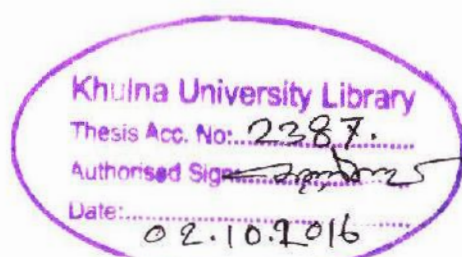


**COMPARATIVE STUDY ON PLANKTON ABUNDANCE AND
DIVERSITY AMONG THE THREE VILLAGES OF SOUTHWEST
REGION IN BANGLADESH**



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Fisheries & Marine Resources Technology Discipline

Khulna University

Khulna, Bangladesh

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**A Thesis
on
Comparative Study on Plankton Abundance and Diversity among the three
villages of Southwest Region in Bangladesh**

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By

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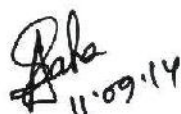
Khulna, Bangladesh

April, 2014

DECLARATION

Comparative Study on Plankton Abundance and Diversity among the three villages of Southwest Region in Bangladesh

The results presented in the thesis with the above mentioned title are entirely of 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.



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Dedicated To

My Beloved Parents

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Abstract

The study was conducted at the water bodies of three villages namely Southkhali, Nolian and Southkadamtala located near the coastal belt of Sundarban mangrove forest to compare abundance and diversity of phytoplankton and zooplankton among the three villages and between the inside and outside of the embankment. In each village plankton samples were collected from three study areas both the inside and outside of the embankment. A total of 32 phytoplankton species from outside of the embankment and 25 species from inside of the embankment were identified. The identified phytoplanktons were under the class Chlorophyceae, Bacillariophyceae, Cyanophyceae, Dinophyceae and Euglenophyceae. Among them Bacillariophyceae was the most dominant class (44.13%). The average phytoplankton abundance was varied from 480 to 2630 ind/l. Phytoplankton abundance was most dominant in Southkadamtala study area (2630 ind/l) and lowest (480 ind/l) in Nolian study area. In case of zooplankton, a total of 27 species from outside of the embankment and 20 species from inside of the embankment were identified. The identified zooplanktons were under the class Rotifera, Copepoda, Branchiopoda, Bivalvia, Crustacea, Hydrozoa, Polychete and Clitellata. Among the classes, Copepoda was the most abundant (56.25%). The average zooplankton abundance varied from 600 to 1908 ind/l. Plankton abundance was recorded highest in inside of the embankment except Southkadamtala. Among the study areas Southkhali study area both outside and inside of the embankment was most diversified for both phytoplankton and zooplankton. Diversity indices such as Shannon-Wiener diversity (H) ranged from 1.86 to 2.69 whereas evenness (J) ranged from .86 to .99, Simpson's diversity (D) ranged from .048 to .169, Margalef index (Da) ranged from 1.46 to 5.05, Menhinicks index (Dmn) ranged from 1.3 to 3.25 in the study areas. According to the diversity index, plankton diversity in the study areas were moderately high. The information obtained from this study can contribute for planning in conducting further research. In addition, the study can also help to manage the aquatic ecosystem.

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CHAPTER ONE

INTRODUCTION

Introduction

1.1 Background of the Study

The coastal area and estuary at Sundarban Mangrove forests accounts for a good amount of revenue from fisheries. Its abundance of tidal rivers, flora, and fauna make it an ecologically interested site. There is many endangered species, the highly interwoven river system and large tracts of lands with their rich avifauna are a matter of great significance. Plankton in the estuaries and seas, enter into the aquatic food chain and thus help directly or indirectly in the production of fish and other animals living in the sea water (Castro and Huber, 2003).

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. The word 'plankton' is originated from the Greek 'planktons' which means 'drifting'. 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 mobbing anywhere as fish do (Zheng Zhong *et al.*, 1984).

Presence of Plankton in the water body directly affects the productivity of any aquatic system. Estimation of the plankton composition and diversity has often been utilized to evaluate the overall health of river ecosystem. Biological potentiality of an aquatic ecosystem depends on the biomass of plankton. The knowledge on the abundance, diversity of the same is a prerequisite for the successful management of the aquatic ecosystem.

Aside from representing the bottom few levels of a food chain that supports commercially important fisheries, plankton ecosystems play a role in the biogeochemical cycles of many important chemical elements, including the ocean's carbon cycle. Primarily by grazing on phytoplankton, zooplankton provide carbon to the planktonic food web, either respiring it to provide metabolic energy, or upon death as biomass or detritus. Organic material tends to be



denser than seawater, and as a result it sinks into open ocean ecosystems away from the coastlines, transporting carbon along with it.

Abundance and diversity of plankton has been reported by several researchers such as Ahsan *et al.*, (2012), Balakrishna *et al.*, (2010), Ramesha and Sophia, (2013) and Mamun *et al.*, (2009).

Phytoplankton and zooplankton are the two major groups of plankton. Phytoplankton are the primary producers for the entire aquatic body and comprise the major portion in the ecological pyramids. The community of phytoplankton especially the different species of diatoms is also used as indicator of water pollution. Phytoplankton has the great importance in the aquatic ecology. Phytoplankton has been used as indicators of water quality. They strongly influence certain non-biological aspects of water quality (such as pH, color, taste and odor). In a practical sense, they are a part of water quality. Moreover their relationship with nutrient cycle, carbon cycles and oxygen cycles is undividable. Phytoplankton is globally the most important amongst the primary producers, which form the base line of many food webs in the aquatic environment. Phytoplankton production is a determinant of fish production and act as a remarkable biological factor in fluctuation of stock. Primary production is also dependent on Phytoplankton production. They are responsible for approximately 40% of the planet's total annual primary production although the magnitude of their contribution to global primary production is not appreciated due to their small fraction of their total photosynthetic biomass (US National report to IUGG 1994). They are also an important source of the fishes in the aquatic food web.

Abundance and diversity of phytoplankton has been reported by several researchers such as Saha, (2012), Akhe (2012), Bagheri *et al.*, (2008), Chakraborty (2011), Alam *et al.*, (1987), Boonyapiwat *et al.*, (2003), Ariyadej *et al.*, (2000), Aziz *et al.*, (2012).

Zooplankton constitutes important food item of many omnivorous and carnivorous fishes. The larvae of white fish (Mullet) feed mostly on zooplankton (Dewan *et al.*, 1977) because zooplankton provides the necessary amount of protein for the rapid growth and especially that of the gonad. Zooplankton contributes about 82% of the food item of *Anabas testudineus*, 32% of *Notoptrus notoptrus* (Mustafa and Ahmed, 1979). The main food item of *Xenentodon cancila* and the zooplankton contributes about 23% of the food item of *Macrobrachium rosenbergii*, 47% of the *Catla catla* (Ali and Islam, 1981), 6.37% of the *Labeo rohita* (Ali and Islam, 1981), 24.19% of the *Oreochromis nilotica* (Islam *et al.*, 1984), 38.5% of the

Rohtee cotio (Ali *et al.*, 1985) and 30% of the *Mystus vittatus* (Bhuiyan and Haque, 1984). Bhuyan (1988) observed that the food of *Cirrhina reba* constitute mainly of zooplankton.

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. Zooplankton plays an important role in the transfer of energy from the primary producer to fish.

Zooplankton due to their large density, shorter life span, drifting nature, high group or species diversity and different tolerance to the stress, they are being used as an indicator organisms for the physical, chemical and biological process in the aquatic ecosystem. Zooplankton has been recommended as regional bio-indicators of aquatic ecosystem. Although zooplankton is usually considered to be good indicators of environmental changes and have a fundamental role in energy flow and nutrient cycling in aquatic ecosystems.

Abundance and diversity of zooplankton has been reported by several researchers such as Keka (2012), Mondal (2012), Shil (2009), Saha (2009), Goldar (2011), Majumdar (2012), and Roy *et al.*, (2008)

Determining the abundance and diversity in an aquatic ecosystem depends not only on the vast data obtained, but also on the distribution of data throughout the aquatic system. Therefore, appropriate methods and tools are needed to reveal this distribution. Geographic Information System (GIS) applications have the exact features to satisfy this requirement. GIS is a kind of information system which can perform functions such as collecting, storing, processing, and analysing the graphical or non-graphical information obtained with location-based observations, and it presents to the user the information as a whole. The most significant advantage of GIS is that it provides the resulting desired map by superposing the distribution maps created with different parameters within a particular database. For this reason, GIS is used in many studies related to the management of natural resources, especially the management of surface water resources. (Xu, *et al.*, 2001, Akdeniz 2005, Karaer and Küçükbalı 2006).

Diversity is a measure of community structure, which can be defined as (1) the number of different kinds (species) of animals that occur in an area or sample, (2) the number of individual organisms that are present, and (3) the distribution of these organisms among the different species. Various indices such as Shannon-wiener, Simpsons, Margalef, Menhinick

and Barger-parker put different weights on the importance of these components because they were originally developed to examine widely differing concepts, some of which do not apply directly to the problems of this area. Every coastal area has a characteristic range of diversity that is influenced by hydrography, exposure, and in these latitudes rhythmic seasonality.

Plankton diversity is important for the stability and functioning of the oceanic ecosystem and ocean biogeochemical cycles (Ptacnik *et al.*, 2008). Diversity indices are good indicators of pollution in aquatic ecosystems. A diversity index greater than 3 indicates clean water and values in the 1 to 3 is characteristic of moderately polluted conditions, values less than 1 characterize heavily polluted conditions (Wilhm and Dorris, 1966; Mason, 1998).

Abundance and diversity of plankton in the river such as Baleswar, Sibsa and Malancha were known (Aziz *et al.*, 2012, Mamun *et al.*, 2009). This study concentrate on the water bodies of purposively selected three study areas namely Southkhali, Nolian and Southkadamtala adjacent to the Sundarban forest. These study area can be grouped on the basis of salinity. The three study area consider as three saline areas. That's why this three villages considered as study areas prospectively. Each village has a river embankment and the sampling for the study was concentrate on both the inside and outside of the embankment. The study use diversity indices for knowing the range of diversity of plankton in the water bodies of three villages emphasizing both the outside and inside of the embankment. Outside embankment represent the adjacent river and inside the embankment represent the ponds of the villages.

1.2 Objectives of the Study

The main objectives of the study are

- ✓ To know abundance and diversity of phytoplankton and zooplankton in the study areas.
- ✓ To compare phytoplankton and zooplankton abundance and diversity
 - Among the three study areas
 - Between the inside and outside of the embankment in each study areas.

It is expected that there is no different in diversity and abundance of plankton among three study areas and between the inside and outside of the embankment.

1.3 Scope

In order to fisheries development and to increase the present production level, proper and scientific management is essential in which the knowledge of natural productivity plays an important role. The data base obtained in this study can be used as base line information for understanding and predicting the abundance and diversity of plankton in that study areas. The information obtained from this study can contribute for planning in conducting further research. In addition, the study can also help to manage the aquatic ecosystem.

CHAPTER TWO

LITERATURE REVIEW

Literature review

Some studies on phytoplankton and zooplankton have been carried out by many researchers in different parts of the world. In recent time there has been growing awareness among the researcher in Bangladesh to study about phytoplankton and zooplankton, their distribution and relationship with physico-chemical parameters. Some important studies that were conducted on the abundance and diversity of phytoplankton and zooplankton are mentioned below-

Saha, 2012 studied on abundance and diversity of phytoplankton at fresh water Prawn farm (*Macrobrachium rosenbergii*) under three probiotic treatments. The study was based on experiment ponds at Khulna University from November 2011 to February 2012. The study identified 60 species under 5 groups of phytoplankton namely Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta, Chrysophycophyta. Phytoplankton was dominated by Chlorophyta (32-41%). Highest peak was recorded in February (2671 individual/L) and lowest in November (667 individual/L). The study showed that probiotic control phytoplankton bloom.

Akhe, 2012 studied on abundance and diversity of phytoplankton in Rupsha-Bhairab system under Khulna region. Samples were collected from 3 spots of the study area. The study identified 60 species under 5 groups of phytoplankton namely Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta, Chrysophycophyta. Diatom was the mostly abundant. The study showed high dissolve oxygen (DO) content (8.8mg/l in March), PH (8.7) and TDS (6460 mgCaCO₃/l). The study showed inverse relationship in case of water temperature, alkalinity, hardness, acidity, TDS and water conductivity.

Keka, 2012 studied on abundance and diversity of zooplankton in Rupsha-Bhairab system under Khulna region. Samples were collected from 3 spots of the study area. The study identified zooplankton under four classes namely Copepod, Crustacean, Monongononta and Ostracoda. Dominant classes were Copepoda.

Mondal, 2012 studied on abundance and diversity of zooplankton at fresh water Prawn farm (*Macrobrachium rosenbergii*) under three probiotic treatments. The study was based on

experiment ponds at Khulna University from November 2011 to February 2012. The study recorded 11 genera of zooplankton under 5 orders. The identified zooplankton belonged to five classes namely Copepod, Rotifer, Crustacean, Monogononta and Ostracoda.

Majumdar, 2012 studied on occurrence and zooplankton abundance in fish farming pond. The study recorded Cladocera 33%, Copepod 26%, Rotifer 22%, Ostracod 12% and insect larvae 7%. The study showed that from May to December copepod and rotifer were dominated group. The study showed highest zooplankton in May. The study showed a seasonal as well as monthly fluctuation both quantitatively and qualitatively with the different physico-chemical parameters.

Shil, 2003 studied on abundance and diversity of Zooplankton in a semi-intensive farm of *Macrobrachium rosenbergii*. Samples were collected every month in a definite time interval. The study conducted from July to December 2008. He identified 10 genera of zooplankton under 5 orders were recorded from the study ponds. The study identified zooplankton under five orders namely Copepoda, Rotifera, Cladocera, Ostracoda and Crustacean Larvae. The study found highest zooplankton at the month of October. The study recorded eight physico-chemical parameters namely, Water temperature, Transparency, Dissolve Oxygen, pH, Free CO₂ Alkalinity, Hardness and Salinity. The study showed relationship between zooplanktons and physico-chemical parameters. Total zooplankton showed significant positive relationship with water temperature ($r = +0.384$), Dissolve Oxygen($r = +0.113$), pH($r = +0.320$), Free CO₂ ($r = +0.319$), Alkalinity($r = +0.269$), Hardness ($r = +0.402$) and negative relationship with Salinity($r = -0.486$), Transparency($r = -0.693$).

Aziz *et al.*, 2012 studied on diversity, distribution and density of estuarine phytoplankton in the Sundarban Mangrove Forests, Bangladesh. The study identified 36 species included Chlorophyceae(3), Euglenophyceae(2), Bacillariophyceae(30) and Xanthophyceae(1). The study showed that occurrence of taxa and their densities were highest near confluence of Hangsha River. Shannon-wiener diversity indices($H=3.494$) was also highest in Hangsha river and lowest density and diversity indices ($H=1.661$) were found in Bal R.

Ahsan *et al.*, 2012 studied on plankton composition, abundance and diversity in Hilsa (*Terualosa ilisha*) migratory rivers of Bangladesh during spawning season. The study identified 58 taxa of plankton of which 19 taxa were phytoplankton and 39 taxa zooplankton.

The study recorded highest abundance of total plankton (692 ind/l) in Godagari, Rajshahi and lowest (4.00 ind/l) in Vharghat, Rajshahi. The highest species richness (SR= 45) was observed in Daulatkhan, Vola. The Shannon-wiener species diversity index (H) ranged from 3.334 in Daulatkhan to 1.5 in Charghat.

Balakrishna *et al.*, 2010 studied on physic-chemical parameters and plankton diversity of Ghanpur Lake, Warangal district, Andhra Pradesh, India. The study recorded that during summer temperature, pH, conductivity, TDS, DO, Alkalinity, total hardness and BOD were found increased and gradually decreased in rainy season. The study identified 13 Zooplanktons, among these rotifers 7 species, Copepods 3 species, Cladocera 2 species, Ostracoda 1 species, of which rotifers and copepods are dominating. The study showed Rotifera, Cladocera and Copepod populations were high during summer season and low in rainy season.

Bagheri *et al.*, 2008 studied on the phytoplankton species composition and abundance in the southwestern Caspian Sea. The study were identified 43 phytoplankton species comprised of diatoms (25 species), dinoflagellates (7 species), chlorophytes (6 species), cyanophytes (4 species), and euglenoids (1 species).

Ramesha and Sophia, 2005 study on species composition and diversity of plankton in the River Seeta at Seetanadi, the Western Ghats, India. The study recorded 78 species of plankton belonging to 29 families. The study recorded highest species diversity (2.7056) and evenness (J) (.9613). The study recorded highest plankton (12300 ind./l) in June.

Mamun *et al.*, 2009 studied on abundance and distribution of plankton in the Sunderban mangrove forest. The study identified 15 genera of phytoplankton and 11 genera of zooplankton. The number of genera under the class Chlorophyceae, Myxophyceae and Bacillariophyceae were identified at 5, 7 and 3 respectively. The study showed that the most abundant were *Coscinodiscus* sp. And *Microcystis* sp. The study showed highest phytoplankton (6250 ind/l) and zooplankton (2038 ind/l) in Summer.

Roy *et al.*, 2008 studied on the diversity and seasonal variation of zooplankton in a brood pond, Bangladesh. Samples were collected from Gallamari fisheries extension & training centre farm, Batiaghata, Khulna. The study identified 6 groups of zooplankton. The identified

zooplanktons were under six orders namely Copepoda, Rotifera, Cladocera, Ostracoda, Crustacean larvae and Bryozoa. The study showed that copepod was the dominant order among the identified zooplanktons.

Chakraborty *et al.*, (2011) studied the impact of salinity and pH on phytoplankton community in a tropical freshwater system: An investigation with pigment by HPLC. Study carried out to understand the effects of salinity shock and variation in pH on phytoplankton communities in a tropical freshwater system of Godavari River (a major peninsular river of India). The effects were assessed by pigment analysis using HPLC technique. Subtle changes in the salinity of freshwater by one practical salinity unit (PSU) completely removed green algae from the system and allowed cyanobacteria to come into dominance. The cyanobacteria were found to tolerate higher osmotic stress until salinity reached a PSU of 16.

Das and Srivastava (1956) made a quantitative study on freshwater plankton of a fish-tank in Lucknow, India. The study showed monthly fluctuations in plankton volume, percentage composition as well as in the individual components and different species showed different peak in different months.

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 from Bay of Bengal of Bangladesh

Santra *et al.*, (1991) studied the systematics of 24 genera and 46 species of phytoplankton from the mangrove delta of west Bengal, India. Study discussed on primary production, qualitative studies on phytoplankton and hydrological parameters such as temperature, salinity, pH etc in the inshore water of Turicorin.

Ariyadej *et al.*, 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. The study identified 135 species in seven divisions of phytoplankton. The study showed greatest number of species were in Division

Chlorophyta (50%), followed by Cyanophyta (21%), Bacillariophyta (13%), Pyrrophyta (6%), Cryptophyta (4%), Chrysophyta (3%) and Euglenophyta (3%).

Booonyapiwat *et al.*, (2003) studied on "Species Composition, Abundance and Distribution of Phytoplankton in the Bay of Bengal" during the year 2007. Samples were collected at surface layer of 24 stations in 3 areas (north, west and east) in the Bay of Bengal. The 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.

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. The study recorded eight physico-chemical parameters namely, Water temperature, Transparency, Dissolve Oxygen, pH, Free CO₂ Alkalinity, Hardness and Salinity. The study showed relationship between zooplanktons and physico-chemical parameters. Total zooplankton showed significant positive relationship with water temperature ($r = +0.354$), Dissolve Oxygen ($r = +0.123$), pH ($r = +0.30$), Free CO₂ ($r = +0.217$), Alkalinity ($r = +0.276$), Hardness ($r = +0.302$), Salinity ($r = +0.486$), and negative relationship with Transparency ($r = -0.793$).

Khondoker and Choudhury (1993) 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, a plankton net of 20 μ m 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.

Islam and Haroon (1975) studies on the abundance of plankton in river Buriganga. The study identified 137 species of algae and 15 species of zooplankton based on one year investigation.

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.

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

CHAPTER THREE

MATERIALS & METHODS



MATERIALS AND METHODS

3.1 Study area

3.1.1 Location of the study area

Location of the study areas are shown in figure 1. GPS location of sampling points are shown in table 2.

The study was conducted at six stations, namely Nolian (between embankment and outside embankment), Southkhali (between embankment and outside embankment), and Southkadamtala (between embankment and outside embankment) which are situated at different locations (figure 1).

Southkhali is one of the most important village of Bagerhat District for its location in the coastal belt. It is in the south-western part of Bangladesh of Bagerhat District. It is a village of Sarankhola Upzila. It is located at 22° 15' 19" N 89° 50' 08" E. It is about 60 km from the Bagerhat town. Baleswar river is adjacent with this village. The village was joined with the river by a sluich gate so that coastal water could enter into the village farm by a canal. The total population of Southkhali village is about 30,000. Here pH was between 6.87 to 7.5, temperature was between 25.13 to 30°C and salinity between 1 to 11 ppt. Turbidity was modearate.

Nolian is another important village of Khulna District for its location in the coastal belt. It is in the south-eastern part of Bangladesh of Khulna District. It is a village of Dacop Upzila. It is located at 22° 27' 967" N 89° 26' 319" E. It is about 54km from the khulna town. Sibsha river and Koyra upzilla. in west side of village. The village was joined with the river by two sluich gate so that coastal water could enter into the village farm by a canal. The total area of Nolian is 639 hector includes 5 and 6 ward. Total population is 7018. Here pH was between 7.0 to 7.4, temperature was between 23 to 29°C and salinity between 1 to 14 ppt. Turbidity was high.

Southkadamtala is the most important village of Satkhira District for its location in the coastal belt. It is in the south-eastern part of Bangladesh of Khulna District. It is a village of Munshiganj upzila. It is located at 22° 13' 91" N 89° 10' 18" E. It is about 97km from the khulna town. Malancha river in west side of village. The village was joined with the river by one sluich gate so that coastal water could enter into the village farm by a canal. The total area of Nolian is 275 hector includes 7 no Munshiganj union. Total population is 2000. Here

pH was between 7.00 to 7.5, temperature was between 24 to 30°C and salinity between 1 to 10 ppt. Turbidity was low.

Physical Characteristics of Study area are given in table 1

Table 1: Physical characteristics of study areas.

Characteristics	Southkhali	Nolian	Southkadamtala
Location	22° 15' 19" N 89° 50' 08" E	22° 27' 967" N 89° 26' 319" E	22° 13' 91" N 89° 10' 18" E
Adjacent river	Baleswar	Sibsha	Malancha
Temperature (Golder et al., 2012)	25.13 to 30°C	23 to 29°C	24 -30°C
pH (Golder et al., 2012)	6.87-7.5	7.0-7.4	7.0-7.5
Salinity (Golder et al., 2012)	1-11 ppt	1-14 ppt	1-10 ppt
Turbidity (Golder et al., 2012)	Medium	High	Low

Location of the study areas are shown in figure 1.

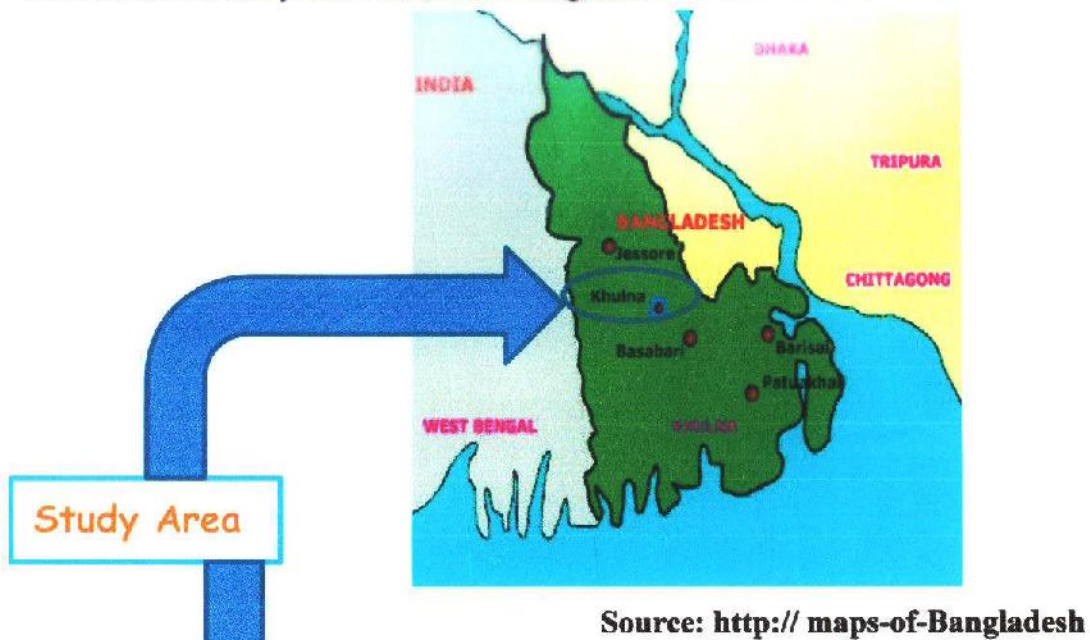
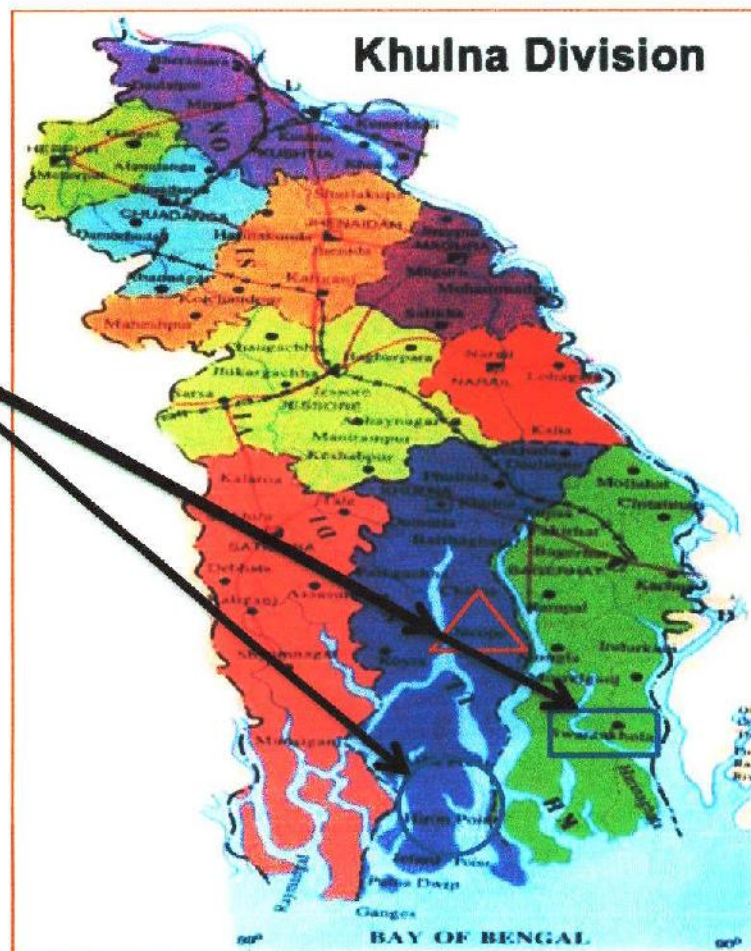
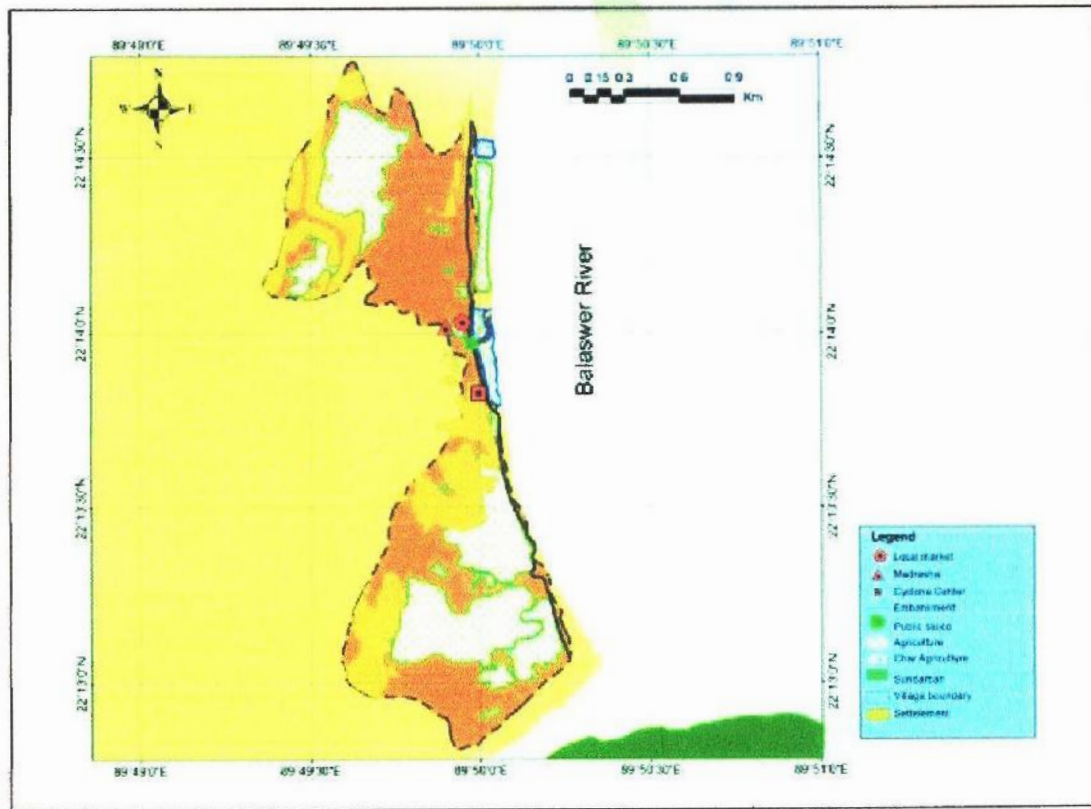
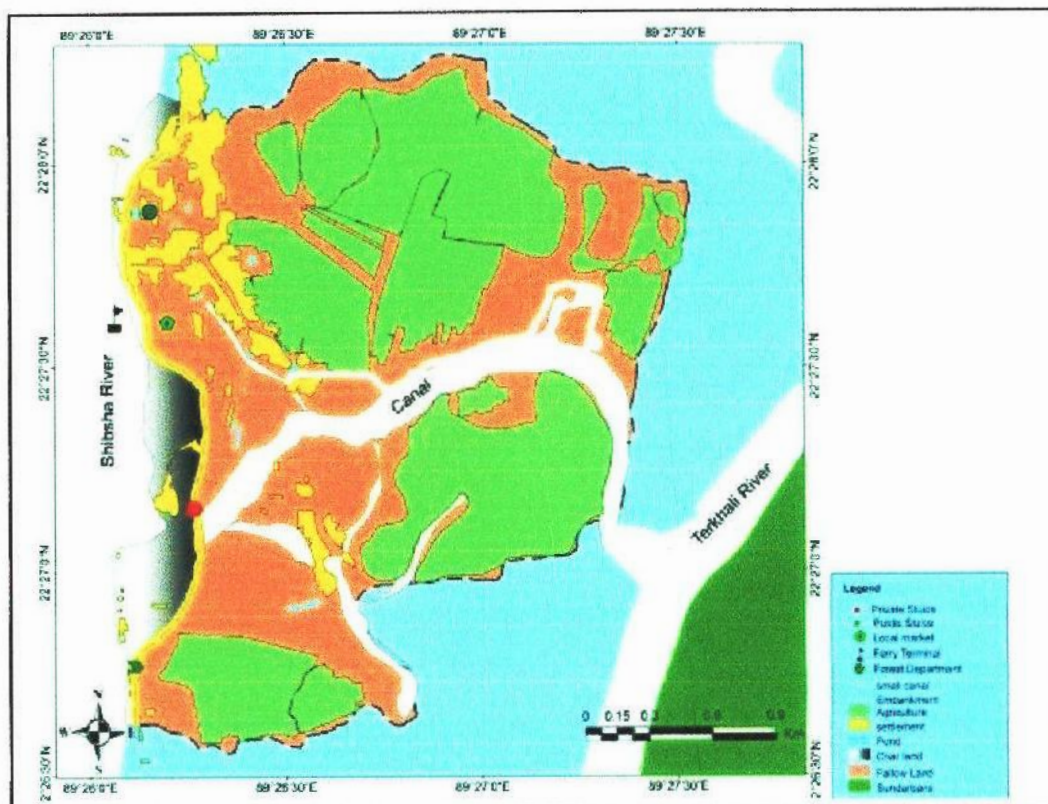


Figure 1: Location of the study areas.

Digitized map of three study areas are shown in figure 2



a. Southkhali Village



b. Nolian Village

3.2.1 Sample Collection

For abundance measurement, plankton samples were collected by passing water through a plankton net (20 μ m mesh sized for phytoplankton and 50 μ m mesh sized for zooplankton, silk bolting cloth or nylon monofilament screen cloth) from the study areas (Figure 3).

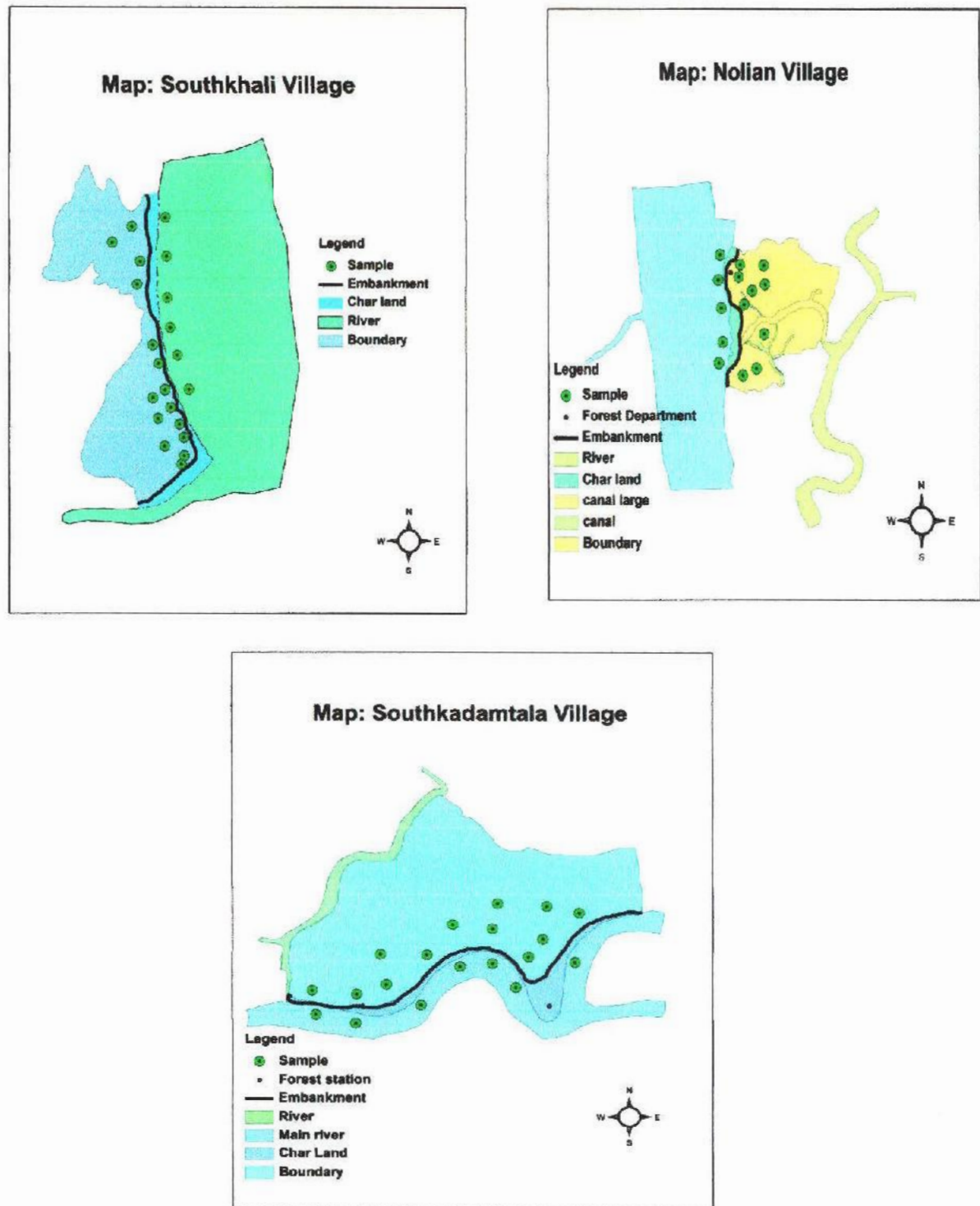


Figure 3: Sample collecting areas (Green colour circles indicate sampling point).

3.2.2 Preservation

The samples were preserved with lugol's solution (20g potassium iodide and 10g iodine crystals dissolved in 200ml distilled water containing 20ml glacial acetic acid) after the samples collection. Lugol's solution was added in an amount of 0.7ml per 100ml of sample.

3.3 Biological Parameters

3.3.1 Identification

Phytoplankton and zooplankton cells were enumerated under a light microscope by using Sedwick-Rafter cell. Phytoplankton and zooplankton species were identified by checklist of different scientist such as Arnold (1989), Charles (1995), Subrahmanyam (1946), Islam and Aziz (1980).

3.3.2 Abundance

Abundance of phytoplankton and zooplankton was measured by direct cell counting method using an electronic Microscope (BOECO Imaging device, ivu 15,000).

Counting cell preparation and counting procedure

The quantitative enumeration of the phytoplankton and zooplankton was carried out with the help of Sedgwick-Rafter (S-R) cell which is 50 mm. long, 20mm. 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 dropper so that no air bubbles in the cell covers were formed. The S-R cell was let standard for at least 15 minute to settle plankton. Then phytoplankton and zooplankton on the bottom of the S-R cell was counted and enumerated by compound microscope. By moving the mechanical stage, the entire bottom of the slide area was examined carefully. Organisms lying between two parallel cross hairs were counted as they passed a vertical line. Number of phytoplankton in the S-R cell was derived from the following formula (APHA, 1976) -

$$\text{No/ml} = \frac{C \times 1000 \text{ mm}^3}{L \times D \times W \times S}$$

Where,

C = Number of Organisms Counted

L = Length of each strip (S-R cell length) in mm.

D = Depth of a strip (whipple grid image width) in mm.

S = Number of strips counted

W = Width of the strip (whipple grid image width) in mm.

The total number of plankton per litre of water was estimated by the following formula:

$$N = \frac{A \times C}{L}$$

Where, A= Average number of plankton counted per ml concentrated sample, C= Volume of concentrated sample in ml, L= Volume of original water in Litre passed through the plankton net, N= Total number of plankton per litre of original water.

3.4 Species Diversity Indices

Diversity is a deceptive concept. Magurran (1991) likens the concept of diversity to an optical illusion; the more it is examined, the less clear it becomes.

3.4.1 Shannon-Wiener Index (Shannon,1949)

Shannon and Wiener independently derived which has become known as Shannon index of diversity. This indeed assumes that individuals are randomly sampled from an independently large population. The index also assumes that all the species are represented in the sample. Shannon diversity is the very widely used index for comparing diversity between habitats (Clarke and Warwick, 2001). The Shannon-Wiener Diversity Index, H, is calculated using the following equation.

$$H = -\sum p_i (\ln p_i)$$

Where p_i is the proportion of each species in the sample.

The value of Shannon diversity is usually found to fall between 0 to 4.6. A value near 0 would indicate that every species in the sample is the same. A value near 4.6 would indicate that the number of individuals is evenly distributed between all the species.

3.4.2 Evenness (Shannon,1948)

The distribution of individuals over species is called evenness. It makes sense to consider species richness and species evenness as two independent characteristics of biological communities that together constitute its diversity (Shannon,1948).

Evenness (E) determined by using following formula

$$D = \frac{H}{H_{\max}}$$

Here H= value of Shannon-Wiener diversity index and $H_{\max} = \ln(S)$ where S= number of species.

An increase in the value of the index accompanies an increase in diversity.

3.4.3 Simpson's Index (Simpson,1949)

Simpson's Index (D) is a measure of diversity, which takes into account both species richness and an evenness of abundance among the species present. In essence it measures the probability that two individuals randomly selected from an area will belong to the same species. The formula for calculating D is presented as

$$D = \sum n_i(n_i-1) / N(N-1)$$

Where n_i = the total number of organisms of each individual species

N = the total number of organisms of all species.

The value D ranges from 0 to 1. With this index, 0 represents infinite diversity and 1 no diversity. That is, the bigger the value the lower the diversity.

3.4.4 Margalef Index (Margalef,1951)

A measure of species diversity. It is calculated from the total number of species present and the abundance or total number of individuals. The formula for calculating Margalef index (D_a) is presented as

$$D_a = \frac{S - 1}{\ln N}$$

Where D_a = Margalef index

S= The number of species

$N = \text{total number of individuals}$

3.4.5 Brillouin index (May, 1975).

For small, completely censused populations, this is a better measure of information/entropy than Shannon's index. It is calculated as:

$$HB = \ln(N!) - \sum \ln(n_i!) / N$$

Where HB = the Brillouin index, N = total number of individuals in the sample, n_i = number of individual of species i, N! means the factorial of N = 1 * 2 * 3 * 4... * N, $\ln(x)$ = natural logarithm of x (or logarithm base e)

The value obtained rarely exceeds 4.5 and both the Brillouin and Shannon Indices tend to give similar comparative measures.

3.4.6 Menhinick's index (Whittaker, 1977)

Menhinick's index, Dmn (Whittaker, 1977), is calculated using

$$Dmn = \frac{S}{\sqrt{N}}$$

Where N is the total number of individuals in the sample and S the species number.

An increase in the value of the index accompanies an increase in diversity.

3.4.7 Berger-Parker Index (Berger and Parker, 1970)

This simple intrinsic index expresses the proportional importance of the most abundant species. As with the Simpson index, the reciprocal form of the Berger-Parker index is usually adopted so that an increase in the value of the index accompanies an increase in diversity.

It is a simple measure of the numerical importance of the most abundant species.

$$D = N_{\max} / N$$

Where $N_{\max}$ is the number of individuals in the most abundant species, and N is the total number of individuals in the sample.

An increase in the value of the index accompanies an increase in diversity.

3.4.8 Alpha diversity

Alpha diversity refers to the diversity within a particular area or ecosystem, and is usually expressed by the number of species (i.e., species richness) in that ecosystem.

3.4.9 Beta diversity

Beta diversity is a comparison of diversity between ecosystems, usually measured as the amount of species change between the ecosystems.

3.4.10 Gamma diversity

Gamma diversity is a measure of the overall diversity for the different ecosystems within a region.

The species diversity index and range of their theoretical value are given in table 3

Table 3: Diversity index and their theoretical value range

Index	Theoretical index value range	Diversity	Reference
Shannon-Wiener Index (H)	0 – 4.6	Value ↑ Diversity ↑	Shannon and Wiener (1949)
Evenness (E)	0 - 1	Value ↑ Richness ↑	Shannon (1948)
Simpson's Index (D)	0 - 1	Value ↑ Diversity ↓	Simpson (1949)
Margalef Index (Da)	0 - ∞	Value ↑ Diversity ↑	Margalef (1951)
Brillouin index (HB)	0 - ∞	Value ↑ Diversity ↑	May (1975)
Menhinick's index (Dmn)	0 – 4.6	Value ↑ Diversity ↑	Whittaker (1977)
Berger-Parker Index (d)	0 - 1	Value ↑ Diversity ↓	Berger and Parker (1970)



CHAPTER FOUR

RESULTS

RESULTS

Abundance and diversity of phytoplankton and zooplankton were studied through the present study. The study divided into two major subsections such as phytoplankton and zooplankton. Both subsections included the abundance and diversity in outside and inside of the embankment.

4.1 Phytoplankton abundance

4.1.1 Abundance of Phytoplankton in the outside of the embankment

Phytoplankton abundance was varied from 480 ind/l to 2629.5 ind/l (Table 4) in the water bodies situated outside of the embankment throughout the study area. In Southkhali, Nolian and Southkadamtala villages phytoplankton abundance were recorded as 1395 ind/l, 480 ind/l and 2629.5 ind/l respectively. Phytoplankton abundance was highest in Southkadamtala village (2629.5 ind/l) and lowest in Nolian village (480 ind/l) (table 4). The study identified 32 species of phytoplankton. The species wise abundance of phytoplankton in three villages is shown in table 5.

Table 4: Phytoplankton abundance in three stations

Station name	Ind/l
Southkhali	1395
Nolian	480
Southkadamtala	2629.5

Table 5: Species wise abundance of Phytoplankton (ind/l).

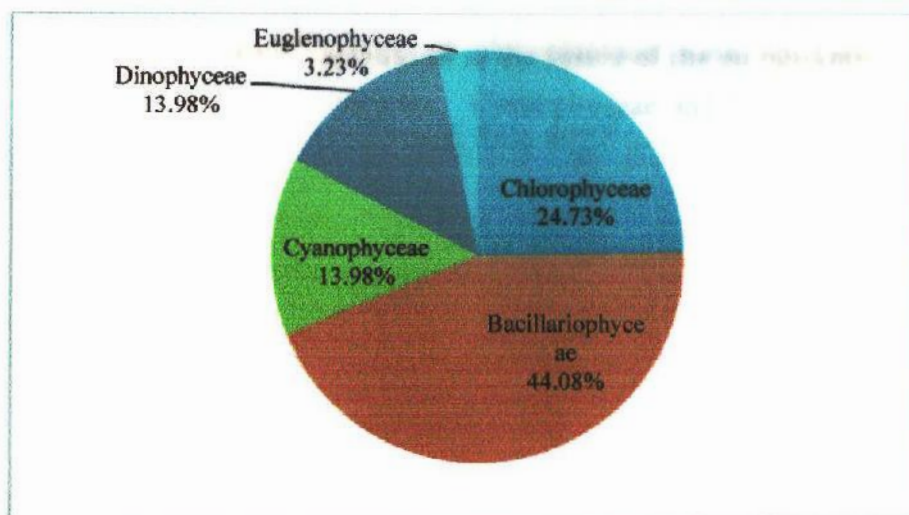
Name of Taxa	Southkhali	Nolian	Southkadamtala
Dinophyceae			
<i>Dinophysis rotundata</i>	195		615
Chlorophyceae			
<i>Volvox aureas</i>	75	45	
<i>Ulothrix sp.</i>	75		75
<i>Oocystis pusilla</i>	30		105

<i>Spirogyra sp.</i>	120	120	123
<i>Bulbocheate sp.</i>			195
<i>Uronema sp.</i>	45	15	
Bacillariophyceae			
<i>Bacteriastrum delicatulum</i>	75		
<i>Gonatozygon sp.</i>	30	15	150
<i>Leptocylicus danicus</i>	105	30	
<i>Coscinodiscus asteromphalus</i>	105		
<i>Coscinodiscus granii</i>	90		225
<i>Coscinodiscus marginatus</i>	75		
<i>Coscinodiscus stellaris</i>			247.5
<i>Centrictus sp.</i>	15		
<i>Nitzschia sp.</i>	45		
<i>Thalassiosira decipiens</i>		75	
<i>Thalassiosira rotula</i>	75		45
<i>Navicula sp.</i>		15	
<i>Suneda sp.</i>			300
<i>Stigeoclonium sp.</i>		45	
<i>Nannochloris</i>			123
<i>Pleurosigma directum</i>			75
<i>Rhizosolenia hebertii</i>		60	
Cyanophyceae			
<i>Trichodesmium erythraea</i>	75		
<i>Oscillatoria agardhii</i>	90		123
<i>Spirulina sp.</i>	30		
<i>Anabaena sp.</i>		15	
<i>Microcystis aeruginosa</i>		30	
Euglenophyceae			
<i>Euglena spathulifera</i>	45		
<i>Phacus sp.</i>		15	123
<i>Dunellia sp.</i>			105
Total density(ind/l)	1395	480	2629.5

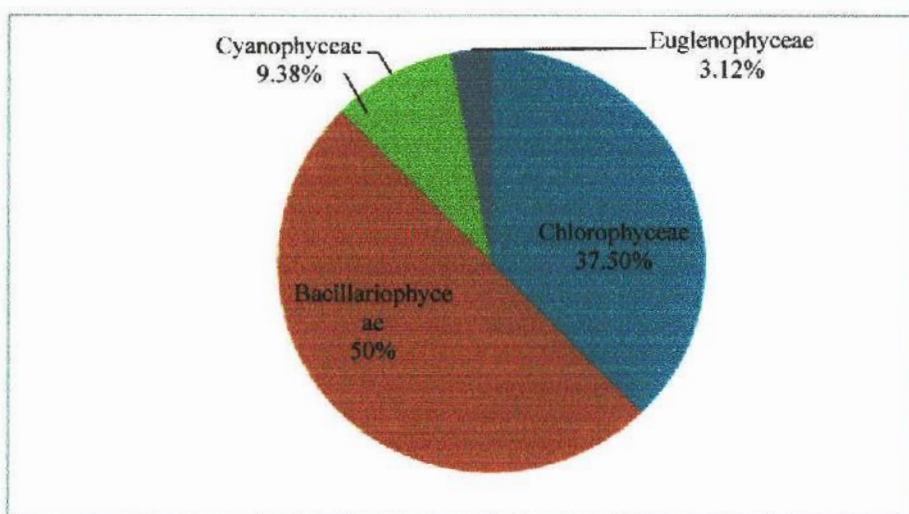
In the present study 5 groups of phytoplankton were observed namely Dinophyceae, Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae. During the study period, Bacillariophyceae was found as dominant group representing as 44.08% (Southkhali village), 50% (Nolian Village) and 44.32% (Southkadamtala village) (figure 4). Highest number of Bacillariophyceae (1165.5 ind/l) was found in southkadamtala village (table 6). Remarkably, Dinophyceae was not found in Nolan. Percentage wise abundance of phytoplankton outside of the embankment is shown in figure 4.

Table 6: Group wise abundance of different groups of Phytoplankton (ind/l).

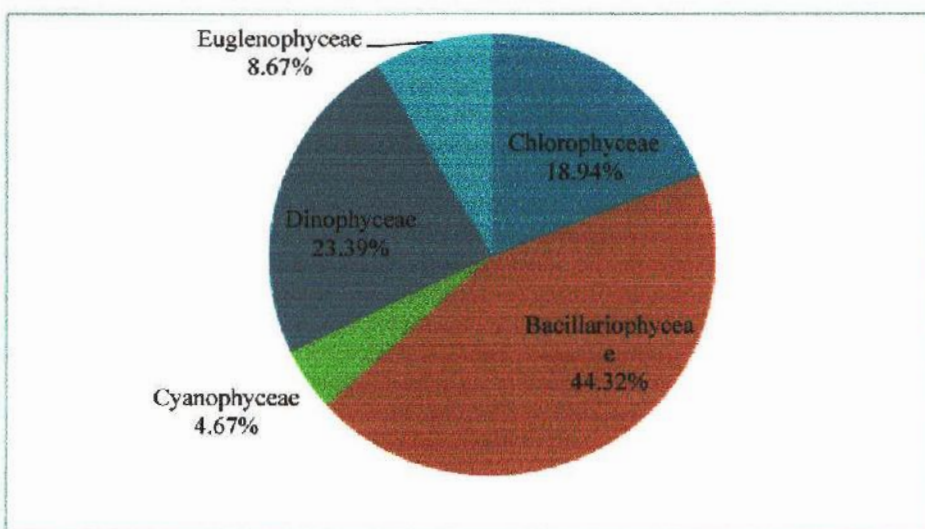
Class	Southkhali	Nolian	Southkadamtala
Dinophyceae	195		615
Chlorophyceae	345	180	498
Bacillariophyceae	615	240	1165.5
Cyanophyceae	195	45	123
Eglenophyceae	45	15	228
Total (ind/l)	1395	480	2629.5



1. Southkhali Village



2. Nolian Village



3. Southkadaamtala Village

Figure 4: Percentage wise abundance of Phytoplankton

4.1.2 Abundance of Phytoplankton in the inside of the embankment

Phytoplankton abundance was varied from 892.5 ind/l to 2107.5 ind/l (Table 7) in the water bodies situated inside of the embankment throughout the study area. In Southkhali, Nolian and Southkadamtala phytoplankton abundance were recorded as 2107.5 ind/l, 1200 ind/l and 892.5 ind/l respectively. The study identified 25 species of phytoplankton. The species wise abundance of Phytoplankton in three villages is shown in table 8.

Table 7: Phytoplankton abundance(ind/l) in three stations

Station name	Ind/l
Southkhali	2107.5
Nolian	1200
Southkadamtala	892.5

Table 8: Species wise abundance of Phytoplankton (ind/l)

Name of Taxa	Southkhali	Nolian	Southkadamtala
Chlorophyceae			
<i>Volvox aureas</i>	450		127.5
<i>Ulothrix sp.</i>	127.5		127.5
<i>Spirogyra sp.</i>	255	255	165
<i>Closterium parvula</i>	172.5		
<i>Cladophora sp</i>			90
<i>Fritschella sp.</i>			30
<i>Uronema sp.</i>	90		
Bacillariophyceae			
<i>Gonatozygon sp.</i>			67.5
<i>Leptocylidricus danicus</i>		405	
<i>Coscinodiscus granii</i>	127.5	90	
<i>Nitzschia sp.</i>	112.5		
<i>Thalassiosira decipiens</i>		90	
<i>Thalassiosira nitzschoides</i>		90	
<i>Navicula sp.</i>		90	
<i>Navicula cuspidate</i>	247.5		
<i>Stigeoclonium sp.</i>			90

<i>Asterionella sp.</i>			30
Cyanophyceae			
<i>Trichodesmium erythraea</i>	127.5		
<i>Oscillatoria agardhii</i>	90	45	
<i>Spirulina sp.</i>	90		
<i>Anabaena sp</i>		90	
<i>Microcystis incerta</i>		45	
Euglenophyceae			
<i>Euglena spathirhyncha</i>	127.5		
<i>Phacus sp.</i>	90		
Total density(ind/l)	2107.5	1200	892.5

The abundance of different groups of Phytoplankton population was studied. In the present study, 4 groups of phytoplankton were observed namely Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae. Among four groups Chlorophyceae (1095 ind/l) was most dominant in Southkhali village and Bacillariophyceae (765 ind/l) was dominant in Nolian village. In Nolian and Southkadamtala, there was no euglenophyceae (table 9). Percentage wise abundance of phytoplankton inside of the embankment is shown in figure 5.

Table 9: Group wise distribution of Phytoplankton (ind/l).

Class	Southkhali	Nolian	Southkadamtala
Chlorophyceae	1095	255	540
Bacillariophyceae	487.5	765	352.5
Cyanophyceae	307.5	180	
Eglenophyceae	217.5		
Total (ind/l)	2107.5	1200	892.5

4.2 Diversity of Phytoplankton

4.2.1 Diversity of Phytoplankton in the outside of the embankment

Thirty two (32) Phytoplankton species(Gamma diversity) have been identified from the study areas. Among them 17 belongs to Bacillariophyceae, 6 belongs to Chlorophyceae, 5 belongs to Cyanophyceae, 3 belongs to Euglenophyceae and 1 belongs to Dinophyceae. The values of the Shannon- Wiener index (H) and evenness (E) were respectively, 2.69 and .992 for Southkhali, 2.52 and .943 for Nolian and 2.34 and .929 for Southkadamtala villages (table 10). The results indicate that the values of the diversity indices H and E was highest in Southkhali. When species diversity was compared among the three villages, the Southkhali Village was the most diverse. This is because the highest species richness (32) (Gamma diversity) and evenness in the Southkhali village resulted in the highest H value.

Table 10: Diversity index for Phyttoplankton

Diversity Index	Value range	Diversity	Southkhali	Nolian	Southkadamtala
Shanon-Wiener index diversity(H)	0 – 4.6	Value↑Diversity↑	2.69	2.52	2.34
Evenness (E)	0 - 1	Value↑Richness↑	.992	.943	.929
Simpson's diversity index (D)	0 - 1	Value↑Diversity↓	.048	.082	.096
Margalef Index	0 - ∞	Value↑Diversity↑	4.68	3.96	3.14
Brillouin index	0 - ∞	Value↑Diversity↑	2.05	2.09	1.25
Menhinick's index	0 – 4.6	Value↑Diversity↑	2.59	2.56	1.64
Berger-Parker Index	0 - 1	Value↑Diversity↓	.13	.17	.2
Alpha diversity			19	12	15
Beta diversity			S.khali outside vs Nolian outside:20	Nolian outside vs S.tala outside: 21	S.tala outside vs S.khali outside: 17
Gamma diversity			32		

4.2.2 Diversity of phytoplankton in the inside of the embankment

Twenty five (25) phytoplankton species (Gamma diversity) have been identified from the study areas. Among them 11 belongs to Bacillariophyceae, 7 belongs to Chlorophyceae, 5 belongs to Cyanophyceae and 2 belongs to Euglenophyceae. The considered diversity index of phytoplankton are shown in table 11. The values of the Shannon- Wiener index (H) and evenness (E) were respectively, 2.42 and .945 for Southkhali, 1.91 and .869 for Nolian and 2.07 and .942 for Southkadamtala villages (table 11). The results indicate that the values of the diversity indices H and E was highest in Southkhali. When species diversity was compared among the three villages, the Southkhali Village was the most diverse. This is because the highest species richness (25) (Gamma diversity) and evenness in the Southkhali village resulted in the highest H value.

Table 11: Diversity index for Phytoplankton

Diversity Index	Value range	Diversity	Southkhali	Nolian	Southkadamtala
Shanon-Wiener index diversity(H)	0 – 4.6	Value↑Diversity↑	2.42	1.91	2.07
Evenness (E)	0 - 1	Value↑Richness↑	.945	.869	.942
Simpson's diversity index (D)	0 - 1	Value↑Diversity↓	.092	.169	.107
Margalef Index	0 - ∞	Value↑Diversity↑	2.85	2.19	2.4
Brillouin index	0 - ∞	Value↑Diversity↑	2.04	1.52	1.6
Menhinick's index	0 – 4.6	Value↑Diversity↑	1.59	1.46	1.51
Berger-Parker Index	0 - 1	Value↑Diversity↓	.15	.24	.18
Alpha diversity			13	9	9
Beta diversity			S.khali inside vs Nolian inside:16	Nolian inside vs S.tala inside: 15	S.tala inside vs s.khali inside:16
Gamma diversity(inside)	25				

4.3 Zooplankton abundance

4.3.1 Abundance of Zooplankton in the outside of the embankment

Zooplankton abundance was varied from 600 ind/l to 1908 ind/l (Table 12) in the water bodies situated outside of the embankment throughout the study area. In Southkhali, Nolian and Southkadamtala Zooplankton abundance was recorded as 630 ind/l, 600 ind/l and 1908 ind/l respectively (table12). The study identified 27 species of Zooplankton. The scientific name and species wise abundance of zooplankton in three villages is given in table 13

Table 12: Zooplankton abundance in three stations

Station name	Ind/l
Southkhali	630
Nolian	600
Southkadamtala	1908



Table 13: Species wise abundance of Zooplankton (ind/l)

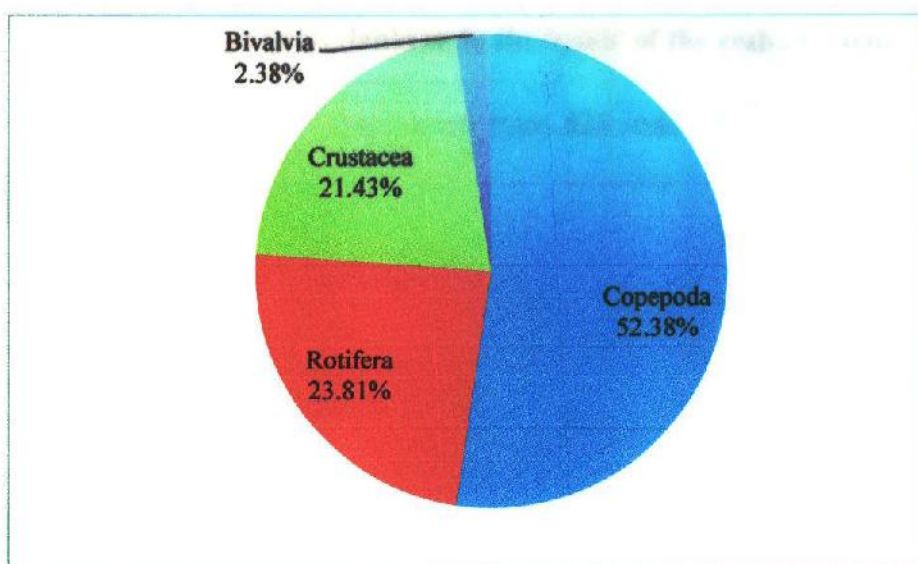
Name of taxa	Southkhali	Nolian	Southkadamtala
Rotifera			
<i>Acrocalanus gracillis</i>	37.5		
<i>Acartia spinicuada</i>	37.5		
<i>Acartia clausi</i>	30		
<i>Brachionus sp.</i>	45		124.5
<i>Acartia tranteri</i>		45	
Copepoda			
<i>Calanus finmarchicus</i>	67.5	45	
<i>Calanoidia euchaeta</i>	52.5	45	195
<i>Calanus helgolandicus</i>	75	75	124.5
<i>Calanoidia calanus</i>	90	105	375
<i>Calanoidia metridia</i>			150
<i>Calanoidia armata</i>		30	
<i>Harpacticoida metridia</i>			150
<i>Eucalanus bungii</i>			150
<i>Microcalanus pusillus</i>			124.5

<i>Calanus sp.</i>		60	
<i>Bicuspidatus thomasi</i>		45	
<i>Euchaeta marina</i>	45		
<i>Leptodiaptomus ashlandi</i>		45	
Gastropoda			
<i>Littorina littorica</i>	15		
Crustacea			
<i>Megalopa of crab</i>	15	30	
<i>Euphausia diomediae</i>	15		
<i>Crustacean larvae</i>	30	45	90
<i>Cypris sp.</i>	30		75
<i>Mesocyclope sp.</i>	45		165
<i>Cyclope sp.</i>			124.5
<i>Daphnia longispinaria</i>			45
Sedantaria			
<i>Owenia fusiformis</i>		30	
Total density(ind/l)	630	600	1908

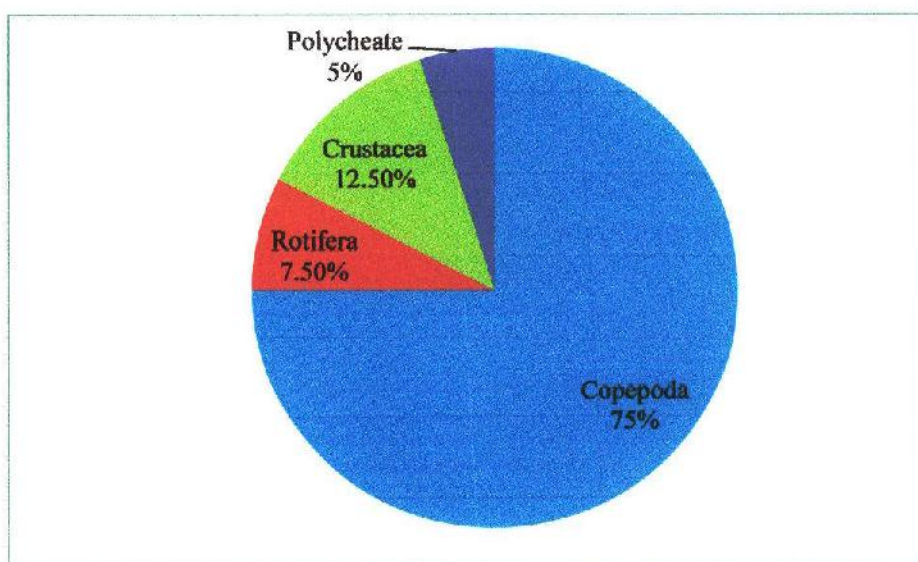
The study identified 4 groups of Zooplankton such as Rotifera, Copepod, Bivalvia, Cusacea. Copepoda was found dominant. There was no polychaete in Southkadamtala and Southkhali. Bivalvia was found in Southkhali. The group wise abundance of Zooplankton is shown in table 14. Percentage wise abundance of zooplankton outside of the embankment are shown in figure 6

Table 14: Group wise abundance (ind/l) of Zooplankton.

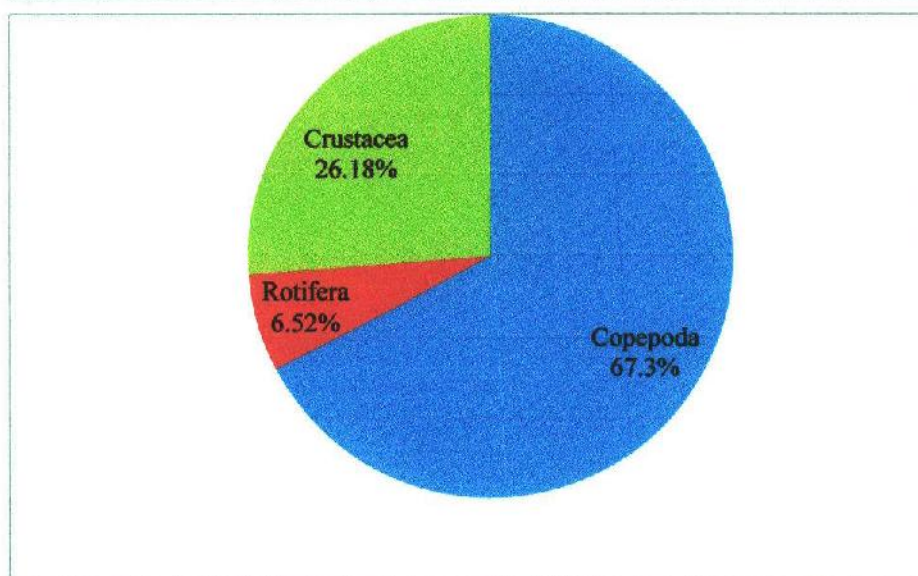
Class	Southkhali	Nolian	Southkadamtala
Rotifera	150	45	124.5
Copepoda	330	450	1284
Gastropoda	15		
Crustacea	135	75	499.5
Sedantaria		30	
Total (ind/l)	630	600	1908



1. Southkhali Village



2. Nolian Village



3. Southkadamtala Village

Figure 6: Percentage wise abundance of Zooplankton

4.3.2 Abundance of Zooplankton in the inside of the embankment

Zooplankton abundance was varied from 825 ind/l to 1065 ind/l. (Table 15) in the water bodies situated inside of the embankment throughout the study area. The study identified 18 species of zooplankton. The scientific name and species wise abundance of Zooplankton are given in table 16

Table 15: Zooplankton abundance (ind/l) in three villages

Station name	Ind/l
Southkhali	937.5
Nolian	1065
Southkadamtala	825

Table 16: Species wise abundance of Zooplankton (ind/l)

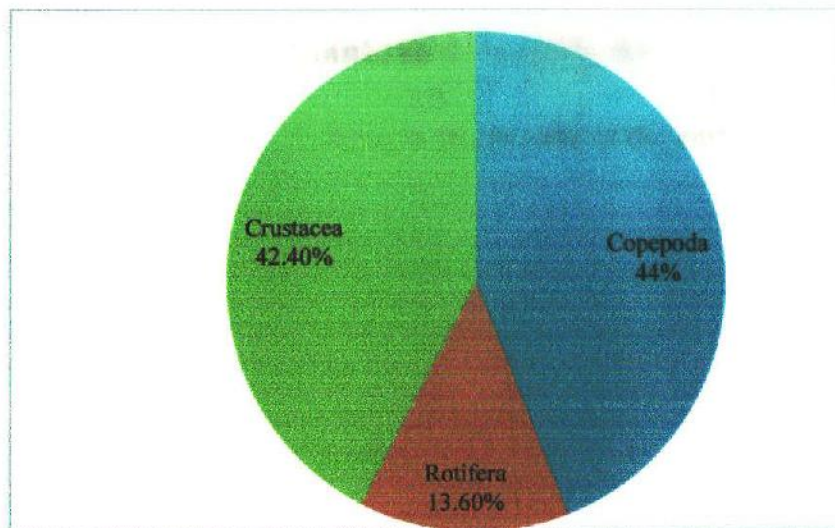
Name of taxa	Southkhali	Nolian	Southkadamtala
Rotifera			
<i>Brachionus sp.</i>	127.5		
Copepoda			
<i>Calanus finmarchicus</i>	120		
<i>Calanoidia euchaeta</i>	142.5		
<i>Calanoidia calanus</i>	180	345	225
<i>Calanoidia metridia</i>			105
<i>Eucalamus bungii</i>			75
<i>Copepod naupli</i>		45	
<i>Copepode sp.</i>			105
Branchiopoda			
<i>Leptodora kindtii</i>		90	
<i>Mysis sp.</i>		90	
Crustacea			
<i>Megalopa of crab</i>		45	
<i>Euphausia diomediae</i>			105
<i>Crustacean larvae</i>	45	90	30

<i>Cypris sp.</i>	127.5		
<i>Cyclope sp.</i>	225	135	
<i>Daphnia longispinosa</i>			105
<i>Bosmina sp.</i>		135	
Hydrozoa			
<i>Corimorpha nutans</i>			75
clitellata			
<i>leech</i>		90	
Total density (ind/l)	937.5	1065	825

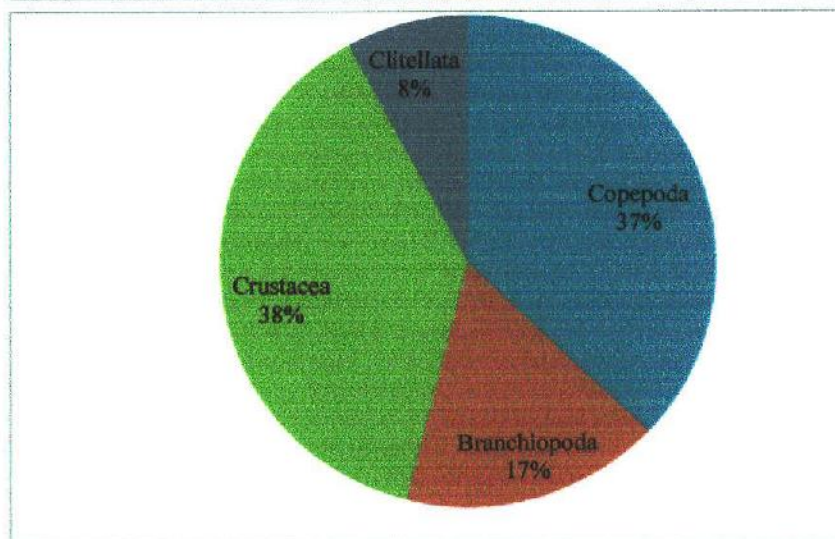
The abundance of different groups of zooplankton population was studied. In the present study 6 groups of zooplankton were observed. These groups were Rotifera, Copepod, Bivalvia, Crustacea, Branchiopoda, Hydrozoa and Clitellata. Copepoda was found dominant. Group wise abundance of zooplankton is given in table 17. Percentage wise abundance of zooplankton outside of the embankment is shown in figure 7.

Table 17: Abundance of different groups of Zooplankton (ind/l).

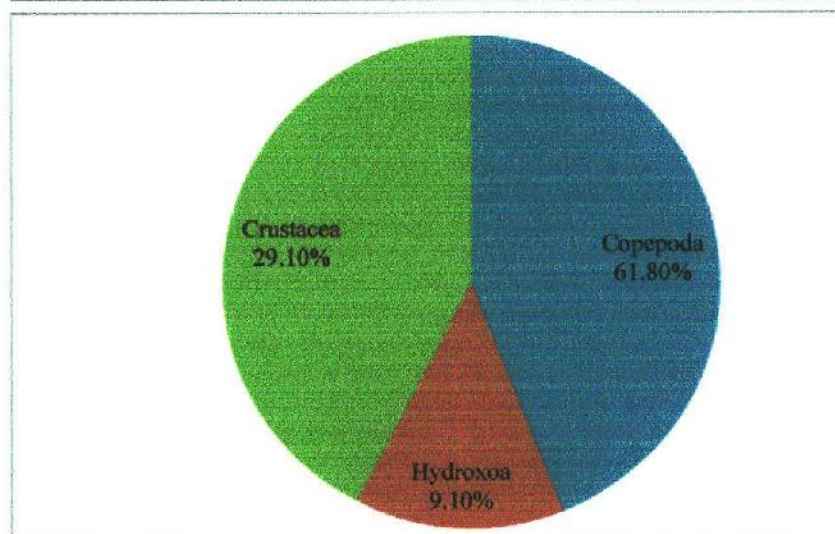
Class	Southkhali	Nolian	Southkadamtala
Rotifera	127.5		
Copepoda	412.5	390	510
Branchiopoda		180	
Crustacea	397.5	405	240
Hydrozoa			75
Clitellata		90	
Total (ind/l)	937.5	1065	825



1. Southkhali Village



2. Nolian Village



3. Southkadamtala Village

Figure 7: Percentage wise abundance of Zooplankton

4.4 Diversity of Zooplankton

4.4.1 Diversity of Zooplankton in the outside of the embankment

Twenty seven (27) Zooplankton species (Gamma diversity) have been identified from the outside of the embankment throughout the study area. Among them 13 belongs to Copepoda, 5 belongs to Rotifera, 7 belongs to Crustacea, 1 belongs to Bivalvia and 1 belongs to Polychaete. The different diversity index of Zooplankton is given table 18. The values of the Shannon- Wiener index (H) and evenness (E) were respectively, 2.58 and .96 for Southkhali, 2.41 and .95 for Nolian and 2.45 and .955 for Southkadamtala villages (table 18). The results indicate that the values of the diversity indices H and E was highest in Southkhali. When species diversity was compared among the three villages, the Southkhali Village was the most diverse. This is because the highest species richness (27) (Gamma diversity) and evenness in the Southkhali village resulted in the highest H value.

Table 18: Diversity index for Zooplankton

Diversity Index	Theoretical index value range	Diversity	Southkhali	Nolian	Southkadamtala
Shanon-Wiener index diversity(H)	0 – 4.6	Value↑Diversity↑	2.58	2.41	2.45
Evenness (E)	0 - 1	Value↑Richness↑	.96	.95	.955
Simpson's diversity index (D)	0 - 1	Value↑Diversity↓	.03	.08	.05
Margalef Index	0 - ∞	Value↑Diversity↑	5.05	2.93	3.69
Brillouin index	0 - ∞	Value↑Diversity↑	2.03	1.46	1.59
Menhinick's index	0 – 4.6	Value↑Diversity↑	3.25	1.68	2.32
Berger-Parker Index	0 - 1	Value↑Diversity↓	.12	.2	.13
Alpha diversity			15	12	13
Beta diversity			15	17	14
Gamma diversity(outside)		27			

CHAPTER FIVE

DISCUSSION

Discussion

Number of individuals per liter was highest (2629.5 ind/l) in Southkadamtala study area (outside of the embankment). Lowest number (480 ind/l) of individuals was found in the Nolian study area (outside of the embankment) (table 4). The abundance varied due to turbidity, salinity and sample collecting time. High turbidity reduces plankton abundance. If there are more surfactants and higher turbidity, there would be less phytoplankton because more surfactants and higher turbidity would block photosynthesis (Frew 1997). The study area was similar with same atmospheric condition. Because in Nolian turbidity was very high than Southkadamtala. So plankton abundance was highest in Southkadamtala.

The study recorded thirty nine (39) phytoplankton species belonging to diverse groups such as Bacillariophyceae (21), Chlorophyceae (9), Cyanophyceae (5), Euglenophyceae (3) and Dinophyceae (1) (table 2 and table 5). Aziz *et al.*, (2012) reported 36 species of phytoplankton belonging to Bacillariophyceae (30), Chlorophyceae (3), Euglenophyceae (2) and Xanthophyceae (1). The present study findings and findings of Aziz *et al.*, (2012) is about to similar due to same mangrove ecosystem where the water quality parameters such as temperature, pH, salinity playing an important role.

Mamun *et al.*, (2009) reported 15 genera of phytoplankton which was varied from present study due to different river system as well as water quality parameters and mesh size (90 μ m) of net.

Phytoplankton abundance varies from one river system to another. Table 20 provides mean abundance of species composition of phytoplankton cell for different river system where Bacillariophyceae was found to vary from 44.08% to 50%, Chlorophyceae from 18.94% to 37.5%, Cyanophyceae from 4.68% to 13.98%, Euglenophyceae 3.12% to 8.67% and Dinophyceae 13.98% to 23.39%. The highest mean abundance of phytoplankton was 50% and the lowest was 3.12%. The species composition of the study area shows that Bacillariophyceae was the highest which is similar to which is about similar to species composition of Baleswar river, Sibsa river, Hangsha river given by Aziz *et al.*, (2012) and Baleswar-Supati river, Passur –Sibsa river, Arpangasia-Batla river given by Mamun *et al.*, (2009).

During the study period group Bacillariophyceae was the most abundant. Because most of the species of group Bacillariophyceae live pelagically in open water, although some live as

Table 20: Class wise percentage of phytoplankton in different ecosystem in Bangladesh

Classes	Abundance (%)							
	Aziz <i>et al.</i> , (2012)				Mamun <i>et al.</i> , (2009)			
	Baleswar river	Sibsa river	Hangsha river	Baleswar-Supati river	Passur-Sibsa river	Arpangasia-Batla river	Southkhali	Nolian Kadamtala
Chlorophyceae	7.14	33.33	16.67	14	21	18	14.73	18.94
Bacillariophyceae	92.86	66.67	79.16	44	31	23	44.08	44.32
Cyanophyceae							13.98	4.68
Euglenophyceae			4.17				3.23	8.67
Dinophyceae							13.98	23.39
Myxophyceae				42	48	59		



surface films at the water-sediment interface (benthic), or even under damp atmospheric conditions. They are especially important in oceans, where they are estimated to contribute up to 45% of the total oceanic primary production (Toby *et al.*, 2003). Bacillariophyceae in marine environments typically exhibit a bloom and bust lifestyle. When conditions in the upper mixed layer (nutrients and light) are favourable their competitive edge allows them to quickly dominate phytoplankton communities (Furnas and Miles 1990). The study area was similar with same atmospheric condition. So Bacillariophyceae was most dominant in the study areas.

Among Bacillariophyceae *Coscinodiscus* and *Thalassiosira* contributed highest number of taxa (table 5). *Spirogyra* sp. occurred more abundantly. *Coscinodiscus asteromphalus*, *Coscinodiscus marginatus*, *Centritractus* sp. *Nitzschia* sp. *Thalassiosira decipiens*, *Navicula* sp. *Sunetra* sp. *Stigeoclonium* sp. *Trichodesmium erythraea*, *Anabaena* sp were rare in occurrence.

The study reported that the phytoplankton abundance was highest (2107.5 ind/l) in Southkhali study area and lowest (892.5 ind/l) in Southkadamtala study area inside of the embankment. Because in Southkhali study area samples were collected from ongoing culture Gher but in Southkadamtala new water was entered that's why there were lacking of nutrient and plankton abundance depends on nutrient.

Phytoplankton abundance varies from one pond system to another. Table 21 provides mean abundance of species composition of phytoplankton cell for different river system where Bacillariophyceae was found to vary from 63.75% to 23.13%, Chlorophyceae from 21.25% to 60.5%, Cyanophyceae from 14.59% to 15%, Euglenophyceae 10.32% . The highest mean abundance of phytoplankton was 63.75% and the lowest was 14.59%. The species composition of the study area shows that Bacillariophyceae > Chlorophyceae > Cyanophyceae > Euglenophyceae which is about similar to species composition of pond given by Khondker and chowdhury, 1993.

Table 21: Class wise percentage of phytoplankton in different ecosystem in Bangladesh

Abundance (%)					
Classes	Khandaker and Chowdhury (1993)	Chowdhury and Mazumder 1981.,	Present study(Gher)		
	Pond	Lake	Southkhali	Nolian	Kadamtala
Chlorophyceae	32.15	25	51.96	21.25	60.5
Bacillariophyceae	37.19		23.13	63.75	39.5
Cyanophyceae	19	40.03	14.59	15	
Euglenophyceae	11.66	25.80	10.32		
Diatom		9.17			
Myxophyceae					

In Southkhali and Nolian the phytoplankton abundance was highest in inside of embankment where outside of the embankment was lowest except Southkadamtala study area where phytoplankton abundance was highest in outside of the embankment and lowest in inside of the embankment. The amount of nutrient was higher in Gher than river. Beside these the water quality also maintained good for culture. Plankton abundance depends on water quality. That's why the abundance of phytoplankton was high in inside of the embankment except Southkadamtala.

In outside of the embankment the ranges of zooplankton abundance were varied from 600 ind/l to 1908 ind/l (table 12). The highest (1908 ind/l) amount of zooplankton was found in Southkadamtala and lowest (600 ind/l) amount was found in Nolian. Because in Nolan water turbidity was high and water turbidity affected the zooplankton abundance.

In inside of the embankment the zooplankton abundance was highest (1065 ind/l) in Nolian and lowest (825 ind/l) in Southkadamtala study area. Because in Nolian samples were collected from culture Gher and in Southkadamtala samples were collected from new entered water bodies.

During the study period Copepoda was the most dominant group. Copepoda are usually the dominant members of the zooplankton, Johannes and Thorsten, (1997) reported that copepoda form the largest animal biomass on earth, where they alone comprise up to 80% of zooplankton biomass. Because of their smaller size and relatively faster growth rates, however, and because they are more evenly distributed throughout more of the world's oceans, have strongly modified bodies (Suh *et al.*, 1992). Copepoda are especially important in oceans. When conditions in the upper mixed layer (nutrients and light) are favourable their competitive edge allows them to quickly dominate zooplankton communities. The study area was similar with same atmospheric condition. So Copepoda was most dominant in the study areas.

CHAPTER SIX

CONCLUSION

Conclusion

The plankton is considered to be the best index of the biological productivity and the nature of aquatic habitat. The present biological investigation revealed the information regarding the abundance and diversity of plankton in the three study areas adjacent of the Sundarban mangrove forest. The study area showed a rich and diverse plankton population. In the study areas a total of 32 species from outside of the embankment and 25 species from inside of the embankment were identified. The identified species were under the class Chlorophyceae, Bacillariophyceae, Cyanophyceae, Dinophyceae and Euglenophyceae. Among them Bacillariophyceae was found dominated class throughout the study period in the study areas. Among Bacillariophyceae *Coscinodiscus* and *Thalassiosira* contributed highest number of taxa. Southkhali study area was the diversified for both Phytoplankton and Zooplankton in outside and inside of the embankment. A total of 27 species of zooplankton from outside of the embankment and 20 species from inside of the embankment were identified. The identified species were under the class Rotifera, Copepoda, Branchiopoda, Bivalvia, Crustacea, Hydrozoa, Polychete and clitellata. Among them Copepoda was found the most dominant class. The findings of this study will be helpful for proper management of aquatic system.

CHAPTER SEVEN

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APPENDIX



Appendix

Diversity of Phytoplankton in the outside of the embankment

Table 22: Alpha , Beta Gamma Diversity.

Name of Taxa	Southkhali Outside	Nolian Outside	Southkadamtala Outside
<i>Dinophysis rotundata</i>	×		×
<i>Trichodesmium erytgraea</i>	×		
<i>Volvox aureas</i>	×	×	
<i>Bacteriastrium delicatulum</i>	×		
<i>Gonatozygon sp.</i>	×	×	×
<i>Leptocylidricus danicus</i>	×	×	
<i>Ulothrix sp.</i>	×		×
<i>Coscinodiscus asteromphalus</i>	×		
<i>Coscinodiscus granii</i>	×		×
<i>Coscinodiscus marginatus</i>	×		
<i>Coscinodiscus stellaris</i>			×
<i>Oscillatoria agardhii</i>	×		×
<i>Oocystis pusilla</i>	×		×
<i>Thallasiosira rotule</i>	×		×
<i>Nitzschia sp.</i>	×		
<i>Centritractus sp.</i>	×		
<i>Uronema sp.</i>	×	×	
<i>Spirogyra sp.</i>	×	×	×
<i>Spirulina sp.</i>	×		
<i>Euglena spathirhyncha</i>	×		
<i>Phacus sp.</i>		×	×
<i>Stigeoclonium sp.</i>		×	
<i>Rhizosolenia hebata</i>		×	
<i>Thalassiosira decipians</i>		×	
<i>Anabeana sp</i>		×	
<i>Microcystis incerta</i>		×	
<i>Navicula sp.</i>		×	
<i>Sunendra sp.</i>			×
<i>Bulbocheate sp.</i>			×
<i>Nanomia cara</i>			×
<i>Dunellia sp.</i>			×
<i>Pleurosigma directum</i>			×
Alpha Diversity	19	12	15
Beta Diversity	20	21	17
Gamma Diversity		32	

Diversity of Phytoplankton in the outside of the

Table 23: Alpha , Beta Gamma Diversity.

Name of Taxa	Southkhali Inside	Nolian Inside	Southkadamtala Inside
<i>Trichodesmium erytgraea</i>	×		
<i>Volvox aureas</i>	×		×
<i>Ulothrix sp.</i>	×		×
<i>Coscinodiscua granii</i>	×	×	
<i>Oscillatoria agardhii</i>	×	×	
<i>Nitzchia sp.</i>	×		
<i>Uronema sp.</i>	×		
<i>Spirogyra sp.</i>	×	×	×
<i>Spirulina sp.</i>	×		
<i>Euglena spathirhyncha</i>	×		
<i>Phacus sp.</i>	×		
<i>Closterium parvula</i>	×		
<i>Navicula cuspidate</i>	×		
<i>Leptocylidricus danicus</i>		×	
<i>Thalassiosira decipians</i>		×	
<i>Thalassiosira nitzchoides</i>		×	
<i>Anabeana sp</i>		×	
<i>Microcystis incerta</i>		×	
<i>Navicula sp.</i>		×	
<i>Gonatozygon sp.</i>			×
<i>Thread algae</i>			×
<i>Stigeoclonium sp.</i>			×
<i>Cladophora sp</i>			×
<i>Fritschella sp.</i>			×
<i>Asterionella sp.</i>			×
Alpha Diversity	13	9	9
Beta Diversity	16	15	16
Gamma Diversity	25		

Diversity of zooplankton in the outside of the

Table 24: Alpha , Beta Gamma Diversity.

Name of Taxa	Southkhali Outside	Nolian Outside	Southkadamtala Outside
<i>Calanus finmarchicus</i>	×	×	
<i>Acrocalanus gracillius</i>	×		
<i>Littorina littorica</i>	×		
<i>Euchata marina</i>	×		
<i>Megalopa of crab</i>	×	×	
<i>Acartia spinicuada</i>	×		
<i>Euphausia diomediae</i>	×		
<i>Calanoidia euchaeta</i>	×	×	×
<i>Acartia clausi</i>	×		
<i>Calanus helgolandicus</i>	×	×	×
<i>Crustacean larvae</i>	×	×	×
<i>Brachionus sp.</i>	×		×
<i>Cypris sp.</i>	×		×
<i>Mesocyclope sp.</i>	×		×
<i>Calanoidia calanus</i>	×	×	×
<i>Calanoidia armata</i>		×	
<i>Calanus sp.</i>		×	
<i>Acartia tranteri</i>		×	
<i>Leptodiaptomus ashlandi</i>		×	
<i>Bicuspidatus thomasi</i>		×	
<i>Owenia fusiformis</i>		×	
<i>Harpacticoida metridia</i>			×
<i>Calanoidia metridia</i>			×
<i>Daphnia longispuria</i>			×
<i>Eucalanus bungii</i>			×
<i>Microcalanus pusillus</i>			×
<i>Cyclope sp.</i>			×
Alpha Diversity	15	12	13
Beta Diversity	15	17	14
Gamma Diversity		27	

Diversity of zooplankton in the inside of the embankment

Table 25: Alpha , Beta Gamma Diversity.

Name of Taxa	Southkhali Inside	Nolian Inside	Southkadamtala Inside
<i>Calanus finmarchicus</i>	×		
<i>Calanoidia euchaeta</i>	×		
<i>Crustacean larvae</i>	×	×	×
<i>Brachionus sp.</i>	×		
<i>Cypris sp.</i>	×		
<i>Calanoidia calanus</i>	×	×	×
<i>Cyclope sp.</i>	×	×	
<i>Megalopa of crab</i>		×	
<i>Bosmina sp.</i>		×	
<i>Copepod naupli</i>		×	
<i>Leptodora kindtii</i>		×	
<i>Mysis sp.</i>		×	
<i>leech</i>		×	
<i>Calanoidia metridia</i>			×
<i>Daphnia longispuria</i>			×
<i>Eucalanus bungii</i>			×
<i>Copepode sp.</i>			×
<i>Corimorpha nutans</i>			×
<i>Euphausia diomediae</i>			×
Alpha Diversity	7	9	8
Beta Diversity	10	13	11
Gamma Diversity		20	

Division: Thallophyta

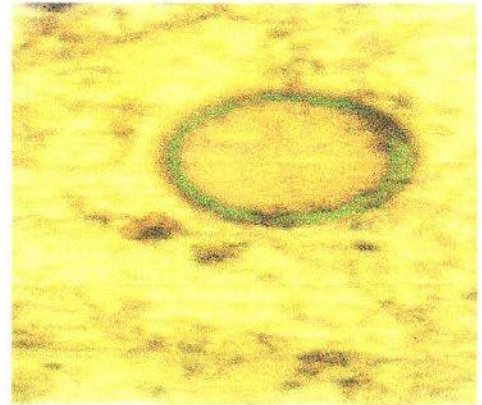
Class: Bacillariophyceae

Order: Centrales

Family: Coscinodisceae

Genus: Coscinodiscus

Species: *Coscinodiscus marginatus*



Division: Thallophyta

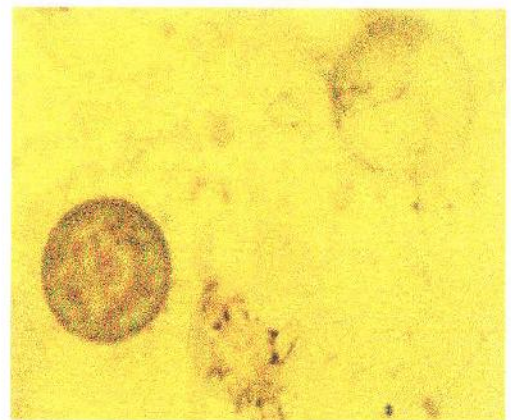
Class: Bacillariophyceae

Order: Centrales

Family: Coscinodisceae

Genus: Coscinodiscus

Species: *Coscinodiscus stellaris*



Phylum: Chlorophyta

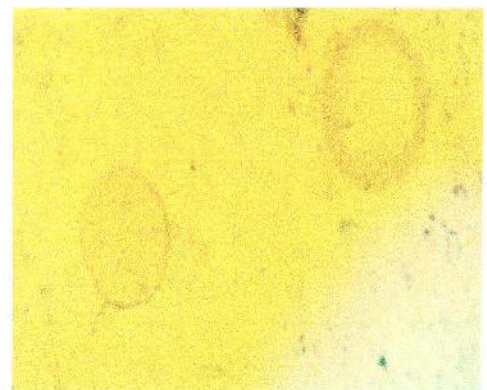
Class: Chlorophyceae

Order: Oocystales

Family: Oocystaceae

Genus: Oocystes

Species: *Oocystes pusilla*



Division: Thallophyta

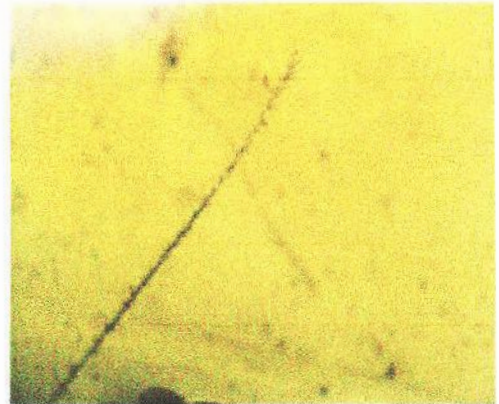
Class: Bacillariophyceae

Order: Centrales

Family: Coscinodiscaeae

Genus: Thallossiosira

Species: *Thallossiosira rotule*



Division: Thallophyta

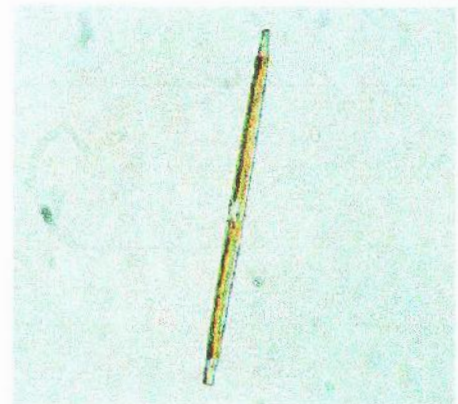
Class: Bacillariophyceae

Order: Pennales

Family: Naviculoideae

Genus: Nitzschia

Species: *Nitzschia sp.*



Phylum: Chlorophyta

Class: Chlorophyceae

Order: Zygnematales

Family: Zygnemataceae

Genus: Spirogyra

Species: *Spirogyra sp.*



Phylum: Cyanobacteria

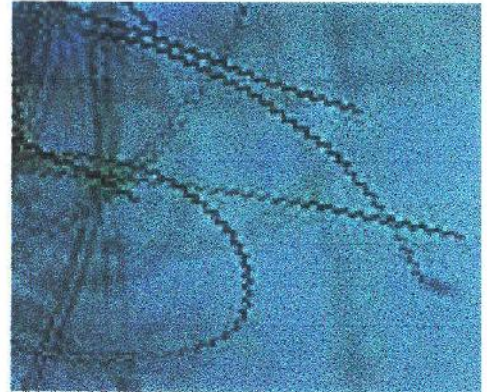
Class: Cyanophyceae

Order: Oscillatoriales

Family: Oscillatoriaceae

Genus: *Spirulina*

Species: *Spirulina sp.*



Division: Thallophyta

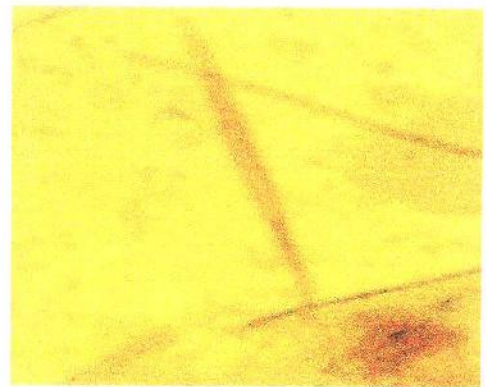
Class: Bacillariophyceae

Order: Pennales

Family: Naviculoideae

Genus: *Navicula*

Species: *Navicula sp.*



Division: Thallophyta

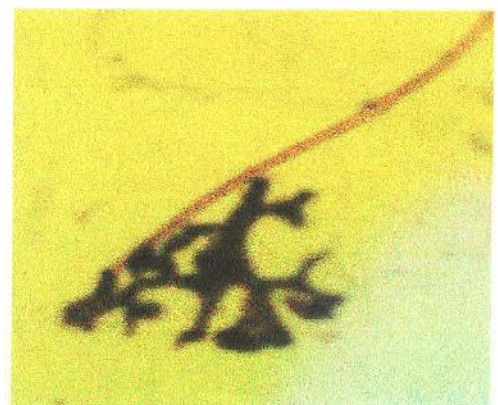
Class: Bacillariophyceae

Order: Pennales

Family: Fragilariaceae

Genus: *Asterionella*

Species: *Asterionella sp.*



Division: Thallophyta

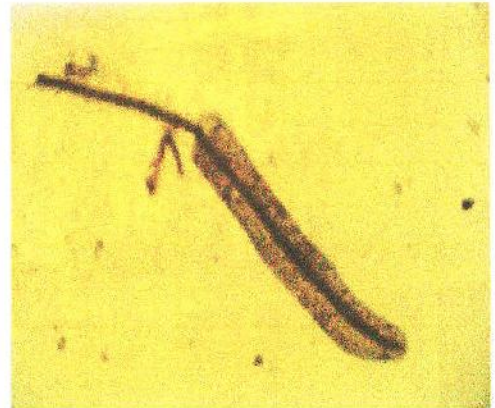
Class: Bacillariophyceae

Order: Centrales

Family: Solenidae

Genus: *Rhizosolenia*

Species: *Rhizosolenia hebatata*



Phylum: Chlorophyta

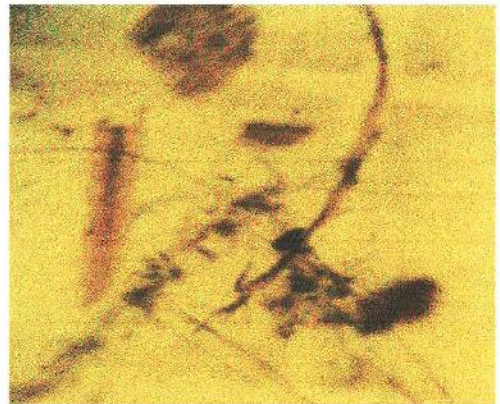
Class: Chlorophyceae

Order: Oedogoniales

Family: Oedogoniaceae

Genus: *Bulbocheate*

Species: *Bulbocheate sp.*

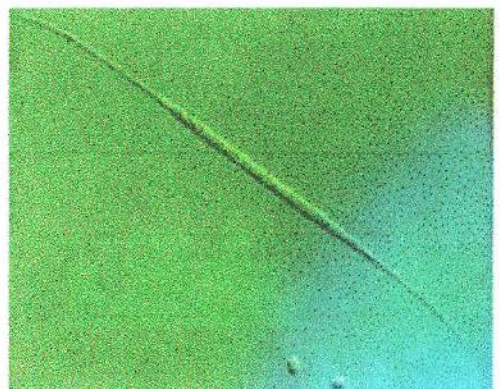


Phylum: Chlorophyta

Class: Chlorophyceae

Genus: *Closterium*

Species: *Closterium parvula*

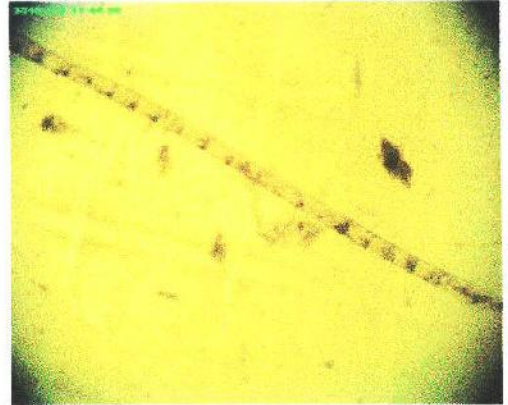


Phylum: Chlorophyta

Class: Chlorophyceae

Genus: *Frittschiella*

Species: *Frittschiella* sp.



Class: Euglenophyceae

Order: Euglenales

Family: Euglenidae

Genus: *Euglena*

Species: *Euglena spathirhyncha*



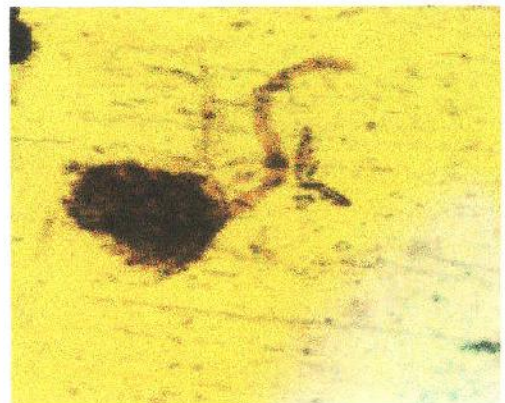
Class: Euglenophyceae

Order: Euglenales

Family: Euglenidae

Genus: *Phacus*

Species: *Phacus* sp.



Class: Euglenophyceae

Order: Euglenales

Family: Euglenidae

Genus: *Dunellia*

Species: *Dunellia sp.*



Phylum: Cyanobacteria

Class: Cyanophyceae

Order: Nostocales

Family: Nostocaceae

Genus: *Anabeana*

Species: *Anabeana sp.*



Phylum: Cyanobacteria

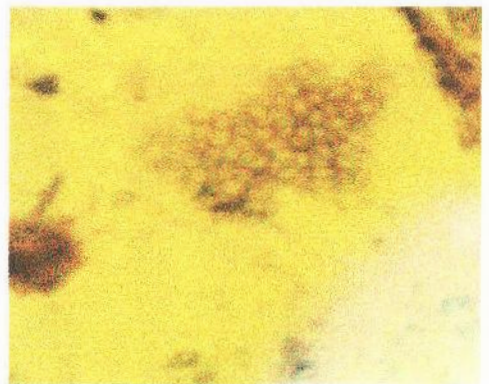
Class: Cyanophyceae

Order: Chroococcales

Family: Microcystaceae

Genus: *Microcystis*

Species: *Microcystis incarta*



Classification of Zooplankton

Phylum: Rotifera

Class: Monogononta

Order: Ploima

Family: Acartidae

Genus: *Acartia*

Species: *Acartia spinicuata*



Phylum: Rotifera

Class: Monogononta

Order: Ploima

Family: Acartidae

Genus: *Acartia*

Species: *Acartia clausi*



Phylum: Rotifera

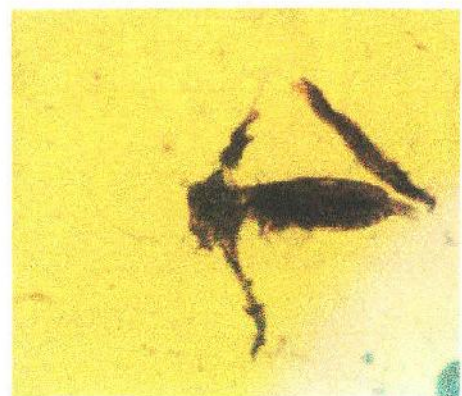
Class: Monogononta

Order: Ploima

Family: Acartidae

Genus: *Acartia*

Species: *Acartia tranteri*



Phylum: Arthropoda

Class: Maxillipoda

Sub class: Copepoda

Order: Calanida

Family: Euchaetidae

Genus: Euchaeta

Species: *Euchaeta marina*



Phylum: Arthropoda

Class: Maxillipoda

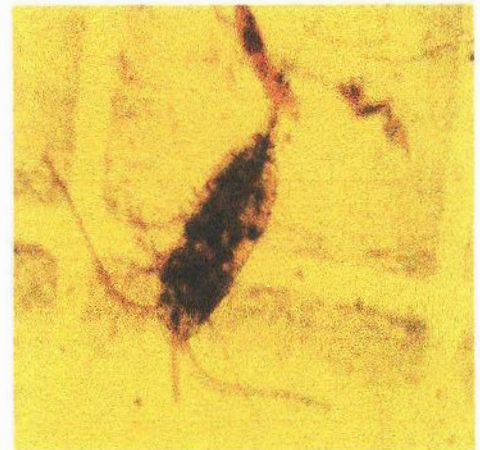
Sub class: Copepoda

Order: Calanida

Family: Eucalanidae

Genus: Eucalanus

Species: *Eucalanus bungii*



Phylum: Arthropoda

Class: Maxillipoda

Sub class: Copepoda

Order: Calanida

Family: Calanoidae

Genus: Calanus



Species: *Calanus sp.*

Phylum: Arthropoda

Class: Maxillipoda

Sub class: Copepoda

Order: Calanida

Family: Microcalanidae

Genus: Microcalanus

Species: *Microcalanus pusillus*



Phylum: Arthropoda

Class: Maxillipoda

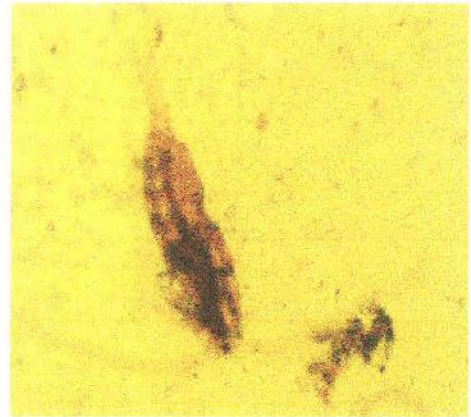
Sub class: Copepoda

Order: Cyclopoida

Family: Cyclopidae

Genus: Bicuspidatus

Species: *Bicuspidatus thomasi*



Phylum: Arthropoda

Class: Crustacea

Order: Cyclopoida

Family: Cyclopidae

Genus: Mesocyclop



Species: *Mesocyclop sp.*

Phylum: Arthropoda

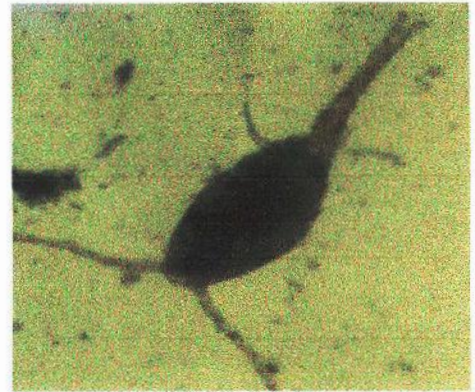
Class: Crustacea

Order: Copepoda

Family: Copepoidae

Genus: *Copepod*

Species: *Copepod sp.*



Phylum: Arthropoda

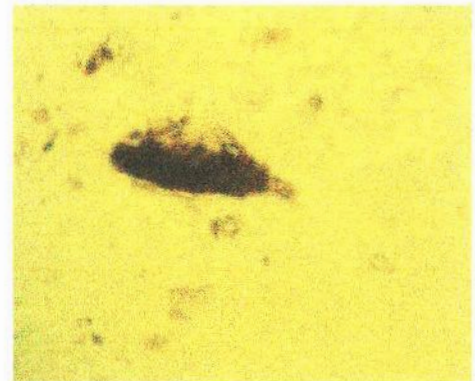
Class: Crustacea

Order: Copepoda

Family: Copepoidae

Genus: *Copepod*

Species: *Naupli of Copepod sp.*



Phylum: Arthropoda

Sub phylum: Crustacea

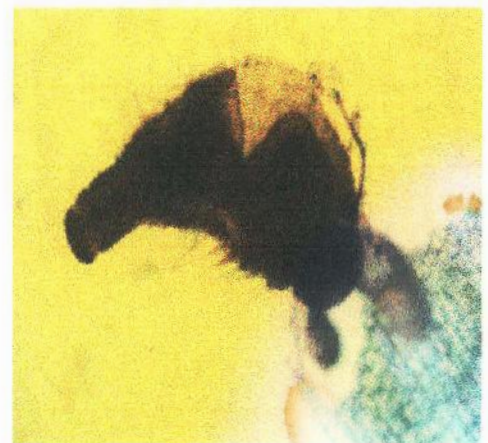
Class: Branchiopoda

Order: Caladocera

Family: Bosminidae

Genus: *Bosmina*

Species: *Bosmina sp.*



Phylum: Arthropoda

Sub phylum: Crustacea

Class: Branchiopoda

Order: Caladocera

Family: Leptodoridae

Genus: Leptodora

Species: *Leptodora kindii*



Phylum: Arthropoda

Sub phylum: Crustacea

Class: Malacostraca

Order: Mysida

Family: Mysidae

Genus: Mysis

Species: *Mysis sp.*



Phylum: Arthropoda

Sub phylum: Crustacea

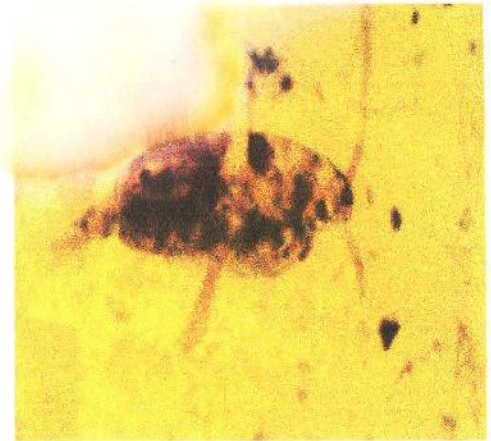
Class: Branchiopoda

Order: Caladocera

Family: Daphnidae

Genus: Daphnia

Species: *Daphnia longispuria*



Phylum: Arthropoda

Class: Crustacea

Order: Euphausiacea

Family: Euphausiadae

Genus: Euphausia

Species: *Euphausia diomediae*

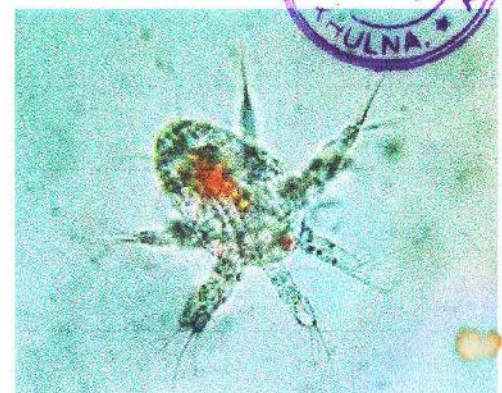


Phylum: Arthropoda

Class: Crustacea

Order: Cirripedia

Species: Megalopa of crab (*Scylla serrata*)



Phylum: Arthropoda

Class: Crustacea

Order: Decapoda

Species: Larvae of crustacean



Phylum: Mollusca

Class: Bivalvia

Genus: Littorina

Species: *Littorina littorica*



Phylum: Annelida

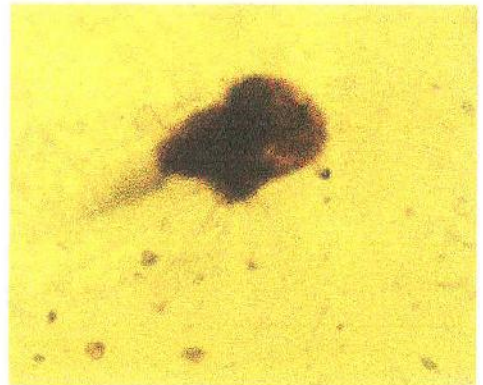
Class: Polychaete

Order: Sabellida

Family: Owenidaedae

Genus: Owenia

Species: *Owenia fusiformis*



Phylum: **Annelida**

Class: Clitellata

Species: leech



Phylum: Cnidaria

Class: Hydrozoa

Order: Anthoathecata

Family: Corymorphidae

Genus: *Corymorpha*

Species: *Corymorpha nutans*



Classification of phytoplankton

Phylum: Dinoflagellata

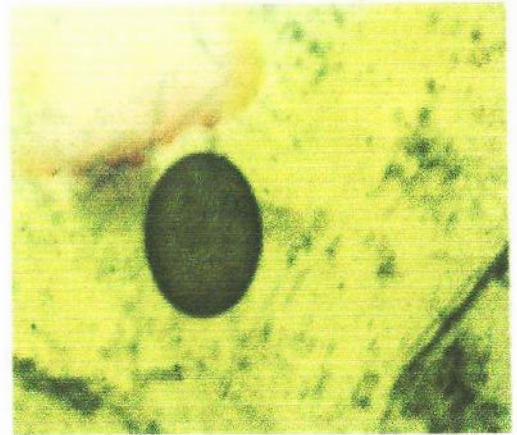
Class: Dinophyceae

Order: Dinophysiales

Family: Dinophysiaceae

Genus: *Dinophysis*

Species: *Dinophysis rotundata*

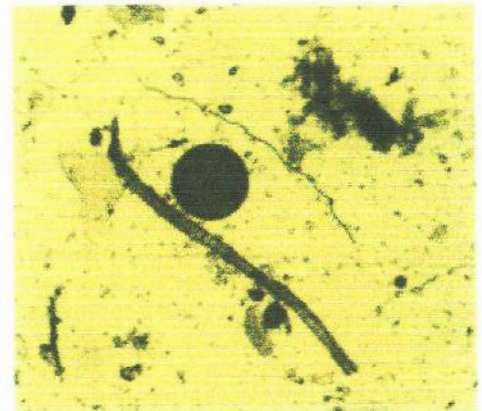


Division: Thallophyta

Class: Cyanophyceae

Genus: *Trichodesmium*

Species: *Trichodesmium erythraea*



Division: Thallophyta

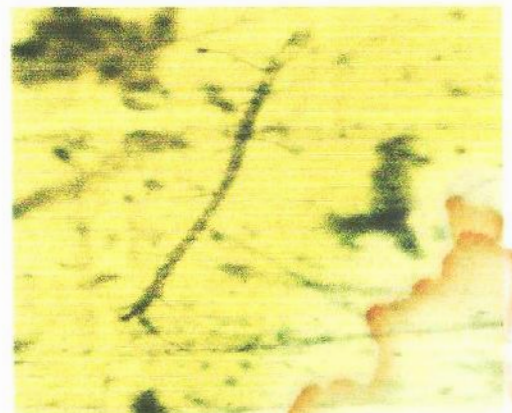
Class: Bacillariophyceae

Order: Centrales

Family: Chaetocereae

Genus: *Bacteriastrum*

Species: *Bacteriastrum delicatulum*



Division: Bacillariophyta

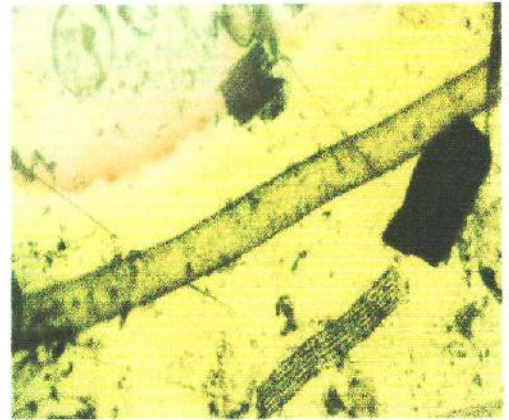
Class: Coscinodiscophyceae

Order: Leptocylindriles

Family: Leptocylindriaceae

Genus: Leptocylindrius

Species: *Leptocylindrius danicus*



Division: Bacillariophyta

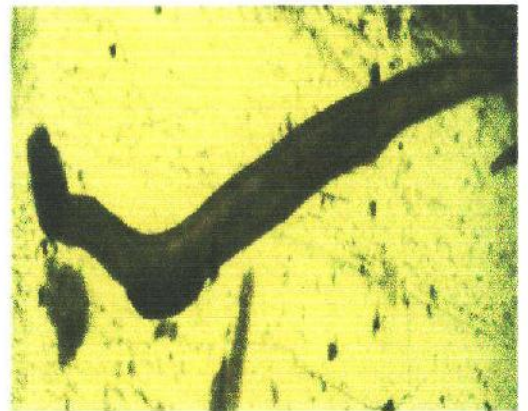
Class: Bacillariophyceae

Order: Bacillariales

Family: Bacillariaceae

Genus: Gonatozygon

Species: *Gonatozygon* sp.



Division: Thallophyta

Class: Bacillariophyceae

Order: Centrales

Family: Coscinodisceae

Genus: Coscinodiscus

Species: *Coscinodiscus asteromphalus*

