities of *Utricularia* spp. were affected by the ammonium nitrogen. When ammonium nitrogen content started to increase from 0.05 mg/l, the biological activities of *Utricularia* spp. show sign of decrease. When ammonium nitrogen content goes above 0.10 mg/l, all parts of *Utricularia* spp. start to die within 5-7 days and decomposes.** Similar observations were also made by Sahai and Srivastava (1976), Kulshreshtha and Gopal (1981) and Chamanlal (1989). It was also observed that, when ammonium nitrogen exceeds 0.05 mg/l, the abundance of all Copepods, Cladocera and some Rotifera (which are prey of *Utricularia* spp., Table 9) have started to fall rapidly, and the abundance of Protozoa started to rise. Under such condition the *Utricularia* spp. shows almost retarded activity of capturing prey. Lackey (1957) and Chowdhury (1999) reported that high abundance of Protozoa indicates a polluted condition of a water body.

TOTAL SULPHIDE

The sulphate undergoes transformation and forms sulphide, which mainly depends on the redox conditions of water system (Gautam 1990 and APHA 1989). It causes objectionable taste and colour of water at higher concentration. Different forms of sulphide are SO_4, H_2S, SO_2, etc. Sulphides are compounds of various industrial and sewage wastes and many natural waters get it from the anaerobic decomposition of organic matter. Discharge of industrial effluent also contributes to the concentration of sulphides (Chowdhury *et al.* 2000 and Chowdhury 1999). When sufficient organic matter and constant supply of sulphide from the wastes are insured, this stimulate the activation for sulpher reducing bacteria capable of producing hydrogen sulphide, a gas highly toxic to fish and other biota as well (Smith and Oseid 1973, Chowdhury *et al.* 2000 and Chowdhury 1999). Biologically produced H_2S, when oxidized, produces sulpher dioxide (SO_2). SO_2 can damage materials and properties, mainly through their conversion into the highly reactive H_2SO_4. SO_2 and H_2SO_4 are both capable of causing irritation in respiratory tracts of animals and humans and high concentration of SO_2 cause severe heart and lung disease (Chowdhury 1999, APHA 1989, Jacob *et al.* 1999 and Gautam 1990).

In the **WBWU**, the total sulphide content was always found to be nil during the period of study. Similar observations also made by Rahman (1997) and Fakruzzaman (1997), who worked on the different water bodies in Rajshahi. Chowdhury and Zaman (2000b) recorded <0.50 M mol l^{-1} total sulphide in the river Padma near Rajshahi city. According to Jacob *et al.* (1999), the natural water always should be free form sulphide.

In the **WBWTU**, the maximum total sulphide value (4.49 M mol l^{-1}) was recorded in summer period, in the month of May, when water level was minimum, may be due to high evaporation. Jacob *et al.* (1999) also recorded the maximum sulphide content in summer period. The lowest sulphide content (0.64 M mol l^{-1}) was recorded in the month of August when water level was maximum due to rainfall and water was more diluted. The yearly mean of sulphide content was 2.49±1.15 M mol l^{-1} which is the higher than that of Chowdhury *et al.* (2000) and Chowdhury and Zaman (2000 a,b) findings. The present findings indicate that the water bodies without *Utricularia* were polluted by different sources, such as industrial wastes, domestic sewage, chemical fertilizers etc. Similar findings were also made by Sharma *et al.* (1981), Singh *et al.* (1969), Prasad *et al.*(1993) and Rana *et al.* (1991). A higher concentration of total sulphide is highly toxic to all aquatic lives (Smith and Oseid 1973 and Chowdhury 1999).

During the period of study, it was observed that **the growth and biological activity of *Utricularia* spp. were affected by higher total sulphide content. The biological activities of *Utricularia* spp. have started to retard gradually when total sulphide content begins to rise from 0.50 M mol l^{-1}. All parts of *Utricularia* plants start to die and get decomposed within 7-10 days when total sulphide content rises above 0.80 M mol l^{-1}**. Sahai and Srivastava (1976), Kulshreshtha and Gopal (1981) and Chamanlal (1989) also made similar observations in their works on *Utricularia*, *Ottelia*, *Salvinia*, etc. It was also recorded that, when total sulphide content exceed 0.50 M mol l^{-1} the abundance of prey of *Utricularia* spp. (Copepods, Cladocera and some Rotifera) rapidly start to fall and the abundance of Protozoa start to increase. At such high content the capture of prey by *Utricularia* stops completely. According to Lackey (1957), Chowdhury *et al.* (2000) and Chowdhury (1999), the high abundance of protozoa is an indication of pollution of a water body.

BOTTOM SOIL CONDITIONS

WATER BODIES WITH *UTRICULARIA*

During the period of study the bottom soil conditions of **WBWU** were always found to be alkaline in nature round the year. Low content of organic matter (1.26-1.29%) supported this finding because higher content of organic matter can make acidic conditions in soil and water (Gautam 1990, Trivedy and Goel 1984 and Palhareya *et al.* 1993). Calcium content was always higher (30.70-31.00 milli equivalent/100g soil) than magnesium (2.42-2.47 milli equivalent /100g soil). Similar observations were also made by Islam and Irfanullah (2000). Calcium content was also higher than magnesium (Table 1) in the present WBWU.

Potassium was recorded from 0.10 to 0.12 milli equivalent/100g soil. Almost similar potassium value was recorded by Fakruzzaman (1997) in different water bodies in Rajshahi. Total nitrogen ranged from 0.06 to 0.08% during the period of study. Fakruzzaman (1997) recorded 0.07-0.10% of total nitrogen in some water bodies at Mohonpur in Rajshahi, which are at a distance of 3 km from study Spots 1 and 2. Islam and Irfanullah (2000) recorded 0.07-0.09% total nitrogen in their studies. Phosphorus, sulpher, boron, copper, iron, manganese and zinc values were found to range from 2.40-2.60; 23.50-23.70; 0.15-0.17; 3.68-3.73; 24.40-24.50; 7.80-8.05 and 0.96-0.97 µg/g soil respectively during the period of study. Fakruzzaman (1997) recorded also similar values of phosphorus (2.30-2.54 µg/g), Copper (3.60-3.80 µg/g), Iron (25.00-25.30 µg/g) in his studies, in some unpolluted ponds in Rajshahi.

WATER BODIES WITHOUT *UTRICULARIA*

The pH value (6.8-7.6) indicates that the bottom soil conditions of **WBWTU** were slightly acidic to alkaline in nature. According to Trivedy and Goel (1984), Palhareya *et al.* (1993) and Gautam (1990) the high content of organic matter (4.23-4.28%) indicates that the study soil was acidic. During the period of study, it was observed that the recorded values of organic matter, calcium, magnesium, potassium, total nitrogen, phosphorus, sulpher, boron, copper, iron, manganese and zinc in WBWTU were higher than that of *Utricularia* containing water bodies (Table 3). High TSS, calcium, magnesium, NH_4.N, PO_4 and low Eh and rH_2 values were recorded in water of WBWTU. Gautam (1990) and Palhareya *et al.* (1993) recorded high calcium, magnesium, potassium, total nitrogen, phosphorus, sulpher, boron, copper, iron, manganese and zinc in water and bottom soil of polluted water bodies in India. The present findings bear similarity with Gautam (1990) and Palhareya *et al.* (1993). Sufficient report on the bottom soil conditions of polluted water bodies is not available in Bangladesh as far as the related literature is concerned.

ALGAL PLANTS ON THE SURFACE OF *UTRICULARIA*

During the period of study it was recorded that the Bacillariophycean members were in highest number attached on the surface of *Utricularia* spp. and the Cyanophycean group had the minimum number of genera occurring as attached form (Table 4). A total 32 genera of phytoplankton were recorded from inside the bladder, on leaf surface and on stem surface of *Utricularia* spp. Maximum (27genera) number of phytoplankton were recorded on the stem surface and the minimum number (16 genera) were recorded from inside the bladder. 24 genera were recorded from the leaf surface. During the period of study only 7 genera of phytoplankton (*Fragilaria* sp., *Hantzchia* sp., *Pinnularia* sp. and *Navicula* sp. of Bacillariophyceae; *Oscillatoria* sp. and *Spirulina* sp. of Cyanophyceae and *Chlorella* sp. of Chlorophyceae) were recorded from inside the bladder, on leaf and stem surface of *Utricularia* spp. (Table 4). From inside the bladder, 2 genera of Cyanophyceae, 4 genera of Chlorophyceae and 10 genera of Bacillariophyceae were recorded. On leaf surface, 7 genera of Cyanophyceae, 7 genera of Chlorophyceae and 10 genera of Bacillariophyceae were recorded. On the stem surface, 7 genera of Cyanophyceae, 10 genera of Chlorophyceae and 10 genera of Bacillariophyceae were recorded (Table 4). The present findings indicate that the recorded Bacillariophycean phytoplankton members were the highest associated plankton group of *Utricularia* spp. There is no supportive literature on the association of algal periphytonic forms on *Utricularia* spp. are available in the country.

ASSOCIATED MACROPHYTIC COMMUNITY OF *UTRICULARIA* HABITAT

During the period of study, *Hydrilla verticillata* showed high density and importance value index. *Salvinia rotundifolia*, *Ceratophyllum submersum* and *Limnophylla heterophylla* also showed high importance value index (Table 5) and their relative density varied from 4.12-9.30%. Sahai and Srivastava (1976), Kulshreshtha and Gopal (1981), Chamanlal (1989) and Kulshreshtha (1982) observed in their studies that *Hydrilla verticillata, Utricularia* sp., *Ceratophyllum submersum*, *Salvinia rotundifolia*, and *Azolla pinnata* could not grow in polluted water. At per with the works of Sahai and Srivastava (1976), Kulshreshtha and Gopal (1981), Chamanlal (1989) and Kulshreshtha (1982) the present study water bodies with *Utricularia* spp. were free from pollution. Purohit and Singh (1985), Chamanlal (1989) and Pip (1987) observed in their studies that *Potamogeton crispus* dominated in the eutrophic lakes. In the present study, *Potamogeton crispus* showed lowest relative density (2.73-4.24%) and importance value index (59.78-67.47), which indicates that the water bodies with *Utricularia* spp. were not in eutrophic condition. The BOD_5 value (1.2±0.4 mg/l) of the WBWU also supported the present findings. The lowest relative density (1.86-2.76%) and importance value index (49.28-55.75) of *Utricularia* spp. indicate the poor abundance of *Utricularia* spp. in their habitats.

PLANKTON PREY OF *UTRICULARIA*

It was observed that a total 22 genera of zooplankton were secured by the species of *Utricularia* L., amongst which 8 genera belonged to Rotifera, 9 to Cladocera and 5 to Copepoda. Highest number of genera (20) was preyed upon by *U. aurea* (without float) and lowest (14) by *U. stellaris* and *U. exoleata*. *U. aurea* (with float) captured 19 genera. Rotiferan *Filinia* sp. and Cladoceran *Macrothrix* sp. were preyed upon only by *U. aurea* (without float) and *U. stellaris* respectively. *Philodina* sp. and *Harringia* sp. of Rotifera group and Cladoceran *Diaphanosoma* sp. were captured only by *U. aurea* (with float and without float). Whereas Cladoceran *Dadaya* sp. was captured only by *U. stellaris* and *U. exoleata*. During the period of study, the percentage composition of different prey of all the study plants were - Cladocera 44.9%, Copepods 28.4% and Rotifera 26.7%. The present findings indicate that the recorded Cladoceran members are more preferred as prey by *Utricularia* L. and *Daphnia* sp. alone consisted of 19% of the captured prey.

The present study reveals that the study species of *Utricularia* L. differ in their preference of prey – individual although they grow in the same aquatic environment or in captivity in artificial aquarium. Arber (1972) expressed similar views. The infusorians consisted of the Protozoans, which were not considered here. A number of phytoplankton algae were also obtained from the bladders, most of them were in intact condition.

ANATOMICAL CONDITION OF *UTRICULARIA*

The ecological anatomy of plants reveals their special adaptation to their habitats. The plants which characteristically grow in certain ecological niches, often show a type of structural modification believed to be adapted to their particular environment. (Weaver and Clements 1938). In course of evolution many plant species have become adapted in both in structural and physiological features to their habitats with an excessive supply of water (Weaver and Clements 1938, Sharma 1997 and Metcalfe and Chalk 1965). Plants that grow in water or wet places are generally known as hydrophytes. They may be completely submerged, partly submerged, floating or amphibious. The hydrophytes may differ from each other in some aspects but most of morphological and anatomical modifications are almost common to all of them.

The anatomical modifications or internal tissue differentiation in hydrophytes considered as important features of adaptation to habitat, are achieved in having reduction of the protective tissue; reduction of the mechanical or supporting tissue i.e. lack ofsclarenchyma; reduction or absence of absorbing tissue or roots; increase in aeration by the development of special air chambers and the reduction of the vascular tissue (Weaver and Clements 1938, Metcalfe and Chalk 1965 and Sharma 1997).

As regards the anatomical modifications in the studied species of *Utricularia,* the internal structural modifications are similar to other floating hydrophytes and are characterized by the absence of cuticle, presence of single layered absorptive and protective epidermis, occurrence of large number of air chambers in the upper context, thin walled parenchymatous cortical zone ending in the endodermis, reduced vascular structure of scattered phloem and xylem elements completely surrounded centrally by a ring of mechanical tissue (Plate-7, Photos.-3-5). The air chambers are considered as filled with gasses found in stem and leaves and roots when present. In *Utricularia* spp. the air chambers are moderately large and form a ring like arrangement around the peripheral region of the cortical zone. these spaces are separated by a narrow partition of photosynthetic tissue one cell is thickness. Air chambers prepare an internal atmosphere for the plant to provide buoyancy to the plant for floating, as well as serve to store up oxygen and carbon dioxide (Weaver and Clements 1938 and Sharma 1997). In the leaves of *Utricularia* spp., stomata are developed in a very limited number and are confined to the terminal region on both sides of the leaves. Stomata were also present on the surface of floral stalks.

Mechanical tissue consisting of thick walled selaranchymatous tissue is either absent or poorly developed in the floating and submerged parts of the hydrophytes because buoyant nature of such aquatic plant generally saves them from physical injury due to strong wave action of water or other agents in water (Weaver and Clements 1938). The mechanical tissue, however, may develop in the cortex of amphibious plants particularly in the aerial or terrestrial plants of the plant body. In the species of *Utricularia* a narrow ring of mechanical tissue is prominent below the endodermis, completely surrounding the central vascular region. This mechanical element probably imparts stiffness to the plant against external pressure. As a matter of fact, the studied species of *Utricularia* are commonly found in still water, but they were also found to float away in strongly flowing streams without much fragmentation of the thallus, a fact which may be attributed to the presence of the mechanical tissue in this plant. Like other hydrophytes the conducting tissue is much reduced in *Utricularia* and form patches of phloem and xylem element separated from each other and commonly appearing within the layer of the mechanical ring. The xylem is represented by tracheids while the phloem has seive-tubes and phloem parenchyma. As there is surface absorption of nutrients by the submerged parts of the plant body, there is little need of the vascular tissue in the hydrophytes as in *Utricularia.* A central pith of thin walled parenchymatous cells is also prominent in *Utricularia* as in amphibious *Marsilea*, *Jussiaea*, etc. DeWit (1964) observes that of the 250 species of *Utricularia*, only a small number are genuine aquatics, and others growing in moist place, bogs, rooting in the soil and only the aquatics being rootless. The combination of amphibian and floating submerged hydrophytic characters in connection with the internal tissue differentiation in the present study species of *Utricularia* is therefore significant (Metcalfe and Chalk 1965 and Sharma 1997).

CHROMOSOME OF *UTRICULARIA*

Darlington and Wylie (1955) and DeWit (1964) recorded a basic number of chromosomes for the species of *Utricularia* as 8 and a diploid number of 16 chromosomes. They further stated a triploid and tetraploid condition in different species of this genus. The present investigation fits well with their records. *Utricularia aurea* (without float) was found to have a diploid number of

16 chromosomes while *U. aurea* (without float) had a triploid number of 24 chromosomes. Darlington and Wylie (1955) and DeWit (1964) further mentioned that some species of *Utricularia* have a tetraploid number (32) of chromosomes which is indicative of a genetic diversity in the genus. They mentioned about the cross and self pollination in this genus.

CHLOROPHYLL CONTENT OF *UTRICULARIA*

During the period of study, the maximum chlorophyll 'a' and 'b' content of all species of *Utricularia* were recorded in the month of August, when water level was maximum due to rainfall and temperature, TSS, TDS, BOD_5, electric conductivity, chloride, COD, total hardness, calcium hardness, magnesium hardness and soluble salts values were low and the transparency, DO, % of saturation of oxygen, Eh and rH_2 values were high (Table 1). The minimum chlorophyll 'a' and 'b' content of all species of *Utricularia* were recorded in the month of April and May, when water level was minimum due to high evaporation and water temperature, TSS, TDS, BOD_5, electric conductivity, chloride, COD, total hardness, calcium hardness, magnesium hardness and soluble salts values were high and the transparency, DO, % of saturation of oxygen, Eh and rH_2 values were low (Table 1).

During the period of study, the chlorophyll content was found to have a statistically significant positive correlation with transparency (r=0.912), DO (r=0.908), % of saturation of oxygen (r=0.874), Eh (r=0.882) and rH_2 (r=0.882) values. It was also found to have a statistically significant negative correlation with temperature (r=-0.896), TSS (r=-0.899), TDS=(r=-0.916), BOD_5 (r=-0.923), electric conductivity (r=-0.866), chloride (r=-0.858), COD (r=-0.872), total hardness (r=-0.904), calcium hardness (r=-0.870) and magnesium hardness (r=-0.858) values. The present study indicates that the uphill and downhill patterns of chlorophyll content of all study species of *Utricularia* are dependent on the particular suitable physico-chemical conditions of water of *Utricularia* habitats. Relevant literature on the chlorophyll content of *Utricularia* is not available to compare with the present findings.

PROTEIN CONTENT OF *UTRICULARIA*

During the period of study, higher protein content of old and new parts of all species of *Utricularia* were recorded in the month of September, when water level was high due to rainfall and TSS, TDS, BOD_5, electric conductivity, chloride, COD, total hardness, calcium hardness, magnesium hardness and soluble salts values were low and DO, % of saturation of oxygen, Eh and rH_2 values were high (Table 1). The low protein content of old and new parts of all species of *Utricularia* were recorded in the month of April and May, when water level was minimum due to high evaporation and the TSS, TDS, BOD_5, electric conductivity, chloride, COD, total hardness, calcium hardness, magnesium hardness and soluble salts values were high and DO, % of saturation of oxygen, Eh and rH_2 values were low (Table 1).

The protein content was found to have a statistically significant positive correlation with DO (r=0.848), % of saturation of oxygen (r=0.856), Eh (r=0.867) and rH_2 (r=0.849) values during the period of study. It was also found to have a statistically significant negative correlation with TSS (r=-0.879), TDS (r=-0.854), BOD_5 (r=-0.885), electric conductivity (r=-0.889), chloride (r=-0.842), COD (r=-0.863), total hardness (r=-0.875) and calcium hardness (r=-0.851) values. The present study indicates that the increase and decrease pattern of protein content of all species of *Utricularia* depend on suitable physico-chemical conditions of the *Utricularia* habitats. It indicates that unpolluted water is essential for the higher protein content in all species of *Utricularia*. Such reports on the protein content of *Utricularia* in relation to the physico-chemical conditions of habitats of *Utricularia*, are not available in the country.

PHYSIOLOGICAL STUDY OF *UTRICULARIA* TREATED WITH KNO_3

During the period of study the maximum chlorophyll and protein contents were observed in a concentration of 600 mg/l of KNO_3 level (Table 11). The minimum chlorophyll contents (which were less than 0 mg/l KNO_3 level) were observed in 1000 mg/l KNO_3 level. The minimum protein contents (which were less than 100 mg/l KNO_3 level) were observed in 1000 mg/l KNO_3 level (Table 11). During the period of study it was observed that the chlorophyll and protein contents have started to increase gradually from 100 mg/l KNO_3 level and reached to their maximum contents. Chlorophyll and protein contents also started to decrease from 700 mg/l KNO_3 level and reached to its minimum. This experiment reveals that the nutrients (K, N etc.) are essential for the physiological activities of *Utricularia* spp., but excess of these nutrients were harmful. Different plants have different level of nutrients demand (Ambasht 1974). Ambasht (1990) expressed that all plants follow a 'law of limitation' for their nutrients use and when nutrients cross the maximum level, they tend to create pollution in the aquatic ecosystem. Gautam (1990) observed that excess nitrogen, calcium and potassium compounds create water pollution. *Utricularia* failed to survive in polluted water (Table 10). The present experiment indicates that the maximum consumption level of KNO_3 is 600 mg/l by *Utricularia* and the excess of KNO_3 (> 600 mg/l) is not suitable for their normal physiological activities.

UTRICULARIA AND BIOLOGICAL CONTROL IN NATURE

Biological control is the management of pest population by parasitoids, predators and pathogens. It is the deliberate pitting of beneficial organisms (agents) against harmful ones (targets) and is, thus, the deployment of natural enemies against specific animal pests or weeds (Khan and Mannan 1991). However, the use of resistant varieties, radiation, sterilization and hormone manipulation are also effective in the biological control mechanism (Begum *et al.* 1979, Huda *et al.* 1989 and Wilcox 1987). Prolonged and indiscriminate use of chemical pesticides, herbicides, fungicides and other harmful agro-chemicals lead to serious environmental problems, and as such the pest control experts and scientists are becoming more concerned about the introduction of non-chemical methods, including the use of biological methods (Khan and Mannan1991).

The management of nursery pond is very vital in modern pisciculture. Fish larvae or hatchlings are reared in the nursery ponds. In a few weeks they grow up into fingerlings which become ready to be released into stocking ponds. Although the members of Cladocera and Copepoda including Rotifers are first and best food for fish hatchlings, the Cladocerans and the Copepods are known to prey upon the hatchlings and completely devour them (Kumar 1992, Tripathi 1991 and Jhingran 1975). Unless otherwise the Copepods and Cladocerans are eliminated by using different types of organophosphates, non-organophosphates, organochlorines, DDT and arsenicals, the net return of the fingerlings from the entire released larvae or hatchlings is almost 0% to 1% (Jhingran and Pullin 1985 and Chakrabarty *et al.* 1973). The common practices in the present day fishery is the eradication of the enemies of fish hatchling and spawns like the weed fishes (non-culture fishes), carnivorous fishes, fish ectoparasites, tadpoles, insects, Copepods, Cladocerans etc. by using various chemical poisons of different trade names which belong to the above mentioned groups. The indiscriminate use of chemical poisons (Benzinhexachlorides, eldrin, dieldrin, thiomation, phosphamation, fumadol, sumithion, neguvon, lindane, nogos, DDT, rotenon, malathion, diaginon, ditrion, thionex, etc.) for the eradication of unwanted organism which are indispensable parts of the natural ecosystem bring about environmental pollution and ecosystemological disaster (Classen 2000, Mian 2000, Hongliang *et al.* 2000, Hagen 2000, Das 2000, Kawashima *et al.* 2000 and Bhowmik 2000). The productive aquatic ecosystems are so balanced that removal of any organism from the food chain shall result in the break down of the ecosystem as energy flow is blocked by the removal of any organism at any trophic level (Odum 1971 and Ambasht 1990).

Against this back drop, a research programme was undertaken in the Phycology and Limnology laboratory of the Department of Botany, Rajshahi University in collaboration of the Fisheries laboratory of the Department of Zoology of the same University with a view to eradicating the zooplankton from nursery/hatchery ponds, which are harmful to fish hatchlings (larvae) by using simple biological control methods. The main theme of such study is the eradication of the harmful zooplankton from the nursery ponds temporarily for higher return of fish fingerlings without disturbing the pond environment.

It is generally observed that hatchlings of all culture fishes (Carps) having a size of 6-8mm are immediately attacked by the members of Copepods and Cladocerans following their release into the nursery ponds. All hatchlings are consumed by them in about seven days if these hatchling feeders are not eradicated from the nursery ponds prior to the release of the hatchlings. The fingerlings of Catla and Silver carp fish having a size range of 17-24cm were used in this case as beneficial agents against the harmful targets e.g. the Copepods and the Cladocerans. The hatchlings of Catla and Silver carp are known as voracious and effective zooplankton feeders, especially the Copepods and Cladocerans (Kumar 1992, Biswas 1966, Das 1997, Jhingran and Ahmed 1991).

Considering the effectiveness of different species of *Utricularia* in capturing the members of Copepoda, Cladocera and Rotifera; they were chosen as agent organisms against the harmful target organism alongside the above investigation. As is known from Chowdhury *et al.* (2001), that of the total zooplankton prey of *Utricularia* spp., the Copepoda and Cladocera together amounts to 73.3% and the Rotifera amounts to only 26.7 %. So this plant can play an effective role in the eradication of the zooplankton, which is harmful to fish hatchlings. In the present investigation 5 managed ponds, each of 130m^2 area and an average depth of 1.5 meter, were used as study ponds.

The abundance of the Copepods, Cladocerans, and the Rotifers in all 5 ponds were determined before hand following Welch (1948), as well as their abundance were also determined after the experiments. In the three ponds (Pond-1, 2 & 3) Catla and Silver carp fingerlings were introduced for the eradication of the target organisms 7 days prior to the release of hatchlings into the ponds. In Pond-4 fingerlings of Rui, Mrigal and common carp were introduced 7days prior to the release of culture fish hatchlings. In Pond-5, fingerlings of Rui, Mrigal and common carp along with a large number of *Utricularia* plants were introduced similarly. The results were that in Ponds-1, 2 & 3, all the Copepods and Cladocerans were consumed by the Catla and Silver carp fingerlings, while in Pond-4 their number fell very slightly. In Pond-5, the number of zooplankton fell considerably indicating the role of the *Utricularia* plants in eradicating the target organisms to a considerable extent. After 7 days following the introduction of the fingerlings in the 5 study ponds, the agent fish fingerlings were removed from the ponds by intensive netting; culture fish hatchlings (larvae) were introduced into the pond at the rate of 3 liters per acre. Generally, one liter of Catla, Rui, Mrigal and Silver carp hatchling contain about 3.5, 4, 4 and 2.5 lacs of larvae or hatchlings respectively. The astonishing result was that in Pond 1, 2 & 3, the return of fingerlings were roughly 80-90% after 15-20 days following their release, while the return was less than 1% in Pond-4 and 17-21% in Pond-5. The return of the fingerlings from Pond-5 is indicative of the extent of effectiveness of the *Utricularia* plants as beneficial agents of biological control (Partial results were shown in Table 14 and the informations of the on going research work were received through personal communication of Mr. Azizul Islam, Ph. D. fellow of the Phycology and Limnology laboratory, Department of Botany, University of Rajshahi). The experiments are being repeatedly conducted during the period from 2000 up to date and the results were similar.

The ecosystemological implication of this finding is that the carnivorous *Utricularia* spp. contribute enormously to the survival of the hatchlings of almost all non-culture and culture fishes in the aquatic bodies by controlling the population density of the harmful zooplankton. This can be regarded as an example of check and balance system operating spontaneously in the aquatic environment and highlights the urgency for the conservation of *Utricularia* spp. in nature.

STATUS OF *UTRICULARIA* IN IUCN CATEGORIES

The present study reveals the delicacy and responsive behaviour of the species of *Utricularia* to the changes in certain physico-chemical factors in their aquatic environment. The polluted habitats are almost free from this plant although some other hydrophytes are capable of withstanding the different levels of pollution caused by industrial effluent or discharge of municipal or domestic refuges in water. This plant, as evident from Table 10, seems to live in a very delicate environment and a change in certain environmental factors makes its habitat fragile. During the present study it transpired that the species of *Utricularia* favours a clean and unpolluted water for its normal biological activities including growth, development and reproduction.

U. stellaris and *U. exoleata* were always found to occur in extremely clear and undisturbed water bodies. The major physico-chemical factors in an aquatic ecosystem are subject to spontaneous changes and readjustment and always operate as a factor complex in which the organisms accommodate themselves (Lakshminarayana 1965). During the present study the species of *Utricularia* exhibited sharp response to the major physico-chemical factors and clearly marked the lethal as well as death levels of values of Transparency of water, TSS, TDS, DO, BOD, COD, electric conductivity, Eh, rH_2, chloride, total hardness, calcium hardness, PO_4, NH_4.N, and total sulphide. Biological impairment, death and decomposition of this plant under such changed conditions occur in about a few days time. All the aquatic bodies which receive effluents from every industrial unit in the Northern zone of Bangladesh have been carefully searched for *Utricularia* spp. But this plant was not available from such polluted habitats. Side by side unpolluted water bodies around these industrial units had enough of *Utricularia* spp. Many ponds and ditches are used temporarily for retting of 'Jute' in Bangladesh. During this study, intensive observations were made on the impact of jute retting on the hydrophytes of retting ditches. It was found that *Utricularia* spp. are the first to disappear from the habitat in about a month time following the dipping of bundles of jute plants for retting. As retting of jute follows, the water of the retting ditches become dark black and almost all hydrophytes except *Eichhornia* sp. die and decompose in the water giving a foul odour.

The marsh land, lagoons and ditches which receive the detergent mixed waste water from the Students Halls of residences of Rajshahi University are also completely devoid of *Utricularia* spp. Probably the detergents have a deleterious effect on *Utricularia* spp. It is apparently clear from the above discussion that species of *Utricularia* are to be termed as not efficient as they are not capable of withstanding even moderate changes in the physico-chemical factors in the habitat water. As changes in the physico-chemical conditions in habitat water are likely to occur in an extensive scale due to rapid industrialization in the country, the loss of habitat in this way will bring this plant at high risk and calls for the application of conservation techniques, immediate categorization of this plant based on the IUCN global categories and criteria for extinct, critically endangered, endangered, vulnerable, risked and data deficient on this taxon. The population dynamics of species or taxon is an important component in the understanding of species biology indicating the increasing or decreasing trends in their distributions (Cole 1954). The description of species is an important component for the understanding of a taxon. It is necessary to investigate the life history patterns, demographic studies and genetic factors responsible for reducing genetic variation in isolated marginal population. Species which are on the verge of extinction may come under the following categories: population crash, fragmented population, loss of reproductive success, loss of pollinators, habitat loss, over exploitation, commercial extinction, genetic loss or variability, genetic swamping, predation and competition. As a matter of fact, as the present study reveals the species of *Utricularia* appear to be at risk due to the loss of habitat caused by pollution of their natural habitats. The loss of special habitats may lead to eventual reduced population, fragmentation of population and finally the extinction. The habitat loss may be due to urbanization, habitat clearance, agricultural operation, nutrient enrichment, water pollution and pressure from the introduced and other population. However, the main function of the management strategy for conservation is that once a species is listed as vulnerable, threatened or endangered, there should be ways to prevent the loss of the listed species. There should be organized methods to restore the species in its original habitat. Each species requires its own strategy as per its distributional range, its biology and reproductive potential (Ahmedullah and Nayar 1986). The 1996 IUCN global categories and criteria as envisaged are as follows (IUCN 2000): A taxon is extinct when there is no reasonable doubt that the last individual died.

A taxon is "Critically Endangered" when it is facing an extremely high risk of extinction in the wild in the immediate future.

A taxon is "Endangered" when it is not Critically Endangered but it is facing a high risk of extinction in the wild in near future.

A taxon is "Vulnerable" when it is not Critically Endangered or Endangered but it is facing a high risk of extinction in the wild in the medium-term future.

A taxon is "Lower Risk" when it has been evaluated, does not satisfy the criteria for any of the categories-critically Endangered, Endangered or Vulnerable.

A taxon is "Data Deficient" when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and population status. A taxon in this category may be well studied and its biology well known, but appropriate data on abundance and distribution is lacking.

Although data deficient is not regarded as a category of threatened or lower risk, the present study material i.e. *Utricularia* spp. is facing a colossal risk at least locally. The loss of habitat due to pollution, modern agricultural practices, disappearance of wetlands caused by the continuous siltation and alluviation, nutrient enrichment and eutrophication of pond and other water bodies and many other anthropogenic activities, ultimately lead to a condition of risk for this taxon. Botanical Survey of India in its Endemic Plants of Indian Region (Ahmedullah and Nayar 1986) reports six species of endemic *Utricularia* are at high risk due to habitat loss. In Bangladesh this taxon warrants a thorough and detailed investigation regarding its biology, ecology, distribution and population status, abundance, periodicity and seasonal variation, reproductive potential and genetic diversity to make an assessment of its location in the IUCN global categories and criteria.

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COMMON PLANKTON PREY OF *UTRICULARIA* L. IN RAJSHAHI

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Species of the genus *Utricularia* L. are insectivorous plants belonging to the Family Lentibulariaceae which capture and digest insects and other tiny animalcules. They are commonly known as bladderworts. There are 275 species of *Utricularia* distributed world wide (Basak 1975). From this only a small part are truely aquatic, some sparingly rooted and some are floating or immersed in the water (DeWit 1964). The bladders (trap) may be compared to bags which occur on the leaves or stems. The bladders are closed by a movable valve flap. When an aquatic animal (zooplankton and infusoria) touches the "spiny hairs" on the bladder, the flap gives way and the outside water rushes in, dragging along the animalcule. The wave rebounds against the inner wall of the bladder and closes the flap again. The prey cannot escape and dies. In Bangladesh 4 species of aquatic *Utricularia* have been described by Khan and Halim (1987). Basak (1975) and Subramanyam (1981) also described 4 species of aquatic *Utricularia* in their studies. In Bangladesh although the systematics of aquatic *Utricularia* have been worked out by Khan and Halim (1987), no information is available about the type and number of preyed zooplankton of these plants. Therefore, the present study deals with the type and quantification of common zooplankton preyed upon by *Utricularia* in Rajshahi, Bangladesh.

U. aurea (with float), *U. aurea* (without float), *U. stellaris* and *U. exoleta* were used for this study. The growing part of these plants were cultured separately in zooplankton free aquarium for three days, to complete the digestion of previously captured zooplankton. It may be mentioned that a bladder can capture preys only once, and it turns black in about three days following the digestion of captured individuals in it. The used bladder is persistent. After three days enough zooplankton were released in these aquarium. Zooplankton were captured form ponds by a plankton net (mesh size 0.076). After three hours following the release of zooplankton, 50 cm long part of *Utricularia* were collected from the aquarium and immediately preserved in 5% formaldehyde to prevent digestion. Simultaneously similar sized growing part of *Utricularia* was also collected from natural water bodies and preserved in 5% formaldehyde. The study was repeated at three months interval during the period from July 1999 to June 2000. On each occasion 100 bladders of a particular species of *Utricularia* were opened and the type of the zooplankton captured was noted and quantified. One bladder was opened on a slide and covered with cover slip for microscopic examination. A total of 800 bladders were studied for each species but later on an average of zooplankton density per 100 bladders from each of aquarium and natural water bodies were calculated. As the variations of data from natural water bodies and that from the aquarium were negligible, only the data from the natural water bodies were presented. The bladders ranged from 1.2-3.9 mm in diameter. The abundances of zooplankton obtained after breaking the bladder were quantified with a Sedgewick Rafter Counting Chamber (Welch 1948) and identified by consulting Edmondson (1966).

The type and number of preyed zooplankton in 100 bladders of different species of *Utricularia* are given in Table 1. Percentage of the total food ingested by different stage/species of *Utricularia* from different groups of zooplankton are given in Table 2.

Utricularia aurea (with float), captured 328 individuals of 19 genera which consisted 94 (28.6%) Rotifers (*Notholca* sp., *Keratella* sp., *Brachionus* sp., *Philodina* sp., *Trichocerca* sp., *Rotaria* sp. and *Harringia* sp.), 145 (44.2%) Cladocerans (*Daphnia* sp., *Moina* sp., *Bosmina* sp., *Alona* sp., *Ceriodaphnia* sp., *Diaphanosoma* sp. and *Sida* sp.) and 89 (27.1%) Copepods (*Cyclops* sp., *Mesocyclops* sp., *Macrocyclops* sp., *Diaptomus* sp. and Naupilus).

Utricularia aurea (without float) secured 322 individuals of 20 genera which consisted 84 (26.1%) Rotifers (*Notholca* sp., *Keratella* sp., *Brachionus* sp., *Filinia* sp., *Philodina* sp., *Trichocerca* sp., *Rotaria* sp. and *Harringia* sp.), 145 (45.0%) Cladocerans (*Daphnia* sp., *Moina* sp., *Bosmina* sp., *Alona* sp., *Ceriodaphnia* sp., *Diaphanosoma* sp. and *Sida* sp.) and 93 (28.8%) Copepods (*Cyclops* sp., *Mesocyclops* sp., *Macrocyclops* sp., *Diaptomus* sp. and Naupilus).

U. stellaris preyed upon 233 individuals of 14 genera which consisted 44 (18.9%) Rotifers (*Notholca* sp., *Keratella* sp., *Brachionus* sp. and *Trichocerca* sp.), 121 (51.93%) Cladocerans (*Daphnia* sp., *Moina* sp., *Bosmina* sp., *Ceriodaphnia* sp., *Dadaya* sp. and *Macrothrix* sp.) and 68 (29.1%) Copepods (*Cyclops* sp., *Mesocyclops* sp., *Macrocyclops* sp., and Nauplius).

U. exoleta trapped 154 zooplankton individuals of 14 genera in which there were 51 (33.1%) Rotifers (*Notholca* sp., *Keratella* sp., *Brachionus* sp. and *Rotaria* sp.), 54 (38.3%) Cladocerans (*Daphnia* sp., *Moina* sp., *Bosmina* sp., *Alona* sp., *Dadaya* sp. and *Sida* sp.) and 44 (28.6%) Copepods (*Cyclops* sp., *Mesocyclops* sp., *Diaptomus* sp. and Naupilus).

Table 1. Number of captured zooplankton per 100 bladders of different species of *Utricularia* in natural water bodies.

Zooplankton	*U. aurea* (with float)	*U. aurea* (without float)	*U. stellaris*	*U. exoleta*
ROTIFERA				
Notholca (3spp.)	19	24	21	16
Keratella (2spp.)	11	9	4	3
Brachionus (3spp.)	24	21	16	29
Filinia sp.	–	7	–	–
Philodina sp.	9	4	–	–
Trichocerca sp.	6	10	3	–
Rotaria sp.	15	7	–	3
Harringia sp.	10	2	–	–
CLADOCERA				
Daphnia (3spp.)	64	59	52	21
Moina (2spp.)	21	18	12	9
Bosmina (2spp.)	19	22	28	14
Alona sp.	14	9	–	5
Ceriodaphnia sp.	13	15	6	–
Dadaya sp.	–	–	14	8
Diaphanosoma sp.	6	10	–	–
Sida sp.	8	12	–	2
Macrothrix sp.	–	–	9	–
COPEFODA				
Cyclops (2spp.)	28	31	17	21
Mesocyclops	7	16	12	5
Macrocyclops sp.	16	11	8	–
Diaptomus sp.	13	9	–	2
* Nauplius	25	26	31	16
Total	328	322	233	154

*baby copepods, – = not detected/found

Table 2. Percentage (%) of the total food ingested by different stage/species of *Utricularia* from different groups of zooplankton.

Species	Rotifera	Cladocera	Copepoda
U. aurea (with float)	28.6	44.2	27.1
U. aurea (without float)	26.1	45.0	28.8
U. stellaris	18.9	51.93	29.1
U. exoleta	33.1	38.3	28.6
Mean %	26.7	44.9	28.4

A total 22 genera of zooplankton were secured by the species of *Utricularia* L., amongst which 8 genera belonged to Rotifera, 9 to Cladocera and 5 to Copepoda. Highest number of genera (20) was preyed upon by *U. aurea* (without float) and lowest (14) by *U. stellaris* and *U. exoleta. U. aurea* (with float) captured 19 genera. Rotiferan *Filinia* sp. and Cladoceran *Macrothrix* sp. were preyed upon only by *U. aurea* (without float) and *U. stellaris* respectively. *Philodina* sp. and *Harringia* sp. of Rotifera group and Cladoceran *Diaphanosoma* sp. were captured only by *U. aurea* (with float and without float). Whereas Cladoceran *Dadaya* sp. was captured only by *U. stellaris* and *U. exoleta*. During the period of study, the percentage composition of different prey of all the study plants were- Cladocera 44.9%, Copepods 28.4% and Rotifera 26.7%. The present findings indicate that the recorded Cladoceran members are more preferred as prey by *Utricularia* L. and *Daphnia* sp. alone consisted of 19% of the captured prey.

The present study reveals that the species of *Utricularia* L. differ in their preference of prey, although they grow in the same aquatic environment or in captivity in artificial aquarium. Arber (1972) expressed similar views. The infusorians consisted of the protozoans which were not considered here. A number of phytoplankton algae were also obtained from the bladders, most of them were in intact condition.

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