

Abundance and Diversity of Plankton in Different Stocking Densities of
Mola (*Amblypharyngodon mola*) in Prawn-Carp Gher Culture System



Student ID: MS-130613



Fisheries and Marine Resource Technology Discipline

Khulna University, Khulna

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**Abundance and Diversity of Plankton in Different Stocking Densities of
Mola (*Amblypharyngodon mola*) in Prawn-Carp Gher Culture System**

**A Thesis
By**

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Student ID: MS-130613

Session: 2012-2013



**The thesis submitted to the Fisheries and Marine Resource Technology Discipline, Khulna
University, Khulna, in partial fulfillment of the requirements for the degree**

Of

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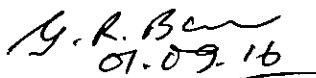
**Fisheries and Marine Resource Technology Discipline
Khulna University, Khulna
Khulna-9208, Bangladesh**

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DECLARATION

Abundance and Diversity of Plankton in Different Stocking Densities of Mola (*Amblypharyngodon mola*) in Prawn-Carp Gher Culture System

The results submitted in this project thesis are entirely the candidate's own investigations and no part of the results has been accepted for any degree, nor is it being concurrently submitted for any degree.



17.08.2016

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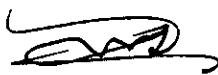
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Dedicated to

MY BELOVED PARENTS

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All praises are to the Supreme Being, The creator and Ruler of the Universe, whose mercy keeps me alive and enables me to pursue my education in Fisheries & Marine Resource Technology Discipline and to complete my thesis for the degree of M.Sc. in Fisheries. It is a great pleasure for me to express my unfettered gratitude, sincere appreciation and profound respect to my honorable Supervisor **Dr. Khandaker Anisul Huq**, Professor, Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna, for his scholastic guidance, constant inspiration, valuable advice and constructive criticism for the successful completion of the investigation and writing up this thesis.

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ABSTRACT

The present study was conducted to assess the abundance and diversity of plankton among the ponds of three different stocking densities of mola fish (*Amblypharyngodon mola*) at Dumuria upazilla, Khulna, from September to December, 2015. The present experiment consists of three treatments each of which has three replications. Stocking density of mola fish 1, 2 and 4 indiv./m² were considered as Treatment-1, Treatment-2 and Treatment-3 respectively. Plankton samples were collected fortnightly by conical shaped monofilament nylon net (Phytoplankton net) and Lugol's solution was used for preservation. In the present study 25 genera belong to 5 groups of phytoplankton namely Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta, Chrysophycophyta were found. Among all groups Chlorophyta was the dominant and the average percentages of Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta, Chrysophycophyta in the three treatments were 34.72%, 21.67%, 18.81%, 14.15% and 10.55% respectively. The mean ($\pm$ SD) values were 4506.5 $\pm$ 803.49, 4308.25 $\pm$ 771.91 and 4097 $\pm$ 774.46 indiv./l of total phytoplankton in T₁, T₂ and T₃ respectively. During the study 8 genera belong to 5 groups of zooplankton were observed. These are copepod, rotifer, cladocera, ostracoda and crustacean larvae. Among all groups, Copepod was the dominant and the average percentages of Copepoda, Rotifera, Cladocera, Ostracoda and Crustacean Larvae were 55.84%, 28.18%, 10.39%, 3.57% and 1.98% respectively. The mean ($\pm$ SD) values were 1462.5 $\pm$ 203.32, 1376.75 $\pm$ 160.16 and 1288.25 $\pm$ 156.75 indiv./l of total zooplankton in T₁, T₂ and T₃ respectively. Chlorophyta was significantly higher than other groups of phytoplankton and Copepoda was significantly higher than other groups of zooplankton. This experiment indicates that the abundance of various groups of Plankton was significantly fluctuated by the three different stocking densities of mola fish (*Amblypharyngodon mola*).

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CHAPTER -1

INTRODUCTION



1. Introduction

1.1 General Background

Fisheries resources play a vital role in the socio-economic development of the country and supply about 80% animal protein of our meal. About 4.73% GDP (Gross domestic product), 12% total foreign exchange and about 20 million people are engaged in the exploitation and conservation of fish and fisheries product (DoF, 2006). Among fisheries products, prawn (*Macrobrachium rosenbergii*), carp and shrimp (*Penaeus monodon*) are very important. In world market, prawn is very attractive product. Its demand knows no bounds for its nutrition and taste. For increasing the demand of prawn in international market prawn culture has been increasing from the 70th decades and now it is known as a large commerce. This commerce has a great contribution on the increase of national income, industrialization, employment and earning of foreign exchange. Greater Khulna region is consider as the most suitable area for prawn cultivation as over 75% of prawn production comes from this coastal area. Farmers of Khulna district developed gher farming technology in 1980. Gher faming was then spreaded rapidly to other district in coastal region, number of increase by approximately 10-20% every year. Gher farming is now primary livelihood strategy of more than 100,000 rural households in the south west region of Bangladesh. Mola fish has also highly nutritive value & can culture with prawn in gher.

The successful farm management depends on natural feed and good water quality management into culture able pond. Plankton is the main sources of natural feed. The fresh water giant prawn (*Macrobrachium rosenbergii*) is a carnivorous and mainly bottom feeder species. They feed mainly zooplankton, so the study of zooplankton is so much important.

Plankton is microscopic organisms that formulate the base of food chains and food webs in all aquatic ecosystems. It is an enormous group of aquatic organism drifting about in water under the action of water movement. They are mostly small, many of them are minute, and their structure can only be seen clearly with the aid of a binocular or compound microscope, with the exception of some large animals, such as certain medusae (*Chynea*, *Physalia*, etc), heteropods (*Pterotrachea*) and tunicates (*Pyrosoma*). Although they belong to different taxa, they have one thing in common, i.e. owing to the lack of strong locomotory organs (like fish fins), they are weak in locomotion and can only drift about in water at mercy of waves and currents, being incapable of moving anywhere as fish do (Zheng, 1984). Phytoplankton and

zooplankton are the two major groups of plankton. Phytoplankton has the importance in the aquatic ecology. Biotic communities of the water consists of major groups of organisms namely plankton, nekton and benthos. Among these plankton is the fundamental fish food organisms and plays a vital role in fish production. Abundance of phytoplankton indicates the productive status of water body, whether it is an oligotrophic or a eutrophic one and serves as food by fish and prawn directly or indirectly. Therefore, a thorough knowledge of abundance of phytoplankton and its quality in time and space in relation to environmental condition has become prerequisite for higher fish production.

1.2 Phytoplankton

Phytoplanktons are natural sources of food for aquaculture. It plays an important food item of zooplankton, Herbivorous, and omnivorous fishes (Alam *et al.*, 1987). Because of its short lifecycle, phytoplankton respond very quickly to environmental changes, and hence their standing crop and species composition are more likely to indicate the quality of water mass in which they are found (Standard Methods). So phytoplankton composition is a natural bio indicator because of its rapid responses to fluctuations of environmental conditions. Phytoplankton is widely used in the aquaculture for a variety of purposes. Phytoplankton is necessary in prawn farm because it enriches zooplankton and provides indirect and direct nutrition to fish or prawn larvae. They also produce antibacterial substances that can prevent disease outbreaks.

Phytoplankton plays an important role as primary producers, forming the basis of the food chain. In nature, fish and prawn larvae during their "critical phase" receive nourishment by selectively feeding upon phytoplankton and zooplankton available in their habitat. These assemblages exhibit excellent continuity through time and with changes in water quality. Phytoplankton has also economic importance. Some algal green algae are capable to form sheaths of CaCO_3 , which may build up quite extensive lime deposit. In Java and Equador *Nostoc commences* is eaten as food. Diatomaceous earth formed by fossil diatom has great industrial value. They are used in light and heat resistant bricks, powder and toothpaste, polishing materials, pharmaceutical jellies, lotion etc. They are also used in whisky chaser for a cold cure. The abundance and diversity of plankton also affect the survival and growth rate of cultured fish. Their abundance and diversity greatly influence the culture system through maintaining oxygen concentration in water, ensuring the balance between O_2 and CO_2 , enhancing the decomposition of organic matters accumulated in the pond, stabilizing water

temperature in the pond, regulating pH value and the ecosystem of the pond and also minimizing the variation of water quality parameters. (Das and Bhuiyan, 1974).

Water body is an ecosystem with a complicated network of various physico-chemical parameters and its biota. The physico-chemical parameters and plankton communities together form a comprehensive ecosystem and as in any ecosystem, there are interactions between the plankton and the physico-chemical parameters. These interactions are directly or indirectly subjected to the complex influences, some of which results in quantitative changes e.g. the size of the population increases or decreases. Such variation in population is occurred for the variation in nutrients and other favorable conditions of water (e.g. water temperature, pH, salinity, DO, alkalinity, free CO₂ etc.) during the plankton production (Welch, 1952). The physico-chemical factors and nutrient status of water play the most important role in governing the production of planktonic biomass.

The relationship between the physico-chemical parameters and plankton production of pond water and their relation with monthly fluctuations of phytoplankton are of great importance and basically very much essential in case of fish culture and fisheries management. Several environmental factors which determine the characters of water have great importance upon the growth, maturity, reproduction and development of fish. The relationships between the fishes and their biotic and abiotic (elements) environment is not as isolated phenomenon, but changes in one may reflect on the other effectively. Fishes are more dependent on water temperature, pH, dissolve oxygen, free CO₂, alkalinity and some other salts for growth and developments (Nikolsky, 1963). Any changes of these parameters may affect the growth; development and maturity of fish (Nikolsky, 1963). A very few researcher worked on the percentage, composition, and seasonal variation of plankton of semi-intensive culture system. A common system when part of the nutritional needs are supplied from external sources, higher farm stocking densities, fertilization is used, water exchange is moderate, regular monitoring of pond environment and fish biomass and yields are moderately high.

1.3 Zooplankton

Zooplankton species constitute the 2nd trophic level. Species such as copepods and scalps for instance, are herbivorous species, i.e. they feed directly on phytoplankton, and therefore they are primary consumers. Zooplanktons usually are distributed throughout the aquatic ecosystem such as ponds, lakes, rivers, oceans etc. Most forms of zooplankton are motile, and thus their distribution both vertically and horizontally may be quite variable. Species have

different habitat preferences that further accentuate spatial and temporal heterogeneity. Zooplanktons are major herbivores as well as important predators in aquatic ecosystems. It plays an important food item of omnivorous and carnivorous fishes (Alam *et al.*, 1987). The larvae of carps feed mostly on zooplankton (Bardach *et al.*, 1972), because zooplankton provide the necessary amount of protein requires for the rapid growth and development of different organs specially the gonad of fishes.

1.4 Plankton in Fresh water Gher System

Plankton is very important in fresh water gher system. The successful farm management depends on natural feed and plankton comprises about 25% of total food items in fish pond. The zooplankton contributes about 23% of the food item of *Macrobrachium rosenbergii* and 32% of the *Notopterus notopterus* (Mustafa and Ahmed, 1979), 47% of the *Catla catla* and 6.37% of the *Labeo rohita* (Menon *et al.*, 1981). *Amblypharyngodon mola* is planktivorous in nature feeding mostly phytoplankton (94.38%), zooplankton (5.62%) and could be a suitable species for integrated rich-fish farming given by (Mondal *et al.*, 2013). Zooplankton plays a very important role in the food chain as they are in the second trophic level as primary consumer and as contributors to the next trophic level. Planktonic biomass available in an ecosystem is of fundamental importance for fish production. In polyculture system carp-mola fish compete with each other for food and habitat.

The present study has been undertaken to understand the effect of different stocking density of mola fish (*Amblypharyngodon mola*) in prawn-carp gher system on the abundance & diversity of plankton. It is important to know the effect of mola fish intensity on plankton abundance because it may affect on other carp fish by altering the plankton abundance as mola fish is planktivorous. The results will provide an ecological baseline for future studies in this region; it will broaden the information and will give a more clear view of the effect fish stocking density on plankton biomass.

Objectives of the Study:

- ✓ To know the abundance and diversity of Phytoplankton due to the different stocking density of mola (*Amblypharyngodon mola*) fish in prawn-carp gher system.
- ✓ To know the abundance and diversity of Zooplankton due to the different stocking density of mola (*Amblypharyngodon mola*) fish in prawn-carp gher system.

CHAPTER -2

LITERATURE

REVIEW



2. Literature Review

Some studies on plankton have been carried out by many researchers in different parts of the world but in Bangladesh no notable works have been done. However, in recent time there has been growing awareness among the researcher in our country to study about plankton, their distribution and relationship with physico-chemical parameters. Some of related studies are discussed below-

2.1 Phytoplankton

Bhat *et al.* (2015) studied on variability in water quality and phytoplankton community during dry and wet periods in the tropical wetland, Bhopal, India. They observed the phytoplankton diversity belonging to six groups of which Chlorophyceae (46%), Bacillariophyceae (28%), Cyanophyceae (15%), Euglenophyceae (9%), while Pyrophyceae and Chrysophyceae contributed 1% each, respectively. The higher abundance of (*Closterium*, *Pediastrum*, *Scenedesmus*, *Navicula*, *Anabaena*, *Microcystis* and *Phacus*) and nutrient concentration (nitrate-nitrogen and phosphorus) during the dry and wet periods reflect higher organic pollution in the Bhoj wetland.

Nair *et al.* (2015) studied on effect of water quality on phytoplankton abundance in selected ponds of Nedumangad Block Panchayat, Kerala they observed that Phytoplankton are greatly affected by ecological conditions like salt stress, temperature, pH, biological oxygen demand and other environmental factors. The plankton abundance was calculated for 10 selected ponds. Carl Pearson's correlation coefficients were calculated for abundance with pH, EC, DO and temperature. Abundance depends on the temperature variations and levels of DO as they are positively correlated while abundance does not have any interdependence on both the EC and pH as they are negatively correlated.

Sopana *et al.* (2003) studied on "Species Composition, Abundance and Distribution of Phytoplankton in the Bay of Bengal" during the year 2007. Species composition, abundance and distribution of phytoplankton were studied from water samples collected at surface layer of 24 stations in 3 areas (north, west and east) in the Bay of Bengal. This study identified a total of 58 genera with 135 species which are belonging to 2 species of cyanobacteria, 78 species of diatoms, 53 species of dinoflagellates and 1 species of silicoflagellate.

Chalinda and Sommerfeld (2000) studied on phytoplankton diversity and its relationships to the physico-chemical environment in the Banglang Reservoir, Yala Province during May 2000 to April 2001. Samples were collected monthly from May 2000 to April 2001 at three stations. Physico-chemical parameters: temperature, pH, dissolved oxygen, alkalinity, conductivity, water transparency, and nutrients were measured. One-hundred and thirty-five species in seven divisions of phytoplankton were found. The greatest number of species were in Division Chlorophyta (50%), followed by Cyanophyta (21%), Bacillariophyta (13%), Pyrrophyta (6%), Cryptophyta (4%), Chrysophyta (3%) and Euglenophyta (3%). The computer statistical package was used to calculate the correlation coefficient between phytoplankton density and physico-chemical factors. They identified that Banglang Reservoir belonged to oligo-mesotrophic status.

From Bay of Bengal of Bangladesh, Islam and Aziz (1975) reported the systematic accounts, population density and percentage composition of different groups of phytoplankton in different session and seasonal variations of ecological condition and nutrients content.

2.2 Zooplankton

Mozumder *et al.* (2014) studied on abundance of zooplankton and physico-chemical parameters of a polyculture fish pond of manikganj, bangladesh. They conducted study during June 2003 to May 2004. They observed a total of 33 major species of zooplankton including 11 genera of Rotifera, 4 of Copepoda, 4 genera of Cladocera and 2 genera of Protozoa were identified. The monthly abundance of zooplankton varied from 4228 indiv/l in October 2003 to 169 indiv/l in January 2004. Among the total zooplankton, Rotifera comprised of 71.07%, Copepoda comprised of 12.49% Nauplii comprised of 11.96%, Cladocera comprised of 1.49% and Protozoa comprised of 2.99%.

Hossain *et al.* (2015) studied on species composition and abundance of zooplankton population in freshwater pond of Noakhali district, Bangladesh. They categorized the experimental pond as culture, household and unused and samples were drawn from 15 May to 15 November, 2012 during the entire study period using a plankton net (90 µm mesh size). They observed four groups of zooplankton viz.; Rotifera, Cladocera, Copepoda and Crustacean larvae consisting of 14 genera were identified. Total zooplankton density was found 5550, 2655 and 1670 units/l respectively in culture, household and unused pond. They also noticed rotifera as most dominant group with the density of 2100 ind/l, 983 ind/l and 1370 ind/l respectively in culture, household and unused pond. Lowest density was found for

Cladocera with 890 ind/l, 500 ind/l and 200 ind/l respectively in culture, household and unused pond. In culture pond, percentage of Rotifers, Copepod, Cladocerans and Crustacean larvae were 38%, 23%, 16% and 23% respectively. In household pond, percentage composition of zooplankton group was 37% (Rotifers), 37% (Copepod), 19% (Cladocerans) and 7% (Crustacean larvae). And in unused pond, Rotifers, Copepod, Cladocerans and Crustacean larvae were found 53%, 27%, 8% and 12% respectively. Rotifer was found more abundantly (54%) in unused pond whereas Copepoda was in household pond (37%).

Rahi add Sabbir (2010) studied on assessment of the abundance and genus composition of zooplankton of the Mouri River, Khulna. They observed four different groups and 24 different genera of zooplankton where copepods were the dominant group throughout the river constituting 33 - 83.33% of total zooplankton biomass at different stations. They found the maximum abundance of zooplankton was 1230 individuals/l at station-VI and minimum 200 individuals/l at station-II. They showed positive correlation with plankton abundance and water temperature, transparency, free CO₂, pH, dissolved O₂, alkalinity and hardness whereas sulphate, phosphate, calcium, nitrate and magnesium showed negative correlation.

Kabir *et al.* (2014) studied on zooplankton of harda baor of Meherpur district: composition and seasonal succession. They conducted their study from September 2006 to August 2007 and a total of 64 species of zooplankton were identified, of which, 7 were protozoans, 37 rotifers, 13 copepods and 7 belonged to the cladocerans. The monthly average of zooplankton was 507.25 indiv/L, of which protozoans occupied 28.08 indiv/L, cladocerans 28.67 indiv/L, copepods 80.08 indiv/L and rotifers 370.42 indiv/L respectively. The zooplankton population showed one distinct highest peak which occurred in the month of June with 1588 indiv/L. The lowest numbers of zooplankton population were recorded as 55 indiv./L in the month of September. Among zooplankton rotifers were the most dominant (73.02%) followed by copepods (15.78%), cladocerans (5.66%) and protozoans (5.54 %).

Rahman and Hussain (2008) studied on the abundance of zooplankton of a culture and a non-culture pond of the Rajshahi university campus. The study was carried out in a culture and a non-culture pond of Rajshahi University campus was carried out from September, 2004 to February, 2005. Monthly fluctuations of some physico-chemical parameters were noted. The ponds showed alkaline in nature with moderate bicarbonate alkalinity. Diurnal change of water temperature, free CO₂ and dissolved Oxygen were also studied. Four groups of zooplankton were identified, of which copepods (1260 units/l and 973.33 units/l in pond-1

and pond-2 respectively) were most dominant. A total of 9 genera of zooplankton were identified of which *Cyclops* (68.25% and 60.28% of total copepods) was most abundant in both ponds. They also concluded that the culture pond showed better result than that of the non-culture pond regarding zooplankton production.

Michael (1970) was also worked on diurnal variation of zooplankton. He described that many aquatic organisms exhibit diurnal rhythms in their activities. The main objective of his study was the variation patterns of the different physico-chemical factors, individual species of plankton and their interrelationships.

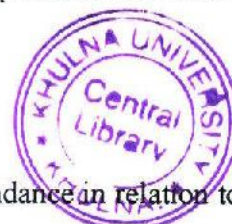
Straskraba (1965) made a qualitative study of the littoral zooplankton of the rich vegetation of the black water Labicko and observed the contribution to the productivity of the littoral regions of pools and ponds.

Bal and Pradhan (1952) recorded zooplankton in Bombay waters during 1944-1947. He observed two or three peaks of copepods during May to September. The plank tonic larvae showed more than one peak during his study period.

2.3 Relation between plankton to water quality

Hossain and Chowdhury (2004) studied on "Phytoplankton abundance in relation to physico-chemical conditions of the Sundarbans estuary". The study was carried out during August 2004 to July 2005 near Burigoalini forest station. A total of 14 genera of phytoplankton belonging to Cyanophyceae, Chlorophyceae, and Bacillariophyceae were recorded.

Ratha *et al.* (2003) studied In India, inland water bodies attracted the attention of various workers leading to the studies on water quality and distribution of phytoplankton from time to time. Moniruzzaman Khondoker (Department of Botany, University of Dhaka, Dhaka 1000, Bangladesh) gave new records of phytoplankton for Bangladesh. The study was carried out in the cholera prone Mathbaria Upazila of Pirojpur district and Bakerganj Upazila of Barisal district of Bangladesh. Samples of phytoplankton were collected from eight and six stations of Bakerganj. To collect concentrated samples of phytoplankton, plankton net of 20µm mesh size was used. The samples were viewed under a magnification range of 400-1000 via a Nikon research microscope fitted with a photographic attachment. Ten taxa belonging to Chlorophyceae, Cyanophyceae, Bacillariophyceae and Euglenophyceae, and one with an uncertain taxonomic position have been described.



Khondaker and Parveen (1992) was also studied on the physical and chemical limnology of a shallow, hypertropic artificial lake in Bangladesh. Physico-chemical parameters of semi intensively managed fish pond were also observed by Begum *et al.* (1994) and noticed fluctuations. The pH value of the pond water was found to have to lowest variability while carbonate had the highest variability.

Amanu, (2015) studied on composition and abundance of major planktons and physico-chemical characteristics among two ponds and Lake Tana, Ethiopia. He observed zooplankton species richness is higher in lake water than ponds. The lake also had the highest mean value of both Shannon-Wiener index and evenness index in phytoplankton. He also suggests that the supplementary feed added to each pond had influence on nutrient content which enhanced algal biomass and productivity of the ponds.

Balakrishna *et al.* (2013) studied on physico-chemical parameters and plankton diversity of ghanpur lake, warangal, a.p., india. They identified a total of 13 Zooplanktons among these rotifers 7 species, Copepods 3 species, Cladocera 2 species, Ostracoda 1species, of which rotifers and copepods are dominating. Rotifera, Cladocera and Copepod populations were high during summer season and low in rainy sea-son. While the Ostracode species were recorded high in rainy season and low in winter season.

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Ganai and Parveen (2013) studied on effect of physico-chemical conditions on the structure and composition of the phytoplankton community in Wular Lake at Lankrishipora, Kashmir. They conducted their study from March, 2007 to February, 2008 to study abundance and distribution of phytoplankton. They observed a total of 64 phytoplankton belonging to bacillariophyceae, chlorophyceae, cyanophyceae and euglenophyceae. Phytoplankton in general, showed two growth periods, one in spring and other in winter. A clear dominance of bacillariophyceae over chlorophyceae, cyanophyceae and euglenophyceae was observed throughout the study period. *Navicula* spp. with population density of 118 no./ml was recorded to be the most abundant species amongst bacillariophyceae at the selected site.

Chlorophyceae formed the second most dominant group of phytoplankton with *Chlorella* spp. (112 no./ml) as the most abundant species. *Osillatoria* spp. with population density of 119 no./ml was found to be the most abundant amongst cyanophyceae. Euglenophyceae formed the least represented group of phytoplankton with peak population in spring.

Khan *et al.* (1990) studied on seasonal variation of Plankton in physico-chemical conditions of Dhanmondi lake water made a description and illustration of about 135 species of algae and 13 species of zooplankton. He noticed during winter season the abundance was high where chlorophyta and copepoda were dominant.

Anadu (1991) showed that there is a relationship between the physico-chemical parameters of zooplankton and fish growth in different season. He observed zooplankton abundance was positively related with P^H .

Ferrari (1976) studied on winter Limnology of a mountain lake, northern Appennines Italy. He observed the changes in biomass and production rate of phytoplankton analyzed in relation to the changes in physical and chemical characteristics of the waters and abundance and biomass of the zooplankton.

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2.4 Plankton Distribution in running water system

Ramesha and Sophia (2013) studied on species composition and diversity of plankton in the river seeta at seetanadi, the Western Ghats, India. They studied for a period of 14 months in the river Seeta from April 2005 to May 2006, the Western Ghats, India. A total of 4 phytoplankton divisions (Chlorophyta, Bacillariophyta, Rhodophyta, Cyanophyta) and 4 zooplankton phyla (Protozoa, Porifera, Nematoda, Arthropoda) were recorded during the study period. A total of 78 species of plankton belonging to 29 families have been documented. Of these, a total of 71 species of phytoplankton and 7 species of zooplankton

were recorded. Among the 22 families of phytoplankton, Naviculaceae (13 spp.), Desmidiaceae (13 spp.), Zygnemataceae (7 spp.) and Fragilaraceae (7 spp.) had the highest species representation followed by Cymbellaceae (4 spp.), Ulotrichaceae (3 spp.), and Hydrodictyaceae (3 spp.). A total of 6 and 9 families were represented by 2 and 1 species respectively. Among zooplankton, a total of 7 species belonging to 7 families were recognised.

Satra *et al.* (1991) studied the systematic on 24 genera and 46 species of phytoplankton from the mangrove delta of west Bengal; they observed seasonal variation of phytoplankton and suggest that phytoplankton abundance increase in winter season. India.

Gopinath and Redrigo (1991) discussed on primary production, qualitative studies on phytoplankton and hydrological parameters such as temperature, salinity, pH etc in the inshore water of Turicorin.

Phytoplankton in two English rivers was illustrated. Crayton and Sommerfield (1979) have investigated phytoplankton distribution and abundance in eleven tributaries of the Colorado River within the Grand Canyon.

Islam and Saha (1975) investigated the biological aspects of the river Buriganga near Dhaka city and they made a description and illustration of about 137 species of algae and 15 species of zooplankton.

2.5 Planktons in gher system

Singh (2011) studied on plankton abundance in fresh water fish pond at Malawan, Etah (U.P.). She conducted her study for a period of 8 month, from Oct. 2009 to May 2010. She observed thirteen genera of zooplankton and sixteen genera of phytoplankton. She also noticed phytoplankton is always dominant over zooplankton population. The monthly fluctuations of density and occurrence of different genera of plankton population and its correlation with some physico-chemical-variables had been discussed in the study.

Uddin *et al.* (2009) studied the Effects of substrate addition and supplemental feeding on plankton composition and production in tilapia (*Oreochromis niloticus*) and freshwater prawn (*Macrobrachium rosenbergii*) polyculture. They noticed the use of organic food increase plankton.

Ikpi *et al.* (2013) studied on plankton distribution and diversity in tropical earthen fish ponds. The observed that phytoplankton were more abundant during the dry season than the wet season, while occurrence zooplankton was more during the wet season than the dry. There was seasonal variation in the physico-chemical parameters of the pond water which in turn influenced the distribution and abundance of phytoplankton and zooplankton.

Lucas *et al.* (2010) studied the Eutrophication in a tropical pond: Understanding the bacterioplankton and phytoplankton dynamics during a vibriosis outbreak using flow cytometric analyses.

Ganapati (1943) studied the ecology of a garden pond containing abundant zooplankton. He noticed seasonal changes in the physico-chemical variables. Among zooplankton copepod was dominant. The highest abundance of copepod was found in December.

Roy *et al.* (2008) was also studied on zooplankton in a managed pond in Rajshahi, Bangladesh. He identified 21 genera of zooplankton and noticed that the highest peak of zooplankton was in October and lowest in September.

Islam *et al.* (2007) observed 16 genera of zooplankton of which rotifera was dominant. He worked on zooplankton of two shrimp ghers at Khulna, Bangladesh. He also noticed the higher the density of Prawn the lower the abundance of plankton.

Diurnal migration of plankton was observed by Ganapati (1955). He noticed diurnal variations in dissolved gasses, hydrogen ion concentration and some of the important dissolved substances of biological significance in three temporary rock ponds in stream-bed of Mettur dam. He marked a definite thermal, oxygen, carbonate and bicarbonate stratification at 2 p.m. and a complete circulation occurred by 6 a.m. daily. He found that the surface layer was supersaturated and the bottom layer under saturated. Diurnal movement of plankton was also observed by Bhuiyan *et al.* (1981).

CHAPTER -3

MATERIALS &

METHODS

3. Materials and Methods:

3.1 Location of the study area

The experiment was conducted in a village (Amvhta, Ramkrishnopur) at Dumuria, Khulna. Nine ghers were selected randomly from this village. All the experimental units were selected in the areas where farmers are practicing freshwater prawn culture for several years and possess knowledge on integration. The average size of all the ghers/ponds to be used for the experiment were about 50 decimal with the water depth of 1-1.5 m. Actually the culture pond surrounded with 2-3 ft high embankment that used as paddy field at the time of January to May when the water is completely dried. After harvesting paddy, the gher used as pond for prawn culture at the time of June to December through the help of rain water.

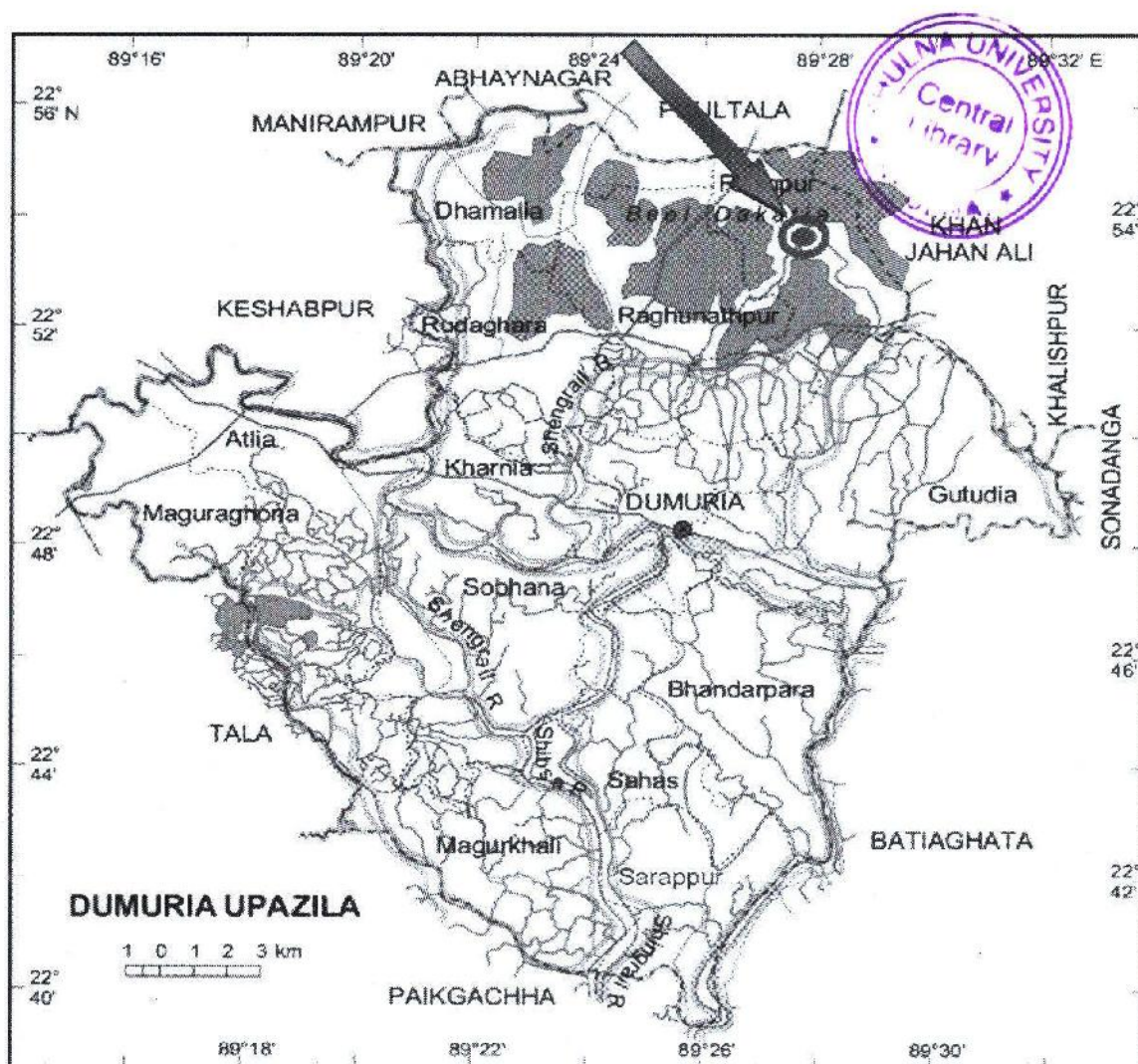


Fig: 1 Map of Dumuria Upazila location of the study area

3.2 Experimental design:

There were three types of research ponds (T_1 , T_2 , and T_3) with different stocking density of mola fish in prawn-carp gher system including three replications. Three representative samples were collected to increase accuracy of the result.

Table1. Experimental design

Fish	T_1	T_2	T_3
Prawn(<i>M. rosenbergii</i>)	$2/m^2$	$2/m^2$	$2/m^2$
Rohu (<i>L. rohita</i>)	$0.1/m^2$	$0.1/m^2$	$0.1/m^2$
Mola (<i>M. mola</i>)	$1/m^2$	$2/m^2$	$4/m^2$
Replication	3	3	3

3.3 Fertilization:

The ponds were fertilized with molasses and yeast powder at the rate of 30 kg molasses/ha, and 400g/ha, respectively in early September 2015.

3.4 Sample Collection and preservation:

Plankton samples were collected in 15 days interval at 09.30am to 10.30 am on each sampling date from September to December, 2015. Sample water was filtered using a 50 μm and 90 μm plankton net for phytoplankton and zooplankton respectively (Amanu, 2015). 20 liters of pelagic water from 4 different parts of the farm was passed through the plankton net with the help of a plastic pan of 10 liter capacity. The water was passed down through the net and the plankton condensed at the lower end of the plankton net then it was collected into a glass test tube and fixed firmly (Welch, 1952). The volume of concentrated water was 50 ml. After collection, the plankton materials were transferred into glass bottles and preserved with Lugol's solution. About 250 ml samples of plankton were preserved with 1.5 ml Lugol's solution (Rahi and Sabbir, 2010). After preservation the plankton samples were carried out to the Biology laboratory of FMRT Discipline for further analyses.

3.5 Plankton Identification

Plankton cells were enumerated under a light microscope by using Sedgwick-Rafter cell. Recognition of species is a matter of experience. Thus, a series of pencil and ink drawing on

postcards of the species of the observed were prepared to identify the organisms. Identification was done following Davis and Srivastava (1956), Zheng (1984).

3.6 Counting:

The quantitative enumeration of the zooplankton was carried out with the help of a Sedgwick-Rafter (S-R) counting cell which is 50 mm long, 20 mm wide and 1 mm deep. Before filling the S-R cell with sample, the cover glasses were diagonally placed across the cell and then samples were transferred with a large bore pipette so that no air bubbles in the cell covers were formed. The S-R cell was let stunned for at least 15 minutes to settle zooplankton. Then plankton on the bottom of the S-R cell was enumerated by using Electronic Microscope (Labomed Imaging Device, ivu 15,000) (Standard Methods). By moving the mechanical stage, the entire bottom of the slide area was examined carefully. To achieve a random sampling, each time 3 fields were examined for each sample and an average of the counts had been recorded. The organisms thus counted, were expressed as cells per liter (cells) of the sample. From each sample 40 cells counts in 3 slides have been made to achieve random counts and an average of the counts has been recorded. Number of plankton in the S-R cell was derived from the following formula Stirling (1985)-

$$N = \frac{A \times 1000 \times C}{V \times F \times L}$$

Where,

N= Number of plankton cells or units per liter of original water

A= Total number of plankton counted

C= Volume of final concentration of the samples in ml

V=Volume of a field in cubic mm

F= Number of fields counted

L= Volume of original water in liters

3.7 Statistical analyses

Statistical analysis was done using MS Excel, SPSS programme.

3.8 Parameters Analyzed for the Study

Different physico-chemical, biological and water quality parameters were investigated in this study as plankton abundance is influenced by water quality. The analysis was done both in the field and laboratory.

Different analytical methods were adopted for the determination of different physical, chemical, and biological parameters which are listed in table 2.

Table 2. Analytical methods used for the determination of water quality parameters

Category of Parameters	Parameters	Units	Method/ Instruction	References
Physical Parameters	Temperature	$^{\circ}\text{C}$	Centegrade Mercury Thermometer	Ramesh and Sophia, 2013
	Transparency	cm	Secchi disc	
Chemical parameters	DO	mg/L	Titration Method	
	Salinity	ppt	TDS meter (HI 9635, portable multirange conductivity/TDS meter, HANNA.	
	p^{H}		Microprocessor pH meter (HANNA instruments, pH 211	
	Ammonia (NH_3 -)	mg/L	Ammonia Test Kit, Model NI-SA	
	Nitrate(NO_3^-)	mg/L	Nitrate-Nitrite Test Kit, Model NI-12	
Biological Parameters	Phytoplankton Abundance	individual/L	Total cell counts	Standard Methods

CHAPTER -4

RESULTS



4. Results

4.1 Physico-chemical Parameters

4.1.1. Temperature

Temperature of water of the farm showed considerable variations throughout the study period. The maximum water temperature was recorded as 29°C in September, 2015 and minimum was recorded as 26 in December, 2015. Mean of water temperature during study period was found as $27.5 \pm 2.88^\circ\text{C}$

4.1.2. Dissolved O₂

The Dissolved Oxygen (DO) concentration of the farm was measured during study period. The Dissolved Oxygen (DO) of water ranged from 4.5 to 6 the maximum Dissolved Oxygen (DO) value was in the month of September and minimum in the month of December. Mean of Dissolved Oxygen (DO) value of water in the farm was found 5.18 ± 0.81 .

4.1.3. Water transparency

Transparency of water of the farm showed variations during the study period. The maximum transparency was recorded as 30 cm in September 2015 and minimum was recorded as 24 cm in December, 2015. Mean of water transparency during study period was found as 28.2 ± 4.63 .

4.1.4. pH

The hydrogen ion concentration or pH of the farm was measured during study period. The pH value of water ranged from 7.1 to 8.1. The maximum pH value was 8.1 in the month of December and minimum in the month of September. Mean of pH value of water in the farm was found 7.55 ± 0.39 . This may vary for different causes, such as food, water temperature, rainfall, and some other activities.

4.1.5. Salinity

Salinity indicates how much ion present in water. In this experiment rain water is used. And the water salinity is almost similar in all pond. There is no salinity in the water.

4.1.6. Hardness and Alkalinity

There is not so wide different in hardness and alkalinity among the pond. Generally Hardness varies between 500-650 CaCO₃/L and Alkalinity varies between 180-240 CaCO₃/L

4.1.7. Ammonia and Nitrate

Ammonia and nitrate are important water parameter for aquaculture. Change of ammonia concentration influence other parameter. As a result different deformities found in cultivable species. In culture pond ammonia and nitrate ranges from 0.4-1.2 and 0.3-1.0.

4.1.8. Free CO₂

Free carbon dioxide content was determined at monthly interval. Monthly variations were also noted. Free carbon dioxide of water ranged from 6.67 mg/L to 9.94mg/L.

Table 3. Mean water parameters in prawn-carp gher from September to December 2015.

Parameters	T1	T2	T3
Temperature (°C), range	26.0 - 29.25	26.55 - 29.75	26.55 - 29.0
Secchi depth (cm)	26.2±4.15	29.2±6.45	28.2±4.63
pH	7.7±0.68	7.18±0.39	7.18±0.29
DO (mg/L)	5.18±0.81	5.16±0.41	5.62±0.43
Alkalinity (mg/L)	223±33	218±33	189±29.31
Ammonia (mg/L)	0.31±.02	0.37±.02	0.36±.02
Nitrate Nitrogen (mg/L)	2.46±0.72	2.96±0.72	3.16±0.64
Free CO ₂	7.2375±2.12	7.575±2.12	7.575±2.12

4.2 Abundance and diversity of phytoplankton

In the present study 5 groups of phytoplankton were observed. These are Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta and Chrysophycophyt. A total of 25 phytoplankton genera, 7 belonging to Cyanophyceae, 7 to Chlorophyceae, 8 to Bacillariophyceae and 3 to Euglenophyceae were recorded. Throughout the study area phytoplankton species distribution was not uniform. It varied spatially and temporally e.g chlorophyta species were dominant. Most common species were *Gonium sp*, *Zygnem sp*, *Gonotozygon sp*, *Clamyolomonas sp*, *Dunaliella sp*, *Mougeotia parvula*, *Actinastrum sp*, *Volvox sp*, *Euglena sp*, *Phacus sp*, *Phacus pleuronectes*, *Cyclotella sp*, *Thalassiosira eccentric*, *Navicula sp*.

4.2.1 Monthly abundance of different groups of phytoplankton in Treatment-1 (Indiv./L)

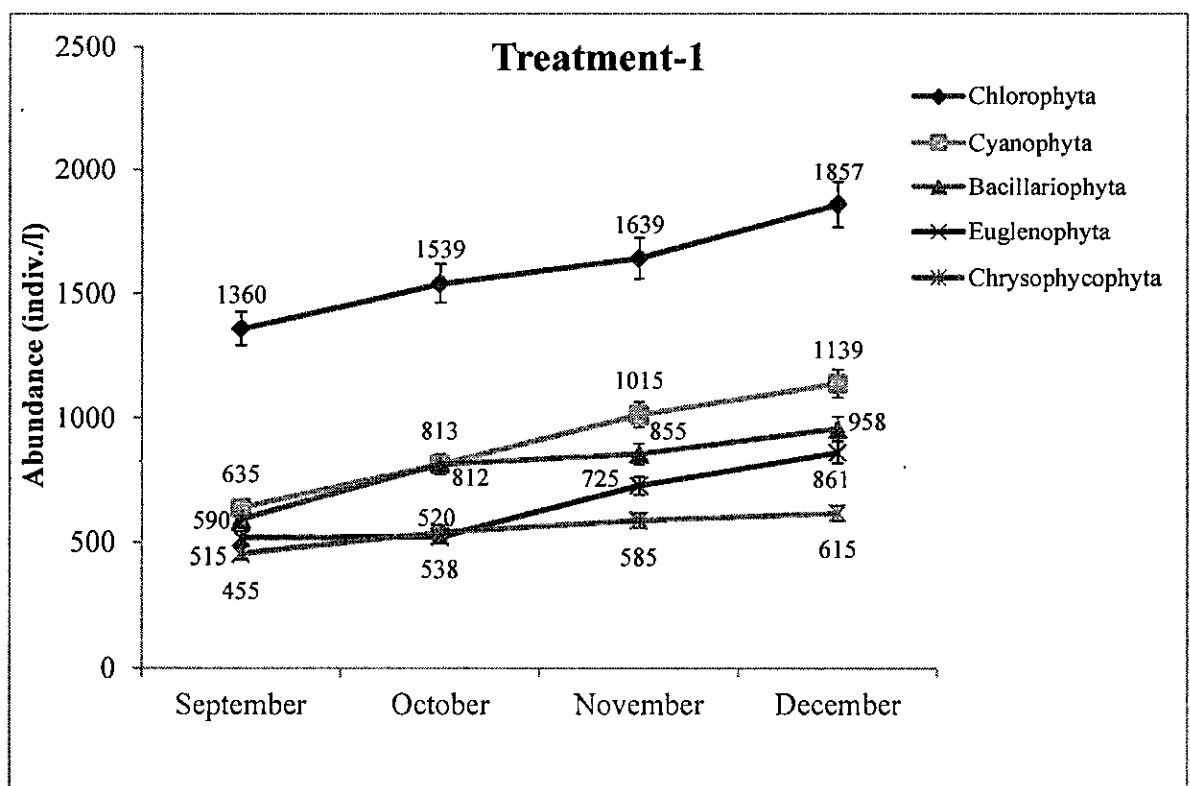


Fig 2. Different groups of phytoplankton in Treatment-1

4.2.2 Monthly abundance of different groups of phytoplankton in Treatment-2 (Indiv./L)

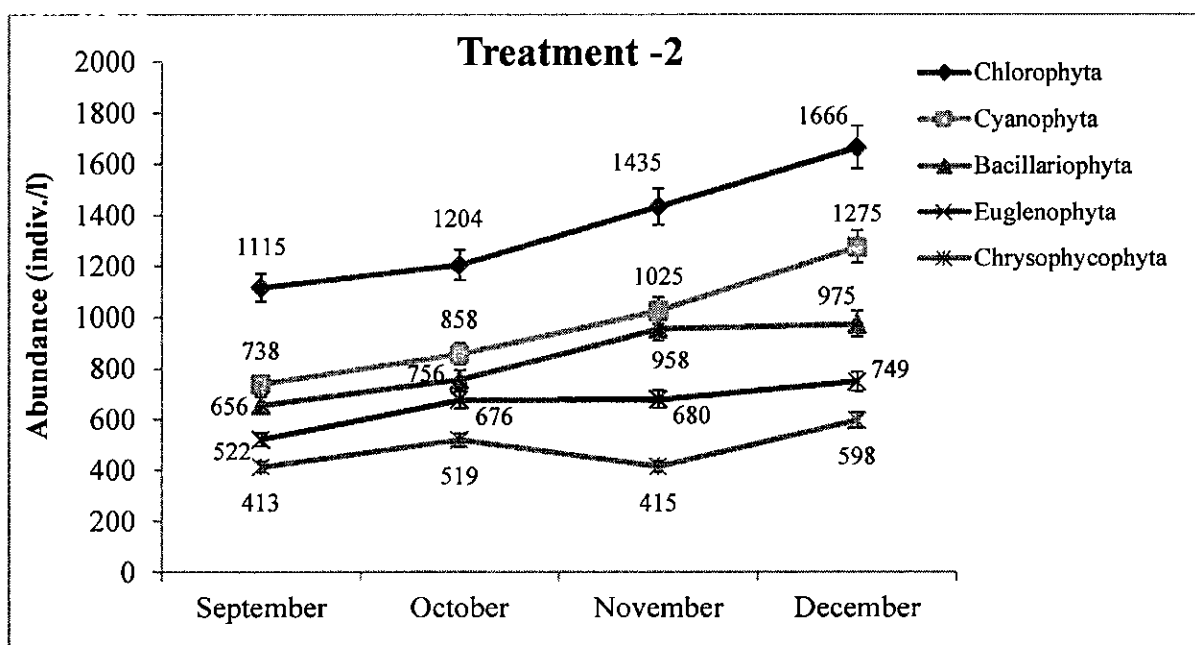


Fig 3. Different groups of phytoplankton in Treatment-2

4.2.3 Monthly abundance of different groups of phytoplankton in Treatment 3 (Individuals/L)

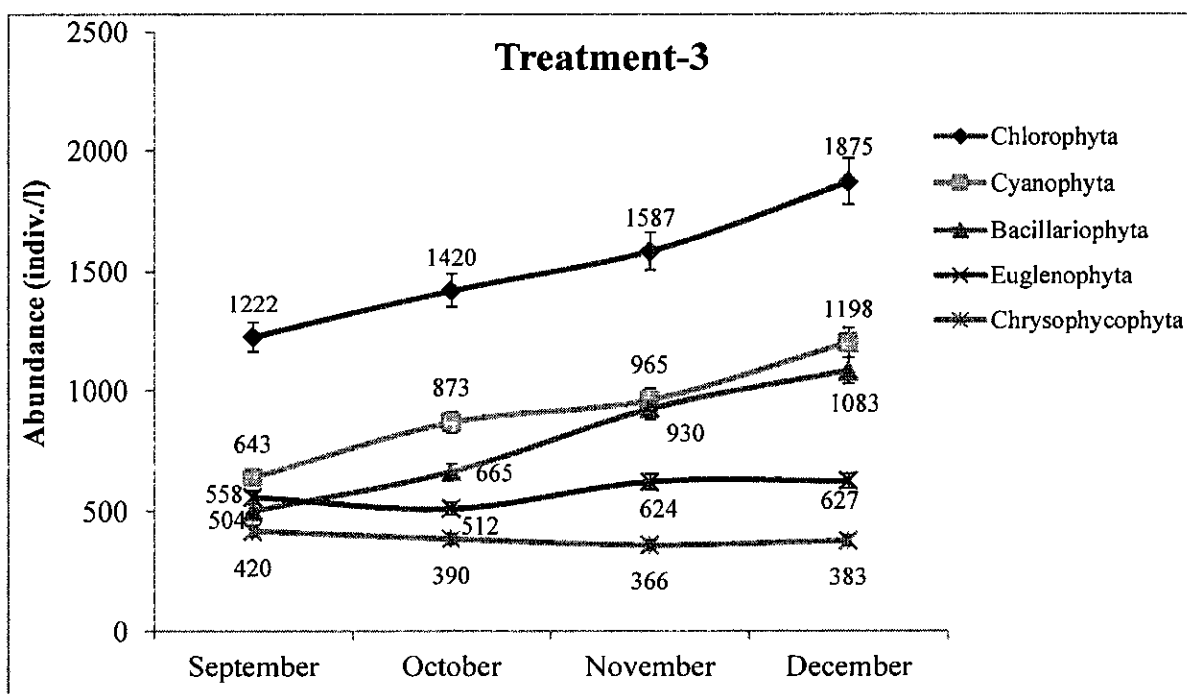


Fig 4. Different groups of phytoplankton in Treatment 3

4.3.1 Average abundance of different groups of phytoplankton in Treatment-1(Indiv./L)

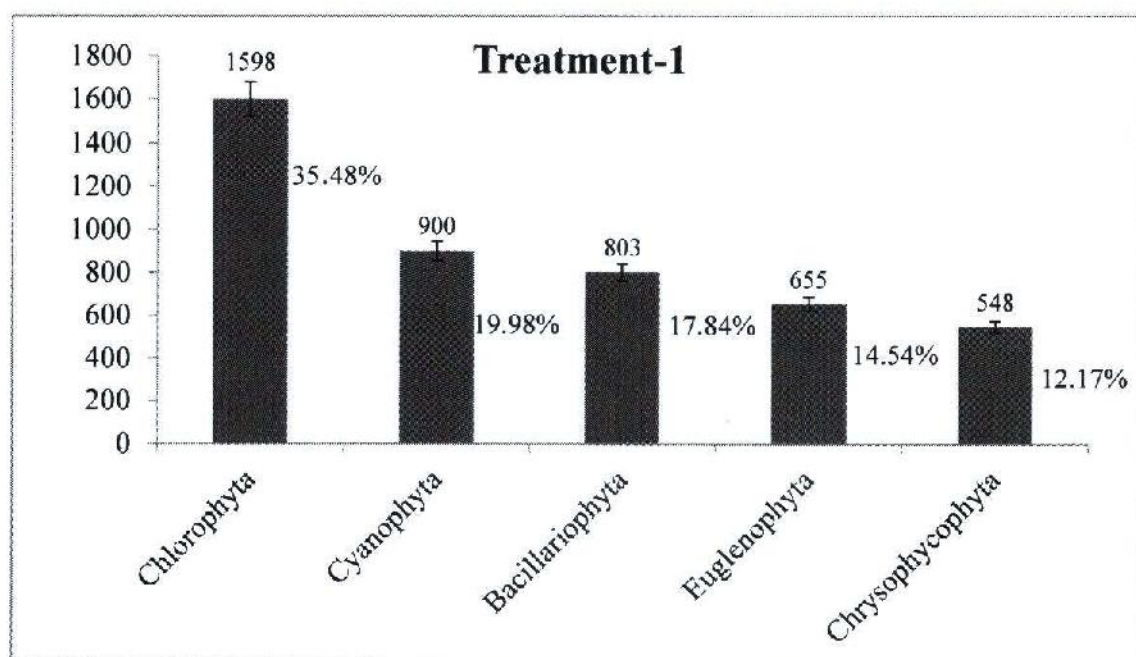


Fig 5. Average abundance of different groups of phytoplankton in Treatment 1 (Indivi./L)

4.3.2 Average abundance of different groups of phytoplankton in Treatment -2 (Indiv./L)

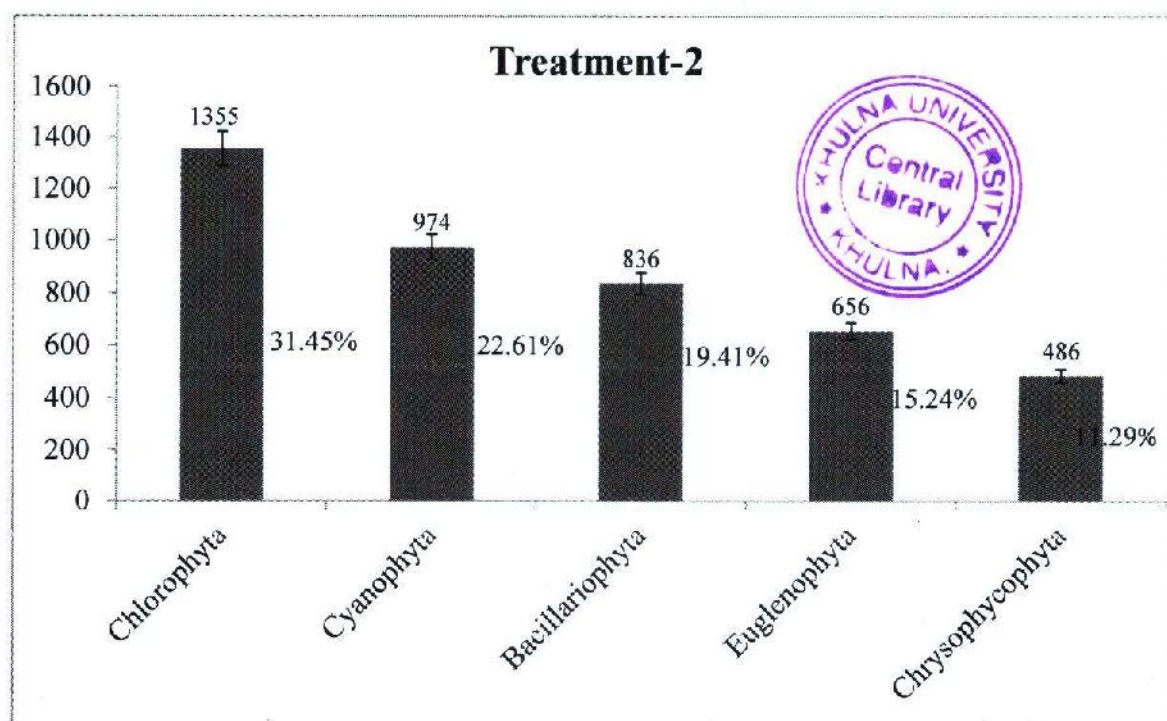


Fig 6. Average abundance of different groups of phytoplankton in Treatment -2 (Indivi./L)

4.3.3 Average abundance of different groups of phytoplankton in Treatment -3 (Indiv./L)

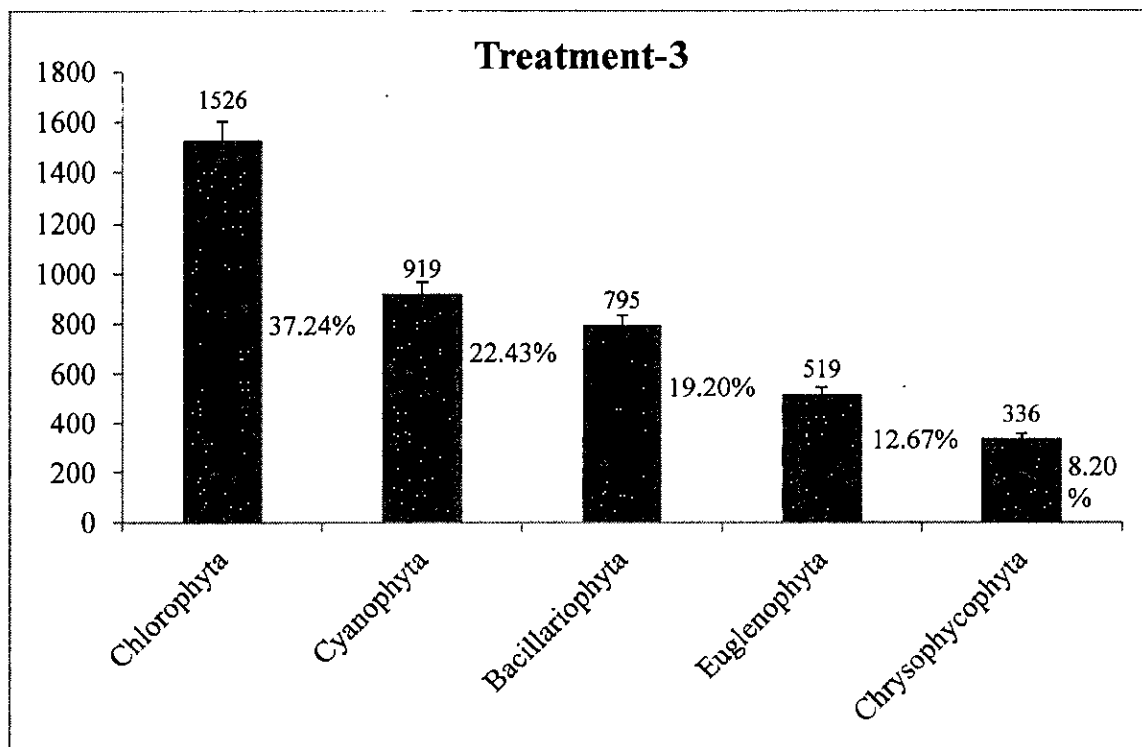


Fig 7. Average abundance of different groups of phytoplankton in Treatment -3 (Indiv./L)

Table. 4 Mean ($\pm$ SD) and range of abundance of phytoplankton in three different treatments (September, 2015 to December, 2015).

Group	T-1		T-2		T-3	
	Mean $\pm$ SD (indv./l)	Range	Mean $\pm$ SD (indv./l)	Range	Mean $\pm$ SD (indv./l)	Range
Chlorophyta	1598.75 $\pm$ 207.27 ^a	1360- 1857	1355 $\pm$ 247.33 ^a	1115- 1666	1526 $\pm$ 276.38 ^a	1222- 1875
Cyanophyta	900 $\pm$ 222.21 ^b	635-1139	974 $\pm$ 232.63 ^b	738-1275	919.75 $\pm$ 229.67 ^b	643- 1198
Bacillariophyta	803.75 $\pm$ 155.10 ^c	590-958	836.25 $\pm$ 155.99 ^c	656-975	795.5 $\pm$ 259.96 ^c	504- 1083
Euglenophyta	655.25 $\pm$ 168.48 ^d	515-861	656.75 $\pm$ 95.87 ^d	749-522	519.5 $\pm$ 39.94 ^d	475- 571
Chrysophycophyta	548.25 $\pm$ 69.77 ^e	455-615	486.25 $\pm$ 89.44 ^e	598-413	336.25 $\pm$ 27.91 ^e	302- 370

Chlorophyta were 1st dominant in the three treatments. The mean ($\pm$ SD) values were 1598.75 $\pm$ 207.27, 1355 $\pm$ 247.33 and 1526 $\pm$ 276.38 of total phytoplankton in T-1, T-2 and T-3 respectively (Table 4).

Cyanophyta were 2nd dominant in three treatments. The mean ($\pm$ SD) values were 900 $\pm$ 222.21, 974 $\pm$ 232.63 and 919.75 $\pm$ 229.67 of total phytoplankton in T-1, T-2 and T-3 respectively (Table 4)

Bacillariophyta were 3rd dominant in three treatments. The mean ($\pm$ SD) values were 803.75 $\pm$ 155.11, 836.25 $\pm$ 155.99 and 795.5 $\pm$ 259.96 of total phytoplankton in T-1, T-2 and T-3 respectively (Table 4).

Euglenophyta were 4th dominant in three treatments. The mean ($\pm$ SD) values were 655.25 $\pm$ 168.48, 656.75 $\pm$ 95.88 and 519.5 $\pm$ 39.94 of total phytoplankton in T-1, T-2 and T-3 respectively (Table 4).

Chrysophycophyta were the least dominant in three treatments.

The difference of phytoplankton abundance was significant in different treatments.

Table 5. Abundance of phytoplankton in different treatments from September, 2015 to December, 2015 (Indiv./L)

Treatment	Month				Average
	September	October	November	December	
T ₁	3555 ^a	4222 ^a	4819 ^a	5430 ^a	4506
T ₂	3444 ^b	4013 ^b	4513 ^b	5263 ^b	4308
T ₃	3247 ^c	3773 ^c	4308 ^c	5060 ^c	4097

4.4 Monthly variation in the abundance (indiv./l) of phytoplankton in different treatments.

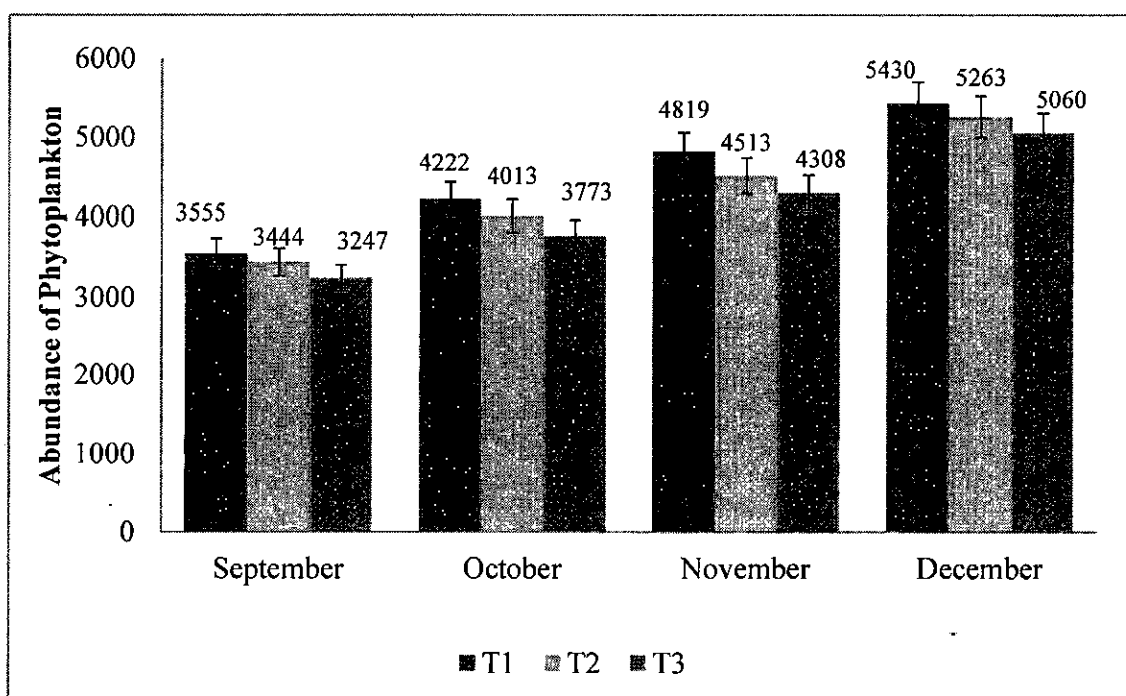


Fig 8. Monthly variation in the abundance (indiv./l) of phytoplankton in different treatments.

This figure shows that the abundance (indiv./l) of phytoplankton in every month was the highest in T-1 moderately high in T-2 and lowest abundance was in T-3. And the difference of phytoplankton abundance was significant in different treatments.

4.5 Comparison among different treatments of average phytoplankton abundance

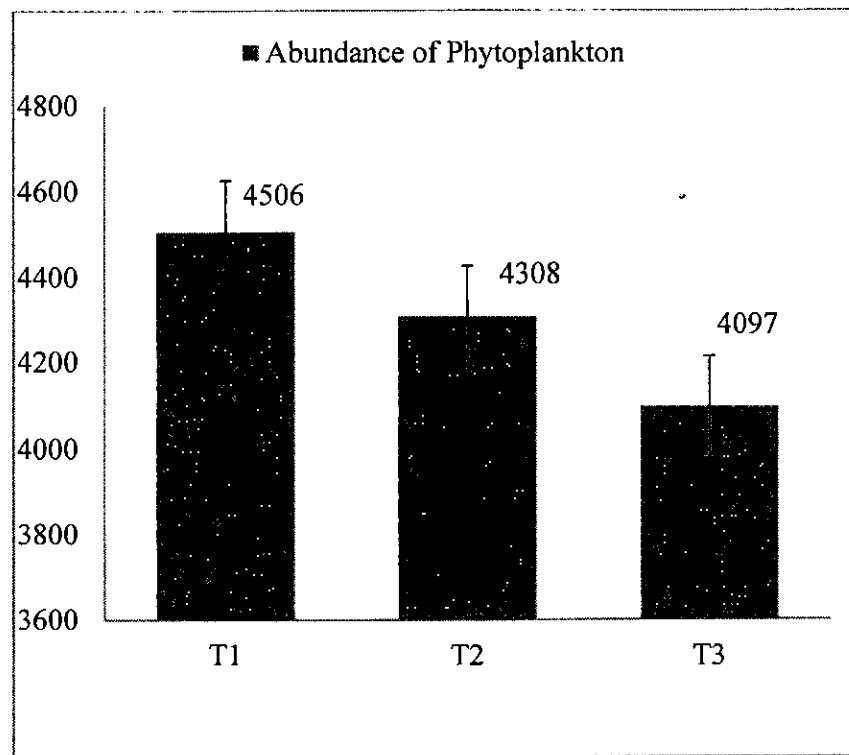


Fig 9. Average phytoplankton abundance (indiv./l) at different treatments.

This graph shows that the average abundance of phytoplankton is highest in T-1 in which the stocking density (1 indiv. /m²) of mola fish was lowest. The lowest abundance was found in T-3 in which the stocking density (4 indiv. /m²) of mola fish was highest.

4.6 Zooplankton abundance and diversity

The zooplankton population was composed of the numbers of copepod, rotifer, cladocera, ostracoda and different crustacean larvae. A total of 8 genera were recorded from the study farm. Among them 3 belonged to copepod, 2 to rotifer, 2 to cladocera, 1 to ostracoda and others crustacean larvae. Diaptomus, Cyclops and Mesocyclops were under the group of copepod of which Mesocyclops was dominant. Two genera namely Diaphanosoma and Daphnia were observed belong to cladocera while only cypris was found under the group of ostracod.

4.6.1 Monthly abundance of different groups of zooplankton in Treatment 1 (Indiv./L)

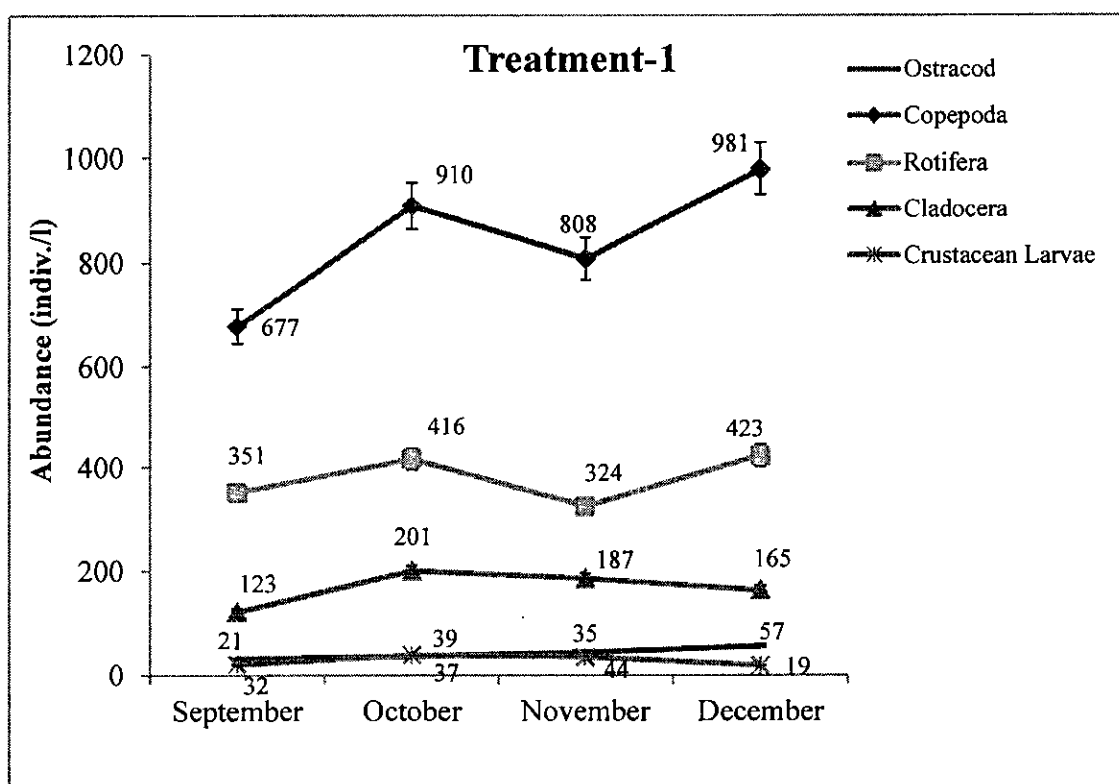


Fig 10. Different groups of zooplankton in Treatment 1

4.6.2 Monthly abundance of different groups of zooplankton in Treatment 2 (Indiv./L)

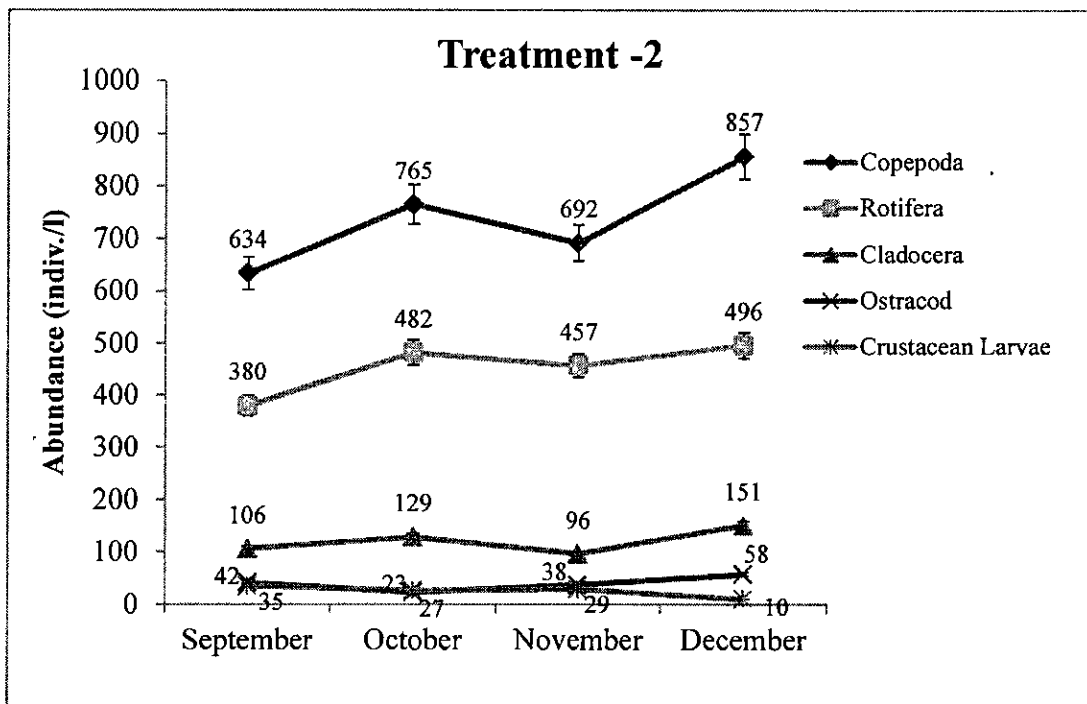


Fig 11. Different groups of zooplankton in Treatment-2

4.6.3 Monthly abundance of different groups of zooplankton in Treatment 3 (Indiv./L)

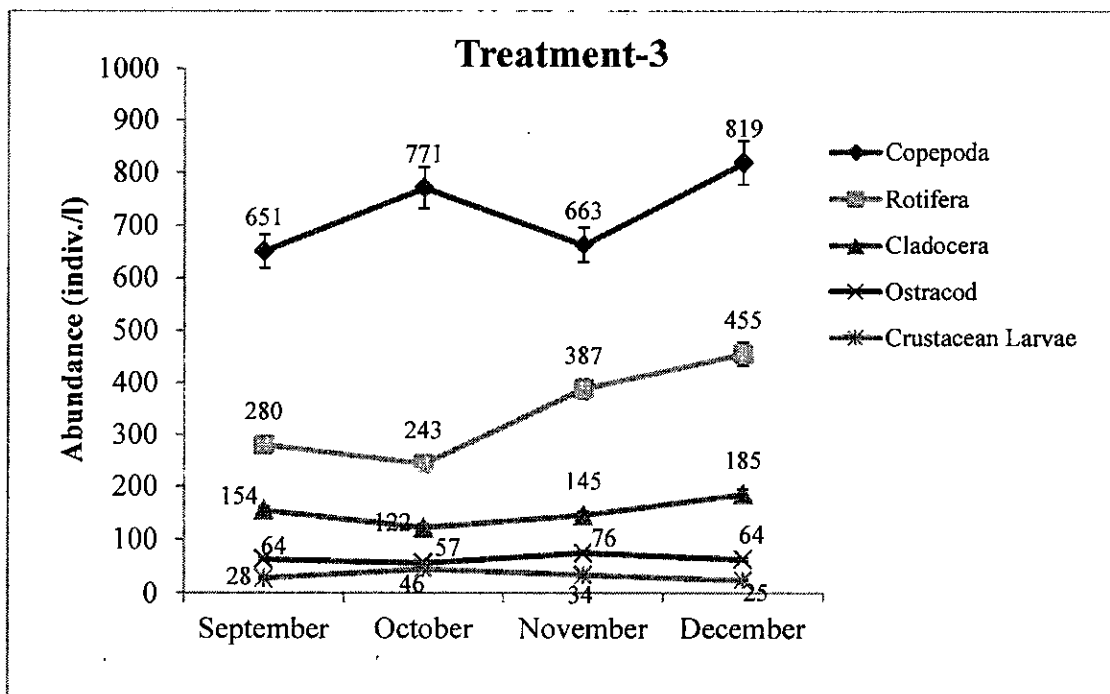


Fig 12. Different groups of zooplankton in Treatment-3

4.7.1 Average abundance of different groups of zooplankton in Treatment-1 (Individuals/L)

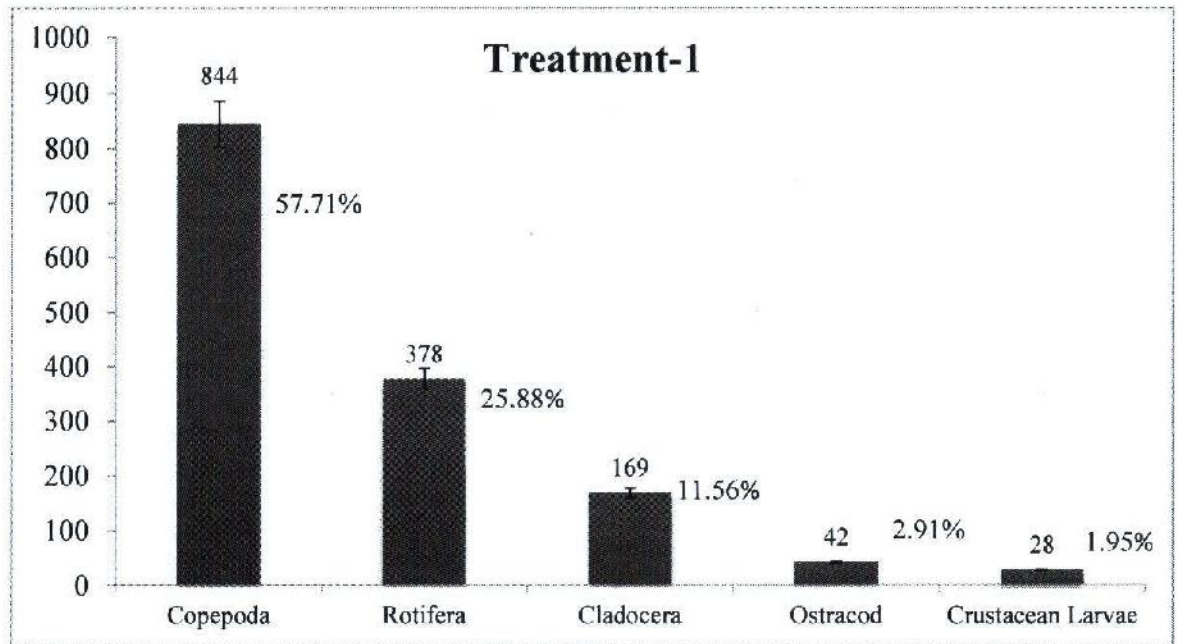


Fig 13. Average abundance of different groups of zooplankton in Treatment -1 (Indiv./L)

4.7.2 Average abundance of different groups of zooplankton in Treatment -2 (Indiv./L)

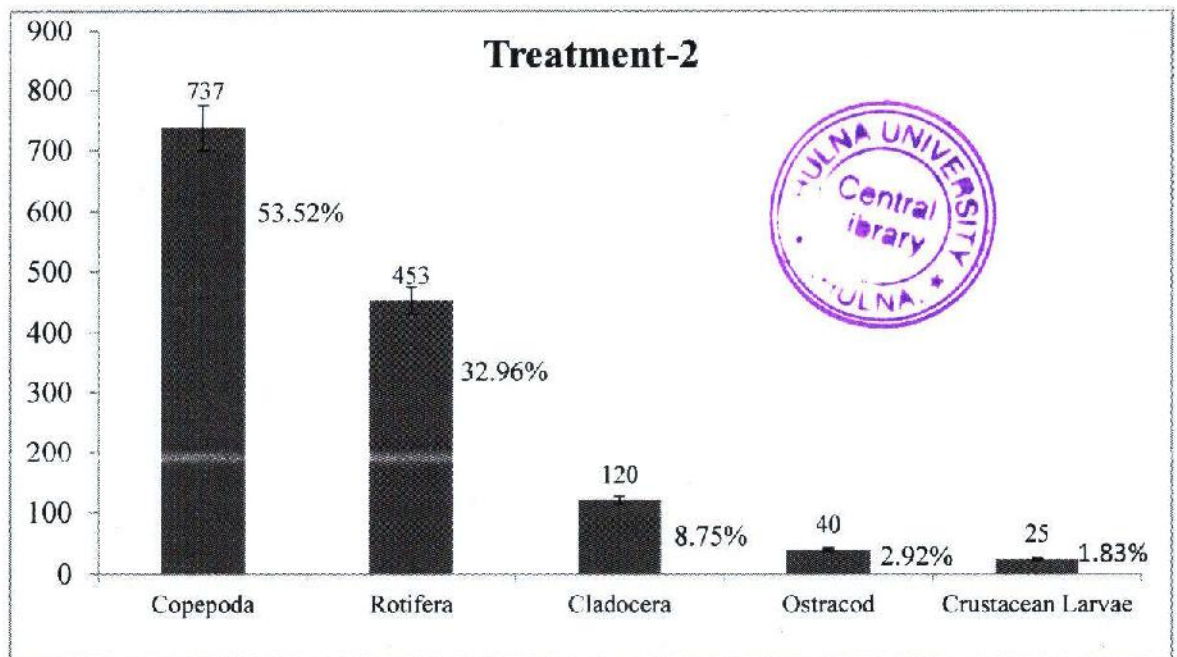


Fig 14. Average abundance of different groups of zooplankton in Treatment -2 (Indiv./L)

4.7.3 Average abundance of different groups of zooplankton in Treatment -3 (Indiv./L)

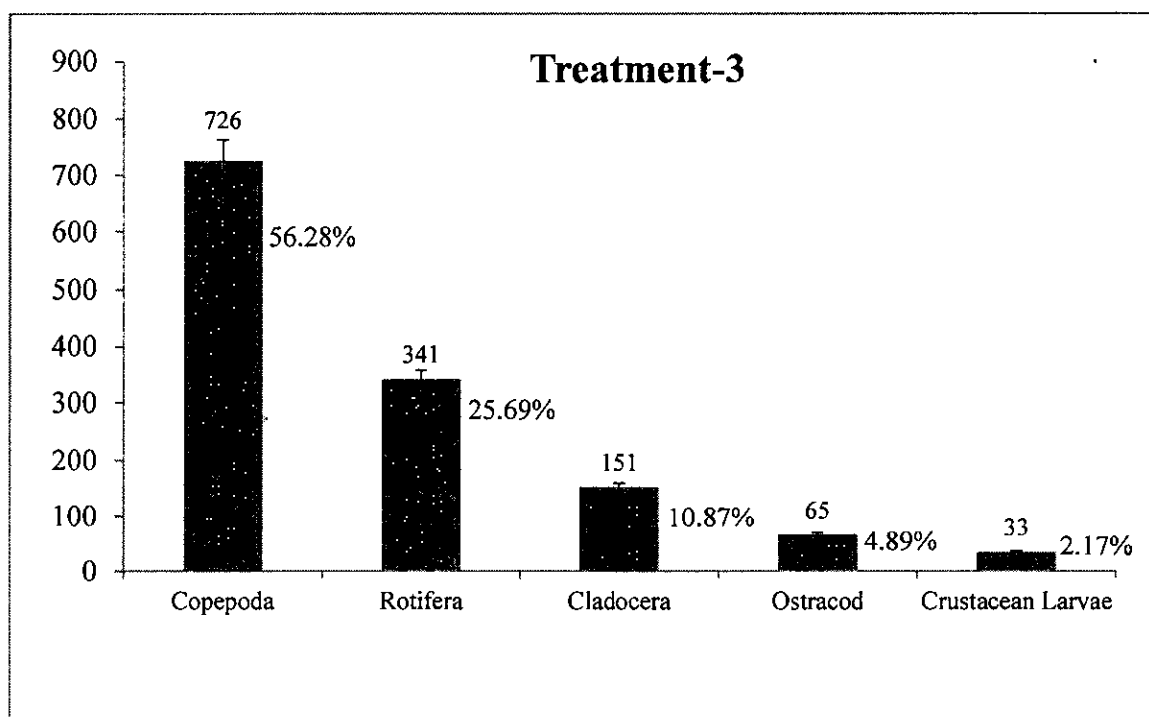


Fig 15. Average abundance of different groups of zooplankton in Treatment -3 (Indiv./L)

Table 6: Mean ($\pm$ SD) and range of zooplankton abundance (indv./l) in three different treatments (September, 2015 to December, 2015).

Group	T 1		T2		T3	
	Mean+SD	Range	Mean+SD	Range	Mean+SD	Range
Copepod	844 $\pm$ 132.05 ^a	677-981	737 $\pm$ 96.29 ^a	634-857	725 $\pm$ 82.97 ^a	651-819
Rotifera	378.5 $\pm$ 48.69 ^b	312-423	453.75 $\pm$ 51.74 ^b	380-496	331.25 $\pm$ 93.05 ^b	243-455
Cladocera	169 $\pm$ 34.06 ^c	123-201	120.5 $\pm$ 24.58 ^c	96-151	140.5 $\pm$ 22.40 ^c	107-154
Ostracod	42.5 $\pm$ 10.85 ^d	32-57	40.25 $\pm$ 14.38 ^d	23-58	63.5 $\pm$ 10.63 ^d	50-76
Crustacean Larvae	28.5 $\pm$ 9.98 ^e	19-39	25.25 $\pm$ 10.72 ^d	10-35	28.25 $\pm$ 4.03 ^e	25-34

Copepods were the 1st dominant in three treatments. The mean values were 844 $\pm$ 132.05, 737 $\pm$ 96.29 and 725 $\pm$ 82.97 of total zooplankton in T-1, T-2 and T-3 respectively (Table 6).

Rotifers were 2nd dominant group during study period in different treatments. The mean values were 378.5 $\pm$ 48.69, 453.75 $\pm$ 51.74 and 331.25 $\pm$ 93.05 of total zooplankton in T-1, T-2 and T-3 respectively (Table 6).

cladocerans constituted the 3rd dominant group in all treatments. The mean values were 169 $\pm$ 34.058, 120.5 $\pm$ 24.583 and 140.5 $\pm$ 22.40 of total zooplankton population in T-1, T-2 and T-3 respectively (Table 6).

Ostracod were 4th dominant group during study period in different treatments The mean values of Ostracod were 42.5 $\pm$ 10.847, 40.25 $\pm$ 14.385 and 63.5 $\pm$ 10.63 of total zooplankton population in T-1, T-2 and T-3 respectively (Table 6).

Crustacean Larvae were the lowest dominant group. The mean values were 28.5 $\pm$ 9.983, 25.25 $\pm$ 10.719 and 28.25 $\pm$ 4.03 of total zooplankton population in T-1, T-2 and T-3 respectively (Table 6).

And the difference of zooplankton abundance was significant in different treatment.

Table 7. Abundance of zooplankton in different months (Individuals/L)

Treatment	Month				Average
	September	October	November	December	
T ₁	1204 ^a	1603 ^a	1398 ^a	1645 ^a	1462
T ₂	1197 ^b	1426 ^b	1312 ^b	1572 ^b	1376
T ₃	1177 ^c	1197 ^c	1262 ^c	1517 ^c	1288

4.8 Monthly variations in the abundance of zooplankton in different treatments.

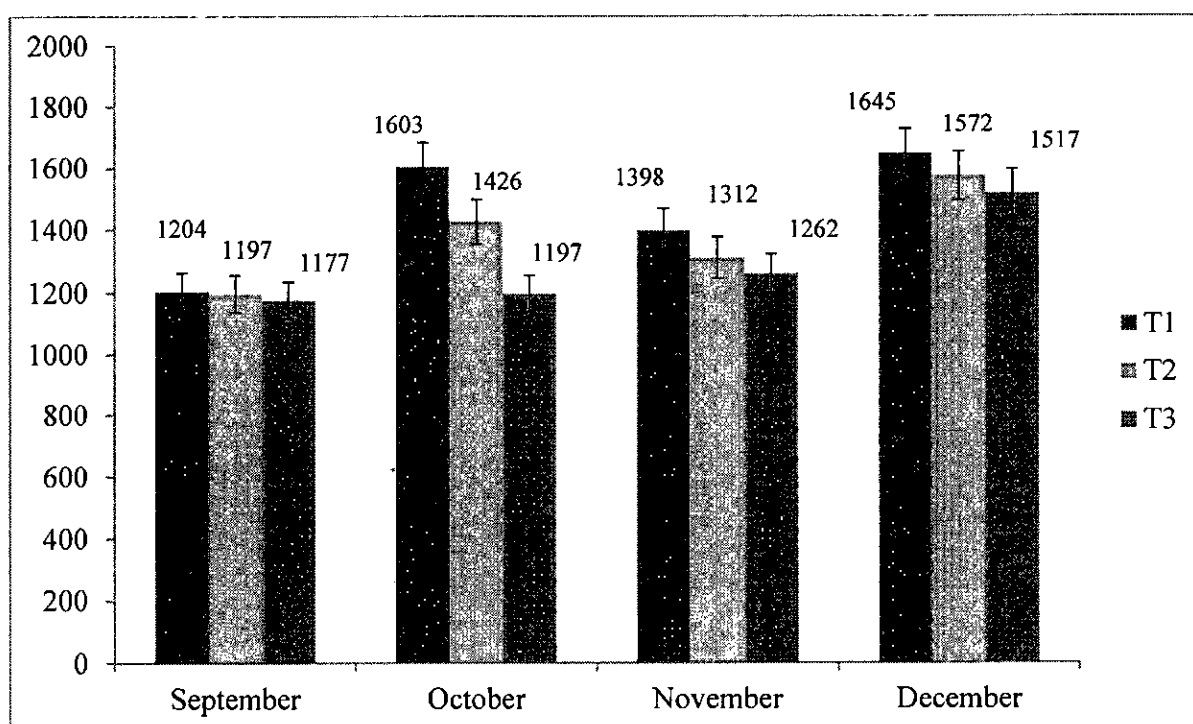


Fig 16. Monthly variations in the abundance of zooplankton in different treatments.

This figure shows that the abundance (1645 indiv./l) of zooplankton was highest T-1. In case of T-2 the abundance was moderately high. The lowest abundance (1177 indiv./l) was in T-3. And the difference of zooplankton abundance was significant in different treatment.

4.9 Comparison among different treatments of average zooplankton abundance.

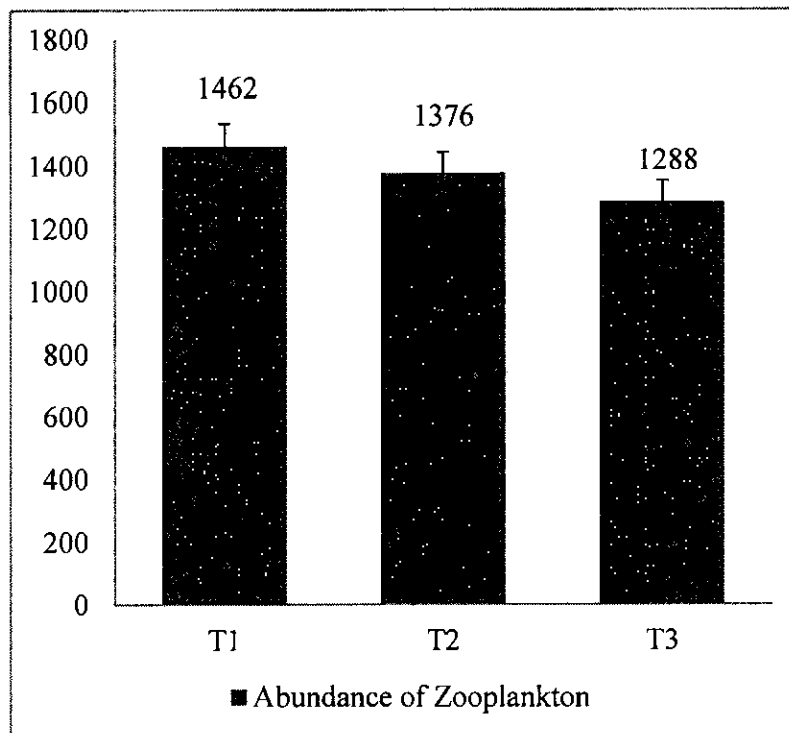


Fig 17. Average zooplankton abundance at different treatments.

This graph shows that the average abundance of zooplankton (1462 indv./l) was highest in T-1 in which the stocking density (1 indv./m²) of mola fish was lowest. The lowest abundance (1288 indv./l) was found in case of T-3 where the stocking density (4 indv./m²) of mola fish was highest. And the difference of zooplankton abundance was significant in different treatment.

Phytoplankton Picture

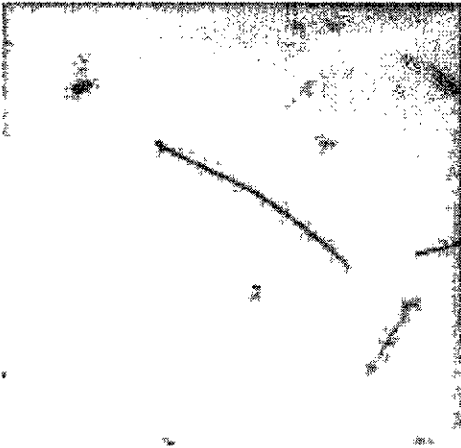


Fig. 7. *Thalassionema*

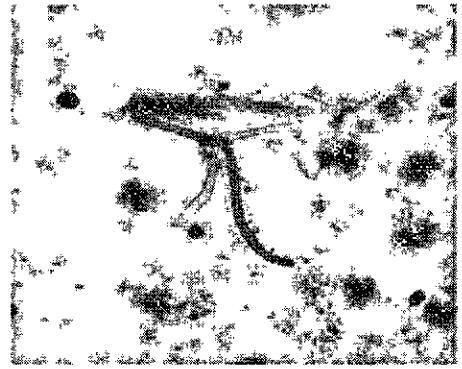


Fig. 8. *Oscillatoria* sp

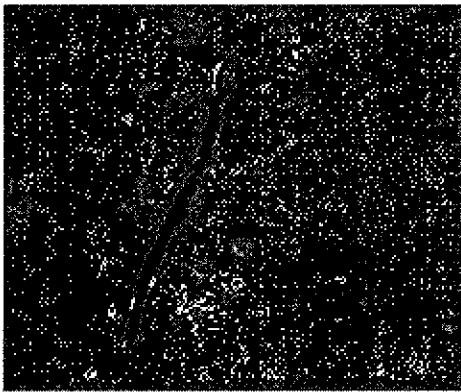


Fig. 9. *Oscillatoria agardhii*

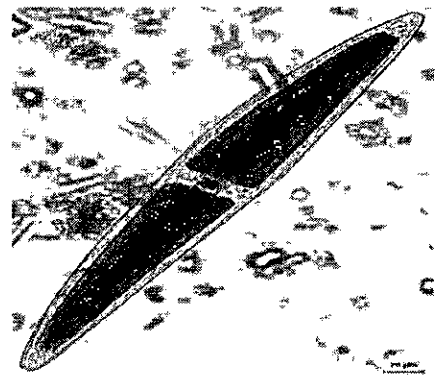


Fig. 10. *Closterium acerosum*

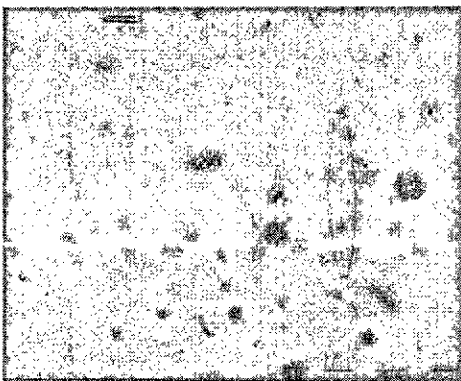


Fig. 11. *Navicula* sp.

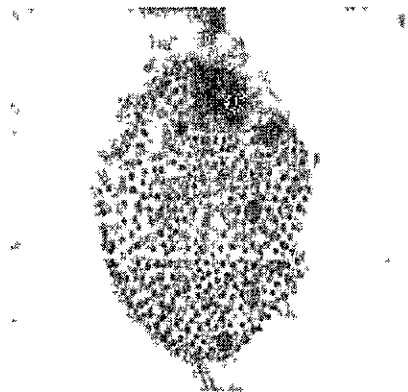


Fig. 12. *Volvox* sp.

CHAPTER -5

DISCUSSION

5. Discussion

Plankton plays an important role in the water of prawn-carp farm ecosystem as a primary producer and is an important source of food for the fish (Habib *et al.*, 1984 and Ali *et al.*, 1985). There have been relatively a few studies of plankton species diversity in the Prawn-carp farm water.

In present study the abundance of plankton was the highest in case of treatment T₁ (1 indiv./m²), moderately high in treatment T₂ (2 indiv./m²) and the lowest abundance was found in treatment T₃ (4 indiv./m²). Mola fish is a surface feeder and it feeds on plankton. That is why plankton abundance in treatment T₃ (4 indiv./m²) was comparatively low where the mola fish stocking was highest. It was observed through the investigation that the abundance of plankton was decreased by higher stocking of mola fish through consumption. Mola fish is planktivorous in nature feeding mostly phytoplankton and could be a suitable species for integrated rich-fish farming given by Mondal *et al.* (2013).

5.1 Phytoplankton

In the present study, I recorded Chlorophyta (35.48%), Cyanophyta (19.98%), Bacillariophyta (17.84%), Euglenophyta (14.45%) and Chrysophyta (12.17%) in T₁, in T₂ Chlorophyta (31.45%), Cyanophyta (22.61%), Bacillariophyta (19.41%), Euglenophyta (15.24%) and Chrysophyta (11.29%) and in T₃ Chlorophyta (37.24%), Cyanophyta (22.43%), Bacillariophyta (19.20%), Euglenophyta (12.67%) and Chrysophyta (8.20%) respectively. Similar findings were made by Affan *et al.* (2005).

They studied on Seasonal Cycle of Phytoplankton in Aquaculture Ponds in Bangladesh in Ishakha Lake, BAU and found Chlorophyta (42.4 %), Cyanophyta (19.5%), Bacillariophyta (31.40 %), Euglenophyta (6.70 %) in Lake Ecosystem.

Boonyapiwat *et al.* (2008) also studied on Species Composition, Abundance and Distribution of Phytoplankton in the Bay of Bengal in North, west and east station in the Bay of Bengal and found Cyanophyta (68.12%), Bacillariophyta (27.67%), Dinophyta (2.63%) and Dictyochophyta (1.59 %) in ocean ecosystem.

The species composition of the treatment ponds showed group composition Chlorophyta>Bacillariophyta>Cyanophyta>Euglenophyta>Chrysophyta which is similar with Akteret *al.*, (2015). The study area was mostly dominated by chlorophyta, fewer cyanophyta,

and some bacillariophyta and euglenophyta. The highest density of Chlorophyta 1875(individual/L) was found in December, 2015 and lowest 1115(individual/L) in September when p^H values were found 7.8 and 7.2 respectively. DO values were recorded 5.16 mg/l, 5.45 mg/l respectively. Similar findings were made by Ikpi *et al.* (2013) also recorded.

During this study period the mean ($\pm$ SD) values were 4506.5 ± 803.49 (indv./l), 4308.25 ± 771.91 indv./l and 4211.25 ± 785.24 (indv./l) of total phytoplankton in T₁, T₂ and T-3 respectively. Present study shows that, group composition of phytoplankton was highest in T₁ where the mola fish stocking was lowest (1 indiv./m²) and the lowest abundance was in T₃ where the mola fish stocking was highest (4 indiv./m²). The reason of this phytoplankton abundance variation was the different stocking density of mola fish in the treatment ponds.

A total of 25 phytoplankton genera, 7 belonging to Cyanophyceae, 7 to Chlorophyceae, 8 to Bacillariophyceae and 3 to Euglenophyceae were recorded. Chowdhury and Mamun (2006) also reported similar findings.

During the study period the total number of phytoplankton was dominated by Chlorophyta about 35.48% among all the groups. Similar result was also given by Amanu (2015), Chalinda and Sommerfeld (2000).

5.2 Zooplankton

In the present study, 5 groups of zooplankton were observed. These are copepod, rotifer, cladocera, ostracoda and crustacean larvae. The average percentages of Copepoda, Rotifera, Cladocera, Ostracoda and Crustacean Larvae in the treatment ponds were 55.5%, 28.3%, 10.61%, 3.56% and 2.09% respectively. The mean values were 1462.5 ± 203.32 (indv./l), 1376.75 ± 160.16 indv./l and 1317.25 ± 162.46 indv./l of total zooplankton in T-1, T-2 and T-3 respectively. Similar finding was made by Mozumder *et al.* (2014).

They studied the abundance of zooplankton and physico-chemical parameters of a polyculture fish pond of manikganj, Bangladesh. They conducted study during June 2003 to May 2004 and found Copepoda 56.07%, Rotifera 27.49% Nauplii 11.96%, Cladocera 1.49% and Protozoa 2.99% of total zooplankton.

Kabir *et al.* (2014) also studied on zooplankton of harda baor of Meherpur district; composition and seasonal succession and found rotifers (38.02%), copepods (50.78%), cladocerans (5.66%) and protozoans (5.54 %) of total zooplankton.

Rahman and Hussain (2008) also studied on the abundance of zooplankton of a culture and a non-culture pond of the Rajshahi university campus. They found 9 genera belongs to five groups of zooplankton where copepods (1260 units/l and 973.33 units/l in pond-1 and pond-2 respectively) were most dominant.

In the present study, the zooplankton showed its peak, 1645 units/l (November and December) in winter. Such peak was recorded by Menon *et al.* (1981) from a fish pond at Mymensingh. George (1961) observed maximum population of zooplankton in December, 1399 units/l was observed in different habitats. Patra and Azadi (1987) also found the peak in winter from the Halda River in Bangladesh.

Copepod was the dominant group (55.5%) among the zooplankton during study period which supports Kabir *et al.* (2014).

Islam *et al.* (2007) also found the highest abundance of Copepod (60%) was in the month of December and the lowest in September. They worked on zooplankton of two shrimp ghers in Khulna, Bangladesh.

Roy (2008) was also observed a peak (59%) in the copepod populations in October and other peaks in December when pH values were found 7.6 and 8.4 and DO values were recorded 5.52 mg/l and 5.75 mg/l.

The peak in winter might be due to the favorable conditions of physico-chemical parameters and the availability of nutrients in the pond.

In the present study the rotifer was second dominant (28.23% of total zooplankton) group among the zooplankton. The highest population (496 units/l) was found in December and lowest (243 units/l) in October. Similar finding was made by Kabir *et al.* (2014), during the winter season due to higher degree of photosynthesis; amount of phytoplankton increased and in turn resulted in the higher production of nutrients of rotifers which might result in flourish of rotifers during winter season. Though the photoperiod was shorter in winter yet photosynthesis increased due to clear sky.

The abundance of zooplankton not only depends on season but also different water quality parameters. Nair *et al.* (2015) pointed out that pH and dissolve organic content of water influence the abundance of rotifera population, where water temperature played a positive role. In the present investigation water was always alkaline.

In present study Cladocera contributed 10.61% of the total zooplankton. The highest density 201(units/l) was found in October and lowest 96 (units/l) in November. The members of cladocera were very poor in number. This group showed irregular pulses during the study period. Irregular pulses of cladocerons were also reported by Islam (2007) in different conditions.

Islam (2007) reported that the irregular pulses of cladocerans might have been caused by different duration of life span of different genus. Life span of various genera depends upon various physico-chemical factors. During field observation, the abundance of crustacean larvae 45(units/l) was higher in the months of October.

CHAPTER -6

CONCLSION

6. Conclusion

The study represents the abundance of various groups of Plankton that was significantly fluctuated by the three different stocking densities of mola fish (*Amblypharyngodon mola*). It was observed through the investigation that the abundance of plankton was decreased by higher stocking of mola fish through consumption. During study period 25 genera belong to 5 groups of phytoplankton namely Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta were observed. Among all groups Chlorophyta was the dominant and the average percentages of Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta, and Chrysophycophyta in the three treatments were 34.72%, 21.67%, 18.81%, 14.15% and 10.55% respectively. In the study area 8 genera belong to 5 groups of zooplankton were identified. Copepod was the most dominant group among the identified zooplankton in the culture farm. Among various groups of zooplankton, the percentages of Copepoda, Rotifera, Cladocera, Ostracoda and Crustacean Larvae were 55.84%, 28.18%, 10.39%, 3.57% and 1.98% respectively. Present study was such an attempt to know the abundance and diversity of plankton between the ponds of three different stocking densities of plankton in those ponds. The findings of the present study would be helpful as baseline information for further plankton related research. However, more studies are required to know broadly the effect of stoking density of fish on the abundance and diversity of plankton in fish farm.

CHAPTER -7

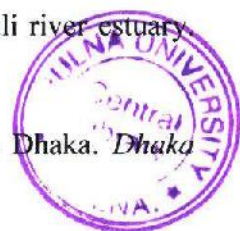
REFERENCE

Reference:

- Affan, A., Jewel, A. S., Haque, M., Khan, S., & Lee, J. B. (2005). Seasonal cycle of phytoplankton in aquaculture ponds in Bangladesh. *Algae*, 20(1), 43-52.
- Alam, A.K.M.N., Islam, M.A., Mollah, M.F.A. and Haque, M.S. 1987. Status of zooplankton in newly constructed ponds and their relation to some meteorological and limnological factors. *Bangladesh Journal of Fisheries*, 14(1): 83-88.
- Ali, M.M., Islam, M.A. and Habib, M.A.B. 1985. Monthly abundance of zooplankton and correlation of various dominant species and nauplius of zooplankton with some water characters in a pond. *University Journal of Zoology, Rajshahi University*, 4:42-49.
- Amanu, W.Z. 2015. Comparative study on composition and abundance of major planktons and physico-chemical characteristics among two ponds and Lake Tana, Ethiopia. *Journal of Coastal Life Medicine* 2015; 3(11): 852-856.
- Anadu, D.I., Obioha, A. and Ejike, C. 1991. Water quality and plankton periodicity in two contrasting mine lakes in Joss, Nigeria. *Hydrobiologia*, 208(1-2): 17-26.
- Arora, H.C. 1963. Rotifera as indicators of trophic nature of environments. *Hydrobiologia*, 27: 146-158.
- Bairagi, A., Sakar Ghosh, K., Sen, S.K. and Ray, A.K. 2002. Enzyme producing Bacterial flora isolated from fish digestive tracts. *Aquaculture International* 10, 109–121.
- Bal, D.V. and Pradhan, L.B. 1952. A preliminary note on the plankton of Bombay harbor. *Current science*, 14: 211-212.
- Balakrishna, D., Reddy, T.R., Reddy, K.V. and Samatha, D. 2013. Physico-chemical parameters and plankton diversity of ghanpur lake, WARANGAL, A.P., INDIA. *International Journal of Zoology Research*. Volume 3, Issue 1, 2013, pp.-44-48.
- Bardach, E.J., Ryther, H.J. and Melarny, O.W. 1972. The farming and husbandry of fresh water and marine organisms. *John-Wiley and Sons, Inc.* New York.
- Bhat, N.A., Wanganeo, A. and Raina, R. 2015. Variability in water quality and phytoplankton community during dry and wet periods in the tropical wetland, Bhopal, India. *J Ecosys Ecograph* 2015, 5:1.

- Bhuiyan, A.M., Hafizuddin, A.K.M. and Pasha, M.K. 1981. Diurnal movement of plankton in a pond. *Chittagong University Studies*, Part II (5): 41-49.
- Boonyapiwat, S., Sada, M. N., Mandal, J. K., & Sinha, M. K. (2008). Species composition, abundance and distribution of phytoplankton in the Bay of Bengal. The ecosystem-based fishery management in the Bay of Bengal. SEAFDEC, Thailand, 53-64.
- Chalinda, A. and Sommerfeld, M.R. (2000). Composition and abundance of phytoplankton in tributaries of the Lower Colorado River, Grand Canyon region. *Hydrobiologia*, 166:81-93.
- Chowdhury, A., H. and Mamun, A. 2006. Physio-chemical conditions and plankton population of two fishponds in Khulna. Univ. j. zool. Rajshahi Univ. Vol. 25, 2006. pp. 41-44
- Crayton, M.W. and Sommerfeld, M.R. 1979. Composition and abundance of phytoplankton in tributaries of the Lower Colorado River, Grand Canyon region. *Hydrobiologia*, 166:81-93.
- Das, N.G. and Bhuyan, A.L. 1974. Limnoplankton of some inland waters of Dhaka city. *Bangladesh Journal of Zoology*, 2(1):27-42.
- Das, S.M. and Srivastva, V.K. 1956. Some new observations on plankton from fresh water ponds and tanks of Lucknow, India. *Science of aquaculture*, 21(8):466-467.
- DoF (Department of Fisheries). 2006. "Matshya Pakkha 2003". A publication on the occasion on of Fisheries Fortnight, Department of fisheries. Matshya Bhaban, Park Avenew Ramna, Dhaka. 68. *Emer Life Sci Res* (2015) 1(2): 35-40
- Ferrari, I. 1976. Winter limnology of a mountain lake. *Hydrobiologia*. 51(3): 245-257.
- Ganai, M. and Parveen, M. 2013. Effect of physico-chemical conditions on the structure and composition of the phytoplankton community in Wular Lake at Lankrishipora, Kashmir.
- Ganapati, S.V. 1943. An ecological study of garden pond containing abundant zooplankton. *Indian academic science (Botany)*, 17(2): 41-58.
- Ganapati, S.V. 1955. Diurnal variations in dissolved gases, hydrogen-ion concentration and some of the important dissolved substances of biological significance in three temporary rocky pools in stream bed of Mettur Dam. *Hydrobiologia*, 7: 285-303.
- George, M.G. 1961. Diurnal variation in two shallow ponds in Delhi. *Hydrobiologia*, 18: 265-273.
- Gopinath and Redrigo, 1991. The use of probiotics in aquaculture. *Aquaculture* 180, 147-165.

- Habib, M.A.B.; Islam, M.A.; Mohsinuzzaman, M. and Rahman, M.S. 1984. Effect of some physico-chemical factors of water on the abundance and fluctuation of zooplankton of two selected ponds. *University Journal of Zoology, Rajshahi University*, 3: 27-34.
- Hossain, M. Z. and Chowdhury, A. H. 2004. Phytoplankton abundance in relation to physico-chemical conditions of the Sundarbans estuary in Burigoalini forest station. *Journal of Environmental Biology*.2:30-52.
- Hossain, S., Rahman, M., Akter, M. and Bhowmik, S. 2015. Species composition and abundance of zooplankton population in freshwater pond of Noakhali district, Bangladesh. *World Journal of Fish and Marine Sciences* 7 (5): 387-393, 2015
- Ikpi, G.U., Offem, B.O. & Okey, I.B. 2013. Plankton distribution and diversity in tropical earthen fish ponds. *Environment and Natural Resources Research*; Vol. 3, No. 3; 2013
- International Journal of Biodiversity and Conversation*. Vol. 6(1), pp. 71-84, January 2014
- Islam, A.B.M.W., Manira, M.S., Rahman, M.M. and Zaman, M. 2007. Zooplankton of two Shrimp Ghers at Khulna, Bangladesh. *South Asian Journal of Agriculture*, 2 (1&2): 117-122.
- Islam, A.K.M.N. and Aziz, Z. 1975. Studies on the phytoplankton of the Karnaphuli river estuary. *Journal of Bangladesh academy of Sci.* Vol. 1. No. 2. 141-154.
- Islam, A.K.M.N. and Saha, J.K. 1975. Limnological studies of the Ramna lake in Dhaka. *Dhaka University studies*, 23(2): 39-46.
- Kabir, A.K.M.N. and Naser, M. N. 2014. Zooplankton of harda baor of Meherpur district: composition and seasonal succession. *National University Journal of Science* Vol. 1, No. 1, 2014
- Khan, A.A., Munzurul, H., Aziz, K.M.S., Morshed, M.G. and Shafi, M. 1990. Seasonal variations in physico-chemical conditions of Dhanmondi lake water. *Bangladesh Journal of Zoology*, 8(1): 61-66.
- Khondaker, M. and Walker, L. 1993. Study on the physical and chemical limnology of a shallow, hypertrophic artificial lake in Bangladesh. *Bangladesh Journal of Science*, 10(1): 9-16.
- Krishnamoorthi, K.P. and Visweswara, V.G. 1966. Hydrobiological studies in the Gandhi Sagar (Jumna Tank) and seasonal variation in plankton. *Hydrobiologia*, 127:50- 54.
- Lucas, R., Courties, C., Herbland, A., Gouilletquer, P., Marteau, A.L. and Lemonnier, H. 2010. Eutrophication in a tropical pond: Understanding the bacterio plankton and Phytoplankton



- Ratha, S.K., Naik, K. and Padhi, S.B. 2003. Epiphytic algal diversity associated with different aquatic macrophytes of fresh water ponds in and around Berhampur university campus, Orissa, India. *Nat. Env.and Poll. Tech.* vol.2 no.2: p. 205-208.
- Riley, G.A. 1946. Factors controlling phytoplankton populations on Georges Bank. *Journal of Marine Research*,6:54-73.
- Roy, K.R., Islam, A.B.M.W., Khan, M.A.M., Rahaman, M.M. and Zaman, M. 2008. Zooplankton in a managed pond in Rajshahi, Bangladesh. *Khulna Univresity Studies*, 9(1): 91-100.
- Satra, S.C., Pal, V.C. and Choudhury, A. 1991. Marine phytoplankton of the Mangrove delta region of West Bengal India. *J. mar, boil.Ass. India*,33, 192-307pp.
- Singh, M. 2011. Study of plankton abundance in fresh water fish pond at Malawan, Etah(U.P.). *Ind Boil Stud Res Vol.* 1(1). 2011pp39-44.
- Sopana, Booonyapiwat, Sada, M. N., Mandal, J. K. and Sinha, M. K. 2003. Species Composition, Abundance and Distribution of Phytoplankton in the Bay of Bengal. In Report on Fisheries Resources Survey in Myanmar Waters. SEAFDEC (in press).4:53-64.
- Stirling, H.P. 1985. Chemical and Biological methods of water analysis for aquaculturists. Institute of Aquaculture, University of Stirling, Scotland.119pp.
- Straskrba, M. 1965. Contribution to the productivity of the littoral region of pools and ponds.1. Quantitative study of the littoral zooplankton of the rich vegetation of the back water labicko. *Hydrobiologia*, (3): 421-443.
- Uddin, M.S., Azimb, M.E., Wahab, M.A. and Verdegem, M.C.J. 2009. Effects of substrate addition and supplemental feeding on plankton composition and Production in tilapia (*Oreochromis niloticus*) and fresh water prawn (*Macrobrachium rosenbergii*) polyculture. Department of Fisheries Management, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh,3:130-142.
- Welch, P.S. 1952. Limnological Methods. McGraw Hill, New York. PP. 429.
- Zheng, Z. 1984. Marine Planktology. *China Ocean Press*, Beijing.

Appendix

Table 5: Abundance (indiv./l) of phytoplankton in T-1 with three replicates

	T-1			Average
	P-1	P-2	P-3	
September	3541	3500	3625	3555.333
October	4125	4250	4291	4222
November	4791	4875	4791	4819
December	5416	5500	5375	5430.333
Average	4468.25	4531.25	4520.5	4506.667

Table 6: Abundance (indiv./l) of phytoplankton in T-2 with three replicates

	T-2			Average
	P-1	P-2	P-3	
September	3500	3457	3375	3444
October	3875	4041	4125	4013.667
November	4375	4666	4500	4513.667
December	5125	5375	5291	5263.667
Average	4218.75	4384.75	4322.75	4308.75

Table 7: Abundance (indiv./l) of phytoplankton in T-3 with three replicates

	T3			Average
	P-1	P-2	P-3	
September	3416	3250	3375	3247
October	3957	3875	3750	3773
November	4500	4625	4291	4308
December	5166	5291	5041	5060
Average	4259.75	4260.25	4114.25	4097

Table 8: Average abundance (indiv./l) of phytoplankton in three treatments

	T-1	T-2	T-3
September	3555	3444	3247
October	4222	4013	3773
November	4819	4513	4308
December	5430	5263	5060
average	4506.5	4308.25	4097

Table 9: Abundance (indiv./l) of zooplankton in T-1 with three replicates

	T1				Average
	P1	P2	P3	Total	
September	1187	1156	1270	3613	1204.333
October	1562	1687	1562	4811	1603.667
November	1406	1437	1353	4196	1398.667
December	1656	1718	1562	4936	1645.333
Average	1452.75	1499.5	1436.75	1463	1463

Table 10: Abundance (indiv./l) of zooplankton in T-2 with three replicates

	T2			Average
	P1	P2	P3	
September	1218	1125	1250	1197.667
October	1406	1437	1437	1426.667
November	1250	1375	1312	1312.333
December	1468	1687	1562	1572.333
Average	1335.5	1406	1390.25	1377.25

Table 11: Abundance (indiv./l) of zooplankton in T-3 with three replicates

	T3			Average
	P1	P2	P3	
September	1125	1281	1125	1177
October	1437	1125	1156	1197
November	1312	1250	1353	1262
December	1520	1625	1500	1517
Average	1348.5	1320.25	1283.5	1288.25

Table 12: Average abundance (indiv./l) of zooplankton in three treatments

	T1	T2	T3
September	1204	1197	1177
October	1603	1426	1197
November	1398	1312	1262
December	1645	1572	1517
Average	1462.5	1376.75	1288.25

Table 13: Phytoplankton abundance (indiv./l) and diversity in T-1

	Chlorophyta	Cyanophyta	Bacillariophyta	Euglenophyta	Chrysophycophyta	Total Phytoplankton
September	1360	635	590	515	455	3555
October	1539	813	812	520	538	4222
November	1639	1015	855	725	585	4819
December	1857	1139	958	861	615	5430
Total	6395	3602	3215	2621	2193	18026
Average	1598.75	900.5	803.75	655.25	548.25	

Table 14: Phytoplankton abundance (indiv./l) and diversity in T-2

	Chlorophyta	Cyanophyta	Bacillariophyta	Euglenophyta	Chrysophycophyta	Total Phytoplankton
September	1115	738	656	522	413	3444
October	1204	858	756	676	519	4013
November	1435	1025	958	680	415	4513
December	1666	1275	975	749	598	5263
Average	1355	974	836.25	656.75	486.25	4308.25

Table 15: Phytoplankton abundance (indiv./l) and diversity in T-3

	Chlorophyta	Cyanophyta	Bacillariophyta	Euglenophyta	Chrysophycophyta	Total Phytoplankton
September	1222	643	504	508	370	3247
October	1420	873	665	475	340	3773
November	1587	965	930	524	302	4308
December	1875	1198	1083	571	333	5060
Average	1526	919.75	795.5	519.5	336.25	4097

Table 16: Zooplankton abundance (indiv./l) and diversity in T-1

	Copepoda	Rotifera	Cladocera	Ostracod	Crustacean Larvae	Total Zooplankton
September	677	351	123	32	21	1204
October	910	416	201	37	39	1603
November	808	324	187	44	35	1398
December	981	423	165	57	19	1645
Average	844	378.5	169	42.5	28.5	

Table 17: Zooplankton abundance (indiv./l) and diversity in T-2

	Copepoda	Rotifera	Cladocera	Ostracod	Crustacean Larvae	Total Zooplankton
September	634	380	106	42	35	1197
October	765	482	129	23	27	1426
November	692	457	96	38	29	1312
December	857	496	151	58	10	1572
Average	737	453.75	120.5	40.25	25.25	1376.75

Table 18: Zooplankton abundance (indiv./l) and diversity in T-3

	Copepoda	Rotifera	Cladocera	Ostracod	Crustacean Larvae	Total Zooplankton
September	651	280	154	64	28	1177
October	771	243	107	50	26	1197
November	660	347	145	76	34	1262
December	819	455	154	64	25	1517
Average	725	331.25	140	63.5	28.25	1288.25



Analysis of ANOVA for different Treatment (phytoplankton)

Tests of Between-Subjects Effects

Dependent
Variable: Abundance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	251410.889 ^a	2	125705.444	26.204	.001
Intercept	1.667E8	1	1.667E8	3.475E4	.000
Treatment	251410.889	2	125705.444	26.204	.001
Error	28782.667	6	4797.111		
Total	1.670E8	9			
Corrected Total	280193.556	8			

a. R Squared = .897 (Adjusted R Squared = .863)

Abundance

Tukey B

Treatment	N	Subset		
		1	2	3
3	3	4.0970E3		
2	3		4.3080E3	
1	3			4.5063E3

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square (Error) = 4797.111.

Analysis of ANOVA for same treatment among different phytoplankton groups in T₁

Tests of Between-Subjects Effects

Dependent

Variable: Abundance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.042E6 ^a	4	510404.100	1.276E3	.000
Intercept	1.217E7	1	1.217E7	3.043E4	.000
Treatment	2041616.400	4	510404.100	1.276E3	.000
Error	4000.000	10	400.000		
Total	1.422E7	15			
Corrected Total	2045616.400	14			

a. R Squared = .998 (Adjusted R Squared = .997)

Abundance

Tukey B

Treatment	N	Subset				
		1	2	3	4	5
5	3	5.4800E2				
4	3		6.5500E2			
3	3			8.0300E2		
2	3				9.0000E2	
1	3					1.5980E3

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square (Error) = 400.000.

Analysis of ANOVA for same treatment among different phytoplankton groups in T₂

Tests of Between-Subjects Effects

Dependent
Variable: Abundance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.320E6 ^a	4	330059.400	880.158	.000
Intercept	1.113E7	1	1.113E7	2.968E4	.000
Treatment	1320237.600	4	330059.400	880.158	.000
Error	3750.000	10	375.000		
Total	1.245E7	15			
Corrected Total	1323987.600	14			

a. R Squared = .997 (Adjusted R Squared = .996)

Abundance

Tukey B

Treatment	N	Subset				
		1	2	3	4	5
5	3	4.8600E2				
4	3		6.5600E2			
3	3			8.3600E2		
2	3				9.7400E2	
1	3					1.3550E3

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square (Error) = 375.000.

Analysis of ANOVA for different Treatment (zooplankton)

Tests of Between-Subjects Effects

Dependent
Variable: Abundance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	45419.556 ^a	2	22709.778	20.511	.002
Intercept	1.704E7	1	1.704E7	1.539E4	.000
Treatment	45419.556	2	22709.778	20.511	.002
Error	6643.333	6	1107.222		
Total	1.709E7	9			
Corrected Total	52062.889	8			

a. R Squared = .872 (Adjusted R Squared = .830)

Abundance

Tukey B

Treatment	N	Subset		
		1	2	3
3	3	1.2883E3		
2	3		1.3770E3	
1	3			1.4623E3

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square (Error) = 1107.222.

Analysis of ANOVA for same treatment among different zooplankton groups in T₁

Tests of Between-Subjects Effects

Dependent
Variable: Abundance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	984407.067 ^a	4	246101.767	1.553E3	.000
Intercept	994336.267	1	994336.267	6.275E3	.000
Treatment	984407.067	4	246101.767	1.553E3	.000
Error	1584.667	10	158.467		
Total	1980328.000	15			
Corrected Total	985991.733	14			

a. R Squared = .998 (Adjusted R Squared = .998)

Homogeneous Subsets

Abundance

Tukey B

Treatment	N	Subset				
		1	2	3	4	5
5	3	28.0000				
4	3		63.3333			
3	3			1.4000E2		
2	3				3.3100E2	
1	3					7.2500E2

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square (Error) = 158.467.

Analysis of ANOVA for same treatment among different zooplankton groups in T₂

Tests of Between-Subjects Effects

Dependent

Variable: Abundance

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.161E6 ^a	4	290158.500	1.025E3	.000
Intercept	1134375.000	1	1134375.000	4.006E3	.000
Treatment	1160634.000	4	290158.500	1.025E3	.000
Error	2832.000	10	283.200		
Total	2297841.000	15			
Corrected Total	1163466.000	14			

a. R Squared = .998 (Adjusted R Squared = .997)



Abundance

Tukey B

Treatment	N	Subset			
		1	2	3	4
5	3	25.0000	1.2000E2	4.5300E2	7.3700E2
4	3	40.0000			
3	3				
2	3				
1	3				

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square (Error) = 283.200.