

**EFFECTS OF PHYSICO-CHEMICAL REGIME ON
ECOLOGY OF ROTIFERS IN POND ECOSYSTEM**

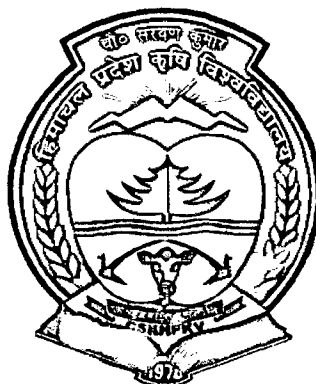
THESIS

By

NUTAN SHARMA

(S-2008-30-16)

Submitted to



**CHAUDHARY SARWAN KUMAR
HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA
PALAMPUR – 176062 (H.P.) INDIA**

IN

Partial fulfilment of the requirements for the degree

OF

**MASTER OF SCIENCE IN BASIC SCIENCES
(DEPARTMENT OF BIOLOGY AND ENVIRONMENTAL SCIENCES)
(ENVIRONMENTAL SCIENCES)**

2010

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**Is there anything I can say,
anything I can give
or do for you.....
Because all that I am
all that I have
I owe to you.....
Affectionately dedicated to my
Guru Ji**



Maharaj Kamal Bir Ji

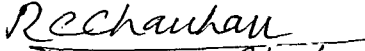
Dr. R.C. Chauhan
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Department of Biology and
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176062 (H.P.) India

CERTIFICATE - I

This is to certify that the thesis entitled, "**Effects of Physico-chemical Regime on Ecology of Rotifers in Pond Ecosystem**", submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science (Basic Sciences)** in the discipline of **Environmental Sciences** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, is a bonafide research work carried out by **Ms Nutan Sharma (Admission No. S-2008-30-16)** daughter of **Shri Ranbir Sharma** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.


(Dr. R.C. Chauhan) 8/7/2010
Major Advisor

Place: Palampur
Dated : 8 July, 2010

CERTIFICATE - II

This is to certify that the thesis entitled, "Effects of Physico-chemical Regime on Ecology of Rotifers in Pond Ecosystem", submitted by Ms Nutan Sharma (Admission No. S-2008-30-16) daughter of Shri Ranbir Sharma to CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfillment of the requirements for the degree of **Master of Science (Basic Sciences)**, in the discipline of **Environmental Sciences** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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Needless to say, all omissions and errors are mine.

Place: Palampur

Dated: 8 July, 2010

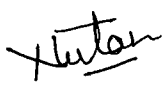

(NUTAN SHARMA)

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LIST OF ABBREVIATIONS

%	-	Per cent
°C	-	Degree centigrade
µg/l	-	Micro gram per litre
µmhos/l	-	Micro mhos per litre
AgNO ₃	-	Silver Nitrate
APHA	-	American Public Health Association
BOD	-	Biological Oxygen Demand
Ca	-	Calcium
cm	-	Centimeter
CO ₂	-	Carbon dioxide
COD	-	Chemical Oxygen Demand
Cu	-	Copper
Dd	-	Depth of disappearance
DO	-	Dissolved Oxygen
Dr	-	Depth of reappearance
<i>et al.</i>	-	Co workers (et alii)
etc.	-	And others (et cetra)
Fe	-	Iron
H ₂ SO ₄	-	Sulphuric acid
HCl	-	Hydrochloric acid
<i>i.e.</i>	-	That is (id est)
mg	-	Milligram
mg/l	-	Milligram per litre
ml	-	Millilitre
Na	-	Sodium
NaOH	-	Sodium hydroxide
Org. /l	-	Organisms per litre
p<0.01	-	Statically significant at 1% level
p<0.05	-	Statically significant at 5% level
pH	-	Negative logarithm of hydrogen (potentia hydrogenii)
<i>viz.</i>	-	Namely (videlicet)
Zn	-	Zinc

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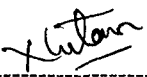
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**Department of Biology and Environmental Sciences
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Title of the thesis : Effects of Physico-chemical Regime on Ecology of Rotifers in Pond Ecosystem
Name of the student : Nutan Sharma
Admission number : S-2008-30-16
Major discipline : Environmental Sciences
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ABSTRACT

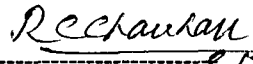
Zooplankton community analyses can reveal valuable information about the trophic status of pond. Among zooplanktons the rotifers have a potential to indicate productive and trophic conditions of aquatic ecosystem. They respond quickly to environmental changes and their presence and composition is determined by physico chemical regime. Since most species are widely distributed in diverse environments, those with greatest value are ones limited to extremes of trophic types (*i.e.* oligotrophy, mesotrophy and eutrophy). The present study deals with the presence and abundance of rotifers in a pond ecosystem. The monthly variations and relationship between rotifer species and certain physico-chemical parameters of the water were studied and discussed. A total of 5 species; *Brachionus havanaensis*, *Keratella cochlearis*, *Keratella volga*, *Mytilina mucronata* and *Monostylla bulla* were found present in the pond ecosystem during study period *i.e.* from June 2009 to May 2010. The population density of rotifers was maximum (185rotifers/l) in the month of June during the rainy season and minimum (102rotifers/l) in the month of January. The higher concentration of free carbon dioxide (20.0mg/l), chloride (31.0mg/l), nitrate-nitrogen (562.0µg/l), total phosphate phosphorous (1570.0µg/l) and the presence and dominance of *Keratella* species (76org. /l) and co-dominance of *Brachionus havanaensis* (30org. /l) indicated eutrophication in the pond ecosystem. Rotifers showed highly significant and positive correlation with water temperature ($r=0.86$, $p<0.01$), chloride ($r=0.85$, $p<0.01$), nitrate nitrogen ($r=0.70$, $p<0.01$) and significant positive with total phosphate phosphorous ($r=0.68$, $p<0.05$) and highly significant and negative correlation ($r=-0.80$, $p<0.01$) with secchi transparency and some other correlations were also found. Thus, various correlations between rotifers and physico-chemical characteristics indicated that the physico-chemical regime of pond ecosystem determines the ecology of rotifers by influencing their presence, abundance and distribution.



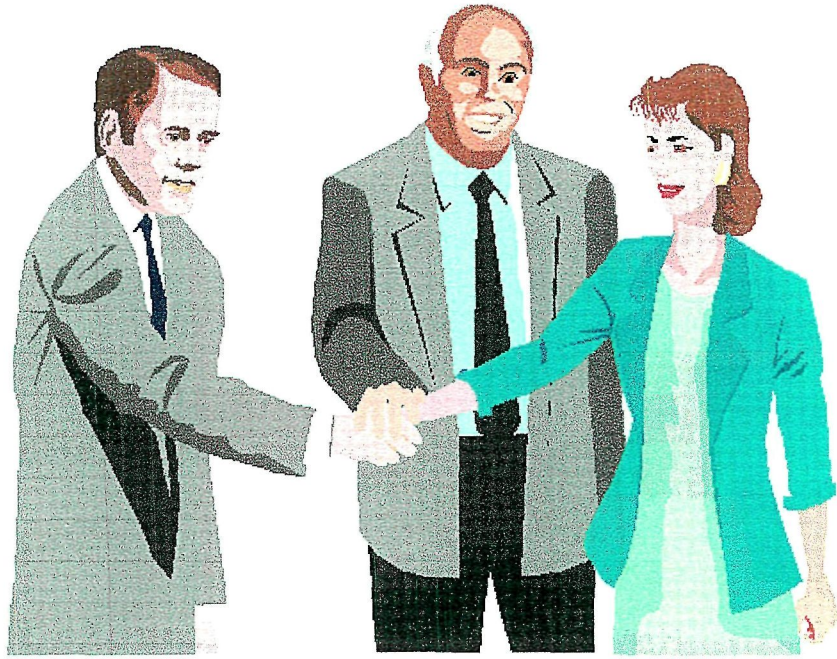
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Major Advisor
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INTRODUCTION

1. INTRODUCTION

Ecosystem is the complex of living organisms, their physical environment and all their inter-relationships in a particular unit of space. Different types of ecosystems exist such as natural and artificial ecosystem, terrestrial and aquatic ecosystem. Aquatic ecosystems are characterised by small temporary puddles to large ocean. It is the most diverse and productive ecosystem in the world (Encyclopaedia Britannica 2010). The first life originated in the water, where water was the principal external as well as internal medium for the organisms. An aquatic ecosystem includes rivers, streams, ponds, lakes, oceans, bays, swamps and marshes. A pond is a good example of self sufficient and self regulating ecosystem. The biology of pond ecosystem is determined by its location, size, depth and substratum.

Physico-chemical regime includes physical and chemical characteristics. It is closely related to hydrobiology, which is concerned with the application of principles and methods of physics, chemistry, geography, geology and biology to ecological problems. The physico-chemical regime determines the presence and abundance of biota. Plankton is a collective name for all such organisms which are nonmotile, too small or too weak to swim against the current. They exist in drifting and floating state and are composed of certain algae, bacteria, protozoan, crustaceans, coelenterates *etc.* Planktons are mainly of two types phytoplankton and zooplankton. The microscopic plants in an aquatic environment are known as phytoplankton and the microscopic animals are called zooplanktons. Zooplanktons are mainly composed of three groups *i.e.* cladocerans, copepods and rotifers. These are consumer in aquatic food chain and feed chiefly on phytoplanktons. Whereas, rotifers are microscopic invertebrates that constitute the class Rotifera or Rotaria (phylum-Aschelminthes). These are also called animalcule because of the circular arrangement of moving cilia at the front and resembles a rotating wheel and are common in fresh water (Sladeczek 1983).

Rotifers constitute an important part of the freshwater zooplankton, forming the second step of the food chain and are important food sources for some invertebrate animals and fishes. These are one of the basic groups of the zooplankton community providing the energy flux to freshwater ecosystems and they inhabit virtually in all aquatic habitats. Rotifers can be found in many freshwater environments and majority of which are free living. They are often found between the high and low water marks of pond, lakes and other freshwater bodies around the world (Nogrady *et al.* 1993).

Rotifers are microscopic aquatic animals characteristically prevalent in freshwater. A few rotifers are cosmopolitan while majority of these animals are highly adapted to a wide range of freshwater conditions (Fafioye and Omoyinmi 2006). Rotifers are used as a food by many fish and its larvae. They are highly nutritive to planktivorous fish; its protein supports fast growth of fish larvae and juveniles and as such a booster to fish farmers (Kitto and Bechara 2004).

Presently, the natural environment suffers from the detrimental effects of pollution due to technological advancement. The natural process of transportation of metal ions between soil and water consolidates metal contamination, in high concentrations, that affect the areas of natural aquatic ecosystems. The discharge of industrial effluents has lead inevitably, to alterations in the quality and ecology of water bodies. This brings new challenges to both water resource managers and aquatic ecologists. Several attempts have been made to regulate and control the quality of effluents that are discharged from waste generating industries into our water systems. The geometrical increase in human population has mounted a tremendous pressure on the environment including aquatic ecosystem, which is the most serious problem of our age. Recently this problem has increased too much and posing a serious threat to the survival of human beings.

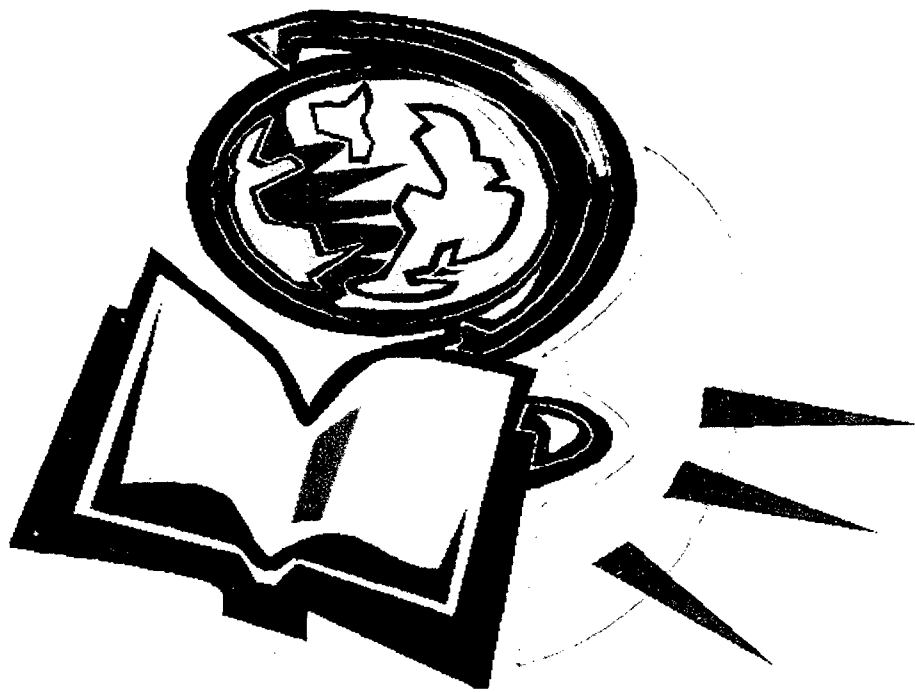
The structural functioning of an aquatic environment is being disturbed by an addition of industrial and sewage effluents including many other toxic substances due to anthropogenic activities. Such anthropogenic activities affect

many organisms, which are the components of food chain and sensitive to environmental changes. A degree of water pollution is determined by physico-chemical characteristics followed by the presence and abundance of aquatic organisms. Some of the most important of these aquatic organisms are rotifers. These play very significant role in the food chain and biological productivity of aquatic ecosystem and can be treated as an index of water pollution and eutrophic status (Marneffe *et al.* 1998). Some of rotatorians species may be used to access the trophic status of aquatic ecosystem and the physico-chemical regime determines their species composition.

Rotifers are excellent indicators of environmental conditions and aquatic health within ponds because they are very sensitive to the changes in water quality. They respond to dissolved oxygen, pH, free carbon dioxide levels *etc.* A good picture of the current conditions of water quality in the ponds can be derived by looking at plankton indicators, such as their biomass, abundance, and species diversity (Burford *et al.* 2003).

It is desirable that pond and other waters should support phytoplankton and zooplankton. The planktonic population in an aquatic ecosystem plays a very significant role in maintaining good water quality as well as providing a quality food source for the other consumers and is therefore important to elucidate the trends of their species dominance and the probable physico-chemical factors controlling the community structure. Thus, in the present investigation an attempt has been made to study "Effects of Physico-chemical Regime on Ecology of Rotifers in Pond Ecosystem" with a following objective:-

To study the effect of physico-chemical characteristics on the presence and abundance of rotatorians in fresh water pond ecosystem.



REVIEW OF
LITERATURE

2. REVIEW OF LITERATURE

The presence and abundance of rotifers play a very significant and important role in structural functioning of pond ecosystem. Since the rotifers have short reproductive stages they increase in abundance rapidly under favorable environmental conditions. They play an important role in balancing the pond ecosystems. The physico chemical regime determines the species composition of biota and some of the rotatorians species may be used to access the trophic status of aquatic ecosystem.

Viewing the importance of rotifers, efforts are being made to evaluate effect of physico-chemical regime on the presence and abundance of rotatorians in fresh water pond ecosystem. However, limited information appears to be available on evaluation of effect of physico-chemical regime on the presence and abundance of rotatorians in fresh water pond ecosystem. The limnological research work related to the present study is reviewed briefly under the following sub headings:

2.1 Physico-chemical parameters of water

2.2 Planktonic population

2.3 Zooplanktons

2.4 Rotifers

2.1 Physico-chemical parameters of water

Lewis and Peters (1955) studied physico-chemical characteristics of ponds in southern Illinois and observed under both winter and summer conditions. In addition to a general discussion of the areas, a detailed report was made on dissolved oxygen as associated with thermal stratification, pH and specific conductance.

Kara *et al.* (2004) took water samples from Lake Isykli in Denizli region, Turkey, during the four seasons and which were analyzed them for chemical and physical properties. The results were within the acceptable limits of pollution according to Turkish Standards except organic matter, phosphate, ammonia nitrogen and nitrite.

Fafioye *et al.* (2005) studied the physico-chemical parameters of Omi water body such as dissolved oxygen which ranged from 1.4 to 4.8 mg/l; pH 6.7 to 7.2; temperature 26.5 to 31.5°C; alkalinity 24.2 to 25.4 ppm; conductivity 23.0 to 28.3 Ohms/cm; turbidity 0.11 to 0.15 m; and free carbon dioxide from 3.5 to 4.5 mg/l. Dissolved oxygen, pH and water temperature served as variables since the fluctuation of one affects the values of others.

Ribeiro *et al.* (2005) examined superficial water source utilized in a trickle irrigation system by analyzing the principal physical, chemical and biological parameters of the irrigation water (pH, turbidity, suspended solids, dissolved solids etc) in emitters. A correlation was found between turbidity and suspended solids, and between algae and total suspended solids.

Daniela *et al.* (2006) assessed the quality of three different aquatic ecosystems. Physical, chemical and microbiological parameters of water, as well as the aquatic invertebrates were studied. A comparative analysis of the characteristics of lake showed a better quality of the natural water ecosystem than the changed and created ecosystems.

Alam *et al.* (2007) collected water samples from a part of Surma River along different points and analyzed for various water quality parameters during dry and monsoon periods. Effects of industrial wastes, municipal sewage and agricultural runoff on river water quality were investigated. This study involved determination of physical, biological and chemical parameters of surface water at different points. The river was found to be highly turbid in the monsoon season. A model study was also conducted and values of different model parameters were estimated.

Borda *et al.* (2007) evaluated the seasonal variation of the abiotic and biotic factors; three different aquatic ecosystems were investigated: a natural ecosystem, a transformed ecosystem and an artificial ecosystem. The physical, chemical and bacteriological parameters of water, as well as the aquatic invertebrates from surface and benthic zone were determined. A comparative analyze of the seasonal dynamics in the three lakes showed that the artificial ecosystem was the least stable of all. The biodiversity of aquatic ecosystem was highest in the natural ecosystem, followed by the transformed and artificial ecosystems.

Lima *et al.* (2008) evaluated water quality in an integrated cultivation system of agriculture and fish culture, the physical, chemical and biological parameters of the water in irrigation channels were also observed. The results of the analysis ranged from 29.0 to 30.9 °C for water temperature; from 41.0 to 78.0 cm for transparency; from 19.5 to 28.7 mg/liter for total alkalinity; pH 6.6 to 7.9; hardness 26.0 to 66 mg/liter; dissolved oxygen 4.3 to 6.9 mg/liter; electrical conductivity 0.059 to 0.150 m S/cm; carbonic gas 3.4 to 5.3 mg/liter; nitrite 1.93 to 3.36 mg/liter; orthophosphate 0.00 to 0.07 mg/liter and chlorophyll a 0.00 to 3.36 micro g/liter. Results indicated that raising tilapia in the channels, for the tested densities, did not adversely alter the quality of the water for irrigation.

2.2 Planktonic population

Chowdhury *et al.* (2007) studied seasonal variation of the plankton populations with some water quality parameters of Borobila beel, Rangpur district. A total of 51 genera of planktons were recorded belonging to chlorophyceae, bacillariophyceae, cyanophyceae, euglenophyceae, dinophyceae, crustacea and rotifera. Among the phytoplankton, euglenophyceae was the most dominant group and contributing 33% of total phytoplankton in Borobila beel. The greatest abundance of phytoplankton was recorded in November with an average number 28.83×10^5 cells/l. The minimum abundance of phytoplankton was recorded in January (61.7×10^4 cells/l). Among the zooplanktons crustacea was dominant, contributing 71% of the total zooplankton population. The

abundance of zooplankton showed two peaks of which one in the month of August (81.7×10^4 cells/l) and another in the month of May (16.7×10^4 cells/l). Phytoplankton and zooplankton have a nominal positive relationship. Zooplankton was less increased with the increasing of phytoplankton.

Singh and Singh (2008) studied the inter-relationship of certain parameters and planktonic community of Motipur ox-bow Lake (Muzaffarpur, Bihar). A positive correlation between temperature and planktonic population was not established and showed inverse relationship. In studies no relationship established between pH, zooplankton and phytoplankton. Similarly no distinct relationship was found between total alkalinity and phytoplankton. Phosphate and chloride did not show any distinct relationship with plankton production. Low concentration of dissolved oxygen was found to be related with high plankton production. It may be concluded that the plankton community depends greatly on different physico-chemical parameters. No single factor was responsible for the fluctuation in the abundance of plankton and different ecological parameters jointly might be influencing the plankton production.

2.3 Zooplanktons

Tiwari *et al.* (1991) monitored physico-chemical and biological parameters of the river Alaknanda. Water quality was assessed by comparison with existing standards of important parameters. Dissolved oxygen showed positive relationships with temperature. Turbidity, total alkalinity, hardness, free carbon dioxide, chloride concentration, total dissolved solids, zooplanktons and phytoplanktons showed significance variations during monsoon and winter seasons.

Cardoso *et al.* (2004) studied the structure of the zooplankton community in Itapeva Lake and reported that it was constituted of four groups and more than 127 zooplankton species, in which micro plankton was the predominant size structure. The seasonal distribution revealed that during summer, mean density increased in the zooplankton community, exactly the opposite of phytoplankton (that blooms during the cold season). However, the maximum density was

recorded during autumn. Rotifers were generally the second most representative groups in terms of density. Rotifers and Cladocera were more abundant in summer, whereas copepods were in spring and winter. The Shannon-Wiener index showed that the smallest zooplankton diversity average occurred during the winter, while in autumn the largest zooplankton diversity average was observed. Correlations (r-Pearson, $p < 0.05$) with wind velocity were significant for zooplankton density (groups and/or abundant species), diversity, and richness. The analysis of variance showed a seasonally significant spatial-temporal variation for the factors sampling point, day and shift ($p < 0.01$).

Kiran *et al.* (2007) collected zooplanktonic samples from fish culture pond of Bhadra fish farm, Karnataka, India, at monthly intervals. Quantitative enumeration was done using Sedge wick Rafter plankton counting cell and the results were expressed as organisms per liter. The population of zooplankton consisted of rotifers, copepods, cladocerans, ostracods and protozoans. The total numbers recorded were 1018 per litre of which 259 (25.44%), 234 (22.99%), 254 (24.95%), 175 (17.19%) and 96 (9.43%) were rotifers, cladocerans, copepods, ostracods and protozoans, respectively. All the dominant groups of zooplankton were present throughout the year. Diversity analysis showed that rotifers had seven species, cladocerans had four, copepods had two, ostracods had two and protozoans had two species.

Singh M (2008) studied qualitatively phytoplankton and zooplankton in the upper lake of Bhopal and reported that phytoplanktons composed of 9 species of Chlorophyceae, 5 species of Bacillariophyceae, 6 species of Cyanophyceae, Euglenophyceae, Charophyceae and Zooplankton composed of 3 species of protozoas, 5 species of Rotifers, 8 species of Crustaceae and Meroplankton organisms mainly consisting of insects. Zooplanktons as indications of eutrophication as observed were Daphnia, Amoeba, Euglena, Mesocyclops and Dapharosoma.

Mulani *et al.* (2009) investigated zooplanktons with respect to water quality of Panchganga river, in Kolhapur city, Maharashtra. This investigation was undertaken for a period of one year. The high value of CO₂, BOD, COD,

phosphate, nitrate, Zn, Fe, Cu and low value of DO at discharge zone indicates increase in organic pollution as go down the river. The discharge zone is dominated by pollution tolerant zooplankton species such as *Brachionus*, *Keratella*, *Filinia*, *Anuraeopsis* etc.

2.4 Rotifers

Hettiarachchi *et al.* (1995) studied on freshwater rotifer *Brachionus calyciflorus*, which was cultured using a freshwater *Chlorella* sp. as feed. Morphometric characteristics of adults and eggs and the effects of pH on population density, growth and the rate of appearance of mictic females were examined. The results indicated that rotifer population was composed of 3 size groups, each producing a particular type egg. Maximum rotifer density was observed at pH 7.0 (163 individuals/ml), followed by pH 6.0 (115 individuals/ml) and the lowest at in the control, pH 5.2-8.6 (51 individuals/ml). Though, density and growth rates were not significantly affected by pH, the appearance of mictic females at different pH levels varied ($p < 0.05$). Significantly the lowest mictic female appearance was at pH 7.0, indicating parthenogenesis at its highest. A change in pH resulted in a shift towards sexual reproduction in these rotifers.

Gonzalez (1998) studied the effect of *Chaoborus* spp. on the vertical distribution of 3 rotifer species *Kellicottia longispina*, *Keratella cochlearis* and *Polyarthra* sp. and on the spatial overlap of these rotifer species with 3 *Daphnia* species (*D. pulicaria*, *D. rosea* and *D. retrocurva*) were examined. In the presence of *Chaoborus*, rotifer abundance increased, while cladoceran abundance decreased. Patterns of migratory behavior varied among rotifer species. Rotifer populations could be released from competition due to *chaoborus* predation on *daphnia*. *Chaoborus* presence, however, could intensify rotifer-*daphnia* competitive interactions by increasing their spatial overlap.

Akinbuwa and Adeniyi (2008) studied seasonal variations, spatial distribution and interrelationships of rotifers in Opa Reservoir, Nigeria and the relationship between rotifer species and certain physico-chemical parameters of the water were described. The population density of rotifers was maximum during

the rainy season. Rotifer communities in the riverine source station were different from the open lake communities and rotifer population density was poorest in the riverine section. Significant correlations were found between rotifers and several physico-chemical parameters of which oxygen was the most pronounced. Considerable affinity and close associations were also found between rotifer species.

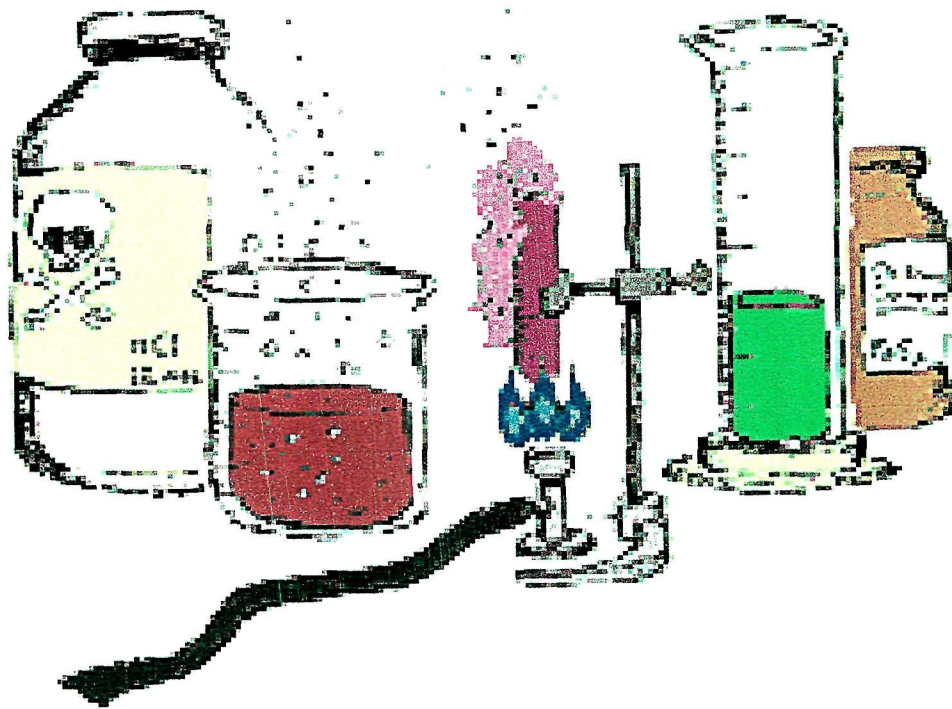
Shayestehfar *et al.* (2008) analyzed water samples from 3 stations of Kor River, Iran were analyzed for seasonal fluctuation of physico-chemical parameters, i.e. air and water temperature, dissolved oxygen, BOD, COD, total nitrogen, total hardness, pH, alkalinity, acidity, total dissolved solid and water current. Effect of physico-chemical parameters on surface water density of rotifers was also studied. During one year study 13 species of rotifers belonging to 2 classes and 3 orders, 6 families and 10 genera were recognized. Maximum population density belongs to *Lecane luna* and the minimum population density was observed in *Keratella volga* and *Monostyla lunaris*. An inverse relationship between the population density of rotifera and the water current as well as a direct relationship between the water temperature and the population density of rotifers was observed in all sampling stations and throughout the study period.

Dirican *et al.* (2009) estimated some physico chemical characteristics and rotifers of Camligoze Dam Lake located northeastern part of Turkey. Water and rotifer samples were taken from 2 stations in Camligoze Dam Lake. A total of 11 rotifer species were found in Camligoze Dam lake. In the water samples, 5 physico-chemical parameters, water temperature, electrical conductivity, pH, secchi disc depth and dissolved oxygen were analyzed.

Ikbel *et al.* (2009) studied the spatial and temporal dynamics of rotifers in relation to the physico-chemical parameters in fish-culture. Thirteen rotifer species were found. The most dominant rotifer was *B. urceolaris* (76% of total abundance). Rotifer's density and water temperature were negatively correlated ($r=-0.94$, $n=12$, $p=0.01$). The abundance (1.5×10^5 ind m^{-3}) of rotifers was found in June month.

Sharma (2009) studied the rotifer communities of Loktak lake (Ramsar site), Manipur, N.E. India. They found 120 species belonging to 36 genera and 19 families and the richest biodiversity of phylum rotifera. The rotifer communities have 52.3-80.6% temporal similarity, and show lack of seasonal periodicity of occurrence of different families. The Rotifera form an important quantitative component of zooplankton ($45.8 \pm 8.1\%$), and had higher species diversity, lower dominance and higher evenness. Richness and density were inversely correlated with water, temperature, rainfall, hardness, nitrate, chloride and total dissolved solids and positively correlated with dissolved oxygen. In addition, richness was inversely correlated with pH.

David *et al.* (2010) studied the usefulness of rotifers emergence from dry soils to indicate the environmental status of a remnant temporary pond complex in an agricultural area in central Spain. Results suggested that rotifer emergence from rewetted sediments using microcosms can be useful for evaluating the nutrient status during the dry phase of temporary wetlands. While results from this approach are conservative, requiring comparisons with field observations, their tentative value lies in alerting management and providing a basis for future research of poorly studied but threatened temporary habitats. Rotifer emergence could be a useful alternative to traditional biological indicators of nutrient status that depend on the presence of water.



MATERIALS AND METHODS

3. MATERIALS AND METHODS

The selection and application of scientific methodology is a pre-requisite for conducting any investigation as it adds to precision, reliability and validity relating to the research problem. Therefore, this chapter is devoted to explain the methodology used in the present study. This includes the selection of the study pond and analytical methods.

3.1 Material

The production pond of a farmer at village-Bodhal, near Rajpur, Tehsil-Palampur, District-Kangra (Plate-3.1) was selected for this limnological study at monthly interval over a period of one year from June 2009 to May 2010.

3.2 Estimation of Physico-chemical characteristics

For the estimation of physico-chemical characteristics, water samples were collected from the production pond at an interval of a month from June 2009 to May 2010. Parameters like air and water temperature, transparency, dissolved oxygen, free carbon dioxide, alkalinity and chloride content were analyzed on the spot and the rest of the parameters were analyzed in laboratory within 48 hours of the sampling. The methods followed are described as under-

3.2.1 Temperature and Transparency

Temperature was recorded by using a centigrade mercury thermometer and water transparency was measured by using a secchi disc. The secchi disc is a metallic plate of 20 cm diameter with four alternate black and white quadrants on the upper surface and hook in the center to tie a rope. The values for Secchi disc transparency were calculated as follows:

$$\text{Transparency (cm)} = \frac{Dd - Dr}{2}$$

Where, Dd = depth of disappearance

Dr = depth of reappearance



Plate-3.1 The study pond

3.2.2 pH and Conductivity

pH and conductivity were recorded with portable pH meter and conductivity bridge respectively (APHA 2000). The conductivity was calculated as under-

$$\text{Conductivity } (\mu\text{mhos/cm}) = \frac{(1000000) (C)}{R [1+0.0191(t-25)]}$$

Where:

- C = cell constant
- R = measured resistance of sample
- t = temperature of measurement

3.2.3 Dissolved oxygen

It was estimated by Winkler modified method (APHA 2000). The values were calculated as follows-

$$\text{Dissolved oxygen (mg/l)} = \frac{(8 \times N \times 1000) \times v}{V}$$

Where:

- N = Normality of sodium thiosulphate solution i.e. 0.025
- V = Volume of sample titrated
- v = Volume of titrant used

3.2.4 Free carbon dioxide

It was estimated by following (APHA 2000) by using phenolphthalein as indicator. The values were calculated as follows-

$$\text{Free carbon dioxide (mg/l)} = \frac{A \times N \times 44000}{\text{ml sample}}$$

Where:

$$\begin{aligned} A &= \text{ml titrant} \\ N &= \text{normality of NaOH} \end{aligned}$$

3.2.5 Total Alkalinity

The carbonate and bicarbonate alkalinity was estimated following (APHA 2000) by using phenolphthalein and methyl orange as indicators respectively. The values for both were calculated as under-

$$\text{Alkalinity (mg/l)} = A \times 100$$

Where:

$$A = \text{ml of H}_2\text{SO}_4 \text{ used}$$

3.2.6 Chloride

It was estimated by argentometric method of (APHA 2000) by using potassium chromate as an indicator. The values were calculated as follows-

$$\text{Chloride (mg/l)} = \frac{(A-B) \times N \times 35450}{\text{ml sample}}$$

Where:

$$\begin{aligned} A &= \text{ml titration for sample} \\ B &= \text{ml titration for blank} \\ N &= \text{normality of (AgNO}_3\text{) Silver Nitrate} \end{aligned}$$

3.2.7 Nitrate-Nitrogen

It was estimated by spectrophotometric screening method of (APHA 2000). The amount was calculated from standard curve prepared for it.

3.2.8 Total Phosphate-Phosphorous

The stannous chloride method of (APHA 2000) was used to estimate total phosphate phosphorous. The values were calculated from the calibration curve prepared for it.

3.2.9 Sodium and Potassium

Sodium and potassium were estimated by flame photometric method followed by (APHA 2000).

3.3 Qualitative and Quantitative enumeration of rotifers

For qualitative and quantitative enumeration of rotifers, samples were collected with the help of water sampler of one litre capacity at an interval of month over the period of one year. 500 ml of water samples were filtered through nylobolt silk cloth plankton net of small mesh size (100mesh/mm²) for the enumeration. The filtered samples were fixed with 4% neutralized formaline, lugol's solution and a few drops of glycerine. Samples were allowed to settle over night. After siphoning off the supernatant without disturbing the sediments, the volume was made to 5ml. After uniform stirring, 1ml of final volume was counted in zooplankton counting chamber under planktonic microscope. The numbers of rotifers per litre were calculated following (APHA 2000) as under:-

$$\text{Rotifers per litre} = \frac{C \times V_1}{V_2 \times V_3}$$

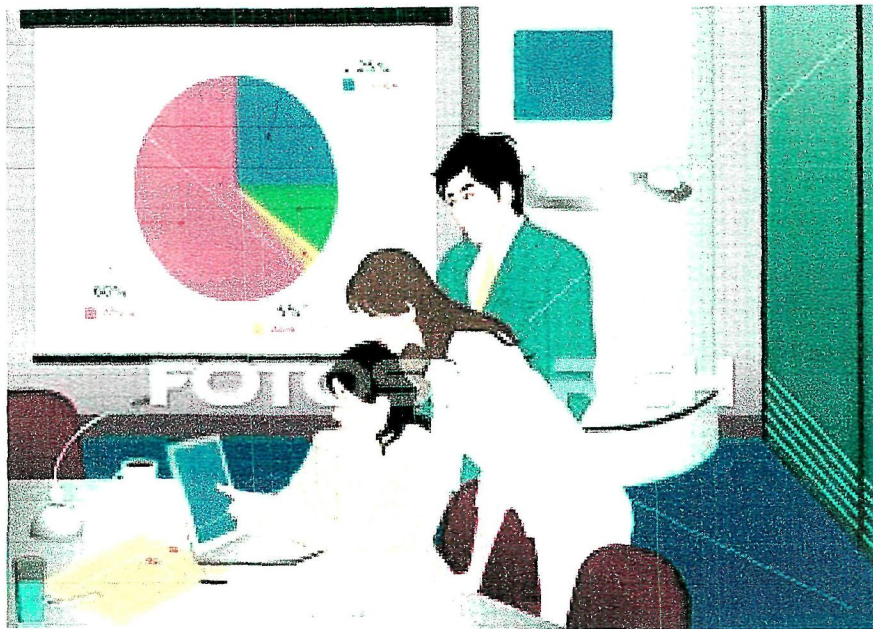
Where,

C = Number of rotifers counted

V₁ = Volume of concentrated sample

V₂ = Volume of counted strips

V₃ = Volume of samples filtered



RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The results of the present investigation entitled “**Effects of Physico-Chemical Regime on Ecology of Rotifers in Pond Ecosystem**” have been presented and discussed in this chapter under ensuing headings:-

4.1 Physico-chemical characteristics

The seasonal variation in qualitative and quantitative presence and abundance of zooplankton in general and rotifers in particular differ from environment to environment depending upon the physico-chemical regime of aquatic ecosystem. The fresh water ecosystem, which differ in climatic context will obviously differ in physico-chemical regime and thus, in their biological composition (Mahboob and Sheri 2001).

4.1.1 Temperature and Transparency

Temperature regulates the speed and intensity of chemical reactions in an aquatic ecosystem. No other single factor has so many profound influences on the aquatic environments as temperature (Welch 1952). During the present investigation the air temperature was recorded maximum (35.0°C) in the month of June during rainy season and minimum (12.0°C) during winter season in the month of January. Whereas water temperature ranged from 12.0°C in December and January to 27.0°C in the month of June. The air temperature showed highly significant and positive relationships with water temperature ($r=0.96$, $p<0.01$), conductivity ($r=0.81$, $p<0.01$), free carbon dioxide ($r=0.78$, $p<0.01$) and significant positive with chloride ($r=0.56$, $p<0.05$) and highly significant and negative with secchi transparency ($r=-0.73$, $p<0.01$) and significant negative with sodium ($r=-0.69$, $p<0.05$). Almost the similar pattern of relationships has been recorded for water temperature (Appendix-3). The above associations indicate that the water temperature is regulated by an atmospheric temperature. The significant relationship of air and water temperature with secchi transparency may be ascribed to the planktonic population and total suspended particles, as at higher temperature there is more formation of plankton which reduces light intensity.

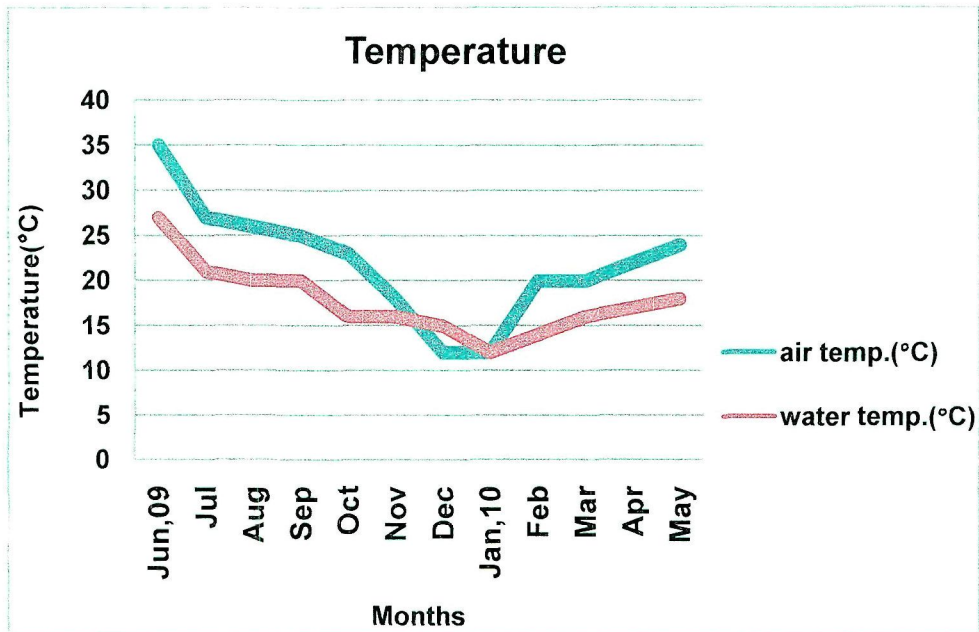


Fig.- 4.1 Monthly variation in air and water temperature from June 2009 to May 2010.

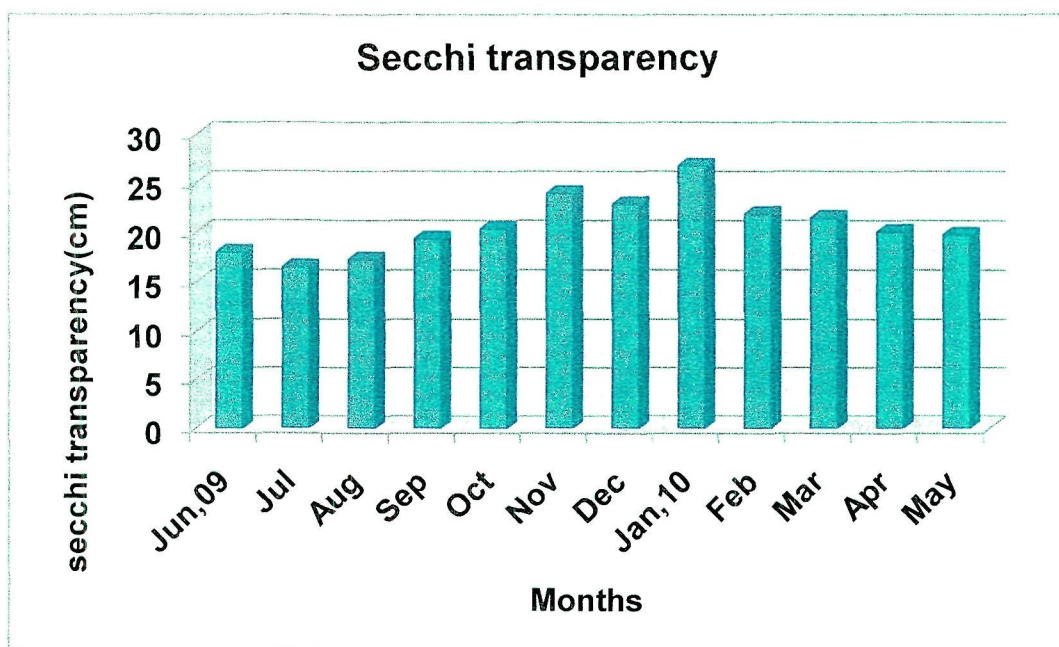


Fig.- 4.2 Monthly variation in secchi transparency from June 2009 to May 2010.

Similar findings have been reported by Chauhan (1995) while working on the fresh water ecosystem of Rewalsar lake, Himachal Pradesh. Whereas a very less difference between atmospheric and water temperature during winter season in the month of December and January may be attributed to the increased humidity which decreases the heat loss through evaporation.

The light transparency regulates the primary productivity in aquatic environments. It is a scale of turbidity. The secchi transparency ranged from 16.5 to 26.8 cm during the course of investigation. The secchi transparency was maximum (26.8cm) in January during winter season and minimum (16.5cm) in the month of July (Fig.-4.2). The low secchi transparency during rainy season may be ascribed to the more allochthonous materials such as clay, silt, inorganic and organic particles from the catchment area consisting of agricultural land and human settlements. While the higher values of secchi transparency in the month of January during winter season may be due to the low amount of allochthonous material from catchment and low planktonic population at low temperature. This finding has also been supported by the highly significant and negative ($r=-0.73$, $p<0.01$) relationship of secchi disc transparency with air and water temperature (Appendix- 3).

4.1.2 pH and Conductivity

The pH values varied from 6.8 to 8.25 during the study period. It was recorded maximum in the month of June (8.25) and minimum in July (6.8) (Fig.- 4.3). Higher values of pH in the month of June during summer season may be due to the use of free carbon dioxide to form HCO_3^- and release of H^+ ions in photosynthetic activities. An increase in pH values has also been reported by Adamo (1968) during summer season.

The value of conductivity was found highest during summer and lowest during winter season. It was maximum (185.0 $\mu\text{mhos/cm}$) in the month of May and minimum (110.0 $\mu\text{mhos/cm}$) in the month of December (Fig.- 4.4). It showed highly significant and positive correlation with air ($r=0.81$, $p<0.01$) and with water temperature ($r=0.79$, $p<0.01$). It also revealed highly significant and negative

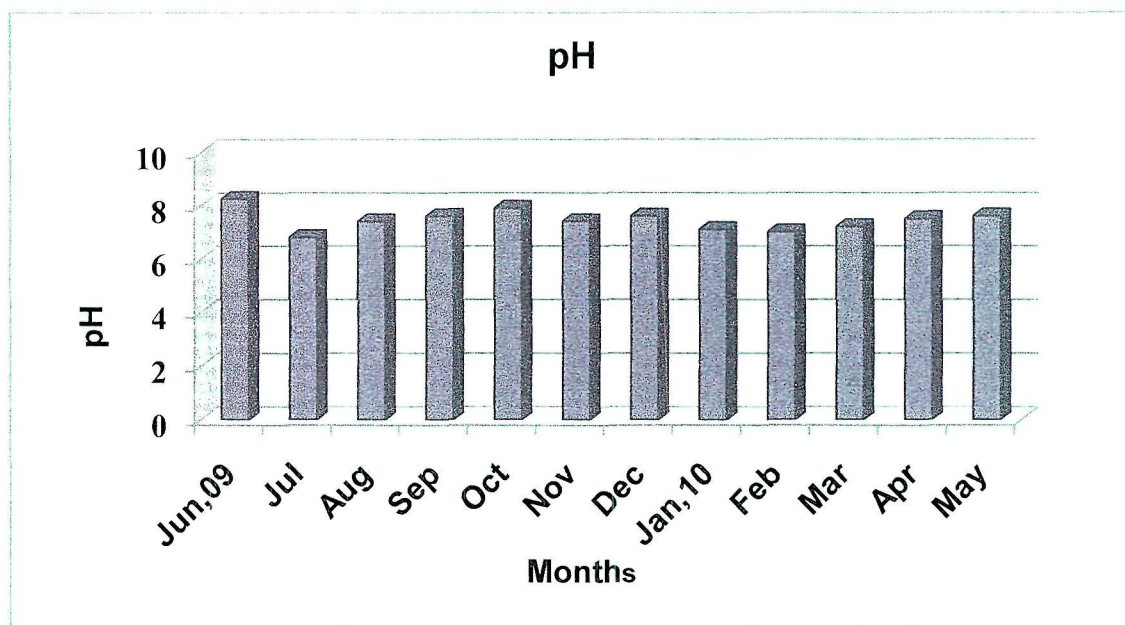


Fig.- 4.3 Monthly variation in pH from June 2009 to May 2010.

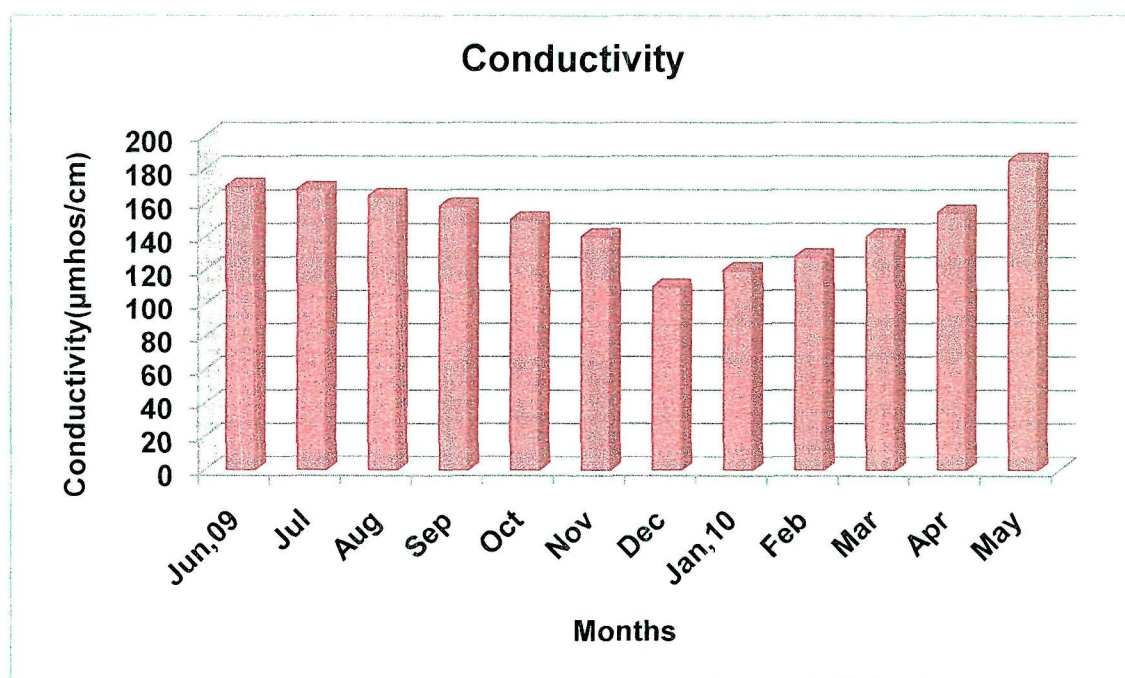


Fig.- 4.4 Monthly variation in conductivity from June 2009 to May 2010.

relationship ($r=-0.71$, $p<0.01$) with secchi disc transparency (Appendix-3). The higher conductivity values in May during summer may be attributed to the more leaching of ions particularly Na^+ and Ca^{++} ions from the catchment soils or bottom sediments, whereas minimum values in December during winter season may be ascribed to the adsorption of ions into the surfaces of suspended particles. High and low conductivity values due to these factors were also obtained by Hall *et al.* (1970).

4.1.3 Dissolved oxygen

Dissolved oxygen (DO) values did not show significant variations throughout the study period. Its concentration was recorded higher in winter season as compared to summer and rainy season. The dissolved oxygen concentration was found maximum (5.9 mg/l) in January and minimum (3.8 mg/l) in August during rainy season (Fig.-4.5). It was significantly and positively related ($r=0.58$, $p<0.05$) to the secchi disc transparency (Appendix-3). The highest concentration of dissolved oxygen during winter season was due to high secchi-transparency and low chemical oxygen demand at low temperature. The lowest concentration of dissolved oxygen during rainy season and low in summer may be due to the low rate of diffusion and increased temperature and higher biochemical oxygen demand at high rate of decomposition. Similar findings have been reported by Welch (1952) and Adkins (1970).

4.1.4 Free carbon dioxide

Free carbon dioxide was found present throughout the study period. It was minimum (9.8mg/l) in December during winter season and maximum (20.0mg/l) during rainy season in the month of August (Fig.- 4.6). Similar results were obtained by Rao and Govind (1964). Free carbon dioxide showed significant and negative relation with dissolved oxygen ($r=-0.63$, $p<0.05$) and highly significant and negative with secchi transparency ($r=-0.73$, $p<0.01$) and sodium ($r=-0.87$, $p<0.01$) (Appendix-3). The high concentration of free carbon dioxide in August

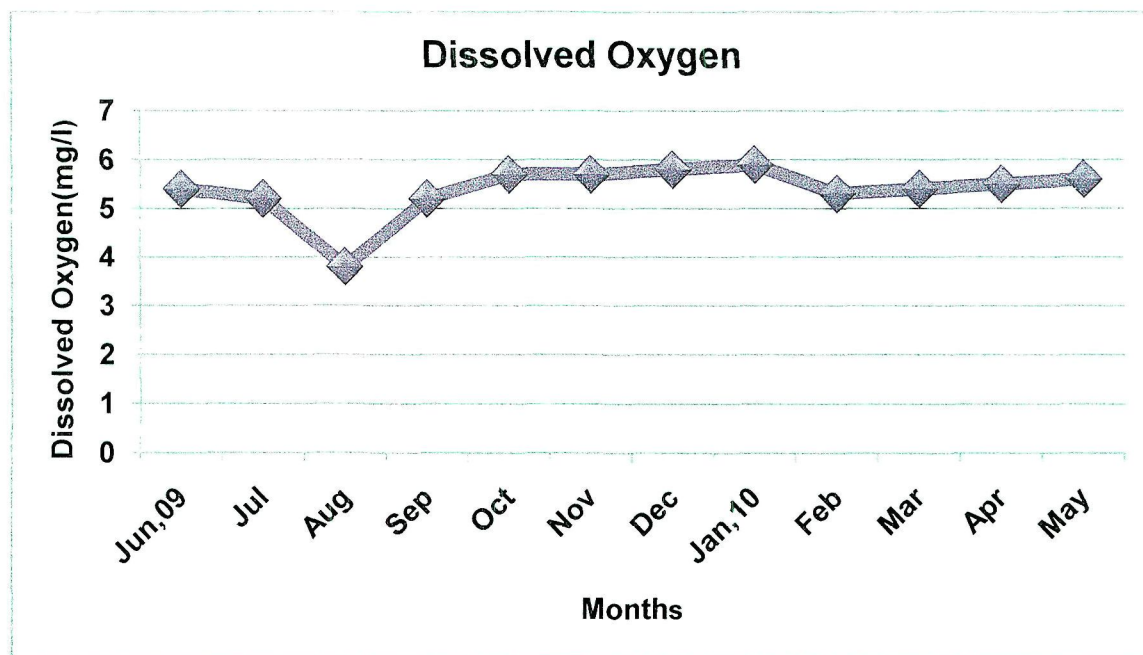


Fig. – 4.5 Monthly variation in dissolved oxygen from June 2009 to May 2010.

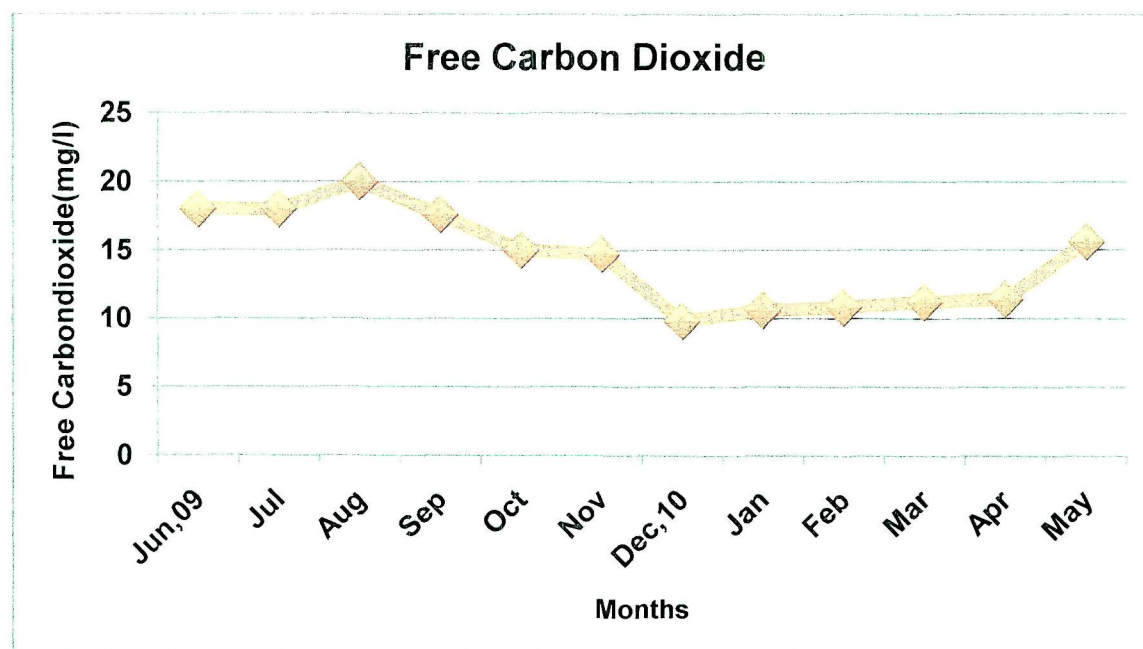


Fig.– 4.6 Monthly variation in free carbon dioxide from June 2009 to May 2010.

may be due to the rise in temperature, which enhances the microbial activities and increases bio-chemical oxygen demand. Ganvati (1973) also reported more carbon dioxide due to rise in temperature. This finding has also been supported by the highly significant and positive relationship of free carbon dioxide with conductivity ($r= 0.78$, $p<0.01$), air ($r=0.78$, $p<0.01$) and water temperature ($r=0.81$, $p<0.01$) (Appendix- 3).

4.1.5 Total Alkalinity

The phenolphthalein alkalinity was not recorded throughout the study period. Therefore, it can be said that OH^- and CO_3^{2-} ions made insignificant contribution to the total alkalinity. Thus, the total alkalinity was principally due to HCO_3^- ions. Total alkalinity revealed highly significant and positive relationship with dissolved oxygen ($r=0.81$, $p<0.01$) and significant and positive relationship with free carbon dioxide ($r=0.61$, $p<0.05$) (Appendix-3). Total alkalinity showed slight variation throughout the study period. It varied from 92.0mg/l to 106.0 mg/l during course of investigation. The maximum values (106.0mg/l) were obtained in August during rainy season and minimum (92.0mg/l) in January in winter season (Fig.- 4.7). The higher concentration of total alkalinity in August during rainy season may be ascribed to the higher bicarbonate ions and low dissolved oxygen concentration.

4.1.6 Chloride

The chloride ion had no definite patterns of variation throughout the study period. The values were recorded maximum (31.0 mg/l) in May during summer season and minimum (20.0 mg/l) during winter in the month of January (Fig.- 4.8). It showed highly significant and positive relation with conductivity ($r= 0.82$, $p<0.01$) and significant and negative relationship with secchi transparency ($r=-0.65$, $p<0.05$) and sodium ($r=-0.51$, $p<0.05$) (Appendix-3). The higher values of chloride during summer followed by the rainy season may be due to the more interference or the activities of animal origin. It was recorded more than 18.0 mg/l throughout the study period. Thus, it can be concluded that the pond ecosystem under investigation is at an advance stage of eutrophication. This can be strengthened by the findings of Hickel (1973) and Rao (1971). They reported chloride contents (18.0 mg/l to 28.0 mg/l) as an integral part of eutrophication.

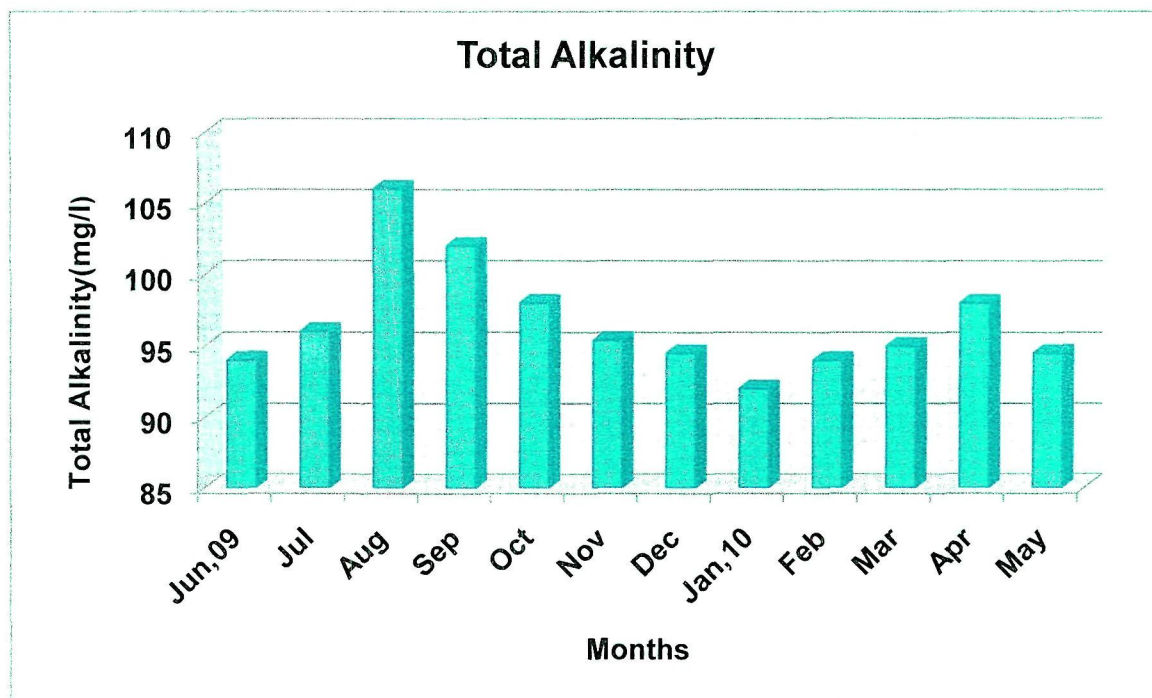


Fig.- 4.7 Monthly variation in total alkalinity from June 2009 to May 2010.

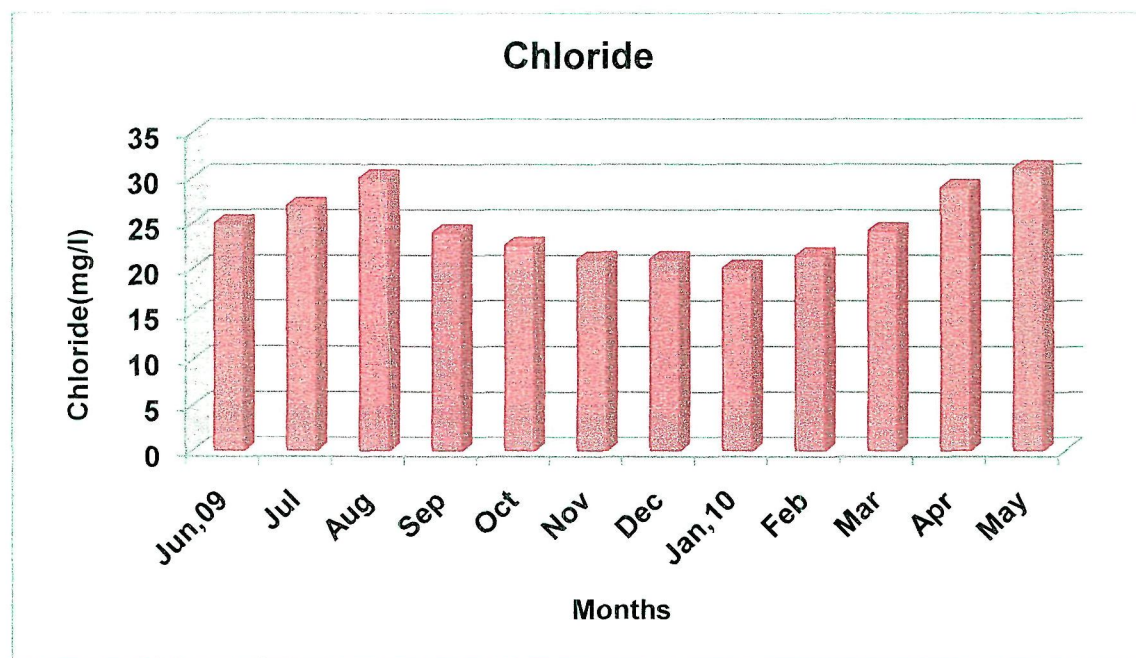


Fig.- 4.8 Monthly variation in chloride from June 2009 to May 2010.

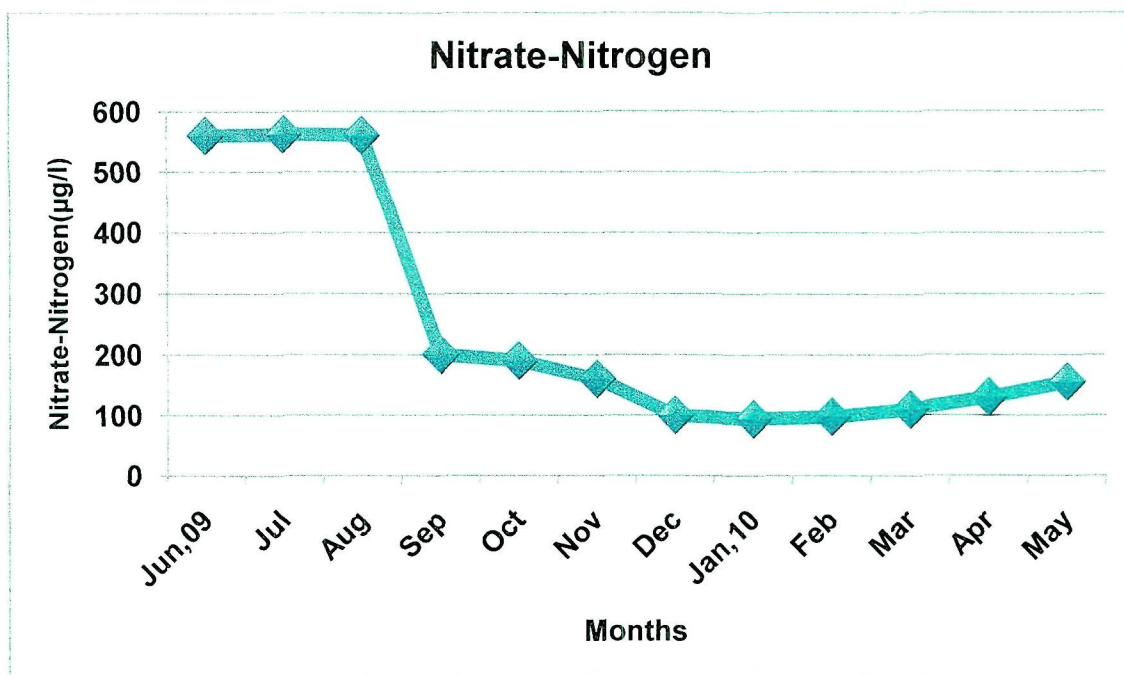


Fig.– 4.9 Monthly variation in nitrate nitrogen from June 2009 to May 2010.

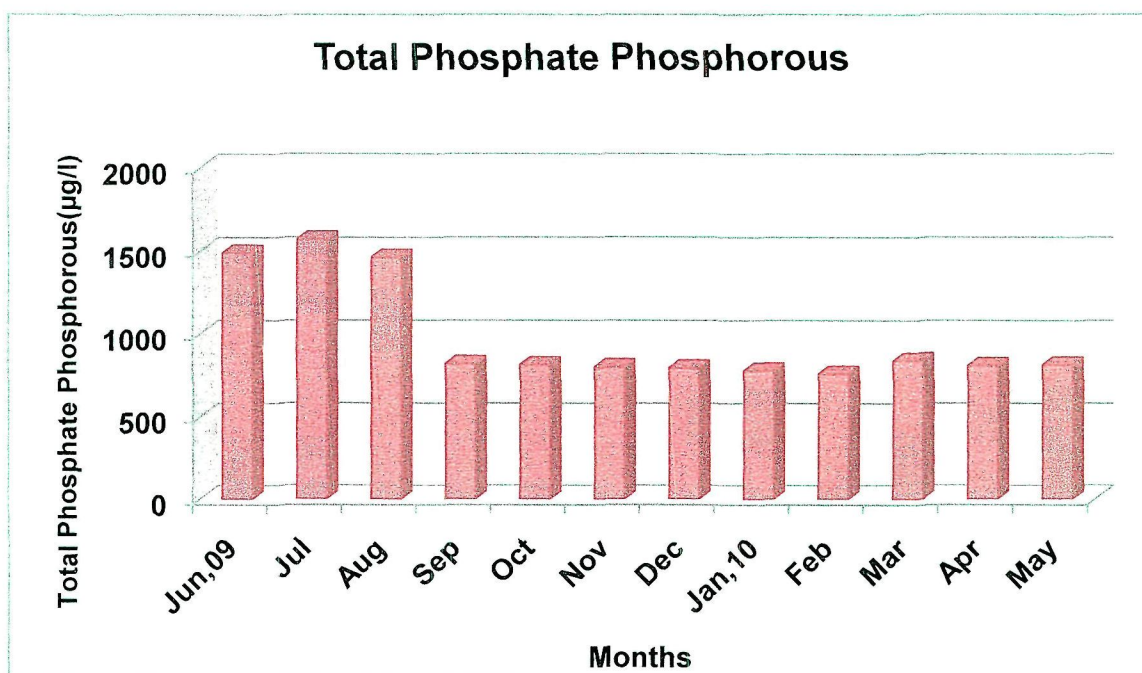


Fig.– 4.10 Monthly variation in total phosphate phosphorous from June 2009 to May 2010.

4.1.7 Nitrate-Nitrogen

Nitrate-nitrogen showed significant variation during the course of investigation. It varied from 94.0 $\mu\text{g/l}$ to 562.0 $\mu\text{g/l}$. The maximum was recorded in July during rainy season and minimum in January during winter (Fig.- 4.9). Nitrate-nitrogen showed highly significant and positive relationship with air temperature ($r=0.77$, $p<0.01$) and water temperature ($r=0.81$, $p<0.01$) and total phosphate-phosphorous ($r=0.98$, $p<0.01$) whereas it showed highly significant and negative relation with secchi transparency ($r=-0.82$, $p<0.01$), sodium ($r=-0.71$, $p<0.01$) and significant and negative correlation with dissolved oxygen ($r=-0.64$, $p<0.05$) (Appendix-3). Such an association indicated nutrient enrichment of pond ecosystem. The high value of nitrate-nitrogen during rainy season may be ascribed to the inflows of nitrogen-nitrates from the agricultural lands and human settlement to the pond ecosystem. The similar reason has been ascribed by Schindler (1974) for the maximum values of nitrate-nitrogen in rainy season.

4.1.8 Total Phosphate-Phosphorous

Total phosphate-phosphorous contents were highest during rainy season. It decreased in winter and was slightly increased during summer season. It was maximum in July (1570.0 $\mu\text{g/l}$) and minimum in February (760.0 $\mu\text{g/l}$) (Fig.- 4.10). Total phosphate-phosphorous showed highly significant and positive relation with air temperature ($r=0.72$, $p<0.01$), water temperature ($r=0.76$, $p<0.01$), free carbon dioxide ($r=0.73$, $p<0.01$) and with secchi transparency ($r=-0.81$, $p<0.01$) it showed highly significant and negative correlation. It was found maximum during rainy season which may be attributed to the inflows from the catchment area consisting of agriculture land and human settlement; similar findings have been reported by Schindler (1974). The minimum concentration in February during winter may be ascribed to the decreased planktonic population. Similar reasoning has been given by Sharma and Pant (1979) for recording low values of total phosphate-phosphorous during winter season.

4.1.9 Sodium and Potassium

No significant variation has been recorded in the concentrations of sodium and potassium contents during different seasons. The low values of sodium and potassium during rainy season may be due to the dilution of pond water. The values of sodium varied from 5.8mg/l to 10.4mg/l and potassium from 2.2 mg/l to 4.5 mg/l (Fig.- 4.11). However, higher concentration of sodium than potassium was obtained throughout the study period, due to more chloride values. Sodium gave significant and negative correlation with air temperature ($r=-0.69$, $p<0.05$), water temperature ($r=-0.68$, $p<0.05$), total alkalinity ($r=-0.54$, $p<0.05$) and with total phosphate-phosphorous ($r=-0.62$, $p<0.05$) whereas it gave highly significant and negative relation with conductivity ($r=-0.70$, $p<0.01$), free carbon dioxide ($r=-0.87$, $p<0.01$) and nitrate-nitrogen ($r=-0.71$, $p<0.01$). Potassium showed highly significant and negative relation with free carbon dioxide ($r=-0.73$, $p<0.01$) and significant and negative with nitrate nitrogen ($r=-0.64$, $p<0.05$). Potassium also indicated significant and positive relation with chloride ($r=0.69$, $p<0.05$) and sodium ($r=0.66$, $p<0.01$) (Appendix-3).

4.2 Ecology of Rotifers in relation to Physico-chemical Regime

The rotifers are pseudo-coelomate micro organisms with well organized bodies. They are commonly called “Wheel animalcules” because of their characteristic wheel organ. These fascinating micro organisms represent one of the oldest groups of invertebrates (Sladeck 1983). The present investigation recorded five species of rotifers from the studied pond ecosystem. The rotifers fauna was found composed of *Brachionus havanaensis*, *Keratella cochlearis*, *Keratella volga*, *Mytilina mucronata* and *Monostylla bulla*. All the above species were recorded throughout the study period. However, their abundance varied significantly during different seasons. Generally rotifers richness was recorded maximum during summer and rainy season and minimum during winter season (Fig.- 4.12). The maximum richness of rotifers in summer and rainy season indicated the influence of atmospheric and water temperature, which is supported by the highly significant and positive correlation between air ($r=0.88$, $p < 0.01$) and water ($r=0.86$, $p<0.01$) temperature with rotifer’s population. This observation

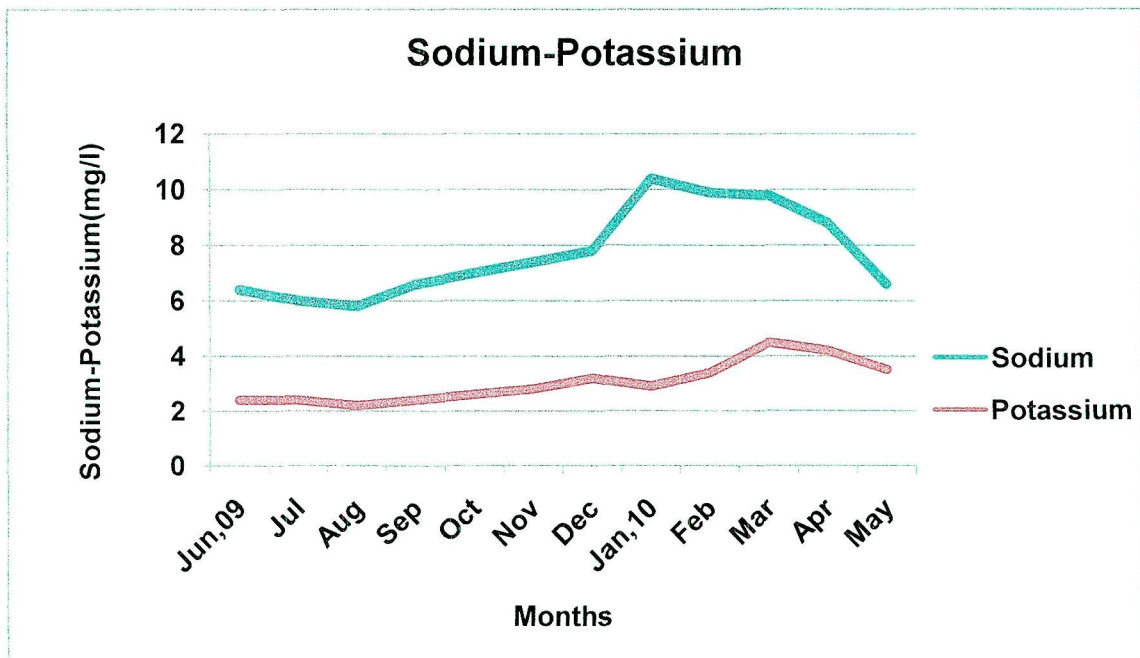


Fig.– 4.11 Monthly variation in sodium potassium from June 2009 to May 2010.

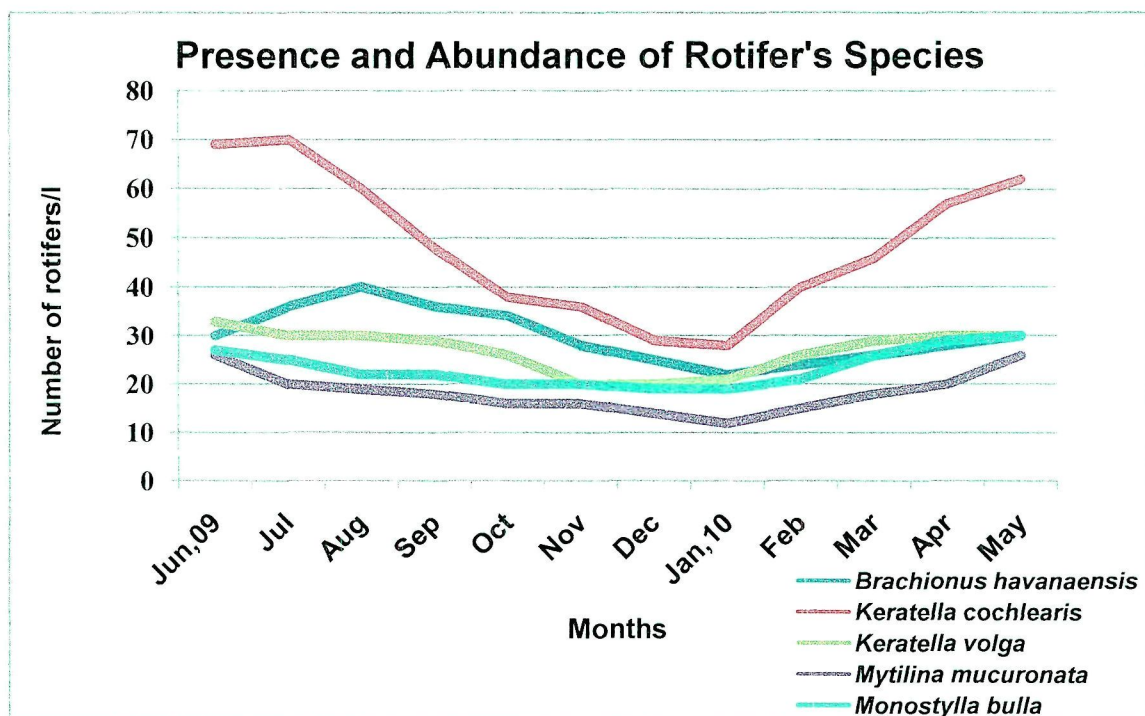


Fig.– 4.12 Monthly variation in rotifers from June 2009 to May 2010 in pond ecosystem.

is in concurrence with the work of Chauhan (1988) and Singh (2000). The most important factor in the presence and abundance of rotifers was thermal structure. Similar findings have been given by Chauhan (1988). The presence and abundance of *Branchionus* and *Keratella* species indicated the alkaline nature of pond water, which is further supported by the positive correlation of rotifers with total alkalinity (Appendix-3) and the pH range of 6.8 to 8.25 (Appendix-1). The five species of rotifers recorded during the course of study were found highly significant and positively related to electrical conductivity ($r=0.92$, $p < 0.01$) and free carbon dioxide ($r=0.72$, $p < 0.01$). The relationship between the concentration of free carbon dioxide and these five species of rotifers can be treated as an index of eutrophication. These rotifers were also found highly significant and positively related with the chloride ($r=0.85$, $p < 0.01$) and such an association is an indicator of pollution as during the course of present study the values of chloride were always more than 18.0mg/l, which is the minimum range indicating pollution in fresh water ecosystem.

The ecology of rotifers in the present investigation revealed that among these five species *Keratella cochlearis* dominated the population followed by *Branchionus havanaensis* and *Keratella volga* (Fig.-4.13). Such a pattern of dominance and co-dominance of these species indicated eutrophication in an aquatic ecosystem. While working on fresh water lake ecosystems of Himachal Pradesh, Chauhan (1988) also reported the same pattern of dominance and co-dominance of rotifer's species. The minimum population of the species in the month of December and January (Fig.-4.12) during winter season may be ascribed to the low temperature. The low population density has also been reported by Chauhan (1993) at low temperature. And this may further be supported by the highly significant and positive relationship of temperature with these species of rotifers. These species were further highly significant and positively related to the nitrate-nitrogen ($r=0.70$, $p < 0.01$) and significant and positively related with total phosphate-phosphorous ($r=0.68$, $p < 0.05$) (Appendix-3). Similar findings have been reported by Chauhan (1993) while working on Rewalsar and Renuka lakes, Himachal Pradesh. The highly significant and

negative relationship was obtained in between rotifer's species and secchi transparency ($r=-0.80$, $p<0.01$) and significant negative with sodium ($r=-0.63$, $p<0.05$) and negative with dissolved oxygen and potassium (Appendix-3). The highly significant and negative correlation with secchi transparency ($r=-0.80$, $p<0.01$), negative correlation with dissolved oxygen and potassium (Appendix-3) showed that these five species of rotifers are inversely related to these physico-chemical characteristics. The negative relationship in the present investigation may be ascribed to the less species biodiversity of rotifers and presence and abundance of pollution indicator species like *Branchionus havanaensis*, *Keratella cochlearis* and *Keratella volga*. Thus, it be inferred that the presence and abundance of rotifers in a pond ecosystem play a significant role in its structural functioning. The change in their species biodiversity and abundance is greatly influenced by physico-chemical regime of the aquatic environment.

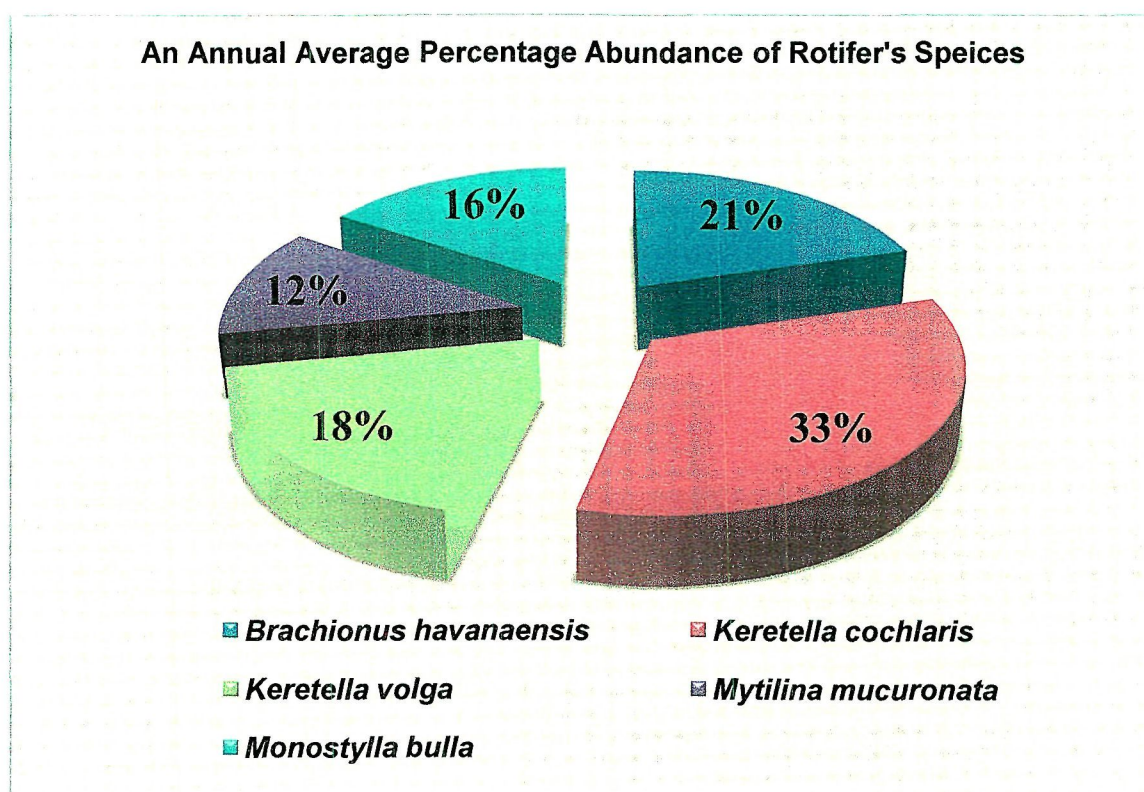


Fig.- 4.13 An annual average percentage abundance of different rotifers in pond ecosystem.



SUMMARY AND **CONCLUSION**

5. SUMMARY AND CONCLUSIONS

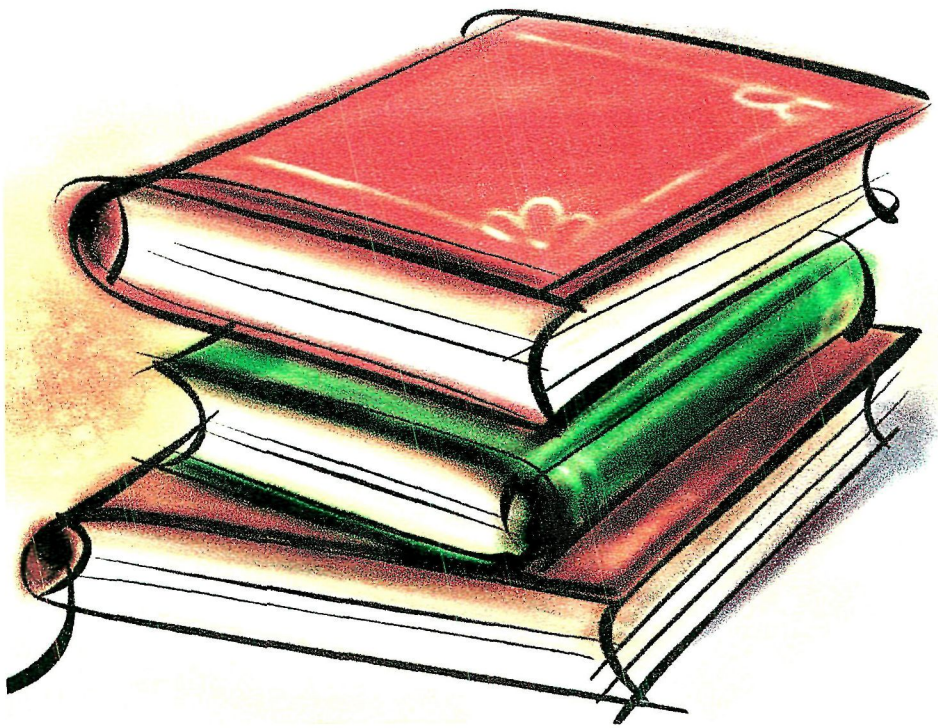
The fresh water ecosystems are most productive systems and play very significant role in the structural functioning of biosphere. A pond is good example of self sufficient and self regulating ecosystem. Physico-chemical regime includes physical and chemical characteristics. These characteristics determine the presence and abundance of biota in the aquatic environment. Plankton is a collective name for all such organisms which are non-motile, too small or too weak to swim against water current. Planktons are mainly of two types phytoplankton and zooplankton. Zooplanktons are further composed of three major groups viz. cladocerans, copepods and rotifers. Rotifers are microscopic invertebrates that constitute the class Rotifera or Rotatoria (phylum-Aschelminthes). These are one of the basic groups of zooplankton community providing the energy flux of fresh water ecosystems and they inhabit virtually all aquatic habitats. They are often found between the high and low water marks of pond, lakes and other fresh water bodies around the world. In the present study, an attempt has been made to assess the impact of physico-chemical regime on ecology of rotifers in pond ecosystem. The production pond of a farmer at village Bodhal near Rajpur, Tehsil- Palampur, District. Kangra (Plate-3.1) was selected for this limnological study at monthly interval over a period of one year from June 2009 to May 2010.

During study period water temperature was found maximum (27.0°C) in the month of June and minimum (12.0°C) in the month of January and December. The value of pH was maximum in the month of June (8.25) and minimum in the month of July (6.8). Conductivity was recorded highest (185.0 µmhos/cm) in the month of May and minimum (110.0 µmhos/cm) in the month of December. Free carbon dioxide was found maximum (20.0mg/l) in August and minimum (9.8mg/l) in December month. Maximum (106.0mg/l) total alkalinity was recorded in August and minimum (92.0mg/l) in January. The value of total phosphate phosphorous was recorded maximum (1570.0µg/l) in the month of July and minimum (760.0µg/l) in February. Maximum (562.0µg/l) value of nitrate-

nitrogen was obtained in the month of July and minimum (94.0 μ g/l) in the month of January. Chloride's value was maximum (31.0mg/l) in May and minimum in (20.0mg/l) January (Appendix-1).

Whereas in the present investigation the five species of rotifers namely *Brachionus havanaensis*, *Keratella cochlearis*, *Keratella volga*, *Mytilina mucronata* and *Monostylla bulla* were recorded (Fig.- 4.13). The presence and abundance of *Brachionus* and *Keratella* species indicated alkaline nature of pond water, which is also supported by the positive relation of rotifers with total alkalinity (Appendix-3). The rotifers abundance was recorded in summer and rainy season and were found minimum during winter season (Fig.- 4.12). This indicated that the presence and abundance of rotifers in pond ecosystem is influenced by the atmospheric and water temperature, which is further strengthened by the highly significant and positive correlation ($r=0.86$, $p<0.01$) between water temperature and rotifers population. The total number of rotifers showed highly significant and positive relationship with conductivity ($r=0.92$, $p<0.01$) and with free carbon dioxide ($r=0.72$, $p<0.01$) (Appendix-3). The relationship between free carbon dioxide and total number of rotifers can be treated as an index of eutro'phication. A highly significant and positive relation ($r=0.85$, $p<0.01$) between chloride concentration and rotifers was also obtained during investigation (Appendix-3). Such an association is an indicator of pollution as during the course of present investigation the values of chloride were always obtained more than 18.0 mg/l which is the minimum range indicating pollution in fresh water ecosystem. Among the five species of rotifers, *Keratella cochlearis* quantitatively dominated the population followed by *Brachionus havanaensis* and *Keratella volga* (Fig.- 4.13). Such a pattern of dominance and co-dominance of these species indicated eutro'phication in a pond ecosystem. These species of rotifers were further found highly significant and positively related to nitrate-nitrogen ($r=0.70$, $p<0.01$) and with total phosphate-phosphorous ($r=0.68$, $p<0.05$) it is significantly and positively correlated. The highly significant and negative correlation with secchi transparency ($r=-0.80$, $p<0.01$) and negative with dissolved oxygen and potassium was also recorded (Appendix-3).

The higher concentration of free carbon dioxide, chloride, nitrate-nitrogen, total phosphate-phosphorous (Appendix-1) and the presence and abundance of *Keratella cochlaris*, *Kertella volga* and *Brachionus havanaensis* (Appendix-2) indicated eutroification in the pond ecosystem. Rotifers showed highly significant and positive correlation with water temperature ($r=0.86$, $p<0.01$), chloride ($r=0.85$, $p< 0.01$), nitrate-nitrogen ($r=0.70$, $p< 0.01$), significant and positive correlation with total phosphate-phosphorous ($r=0.68$, $p<0.05$) and highly significant and negative correlation with secchi transparency ($r=-0.80$, $p< 0.01$) and some other correlations were also found (Appendix-3). Thus, various correlations between rotifers and physico-chemical characteristics indicated that the physico-chemical regime of pond ecosystem determines the ecology of rotifers by influencing their presence, abundance and distribution.



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APPENDICES

Appendix-1

Monthly variation in physico-chemical characteristics from June 2009 to May 2010 in pond ecosystem.

	Air temp. (°C)	Water temp (°C)	Secchi transparency (cm)	pH	Conductivity (µmhos/cm)	Dissolved oxygen (mg/l)	Free carbon dioxide (mg/l)	Total Alkalinity (mg/l)	Total Phosphorus (µg/l)	Nitrate- Nitrogen (µg/l)	Chloride (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Number of rotifers (org./l)
Jun, 09	35.0	27.0	18.0	8.25	170.0	5.4	18.0	94.0	1490.0	560.0	25.0	6.4	2.4	185
Jul	27.0	21.0	16.5	6.8	168.0	5.2	18.0	96.0	1570.0	562.0	26.9	6.0	2.4	181
Aug	26.0	20.0	17.3	7.4	164.0	3.8	20.0	106.0	1460.0	560.0	30.0	5.8	2.2	171
Sep	25.0	20.0	19.4	7.6	158.0	5.2	17.6	102.0	820.0	200.0	24.0	6.6	2.4	153
Oct	23.0	16.0	20.4	7.9	150.0	5.7	15.0	98.0	814.0	190.0	22.6	7.0	2.6	134
Nov	18.0	16.0	24.0	7.4	140.0	5.7	14.7	95.4	801.0	160.0	21.0	7.4	2.8	120
Dec	15.0	12.0	22.9	7.6	110.0	5.8	9.8	94.5	795.0	100.0	21.0	7.8	3.2	107
Jan, 10	12.0	12.0	26.8	7.1	120.0	5.9	10.6	92.0	780.0	94.0	20.0	10.4	2.9	102
Feb	20.0	14.0	21.9	7.0	128.0	5.3	10.8	94.0	760.0	98.0	21.4	9.9	3.4	126
Mar	20.0	16.0	21.5	7.2	140.0	5.4	11.2	95.0	840.0	110.0	24.2	9.8	4.5	145
Apr	22.0	17.0	20.1	7.5	154.0	5.5	11.4	98.0	810.0	130.0	28.9	8.8	4.2	164
May	24.0	18.0	19.8	7.6	185.0	5.6	15.6	94.5	815.0	155.0	31.0	6.6	3.5	178

Appendix-2

Presence and abundance of rotifers species from June 2009 to May 2010 in pond ecosystem.

	<i>Brachionus havanaensis</i>	<i>Keratella cochlearis</i>	<i>Keratella volga</i>	<i>Mytilina mucronata</i>	<i>Monostylla bulla</i>	Total number of rotifers
Jun,09	30	69	33	26	27	185
Jul	36	70	30	20	25	181
Aug	40	60	30	19	22	171
Sep	36	48	29	18	22	153
Oct	34	38	26	16	20	134
Nov	28	36	20	16	20	120
Dec	25	29	20	14	19	107
Jan,10	22	28	21	12	19	102
Feb	24	40	26	15	21	126
Mar	26	46	29	18	26	145
Apr	28	57	30	20	29	164
May	30	62	30	26	30	178

Appendix-3

Co-efficient of correlation (r) among physico-chemical characteristics and in between number of rotifers and physico-chemical characteristics

	Air temp. (°C)	Water temp (°C)	Secchi transparency (cm)	pH	Conductivity (µmhos/cm)	Dissolved oxygen (mg/l)	Free carbon dioxide (mg/l)	Total Alkalinity (mg/l)	Total Phosphorus (µg/l)	Nitrate-Nitrogen (µg/l)	Chloride (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Number of rotifers (org./l)
Air temp.(°C)	0.96**	-0.73**		0.46	0.81**	-0.44	0.78**	0.33	0.72**	0.77**	0.56*	-0.69*	-0.38	0.88**
Water temp.(°C)			-0.73**	0.43	0.79**	-0.42	0.81**	0.31	0.76**	0.81**	0.51*	-0.68*	-0.43	0.86**
Secchi transparency(cm)				-0.04	-0.71**	0.58*	-0.73**	-0.43	-0.81**	-0.82**	-0.65*	0.57*	0.45	-0.80**
pH					0.28	0.11	0.26	0.11	0.03	0.13	0.09	-0.40	-0.20	0.22
Conductivity(µmhos/cm)						-0.39	0.78**	0.36	0.52*	0.59*	0.82**	-0.70**	-0.23	0.92**
Dissolved oxygen(mg/l)							-0.63*	0.81**	-0.60*	-0.64*	-0.54*	0.44	0.35	-0.49
Free carbon dioxide(mg/l)								0.61*	0.73**	0.83**	0.52*	-0.87**	-0.73**	0.72**
Total Alkalinity(mg/l)									0.30	0.40	0.47	-0.54*	-0.37	0.36
Total Phosphorus(µg/l)										0.98**	0.43	-0.62*	-0.55*	0.68*
Nitrate-Nitrogen(µg/l)											0.45	-0.71**	-0.64*	0.70**
Chloride (mg/l)												-0.51*	0.69*	0.85**
Sodium(mg/l)													0.66*	-0.63*
Potassium(mg/l)														-0.14
Number of rotifers(org./l)														

**p<0.01; *p<0.05

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