VRIJE UNIVERSITEIT BRUSSEL

STUDY ON PLANKTONIC SHRIMP *ACETES* OF THE MATHAMUHURI RIVER ESTUARY IN THE CHAKARIA MANGROVE ECOSYSTEM OF BANGLADESH

BY

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CONTENTS

List of Tables

List of Figures

DECLARATION

I declare that the present work is original and has not been presented for a degree in any other University.

Brussel, 1996.

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THIS THESIS IS DEDICATED TO MY PARENTS

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ABSTRACT

The present investigation was carried out for three years from May 1982- April 1984 and May 1992-April 1993 in the Mathamuhuri river estuary of the Chakaria mangroves ecosystem of Bangladesh and focused on the occurrence and distribution, spawning, fisheries, food and feeding of *Acetes* shrimps influenced by hydrobiological factors, and chemistry and microbial population.

The hydrological factors of the studied area governed by the monsoons. Salinity distribution of the estuary is a function of the annual rainfall pattern ($r = -0.605$, $P < 0.001$, df. = 34).The highest salinity was recorded in the premonsoon period in March (33.5‰) and the minimum (2‰) in monsoon months (July-September), when 80% of the yearly rainfall occurred. Bimodal pattern of temperature was exhibited in the study area. The maximum water temperature, 31.8°C was recorded in May and a minimum of 21°C in January/ February during the investigation. Dissolved oxygen varies between 6.6 ml/l and 3.6 ml/l, maximum in December and minimum in May, and it was inversely related with water temperature ($r = -0.395$, $P < 0.01$, df. = 34). Maximum sunshine duration occurred in December (9.60 hr/day), and the lowest (2.3 hr/day) in rainmonsoon months (June/July) and it was negatively correlated with air temperature ($r = -0.571$, $P < 0.003$, $F = 16.45$) and rainfall ($r = -0.822$, $P < 0.001$, $F = 70.78$). Tidal amplitude has an average of 2. 11 m. The strong tidal currents result in almost homogeneous vertical distribution of the different factors in the shallow estuarine region of Mathamuhuri river. *Acetes* abundance in the investigated estuary was inversely related to the monsoon and the density of *Acetes* was not related to only one factor, because monsoon is influenced by several factors. Redundancy analysis showed the abundance of *Acetes* shrimps exists parallel relationship with salinity and sunshine, and opposite relationships with rainfall and dissolved oxygen. Regression analyses also inferred similar results.

A total of 91 species under 44 genera were identified among the phytoplankton. Bacillariophyta and Cyanophyta were dominant groups and occupied 50.77% and 47.7% of the phytoplankton population, respectively. The highest abundance of phytoplankton was recorded in early monsoon months (June-July) with a peak in July (31550 cells/l) and shows negative correlation with salinity ($r = -0.058$, $P < 0.05$). The highest net production occurred in spring months (April - May) with a peak in April (1690.5 mg C/ m^3/day and minimum in February (73.07 mg C/ m^3/day. Four *Acetes* species (*A. indicus* , *A. erythraeus* , *A. chinensis* & *A. japonicus*) maintained parallel insignificant relationship only with Bacillariophyta.

Six species of *Acetes* were recorded in the investigation of Mathamuhuri estuary and adds three more species to the list of *Acetes* shrimps (*A. chinensis* , *A. vulgaris* and *A. intermedius*) of this country. *Acetes* shrimp occupied a small fraction (0.50%) of the total zooplankton population (>500 μm), they were recorded throughout the period of investigation, but low density occurred during rainy season. In the Mathamuhuri estuary *Acetes* shrimps showed seasonality which was closely correlated with arrival and departure of monsoon. *Acetes* showed bimodal peak in occurrence, an increasing trend just after the monsoon months (November-January) and another peak season was observed prior to the start of the monsoon (April-May). In the rainmonsoon months (August-September) almost all *Acetes* disappeared from the Mathamuhuri river estuary; this was attributed to fresh-water outflow. Present investigation clearly shows that ingress of *Acetes* shrimp takes place more at night in comparision to the day and they immigrate in higher densities through bottom water. Bottom samples were higher in values than surface samples, even in night and higher abundance of *Acetes* were recorded at lower reaches station, during night maximum *Acetes* shrimps took place in the lower parts of the Mathamuhuri river estuary and immigration from adjacent waters of the offshore Islands (Kutubdia and Moheskhali channel) probably for feeding and spawning. The genus of *Acetes* in the study area was dominated by four species, *Acetes indicus* (45.35%), *A. erythraeus* (33.22%), *A. chinensis* (7.46%), *A. japonicus* (6.80%). All species of *Acetes* occurred in large schools during northeastern monsoon, when the weather was fine and the estuary or sea clam. Higher abundance also reflected by the dense mangroves and before the practice of aquaculture in Chakaria Sundarbans. In the studied estuary and its adjacent area adults of *Acetes* shrimps were recorded throughout years and apparently *Acetes* spawn in the delta of Mathamuhuri river and in the vicinity of Kutubdia, Moheskhali and Sonadia Islands; and these areas are suitable for commercially fished of *Acetes* .

Diatoms, copepods (nauplius), *Sagitta*, amporphous, sand and mud grain are the major food items of *Acetes indicus* and *A. erythraeus* and they showed some seasonality in diet composition.

Chemical analyses of *Acetes* shrimps revealed presence of significant amount of protein (14% of wet weight & 65% of sun dry body weight), calcium (1g/100g) and lower concentration of radioactivity (^{137}Cs 0.09 ± 0.02, ^{40}K 9.83 ± 0.79, ^{238}U 0.8 ± 0.01 and ^{232}Th 0.32 ± 0.09) were recorded.

The bacterial flora of freshly caught *Acetes indicus* and *A. erythraeus* comprise three genera namely -*Micrococcus, Pseudomonas* and *Achromobacter* and three types of bacteria of public health significance such as *Escherichia coli*, faecal *Streptococcus* and coagulase positive *Staphylococcus* were found. In the dry *Acetes* only *Streptococcus* was recorded. The total bacterial load per gram of fresh and dry *Acetes* were recorded 5.12 X 10^5 and 3.1 X 10^5, respectively. Dry *Acetes* are more reliable food for larvae culture.

CHAPTER 1

1.1.GENERAL INTRODUCTION
1.2. REVIEW OF LITERATURE

1. 1. GENERAL INTRODUCTION

The northwardly protruded tongue of the Indian ocean lying between the Peninsular, India and Burma, is known as the Bay of Bengal (Fig.1). It is bounded by Bangladesh, India, Srilanka, Burma (Mayanmar) and Andaman Islands. Roughly it covers the area between latitude 10°N to 22°N and longitude 80°E to 95°E. Out of this, Bangladesh territorial waters lie between the shore line down to latitude 22°N and longitude 90°E to 92°E. The coast of Bangladesh stretches 710 km around the head of the Bay of Bengal, from the mouth of the Naf river in the southeast to the mouth of the Raimongal river in the southwest. It supports the single largest natural mangrove forest of the world (about 585,000 ha) and a further 37,000 ha of planted mangrove forests (Karim and Khan,1980).The coast is criss-crossed by a network of complex estuarine systems created by the Ganges, Brammaputra, Karnaphuli, Meghna, Mathamuhuri and other rivers which open into the Bay of Bengal and carry large amounts of nutrients which facilitate the production of large quantities of plankton in the area. Here, upwelling caused by the southwest monsoon also influences the productivity of the area. The southwest monsoon winds bring about a complete reversal of the surface current pattern which is clockwise from January to July and counter clockwise from August to December according to the direction of the wind (Lambeuf,1987; Zafar,1989). Another picture of the coastal region of Bangladesh falls within the track of the cyclonic storms forming over the Bay of Bengal which suffers almost annually from severe cyclone damage (Ali,1979; Bashirullah *et al.* 1989 and Zafar, 1992).

Lambeuf (1987) and Zafar (1989) stated that the geoclimatic environment of the Bay of Bengal, particularly the Bangladesh portion, is dominated by three main factors: i. Wind direction, ii. Precipitation under the influence of tropical monsoon climate, and iii. River discharge, also related to the monsoon but intensified by the fact that major river systems in India, Bangladesh and Burma empty into the Bay of Bengal. These factors have a strong influence of the marine environment as they affect, to a varying extent and in varying time sequence, the water circulation, salinity, turbidity, productivity, occurrence, distribution and bottom topography.

It was already reported that coastal and offshore waters of Bangladesh are the habitats of a variety of flora and fauna. This region contains a good stock of shrimp (Shahaidullah,1983). Shrimp occupies a very important position in the national economy of Bangladesh. It is the third important foreign exchange earning commodity of this country (Mahmood and Zafar, 1990). But till now information is lacking on Sergestid shrimps. Therefore extensive and intensive investigation on Sergestidae in the coastal water of Bangladesh is essential.The species of the genus *Acetes* under the family Sergestidae are typical planktonic

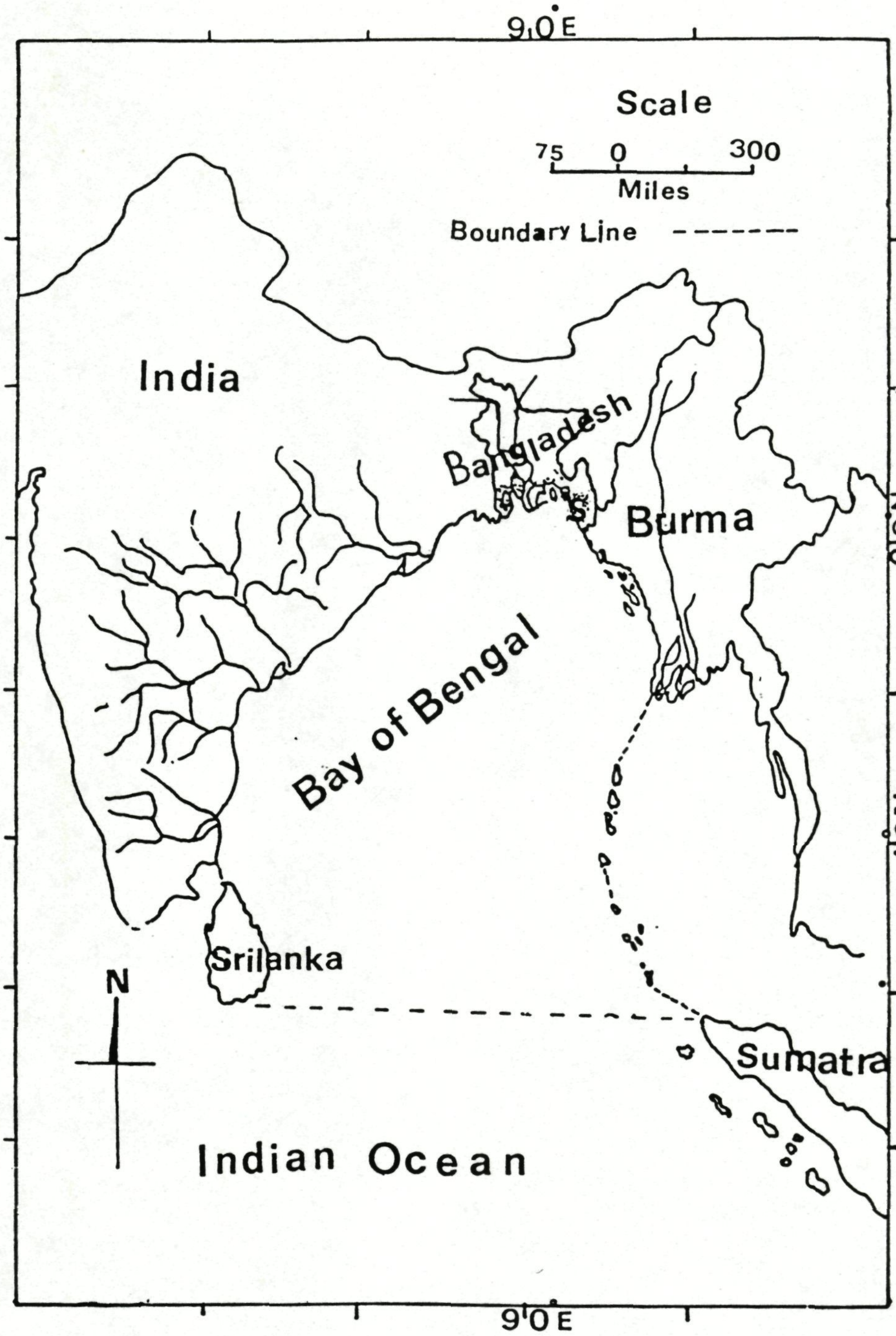

Fig.1. The Bay of Bengal and geographical location of the study area (S) in the southeastern parts of Bangladesh.

shrimps and many are commonly distributed in estuarine and coastal waters of tropical and subtropical regions (Omori, 1975 &1977; Bhattacharya, 1987). This shrimp often becomes a major component in the diet of offshore fishes and large shrimps (Basheruddin and Nayar, 1961; Omori, 1975 and Zafar, 1992). *Acetes* plays a significant role in the food web of neritic waters, particularly in mangroves and seagrass beds which extend over vast areas in tropical and subtropical regions. During certain part of year, *Acetes* forms conspicuous aggregation near the shore. Such accumulations have been exploited as human food for many years in Asia and Africa. The annual world catch of *Acetes* is estimated to be about 170,000 tons, or about 15% of the total shrimp catch in the world (Omori, 1975). *Acetes* belongs to a minor planktonic crustacean group represented by a small number of species, but is one of the economically important organisms, which affords a major source of protein to some people in the Indo-west Pacific region. *Acetes* is also referred as the prime food for Penaeid shrimps and fish (Kungvankij *et al.*,1986). About 71.82% crude protein and 3.22% fat are present in *Acetes* shrimp (Dy Penaflorida,1989). Now a days *Acetes* are used in the hatchery operations and nursery ponds for larval rearing. So, as an ideal food consideration, information about the chemistry and microbial aspects of *Acetes* are essential. Because quality of a food is depends on high nutritional value and bacterial standards.

The present investigation focuses on the ecology, biochemistry and microbial condition of adult *Acetes* shrimps and in the Mathamuhuri river of Chakaria sundarban area with particular emphasis on the following

i. The major environmental factors of a mangrove estuary of the area of investigation.
ii. The relations between *Acetes* with zooplankton and phytoplankton and the environmental factors.
iii. The species composition and structure of the *Acetes* shrimp population.
iv. The pattern of seasonal occurrence of *Acetes* shrimp.
v. The chemistry of *Acetes* (*A. indicus* , *A. erythraeus*) of the Mathamuhuri river estuary (Proximate composition, minerals, radionuclides and chitin content).
vii. Estimate total heterotrophs bacterial population, and specific dangerous species (*Escherichia coli*, faecal *Streptococcus*, *Staphylococcus*, *Salmonella* and *Vibrio. parahaemolyticus*).

1. 2. REVIEW OF LITERATURE

1.2.1. Preface

In the last decade more and more attention is put on qualitative and quantitative variation of plankton related to general economic important organisms (Davis, 1955; Omori, 1975; Mahmood and Zafar, 1990; Zafar, 1992). In the Bangladesh coastal waters information on Sergestid shrimp is scarce. However, few work was publised on *Acetes* by different authors in tropical and subtropical countries. Some aspects on *Acetes* biology, ecology and chemistry are still in need of study, and fundamental gaps in knowledge still exist (Xiao and Greenwood, 1993).

1.2.2. Related work in the Bangladesh coastal waters on *Acetes.*

The occurrence of three sergestid shrimps (*Acetes*) in the Karnaphuli river estuary was reported by Mahmood *et al.* (1978). *Acetes* occurrence in the Satkhira estuary was studied by Zafar and Mahmood (1989). Zafar (1992) reported the spatial and temporal patterns in recruitment of the genus *Acetes* in the Kutubdia channel.

1.2.3. Previous studies on *Acetes* related to the present investigation in the Indian ocean and other regions.

Works on the taxonomy of planktonic shrimp *Acetes* were done by Rao (1968), Achuthankutty and George (1973), Achuthankutty (1975), Omori (1975), Achuthankutty and Nair (1976), Holthuis (1980), Omori and Ikeda (1982), Tirmizi and Ghani (1982) and Burkenroad (1983). The seasonal occurrence and distribution of the planktonic shrimp, *Acetes* were studied by Omori (1974, 1977 & 1978) in the Atlantic and Indo West Pacific oceans. Achuthankutty and Selvakumar (1979) in the estuarine system of Goa; Gajbhiye *et al.* (1982) in the nearshore waters of Bombay; Bhattacharya (1988) studied the distribution of *Acetes indicus* in the Bombay coast; Romimohtarto and Hindarti (1990) in the Northern Arafura sea. Some specific works on *Acetes* were also performed by different workers. Achuthankutty (1973) worked on sexual abnormalities of *Acetes erythraeus* and *A. sibogalis* ; Achuthankutty *et al.* (1973) on shoal of pelagic shrimps including *Acetes* , Ikeda and Skjoldal (1980) worked on changes in physiological activities and biochemical components of *Acetes sibogae.* Ikeda and Raymont (1989) performed research on the growth of *Acetes sibogae,* and Xiao and Greenwood (1992) on the behaviour of *Acetes sibogae* in relation to tidal and diel environmental changes. Biochemical composition and amino acids of *Acetes* were analysed by Yongquan and Jinglin (1987, 1989 a &b) and Xiao and Greenwood (1993) published a review paper on *Acetes* .

CHAPTER 2

CHAKARIA MANGROVE ECOSYSTEM AND THE STUDY AREA

2.1. Introduction

The world's single largest compact mangrove forest lies in Bangladesh and is locally known as the Sundarban. The Sundarban includes two major mangrove areas, one in Khulna including Satkhira, and the other in Chakaria, Cox's Bazar (now degraded). The Chakaria mangrove is a reproductive area from the view point of brackish water aquaculture. It is an isolated compact patch of mangrove forest situated along the delta of the Mathamuhuri river (Fig. 2). It is one of oldest mangrove forests of the sub-continent (Karim and Khan, 1980), which was subjected to various human interferences for collection of fuel wood, conversion into agricultural land, saltpans and recently for aquaculture.

2.2. Physiography of the Mathamuhuri river

The name Mathamuhuri originates from the Bengali version of 'Magh' name 'Muhuri' (Rizvi, 1975). The river has its origin in the range of hills that separates Arakan from Chittagong at Lat. 21°14'N and Long. 92°36'E, only 1° to the north and 1° to the east of the sources of the river Sangu. It flows to the north-west in the Hill Tracts and enters the district of south Chittagong and Cox's Bazar from the east, then flows towards west and finally falls into the Bay of Bengal at Lat. 21°45'N and Long. 91°57'E forming a broad delta at its mouth which extends from Bholakhal to Khutakhali. The delta thus formed include groups of islets intersected by three main tributaries of the Mathamuhuri river, namely Buramori, Gabomori and Mongla; it ends in a net work of tidal creeks covered by mangrove vegetation, a natural mangrove ecosystem known as the Chakaria Sundarbans, and covers an area of 8540 ha.

The delta of Mathamuhuri river is a good nursery area for shrimp and also rich in plankters (Mahmood, 1990; Zafar,1992).The estuarine system of the Mathamuhuri river estuary is shallow and depths are generally 2.5 - 3.5 m. The sediment of the bottom of the river is a mixture of sand and mud. According to Shahid (1982) acid sulphate soils occupy the Mathamuhuri flood plains. But these reports are not correct for surface sediments (Amin,1995). During rainy season (July - September) two banks of the river are often flooded and the salinity of the river becomes very low as a result of heavy runoff from many tributaries. According to Karim and Khan (1980), the Chakaria sundarbans was a dense forest in the past. It comprised large trees and bushes and four phyto-sociological zones were recognized in this forest, each related to different ecological factors. There are about 20 species of trees with a maximal height of 12m. *Avecennia marina* is the commonest of larger trees. Keora (*Sonneratia apetala*) is dominant at the sea side and on the river banks, while on higher tidal levels Sundary (*Heritiera fomes*) is the dominant species. According to

Fig.2. Satellite photograph of the Chakaria mangrove ecosystem, Bangladesh (C S, Chakaria Sundarban; M C, Moheskhali channel; M I, Moheskhali Island).

ESCAP (1988) mangroves of Mathamuhuri delta consists in halophytes with an abundance of *Dalbergia spinosa* and *Aegialitis rotundifolia.*

2.3. Human interference and land use changes

In the past, the Chakaria Sundarbans was occupied by dense mangroves and had the status of a mangrove forest reserve with an area of 18200 ha (Cowan,1926). It was gradually degraded as a result of human interferences, chiefly by the fuel wood cutters, encroachment for expansion of agriculture and clearing for preparation of salt pans. With the recent introduction of shrimp farming the remaining mangroves were rapidly cleared for preparation of salts pans. At present a small patch of the forest remains in the inner part with a few *Heritiera fomes* can be seen as remnant of an old luxurient forest vegetation (Karim and Khan, 1980). The area controlled by the Department of Forestry is also exploited by the local people for shrimp and fish culture. The worst form of exploitation observed in this area are some giant deep ponds created by blocking the natural tidal channels and tributaries of the Mathamuhuri river by dams (Mahmood, 1986). Quader *et al.* (1986) noted considerable changes in the form of destruction of mangroves due to the expansion of shrimp farming in the Chakaria Sundarbans. The photograph before in 1980 depicts a large forest covering nearly all of the Chakaria Sundarban area (Fig. 3.1): at that time no shrimp farming occurred. The photograph from 1983 shows a deforestation of the Chakaria Sundarbans as a consequence of rapid expansion of shrimp farming (Fig. 3.2).

2.4. Description of the sampling stations

The sampling stations were located in the estuarine part of the Mathamuhuri river where it ends up in three main tributaries, one of them being the Buramori.Two stations were selected (in respect to hydro-geographical conditions, such as period of tide) here near two shrimp culture farms (Fig. 4); Station 1: It was located near a private shrimp culture farm, owned by M/S Manumiazi Pvt. Ltd. in the Rampura sector of the Chakaria Sundarbans. Station 2: It was located at the Goalarkoom point, 2 kilometers down stream from station 1, near the shrimp farm owned by M/S shrimps and Duckery Pvt. Ltd.

Fig.3.1. Showing natural mangroves ecosystem of the Chakaria Sundarbans before in 1980, Bangladesh.

Fig.3.2. Showing destruction of mangroves in the Chakaria Sundarbans during 1983, Bangladesh.

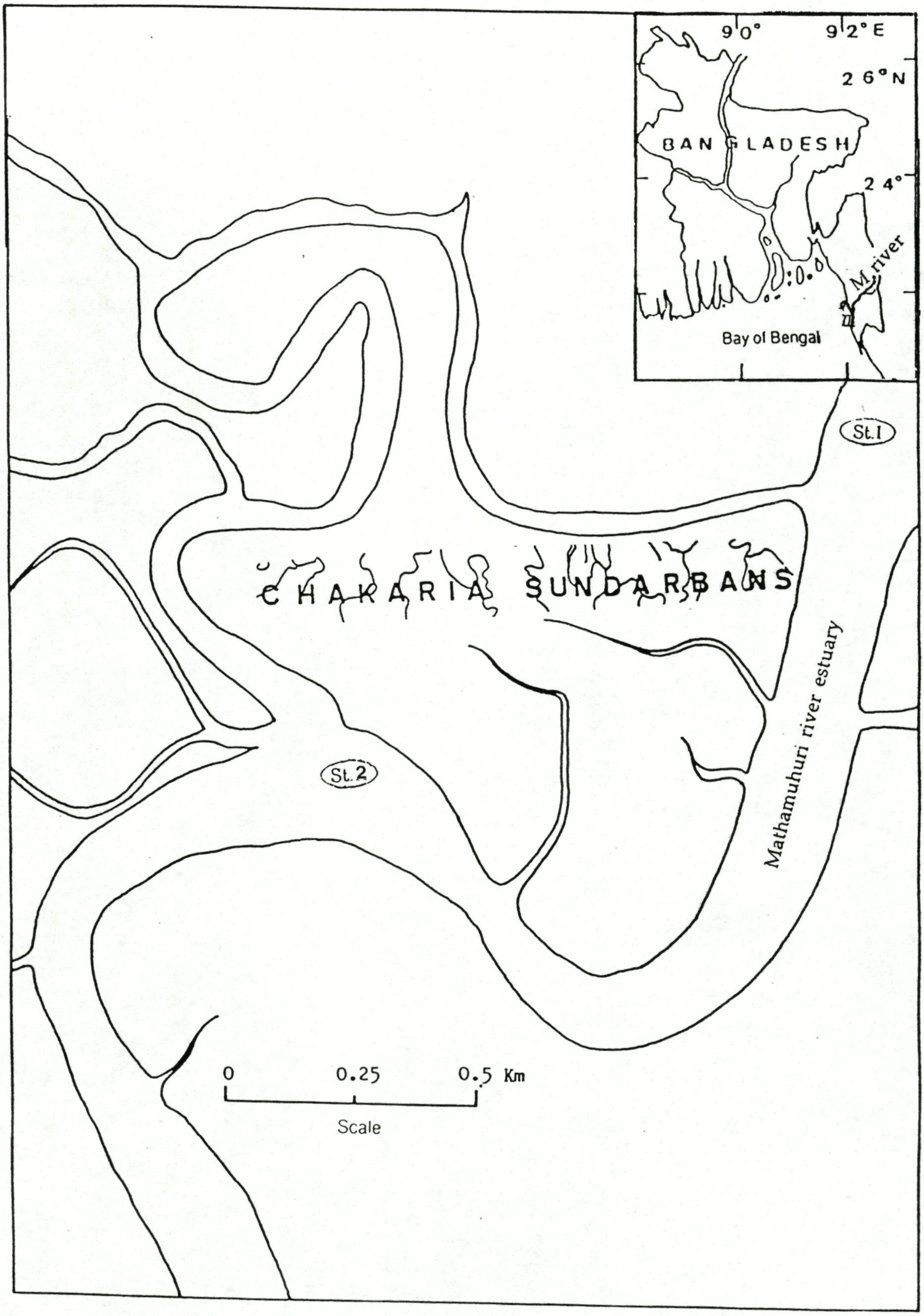

Fig.4. Inset, Bangladesh showing geographical location of the Chakaria Sundarbans (mangroves); has been enlarged to show the exact locations of stations (1&2) occupied for sampling in the Mathamuhuri river estuary during this investigation.

CHAPTER 3

HYDROMETEOROLOGY OF THE MATHAMUHURI RIVER ESTUARY

3.1. Introduction

Estuaries are important places from hydrological and biological points of view. They are productive and hydrologically variable locations where many marine and freshwater fauna spend a particular phase of their life cycles. Hydrological events in an estuary are so dynamic that they affect the biocommunity seasonally, daily and even hourly. Important contributions to estuarine studies in related to mangrove ecosystem and similar as present investigation were performed by Alexander *et al.* (1935), Milne (1937), Tully (1949), Ketchum (1951), Rochford (1951), Preddy (1954), Dutta *et al.* (1954), Spencer (1956), Shetty *et al.*(1961), Devasy and Gopinathan (1970), Goswami and Singbal (1974), and Baidya and Chowdhury (1984). The knowledge on the hydrology of the estuaries of Bangladesh is limited, except for some preliminary works reported by Mahmood and Khan (1976), Mahmood *et al.* (1976), Mahmood and Elias (1984), *Mahmood et al.* (1990) and Zafar (1992).

According to Khan (1990) in Bangladesh there are six seasons (spring, summer, rainy, autumn, dewy and winter). But generally, climatic seasons are distinguished each with four months duration. The premonsoon (February to May) with considerably higher temperature, the monsoon (June to September) characterised by heavy rainfall and the postmonsoon (October to January) comprising the winter, being comparatively dry with lower temperatures. Lamboeuf (1987), Zafar (1992) stated that geoclimatic environment of the Bay of Bengal, particularly the Bangladesh portion, is dominated by wind direction, precipitations under the influence of the tropical monsoon, and river discharge. These factors have a strong influence on the estuarine environment.

3.2. Materials and Methods

Field investigation was done between May 1982 and April 1984 and May 1992 - April 1993. Water samples were taken from two selected stations (Fig. 4) of the study area at fortnightly intervals during the high tide. A speed boat was used for field work. Samples were taken from both surface and bottom waters (about 3.0 m depth) with simultaneous record of temperatures; at the surface from a bucket and from the bottom by a thermometer mounted inside the transparent HYDROBIOS water sampler. Dissolved oxygen content of water was determined following Winkler's method (Barnes, 1959) and salinity by Mohr's chloride titration procedure (Strickland and Parsons, 1965). Data on monthly rainfall, sunshine and air temperature were obtained through courtesy of the Meteorological Department (Cox's Bazar), Government of Bangladesh. Monthly tidal records have been taken from tide tables of the

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BIWTA (Bangladesh Inland Water Transport Authority). One factors ANOVA and Regression (Siegel, 1956; Sokal and Rohlf,1981) were used for data analyses.

3.3. Results

One factors ANOVA showed no significant differences between station 1&2, in water temperature ($P = 0.98$, $F = 0.0004$, $N = 36$), dissolved oxygen ($P = 0.79$, $F = 0.96$, $N = 36$), salinity ($P = 0.37$, $F = 0.85$) and salinity of the surface and of the bottom data ($P = 0. 89$, $F = 0.75$). So, decided to average these results in the further discussions.

3.1.1. Meteorological factors

3.1.1.1. Air temperature (Fig. 5, Table 1)

Maximal values 33.5°C in May 1982, 32.4°C in April 1984 and 32.7°C in May 1992) and minimal values (14°C in January 1983, 15.8°C in January 1984 and 15.1°C in January 1993) were recorded. The highest air temperatures were observed during the monsoon months, the lowest in the winter months (Fig. 5) and had a direct influence on the water temperature, showing significant positive correlation in the three years observation ($P < 0.001$, $r = 0.890$, $N = 36$).

3.3.1.2. Sunshine (Fig. 6 , Table 1)

Maximal sunshine durations (9.60 hrs/day) occurred in December 1982, 1983, 1992, and minimal were recorded during monsoon (in June 3.10 hrs/day, 1982; July 2.30 hrs/day, in 1983; and in August 3.80 hrs/day, in 1992). Sunshine durations dit not significantly vary in the three years of investigation ($P = 0.8128$, $F = 0.2086$, $N = 36$), and were negatively correlated with air temperature ($P < 0.0003$, $r = -0.571$, $F = 16.45$) and rainfall ($P < 0.0001$, $r = - 0.822$; $F = 70.776$) in the Mathamuhuri river area. During monsoon (June-August) the sky was cloudy and high rate of rainfall occurred, and in December the sky was clear and rainfall was low. So, monsoon (June- August) sunshine hours became less in comparison with that of winter (December-February); whereas lower air temperature was recorded during winter months when cold air comes from the Himalay.

3.3.1.3. Rainfall (Fig. 7, Table 1)

The maximum rainfall (1164 mm in June 1982, 996 mm in July 1983 and 831 mm also in July 1992) occurred during the monsoon months, 80% of the yearly rainfall occurs between June and September. In winter months (December - February) almost no rainfall occurs. No significant difference was found in the three years rainfall ($P > 0.05$, $F = 0.2697$, df. = 34).

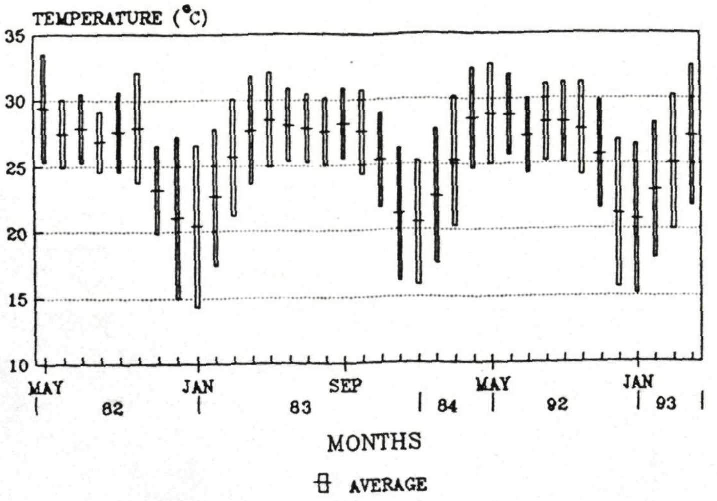

Fig.5. Showing monthly (maximum, minimum and average) fluctuations of air temperature in the Chakaria mangroves area of Bangladesh.

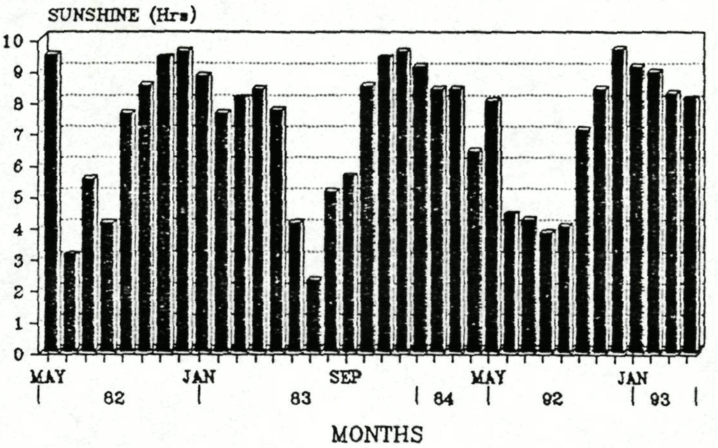

Fig.6. Monthly average duration of sunshine in the study area of Chakaria mangroves.

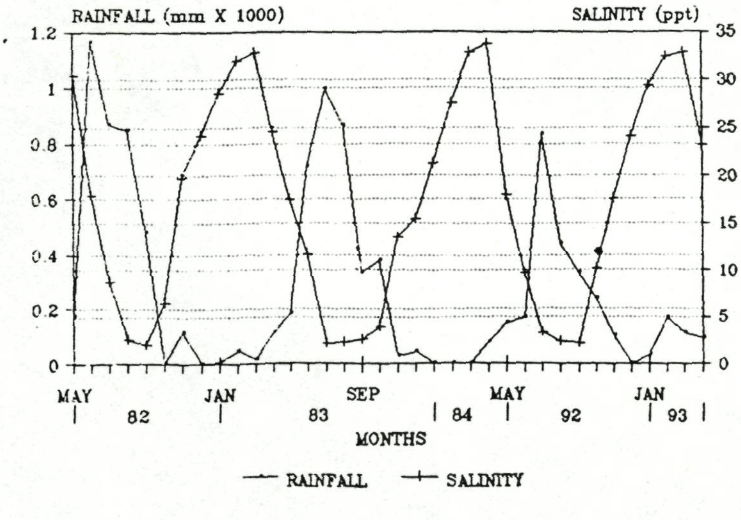

Fig.7. Seasonal variation of rainfall and salinity in the Chakaria mangroves area, Bangladesh.

3.3.2. Hydrological factors

3.3.2.1. Water temperature (Fig.8 , Table 2)

Negligible differences were shown between two sampling stations (Fig.9). Water temperature follows air temperature in the Mathamuhuri river area. No significant differences at 5% level were noticed in the three years recording data (One factor ANOVA, P = 0.4783, F = 0.754, df. = 34). The water temperature recorded its maximum during May 31.8°C in 1982, 31.15°C in 1983 and 29.6°C 1992 and minimum 21.°C in January, 1982; 20.9°C in February, 1983 and 1992. Its shows an inverse relationship with salinity (P = 0.0035, r = -0.474, F = 9.96).

3.3.2.2. Dissolved oxygen (Fig.10 ,Table 3)

In the two stations oxygen showed no significant differences (One factor ANOVA, P = 0.4042, F = 0.9313, N = 36), and fig. 11,12. The maximum values were recorded in December 6.60 ml/l in 1982, 61.7 ml/l in 1983 and 6.65 ml/l in 1992 and minimum in May 3.69 ml/l in 1982, 3.73 ml/l in 1983 and 3.98 ml/l in 1992. It is apparent from regression analysis (P = 0.017, r = -0.395, F = 6.29) that dissolved oxygen content of water was inversely related with the water temperature and as well as air temperature (P = 0.0003, r = 0.567, F = 16.15).

3.3.2.3. Salinity (Fig. 7,Table 4)

There was a little difference in salinity between the two stations (Fig.13 &14) but one factor ANOVA analysis was unable to detect these differences (P > 0.05, F = 0.854). The highest salinity was recorded during premonsoon season in March (33.12 ‰ in 1982, 33.25‰ in 1983 and 33.89‰ in 1992) and minimum was recorded during monsoon months (July to September) ,Table . The salinity of the studied estuary showed an inverse relation with rainfall (P = 0.001, r = 0.625, F = 21.515). Generally bottom water salinity was slightly higher than surface water in the investigated area, but the difference was not significant (P = 0.912, F= 0.1, N = 48).

3.3.2.4. Tidal characteristics (Fig. 15)

In the Mathamuhuri estuary the tidal oscillations are predominantly semidiurnal (Fig. 15) having two high and two low waters within a lunar day. During the two years study period, lowest and highest monthly means tide levels fluctuated from 0.6 m (December, 1982) to 3.6 m (June, 1982) with reference to the datum point, C.D. (Chart datum). It is evident from the (Fig.16) that monthly mean tide level is not constant throughout the year. In general tidal rise and fall of this estuary is very significant (average amplitude 2.11m) to create a strong tidal current throughout the year.

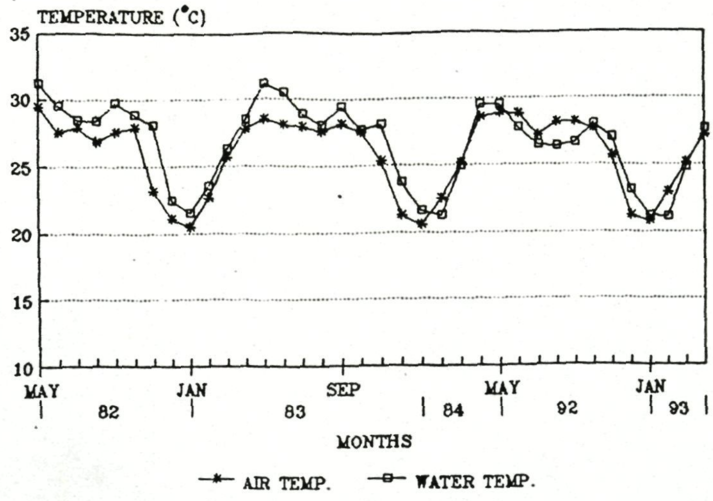

Fig.8. Showing water temperature follows air temperature in the Mathamuhuri river estuary, Bangladesh.

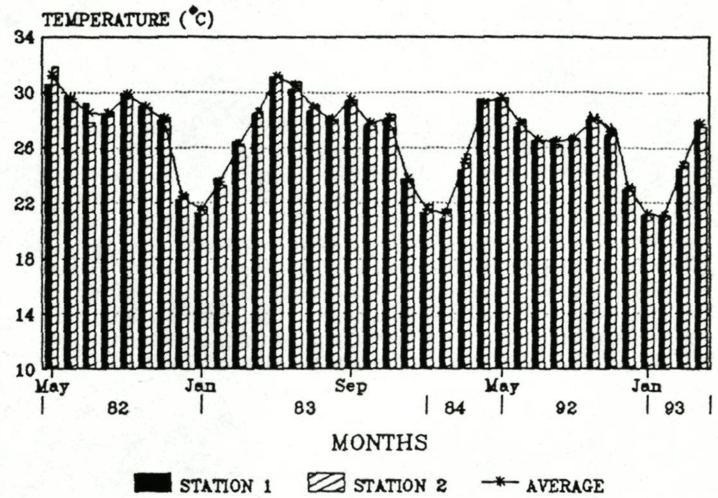

Fig.9. Showing monthly variation of water temperatures in the two sampling stations of the Mathamuhuri river estuary, Bangladesh.

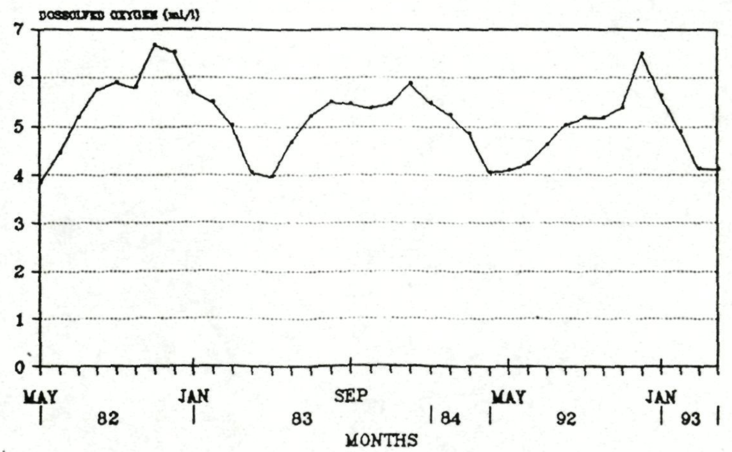

Fig.10. Monthly variation of dissolved oxygen in the Mathamuhuri river estuary, Bangladesh.

Table 1. Monthly distribution of mateorological factors of the Mathamuhuri river area (Chakaria sundarban, Bangladesh)

Year	Factors		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
May 1982-Apr-83	Air Temperature (°C)	Ma	33.51	30.05	30.46	29.13	30.62	32.08	26.54	27.17	26.54	27.75	30.07	31.81
		A	29.44	27.48	27.88	26.85	27.62	27.95	23.20	21.08	20.42	22.60	25.63	27.73
		Mi	25.36	24.91	25.29	24.56	24.61	23.81	19.86	15.00	14.30	17.45	21.18	23.65
	Rainfall (mm)		157.00	1164.00	866.00	850.00	483.00	3.00	119.00	0.00	8.00	47.00	19.00	113.00
	Sunshine (hrs)		9.50	3.10	5.50	4.10	7.60	8.50	9.40	9.60	8.80	7.60	8.10	8.40
May 1983-Apr-84	Air Temperature (°C)	Ma	32.12	30.86	30.48	30.14	30.86	30.75	28.96	26.23	25.28	27.66	30.13	32.38
		A	28.51	28.11	27.88	27.62	28.18	27.50	25.34	21.22	20.56	22.58	25.22	28.53
		Mi	24.89	25.35	25.28	25.09	25.49	24.25	21.73	16.20	15.84	17.51	20.31	24.68
	Rainfall (mm)		182.00	716.00	996.00	863.00	332.00	379.00	30.00	44.00	3.00	0.00	0.00	80.00
	Sunshine (hrs)		7.70	4.10	2.30	5.10	5.60	8.50	9.40	9.60	9.10	8.40	8.40	6.40
May 1992-Apr-93	Air Temperature (°C)	Ma	32.70	31.90	30.00	31.10	31.20	31.20	29.80	26.80	26.50	28.10	30.20	32.50
		A	28.85	28.80	27.15	28.15	28.15	27.65	25.70	21.20	20.80	22.95	25.10	27.15
		Mi	25.00	25.70	24.29	25.20	25.10	24.10	21.60	15.60	15.10	17.80	20.00	21.80
	Rainfall (mm)		149.00	167.00	831.00	442.00	328.00	237.00	103.00	3.00	34.00	167.00	112.00	96.00
	Sunshine (hrs)		8.00	4.40	4.20	3.80	4.00	7.10	8.40	9.60	9.10	8.95	8.25	8.10

Table 2. Monthly distribution of water temperature (°C) in the Mathamuhuri river of Chakaria Sundarban, Bangladesh

Year		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
May 1982-	Station 1	30.60	29.70	29.18	28.25	29.90	28.95	27.97	22.30	21.25	23.75	26.45	28.45
Apr-83	Station 2	31.85	29.25	27.80	28.60	29.65	28.87	28.10	22.67	21.75	23.25	26.12	28.55
	Average	31.23	29.48	28.49	28.43	29.78	28.91	28.04	22.49	21.50	23.50	26.29	28.50
May 1983-	Station 1	31.15	30.22	28.68	28.20	29.38	27.60	27.90	23.75	21.35	20.92	24.32	29.50
Apr-84	Station 2	31.02	30.75	29.03	27.93	29.43	27.80	28.32	23.67	21.85	21.60	25.52	29.45
	Average	31.09	30.49	28.86	28.07	29.41	27.70	28.11	23.71	21.60	21.26	24.92	29.48
May 1992-	Station 1	29.50	27.50	26.50	26.60	26.80	28.00	26.90	23.00	21.10	21.20	24.50	27.90
Apr-93	Station 2	29.60	28.00	26.50	26.20	26.50	27.95	27.10	23.20	21.25	21.00	25.00	27.50
	Average	29.55	27.75	26.50	26.40	26.65	27.98	27.00	23.10	21.18	21.10	24.75	27.70

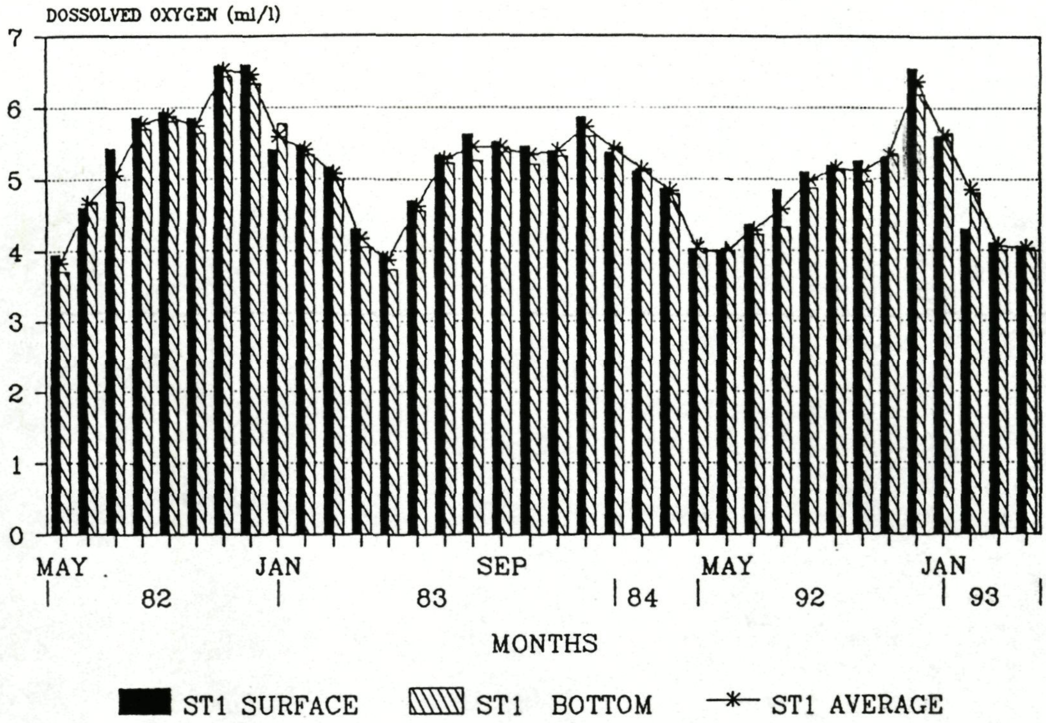

Fig.11. Surface-bottom and average dissolved oxygen at sampling station '1' in the Mathamuhuri river estuary.

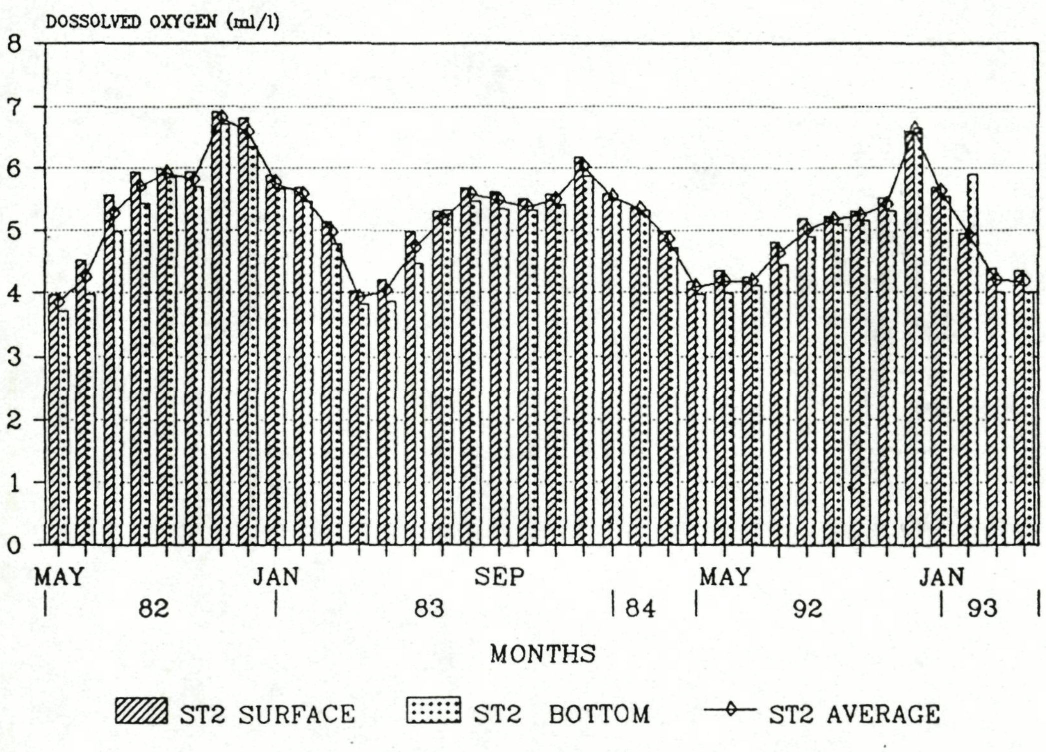

Fig.12. Surface-bottom and average dissolved oxygen at sampling station '2' in the area of investigation.

Table 3. Monthly distribution of Dissolved Oxygen (ml/l) in the Mathamuhuri river of Chakaria Sundarban, Bangladesh

Year			May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
May 1982-Apr-83	Station 1	Surface	3.95	4.60	5.43	5.87	5.95	5.85	6.59	6.60	5.42	5.48	5.16	4.29
		Bottom	3.69	4.69	4.69	5.70	5.81	5.65	6.44	6.33	5.78	5.35	4.98	4.04
		Average	3.82	4.65	5.06	5.79	5.88	5.75	6.52	6.47	5.60	5.42	5.07	4.17
	Station 2	Surface	3.97	4.52	5.56	5.94	5.98	5.94	6.92	6.81	5.88	5.69	5.14	4.02
		Bottom	3.72	3.96	4.97	5.43	5.85	5.69	6.70	6.35	5.66	5.46	4.78	3.81
		Average	3.85	4.24	5.27	5.69	5.92	5.82	6.81	6.58	5.77	5.58	4.96	3.92
	Average		3.83	4.44	5.16	5.74	5.90	5.78	6.66	6.52	5.69	5.50	5.02	4.04
May 1983-Apr-84	Station 1	Surface	3.97	4.70	5.34	5.63	5.52	5.47	5.51	5.87	5.38	5.11	4.86	4.02
		Bottom	3.73	4.55	5.22	5.26	5.37	5.21	5.31	5.60	5.45	5.15	4.79	4.03
		Average	3.85	4.63	5.28	5.45	5.45	5.34	5.41	5.74	5.42	5.13	4.83	4.03
	Station 2	Surface	4.21	4.97	5.30	5.68	5.61	5.51	5.58	6.17	5.57	5.36	4.97	4.18
		Bottom	3.87	4.46	5.02	5.46	5.33	5.23	5.40	5.87	5.47	5.32	4.73	3.97
		Average	4.04	4.72	5.16	5.57	5.47	5.37	5.49	6.02	5.52	5.34	4.85	4.08
	Average		3.95	4.67	5.22	5.51	5.46	5.36	5.45	5.88	5.47	5.24	4.84	4.05
May 1992-Apr-93	Station 1	Surface	4.00	4.35	4.85	5.10	5.20	5.25	5.30	6.55	5.60	4.90	4.10	4.05
		Bottom	3.98	4.21	4.32	4.86	5.10	4.96	5.36	6.20	5.65	4.80	4.00	3.99
		Average	3.99	4.28	4.59	4.98	5.15	5.11	5.33	6.38	5.63	4.85	4.05	4.02
	Station 2	Surface	4.35	4.25	4.80	5.19	5.22	5.30	5.51	6.60	5.70	4.95	4.38	4.35
		Bottom	3.99	4.10	4.45	4.90	5.10	5.15	5.31	6.65	5.55	4.90	4.00	4.01
		Average	4.17	4.18	4.63	5.05	5.16	5.23	5.41	6.63	5.63	4.93	4.19	4.18
	Average		4.08	4.23	4.61	5.01	5.16	5.17	5.37	6.50	5.63	4.89	4.12	4.10

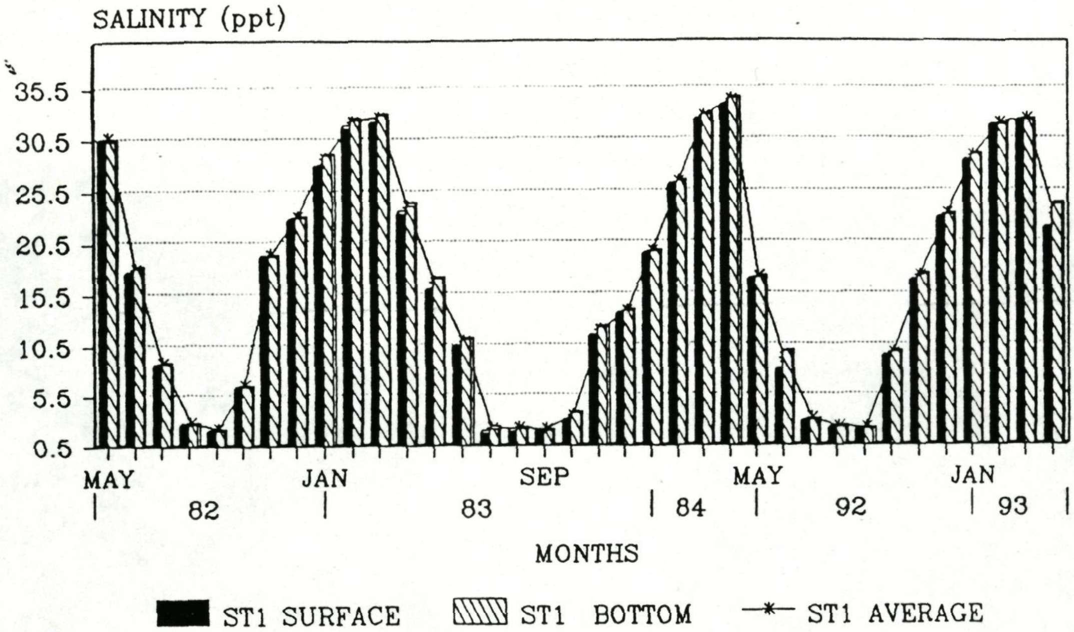

Fig.13. Showing surface-bottom and average salinity at sampling station '1' in the Mathamuhuri river, Bangladesh.

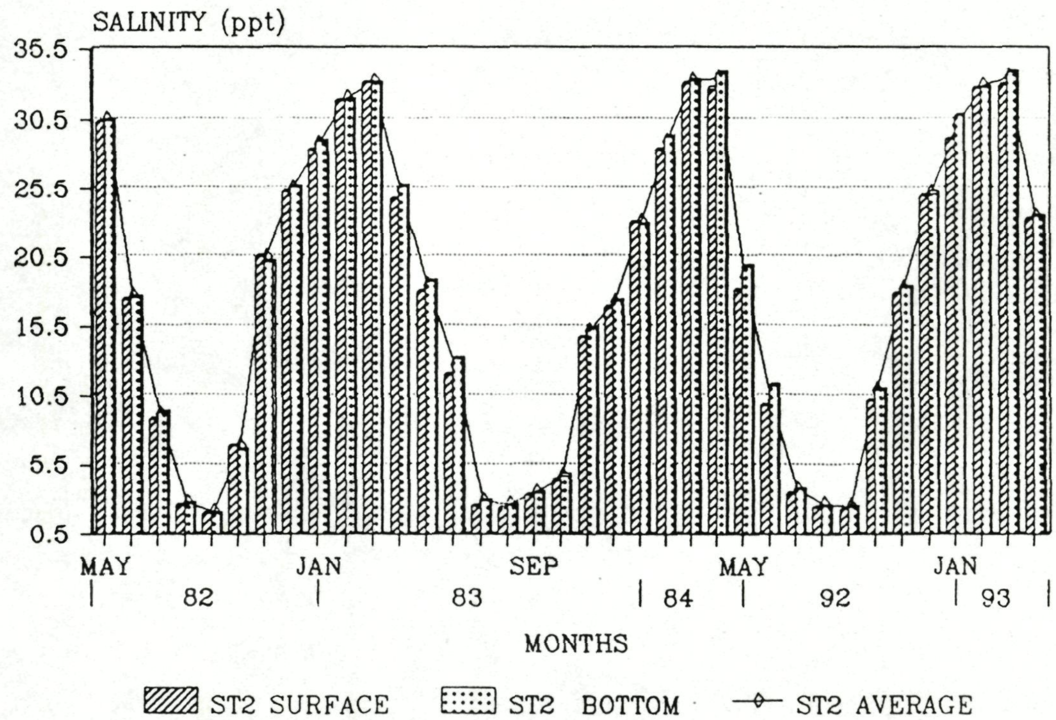

Fig.14. Showing surface-bottom and average salinity at station '2' in the Mathamuhuri river estuary, Bangladesh.

Table 4. Monthly distribution of Salinity in the Mathamuhuri river of Chakaria Sundarban, Bangladesh (S‰)

Year			May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
May 1982-Apr-83	Station 1	Surface	30.51	17.58	8.53	2.65	1.97	6.34	19.17	22.78	27.96	31.69	32.10	23.43
		Bottom	30.38	18.13	8.75	2.67	2.03	6.48	19.24	22.96	29.02	32.37	32.89	24.16
		Average	30.45	17.86	8.64	2.66	2.00	6.41	19.21	22.87	28.49	32.03	32.50	23.80
	Station 2	Surface	30.34	17.40	8.83	2.61	2.04	6.93	20.57	25.29	28.37	31.87	33.12	24.73
		Bottom	30.39	17.56	9.34	2.72	2.03	6.64	20.12	25.60	29.00	31.87	33.00	25.65
		Average	30.37	17.48	9.09	2.67	2.04	6.79	20.35	25.45	28.69	31.87	33.06	25.19
	Average		30.41	17.67	8.86	2.66	2.02	6.60	19.78	24.16	28.59	31.95	32.78	24.49
May 1983-Apr-84	Station 1	Surface	15.95	10.38	1.79	2.00	1.87	2.98	11.44	13.62	19.38	26.07	32.23	33.75
		Bottom	17.03	11.11	2.21	2.12	1.98	3.70	12.33	13.98	19.61	26.42	32.89	34.50
		Average	16.49	10.75	2.00	2.06	1.93	3.34	11.89	13.80	19.50	26.25	32.56	34.13
	Station 2	Surface	18.04	12.07	2.56	2.40	3.35	4.37	14.76	16.86	23.00	28.37	33.00	32.68
		Bottom	18.69	13.17	2.94	2.65	3.45	4.74	15.37	17.32	22.87	29.25	33.25	33.81
		Average	18.37	12.62	2.75	2.53	3.40	4.56	15.07	17.09	22.94	28.81	33.13	33.25
	Average		17.43	11.68	2.38	2.29	2.66	3.95	13.48	15.45	21.22	27.53	32.84	33.69
May 1992-Apr-93	Station 1	Surface	16.92	7.98	2.90	2.12	1.93	9.40	16.80	22.81	28.37	31.86	32.20	21.80
		Bottom	17.12	9.94	3.02	2.28	2.07	9.80	17.30	23.21	29.00	31.88	32.26	24.12
		Average	17.02	8.96	2.96	2.20	2.00	9.60	17.05	23.01	28.69	31.87	32.23	22.96
	Station 2	Surface	18.12	9.80	3.50	2.50	2.30	10.20	17.90	25.00	29.10	32.75	32.95	23.21
		Bottom	19.80	11.30	3.80	2.54	2.50	11.00	18.30	25.18	30.84	32.77	33.89	23.43
		Average	18.96	10.55	3.65	2.52	2.40	10.60	18.10	25.09	29.97	32.76	33.42	23.32
	Average		17.99	9.76	3.31	2.36	2.20	10.10	17.58	24.05	29.33	32.32	32.83	23.14

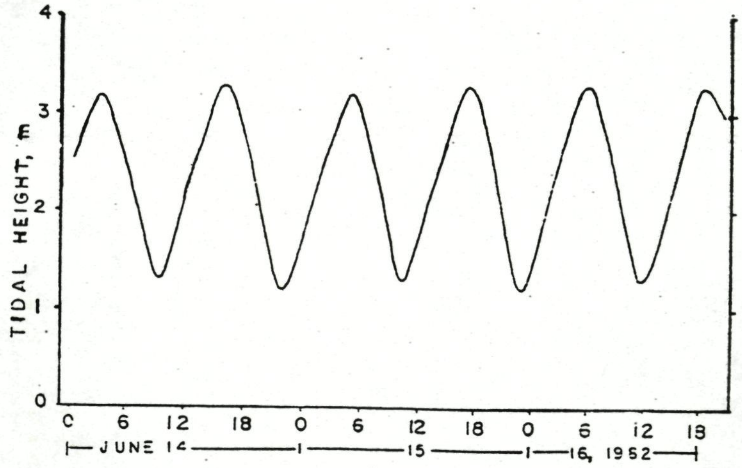

Fig.15. Semidurnal tide in the Mathamuhuri river estuary, Bangladesh (June, 14-16, 1982).

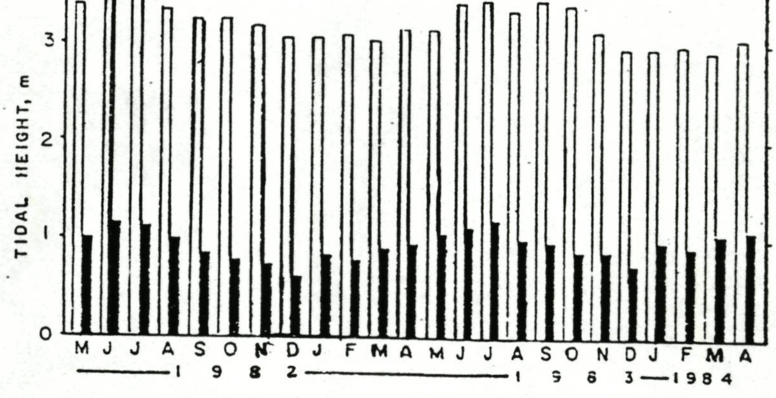

Fig.16. Showing monthly average height of high and low water levels in the Mathamuhuri estuary (at station 1).

3.4. Discussion

The climatic condition of Bangladesh is largely governed by the monsoons (Zafar, 1992). Seasonal change of the northeast monsoon to the southwest monsoon coupled with heavy rainfall dominates the hydrology of the study area. Salinity fluctuations of the Mathamuhuri estuary are a function of the annual rainfall pattern in the investigated area (Fig. 7). During postmonsoon and premonsoon seasons (October-May) which comprise the less rainfall period and during the winter salinity remains higher in the study area. The investigated area being shallow is under direct influence of strong tidal current and mixing, which results in almost an homogeneous vertical distribution of water temperature, dissolved oxygen and salinity. Similar observations were also made by Mahmood *et al.* (1976) in the Karnafuli estuary and in some other estuaries of this country (Mahmood, 1984; Zafar, 1986).

The hydrological features of this country shows regular seasonal patterns of variations. Rochford (1951), Mahmood and Khan (1980), Zafar (1986) reported that the temperature cycle of the surface water follows rather closely the meteorological cycle of the air temperature in a parallel manner. The present investigation is in close agreement with this statement. The bimodality observed in the fluctuation of surface water temperature in the near shore waters off Balashore coast, Bay of Bengal by Pati (1980) and in the Hooghly Matlah estuarine system by Shetty *et al.* (1961) is confirmed in this study, with a summer maximum in May and second autumn maximum in September (Fig. 8). Following the onset of monsoon rains, summer high temperature gradually falls and rises again when the intensity of rainfall lessens during late monsoon months. In the study area increase or decrease of dissolved oxygen content of water was inversely related with the rise and fall of temperature, higher concentration of dissolved oxygen was recorded during winter months (November and December) and minimum level was recorded during summer months (April-June). Dissolved oxygen of surface water samples was insignificantly higher than bottom (P = 0.526, F = 0.41, N= 48), and during summer and rainy months surface oxygen were slightly higher than bottom , and it. was opposite during winter months (Fig. 11,12), it can be hypothesised that seasonal cycle of surface-bottom dissolved oxygen is regulated by the biological processes.

3. 5. General environmental characteristics of the study area

No significant difference between the two sampling stations could be detected concerning the temperature, salinity and dissolved oxygen, as well as between surface and bottom waters. The estuary is characterised by a seasonality of temperature (minimal in January-February and maximal in May-June) & salinity (maximal in February-March and minimal in July-October), this lost being a consequence of the amount of the rainfall. The dissolved oxygen is minimal in April-June and maximal in November-December, feature closely related to the temperature and rainfall-salinity. The amount of hours of sunshine are not directly related to the air and water temperature. The monsoon months are cloudy and warm due to the wind coming from the Indian ocean and the winter months are sunny and relatively colder due to the winds blowing from the Himalaya.

CHAPTER 4

PHYTOPLANKTON IN THE MATHAMUHURI RIVER ESTUARY

4.1. Introduction

Phytoplankton containing chlorophyll is able to utilize dissolved carbondioxide, nutrient salts and the sun's energy to produce carbohydrates, proteins and oils, the food materials of aquatic animals. Estuaries are frequently areas of high fertility and large phytoplankton populations. The high primary production is reflected in the dense population of zooplankton and may be an advantage to the many marine species, which breed in the estuaries, since their larvae have a plentiful supply of food at a critical period (Ketchum, 1967) . Little information is available on the phytoplankton of the northeastern part of the Bay of Bengal. In temperate and polar waters considerable work has been done on the qualitative and quantitative production and fluctuation of the marine phytoplankton, their relationship with zooplankton. But information on phytoplankton relationship with *Acetes* shrimp is comparatively very limited.The present study deals with the seasonal succession, species diversity and interrelationships between phytoplankton and *Acetes* shrimp in the Mathamuhuri river estuary.

4. 2. Materials and Methods.

The field investigations were done for two years. First year (May 1982-April 1983) Phytoplankton was collected fortnightly at high tide during the new and full moon by a plastic container from the surface water of two stations in the Mathamuhuri river estuary (Fig. 4).Two litres of water were taken and preserved in 5% neutral formalin and brought to the laboratory. After allowing 16-20 hours to settle each of the sample was concentrated to 10 ml by careful filtration and decantation (Boyd, 1979). For quantitative study, the number of cells per litre of water was counted on Sedgwick Rafter cell under a compound microscope. Identification of phytoplankton were recorded using, Cupp (1943), , Fritsch (1945 & 1948), Davis (1955), Wickstead (1965), Newell and Newell (1973), Yamazi (1974) , Islam and Aziz (1975) , Salam (1977). Regression and one factor ANOVA were used for data analysis.

During the second year (May 1992-April 1993) monthly surface water samples were collected from station 2 during high tide in the morning (10 am to 1 pm) by three 250 ml pyrex bottle , two of which were white and remaining one was dark and replicate samples were also taken similarly . The light and dark bottle method was followed (Benton and Werner,1972) for the measurement of the primary production. The period of incubation was 3 hours according to Hepher (1962).The concentration of dissolved oxygen was measured by Winkler's Method ((APHA,1976). The data expressed in mg C/m^3 /day.

4.3. Results.

4.3.1. Occurrence and abundance of the phytoplankton

4.3.1.1. Qualitative

A total of 91 species under 44 genera were identified . Bacillariophyta was the most dominant group and 72 species were recorded in this division; and 11 spp under Chlorophyta, 6 spp under Cyanophyta and 2 spp under Pyrrophyta occurred in the Mathamuhuri river estuary (Fig.17-107).

4.3.1.2. Quantitative

4.3.1.2.1. Composition of phytoplankton of the Mathamuhuri estuary

Phytoplankton was counted in four major groups.The yearly average percentage composition of these groups in order of abundance were Bacillariophyta 50.77%, Cyanophyta 47.70%. Chlorophyta 1.5% and Pyrrophyta 0.02% (Fig. 108). Cyanophyta was most dominant and occurred 64.79% at station 1 (Table 6.1), whereas Bacillariophyta was dominant at station 2 amounting 58.53% of the total phytoplankton (Table 6. 2).

4.3.1.2.2. Abundance of phytoplankton in relation to seasonal variation of some hydrological factors

The fluctuations of both average total number of phytoplankton and the observed hydrological factors shows strong seasonal variation. Generally higher densities of phytoplankton were recorded at station 2 (Fig.109). But the abundance of phytoplankton showed no significant difference in the two stations of the Mathamuhuri estuary (Mann Whitney U test $P = 0.64$, $Z = -0.6419$, $U = 64$). The highest abundance of the phytoplankton was recorded in early monsoon months (June and July) and minimum in late winter (February and March)'table 5' . The peak occurrence of the phytoplankton was recorded in July (31550 cells/l) and minimum in Februray (770 cells/l). Significant negative correlation was shown between average salinity and phytoplankton population ($r = -0.588$, $P< 0.05$, df. = 22) and positively correlated with the rainfall ($r = 0.655$, $p < 0.05$, df. = 22). Its abundance also showed a positive relation with water temperature ($r = 0.523$, $P = 0.059$, $F = 3.0644$) and the relationship was negative with sunshine ($r =- 0.574$, $P = 0.003$).

Fig. 17- 107, phytoplankton of the Mathamuhuri river estuary, in the Chakaria mangroves ecosystem, Bangladesh.

Fig.17. *Legerheimia* sp
Fig.18. *Pediastrum simplex*
Fig.19. *Chlorella variegatus*
Fig.20. *Cosmarium globosum*
Fig.21. *C. moniliforme*
Fig.22. *C. granatum*
Fig.23. *Closterium sp*
Fig.24. *Staurestrum aversum*
Fig.25. *Staurestrum* sp
Fig.26. *Desmidium swartzii*
Fig.27. *Spirogyra* sp
Fig.28. *Melosira sulcata*
Fig.29. *M. varians*
Fig.30. *M. nummuloides*
Fig.31. *M. moniliformis*
Fig.32. *Skeletonema costatum*
Fig.33. *Stephenopyxis palmeriana*
Fig.34. *Coscinodiscus centrales*
Fig.35. *C. curvatulus*
Fig.36. *C. lineatus*
Fig.37. *C. excentricus*
Fig.38. *C. nitidus*
Fig.39. *C. radiatus*
Fig.40. *C. marginatus*
Fig.41. *C. gigas*
Fig.42. *C. perforatus*
Fig.43. *C. granii*
Fig.44. *Planktoniella sol*
Fig.45. *Cyclotella comta*
Fig.46. *Thalassiosira gravida*
Fig.47. *T. rutula*
Fig.48. *Coscinosira polychorda*
Fig.49. *Schroderella delicatula*
Fig.50. *Leptocylindrus danicus*
Fig.51. *Rhizosolenia alata*
Fig.52. *R. imbricata*
Fig.53. *R. stolterforthii*
Fig.54. *R. styliformis*
Fig.55. *R. delicatula*

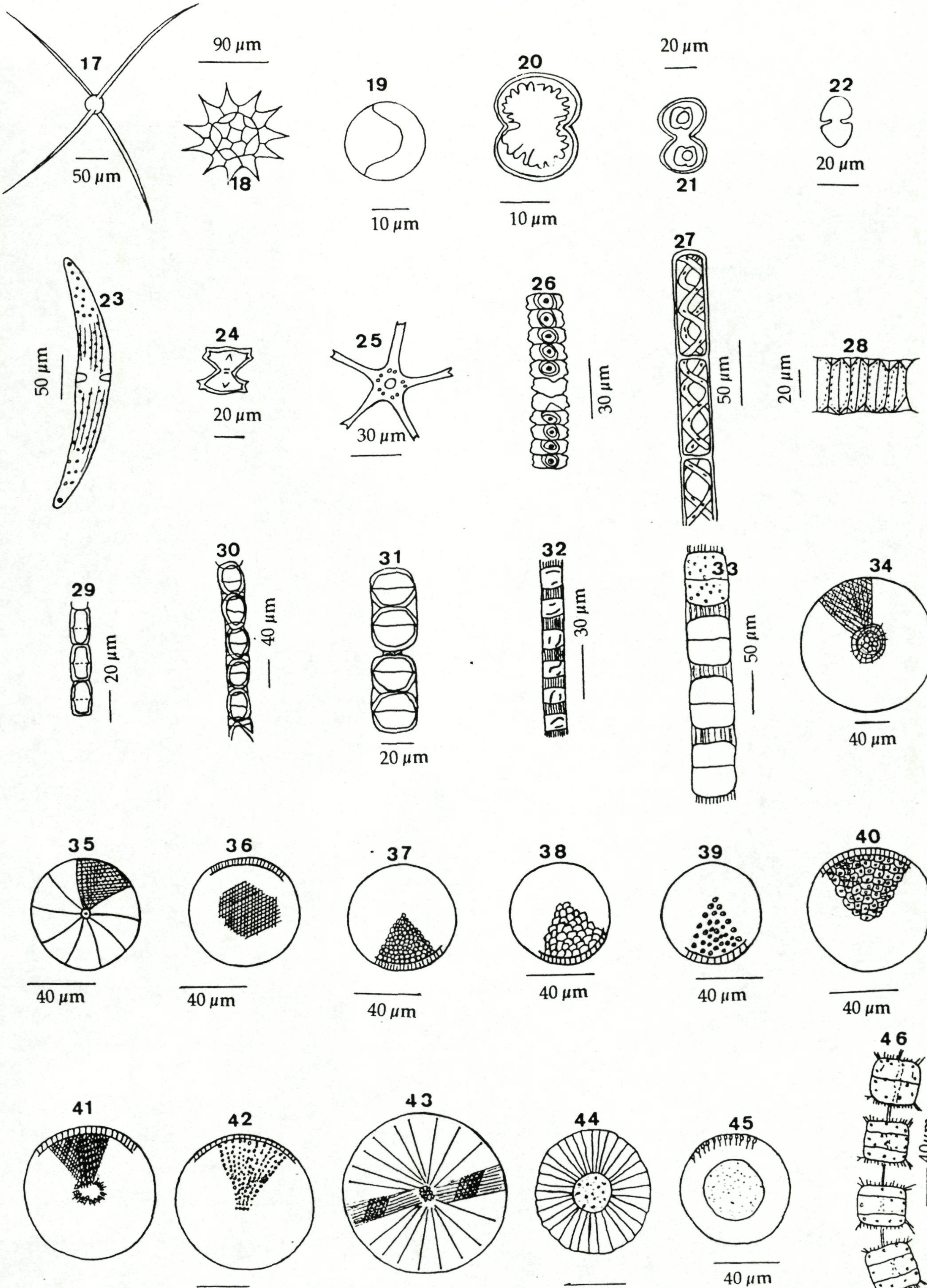
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Fig. continued, phytoplankton of the Mathamuhuri river estuary

Fig.56. *R. setigera*
Fig.57. *R. hebetata*
Fig.58. *R. calcaravis*
Fig.59. *Chaetoceros atlanticus*
Fig.60. *C. curvisetus*
Fig.61. *C. costatus*
Fig.62. *Chaetoceros* sp 1
Fig.63. *Chaetoceros* sp 2
Fig.64. *Chaetoceros* sp 3
Fig.65. *Biddulphia granulata*
Fig.66. *B. mobiliensis*
Fig.67. *Ditylum brightwellii*
Fig.68. *D. sol*
Fig.69. *Triceratium distinctum*
Fig.70. *Hemiaulus hauckii*
Fig.71. *Eucampia zoodiacus*
Fig.72. *Synedra ulna*
Fig.73. *Synedra* sp
Fig.74. *Thalassionema nitzschioides*
Fig.75. *Thalassiothrix longissima*
Fig.76. *T. frauenfeldi*
Fig.77. *Asterionella japonica*
Fig.78. *Grammatophora angulosa*
Fig.79. *Navicula distans*
Fig.80. *N. salinarum*
Fig.81. *Pleurosigma intermedium*
Fig.82. *P. elongatum*
Fig.83. *P. normanii*
Fig.84. *P. affine*
Fig.85. *P. rigidum*
Fig.86. *Gyrosigma spencerii*
Fig.87. *G. balticum*
Fig.88. *Amphora hyalina*
Fig.89. *Nitzschia closterium*
Fig.90. *N. sigma*
Fig.91. *N. pacifica*
Fig.92. *N. seriata*
Fig.93. *N. longissima*
Fig.94. *N. paradoxa*
Fig.95. *N. pungens*

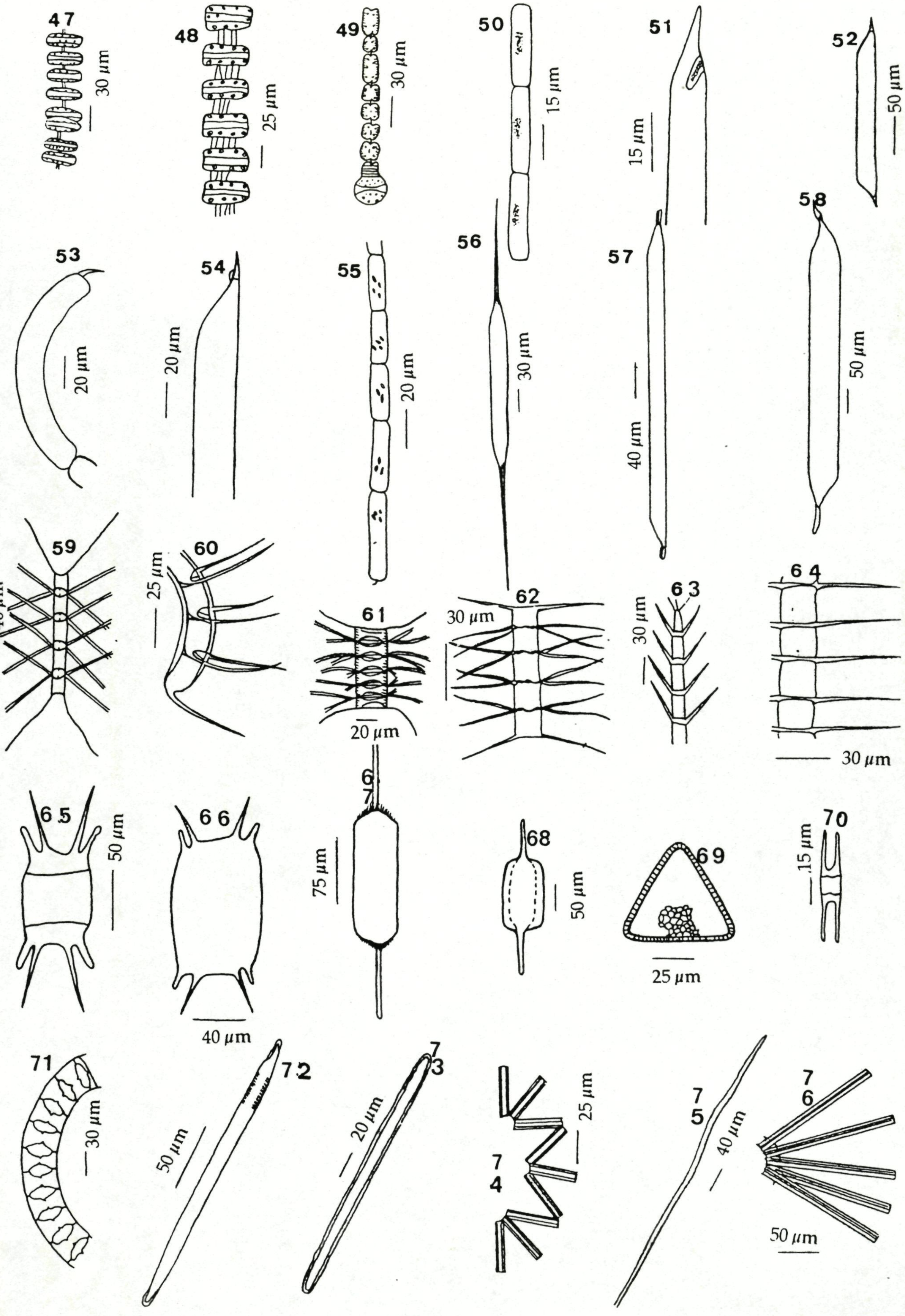
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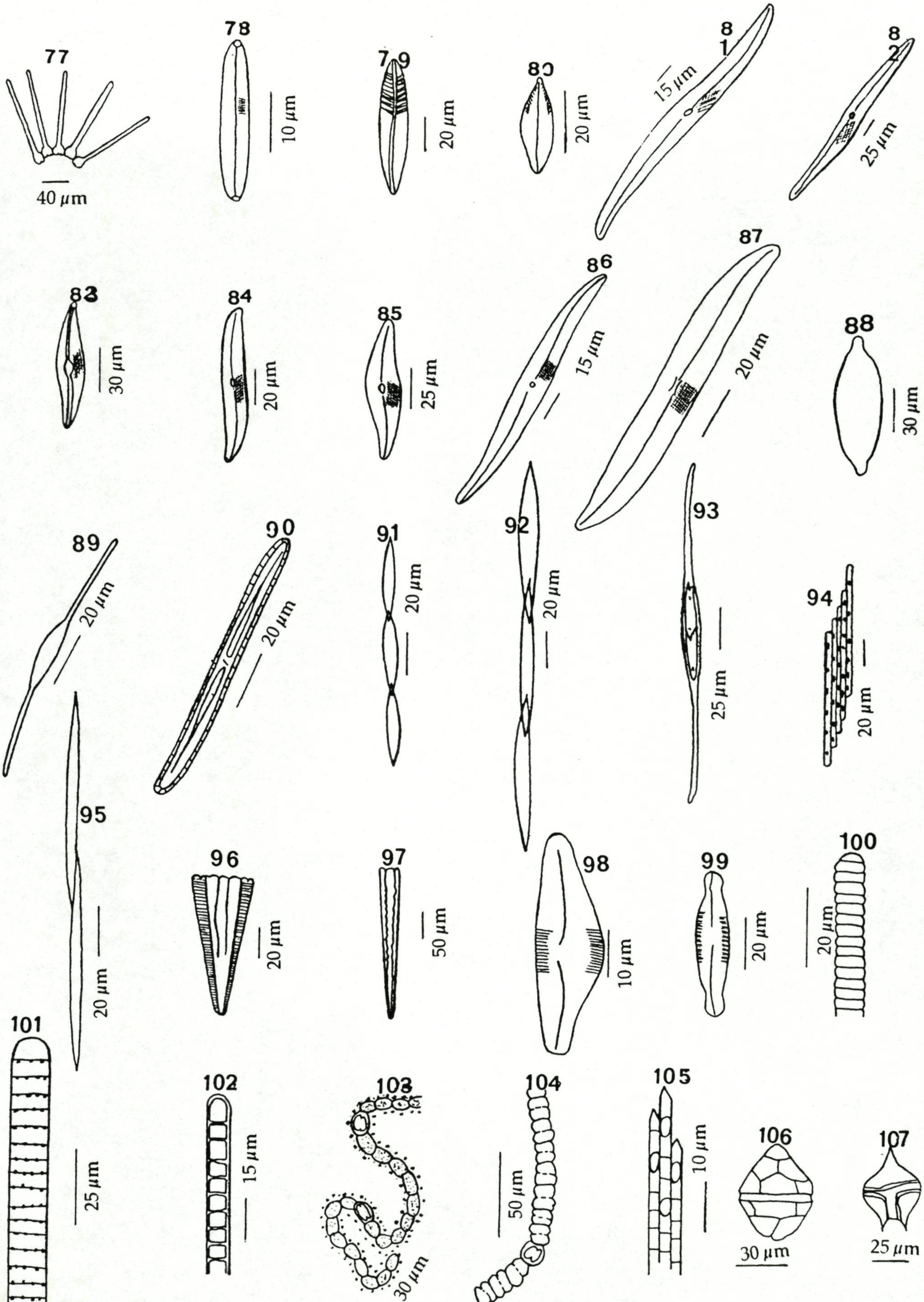
Fig. continued, phytoplankton of the Mathamuhuri estuary

Fig.96. *Licmophora abbreviata*
Fig.97. *Climacosphenia moniligera*
Fig.98. *Cymbella stuxbergii*
Fig.99. *Cymbella* spp
Fig.100. *Oscillatorea tenuis*
Fig.101. *O. limosa*
Fig.102. *Trichodesmium thiebauti*
Fig.103. *Nostoc* sp
Fig.104. *Anabaena circinalis*
Fig.105. *Aphanizomenon flosague*
Fig.106. *Peridinium thorianum*
Fig.107. *Peridinium* sp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4.3.1.2.3. Monthly occurrence and distribution of four groups of phytoplankton in the Mathamuhuri river.

4.3.1.2.3.1. Chlorophyta (Fig.110, Table 6)

Mann Whitney U test showed no significant differences of Chlorophyta distribution between two sampling stations (U = 69, Z = - 0.17, P > 0.05). At station 1 the maximum density of Chlorophyta was found in January (900 cells/l) and 2250 cells/l occurred in October at station 2. The highest (average) abundance was recorded in October (1145 cells/l and absent in September, February and March. No significant relationship was found between density of Chlorophyta and recorded hydrological factors.

Phaenology of the dominant species of Chlorophyta

Legerheima was recorded in July, October and December and mostly found in October at station 2. *Pediastrum* , *Chlorella*, *Desmidium*, *Spirogyra* sp were in higher abundance at station 1 than station 2. *Pediastrum simplex* was found in June. *Cosmarium globosum* was recorded in June and October. *Cosmarium moniliforme* was present only in June. In October *Desmidium swartzii* was found frequently. *Spirogyra* sp. was recorded only in January and *Chlorella variegatus* was rarely found in August.

4.3.1.2.3.2. Bacillariophyta (Fig.110, Table 6)

In average Bacillariophyta was the most dominant group in the phytoplankton population of the Mathamuhuri river estuary. It was present throughout the period of investigation.The average maximum was recorded in July (27220 cells/l) and minimun in January (740 cells/l). Mann Whitney U test showed no significant differences between the two sampling stations (P = 0.544, Z = - 0.60, U= 61.5), but higher density was recorded at station 2 and occupied 58.53% of the total phytoplankton (Table 6.2). Bacillariophyta showed a significant negative correlation with dissolved oxygen at station one (P = 0.02, r = - 0.64, N = 12).

Phaenology of some major species of Bacillariophyta

Skeletonema costatum was the most dominant species of Bacillariophyta and occurred throughout the period of investigation except in September and January (Fig.111& 112). Its higher average abundance was recorded during south-west monsoon months (April- July) with a maximum density (24185

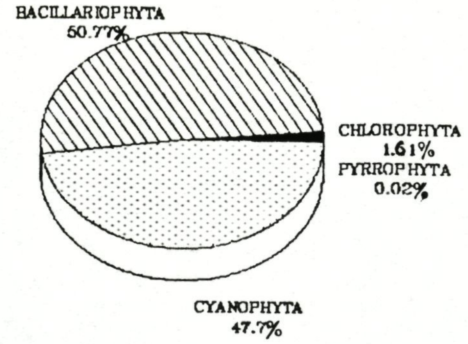


Fig.108. Composition of four groups of phytoplankton (average two stations) in the Mathamuhuri river estuary, Bangladesh.

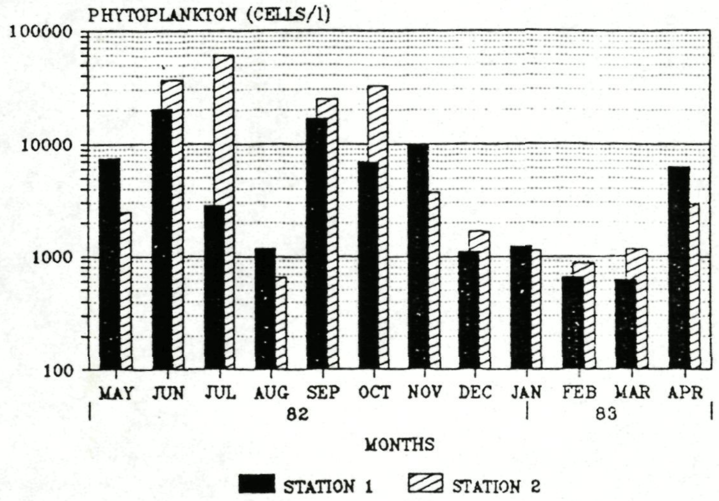


Fig.109. Showing variation of phytoplankton in the two sampling stations of the Mathamuhuri river estuary.

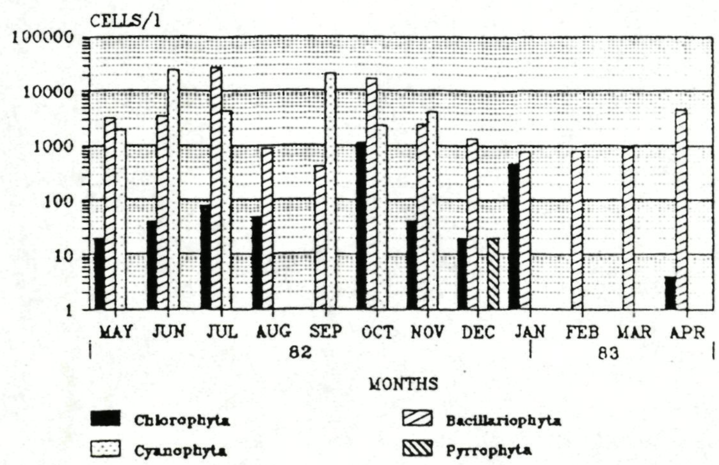


Fig.110. Seasonal variation of different groups of phytoplankton (average two stations) in the Mathamuhuri river estuary, Bangladesh.

cells/l) in July (Table 7) and higher concentration of *S. costatum* was recorded at station 2 (Table 7.1 &7.2). *Ditylum brightwellii* and *D. sol* were recorded in June, October to November and mostly found in the station 2 during the month of October. *Chaetoceros curvisetus* occasionally occurred in December and January, maximum was in December. *Melosira moniliformis* was found in July and November, with maximum in July. *Melosira nummuloides* was only found in August. The phaenology of *Stephanopyxis palmeriana* was in December and April in the investigated area. *Coscinodiscus centrales* was present in May through December almost at the same rate. *Coscinodiscus curvatulas* occurred in September, October and January through March. *Coscinodiscus nitidus* was recorded from May through July and from November to April. *Planktoniella sol* was rarely found in June and August. *Schroderella delicatula* occurred only in June and December. *Leptocylindrus danicus* was present in June, October, November and January, maximum in June. *Rhizosolena delicatula* was recorded throughout the period of investigation except from December to March, maximum in May. *Rhizosolenia alata* occurred almost round the year but absent in the month of October, maximum in the month of June. *Chaetoceros curvisetus* was present only in December and January, maximum was in December. *Biddulphia mobiliensis* was found in May and November. *Eucampia zoodiacus* was present in July and April, maximum in April.*Thalassionema nitzschioides* obtained in almost throughout the year in low quantity, absent in December to March. During the one year observation*Thalassiothrix frauenfeldi* was absent in November and February to March, maximum occurred in October. *Navicula distans* was recorded in April, May and August to October. *Pleurosigma intermedium* occurred in August to November.*Pleurosigma normanii* was found in May and October to March. *Pleurosigma rigidum* occurred in May, August and October. *Nitzschia closterium* was found almost throughout the period of study except January, maximum obtained in August. *Nitzschia sigma* was recorded in May, July, August and September and more or less the same quantity. *Nitzschia longissima* was frequently observed in August, October and January. *Nitzschia pungens* occurred in most of the samples, specially during the month of August to October and December.*Triceratium* sp. and *Synedra* sp. occurred occasionally .

4.3.1.2.3.3. Cyanophyta (Fig.110, Table 6)

Cyanophyta was the top most group of phytoplankton at station one (Manumiazi) and occupied 64.8% of the phytoplankton population (Table 6.1). In average it was the second most abundant group in the Mathamuhuri river estuary. Mann Whitney U test showed no significant difference between the two sampling stations ($P = 0.8422$, $Z = 0.17$, $U= 69$). The highest densities of Cyanophyta were recorded during monsoon season with a peak in June (25090 cells/l) and it was totally absent during the winter months (December to April) . A significant positive correlation was found between the average Cyanophyta abundance and rainfall ($P = 0.038$, $F = 4.837$, $r = 0.4246$). The Cyanophyta was represented by the following genera-*Oscillatoria*,*Trichodesmium*, *Nostoc* ,*Anabaena* and *Aphanizomenon*.

Phaenology of the dominant species of Cyanophyta

Oscillatoria tenuis occurred mainly during the rainy season (May-September), maximum in the month of June.*Trichodesmium thiebauti* was recorded during the month of May to September and April, maximum in June. *Aphanizomenon flosaquae* was found in the month of September and November.

4.3.1.2.3.4. Pyrrophyta (Fig.110, Table 6)

The poorly represented group among the phytoplankters was the Pyrrophyta. It occurred only in December (20 cells/l). In this division only the genus *Peridinium* was found. *Peridinium thorianum* was recorded only in the month of October.

4.3.2. Primary production in the Mathamuhuri river estuary (Fig.113,Table 8)

The highest net production was noticed in the spring months (April-May) with a maximum in April (1690.50 mg C/m^3/day), when suitable temperature and clear sunshine were present.The minimum net production was found during the winter season (December- February) and the lowest was recorded in the February (73.07 mg C/m^3/day.The maximum gross production was observed as 1960.20 mg C /m^3/day in April and lowest in February 272.91, mg C/m^3/day. Primary production (net and gross production) showed significant relationship with water temperature in the investigated area ($P = 0.01$, $r = 0.704$ & $P = 0.024$, $r = 0.643$ respectively).

4.4. Discussion

4.4.1. Occurrence and abundance of phytoplankton

Subrahmanyan (1958) worked in the Arabian sea off the west coast of India and reported 336 species of phytoplankton with Bacillariophyta being the dominant flora. Islam and Aziz (1975) worked on the marine phytoplankton from the northeastern part of the Bay of Bengal and found a total of 76 species in which diatoms formed the dominant flora. In the Mathamuhuri estuary Bacillariophyta was the dominant phytoplankton both qualitative and quantitative studies .

Gopinathan (1972) in Cochin Back-water found two peak periods of phytoplankton during May to June and October to November. He also reported that during January and February phytoplankton production was insignificant and during March and April phytoplankton production was at moderate level.

Table 5. Monthly Phytoplankton abundance (cell/l) in the Mathamuhuri river estuary of Chakaria Mangrove ecosystem, Bangladesh

Sampling stations	1982								1983				Yearly
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average
S1 (Manumiazi)	7560	20540	2800	1180	16940	6880	9500	1100	1240	660	620	6300	6277
S2 (Goalarkoom)	2460	36520	60300	660	24880	32550	3740	1660	1140	880	1160	2920	14073
Average of the two stations	5010	28530	31550	920	20910	19715	6620	1380	1190	770	890	4610	10175

Table 6. Seasonal variation of four divisions of Phytoplankton abundance (cell/l) in the Mathamuhuri river estuary of Chakaria mangrove ecosystem, Bangladesh

Phytoplankton	1982								1983				Yearly	Percentage
Division	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average (X)	composition (%)
Chlorophyta	20	40	80	50	0	1145	40	20	450	0	0	4	154	1.51%
Bacillariophyta	3090	3400	27220	870	410	16270	2380	1340	740	770	890	4606	5166	50.77%
Cyanophyta	1900	25090	4250	0	20500	2300	4200	0	0	0	0	0	4853	47.70%
Pyrrophyta	0	0	0	0	0	0	0	20	0	0	0	0	2	0.02%
Monthly total of Phytoplankton	5010	28530	31550	920	20910	19715	6620	1380	1190	770	890	4610	10175	100.00%

Table 6.1

Seasonal variation of four divisions of phytoplankton abundance (cells/l) in the Mathamuhuri river estuary at Station 1 "Manumiazi" of Chakaria mangroves ecosystem, Bangladesh

Phytoplankton	1982								1983				Yearly	Percentage
Division	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average	Composition
Chlorophyta	0	60	160	100	0	40	80	0	900	0	0	8	112	1.79%
Bacillariophyta	3760	3480	2640	1080	340	2240	2620	1060	340	660	620	6292	2094	33.37%
Cyanophyta	3800	17000	0	0	16600	4600	6800	0	0	0	0	0	4067	64.79%
Pyrrophyta	0	0	0	0	0	0	0	40	0	0	0	0	3	0.05%
Monthly total	7560	20540	2800	1180	16940	6880	9500	1100	1240	660	620	6300	6277	100.00%

Table 6.2

Seasonal variation of four divisions of phytoplankton abundance (cells/l) in the Mathamuhuri river estuary at Station 2 "Goalarkoom" of Chakaria mangroves ecosystem, Bangladesh

Phytoplankton	1982								1983				Yearly	Percentage
Division	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average	Composition
Chlorophyta	40	20	0	0	0	2250	0	40	0	0	0	0	196	1.39%
Bacillariophyta	2420	3320	51800	660	480	30300	2140	1620	1140	880	1160	2920	8237	58.53%
Cyanophyta	0	33180	8500	0	24400	0	1600	0	0	0	0	0	5640	40.08%
Pyrrophyta	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00%
Monthly total	2460	36520	60300	660	24880	32550	3740	1660	1140	880	1160	2920	14073	100.00%

This view is similar to the present findings . Carpenter (1971) in the Cape Fear river estuary obtained the range of phytoplankton between 7.3. x 10^6 - 0.25 x 10^6 cells/l and the major population bloom was in May and June. He also pointed out that phytoplankton was dominated by diatom (*Skeletonema costatum*) .These results are more or less similar to the present investigation.

In the Mathamuhuri river estuary maximum phytoplankton was recorded during the summer and moonsoon season and its abundance was directly influenced by the rainfall . Islam and Aziz in 1975 while working in the north eastern part of the Bay of Bengal obtained the highest concentration of the phytoplankton during the summer season. Chandra (1985) stated that during the monsoon season, the estuary was enriched with nutrients due to heavy rainfall and the consequent land run-off.

In the mangrove area of Mathamuhuri river only Cyanophyta showed a significant positive relation with rainfall and found a negative relation with sunshine. The other groups of phytoplankton were not strongly correlated with recorded hydro-meteorological factors.

4.4.2. Primary production

Bhouyain and Sen (1989) reported a maximum net production (66.93 mg C/m^3/hr in April and the minimum in July (1.87 mg C/m^3/hr) of Foyes Lake, Chittagong, Bangldesh . In a mangrove forest in Thailand Kristensen *et al.* (1988) measured low gross primary production rates ranging from 146 to 250 mg C/m^2 /day . Hargraves (1982) measured the daily net production rate in the *Thalassia* beds ranging from 0.7 to 12.7g C/m^2.The present investigation net production ranged from 73.07 mg C /m^3/ day and 1690.50 mg C/m^3/day. Moiseev (1969) reported that the primary production shows an average 140 mg C/m^2/day in the peripheral regions of equatorial divergences in the Indian ocean. Paul and Selvaraj (1993) recorded 1349.0 mg C/m^2/day primary production in the Cochin backwater during the southwest monsoon season. Sarupria and Bhargava (1993) reported that primary production of the Bay of Bengal varied from 70.0 to 1530 mg C/m^2/day in premonsoon, 49.03 to 3608.23 mg C/m^2/day in south-west monsoon and from 6 to 46.0 mg C/m^2/day in north-east monsoon. Verlencar (1987) stated that during post and premonsoon periods primary production was high in the coastal waters of Goa. Ichimura and Aruga (1958), and Goldman and Wetzel (1963) reported that temperature was an important factor in determing seasonal productivity. In the Mathamuhuri river of Chakaria sundarban highest primary production was recorded in the spring months (April-May), when south-west monsoon just begin. The primary production of the investigated area showed significant correlation with water temperature.

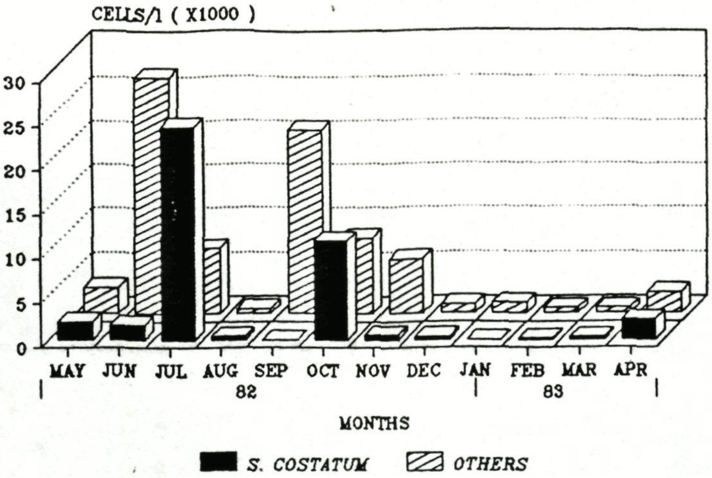


Fig.111. Monthly average distribution of *Skeletonema costatum* and other phytoplankton in the investigated estuary.

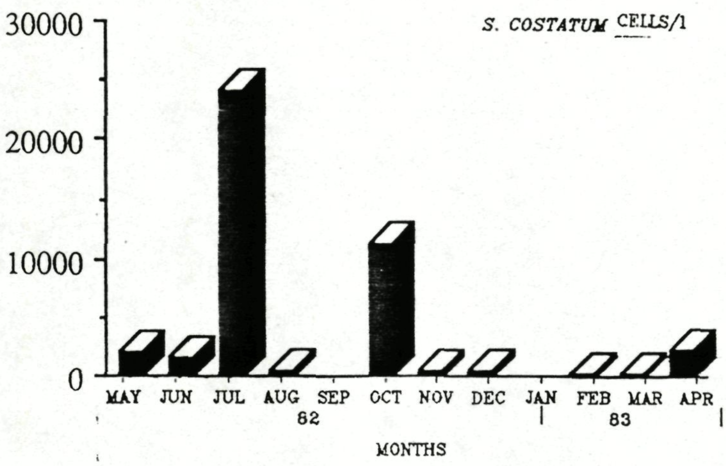


Fig.112. Seasonal variation of *Skeletonema costatum* (average) in the Mathamuhuri estuary (May 1982- April 1983).

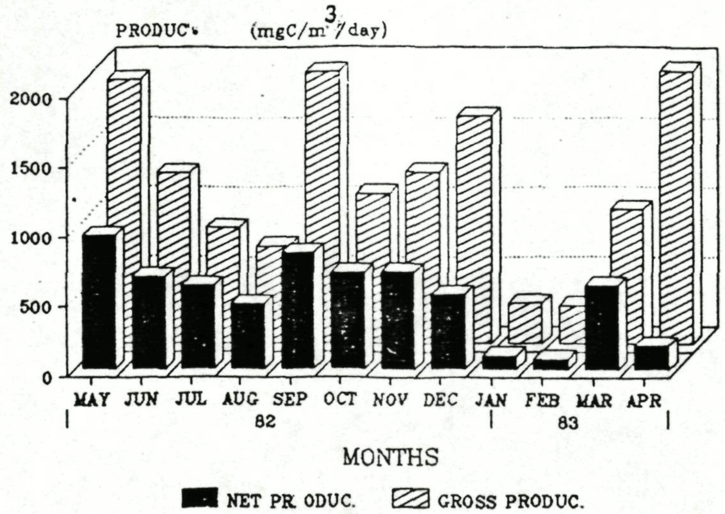


Fig.113. Primary production at station 2 of the Mathamuhuri river estuary (May 1992- April 1993).

Table 7. Abundance (cell/l) and distribution of major Phytoplankton (Skeletonema costatum) of the Mathamuhuri river estuary of Chakaria mangrove ecosystem, Bangladesh

Species	1982								1983				Yearly	Percentage
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average ($\bar{X}$)	composition (%)
Skeletonema costatum	2040	1660	24185	390	0	11175	500	350	0	180	300	2240	3585	35.23%
Other. phytoplankton	2970	26870	7365	530	20910	8540	6120	1030	1190	590	590	2370	6590	64.77%
Total Phytoplankton	5010	28530	31550	920	20910	19715	6620	1380	1190	770	890	4610	10175	100.00%

Table 7.1

Abundance (cells/l) and distribution of major phytoplankton (Skeletonema costatum) at station 1 "Manumiazi" in the Mathamuhuri river. estuary of Chakaria mangrove ecosystem, Bangladesh.

Species	1982								1983				Yearly	Percentage
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average	Composition
Skeletonema costatum	3400	2400	2020	500	0	1600	300	0	0	160	0	3960	1195	19.04%
Other phytoplankton	4160	18140	780	680	16940	5280	9200	1100	1240	500	620	2340	5082	80.96%
Total Phytoplankton	7560	20540	2800	1180	16940	6880	9500	1100	1240	660	620	6300	6277	100.00%

Table 7.2

Abundance (cell/l) and distribution of major phytoplankton (Skeletonema costatum) at station 2 "Goalarkoom" in the Mathamuhuri river estuary of Chakaria mangrove ecosystem, Bangladesh

	1982								1983					
Species	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Yearly Average	Percentage Composition
Skeletonema costatum	680	920	46350	280	0	20750	700	700	0	200	600	520	5975	42.46%
Other phytoplankton	1780	35600	13950	380	24880	11800	3040	960	1140	680	560	2400	8098	57.54%
Total Phytoplankton	2460	36520	60300	660	24880	32550	3740	1660	1140	880	1160	2920	14073	100.00%

Table 8. Primary production of the Mathamuhuri river estuary, Bangladesh (May 1992-April 1993)

	1982								1983				Yearly
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average
Net production (mg C/m^3/day)	956.55	658.124	594.014	465.5	830.88	690.306	694.024	537.05	95.06	73.07	596.33	1690.5	656.784
Gross production (mg C/m^3/day)	1895.81	1223.74	832.532	700.01	1950.58	1074.81	1236.02	1635.28	291.92	272.91	965.82	1960.2	1169.969

4.5. Conclusion

The highest abundance of the phytoplankton was recorded in early south-west monsoon months (June-July) and minimum in late winter (February-March). Diatoms was the most dominant phytoplankton in the Mathamuhuri river of Chakaria sundarban area. Cyanophyta shows a significant positive correlation with rainfall.The other groups of phytoplankton were not strongly related with hydrometeorological factors. The highest primary production was found in the spring months (April-May), when south-west monsoon just begin.The phytoplankton occurrence and abundance indicated that the Mathamuhuri river estuary of Chakaria Sundarban is a productive area of Bangladesh coastal water.

CHAPTER 5

TAXONOMY OF *ACETES* SHRIMP IN THE MATHAMUHURI RIVER ESTUARY.

5.1. Introduction.

The family Sergestidae is divided into two subfamilies, Sergestinae and Luciferinae (Omori,1975).The genus *Acetes* was established by Milne Edwards (1830) from a collection from the mouth of the Ganges, India and was recommended to be placed on the official list of Generic names in Zoology by Holthuis (1962). *Acetes* has now been included in the FAO species catalogue of shrimps and prawns by Holthuis (1980).The genus *Acetes* (Fig.114) is distinguished by the following features (Omori, 1975): rostrum short, without or with one or two denticles, supraorbital and hepatic spines present. Lower antennular flagellum in male with clapsing organ. First maxilla without palp, second maxilla with a single undivided lob, first maxilliped with out the palp. Both branchial lamellae and arthrobranchae present. First three pairs of pereiopods elongate and with small chelae, fourth and fifth pereiopods entirely absent except for a pair of protuberances (genital coxae) in males. In the coastal waters of Bangladesh only Mahmood *et al.* (1978) reported three species of *Acetes* shrimp from the Karnafuli river estuary, Chittagong. Works focusing on the taxonomy of *Acetes* were done by Colefax (1940), Omori (1975), Achuthankutty and Nair (1976) and Ravindranath (1980). However information is still lacking on *Acetes* identification; it is highly probable that new species will be recognised in the Indian ocean, around the New Guinea and Central and South America, none of which have been sampled adequately. Confusion still exists from the synonyms of the species, as recognised by Urita (1926), Burkenroad (1934 a,b), Colefax (1940), Yoshida (1949), Liu (1956), Holthuis (1959), Pathansali (1966), Omori (1975) and Ravindranath (1980), and from inadequate knowledge of ontogenetic and individual morphological variability (e.g.Yoshida 1941,1949; Kim and Park, 1972).

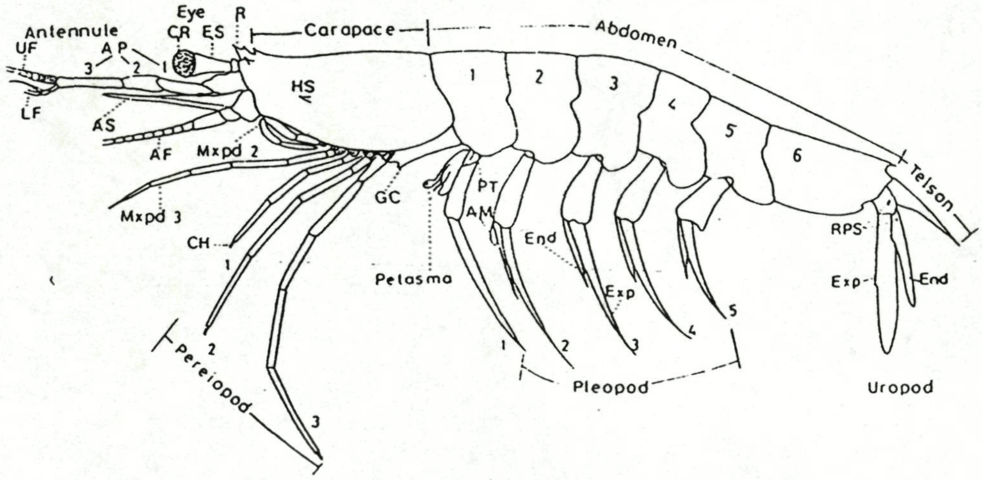


Fig114—Body plan of a male *Acetes* (Omori, 1975). AM, appendix masculina; AF, antennal flagellum; AP, antennular peduncle; AS, antennal scale; CH, chela; CR, cornea; End, endopod; ES, eye stalk; Exp, exopod; GC, genital coxa; HS, hepatic spine; LF, lower flagellum; Mxpd, maxilliped; PT, procurved tooth; R, rostrum; RPS, red pigment spots; UF, upper flagellum.

At present the following 14 species of *Acetes* are recognised in the world:

Phyllum, Subphyllum or Superclass Crustacea, Pennat
Class Malacostraca Latreille
Subclass Eumalacostraca Grobben
Super order Eucarida Calman
Order Decapoda Latreille
Suborder Dendrobranchiata Bate
Superfamily Sergestoidea Dana
Family Sergestidae Dana
Subfamily Sergestinae Bate
Genus *Acetes* H. Milne Edwards 1830
Species *A. americanus* Ortmann 1893
A. binghami Burkenroad 1934
A. Chinensis Hansen 1919
A. erythraeus Nobili 1905
A. indicus H. Milne Edwards 1830
A. intermedius Omori 1975
A. japonicus Kishinouye 1905
A. johni Nataraj 1947
A. marinus Omori 1975
A. natalensis Barnard 1955
A. paraguayensis Hansen 1919
A. serrulatus (Kroyer, 1859)
A. sibogae Hansen , 1919.
A. vulgaris Hansen, 1919.

5.2. Materials and Methods

Acetes species were collected along with other zooplankton during the course of three years between May 1982 and April 1984, and May 1992-April 1993 from the two sampling stations of the Mathamuhuri river estuary (Fig. 4). Samples were drawn by a small rectangular plankton net similar to that described by the Mahmood and Khan (1982) . It has a mouth opening of the 0.5 m^2 made up of nylon meshes (500 µm) and fitted with a removable plastic bucket at the cod end.The collected samples were preserved in 5% neutral formalin for critical examination and identification of the different specimens. Sometimes alive *Acetes* were collected from local fishermen (Fig. 146) or fry catcher and brought to the laboratory for the study of the red spot of uropod and colouration. The work of Nobili (1905), Hansen (1919, 1933), Burkenroad (1934 a,b), Rao (1968), Achuthankutty (1973), Achuthankutty and George (1973), Omori (1975), Achuthankutty and Nair (1976), Mahmood *et al.* (1978), Holthuis

(1980), Ravindranath (1980),Tirmizi and Ghani (1982) and Dore and Frimodt (1987) were consulted and personal observation (Fig. 115,116 &117) for identification.

5.3. Observation and Results.

A total of the 6 species of *Acetes* (*A. indicus* , *A. erythraeus, A. japonicus, A. chinensis, A. intermedius* and *A. vulgaris*) has been encountered in the investigation of the Mathamuhuri river (Fig.117). Three *Acetes* shrimps (*A. intermedius* , *A. vulgaris* and *Acetes chinensis* were recorded for the first time of Bangladesh.

Diagnostic criteria (some changes from the work of Omori, 1975) for the species of the genus *Acetes* found in the Mathamuhuri river, which are given below:

(Female)

1. Rostrum with two denticles behind terminal point 2
2. Apex of the telson round or truncated 3
   Apex of the telson triangular 6
3. Third thoracic sternite produced posteriorly 4
4. Third thoracic sternite without protuberance ,
   Exopod of uropod slender, 4 - 4.5 times as long as broad 5
5. Emargination of posterior margin of the third
   thoracic sternite deep, Endopod of uropod with
   4 - 8 red spots (4 red spots mostly clear). *Acetes chinensis*
   Emargination of posterior margin shallow.
   Endopod of uropod with one red spot *Acetes japonicus*
6. Procurved tooth present between bases of first pairs of pleopods 7
   Procurved tooth absent 9
7. Inner margin of basis of third pereiopod with sharply
   pointed projection, third and fourth thoracic sternite deeply
   channelled longitudinally *Acetes indicus*
   Inner margin of basis of third pereiopod
   without sharply pointed projection .Third and
   fourth thoracic sternite not channelled longitudinally 8
8. First segmant of antennular peduncle longer
   than second and third segments combined .
   Distal inner margin of basis of thrid
   periopod ending without projection *Acetes erythraeus*
9. Lower antennular flagellum with 19-20 segments
   or more distal inner margin of basis of
   third pereiopod ending with out projection.
   Pair of large protuberances on anterior
   part of third thoracic sternite *Acetes vulgaris*

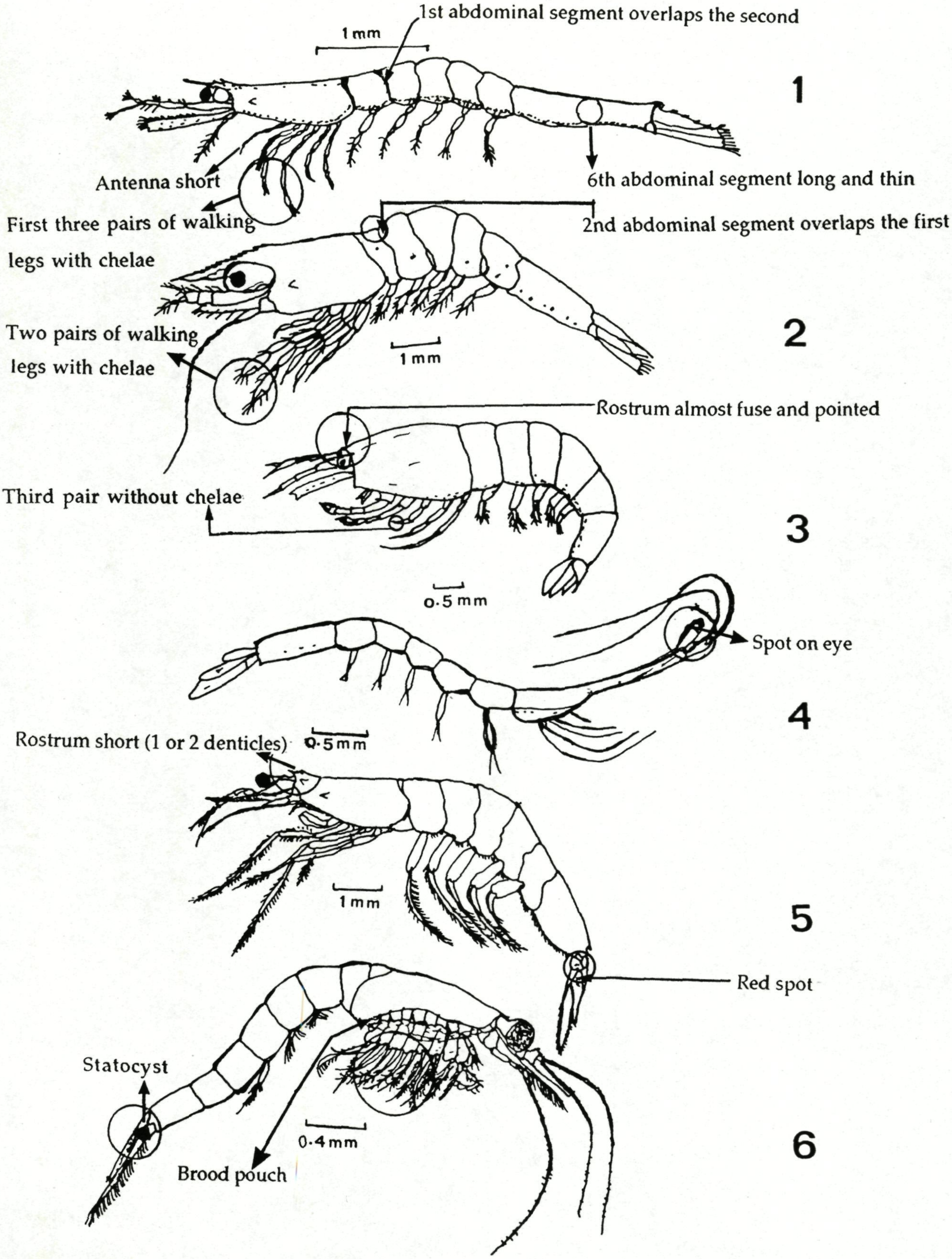


Fig.115. Diagrammatic guide to gross visual identification of *Acetes* shrimp from other allied specimens (1. Penaeid PL, 2. *Macrobrachium* PL, 3. Alpheid PL, 4. Sergestid shrimp'*Lucifer*', 5. *Acetes* sp, 6. Opossum shrimp'Mysid').

Fig.116. Showing photographs of allied specimens (1. Penaeid PL, TL 14mm; 2. *Macrobrachium* PL, TL 8mm; 3. Alpheid PL, TL 4.2mm; 4. *Lucifer*, TL 7.4mm; 5. *Acetes* sp, TL 16mm; 6. Mysid sp, TL 3.8mm) in the Mathamuhuri estuary, coastal water of Bangladesh.

(Male)

1. Rostrum with two denticles behind terminal point . Lower antennular flagellum with 1-2 clasping , spines 2
2. Procurved tooth between bases of first pair of pleopods , lower antennular flagellum with one clasping spines *Acetes indicus*
3. First segment of main branch of lower antennular flagellum without triangular projection 4
4. Distal expanded part of capitulum of petasma cucumber shaped, much longer than basal part of capitulum. Endopod of uropod with 4-8 red spots (mostly 4 red spots are clear.) *Acetes chinensis*
   Distal expanded part of capitulum of petasma bulb-like, proportionally shorter than basal part of capitulum . Endopod of uropod with one red spot *Acetes japonicus*
5. Procurved tooth between bases of first pair of pleopods 6
   Procurved tooth absent 7
6. First segment of antennular peduncle shorter than second and third segments combined . Capitulum of petasma with 3-5 subequally large hooks along outer margin *Acetes intermedius*
   First segment of antennular peduncle longer than second and third segments combined . Capitulum of petasma with one large hook along outer margin *Acetes erythraeus*
7. Lower antennular flagellum with 17 segments or more, capitulum of petasma with 3 large hooks along outer margin *Acetes vulgaris*

5.4. Discussion

Mahmood *et al.* (1978) reported three species of *Acetes* shrimps (*Acetes indicus* , *A. erythraeus* and *A. japonicus* from the Karnafuli river estuary, Bangladesh. Omori (1975) described 10 species of *Acetes* in the Indo-west Pacific. Inthe present study 6 species of the *Acetes* were found from the Chakaria Mangrove area and their identifying characters are closely similar with the results of Omori (1975).

In describing the *Acetes chinensis* , Omori (1975) reported third thoracic sternite produced posteriorly and without protuberance. Emargination of posterior margin of third thoracic sternite deep.

Fig.117. *Acetes* spp (1. *A. indicus*, TL 18mm; 2. *A. erythraeus*, TL 20mm; 3. *A. japonicus*, TL 14mm; 4. *A. chinensis*, TL 28mm; 5. *A. vulgaris*, TL 25mm; 6. *A. intermedius*, TL 13mm) in the Mathamuhuri estuary, Bangladesh.

Exopod of uropod slender. Endopod with the 4-8 red spots. The coxa of the third pereiopod has a tooth on the inner margin. In the petasma the distal part of the capitulum is expanded like a cucumber having several large hooks. Recent observation seems to be close to Omori (1975). But denticles of the rostrum was found directed straightly upward. Yu (1974) reported *Acetes intermedius* as *Acetes erythraeus, Acetes intermedius* is so named because it has some characteristics which seems to be similar with *Acetes erythraeus,* but Omori (1974) stated that the most characteristics features of this species which distinguish itself from *Acetes erythraeus* are the proportional length of the first, second and third segment of the antennular peduncle and the structure of the petasma.The characteristics of the presently investigated specimens were similar to those of the Omori (1974).

In female *Acetes vulgaris* lower antennular flagellum with 20 segments or more, in male is 17 to 21 segmented. Distal inner margin of basis of third pereiopod ending without projection in female and there is no procurved spine but a small conical projection between the bases of the first pleopods in both male and female. Above characteristics were found in the present specimens.

Acetes japonicus was reported by Mahmood *et al.* (1978) but they did not clarify one of the most identifying characteristics that is long antennular flagellum, which are much longer than the whole body found in the present investigation. Dore and Frimodt (1987) also found long, feathery antennae in *Acetes japonicus.*

CHAPTER 6

DISTRIBUTION OF THE *ACETES* IN THE MATHAMUHURI RIVER ESTUARY.

6.1. Introduction

Zooplankton abundance and distribution are an index to the fertility of an area and provides information on the fishery potentiality. It is well recognised that the richest fisheries of the world are closely related to the plankton production. Fish, shrimp and other organisms are directly and indirectly dependant upon planktonic shrimp *Acetes* (Basheeruddin and Nayar, 1961; Zafar, 1992; Xiao and Greenwood, 1993). So the role of *Acetes* shrimp in fisheries is important, and it should be possible to direct fisheries exploitation to the right place at the right time with a good knowledge on distribution of plankton in time and space. *Acetes* biology, abundance and distribution are still in need of study and fundamental gaps in knowledge still exist (Xiao and Greenwood,1993).Therefore the present work on the distribution of *Acetes* is the first of its kind undertaken in the Mathamuhuri river estuary and it is possible to detect the magnitude of *Acetes* population for exploitation in the right place at the right time.

6.2. Materials and Methods

Field work was carried out for three years from May 1982-April 1984 and May 1992-April 1993 at two stations (Fig. 4) in the Mathamuhuri river estuary of Chakaria Mangrove ecosystem. Zooplankton samples with replicate were collected fortnightly by using a speed boat . A rectangular plankton net (Fig.118) made up of nylon meshes (500µm) fitted with a rectangular metalic frame having 0.5m^2 mouth aperture and a plastic bucket of specially designed at the cod end was used to draw zooplankton along with *Acetes* samples (Mahmood and Khan,1982). A flowmeter was mounted at the mouth to record the quantity of water filtered through the net during the sampling . At each station, horizontal tows were made at both surface and bottom waters for about one hour before high water of a semidiurnal tidal cycle during day and night. Samples were preserved in 5% neutral formalin in situ. Concurrently, hydrological factors were also recorded, results of which have been illustrated in chapter'3'.

In the laboratory zooplankton samples were separated into major taxonomic groups as following Davis (1955),Wickstead (1965), Gosner (1971), Schram (1986), Omori (1975) and personal observation, and then the genus of *Acetes* shrimp was sorted out (Fig.115,116). Only *Acetes* shrimp was separated out from zooplankton samples of May 1992-April 1993.Taxonomy and distributional works of individuals *Acetes* spp were mentioned in the separate chapters '5 & 7'.

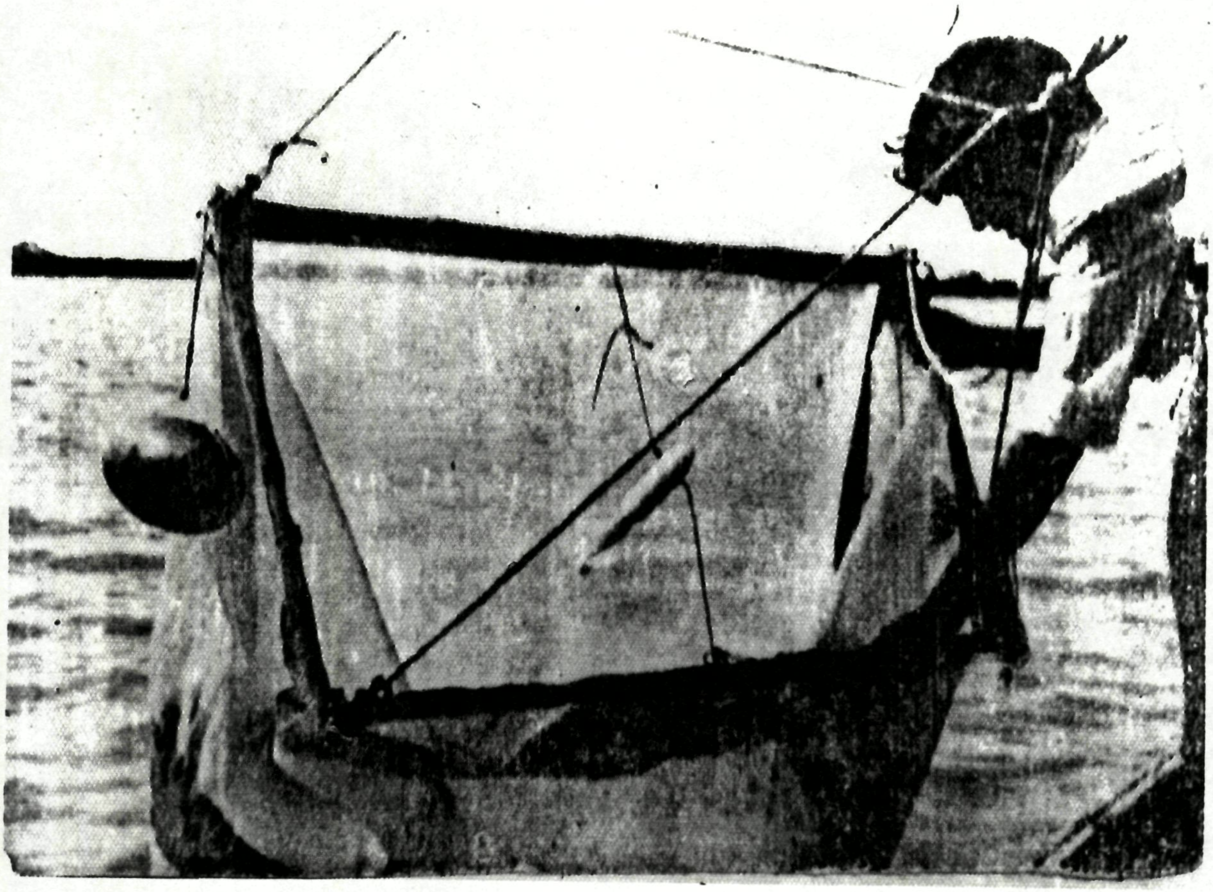


Fig. 118. Showing zooplankton net (mesh size 0.5 mm) used for samples.

The density of the each of the constituents of the zooplankton community was computed as mean number of individuals/100m^3 of water along with the respective percentage composition .

The relation between hydrological factor (salinity, water temperature, dissolved oxygen etc.) and the abundance of *Acetes* shrimps has been statistically analysed. For data analyses CANOCO (Ter Braak,1988), TWINSPAN (Hill,1979), Regression (Sokal and Rohlf, 1981), One factor ANOVA (Siegel,1956; Sokal and Rohlf, 1981) were used.

6.3. Results and Discussion

6.3.1. Temporal and spatial distribution of the adult *Acetes*

In the Mathamuhuri river estuary *Acetes* shrimp occupied numerically 0.50% of the average total zooplankton (larger than 500 µm), Fig.119 and they represent 29.06% of the commercially important planktonic stage of shrimps (Fig. 120). *Acetes* showed an increasing trend just after the moonson months (October-November) and another peak season was observed to be prior to the start of the monsoons (April-May) 'Table 9 & 10'. *Acetes* occurred throughout the period of investigation in the studied area, but during the moonson especially rainy season August to September it almost disappeared from the Mathamuhuri river estuary. Two bi-modal peak occurrence were found (October -November) before in winter season, and in the spring (April-May) during the three years of investigation (Fig.121) and more than 90% of *Acetes* shrimps occurred in the premonsoon and postmonsoon seasons. Maxima were recorded in November (582.17 indivs./100m^3 in 1982, 1060.19 indivs./100m^3 in 1983 and 756.50 indivs./100m^3 in 1992 and May 504.20 indivs./100m^3, in 1982, 595.4 indivs./100m^3 in 1983 and 426.25 indivs./100m^3 in 1992) and the minimum in September 4.25 indivs./100m^3 in 1983, zero indivi./100m^3 in 1983 and 3 indivs./100m^3 in 1992.

RDA plot make a clear distinction between monsoon (June-September) and spring (March-May) seasons, rainfall has a relationship with monsoon months and salinity & sunshine are closely linked to the spring, and four species of *Acetes* shrimps are associated close together as a one group in the Mathamuhuri river estuary (Fig.122). All species of *Acetes* showed the same seasonality (Fig. 129) and *Acetes* abundance of the investigated area was not significantly correlated with phytoplankton.TWINSPAN detected clearly also the monsoon season (June-September), and shows that *Acetes* is an indicator group during premonsoon (April-May) and postmonsoon (October-November), and in winter (December-March) and in monsoon (June-September) polychaetes and *Metapenaeus brevicornis* were the indicator species respectively (Fig.123).

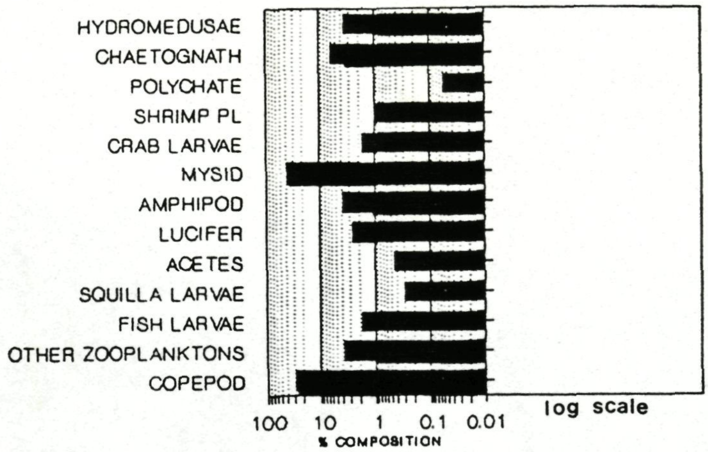


Fig.119. Composition of zooplankton communities in the Mathamuhuri river estuary, Bangladesh.

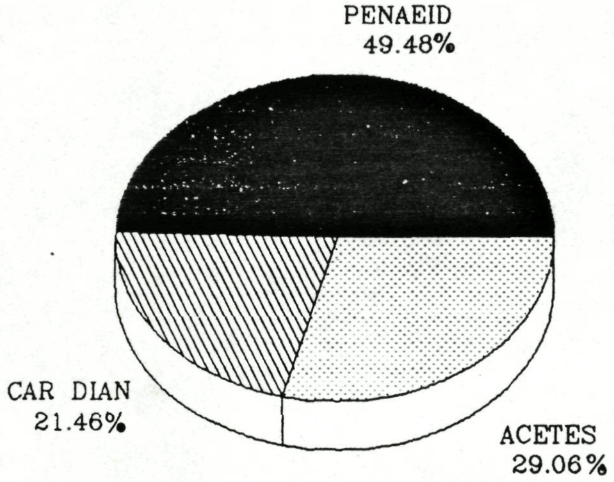


Fig.120. Showing *Acetes* percentage composition in the commercially important planktonic shrimps.

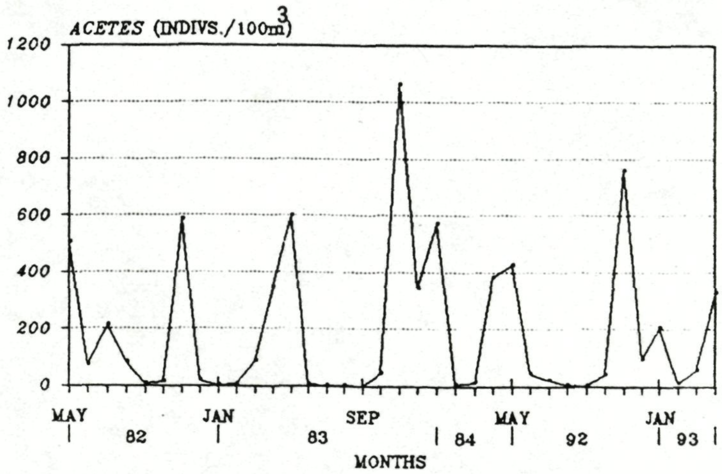


Fig.121. Monthly occurrence of *Acetes* shrimp in the Mathamuhuri river estuary of Chakaria Sundarban, Bangladesh.

Table 9. Monthly average distribution of Zooplankton (individuals/100 m3) in the Mathamuhuri river estuary, Bangladesh (May 1982- April 1983).

	1982								1983				Yearly
Taxa	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**Average (X̄)**
Hydromedusae	26.78	0	1.84	7.31	0.25	748.97	443.44	1255.44	2362.06	145.56	2821.31	100.97	659.49
Chaetognaths	1628.06	1305.3	247.91	31.41	0	1182.16	3056.06	495.66	177.91	41.66	1827.53	5377.34	1280.92
Polychaetes	0	17.59	0	0	0	0	0	0.22	62.52	18.22	4.98	28.36	10.99
Copepods	29858.63	4341.81	10890.22	8869.05	4034	10881.34	1804.56	2556.84	3893.38	6575.44	16878.75	6076.34	8888.36
Penaeus monodon	9.09	10	6.79	5.38	0.97	1.01	1.41	0.44	1.03	3.06	3.29	7.61	4.17
P. indicus	15.47	39.44	52.82	31.6	0.94	1.53	10.47	0.66	0	1.63	7.81	2.91	13.77
Other Penaeus spp	0.29	0.22	8.69	0.81	0.61	0	0	0.22	0.19	0.47	4.25	4.32	1.67
Metapenaeus brevicornis	9.07	21.1	255.44	36.19	33.75	6.75	4.38	0.63	0	7.16	3.26	4.1	31.82
M. monoceros	56.07	131.66	742.44	246.69	96.28	10.85	21	1.44	2.07	27.5	4.01	40.5	115.04
Other Metapenaeus spp	17.54	45.22	103.6	151.19	72.85	8.94	4.04	0	0	0.75	0.63	38.63	36.95
Parapenaeopsis species	8.94	3.5	9.85	4.47	0	0.47	0	39.72	1.16	23.22	6.75	0.5	8.22
Other penaeids	0	5.69	0	1.53	0	0	0	0	0	0	0.13	0	0.61
Alpheid shrimp	205.84	21.5	2.31	0.97	0	1.88	14.25	2.31	0.38	0.69	2.44	8.31	21.74
Other carideans	71.81	8.31	59.84	57.84	51	87.34	90.22	21.66	34.19	26.38	36.28	53.41	49.86
Crab larvae	61.47	136.78	1182.88	165.56	126.81	99.19	332.25	215.19	95.16	4297.19	50.19	17.41	565.01
Mysids	6021.88	30456.09	31560.78	4719.25	3014.03	5615.84	6624.28	43318.72	2637.84	1537.05	259.05	8314.19	12006.58
Amphipods	768.73	97.35	138.75	407.98	1791.65	4959	526.54	1193.84	2175.4	1022.09	337.82	1927.22	1278.86
Lucifer	2051.88	2384.81	4663.34	232.97	5.09	193.47	330.09	1554.19	187.56	133.22	182.94	33.63	996.10
Acetes	504.2	68.24	213.64	81.49	4.25	135.55	582.17	16.17	2.94	7.38	86.34	342.63	170.42
Squilla	37	103.06	13	0.13	0	92.56	192.09	628.81	168	9.25	23.81	34.63	108.53
Fish larvae	108.94	206.97	540.05	151	217.97	293.84	108.84	501.44	28.94	80.44	159.66	397.28	232.95
Other zooplankton	1490.13	397.78	245.53	105.91	155.91	3249.84	98.41	85.79	222.16	586.88	112.41	206.38	579.76
Total	42951.82	39802.42	50939.72	15308.73	9606.36	27570.53	14244.5	51889.39	12052.89	14545.24	22813.64	23016.67	27061.83

Table 10. Monthly average distribution of Zooplankton (indivudual/100 m3) in the Mathamuhuri river estuary, Bangladesh (May 1983 April 1984).

Taxa	1983								1984				Yearly Average ($\bar{X}$)
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	
Hydromedusae	2182.22	21.53	1.22	3.56	4.72	275.47	7278.66	11155.11	1583.56	14881.88	3295.63	4241.34	3743.74
Chaetognaths	1526.28	1372.72	96.59	0	772.03	718.25	1688.22	44510.38	7808.38	8714.72	856.09	7338.05	6283.48
Polychaetes	0	0	0	0	433.28	54.16	73.84	200.34	49.72	22.88	45.84	27.19	75.60
Copepods	16655.03	15340.66	21213.19	5743.81	28228.13	114.03	8243.66	41751.94	18719.28	71731.53	6768.88	10800.97	20442.59
Penaeus monodon	11.6	9.53	9.41	4.63	6.97	0.63	0	2.6	1.53	0	4.94	0	4.32
P. indicus	19.91	35.16	19.79	36.6	0.94	0.16	26.85	39.53	1.53	6.03	0	0	15.54
Other Penaeus spp	0.1	0.41	0.82	1.88	0.16	1.47	3.26	1.22	0	33.97	9.47	8.5	5.11
Metapenaeus brevicornis	7.44	18.25	212.14	162	262.54	23.75	30.38	28.44	1.41	25	8.38	0	64.98
M. monoceros	56.04	93.04	1084.94	294.85	797.81	268.66	96.1	76.41	68.54	404.91	40.38	4.1	273.82
Other Metapenaeus spp	17.63	74.72	381.72	61.22	352.81	103.72	50.04	356.04	6.44	13.26	26.32	1.6	120.46
Parapenaeopsis species	8.47	2	1.47	13.88	30.55	66.13	6.53	47.35	1.32	12.97	20.94	49.13	21.73
Other penaeids	0.13	0	0	1.66	0	0	0	0	0	0	0	0	0.15
Alpheid shrimp	97.63	18	30.69	0.44	0	2.53	9.63	42.97	0.91	12.19	3.05	1.16	18.27
Other carideans	19.09	36.81	14.97	53.22	335.47	599.81	505.94	350.91	313.16	283.63	57.05	92.13	221.85
Crab larvae	262.31	42.63	461.63	673.81	1479.56	1343.63	154.28	3102.63	5389.94	1313.47	809.69	166.28	1266.66
Mysids	9405.13	21665.47	56408.88	26211.05	40024.13	25020.56	9325.66	13446	52677	75455.19	623.75	2506.16	27730.75
Amphipods	1016.43	227.1	460.31	2238.05	8052	2072.12	1015.63	2142.29	4140.73	7001.13	835.83	2755.91	2663.13
Lucifer	559.13	620.28	77.78	1027.78	3356.06	873.06	673.81	4054.53	4162.34	843.34	106.84	1001.91	1446.41
Acetes	595.45	7.13	1.06	3.57	0	41.78	1060.19	341.56	570.78	4.97	13.92	380.87	251.77
Squilla	275.72	63.22	11.63	0	0	0	1884	0	0	0	0	0	186.21
Fish larvae	312.34	711.72	1078.81	1517.38	17500.31	2999.47	514.72	1106.88	420.16	170.91	125	430.63	2240.69
Other zooplankton	28.25	116.91	9394.56	2934.09	13893.22	902.34	764.84	5209	2917.16	12982.69	1044.78	1892.72	4340.05
Total	33056.33	40477.29	90961.61	40983.48	115530.7	35481.73	33406.24	127966.1	98833.89	193914.7	14696.78	31698.65	71417.29

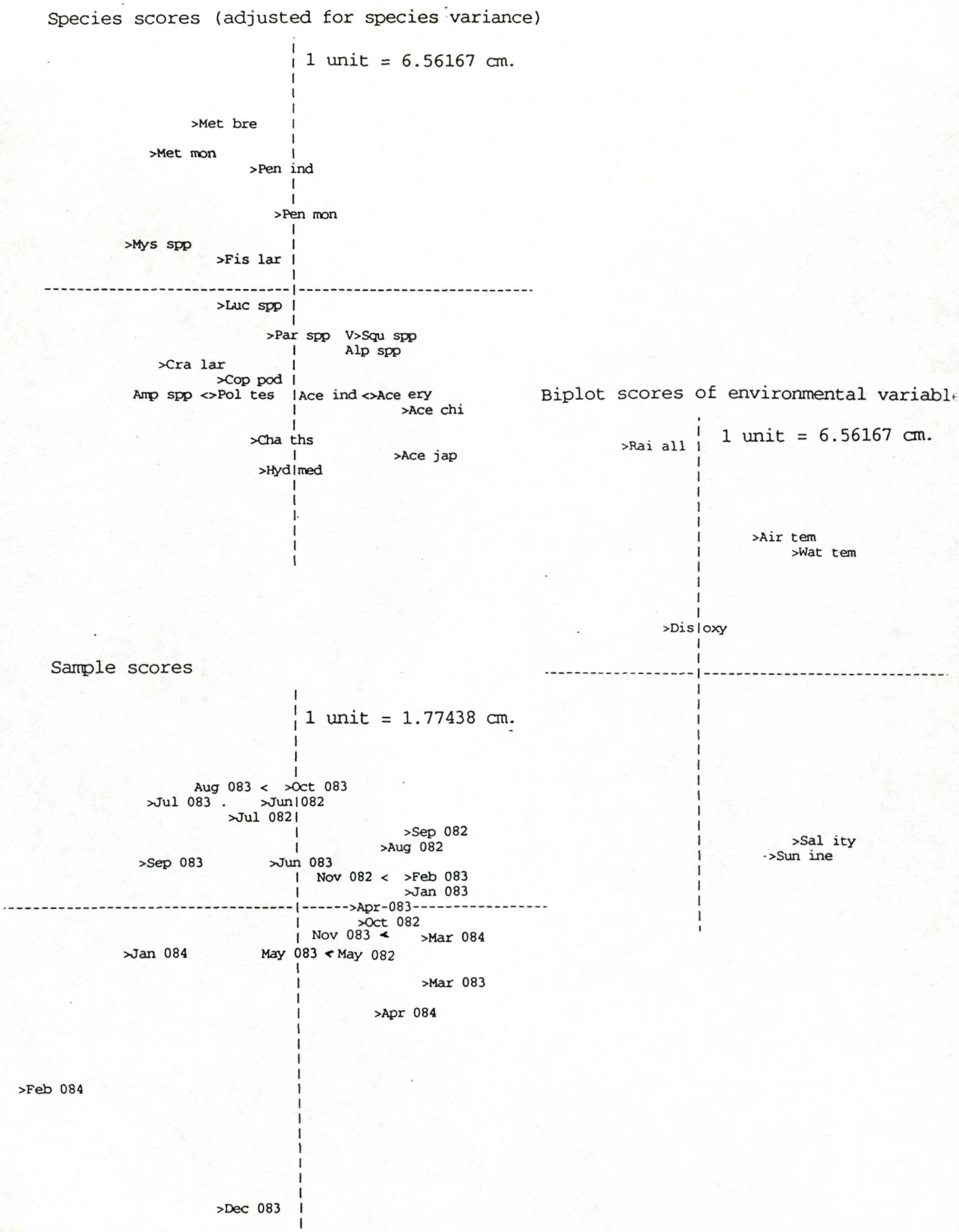


Fig.122. Species scores (zooplankton), sample scores and environmental biplot for the Redundancy analysis (RDA) of the 24 months data.

Kruskal-Wallis one way ANOVA indicates that *Acetes* abundance were not significantly different between the three years ($H = 0.2$, $P = 0.905$, df. = 2). But the slightly higher amount in May 1982 - June 1983 & May 1983 - June 1984 (170.42 indivs./100m^3 and 251.78 indivs./100m^3) when natural mangroves still existed compared with 165.33 indivs./100m^3 in May 1992-April 1993 when almost all mangroves were cleared for shrimp cultutre activities (Table 11, Fig. 3.1 &3.2).

Zafar and Mahmood (1989) reported that *Acetes* was an important constituent of zooplankton populations with 2.85%.They also recorded that *Acetes* had two peaks in the round of the year occurrence, one in the November-December and the other June-July in the estuarine system of Satkhira, Bangladesh. Zafar (1992) stated that *Acetes* occupied 1.05% of the zooplankton communities in the lower delta of the Mathamuhuri river estuary in the Kutubdia channel, Bangladesh. In many localities coastal swarms of *Acetes* are strongly seasonal.The swarming season changes slightly from year to year, the size and density of the swarm also vary considerably (Omori,1975). Achuthankutty and Selvakumar (1979) proposed that seasonality is correlated with arrival and departure of monsoon and thus with variation of the salinity and the other hydrological properties (Rao,1969; Zafar and Mahmood,1994). Larval stages of *Acetes* were recorded throughout the year in the estuarine system of Goa with their peak abundance during November-December and March-April (Achuthankutty and Selvakumar,1979).They also stated that during the monsoon season (June to September), only postlarval stages were present in very small numbers. There was a decline in their abundance in January and February. But again from March to May *Acetes* were distributed in fairly large numbers. Aravindakshan and Karbhari (1988) showed an increasing trend just after the moonson months and another peak season was observed just before monsoons at the three landing centres (Versova, S. Dock and Trombay) in Bombay coast; India. Romimohtarto and Hindarti (1990) reported that *Acetes* larvae reached densities of up to the 20-40/m^3 at the shallow sites, but were not found in the February cathes in the Northern Arafura sea.

In the present investigated estuary, *Acetes* showed a seasonality and high abundance of *Acetes* was oppositely related with monsoon. During the monsoon, especially the rainy season (August-September) very less quantity of *Acetes* shrimps were present in the Mathamuhuri river of Chakaria sundarban area, when maximum freshwater discharge occurred due to heavy rainfall and obtained the low salinity. In this period the velocity of tidal current was very weak towards the upper station for freshwater discharge and it was concluded that low densities of *Acetes* spp were immigrating from the Moheskhali and Kutubdia channel at this period probably to low salinity. Xiao and Greenwood (1992) stated that *Acetes* spp are mainly distributed near the mouths of estuaries, areas generally of considerable salinity fluctuation. Bhattacharya (1987) reported that *Acetes indicus* could not tolerate pure freshwater even after gradual acclimation down to 1% seawater. The migration of *Acetes chinensis* in

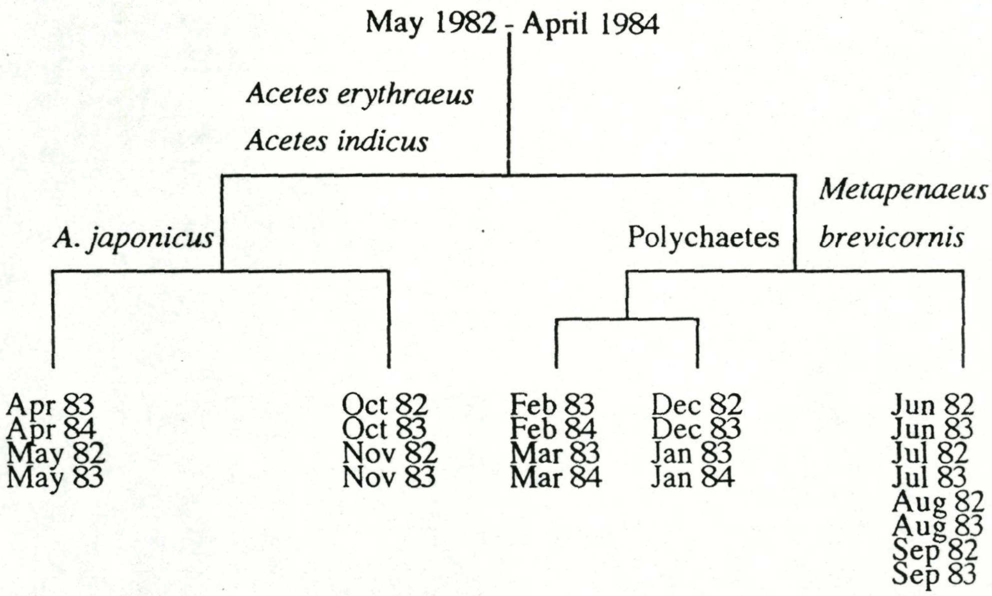


Fig.123. Dendrogram for the temporal structure according to the TWINSPAN using 24 months fourth root transformed density data.

Laizhou Bay and southern Pohai may be affected by changes in salinity (Anonymous, 1990). Omori (1975) noted that *A. sibogae* prefers an estuarine environment and sheltered area. Zafar (1992) reported that during monsoon lesser densities of *Acetes* were recorded than premonsoon and postmonsoon in the Kutubdia channel. Chowdhury (1995) stated that *Acetes* spp were recorded in the Moheskhali channel during the monsoon months.

During the three years of investigation, higher densities of *Acetes* were generally recorded at station 2 (Fig.124,Table 11). One factor ANOVA showed significant differences between station 1 & 2 (P = 0.010, F = 6.94, N = 72). The spatial heterogenous distribution of *Acetes* is due partly to its extremly gregarious nature, as inferred from field samples (e.g. Robertson and Duke, 1989; Xiao and Greenwood,1992) and laboratory experiments (Xiao,1990). Luo and Zhang (1957) studied the spatial distribution of *A. chinensis* in Liaotung Bay and found that such spatial variability led to marked differences in catches at different localities. Similar heterogeneity was found in *A. erythraeus* in Ambaro Bay and Ambazoana estuary, Madagascar (Le Reste,1970). Xiao and Greenwood (1993) stated that adult *Acetes* are mainly distributed near the mouths of estuaries.The higher density at lower reaches station of the Mathamuhuri river could be related to the salinity. The upstream station of the investigated area was more influenced than lower reaches station by fresh water discharge. During the periods of high tide *Acetes* shrimps were immigrating from the Moheskhali channel and other adjacent area.

6.3.2. Diurnal distribution of *Acetes*

The density of *Acetes* was always higher in night samples (Fig.125,126 & 127,Table 12) except in monsoon months (August-September) and in late winter months (February-March), Table 13.1 &13.2). One factor ANOVA indicates no significant differences between day and night samples (average) of *Acetes* (P = 0.069, F = 3.46, N = 48) but at station 2 *Acetes* abundance showed significant difference between day and night occurrence (P = 0.030, F = 4.97, N = 48). The maximum average abundance was recorded at night in November 1142.6 indivs./100m^3 in 1982 and 1187.7 indivs./100m^3 in 1983 (Table 12). Luo and Zhang (1957) collected more *A. chinensis* near the water surface in Liaotung Bay at night than during the day. Harada (1968) caught more *A. japonicus* at night than during the day in Lake Naka-umi, Japan. Le Reste's (1970) reported *Acetes erythraeus* numbers were greater at night in bottom samples in the Ambazoana estuary, north west Madagascar. Henry (1977) noted the usual greater catches of *A. sibogae* at night in the Tuggerah Lakes, Australia.

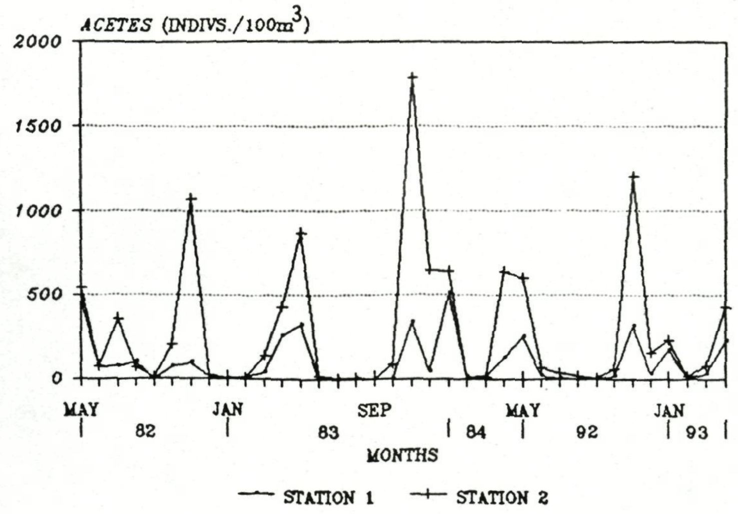


Fig.124. Showing the variation of *Acetes* shrimp in the two sampling stations of the Mathamuhuri river estuary, Bangladesh.

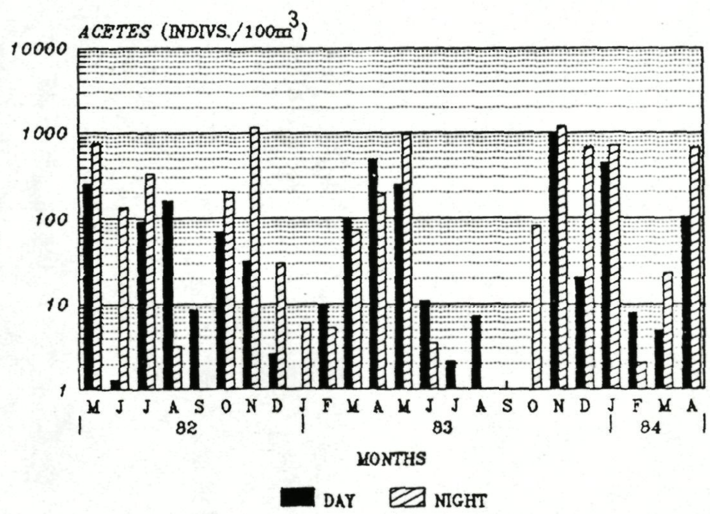


Fig.125. Day-night variation of *Acetes* shrimp (average two stations) in the Mathamuhuri river estuary, Bangladesh.

Table 11. Distribution of Acetes (individuals/100 m3) in the Mathamuhuri river estuary during the three years of investigation

Year	Stations	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Yearly Average
May 1982-	Station 1	465.26	64.78	76.96	98.24	0.00	69.68	92.73	10.39	0.00	9.36	37.28	256.35	98.42
Apr-83	Station 2	543.13	71.71	350.32	64.74	8.49	201.42	1071.60	21.94	5.87	5.41	135.40	428.90	242.41
	Average	504.20	68.25	213.64	81.49	4.25	135.55	582.17	16.17	2.94	7.39	86.34	342.63	170.42
May 1983-	Station 1	321.99	0.00	0.00	0.00	0.00	0.00	331.44	39.75	503.50	7.88	18.51	121.48	112.05
Apr-84	Station 2	868.91	14.25	2.13	7.13	0.00	83.56	1788.94	643.38	638.06	2.06	9.32	640.25	391.50
	Average	595.45	7.13	1.07	3.57	0.00	41.78	1060.19	341.57	570.78	4.97	13.92	380.87	251.77
May 1992-	Station 1	250.00	16.00	4.00	0.00	0.00	15.00	312.00	28.00	175.00	5.00	30.00	228.00	88.58
Apr-93	Station 2	602.50	70.40	39.00	15.00	6.00	62.01	1201.00	156.00	230.00	14.00	81.00	428.00	242.08
	Average	426.25	43.20	21.50	7.50	3.00	38.51	756.50	92.00	202.50	9.50	55.50	328.00	165.33

Table 12. Diurnal variation of Acetes (individuals/100 m3) in the Mathamuhuri river estuary of Chakaria Mangroves ecosystem, Bangladesh

Year	Stations		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Yearly Average
May 1982-Apr-83	Station 1	Day	332.13	0.70	11.19	194.26	0.00	139.35	48.14	0.93	0.00	15.49	70.02	337.47	95.81
		Night	598.39	128.88	142.74	2.22	0.00	0.00	157.32	19.87	0.00	3.23	4.55	175.25	102.70
	Station 2	Day	173.32	1.87	174.33	125.37	16.99	0.00	15.34	4.25	0.00	3.60	128.99	638.94	106.92
		Night	913.05	141.56	526.32	4.11	0.00	402.84	2127.88	39.62	11.73	7.22	141.81	218.83	377.91
	Average	Day	252.73	1.29	92.76	159.82	8.50	69.68	31.74	2.59	0.00	9.55	99.51	488.21	101.36
		Night	755.72	135.22	334.53	3.17	0.00	201.42	1142.60	29.75	5.87	5.23	73.18	197.04	240.31
May 1983-Apr-84	Station 1	Day	224.24	0.00	0.00	0.00	0.00	0.00	101.75	39.88	857.13	15.75	8.15	182.83	119.14
		Night	419.75	0.00	0.00	0.00	0.00	0.00	561.13	39.63	149.88	0.00	28.88	60.13	104.95
	Station 2	Day	270.39	21.45	4.25	14.25	0.00	0.00	1763.63	0.88	33.75	0.00	1.75	26.13	178.04
		Night	1467.43	7.05	0.00	0.00	0.00	167.13	1814.25	1285.88	1242.38	4.13	16.89	1254.38	604.96
	Average	Day	247.32	10.73	2.13	7.13	0.00	0.00	932.69	20.38	445.44	7.88	4.95	104.48	148.59
		Night	943.59	3.53	0.00	0.00	0.00	83.57	1187.69	662.76	696.13	2.07	22.89	657.26	354.96

6.3.3. Surface - Bottom distribution of *Acetes*

In average bottom samples were higher in values than surface samples of the Mathamuhuri river estuary (P = 0.0146, F = 6.45, N = 48). Maximum density was recorded in November (Bottom 1124.9 indivs./100m^3 in1982 and 1522.7 indivs./100 m^3 in 1983) Table 13. Day-night effect in surface-bottom *Acetes* abundance were observed (Appendix Table 5 &6). Surface night densities were found always higher in values than surface day time (Fig.126), one factor ANOVA detect these differences (P = 0.04, F = 4.46, N = 48); but no significant difference was found between day-bottom and night-bottom abundance (P = 0.11, F = 2.65, N = 48). Zafar (1986) stated that bottom samples were higher in values than surface samples in the Satkhira estuarine system, south-western coastal waters of Bangladesh. Romimohtarto and Hindarti (1990) observed that higher abundance of *Acetes* larvae (20 - 40 m^3) in the shallow regions off Irian Jaya in the northern Arafura Sea. Nair and Paulinose (1980) observed an increase in abundance of larval *Acetes* species with increasing water depth in Binge Bay Karwar, India. In average adult *Acetes* densities had higher values in bottom samples in the Mathamuhuri river estuary (Fig.128). Omori (1975) mentioned that *Acetes* shrimps (adult) are epipelagic. Omori (1977) and Bhattacharya (1988) accorded*Acetes* are epiplanktonic shrimps. The present investigation does not agree with their views and concluded that *Acetes* spp are hyperbenthic shrimps not epipelagic shrimps, at least in the shallow estuarine system.

6.3.4. *Acetes* distribution in respect of hydrometeorological factors

Monthly variation of *Acetes* density and fluctuation of salinity, rainfall, water temperature and dissolved oxygen in the Mathamuhuri river estuary are shown in Fig.131,132,133 and 134.The low salinity, high rainfall periods (maximum fresh-water discharge period) and minimum tidal water velocity supported the lowest abundance of *Acetes*; temperature did not affect the occurrence of *Acetes* in the studied estuary. Generally the abundance of *Acetes* were positively correlated with sunshine in the studied estuary (Fig.122). Insignificant negative correlation exists between *Acetes* density and dissolved oxygen concentration during the period of May 1982-April 1984, when mangrove ecosystem of the Chakaria Sundarban was almost undisturbed and positive correlation was found between *Acetes* density and dissolved oxygen concentration during the studied period (May 1992-April 1993), when almost all mangroves were already cleared for shrimps culture.

Acetes are extremely euryhaline and can tolerate salinity changes from virtually fresh water to full sea water (Luo and Zhang, 1957; Le Reste, 1970; Bhattacharya,1988; Anonymous,1990). Greater abundance of adult *Acetes* was found during the dry season (January to June), when the salinity of water was comparatively higher (Ling and Suriyong, 1954). Temperatures tolerated by the shrimp (*Acetes indicus*) ranged from 14°C-34°C (Bhattacharya, 1988).

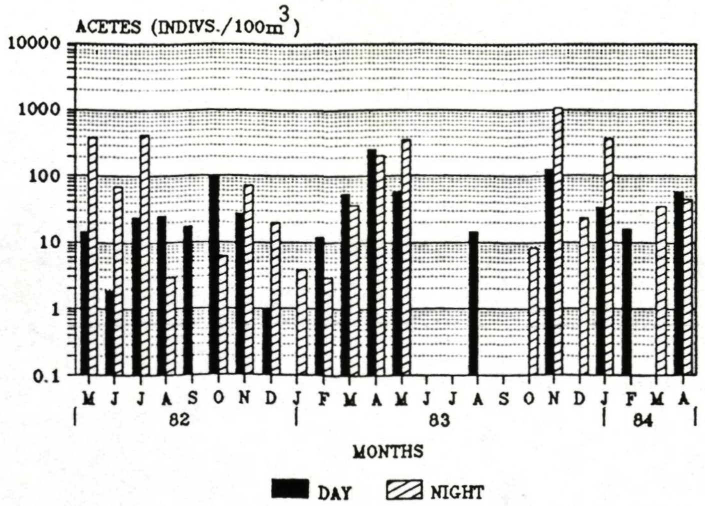


Fig.126. Surface day-night variation of *Acetes* shrimp (average two stations) in the Mathamuhuri river estuary, Bangladesh.

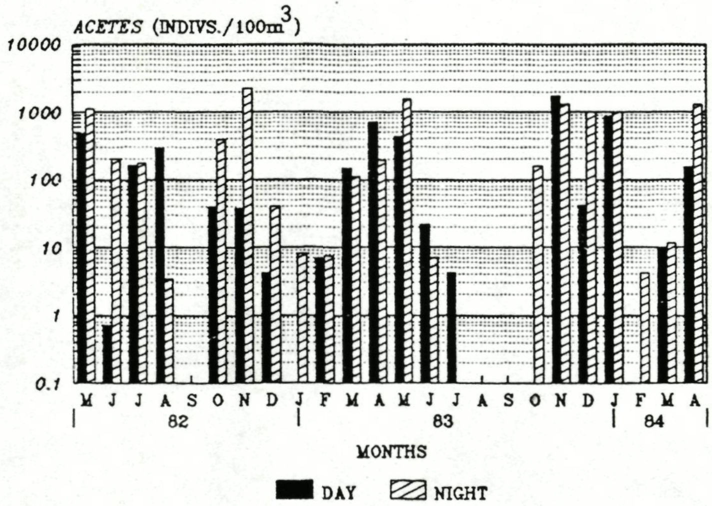


Fig.127. Bottom day-night variation of *Acetes* shrimp (average two stations) in the Mathamuhuri estuary of Bangladesh.

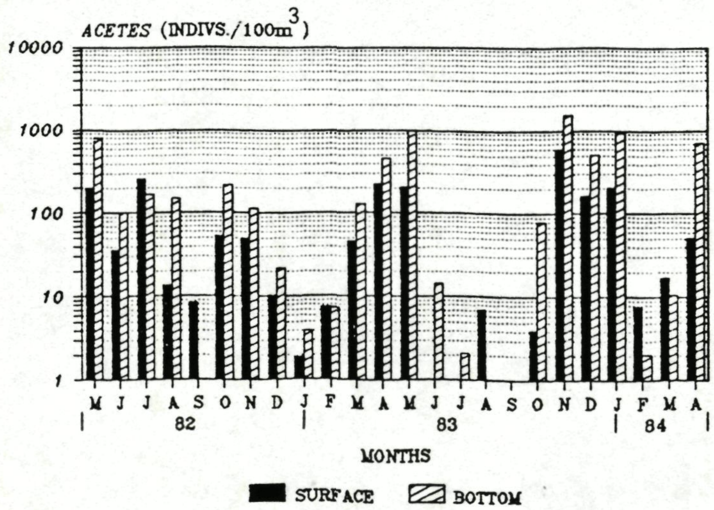


Fig.128. Surface-bottom variation of *Acetes* shrimp (average two stations) in the estuarine area of Mathamuhuri river,Bangladesh.

Table 13. Surface-bottom variation of Acetes (individuals/100 m3) in the Mathamuhuri river estuary of Chakaria Mangroves ecosystem, Bangladesh

Year	Stations		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Yearly Average
May 1982-Apr-83	Station 1	Surface	214.53	0.00	3.08	24.11	0.00	100.00	51.03	11.79	0.00	12.12	41.95	96.98	46.30
		Bottom	715.99	129.58	150.86	172.37	0.00	39.35	154.43	9.00	0.00	6.60	32.62	415.73	152.21
	Station 2	Surface	182.59	71.74	539.23	3.49	16.99	6.03	47.81	9.30	3.77	2.89	48.68	353.76	107.19
		Bottom	903.78	71.69	185.08	125.99	0.00	396.82	2095.41	34.58	7.97	7.93	222.13	504.01	379.62
	Average	Surface	198.56	35.87	271.16	13.80	8.50	53.02	49.42	10.55	1.89	7.51	45.32	225.37	76.74
		Bottom	809.89	100.64	167.97	149.18	0.00	218.09	1124.92	21.79	3.99	7.27	127.38	459.87	265.91
May 1983-Apr-84	Station 1	Surface	171.47	0.00	0.00	0.00	0.00	0.00	391.38	0.00	13.13	15.75	28.88	51.24	55.99
		Bottom	472.53	0.00	0.00	0.00	0.00	0.00	271.50	79.50	993.88	0.00	8.15	191.72	168.11
	Station 2	Surface	236.58	0.00	0.00	14.25	0.00	8.13	803.88	323.13	395.25	0.00	5.51	52.13	153.24
		Bottom	1501.24	28.50	4.25	0.00	0.00	159.00	2774.00	963.63	880.88	4.12	13.13	1228.38	629.76
	Average	Surface	204.03	0.00	0.00	7.13	0.00	4.07	597.63	161.57	204.19	7.88	17.20	51.69	104.61
		Bottom	986.89	14.25	2.13	0.00	0.00	79.50	1522.75	521.57	937.38	2.06	10.64	710.05	398.93

Table 13.1. Distribution of <u>Acetes</u> (indivs./100m3) in the Mathamuhuri river estuary (May 1982-April 1983)

		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Jan		Feb		Mar		Apr		Average	
Station		D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N
S1	S	1.15	427.9	0	0	0	6.15	48.22	0	0	0	200	0	53.75	48.3	1.85	21.73	0	0	24.23	0	81.63	2.26	72.94	121.02	40.31	52.28
	B	663.1	768.87	1.4	257.75	22.38	279.33	340.3	4.43	0	0	78.7	0	42.53	266.33	0	18	0	0	6.75	6.45	58.4	6.84	602	229.45	151.30	153.12
S2	S	26.98	338.29	3.73	139.74	47.33	983.89	1.05	5.93	33.97	0	0	12.05	0.54	95.08	0	18.59	0	7.53	0	5.78	28.2	69.16	427.37	280.15	47.43	163.02
	B	319.65	1487.9	0	143.38	301.32	68.83	249.68	2.29	0	0	0	793.63	3.13	4160.7	8.5	60.65	0	15.93	7.2	8.65	229.79	214.46	850.5	157.52	164.15	592.83
Avg	S	14.065	383.1	1.865	69.87	23.665	495.02	24.635	2.965	16.985	0	100	6.025	27.145	71.69	0.925	20.16	0	3.765	12.115	2.89	54.915	35.71	250.16	200.59	43.87	107.65
	B	491.38	1128.4	0.7	200.57	161.85	174.08	294.99	3.36	0	0	39.35	396.82	22.83	2213.5	4.25	39.325	0	7.965	6.975	7.55	144.1	110.65	726.25	193.49	157.72	372.97

Table 13.2. Distribution of <u>Acetes</u> (indivs./100m3) in the Mathamuhuri river estuary (May 1983-April 1984)

		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Jan		Feb		Mar		Apr		Average	
Station		D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N
S1	S	91.23	251.7	0	0	0	0	0	0	0	0	0	0	8.75	774	0	0	0	26.25	31.5	0	0	57.75	89.73	12.75	18.43	93.54
	B	357.25	587.8	0	0	0	0	0	0	0	0	0	0	194.75	348.25	79.75	79.25	1714.3	273.5	0	0	16.3	0	275.93	107.5	219.85	116.36
S2	S	26.48	446.68	0	0	0	0	28.5	0	0	0	0	16.25	242.25	1365.5	0	646.25	67.5	723	0	0	0	11.02	27	77.25	32.64	273.83
	B	514.3	2488.2	42.9	14.1	8.5	0	0	0	0	0	0	318	3285	2263	1.75	1925.5	0	1761.8	0	8.25	3.5	22.75	25.25	2431.5	323.43	936.09
Avg	S	58.855	349.19	0	0	0	0	14.25	0	0	0	0	8.125	125.5	1069.8	0	323.13	33.75	374.63	15.75	0	0	34.385	58.365	45	25.54	183.68
	B	435.78	1538	21.45	7.05	4.25	0	0	0	0	0	0	159	1739.9	1305.6	40.75	1002.4	857.13	1017.6	0	4.125	9.9	11.375	150.59	1269.5	271.64	526.22

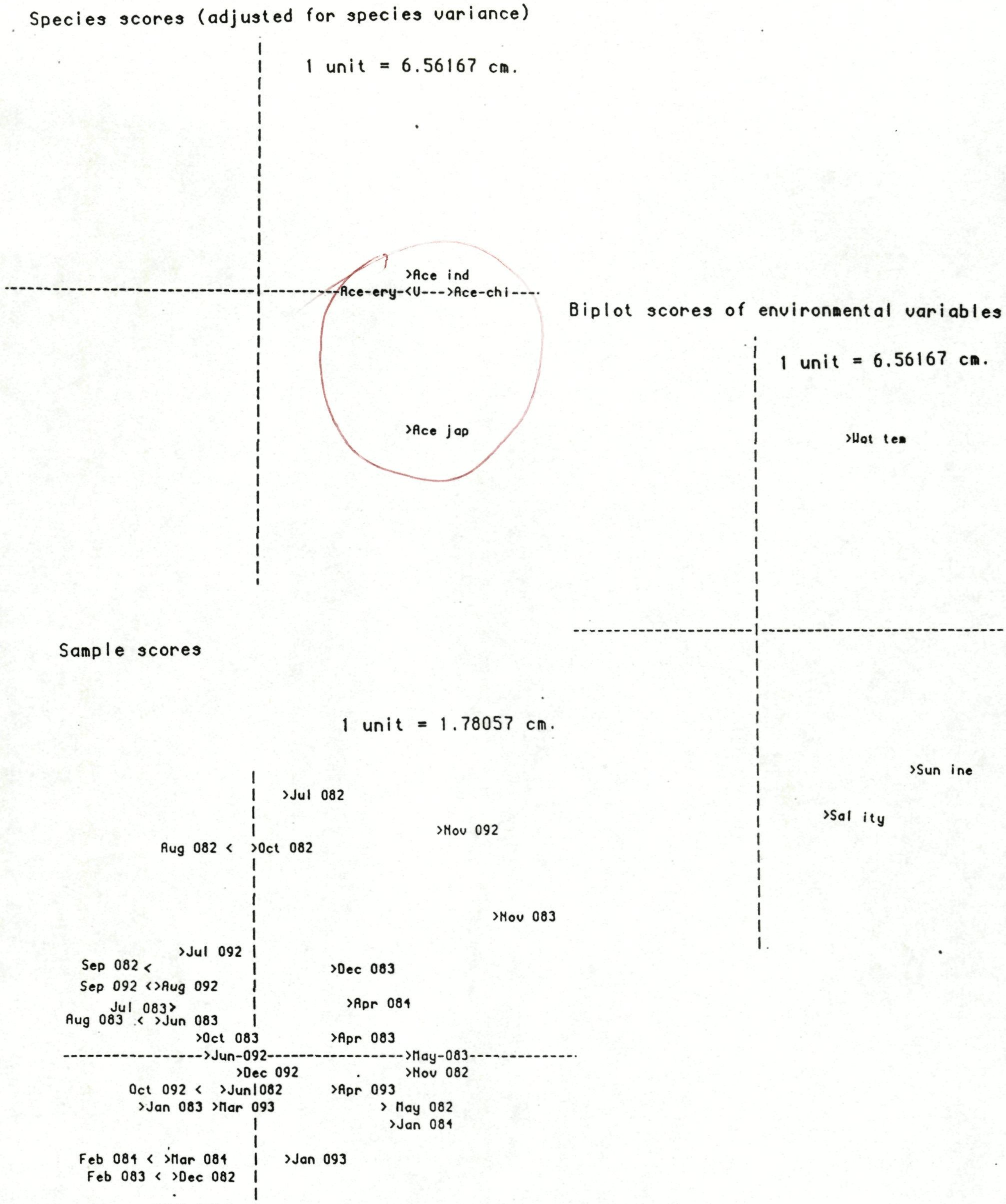


Fig.129. Species scores (*Acetes* spp), sample scores, and environmental biplot for the RDA of the 36 months data.

Anonymous (1990) concluded that *Acetes chinensis* tolerates a temperature range of 0.0-29.5°C in Laizhou Bay and southern Pohai. Xiao and Greenwood (1992) observed that abundances of *A. sibogae* varied with light cycles, with higher catches occuring only in dark periods. Xiao (1990) has experimentally demonstrated that *A. sibogae* do respond to light intensity cycles as exogenous and endogenous stimuli in mediating nocturnal vertical migration. In the Mathamuhuri river estuary maximum densities occurred at night. In monsoon months (August-September) the light intensity was lower and minimum abundances of *Acetes* were also recorded, but in this period surface abundance of *Acetes* were higher than bottom samples.Tidal patterns in the vertical migration of the *Acetes* are not well documented. Luo and Zhang (1957) obtained limited data suggesting a tidal vertical migration of *A. chinensis* in the Liao river estuary. Xiao and Greenwood (1992) sampled *Acetes sibogae* over a period of four tidal cycles in an estuary and found that changes in abundance were related to tidal cycles, higher numbers moving up in the water column during flood tides than during ebb tides. As with the photo-responses, these tidally phased migrations by *Acetes* may also have implications for the population maintenance in estuaries or coastal waters (Xiao and Greenwood,1992).

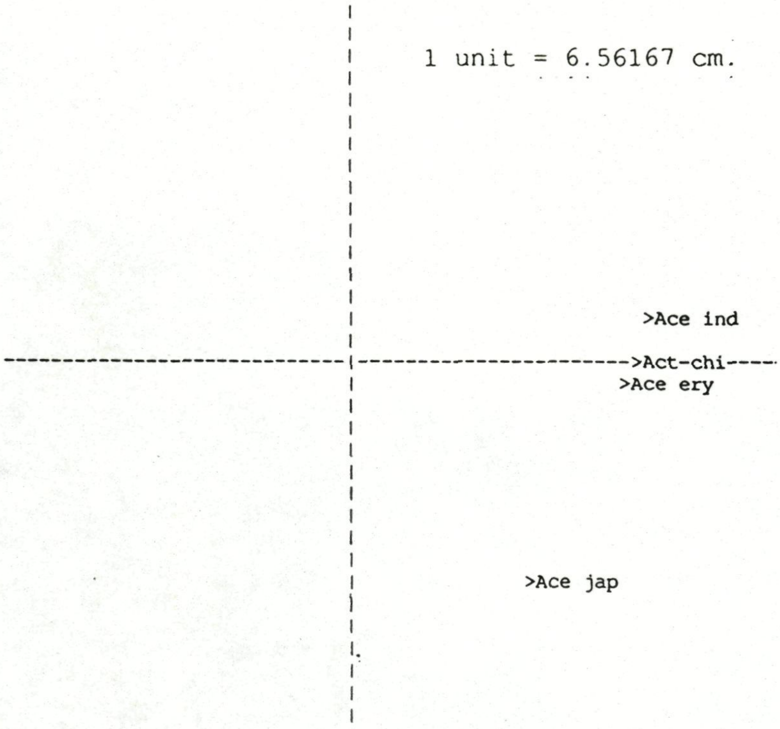
The present study showed that *Acetes* shrimp has a bimodal peak in occurrence, one in premonsoon season (April-May) and the other in postmonsoon season (November-January), and during monsoon season (July-August) *Acetes* abundance were very low or absent, when maximum freshwater discharge occurred due to the heavy rainfall. In this period (July-September) probably for low salinity high abundance of *Acetes* spp were not immigrating in the studied area. CANOCO (RDA) analyses showed (Fig.122) the density of *Acetes* shrimps correlated with salinity and sunshine, these two factors are inversely related to the monsoon in the Mathamuhuri river of Chakaria sundarban area. Ling and Suriyong (1954) reported that when the weather is fine and the sea calm, *Acetes* occur in large schools. The present investigation is in close agreement with this statement.

6.3.5. *Acetes* distribution in respect to phytoplankton and zooplankton

6.3.5.1. *Acetes* distribution in respect to phytoplankton

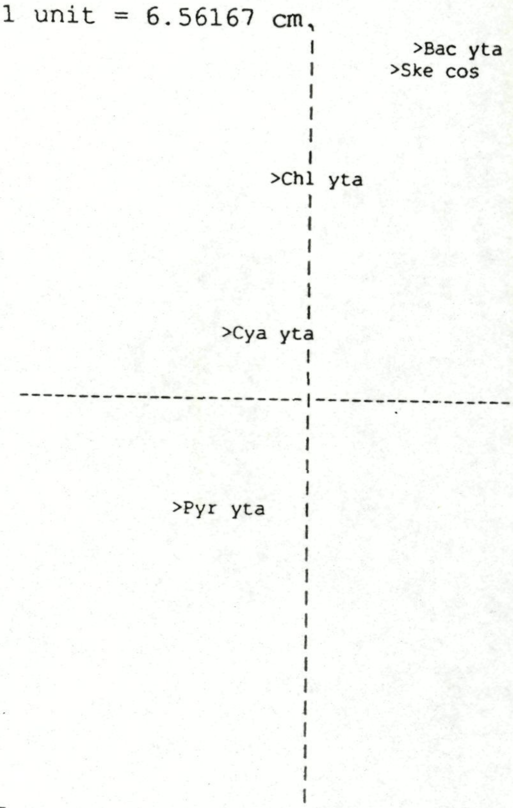
Positive insignificant correlation was observed between *Acetes* density and net production (P= 0.28, r= 0.339, F =1.39). In the Mathamuhuri river estuary *Acetes* abundance has a positive relationship with phytoplankton (Fig.136), and that relationship is influenced by Bacillariophyta (Fig.136). But apparently there is no significant relation between phytoplankton and *Acetes* (r = 0.047, P = 0.884, N = 24). RDA analysis also shows a very weak relationship between *Acetes* shrimps and Bacillariophyta (Fig.130).

Species scores (adjusted for species variance)



Biplot scores of environmental variables

1 unit = 6.56167 cm.



Sample scores

1 unit = 2.53444 cm

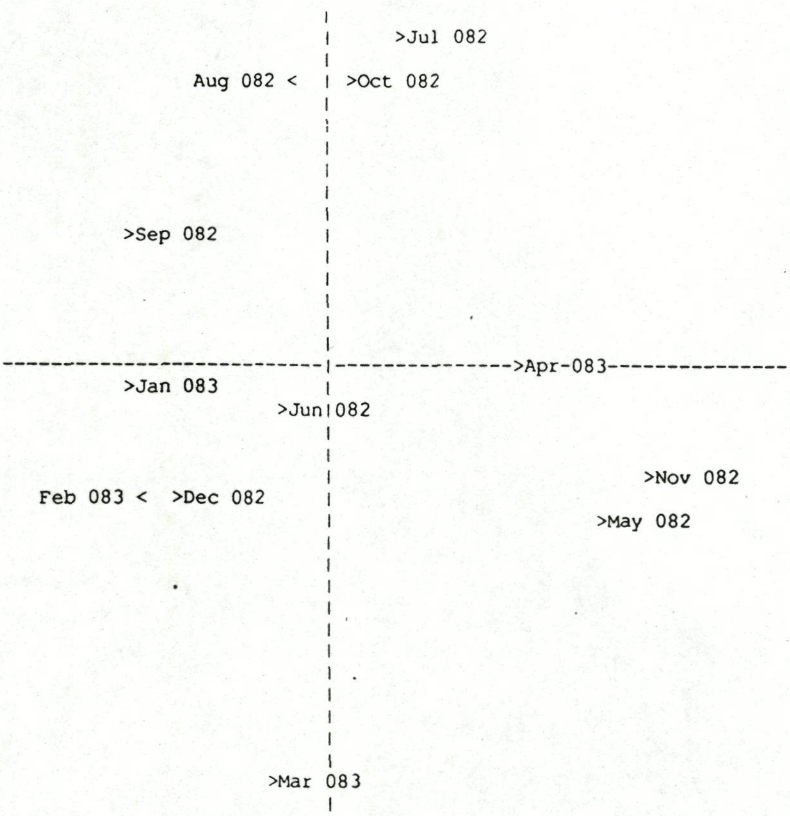


Fig.130. Species scores (*Acetes* spp), sample scores, and phytoplankton biplot for the RDA of the 12 months data.

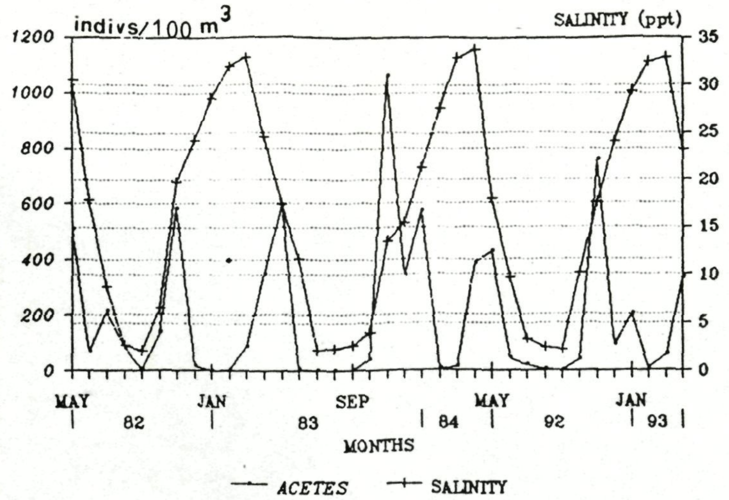


Fig.131. Monthly variation in occurrence of *Acetes* and fluctuation of salinity (average two stations) in the Mathamuhuri river estuary, Bangladesh.

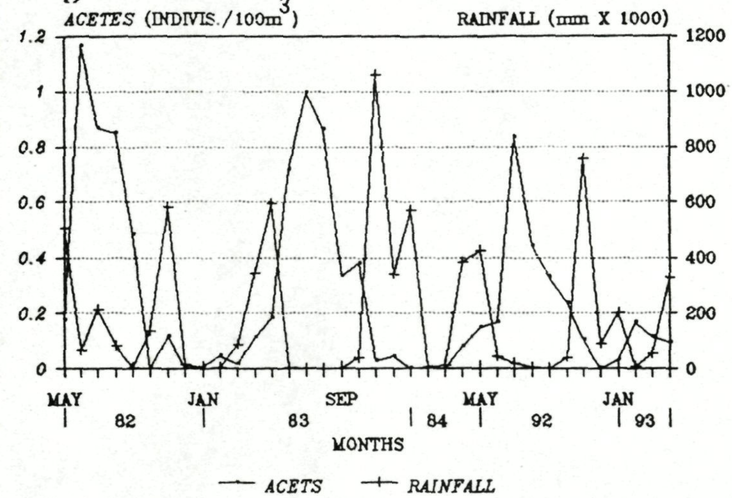


Fig.132. Monthly variation in occurrence of *Acetes* and fluctuation of rainfall (average two stations) in the Mathamuhuri river estuary, Bangladesh.

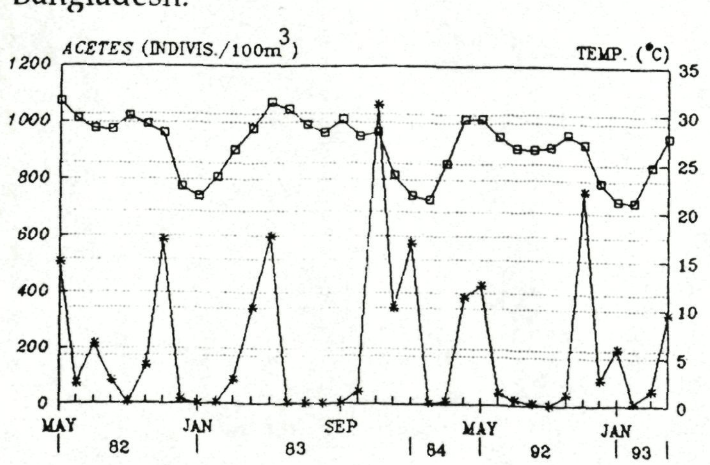


Fig.133. Monthly variation in occurrence of *Acetes* and fluctuation of water temperature (average two stations) in the Mathamuhuri river estuary, Bangladesh.

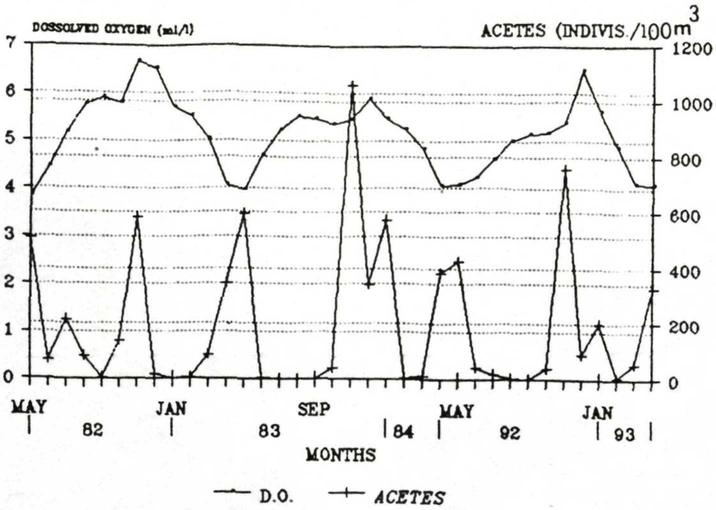


Fig.134. Monthly variation in occurrence of *Acetes* and fluctuation of dissolved oxygen (average two stations) in the Mathamuhuri river estuary, Bangladesh.

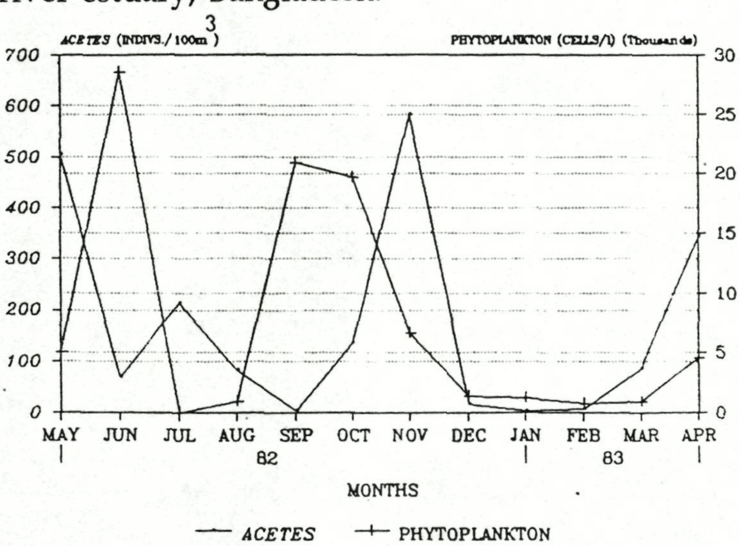


Fig.135. Showing variation in occurrence of *Acetes* and total phytoplankton (average two stations) in the Mathamuhuri river estuary, Bangladesh.

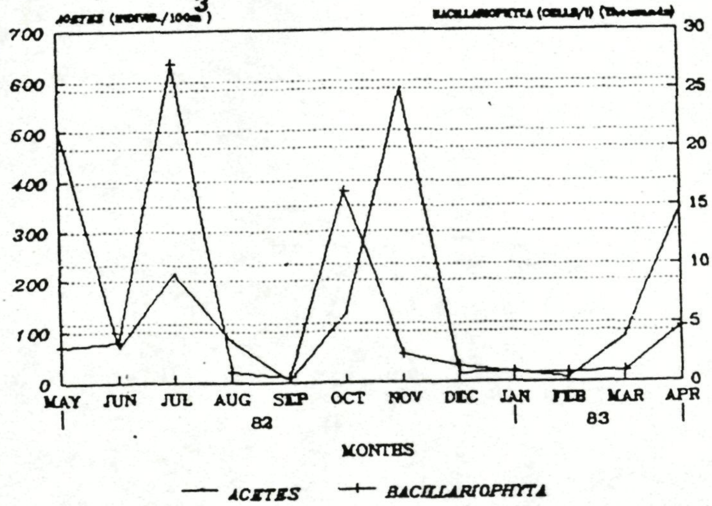


Fig.136. Occurrence of *Acetes* and Bacillariophyta fluctuation (average two stations) in the investigated estuary of Chakaria mangroves ecosystem,Bangladesh.

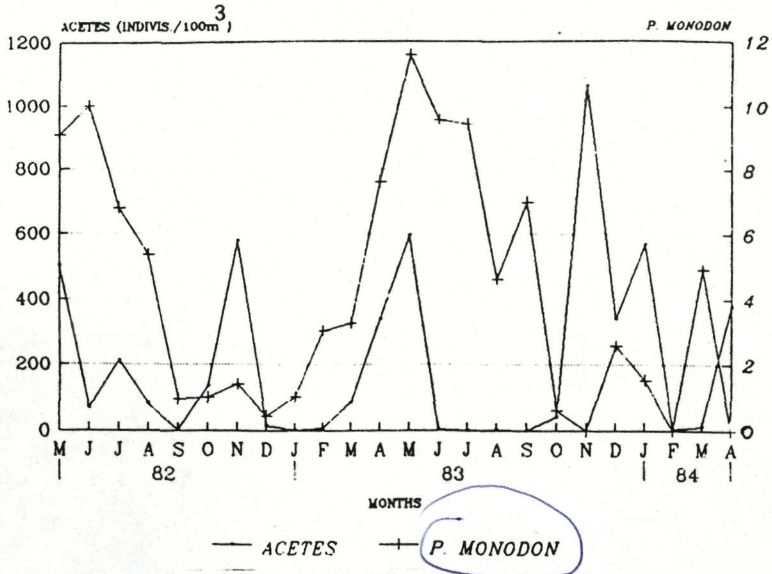


Fig.137. Showing monthly variation in occurrence of *Acetes* and *Penaeus monodon* PL (average two stations) in the Mathamuhuri river estuary, Bangladesh.

Fig.138. Showing monthly variation in occurrence of *Acetes* and *Penaeus indicus* PL (average two stations) in the Mathamuhuri river estuary, Bangladesh.

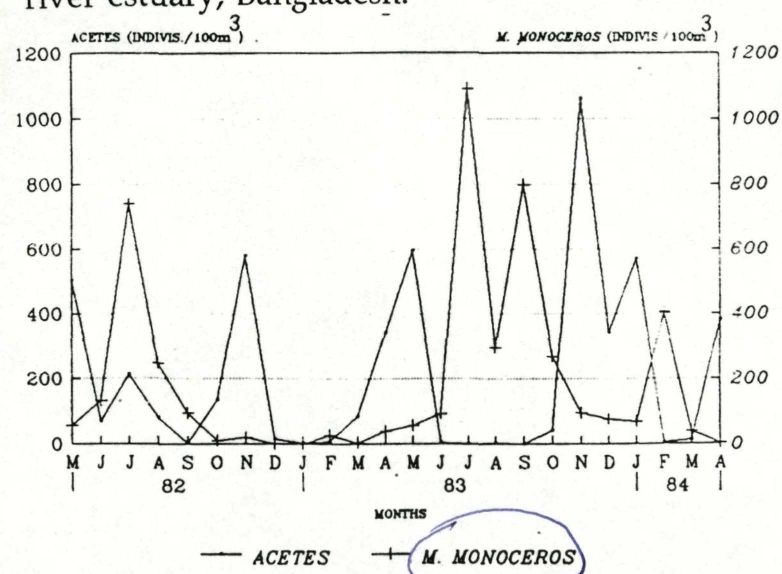


Fig.139. Showing monthly variation in occurrence of *Acetes* and *Metapenaeus monoceros* PL (average two stations) in the Mathamuhuri river estuary, Bangladesh.

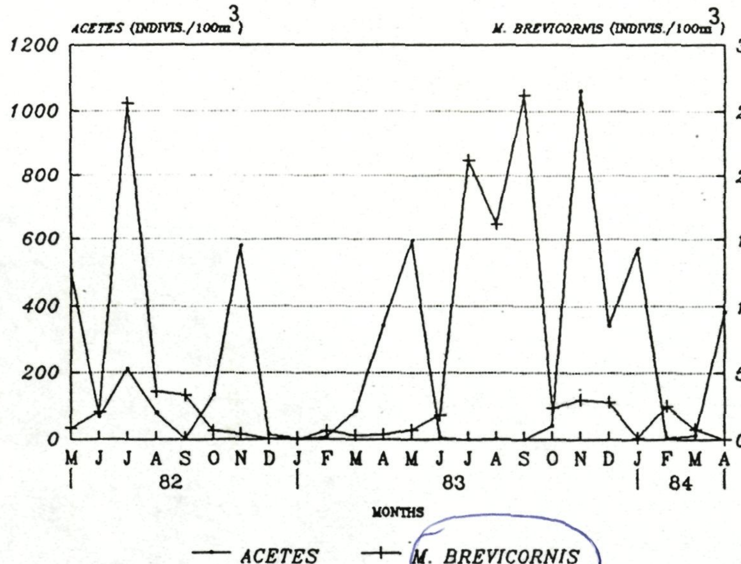


Fig.140. Showing monthly variation in occurrence of *Acetes* and *Metapenaeus brevicornis* PL (average two stations) in the Mathamuhuri river estuary, Bangladesh.

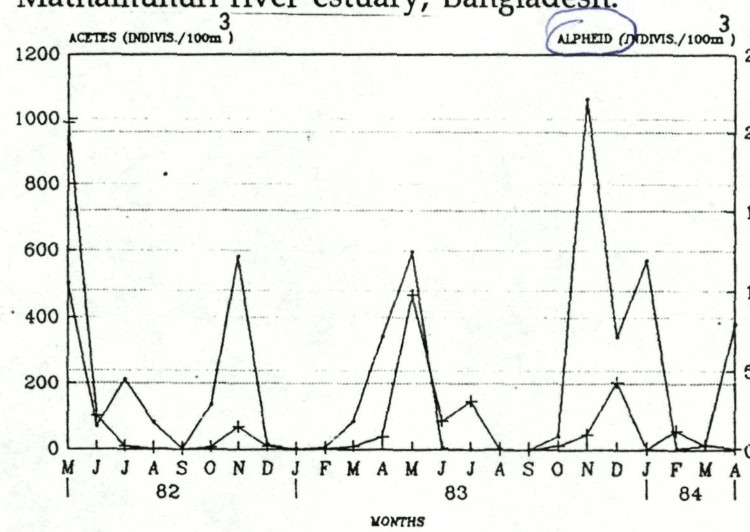


Fig.141. Showing monthly variation in occurrence of *Acetes* and Alpheid PL (average two stations) in the Mathamuhuri river estuary, Bangladesh.

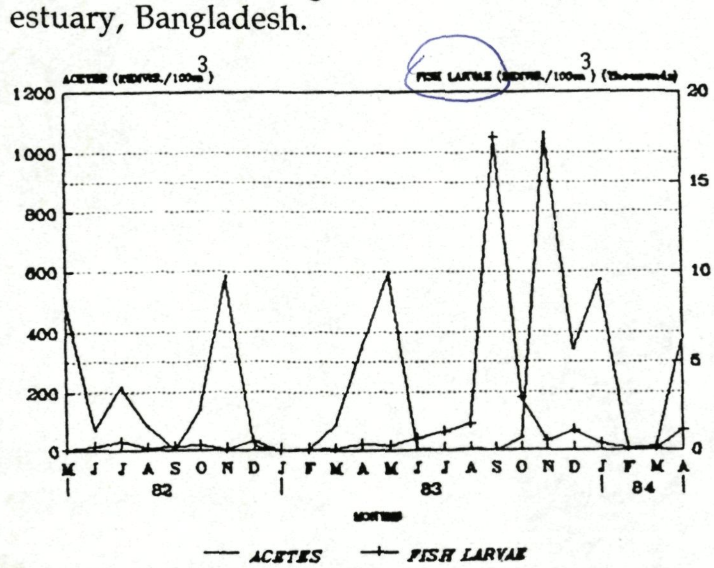


Fig.142. Showing monthly variation in occurrence of *Acetes* and fish larvae (average two stations) in the Mathamuhuri river estuary,

6.3.5.2. *Acetes* distribution in respect of other zooplankton

Positive significant correlation were shown between *Acetes* density and Chaetognaths (P< 0.05, r = 0.649. F = 7.318), with Alpheid shrimp pL (P = 0.05, r = 0.565, F = 4.7); during (May 1982-April 1983) and with squilla (P= 0.002 , r= 0.78, F= 15.57) in the period of May 1983-April 1984. RDA analysis (Fig. 122) clearly indicated that *Acetes* spp has a strong relationship with Alpheid PL, as well as squilla larvae and parallel relationships with Chaetognaths, Hydromedusae and *Parapenaeopsis* shrimp PL and opposite relationships exists with *Penaeus indicus, P. monodon, Metapenaeus monoceros, M. brevicornis,* Mysids, Fish larvae (Fig. 122). The peak occurrence of four commercially important penaeid PL and fish larvae in the Mathamuhuri estuary were related to the monsoon (Fig.137,138,139,140&142), but during the rain-monsoon months (August-September) *Acetes* shrimps were almost absent (Fig.121). So, the southwest monsoon influences the density of *Penaeus* and *Metapenaeus* PL in the investigated estuary but not the density of *Acetes* shrimps in the adjacent waters of Chakaria mangroves area.

Zafar (1992) stated that *Acetes* showed significant relationships with HYdromedusae, *Penaeus monodon, P. semisulcatus,* and *Macrobrachium* sp PL in the Kutubdia channel (Fig.143), but in the Mathamuhuri estuary Alpheid PL shows a very close relationships with *Acetes* (Fig.141). FDDPG (1951) stated that *Acetes chinensis* consume several phytoplankton and zooplankton. Xu (1957) found diatoms, copepods, *Sagitta,* molluscan larvae in the *Acetes chinensis* diet composition. But there is no available published report on *Acetes* occurrence, abundance and distribution in respect to phytoplankton and zooplankton.

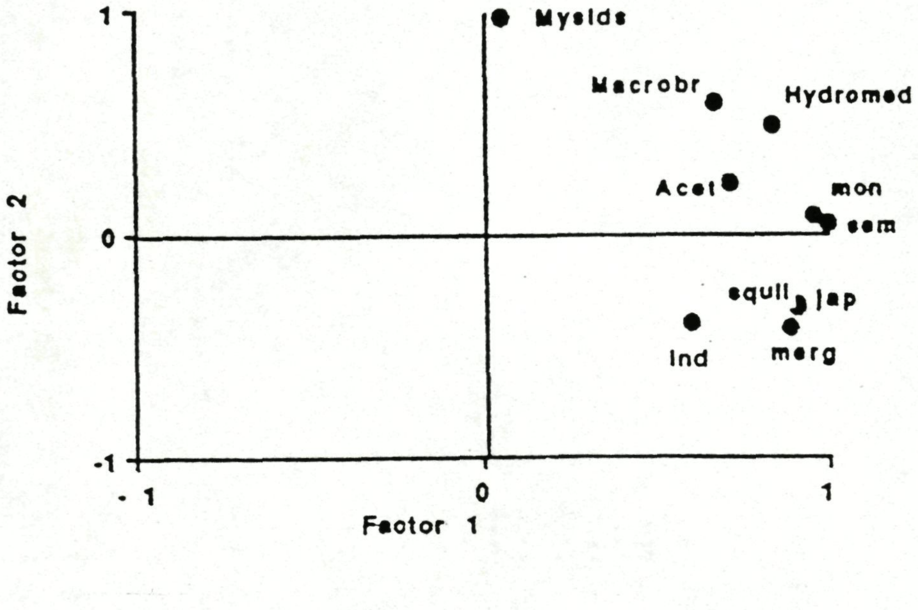


Fig.143. PCA for densities in relation of zooplankton of the Kutubdia channel, Bangladesh.

6.4. General characteristics of adult *Acetes* shrimps (larger than 500µm)

1.The peak abundance of *Acetes* occurred in the Mathamuhuri river estuary of Chakaria sundarban area during non monsoon period and more than 90% *Acetes* shrimps were recorded in the premonsoon and postmonsoon seasons.

2.The density of *Acetes* shrimps positively correlated with salinity and sunshine, and these two factors are inversely related to the monsoon. Temperature did not affect the occurrence of *Acetes* in the studied estuary.

3.*Acetes* shows a weak relationship with phytoplankton (particulary Bacillariophyta).

4. *Acetes* shows asynchrone relation with Penaeids (*Penaeus* and *Metapenaeus* postlarvae. Because Penaeids were well abundant in monsoon.

5. *Acetes* shrimps are more hyperbenthic nature than epipelagic, performing in the nightly vertical migration.

6. The adults *Acetes* shrimps were entering into the Mathamuhuri river of Chakaria sundarban area with saline water during high tide.

CHAPTER 7

OCCURRENCE AND TEMPORAL VARIATION OF FOUR SPECIES OF *ACETES* SHRIMP.

7.1. Introduction

The sergestid shrimp, *Acetes* is widely distributed in the coastal waters and estuaries of Bangladesh (Fig.144), Zafar and Mahmood (1989), Zafar (1992). But still *Acetes* did not support a substantial fishery in Bangladesh. Many of the Asian and African countries have realised the food value of these shrimps and are exploiting them commercially. Omori (1975) had summarised the data available on the fishery of the *Acetes* in various countries. In Bangladesh the potential resources of these shrimps have not been assessed and very little amounts are exploited by small scale fisherman (Fig.146) and used as human food fresh and dried condition.These shrimps occur abundantly in the eleven deltaic Islands at the confluence of the Mathamuhuri river estuary but are not exploited commercially. Considering the importance of *Acetes* shrimp a study was under taken to evaluate their occurrence, seasonal distribution in relation to the variations in environmental factors.

7.2. Materials and Methods.

Field works were done for three years between May 1982-April 1984 and May 1992-April 1993 at two stations of the study area (Fig.4). Zooplankton samples were drawn horizontally at fortnightly intervals by a small rectangular plankton net (Fig.118), simillar to that described by Mahmood and Khan (1982) having $0.5m^2$ mouth opening, made up of the hydrobios nylon meshes (500 µm) and fitted with a plastic bucket at the cod end. A karl kolb digital flowmeter was attached at the mouth of the net to record the quantity of water filtered through the net during sampling. Since the depth at each of the two stations of this shallow estuarine area seldom exceds a few meters (2.5-3.5), it was impractical to take samples at different levels of the water column and thus only surface and bottom waters were sampled, during day and night about one hour before high water of a semidiurnal tidal cycle. Samples were preserved in 5% neutralized formalin in the field. Simultaneously water samples were drawn for determination of hydrological factors results of which have been illustrated in chapter '3'.

In the labaratory *Acetes* species were separated from zooplankton samples as following (Omori,1975, Mahmood *et al.* 1978, Tirmizi and Ghani, 1982) and personal observation (Fig 115,116 &117).Their numbers are expressed as indivis./$100m^3$ of water and species *(A. indicus, A. erythraeus, A. chinensis and A. japinicus)* has been statistically analysed with hydrological and biological factors, the results of which are mentioned in chapter '6'

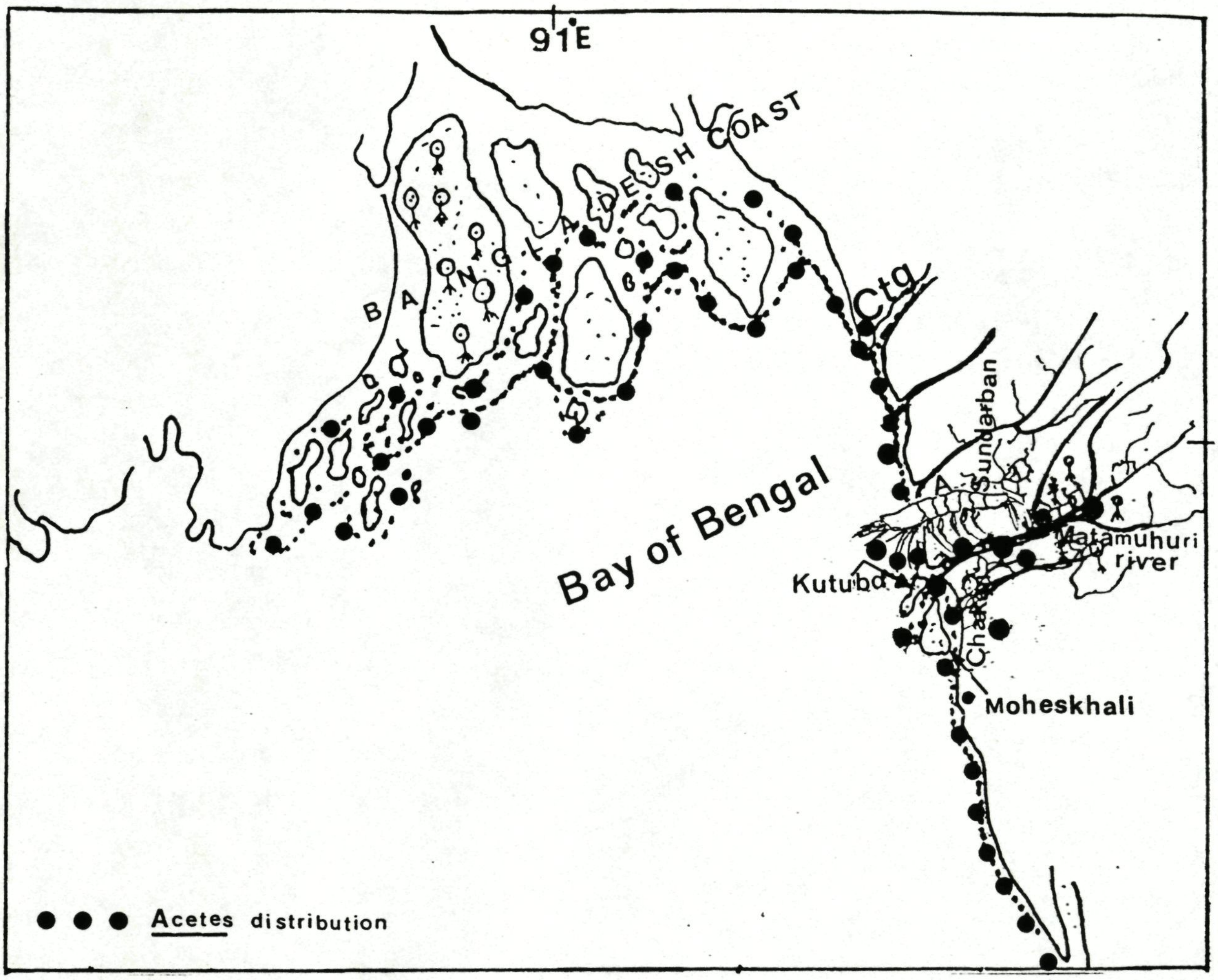


Fig.144. Distribution of adult *Acetes* shrimp in the Bangladesh coastal waters of Bangladesh.

7.3. Results and Discussion

7.3.1. Occurrence and temporal patterns of adult *Acetes* species

The Sergestid shrimp genus *Acetes* has 6 species in the Mathamuhuri river (chapter 5). The occurrence and distribution of the common species of *Acetes* (*A. erythraeus, A. chinensis* and *A. japonicus*) are described. RDA, TWINSPAN analyses clearly indicated that four species of *Acetes* exists in same group and their position are close together (Fig.122 & 123), and two most dominant species of *Acetes* (*A. indicus* and *A. erythreus*) represented 75% and four spp obtained more than 92% of *Acetes* population. In the chapter'6'day-night, surface-bottom and spatial abundance of *Acetes* have been illustrated. The spatial distribution of four common species of *Acetes* shrimps were not significantly different in the two sampling stations. So only average monthly abundance and distribution of four species of *Acetes* in the Mathamuhuri river of Chakaria sundarban are described.

7.3.1.1. Percentage composition of *Acetes* species.

In the three years of investigation, *Acetes indicus* was the most abundant species (Fig.148-150) and in average occupied 45.35% of the total *Acetes* population (Fig.147).The other constituents were *Acetes erythraeus* (33.2%). *A. chinensis* (7.5%) and *A. japonicus* (6.8%). Other *Acetes* accounted for 7.2%. The variation in percentage composition along the three years of the four spp of *Acetes* in the Mathamuhuri river estuary was negligible (Fig.148-150).

7.3.1.2. Distribution of the four commmon species of *Acetes*.

7.3.1.2. *Acetes indicus* (Fig .151, Table 14, 15 and l6) Length

During the three years of observation, *A. indicus* was absent in February (1983, 1984 and 1993) and in September 1983. Higher densities were recorded during the premonsoon months (April-May) and postmonsoon months (November-January). A bimodal peak was recorded, one in May (202.05 indivs./100m^3) in 1982, 240.5 indivs./100m^3 in 1983 and 180.8 indivs./100m^3 in 1992). and the other in November (250.5 indivs./100m^3 in 1982, 495.0 indivs./100m^3 in 1983, and 365.08 indivs./100m^3 in 1992). During the monsoon months (August-September) lower densities of *A. indicus* were recorded .

During the three years of observation *A. indicus* abundance showed negative correlation with rainfall and a positive correlation with salinity and sunshine.The density of *A. indicus* was negatively correlated with dissolved oxygen in two years observation (May 1982- April 1984), but positively in May 1992- April 1993. *A. indicus* showed a weak positive correlation with net production ($P = 0.68$, $r = 0.542$, $F = 4.58$) in May 1992-April 1993 and as well as

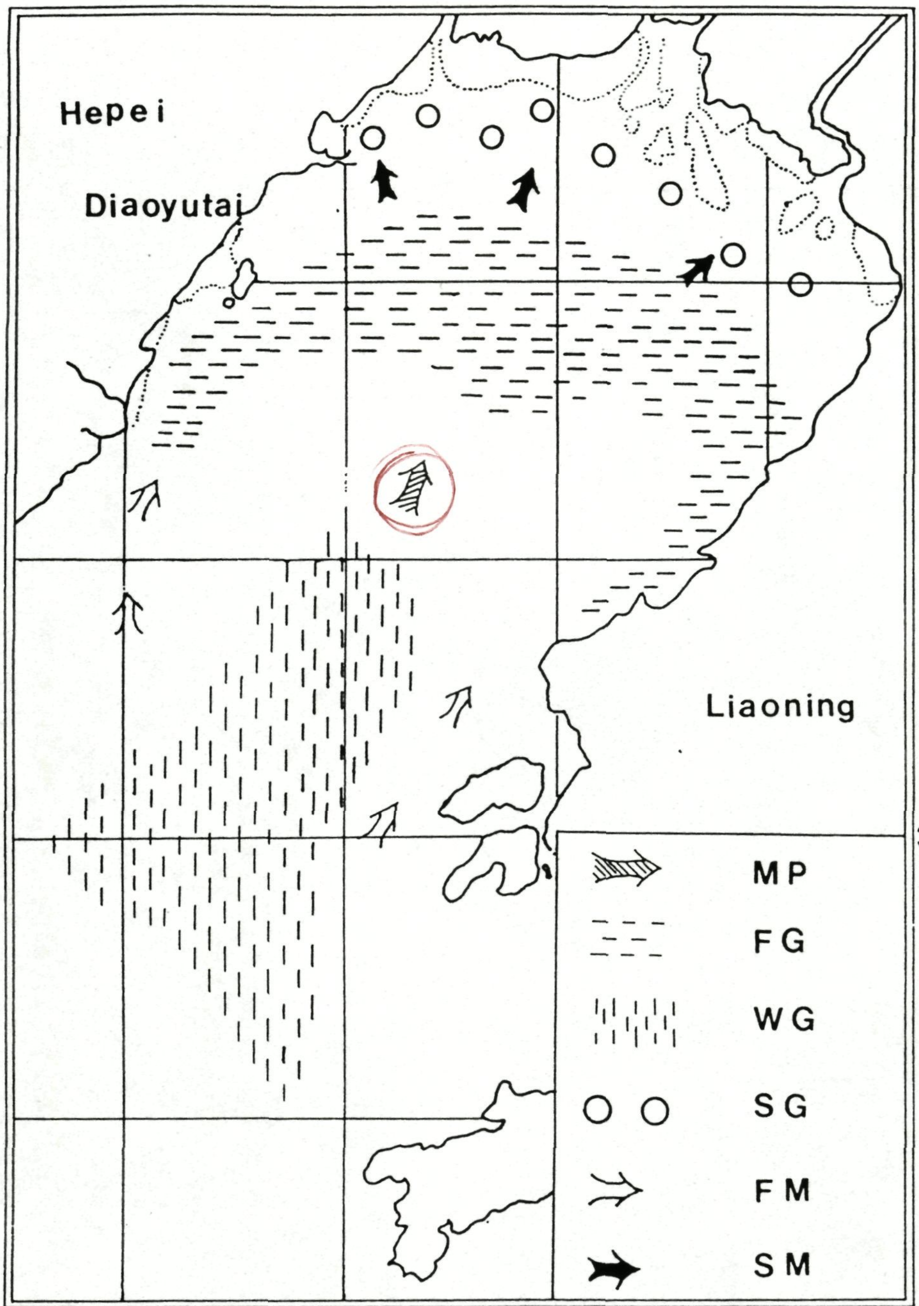


Fig.145. Seasonal migration of *A. chinensis* in Liaotung Bay, China (after Wu, 1991). FG, feeding ground; FM, feeding migration; MP, main population; SG, spawning ground; SM, spawning migration; WG, wintering ground.

with Bacillariophyta (r = 0.132, P > 0.1, F = 0.17) but a negative insignificant correlation with Cyanophyta (P = 0.507, r = -0.184, F = 0.473) and Chlorophyta (P = 0.86, r =- 0.134, F = 0.03).

A significant positive correlation was found between *A. indicus* and *Sagitta* abundance (P < 0.01, r = 0.69, F = 9.28) in first year observation, and with squilla (P = 0.002, r = 0.78, F = 16.07) in second year studied period but a weak negative correlation with mysids and amphipods, RDA analysis also inferred similar results (Fig.122). Omori (1977) found that this species was distributed from the west coast of India through the Andaman sea, Gulf of Siam and the Java sea, to the South China sea. Mahmood *et al.* (1978) reported the presence of postlarvae of *Acetes indicus* in the Karnafuli estuary, Bangladesh; they were found throughout the whole period of investigation (one year) except in May.The peak season occurred in October-January.The postlarvae of the species were always in company of a large number of adults.They also mentioned that the larvae were recorded in all ranges of salinity, but maximal numbers were always recorded with the highest salinity. Bhattacharya (1988) reported that the upper and the lower lethal temparatures were 35°C and 13°C, respectively, for *A. indicus.* In the Mathamuhuri river estuary temperature varies between 20°C-32°C. He also mentioned that the large numbers of *A. indicus* occurred when salinity varied from 26.50‰ to 35‰. Bhattacharya (1988) reported that *A. indicus* are extremely euryhaline, able to tolerate fresh water to full sea water.In the present studied area *Acetes indicus* were recorded from salinity (1.8‰) to the highest salinity (33‰).Thus the present investigation agrees well with the above mentioned results.

7.3.1.2.2. *Acetes erythraeus* (Fig.152, Table 14,15 and 16)

It was the second dominant *Acetes* species in the Mathamuhuri river estuary. *Acetes erythraeus* was present throughout the period of investigation except during September in 1982, August and September, 1983 and 1992, when maximum rainfall occurred (Table 1) and the salinity suddenly dropped.The maximum densities were recorded during the premonsoon (April-May) and postmonsoon (November-January) in the three years observation and peak occurrence in May (178.00 indivis./$100m^3$ in 1982, 239.10 indivs./$100m^3$ in 1983, 154.15 indivs. /$100m^3$ in 1992) and November (210.50 indivs./100m3 in 1982, 405.0 indivs./$100m^3$ in 1983 and 280.10 indivis. /$100m^3$ in 1992).

The abundance of *A. erythraeus* was positively correlated with salinity, sunshine and negatively correlated with rainfall in the Mathamuhuri river estuary during three years investigation (Fig.129). Negative correlations were shown between the density of *A. erythraeus* and dissolved oxygen in May 1982-April 1983 and May 1983-April 1984 but a positive correlation was found in May 1992- April 1993. The abundance of *A erythraeus* was weakly correlated with net production (P = 0.267, r = 0.35, F = 1.39) and Bacillariophyta (P = 0.683, r = 0.132, F = 0.177). Positive significant correlation showed its abundance with Alpheid

Fig.146. Showing *Acetes* fishery activities in the Mathamuhuri river estuary and adjacent areas of the coastal waters off Bangladesh, Related fishermen with *Acetes* shrimps[1]; *Acetes* fished by Behundi net [2]; *Acetes* fished by Push net [3]; Fresh *Acetes* [4]; Solar dried *Acetes* [5]).

larvae ($P < 0.05$, $r = 0.608$, $F = 5.88$) in May 1982 - June 1983 and as well as Squilla larvae ($P < 0.001$, $r = 0.823$, $F = 20.9$) in the period of investigation May 1983 - June 1984).

This species has the most extensive geographical distribution in the Indo-west Pacific. Its range extends from the coast of South Africa to the South China sea, through the south and west coast of India, the Malay Archipelago and the Java sea. A record of the presence of *A. erythraeus* near Mossman, Australia (Omori,1975).The Mathamuhuri river estuary and Bangladesh coastal waters is an additional area. *Acetes erythraeus* appeared in the coastal waters of south India during January to April (Nataraj, 1947). Le Reste (1970) stated that *A. erythraeus* were found in water where the salinity fluctuates seasonally between 1.5‰ and 35‰ and the maximum numbers occurred at night. Omori (1975) reported that shallow area separated from the open ocean at a great distance from the shore, with considerable tidal range, a bottom is covered by mud or sandy mud are suitable features for *A. erythraeus* distribution.The present investigation is in close agreement with these statements.

7.3.1.2.3. *Acetes chinensis* (Fig.153, Table 14,15 & 16)

This species was first recorded in the coastal waters of Bangladesh during the present investigation. The total length of *A. chinensis* varied between 30 -38 mm. In the Mathamuhuri estuary it was the third dominant species in the *Acetes* population.The maximum abundance was recorded during premonsoon months (April-May) and postmonsoon months (October-December). *Acetes chinensis* had one peak in April (38.00 indivis./100m^3 during the period of May 1982-April 1983, in May (45.0 indivis./100m^3 and 35.50 indivis./100m^3 in the period of May 1983 - April 1984 and May 1992 - April 1993, respectively) and the other in November 58.40 indivis./100m^3 in 1982, 65.0 indivis./100m^3 in 1983 and 38.9 indivis./100m^3 in 1992.

The abundance of *A. chinensis* was positively correlated with salinity, sunshine and negatively with rainfall and dissolved oxygen. During the three years of observation all these relationships were insignificant. A positive insignificant correlation was found between *A. chinensis* density and net production ($P = 0.068$, $r = 0.542$, $F = 4.58$) , and Bacillariophyta ($P = 0.68$, $r = 0.132$, $F = 13.8$). But a significant positive correlation showed with squilla density ($P = 0.01$, $r = 0.76$, $F = 13.82$) in second year observation. This species was most abundant in the Gulf of Chihli, the Yellow Sea and the coast of Canton (Omori, 1975). Luo and Zhang (1957) reported spatial distribution of *A. chinensis* in Liaotung Bay and found that spatial variability led to marked differences in the catches at different localities and they also stated that *Acetes chinensis* was extremely euryhaline. No published report was found in *A. chinensis* distribution in the coastal waters of Bangladesh and very limited information about abundance and distribution on *A. chinensis*. However the present results are in agreement with above mentioned results.

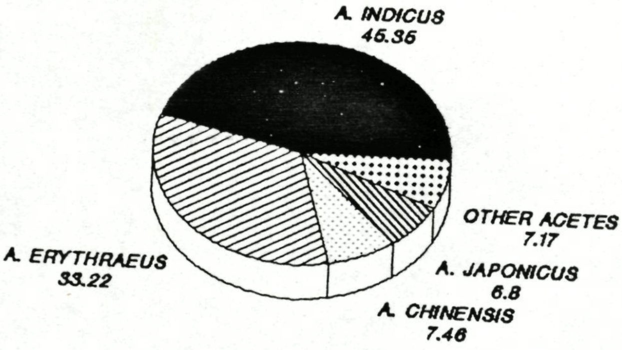


Fig.147. Showing three years average percentage composition of *Acetes* shrimps in the Mathamuhuri estuary.

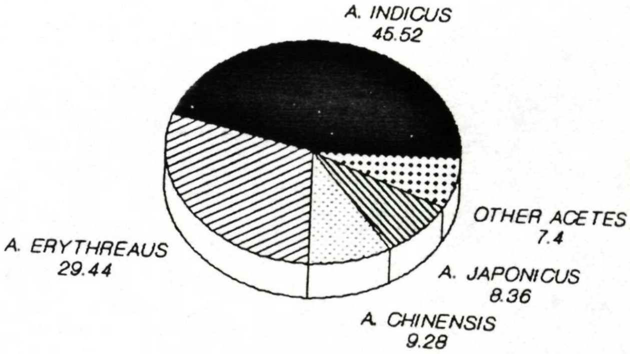


Fig.148. Showing percentage composition of *Acetes* shrimps in the Mathamuhuri river estuary (May 1982- April 1983).

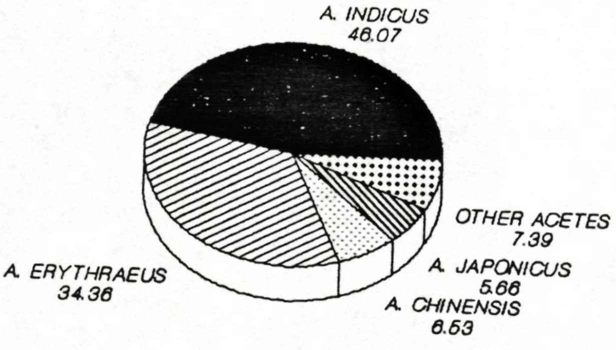


Fig.149. Showing percentage composition of *Acetes* shrimps in the Mathamuhuri river estuary of Chakaria mangroves ecosystem (May 1983-April 1984).

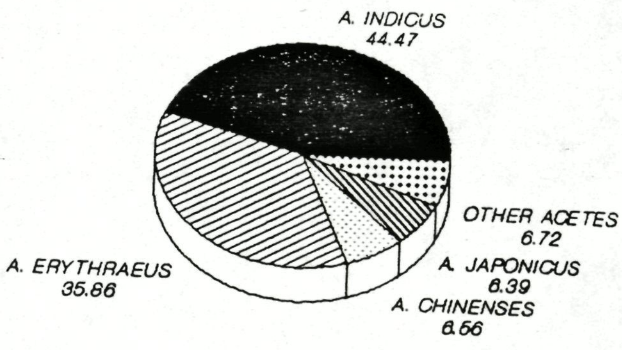


Fig.150. Showing percentage composition of *Acetes* shrimps in the Mathamuhuri river estuary of Chakaria mangroves ecosystem (May 1992- April 1993).

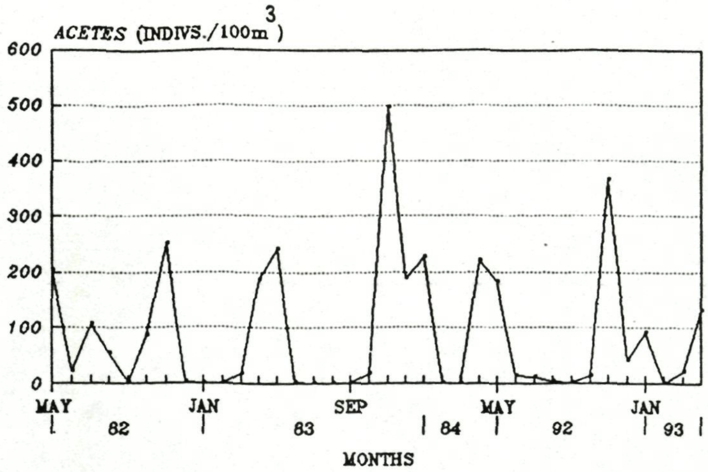


Fig.151. Monthly distribution (average two stations) of *Acetes indicus* in the Mathamuhuri river estuary of Chakaria mangroves ecosystem, Bangladesh.

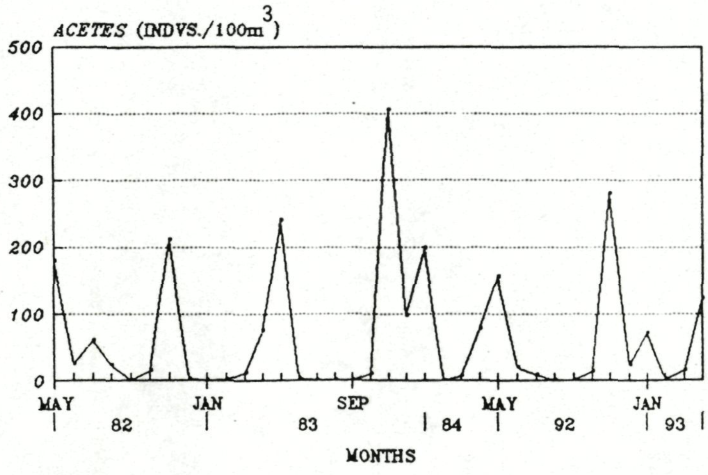


Fig.152. Monthly distribution (average two stations) of *Acetes erythraeus* in the Mathamuhuri river estuary of Chakaria mangroves ecosystem, Bangladesh.

7.3.1.2.4. *Acetes japonicus* (Fig. 154, Table 14,15,16)

Acetes japonicus was first recorded in the Bangladesh coastal waters during the present investigation. Generally it was recorded during October-June. *A. japonicus* was absent in the monsoon months (July-September), when lower salinity prevailed (Table 4). A bimodal peak occurrence of *A. japonicus* as recorded in the Mathamuhuri river estuary, one peak in postmonsoon months (November-January) and another in premonsoon (March- May). In the studied area top most abundance was found in March 48.0 indivis./$100m^3$ during 1983 and in January 45.0 indivis./$100m^3$ and 30.04 indivis./$100m^3$ during 1984 and 1993 respectively.The abundance of *A. japonicus* was significantly correlated with salinity ($P< 0.05$, $r = 0.576$, $F = 4.97$ and $P< 0.05$, $r = 0.56$, $F = 4.55$) in the period of May 1982-April 1983 and May 1992-April 1993 and negatively correlated with rainfall ($P< 0.05$, $r = -0.59$, $F = 5.35$ and $P< 0.05$, $r = 0.56$, $F = 4.7$) during the investigation time May 1983-April 1984 and May 1992-April 1993. *Acetes japonicus* showed a significant positive correlation with sunshine ($P< 0.01$, $r = 0.66$, $F = 7.8$) in May 1992 and April 1993. Positive a weak correlation was shown between the density of *A. japonicus* and net production ($P > 0.05$, $r = 2.13$, $F = 0.48$) and a significant positive relation with *Sagitta* ($P< 0.05$, $r = 0.625$, $F = 15.61$) in the year of May 1982 April 1983). Ikematsu (1953) estimated from field samples that the life span of *A. japonicus* was 9-10 months for winter generation and 2.5 to 3.0 months for the summer generation. Yasuda *et al.* (1953) similarly suggested that the life span of the summer generation of the *Acetes japonicus* may be as short as 25-60 days. Yoshida (1949) suggested that *Acetes japonicus* has a life span of about one year in western Korea. *A. japonicus* were recorded from the coasts of India and from the Andaman Sea to the southern Japan (Omori, 1977).

7.3.2. Spawning and fishing activities of *Acetes* in the adjacent area of Mathamuhuri river estuary in the Chakaria sundarban.

7.3.2.1. Spawning

The presence of large shoals of adults, in the estuarine system of Mathamuhuri river of Chakaria Sundarban, suggests the possibility of their breeding of the lowest delta of Chakaria sundarban in the Kutubdia and Moheskhali channel. Alam (1995) recorded the larvae and adults of *Acetes* spp in the Kutubdia channel. Chowdhury (1995) stated that larvae and adults of *Acetes* shrimps were available in the Moheskhali channel. Mahmood (1978) reported the larvae of *Acetes indicus* and *A. erythraeus* in the Karnafuli estuary. On the basis of above mentioned results *Acetes* apparently spawn in the lower delta of Mathamuhuri river of the vicinity of Kutubdia, Moheskhali Islands (Fig.144).The present recorded data of *Acetes* species showed bimodal peak in a year, one peak in postmonsoon months (November-January) and another in premonsoon (March-May) and more than 90% of *Acetes* shrimps occurred in these seasons, but during monsoon especially rainy months (July-September) low densities of *Acetes* were recorded due to adverse factors of monsoon (large amount of freshwater discharge followed by a drop of salinity and other hydrometeorological factors). In the Mathamuhuri river of Chakaria sundarban area *Acetes indicus and Acetes erythraeus* were found throughout the period of investigation and the other two spp of *Acetes* (*A. chinensis* and *A. japonicus*) occurred all round of the year except during August and September. On the basis of these information probably *Acetes indicus, A. erythraeus* , *A. chinensis* and *A. japonicus* are continuous breeders in the lower delta of Chakaria sundarban in the vicinity of Kutubdia, Moheskhali channel and in-shore water of Cox'sBazar. Chua *et al* . (1974) reported that different stages of *Acetes* spp occurred around different islands off the coast of Sabah. *Acetes australis* shows marked spawning peaks although it spawns throughout the year near Sydney (Morris, 1948). Achuthankutty and Selvakumar (1979) reported that sergestid shrimp of *Acetes* was spawning throughout the year and they found large shoals of larvae & adults in the estuarine system of Goa. Kunju (1969) stated that during the breeding season of adults *Acetes* appear in large shoals in the coastal waters. Wu (1991) reported that *Acetes chinensis* was spawning of the shallow, inshore areas and just lower region of estuarine area or vicinity of inshore Islands in the Liaotung Bay (Fig.145). Although *Acetes* spawns throughout the year in the tropics and subtropics, spawning peaks can be recognised and these almost always lie in the warmer months, as in the cases of *A. indicus, A. serrulatus, A. erythraeus* (Nataraj, 1947; Le Reste,1970, *A. chinensis* (Liu, 1959; Wu and Cheng, 1957; Anonymous, 1990; Zhang, 1992). Spawning patterns in these areas are probably related to monsoonal influences on precipitation and wind direction (Omori, 1974), or water circulation and biological rhythms of *Acetes* (Le Reste, 1970). The present findings more or less supports with the above mentioned results.

7.3.2.2. Fishing activities

In the Mathamuhuri river estuary and adjacent areas only local fishermen fished *Acetes* shrimp with Behundi net. At present *Penaeus monodon* fry collector fished *Acetes* by Push net near the shore against the flow of the tide (Fig.146).The life span of the *Acetes* is less than 6 months and adult dies soon after spawing (Aravindakshan and Karbhari (1988).Yoshida (1949) suggested that *A. japonicus* has a life-span of about one year in western Korea. Wu and Cheng (1957) concluded from field surveys in Liaotung Bay that most *A. chinensis* die soon after spawing. Huang *et al.* (1981) estimated from field sampling in Pohai in 1965 that about 22.0, 18.0, 9.8 and 4.2% of spent *A. chinensis* survived for 5, 14, 21 and 35 days after spawning.They also maintained five spent individuals in an aquarium for 14 days during which three moulted. On the basis of above informations and occurrence of adult *Acetes* spp of the Mathamuhuri river in the Chakaria sundarban it is assumed that the adults represent an ephemeral stock with very rapid turnover, new individuals being consistently recruited from the nearby waters. Since

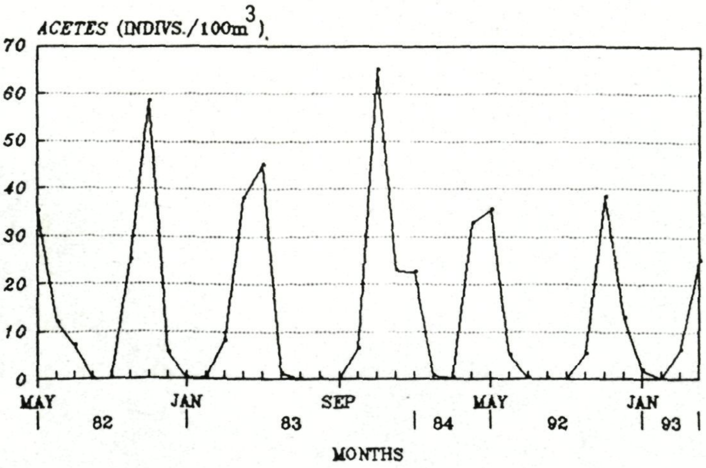


Fig.153. Monthly distribution (average two stations) of *Acetes chinensis* in the Mathamuhuri river estuary of Chakaria mangroves ecosystem, Bangladesh.

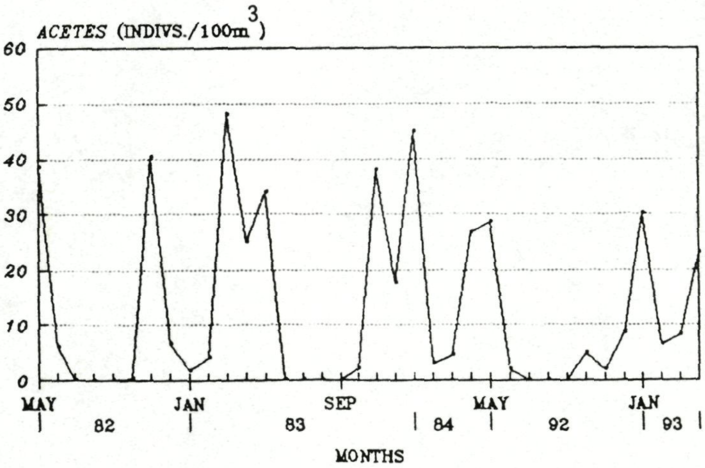


Fig.154. Monthly distribution (average two stations) of *Acetes japonicus* in the Mathamuhuri river estuary of Chakaria mangroves ecosystem, Bangladesh.

Table 14. Monthly abundance (individuals/100 m3) of four Acetes species in the Mathamuhuri river estuary of Chakaria mangrove ecosystem, Bangladesh

	1982								1983				Yearly	Percentage
Species	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average	Composition
Acetes indicus	202.05	23.02	106.10	55.40	3.00	85.25	250.50	1.97	0.65	0.00	18.00	184.90	77.57	45.52%
A. erythraeus	178.06	25.08	60.05	22.50	0.00	14.95	210.50	1.70	0.10	2.60	11.84	74.63	50.17	29.44%
A. chinensis	35.01	12.04	7.05	0.00	0.00	25.10	58.40	5.60	0.00	0.63	8.00	38.00	15.82	9.28%
A. japonicus	38.60	6.00	0.00	0.00	0.00	0.50	40.20	6.70	1.89	4.15	48.00	25.00	14.25	8.36%
Other Acetes	50.48	2.10	40.44	3.59	1.25	9.75	22.57	0.20	0.30	0.00	0.50	20.10	12.61	7.40%
Total Acetes	504.20	68.24	213.64	81.49	4.25	135.55	582.17	16.17	2.94	7.38	86.34	342.63	170.42	100.00%

Table 15. Monthly abundance (individuals/100 m3) of four Acetes species in the Mathamuhuri river estuary of Chakaria mangrove ecosystem, Bangladesh

	1983								1984				Yearly	Percentage
Species	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average	Composition
Acetes indicus	240.50	2.01	0.75	0.60	0.00	18.10	495.00	187.50	225.86	0.00	1.51	220.00	115.99	46.07%
A. erythraeus	239.10	3.75	0.31	0.00	0.00	9.88	405.00	96.88	197.62	1.25	6.91	77.34	86.50	34.36%
A. chinensis	45.00	1.17	0.00	0.00	0.00	6.50	65.00	22.80	22.65	0.67	0.40	32.97	16.43	6.53%
A. japonicus	34.00	0.00	0.00	0.00	0.00	2.23	38.00	17.56	45.00	3.05	4.60	26.56	14.25	5.66%
Other Acetes	36.85	0.20	0.00	2.97	0.00	5.07	57.19	16.78	79.65	0.00	0.50	24.00	18.60	7.39%
Total Acetes	595.45	7.13	1.06	3.57	0.00	41.78	1060.19	341.52	570.78	4.97	13.92	380.87	251.77	100.00%

Table 16. Monthly abundance (individuals/100 m3) of four Acetes species in the Mathamuhuri river estuary of Chakaria mangrove ecosystem, Bangladesh

	1992								1993				Yearly	Percentage
Species	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average	Composition
Acetes indicus	180.80	15.06	11.95	5.50	3.00	15.01	365.08	40.60	91.02	0.00	22.65	131.52	73.52	44.58%
A. erythraeus	154.15	20.21	8.25	0.00	0.00	13.35	280.10	23.80	70.98	2.72	15.30	122.50	59.28	35.95%
A. chinensis	35.50	5.01	0.00	0.00	0.00	5.25	38.34	12.91	2.01	0.00	6.05	25.10	10.85	6.58%
A. japonicus	28.60	2.02	0.00	0.00	0.00	4.90	14.98	8.61	30.04	6.50	8.12	22.90	10.56	6.40%
Other Acetes	27.20	0.90	1.30	2.00	0.00	0.00	58.00	6.08	3.45	0.28	3.38	25.98	10.71	6.50%
Total Acetes	426.25	43.20	21.50	7.50	3.00	38.51	756.50	92.00	197.50	9.50	55.50	328.00	164.91	100.00%

planktonic shrimp *Acetes* often occupy a key trophic level in neritic communities (Olivier *et al.* 1968, Omori 1974, Zafar,1992), the exploitation should be carefully managed so that it is not excessive and unbalance the food web. Omori (1978) reported that Sergestids shrimp *Acetes* species are commercially fished and utilized as food or feed in many tropical and subtropical countries. Thus in Bangladesh the planktonic shrimp *Acetes* could be used for aquaculture development and fulfilment of protein deficiency of people.

7.4. Conclusion

It appears from this study that usually the *Acetes* shrimps in the Mathamuhuri estuary have a bimodal peak in occurrence, one in premonsoon (April to May) and other in postmonsoon (November to January). In monsoon month almost *Acetes* species disappeared, when maximum rainfall occurred followed by a drop of salinity, the presence of cloudy sky & lower sunshine, low velocity of tidal current and rough water circulation. So all these factors could influence the occurrence and abundance of the *Acetes* shrimps in the estuary.The highest abundance of the *Acetes* were also related to the dark period and flood tides. Besides, the presence of mangrove could be another factor influencing the higher density of *Acetes* in the Mathamuhuri river estuary. Omori (1975) stated that wind direction and tide are very important causative factors for spawning of *Acetes*. Xiao and Greenwood (1992) reported that *Acetes sibogae* abundances were related to light-dark periods and flood tides .

On the basis of present investigation the estuary of Mathamuhuri river is an ideal place for *Acetes* shrimps during premonsoon and postmonsoon months and it is possible in Bangladesh that large amount of *Acetes* shrimps are commercially harvested and utilized as food or feed for aquaculture and human consumption to fulfilment of protein defficiency of people.

CHAPTER 8

FOOD AND FEEDING HABITS OF *ACETES INDICUS* & *A. ERYTHRAEUS* IN THE MATHAMUHURI RIVER ESTUARY OF CHAKARIA MANGROVE ECOSYSTEM.

8.1. Introduction

Acetes spp. were used in bheri culture (brackishwater culture in impoundments) in India with some other shrimps and fishes (Jhingran, 1975). *Acetes* spp. are cultured between harvesting rice and the next planting season in Kerala, Travancore and Cochin regions of India (Pillay,1967; Jhingran, 1975). It is preyed upon by widely diverse groups of animals that include protozoans (*Noctiluca miliaris*), ctenophores, cephalopods, crustaceans, fishes and crocodiles. Fishes are certainly the most important predators with 151 species of fish of at least 48 families (incl. Carangidae, Clupeidae, Engraulidae, Lactariidae, Polynemidae, Sciaenidae) being known to include *Acetes* in their diets (Xiao and Greenwood, 1993). Crustaceans of the families Penaeidae, Palaemonidae, Alphidae and Squilidae are the second most important predators of *Acetes* , with three genera of penaeids dominating (i.e. *Penaeus, Metapenaeus* and *Trachypenaeus*). *Acetes* has also been used to feed fish and shrimps in the laboratory or hatchery (Suzuki, 1976; Ali *et al.*, 1984; Kungvankij *et al.*, 1986; Nagabhushanam & Joshi, 1986; Wood *et al.*, 1992). Food and feeding aspects of *Acetes* is generally poorly known. The only intensive and detailed published study on the trophic role of *Acetes* is that by Xu (1957), who not only detailed food composition of *A. chinensis*, but also examined its seasonal and large scale spatial feeding patterns in the Liaotung Bay, China. Aravindakshan & Karbhari (1988) made some observations on feeding contents of *Acetes sibogae* in Versova, Sassoon Dock and Trombay, India. Despite its enormous importance in aquaculture such as feed, information on *Acetes* food and feeding habits is lacking, therefore this research work was undertaken.

8.2. Materials and Methods

To study the food of *Acetes* spp. samples were collected from the Mathamuhuri river estuary for a period of one year, from May 1982 to April 1983. Zooplankton samples were drawn at fortnightly intervals by a small rectangular plankton net similar to that described by Mahmood and Khan (1982), having 0.5 m^2 mouth opening, made up of Hydrobios nylon meshes (0.5 mm) and fitted with a plastic bucket at the cod end. *Acetes indicus* and *Acetes erythraeus* were identified following Omori (1975), Mahmood *et al.* (1978), Tirmizi and Ghani (1982). The gut contents of a total of 300 (25X12) adult specimens in size from 10 mm to 30 mm were examined of *A. indicus* & *A. erythraeus*.. Gut contents of fresh *Acetes* specimens were examined usually every month. Preserved (5% formaldehyde) specimens were also observed for accurate stomach contents. The identification of the food materials consumed by *Acetes* spp. were done according to Davis (1955),Wickstead (1965) Islam and Aziz (1975), Newell and Newell (1977), Salam (1977), Bony (1989). Quantitative study of the gut contents were estimated (Counting method) following Das and Chowdhury,1983.The estimation of various forms of phytoplankton & zooplankton and others were done (in numbers) under the microscope with the help of a haemocytometers and their relative percentage composition was calculated. From values obtained for individual shrimp, monthly averages were counted.

8.3. Results

8.3.1. Food composition (in numbers) of *Acetes indicus* (Fig.155,Table 17 &18)

From the food composition of 300 adults (total length generally found 18 mm to 26 mm, rearly 28 mm) shrimps, it is evident that the diatoms, *Sagitta* , copepods, detritus & amorphous materials, sand grains and mud, foraminiferans, crustaceans appendages, molluscs shell and shell fragments were the important food items.

Diatoms, on the whole, formed 30.08% of the gut contents of *Acetes indicus*. Among the diatoms eight genera were identified, of these *Thalassiothrix, Nitzschia, Rhizosolenia, Pleurosigma* formed the most important genera, whereas *Coscinodiscus, Navicula, Synedra* and *Biddulphia* were the next in importance.

The presence of copepods in the food items of *A. indicus* shrimp was 8.34%. Calanoids were more abundant than cyclopoid and harpacticoid copepods. *Sagitta* accounted for 7% of the food material. Foraminiferans were found only in small quantities (1.66% of the total food contents). Molluscs and shell fragments formed a total of 1.58% of the gut contents. Detritus and amorphous materials formed 27.50% of the stomach contents of *Acetes indicus* and thus ranged as the second most important food items. The rest of the gut contents was sand grains and mud, which constituted 22.6% in *Acetes indicus* (Fig.155,Table 17).

8.3.2. Food composition (in number) of *Acetes erythraeus* (Fig.156,Table 19 &20)

The gut contents of *Acetes erythraeus* (total length generally recorded 18 mm to 30 mm) were identified into seven broad categories as diatoms, copepods, *Sagitta* ,foraminiferans; detritus, and amorphous materials, sand grain and mud, crustaceans appendages, molluscs fragments. Diatoms belonging to the genera *Pleurosigma, Thalassiothrix, Nitzschia, Coscinodiscus, Rhizosolenia, Synedra, Biddulphia, Skeletonema* and *Navicula* spp. were found in the stomach contents (28.92%) of *A. erythraeus*. *Thalassiothrix, Nitzschia, Pleurosigma* were commonly found.The presence of copepods in the food items of adult *A. erythraeus* was 8% and most of copepods was calanoid. *Sagitta* (most of the hook) was recorded (7.16%) of the food contents. Foraminiferans represented only 0.92%, molluscs shell fragments 1.66% and crustaceans appendages 1.00% of the total food materials. Detritus and amorphous materials formed 31.0% of the stomach contents and thus marked as the most important food items.

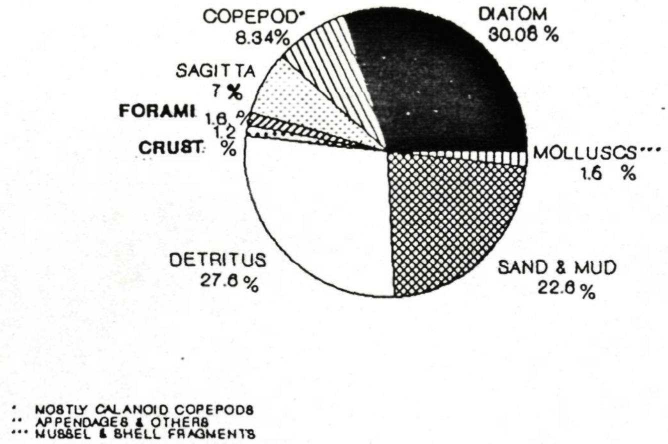


Fig.155. Food composition (in number) of *Acetes indicus* in the Mathamuhuri river estuary of Chakaria Sundarban, Bangladesh.

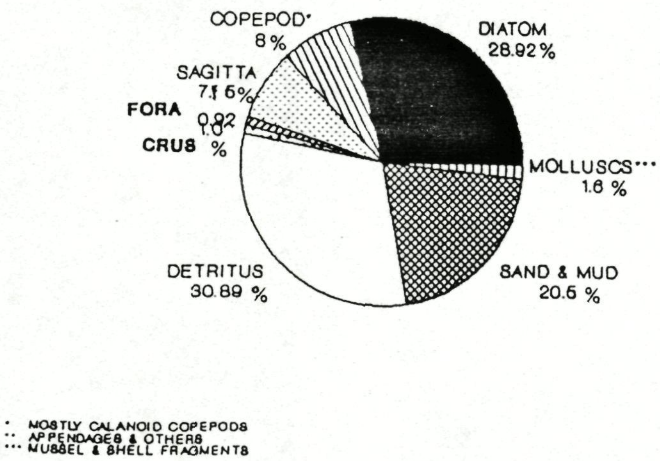


Fig.156. Food composition (in numbers) of *Acetes erythraeus* in the Mathamuhuri river estuary of Chakaria Sundarban, Bangladesh.

Table 17. Qualitative and quantitative stomach contents of Acetes indicus in the Mathamuhuri river estauary of Chakaria mangrove ecosystem, Bangladesh (Counting method).

Stage & Size of shrimp	Diatoms	% of Diatoms	Copepods	% of Copepods	% of *Sagitta*	% of Foraminifera	% of crustacean appendages & others	% of detritus/ amorphous materials	% of sand and mud	% of mollusc parts and shell fragments
Adult 10-28 mm	Pleurosigma affinie P. species Thalassiothrix spp. Nitzschia spp. N. seriata Coscinodiscus sp. C. centralis Rhizosolenia sp. Synedra sp. Navicula sp. Biddulphia sp.	30.08 ± 4.23	Mostly calanoid cyclopoid / Harpacticoid rarely present	8.34 ± 1.55	7.00 ± 1.95	1.66 ± 1.15	1.25 ± 1.14	27.5 ± 3.73	22.58 ± 8.64	1.58 ± 1.44

Table : 18 : Qualitative and Quantitative stomach contents of *Acetes indicus* in the Mathamuhuri river estuary of chakaria mangrove ecosystem.

Month	Diatoms	% of diatoms	Copepods	% of copepods	% of *Sagitta*	% of for-aminifera	% of crustacean appendages & others	% of detritus/ amorphous materials	% of sand and mud	% of mollusc parts and shell fragments
May	*Nitzschia* sp., *Thalassiothrix* sp., *Coscinodiscus* sp., *Rhizosolenia* sp., *Pleurosigma* sp., *Navicula* sp.	31	Calanoid, cyclopoid	8	7	2	2	24	25	1
June	*Nitzschia* sp., *Thalassiothrix* sp., *Pleurosigma* sp., *Coscinodiscus* sp., *Rhizosolenia* sp.	32	Calanoid	8	8	2	1	22	26	1
July	*Nitzschia* sp., *Thalassiothrix* sp., *Coscinodiscus* sp., *Rhizosolenia* sp., *Pleurosigma* sp., *Synedra* sp.	27	Calanoid	7	6	0	0	27	33	0
August	*Nitzschia* sp., *Rhizosolenia* sp., ., *N. seriata* sp.,*Navicula* sp.	23	Calanoid, cyclopoid	6	4	0	0	30	37	0
September	*Nitzschia* sp., *Thalassiothrix* sp., *Rhizosolenia* sp., *Synedra* sp., *Navicula* sp.	24	Calanoid, harpacticoid	7	5	1	0	30	33	0
October	*Nitzschia* sp., *Pleurosigma* sp., *Coscinodiscus* sp., *Synedra* sp.	26	Calanoid	8	6	1	1	31	26	1
November	*Pleurosigma* sp., *Nitzschia* sp., *Coscinodiscus* sp., *Thalassiothrix* sp., *Rhizosolenia* sp.	30	Calanoid, harpacticoid	9	7	2	3	29	17	3
December	*Pleurosigma* sp., *Nitzschia* sp., *Coscinodiscus* sp., *Rhizosolenia* sp., *Biddulphia* sp.	32	Calanoid, cyclopoid	8	7	2	2	32	15	2
January	*Coscinodiscus* sp., *Thalassiothrix* sp., *Biddulphia* sp.	33	Calanoid	10	10	2	3	27	10	5
Februrary	*Synedra* sp., *Pleurosigma* sp., *Coscinodiscus* sp.	32	Calanoid	12	6	1	0	30	17	2
March	*Synedra* sp., *Pleurosigma* sp., *Coscinodiscus* sp.	34	Calanoid	8	7	3	1	28	17	2
April	*Biddulphia* sp., *Navicula* sp., *Pleurosigma* sp., *Thalassiothrix* sp., *Nitzschia* sp., *Rhizosolenia* sp.	37	Calanoid, cyclopoid	9	11	4	2	20	15	2

Table 19. Qualitative and quantitative stomach contents of Acetes erythraeus in the Mathamuhuri river estauary of Chakaria mangroves ecosystem, Bangladesh (Counting method).

Stage & Size of shrimp	**Diatoms**	**% of Diatoms**	**Copepods**	**% of Copepods**	**% of *Sagitta***	**% of Foraminifera**	**% of crustacean appendages & others**	**% of detritus/ amorphous materials**	**% of sand and mud**	**% of mollusc parts and shell fragments**
Adult 10-30 mm	*Pleurosigma affine* *Thalassiothrix spp.* *Nitzschia spp.* *Coscinodiscus sp.* *Rhizosolenia sp.* *Biddulphia sp.* *Skeletonema costatum* *Synedra sp.* *Navicula sp.*	28.92 ± 5.87	Mostly calanoid, rarely found cyclopoid/ harpacticoid	8.00 ± 2.41	7.16 ± 3.41	0.92 ± 0.79	1.00 ± 0.85	31.00 ± 8.76	20.5 ± 9.27	1.66 ± 1.30

Table : 20 : Qualitative and Quantitative stomach contents of *Acetes erythraeus* in the Mathamuhuri river estuary of chakaria mangrove ecosystem.

Month	Diatoms	% of diatoms	Copepods	% of copepods	% of *Sagitta*	% of for-aminifera	% of crustacean appendages & others	% of detritus/ amorphous materials	% of sand and mud	% of mollusc parts and shell fragments
May	*Nitzschia* sp., *Thalassiothrix* sp., *Coscinodiscus* sp., *Biddulphia* sp., *Skeletonema* sp., *Pleurosigma* sp.	30	Calanoid, cyclopoid	6	6	1	1	26	29	1
June	*Nitzschia* sp., *Thalassiothrix* sp., *Pleurosigma* sp.	32	Calanoid	10	7	1	1	20	27	2
July	*Rhizosolenia* sp., *Nitzschia* sp., *Thalassiothrix* sp.	18	Calanoid	8	6	0	0	33	35	0
August	*Nitzschia* sp., *Thalassiothrix* sp., *Coscinodiscus* sp., *Rhizosolenia* sp.	22	Calanoid, harpacticoid	6	2	0	0	34	36	0
September	*Nitzschia* sp., *Thalassiothrix* sp., *Coscinodiscus* sp., *Rhizosolenia* sp., *Synedra* sp., *Navicula* sp.	24	Calanoid	5	0	0	0	48	23	0
October	*Nitzschia* sp., *Thalassiothrix* sp., *Pleurosigma* sp., *Biddulphia* sp., *Synedra* sp.	25	Calanoid	8	8	0	1	40	17	1
November	*Pleurosigma* sp., *Nitzschia* sp., *Coscinodiscus* sp., *Rhizosolenia* sp., *Biddulphia* sp.	31	Calanoid	9	9	2	2	33	12	2
December	*Pleurosigma* sp., *Nitzschia* sp., *Coscinodiscus* sp., *Rhizosolenia* sp., *Biddulphia* sp.	32	Calanoid, cyclopoid	12	8	1	2	30	13	2
January	*Pleurosigma* sp., *Nitzschia* sp., *Coscinodiscus* sp., *Thalassiothrix* sp.	35	Calanoid	10	12	2	2	20	16	3
Februrary	*Synedra* sp., *Pleurosigma* sp., *Coscinodiscus* sp., *Biddulphia* sp.	26	Calanoid	5	8	1	0	41	17	2
March	*Skeletonema* sp., *Nitzschia* sp., *Coscinodiscus* sp., *Thalassiothrix* sp.	35	Calanoid, harpacticoid	6	9	1	1	35	10	3
April	*Biddulphia* sp., *Navicula* sp., *Pleurosigma* sp., *Thalassiothrix* sp.	37	Calanoid	11	11	2	2	22	11	4

The rest of the food materials (20.50%) was sand grain and mud (Fig.156,Table 19).

The present investigation showed that *A. indicus* and *A. erythraeus* consumed diatoms, copepods, *Sagitta*, foraminiferans, molluscs larvae, detritus and amorphous materials, fine sediments (Fig. 157). So, the diet contents and composition of food consumed indicates that *Acetes* shrimps (*A. indicus* and *A. erythraeus*) are omnivorous. During monsoon months (July-August) lower percentage of diatoms and copepods were present in stomach and different food items shows different peak periods in the gut of *Acetes* spp (Table 18 & 20). Among the phytoplankton representatives, a few species of diatoms showed their occurrence in almost all the seasons of the year in the gut contents of *Acetes* shrimps. *Nitzschia* sp. *Thalassiothrix* sp and *Pleurosigma* are commonly available in *Acetes indicus* and *A. erythraeus*. *Skeletonema* sp. was found in the gut of *Acetes erythraeus* during March and May. From the analysis of the gut contents of two species of *Acetes* shrimps it was found that the nature of food was basically similar. A seasonal fluctuation was observed in the composition of food consumed by two *Acetes* shrimps.These fluctuations were probably related with the environmental factors, relative abundance of some food materials and biological response of *Acetes*. The maximum percentage of live food organisms and minimum percentage of soil particles (sand and mud) were found in non monsoon period. During rainy season low salinity, high suspended particles and other adverse factors of monsoon were correlated with the low abundance of *Acetes* shrimps and lower percentage of live food feeding. *Skeletonema costatum* was the most dominant species of diatom in the Mathamuhuri river of Chakaria sundarban area and occurred throughout the year except in September and January (Table 7). But in the gut of *Acetes erythraeus*, *Skeletonema* sp was found only two months March and May and it was absent in *Acetes indicus* during year round investigation, and concluded that probably *Acetes* shrimps are ignoring the *Skeletonema* sp.

8.4. Discussion

Burkenroad (1945) was probably the first to describe food organisms of *Acetes* and concluded, tentatively that the diet comprised small crustacea and thin shelled molluscs (probably larvae). Unfortunately, he examined only a single specimen, the identity of which is also doubtful. Xu (1957) examined seasonal and large scale spatial feeding patterns of *Acetes chinensis* in Liaotung Bay. He found the diet of this shrimp to be composed numerically of diatoms (37.88 ± 4.46% *Coscinodiscus* , 18.21 ± 5.87% *Paralia* , 5.29 ± 1.40% *Thalassiothrix* and 5.19 ± 2.80% *Biddulphia*), zooplankton (11.27 ± 1.97% copepods, 2.80 ± 0.99% *Sagitta* sp., 2.83 ± 1.41% molluscan larvae, amorphous material (43.86 ± 4.36%) and mud (17.37 ± 3.31%). Aravindakshan & Karbhari (1988) found that the stomachs of *Acetes sibagae* contained 'crustaceans appendages, calanoid copepods, foraminiferan and molluscan remains in the form of shells and shell fragments, sand grains and debris". Copepods were also recorded in the stomachs of *A. japonicus*

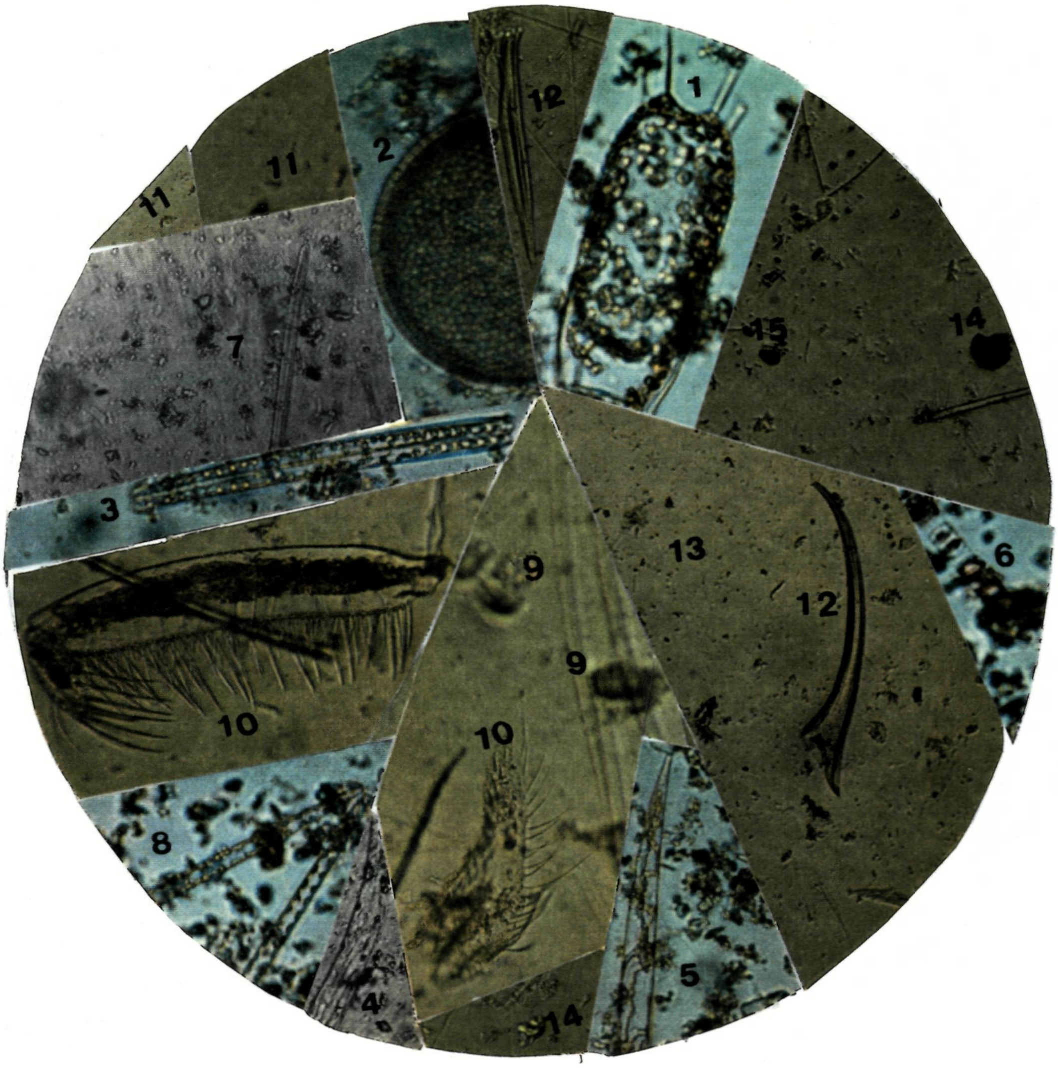


Fig.157. Showing important food items (1. *Biddulphia* sp 2. *Coscinodiscus* sp 3. *Nitzschia* sp. 4. *Pleurosigma* sp. 5. *Rhizosolenia* sp. 6. *Skeletonema* sp 7. *Synedra* sp 8. *T. nitzschioids* 9. Copepods 10.Crustacean parts 11. Foraminifera 12. *Sagitta* or *Sagitta* hook 13. Sand/mud 14.Mollusc 15. Detritus) in the gut of *Acetes* of the Mathamuhuri river estuary, Bangladesh.

(Ikematsu, 1957) and *A. erythraeus* (Le Reste, 1970), but no diatoms were found in the stomachs of *A. japonicus* collected in the Ariake Sea (Ikematsu ,1957). Xu (1957) examined stomachs of over 4300 specimens of *A. chinensis* collected from Liaotung Bay and found marked seasonality in diet composition. He also stated that *A. chinensis* selects its food in terms of species, consuming some while ignoring others. In the Mathamuhuri river estuary *A. indicus* and *A. erythraeus* showed some seasonality in diet composition. Feeding activity of *A. chinensis* has been inferred to be affected indirectly by freshwater input (Xu, 1957), which in the Liaotung Bay, influences distribution patterns of the diatoms, one of the main food organisms of *Acetes*. In the Mathamuhuri river estuary during monsoon months (July to September) freshwater discharge is maximum, and lower percentage of live food (diatoms & copepods) of *A. indicus* & *A. erythraeus* were also recorded. Almost all previous work (Xu, 1957; Le Reste, 1970) on *Acetes* feeding biology in based on occurrence methods and on estimates derived from the numerical density of each food item. Hamner and Hamner (1977) have demonstrated great chemosensitivity of *A. sibogae* in tracking scent trials of certain amino acids, which suggests that *Acetes* is a carnivorous rather than detritivore in nature. Xu(1957) mentioned that *Acetes* consume phytoplankton, small zooplankton, fine sediments and detritus, and also stated that *Acetes* are omnivorous. In the present investigation *Acetes indicus* and *A. erythraeus* consume phytoplankton, small zooplankton, fine sediments and detritus (Fig.157). Dall (1990) stated that penaeids are 'opportunistic omnivores'. Omnivory is also indicated from the methods which have been successful in culturing *Acetes*. Cultures of *Chlamydomonas* sp. (Rao, 1968) and *Artemia nauplii* (Hamner & Hamner, 1977; Ikeda & Skjoldal, 1980; Ball *et al* ., 1986; Xiao, 1990) have been used to feed *Acetes* in the laboratory.

8.5. Conclusion

The present investigation indicates that more or less 50% of plant foods and 50% animal foods are present in stomach of *A. indicus* & *A. erythraeus* . The diet composition indicates that the two species are omnivorous and shows some seasonality in food percentage.This hyperbenthic species feeds mostly on planktonic diatoms and copepods (calanoids). It suggests that *Acetes* could feed at night when they perform vertical migration. But the presence of large amounts of mud, sand and shell debris also suggest that they ingest also a considerable amount of benthic detritic material (probably at day).

CHAPTER 9

CHEMISTRY OF *ACETES* SHRIMPS

9.1. Introduction

Proximate biochemical analysis provides information on the nutritional value of a particular organism used as food source. Four of the major types of compounds are found in living organisms namely, protein, fat, carbohydrate and nucleic acid (Cuningham, 1978). Water, protein, fat and carbohydrate are the main constituents of fish and shellfish with non-protein nitrogenous constituents and salts in small amounts . Fish shellfish are mainly eaten by the people.

Bangladesh is a densely populated country. The people here suffer from protein deficiency.The yearly population growth rate is about 3% while their protein intake is 45 g/day, which is probably the lowest in the world (West, 1973). Fisheries (Fish and Shrimps) is an indispensable component of daily food of almost everybody in Bangladesh. It is one of the most important stable food, and takes the second place after rice and represents an important source of animal protein in the daily food.

Shrimp farming in the coastal tidal areas is the most popular and profitable business in Bangladesh. Recently, in the private sector, modern shrimp culture methods (semi-intensive and intensive) are adopted for enhanced production.This growing interest in the culture of shrimp (*Penaeus monodon, Macrobrachium rosenbergii* etc.) has led to the need for a formulated and complete diet that is economical and viable for the country. Artificial diets in aquaculture production is one of the required inputs and acts as a key element in intensive culture. Even in culture systems where the main source of nutrition for the cultured stock is natural food produced by fertilization, supplimentary item is necessary to accelerate the production. Thus, for successful operation of the intensive and semi-intensive culture, a developed high protein consisting, compounded feed is an essential factor. Information about nutrition of shrimps is limited and no published report is yet available in the biochemistry of *Acetes indicus* and *Acetes erythraeus* . However, it was already reported that *Acetes* is used as prime food for *Penaeus monodon* larvae (Kungvankij *et al.*, 1986); it is consumed in Japan, China, India, South Korea and Thailand as source of protein (Aravindakshan and Karbhari, 1988).

Calcium is essential for coagulation of blood, maintenance of right degree of firmness in soft tissues and normal growth of animal body. Lacking of Ca during period of growth, results is stunted and deformed body frail structure (Wiley and Stevenon,1942).

Iron is widely distributed in the body with major portion in the red blood cells. It is essential to the process of oxidation and forms compounds necessary for the transport of oxygen to the cells for oxidation.

Phosphorous is an important constituent for the activation of enzymes and metabolic activities of the body. It also helps in the utilization of fats and a series of phosphorous compounds are formed in the utilization of carbohydrate. It is an important constituent of proteins, nucleic acids alkaloids, some vitamins, co-enzymes etc. and plays very important role in metabolism, growth, reproduction, and heredity in the body.

In Bangladesh a large quantity of the population has been suffering from Ca, P, Fe, N, malnutrition. The present study accounts on the presence of considerable quantity of Ca, P, Fe & N in*Acetes indicus* and *Acetes erythraeus* and gives new information to mitigate their deficiency.

Variety of radionuclides from both natural and artificial origins normally get entry into aquatic organisms and human body through food chains. Therefore investigation of radionuclids in the *Acetes* shrimp is very important in respect to use an ideal food for larvae rearing.

Chitin is a bio-polymer of monosaccharides -glucose, galactose etc. that is found in hard shell of crustacea. It is a long chain (Fig.158) linear polymer having 2-acetyl-amino glucose as its primary building unit.These units are joined by beta, 1-4 glucosidic linkages as in cellulose with a degree of polymerization of 2000 or more units in the native states (Percival and Percival, 1962). It is used in dyeing and printing of textile fibres. From this, glucosamine hydrochloride can be prepared, with medicinal purpose (Kamasastri and Prabhu, 1961; Nikolaeva *et al* ., 1967). It is also used in the agriculture, biotechnology and water treatment (Ornum,1992).

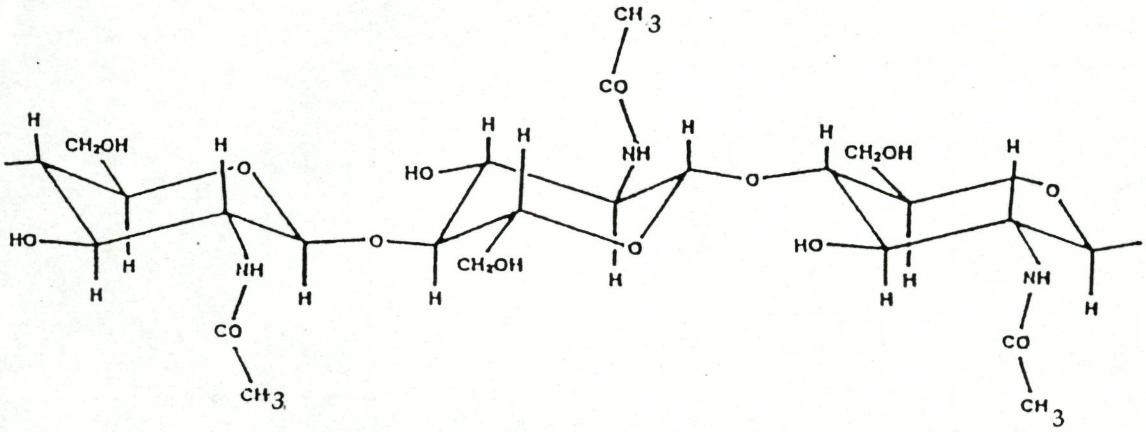


Fig.158. Chemical structure of chitin.

9.2. Materials and Methods

Two common sergestid shrimps *Acetes indicus* and *Acetes erythraeus* were collected during hightide from Mathamuhuri river estuary. Samples were collected during May,June, November, and December,1992. A plankton net was used for collection of *Acetes* similar to that described by Mahmood and Khan (1982) having 0.5m^2 mouth opening and netting material of hydrobios nylon mesh with aperture size of 0.5 mm. In the laboratory. *Acetes indicus* & *Acetes erythraeus* were identfied from zooplankton samples following (Omori, 1975; Mahmood *et al.*, 1978 and Tirmizi and Ghani, 1982). The adult of two species of *Acetes* shrimps were measured for recording total length and *Acetes indicus* varied from 15 mm to 28 mm rearly 30 mm and *Acetes erythraeus* varied between 18 mm to 30 mm.The collected *Acetes shrimps* were preserved in a deep frezeer (-18^{o}C) those samples were taken for different analyses. Analyses were performed in'4' fold.Total nitrogen and protein were estimated by Kjeldhal's method (Bradstreet, 1965). Fat was estimated by Soxhlet method (Pearson, 1976). The percentage of ash content was estimated by burning the materials in a Muffle Furnance at 550-600°C for 4 to 6 hours and moisture content was determined by drying the samples at 100-105°C in an oven (Pearson,1976). Carbohydrate and Ca were analysed following standard procedures (Ranganna, 1986). Iron was estimated by Phenanthroline method (APHA,1976). Phosphorous content of *Acetes* was estimated by spectrophotometeric method (Ranganna, 1986). Gamma spectroscopy was used to determine the gamma activities of ^{238}U, ^{232}Tu, ^{40}K, ^{137}Cs and ^{134}Cs in the *Acetes* shrimps.The collected fresh samples were washed with distilled water and dried in an oven at 110°C for 24 hours. After drying these samples were grounded to powder and stored in a plastic container of 150 ml geometry for 8 weeks before counting to allow time for ^{238}U and ^{232}Tu.The concentrations of activity of these samples were measured by using a High Purity Germanium (HPGe) detector coupled to a personal computer analyzer. The effective volume of the detector was 111 cm^3 and the energy resolution of the 1332 Kev line from ^{60}Co was found to be 1.8 Kev. with a relative efficiency of 23%. The sample container was placed on top of the detector for counting. The counting time for each sample and background was then stripped channel by channel from each sample. The concentration of different radionuclides were calculated based on the measured detector efficiency (Molla *et al.*,1984). Determination of chitin in hard shell of *Acetes* spp were estimated following Nikolaeva *et al.*,1967.

9.3. Results and Discussion

Nutritionl quality of two Sergestid shrimps (*Acetes indicus* and *Acetes erythraeus*) were determined.The result of the biochemical composition (protein, fat, moisture, ash, carbohydrate), four important elements (Ca, Fe, P, N), radioactivity and chitin contents have been described as follows:

9.3.1. Proximate composition on wet weight basis in *Acetes* shrimps (g/100g sample)

9.3.1.1. Protein Content

The protein content (14.13%) was recorded in *Acetes erythraeus* (Fig.159) and 13.15%) in *Acetes indicus* (Fig.160), on wet weight basis. Mann Whitney U test showed a significant differences of protein concentration between two *Acetes* shrimps (P = 0.019, U = 0, Z = -2.34). Protein for sun dried *Acetes* was found in 64.44% of dry weight. Investigation of biochemical composition of *Acetes japonicus* and *Acetes chinensis* were done by Yongquan and Jingling (1989) and they found 40-54% protein in dried sample of dry weight. Gopalakrishnan *et al.* (1977) and Madhupratap *et al.* (1979) found 14.5% protein content of wet weight in *Acetes cochinensis*. Mannan (1977) found 14.9% protein of wet weight in *Penaeus monodon*. Banu *et al.* (1985) reported 18.0% protein in *Macrobrachium villosimanus* on the basis of wet weight. Raymont *et al.* (1967) reported 58-60% protein of dry weight in planktonic decapods and Siddiquie *et al.* (1987) showed 55-60% protein of dry weight in the three edible species of portunid crabs. Omori (1974) reported 71.9% protein of dry weight in *Acetes japonicus*, Japan and Skjoldal (1981) showed 43.7% protein of dry weight in *Acetes sibogae* of Australia. All those results corrobrate the present findings.

Protein concentration in adult *Acetes indicus* and *A. erythraeus* did not vary among the four months (May-June & November-December) study 'Table 21.1 & 21.2', when two peak occurrence of *Acetes* spp were recorded (Table 11).

9.3.1.2. Fat Content

The fat content (0.80%) was recorded in *Acetes indicus* and *A. erythraeus* on wet weight basis (Table 21). Yongquan and Jingling (1989) reported 20-28% lipid of dry weight in *Acetes japonicus* and *Acetes chinensis*. Su and Xiao (1987) published 2.12% lipid content on the basis of wet weight in *Acetes japonicus*, China. Chung & Lee (1976) described 1.2% fat of wet weight in *Acetes chinensis* , Korea. Azim (1982) found 0.85% fat on wet weight basis of *Penaeus monodon*.The present investigation showed lower fat contents in *Acetes indicus* and *Acetes erythraeus* than other recorded *Acetes*.

9.3.1.3. Moisture content

From Table 21 it appears that the average moisture content (81.39%) was recorded in *Acetes erythraeus* and (81.39%) in *Acetes indicus*, (Fig.159,160). Chen *et al.* (1965) reported that 81.7% moisture in *Acetes chinensis* . Nair *et al.* (1975) recorded 81.7% moisture in *Acetes* spp. and Madhupratap *et al.* (1979) determine 79.85% moisture in *Acetes cochinensis* . The present investigation also agrees with these author.

9.3.1.4. Ash content

In two species (*Acetes indicus* and *A. erythraeus*) ash content was nearly same. In 100 g of sample, ash content was 2.82g in *Acetes erythraeus* and in *Acetes indicus* 2.7 g (Fig.159,160). Chung & Lee (1976) reported 3% ash in *Acetes chinensis* of wet weight. Mannan (1977) reported 1.40% ash in shrimp on the basis of wet weight.The present findings allign with the above mentioned results.

9.3.1.5. Carbohydrate content

Higher amount of carbohydrate (1.93%) was found in *Acetes indicus* than for *Acetes erythraeus* (0.34%), on wet weight basis (Table 21), Mann Whitney U test showed significant differences ($P = 0.02$, $Z = -2.32$, $U = 0$). Gopalakrishnan *et al.* (1977) reported 1.5% carbohydrate of wet weight in *Acetes cochinensis* at Cochin backwater, India. Su and Xiao (1987) observed 0.26%· carbohydrate of wet weight in *Acetes chinensis* of Xiamen, China. The above results fairly agree to the present investigation.

9.3.2. Four important elements of *Acetes indicus* and *A. erythraeus* (Table 22, Fig.161)

Four important elements (Ca, Fe, P, and N) of *Acetes* spp. were analysed. Mann Whitney U test showed significant differences of four elements in the two *Acetes* shrimps (*A. indicus* and *A. erythraeus*) at 5% level.The concentration of these elements are described here below

9.3.2.1. Calcium content

The calcium content of two common *Acetes* shrimp of the Mathamuhuri river estuary was recorded (Table 22). In 100g of wet weight sample, Ca content was 1042.02 mg in *Acetes indicus* and 948.81 mg in *Acetes erythraeus* . Chen *et al.* (1965) found calcium content of *A. chinensis* to be 1.9% of its dry body weight. Begum and Hoque (1986) mentioned 114.65 mg/100g of calcium in shrimp and Zafar *et al.* (1993) reported 339.15 mg/100g calcium of *Harpodon nehereus* and 536.5 mg/100g in *Lates calcarifer* (on wet weight basis).

9.3.2.2. Iron content

The higher iron content (5.05 mg/100g) was recorded for *Acetes erythraeus* and (2.57 mg/100g) in *Acetes indicus*. Banu *et al.* (1985) determined 3.0 mg/100 g iron in fresh water *Macrobrachium villosimanus.*

9.3.2.3. Phosphorous content

In 100g of samples phosphorous content was 99.87mg in *Acetes erythraeus,* in *Acetes indicus* 80.90 mg (Table 22) of wet weight. Chen *et al.* (1965) found phosphorous content of *Acetes chinensis* 1.0% of its dry body

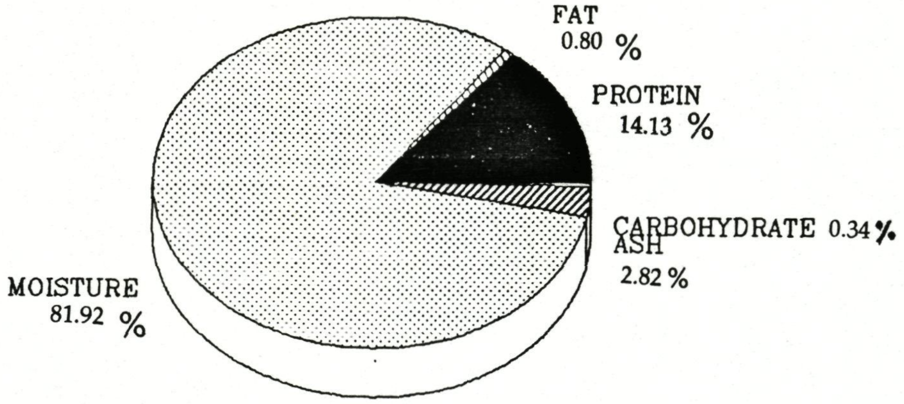


Fig.159.Proximate composition of *Acetes erythraeus* in the Mathamuhuri river estuary, Bangladesh.

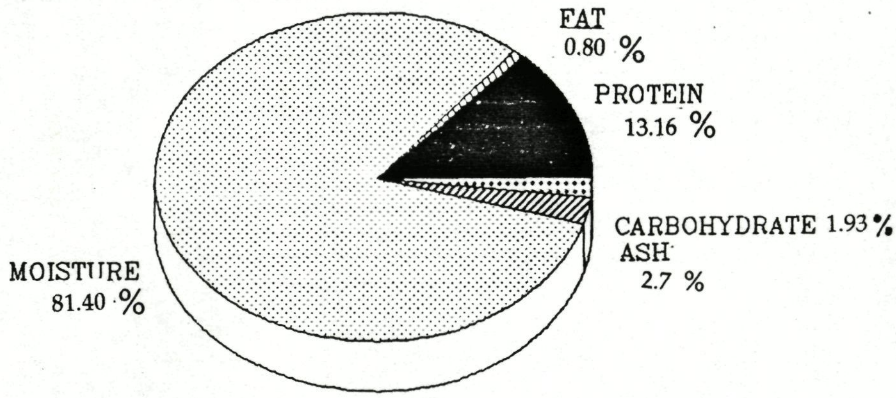


Fig.160. Proximate composition of *Acetes indicus* in the Mathamuhuri river estuary, Bangladesh.

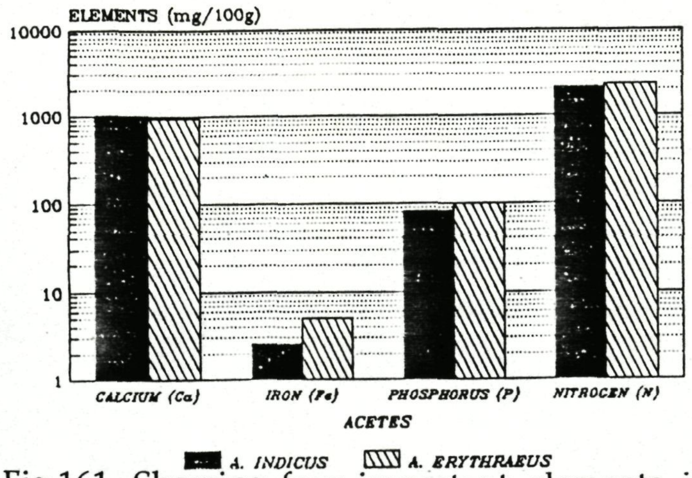
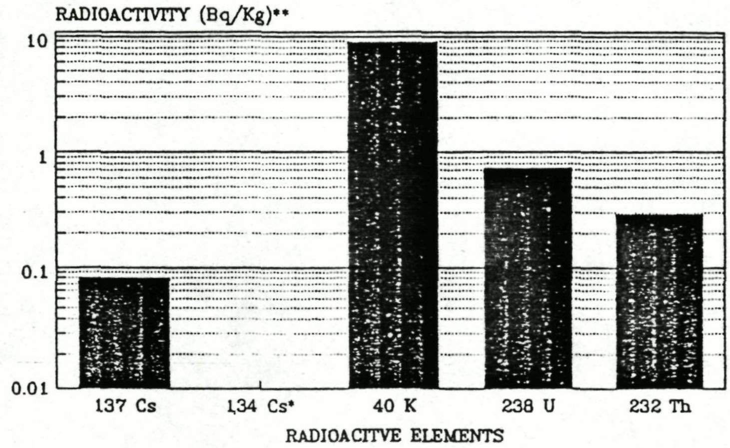


Fig.161. Showing four important elements in the two common *Acetes* shrimp's (*A.indicus and A. erythraeus*) of the Mathamuhuri river estuary, Bangladesh.



* NOT DETACTABLE
**FRESH WEIGHT

Fig.162. Concentration of different radioactive elements in the *Acetes* shrimp of the Mathamuhuri estuary, Bangladesh.

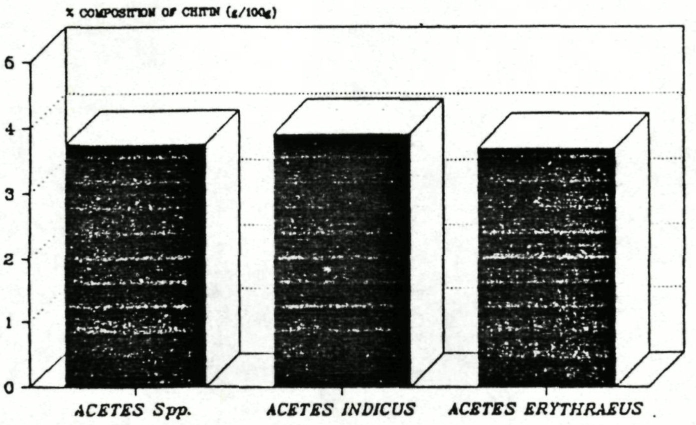


Fig.163. Chitin contents of two sergestid shrimps *Acetes indicus* and *A. erythraeus* in the Mathamuhuri river estuary, Bangladesh.

weight. Uye and Madsuda (1988) estimated phosphorous as 0.53-0.78% (n = 3, 0.68 ±0.08%) of dry weight for male and 0.43 - 0.75% (n = 4, 0.59 ± 0.07) for female *A. japonicus.*

9.3.2.4. Nitrogen content

In wet weight condition 2.11% (2.11g/100 gm) and 2.26% (2.26g/100g) nitrogen content was found in the *Acetes indicus* and *Acetes erythraeus* respectively (Fig. 161). Omori (1974) have determined 11.55% nitrogen in *Acetes japonicus* of dry body weight.

9.3.3. Radioactivity

Radioactivity of *Acetes* shrimp is presented in Table 23. The activity of ^{137}Cs was found 0.09 + 0.02 Bq/Kg of *Acetes* body wet weight. But the ^{134}Cs concentration was not detectable in *Acetes* shrimp. The concentrations of ^{238}U (0.08 + 0.02 Bq/Kg) and ^{232}Th (0.32 + 0.79 Bq/Kg) were detected in fresh *Acetes* shrimps (Fig.162). Su & Xiao (1987) measured radioactivity in *Acetes japonicus* indicating the presence of radioactive materials in *Acetes* shrimp. Molla *et al.* (1985) determined the activity of ^{137}Cs in the *Palaemon carcinus* (prawn) 126.6 $^{PCi/Kg}$ of wet weight. Islam *et al* . (1994) reported the concentration of ^{137}Cs in the sea water at Cox's Bazar ranged from 23.6 ± 2.0 to 33.9 ± 6.0 mBq/l with an average of 27.9 ± 3.9 mBq/l. Wattenberg (1938) reported the Cs 0.0015 µg at./l in sea water. Koezy (1949) determined the Th (0.01-0.001µg at. /l) in sea water.There is no published information about the different concentration of radioactive elements in *Acetes* shrimps.The present account therefore, from the Mathamuhuri river estuary, to the first report on it.

9.3.4. Chitin (Fig. 164) content of *Acetes* shrimp

The average percentage of chitin content of body shell of two species (Fig 163) have been presented in Table 24. Among the two species highest chitin content (3.92%) was recorded in *Acetes indicus* and lowest was found in *Acetes erythraeus* (3.70%) of dry weight.The chitin in *Acetes* spp. was 3.75% (Fig.163). Nair *et al.* (1975) reported that *Acetes* spp. shell contained 4% chitin of dry weight basis. Gopalakrishanan *et al.* (1977) found a chitin content (2.8%) in *Acetes cochinensis* shell. Dutrieu (1960) reported that *Artemia salina* shell contained 10% chitin. Nikolaeva *et al.* (1967) reported 13.7% chitin from *Penaeus semisulcatus.* Raymont *et al.* (1967) reported 3-6% chitin from planktonic decapods. Sultana (1994) found chitin content in *Penaeus monodon* 27.60%, in *Penaeus indicus* 26.10%, in *Metapenaeus monoceros* 25.80%, in *M. brevicornis* 24.75%, in *Macrobrachium rosenbergii* 28.30%, and in *Panulirus polyphagaus* 27.55% of dry weight.

Table 21. Proximate bio-chemical composition (g/100g) on wet weight basis of two major abundance of sergestid shrimp *Acetes indicus* and *A. erythraeus* of the Mathamuhuri river estuary, Bangladesh.

Species	Part of Shrimp	Mean value ± SD				
		Protein	Fat	Moisture	Ash	Carbohydrate
Acetes indicus	Whole body	13.16 ± 0.06	0.80 ± 0	81.40 ± 0	2.7 ± 0.08	1.93 ± 0.11
A. eruthraeus	Whole body	14.13 ± 0.01	0.80 ± 0	81.92 ± 0.05	2.82 ± 0.01	0.34 ± 0.02

Table 21.1

Proximate biochemical composition (g/100g) on wet weight basis of Acetes indicus of the Mathamuhuri river estuary, Bangladesh

No of observation	Month	% composition				
		Protein	Fat	Moisture	Ash	Carbohydrate
1	May	13.15	0.7962	81.398	2.71	1.9348
2	Jun	13.25	0.7961	81.401	2.721	1.8619
3	Nov	13.15	0.7963	81.399	2.81	1.8447
4	Dec	13.1	0.7962	81.397	2.613	2.0938

Table 21.2

Proximate biochemical composition (g/100g) on wet weight basis of Acetes erythraeus of the Mathamuhuri river estuary, Bangladesh

No of observation	Month	% composition				
		Protein	Fat	Moisture	Ash	Carbohydrate
1	May	14.12	0.797	81.39	2.713	1.935
2	Jun	14.14	0.795	81.4	2.714	1.936
3	Nov	14.13	0.796	81.38	2.713	1.935
4	Dec	14.12	0.796	81.39	2.713	1.934

Table 22. Four elements in sergestid shrimp Acetes (mg/100g) on wet basis of the Mathamuhuri river estuary, Bangladesh

	Elements (mean value ± SD			
Species	Calcium (Ca)	Iron (Fe)	Phosphorus (P)	Nitrogen (N)
Acetes indicus	1042.02 ± 0.01	2.57 ± 0.01	80.90 ± 0.28	2104.8 ± 7.87
A. erythraeus	0948.81 ± 0.02	5.05 ± 0.04	99.87 ± 0.01	2260.35 ± 1.58

Table 22.1
Four important elements in Acetes indicus (mg/100g) of the Mathamuhuri river estuary, Bangladesh

No of observation	Month	Calcium (Ca)	Iron (Fe)	Phosphorus (P)	Nitrogen (N)
1	May	1042.02	2.57	80.90	2104.00
2	Jun	1042.03	2.56	81.28	2115.20
3	Nov	1042.01	2.58	80.80	2104.00
4	Dec	1042.02	2.56	80.60	2096.00

Table 22.2
Four important elements in Acetes erythraeus (mg/100g) of the Mathamuhuri river estuary, Bangladesh

No of observation	Month	Calcium (Ca)	Iron (Fe)	Phosphorus (P)	Nitrogen (N)
1	May	948.81	5.05	99.86	2259.20
2	Jun	948.79	4.99	99.88	2262.40
3	Nov	948.83	5.09	99.87	2260.80
4	Dec	948.81	5.06	99.87	2259.20

Table 23. Concentration of radioactivity in fresh Acetes shrimp in the Mathamuhuri river estuary of Chakaria mangroves ecosystem, Bangladesh.

Radioactivity	^{137}Cs	^{134}Cs	^{40}K	^{238}U	^{232}Th
Concentration Bq/Kg, fresh weight	0.09±0.02	ND	9.83±0.79	0.8±0.01	0.32±0.09

ND=Not detectable

Table 24. Chitin contents (g/100g) on dry weight basis of Acetes shrimps of the Mathamuhuri river estuary in the Chakaria mangrove ecosystem, Bangladesh.

Name of the species	Part of shrimp	% composition of Chitin
Acetes indicus	Whole body	3.92 ± 0.08
A. erythraeus	Whole body	3.70 ± 0.04

Table 24.1
Chitin contents (g/100g) on dry weight basis of Acetes shrimp in the Mathamuhuri river estuary, Bangladesh

No of observation	Month	*Acetes* spp.	*Acetes indicus*	*Acetes erythraeus*
1	May	3.75	4.01	3.69
2	Jun	3.80	3.95	3.75
3	Nov	4.00	3.82	3.66
4	Dec	3.45	3.90	3.69

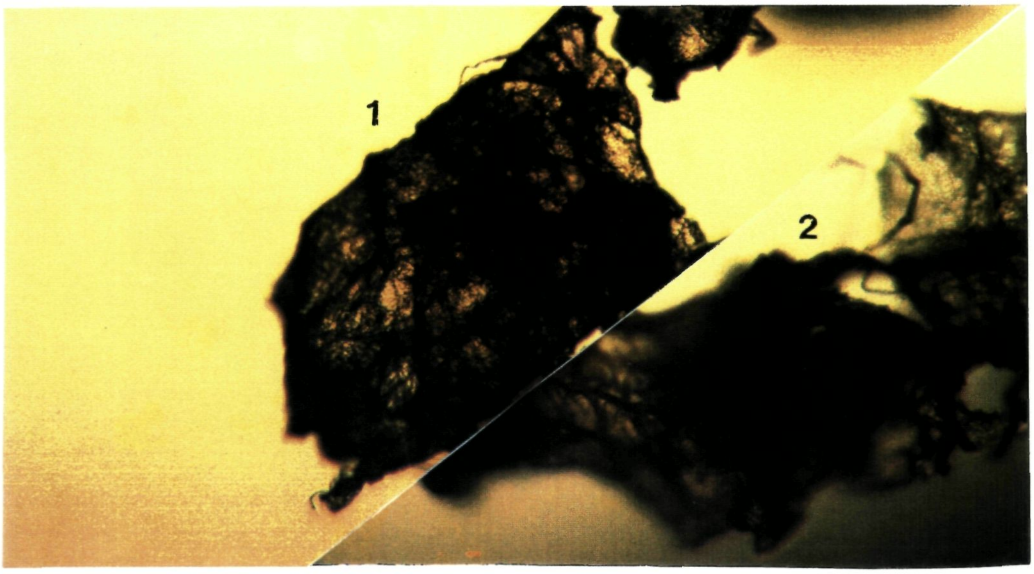


Fig.164. Showing photographs of chitin of *Acetes* shrimps (*Acetes indicus* 1, *A. erythraeus* 2).

9.4. Conclusion

High protein content, significant amount of calcium and phosphorous and low concentration of radionuclides and chitin proved that *Acetes* have a great potential to development and production of feeds for fish, shellfish larvae and humans. Biochemical components (Table 21.1, 21.2, 22.1, 22.2 & 24.1) shows no seasonality during the two peak occurrence of adult *Acetes* shrimps in end of the premonsoon (May & June) and postmonsoon (November & December) months and proximate compositions between two species (*Acetes indicus and A. erythraeus*) are nearly same.

CHAPTER 10

MICROBIAL ANALYSIS OF THE *ACETES* SHRIMPS

10.1. Introduction

Numerous products of *Acetes* are made and sold on markets particularly in Asia (Omori, 1975). They can be categorised, according to processing methods, as raw and fresh; boiled; dried in the sun; dried after boiling and sometimes processed further by removing carapaces; dried after boiling in salt; pickled in salt; permented paste with salt; sauce; and powder (Liu, 1956; Cole & Greenwood-Barton,1965; Yoo & Kim, 1973; Omori, 1975; Malley & Ho, 1978; Yeoh & Merican, 1978; Steinkraus *et al.*, 1983; Adnan & Owens, 1984). Generally, only a very small portion of *Acetes* catches is sold as fresh shrimp; most are dried, pickled or fermented in various ways (Omori, 1975). Dried *Acetes* are common and marketed in almost all Asian countries; fermented shrimp paste and sauce are highly desirable in China and Southeast Asia (Omori, 1975). The paste includes 'Xiajiang' in China, 'Memtep' in Viet Nam, Belcan in Malaysia and Singapore, 'Gapi' in Myanmar, and Trassi in Indonesia.

Ung & Itoh (1989) have studied various nutritional characteristics of *Acetes* of interest to aquaculture nutritionists. In comparison with krill meal, they concluded that meal made from *Acetes* is a cheaper alternative to crustacean meal. Due to its short generation time, great abundance, coastal habit and low capital cost of capture, they forecast that *Acetes* may become a useful renewable resource for use in aquatic diets in the future. There seems to be a great market potential for *Acetes* meal in both Europe and Japan, where euphausiid or krill meal is now being used in prawn and fish feeds (Ung & Itoh, 1989). Kungvankij *et al.* (1986) reported results of experiments with rearing *Penaeus monodon* larvae from nauplius through to postlarvae being finely ground *Acetes* tissues alone. In outdoor tanks, they achieved their highest (68%) dry season larval prawn survival rate when using dried *Acetes* as food which contrasts with survival rates when feed with either *Chaetoceros* (48%) or fresh *Acetes* (39%); the larvae molted to postlarvae within 8-9 days. In an indoor hatchery prawns reared with *Chaetoceros* had higher survival rate (52%) than those fed with either dry (35%) or fresh (24%) *Acetes* , however the molting period from eggs to postlarvae (10-12 days) of P. *monodon* , when fed exclusively with suspensions of both dry and fresh *Acetes* tissue was comparably shorter than those fed diatoms. The larvae fed with fresh *Acetes* tissue seemed to have lower survival rates and have higher bacterial counts, the causes of which are unknown. Nagabhushanam & Joshi (1986) have successfully cultured larval *Parapenaeopsis stylifera* using blended frozen *Acetes* , and forecast the great potential of *Acetes* feed for large-scale field aquacultural operations.

Acetes shrimp is a perishable food items and highly putrescent fishery commodity.The putrefaction is caused by many factors. Among them bacterial activity is most effective in producing undesirable flavour, order and appearance of shrimp (Williams *et al.*, 1952). So, the acceptance and consumption of *Acetes* shrimp mainly depends upon the bacterial standards for fishery products. The quality of numerous products of *Acetes* shrimp is determined mainly by the total number of bacteria present and by the specific count of bacteria of public health significance such as, *Escherichia coli*, faecal *Streptococcus*, coagulase positive *Staphylococcus* and *Salmonella* etc. per gram of shrimp muscles. The presence of pathogens in the fresh or dry or frozen products is "not only dangerous but also not fit for human consumption".Thus bacterial counts are used as an index of quality of the product and sanitation. Fitzgerald and Conway (1937) recommended that frozen foods should have a maximum $1x10^5$ cells/g. For pre-cooked and partially cooked frozen foods, the State of Massachusetts requires standards of less than 50,000 cells/g, 10 coliform cells/g and no coagulase positive *Staphylococcus* . In Bangladesh a total number of bacteria upto $1x10^6$ cells/g , total coliforms 100/g and and *E. coli* 10/g of shrimp muscle is considered to be acceptable. The bacteriological standards for pre-cooked frozen shrimps and prawns of India are a total plate count 2×10^5/g. The absence of *E. coli* in one gram sample, 100 enterococci/g and 100 coagulase positive *Staphylococci* /g (FAO, 1975). International acceptable microbial limits for shrimp and lobster products are total bacterial number 10^6-10^7/g, fecal coliform (MPN) 4 - 400/g, *Staphylococcus* 10^3-$2x10^3$/g and no *Salmonella* (Connell, 1980). So, the present study of the total bacterial counts and the number of pathogen presents in the fresh and dry *Acetes* is very imperative.

10.2. Materials and Methods

The investigation was carried out from May 1992-April 1993 on bacterial analysis of fresh *Acetes indicus* and *Acetes erythraeus*. Fresh species (*A. indicus* and *A, erythraeus*) were collected from the surface waters of Mathamuhuri river estuary by a rectangular plankton net (Mahmood and Khan, 1982). It has a mouth opening of $0.5m^2$ made up of nylon meshes (500µm). The samples were immediately brought in the laboratory (IMS, CU.) and washed in sterile seawater. Sun dried samples of *Acetes indicus* and *Acetes erythraeus* were collected (November 1992 to April 1993) from the Kutubdia Fishery Market, Cox's Bazar. In each sample 50g of fresh or dry whole shrimp were taken and this was blended with 450 ml distilled water in a sterile blender jar and blended for 5 minutes. Sea water agar media were used for total enumeration of bacteria. The total bacterial counts (TBC) of the sample was determined by conventional pour plate technique (APHA, 1976; Collins and Lyne, 1976 and Molla, 1982) and *Achromobacter, Micrococcus* and *Pseudomonas* were determined from fresh *Acetes* spp after testing their morphological, cultural and biochemical test following (Selley, 1962). In order to enumerate the pathogenic bacteria such as *Escherichia coli*, faecal *Streptococcus*, coagulase positive *Staphylococcus*, *Salmonella* and*Vibrio parahaemolyticus* selective different media were used for each of the species and incubated at 35°C.The pour plate technique (APHA, 1976) for enumeration of phathogenic bacteria were based on the fact that each of them gave a characteristics type of colony confirmed by further biochemical test.

Escherichia coli count

1 ml of each decimal dilution of different samples was pipetted into petri plates and the plates were poured with Levine's Eosin Methylen Blue Agar medium and incubated at 35°C for 48 hours. Colonies having a green metalic sheen with dark centre were counted as *Escherichia coli* (APHA, 1976; Volk, 1992). The colonies were picked and straked on the nutrient agar slants and the slants were incubated at 35°C for 24 hours. Then the culture of the slants were subjected to the Gram's stain, IMV (Indole, Methyl Red and Voges-Proskauer) test and fermentation test, biochemical test for further confirmation.

Fecal *Sreptococcus* count

For fecal *Streptococcus* count Blood Agar medium was used. On this medium non-haemolytic deep colonies were counted as faecal *Sreptococcus* (APHA, 1976; Brock *et al.* , 1986). The colonies were picked and streaked on nutrients agar slands. After 24 hours incubation period at 35°C. The culture of the slants were subjected to Gram's stain, fermentation test and biochemical tests for further confirmaton.

Coagulase positive *Staphylococcus* count

One ml of each dilution of different samples was pipetted into petri plates. The plates were poured with tellurite glycine agar incubated at 35°C. Colonies having black surface were confirmed as coagulase positive *Staphylococci* (APHA, 1976 and Volk, 1992). The colonies were transferred to agar slants and incubated at 35°C for 24 hours. The culture of the slants were subjected to Gram's stain and fermentation test for confirmation.

Salmonella count

Brilliant Green Agar medium was used for enumeration and isolation of *Salmonella.* Colonies appeared as opaque and slightly pink colour surrounded by a brilliant red colour (APHA, 1976 and Brock *et al* ., 1986)..

Detection of *Vibrio parahaemolyticus*

Phosphate Buffer medium was used for detection of*Vibrio parahaemolyticus* .The homogenate sample was incubated at 37°C for 24 hours, after which it was diluted to the decimal dilution. The methods were followed as described by the Health and Welfare of Japan (Thatcher and Clark, 1968). Isolation and identification of bacterial flora of fresh and dry *Acetes* spp were determined by following Zobell and Upham (1944), Frobisher (1968), APHA (1976) and Volk (1992).

10.3. Results

Qualitative and quantitative studies on the bacterial flora of fresh and sundried *Acetes indicus* and *Acetes erythraeus* were observed and recorded (Table 25,26,27,28.a.b.c).

10.3.1. Qualitative

Three bacterial genera namely *Micrococcus, Pseudomonas* and *Achromobacter* were identified, from the fresh *Acetes* spp. In addition to these, three types of bacteria of public health significance namely *Escherichia coli,* faecal *Streptococcus* and coagulase positive *Staphylococcus* were found in fresh species (Fig.169).Whereas only fecal *Streptococcus* was recorded from the dried *Acetes* . No *Salmonella* and *Vibrio parahaemolyticus* were found in *Acetes* shrimps of fresh and dried samples (Table 27).

10.3.2. Quantitative

10.3.2.1. *Acetes indicus*

.Average total bacterial counts per gram samples of fresh *Acetes indicus* was recorded $5.11x10^5$.The higher densities of bacteria were recorded in monsoon (Fig.165,Table 25) with the maximum in July and August ($6x10^5$ bacteria/g) and the minimum in January ($4x10^5$ bacteria/g). In dried *Acetes indicus* samples in average 3.38×10^5 bacteria/g occurred (Table 25) and minimum number of bacteria ($2x10^5$ cell/g) was recorded in February (Fig.166). Highest number of pathogenic bacteria were found in fresh *Acetes indicus* samples than dried (Fig.167,Table 26). 2.5 cells of *E, coli* /g, 12 cells of *Streptococcus* /g and 3 cells of *Staphylococcus* /g were recorded of freshly caught *Acetes indicus* and in dried *Acetes indicus* 8 cells of *Streptococcus* /g were found.

10.3.2.2. *Acetes erythraeus*

The highest number of bacteria was found in *A. erythraeus* in monsoon months (May-August) Fig.165,Table 25, with maximum in July (6×10^5 bacteria/g) and the minimum in January (4.0×10^5 bacteria/g) during winter season.The average bacteria in fresh sample of *A. erythraeus* was (5.11×10^5 bacteria/g) and (3.03×10^5 bacteria/g) in dried sample was noticed. Highest number of pathogenic bacteria (3 cells of *E. coli* /g, 10 cells of *Streptococcus* /g and 2 cells of *Staphylococcus* /g) were counted for fresh samples, whereas in dried samples only 6 cells of *Streptococcus* /g was recorded (Fig. 168, Table 26).

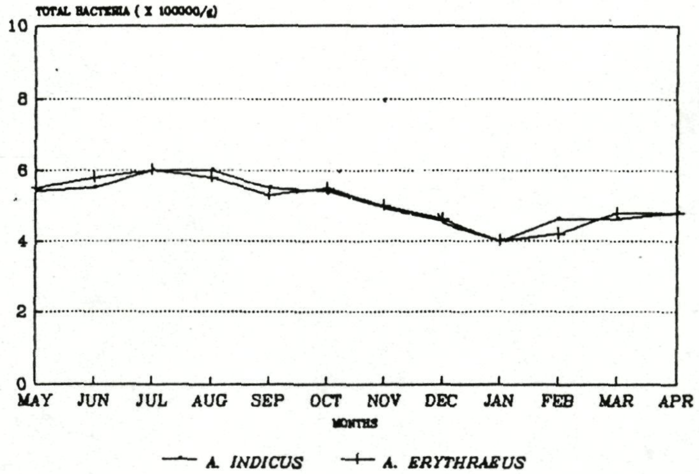


Fig.165. Monthly variation of total bacterial load in fresh *Acetes* shrimps (*A. indicus and A. erythraeus*) in the investigated area.

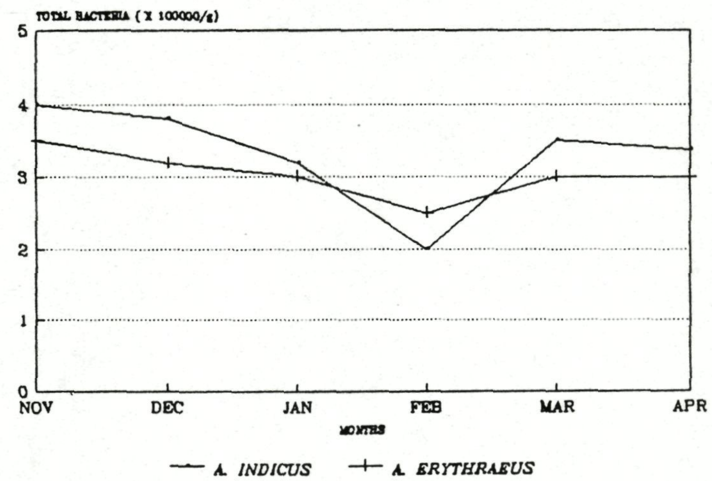


Fig.166. Variation of total bacterial load in the sun dried *Acetes* shrimps.

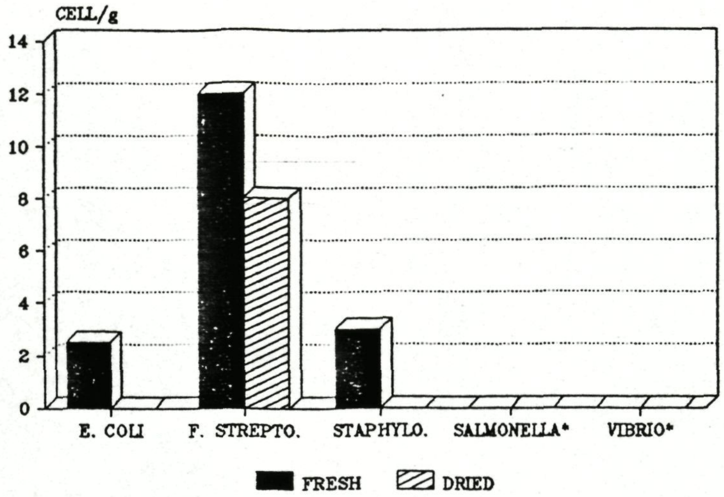


Fig.167. Showing different types of public health significance bacteria in the fresh *Acetes indicus* of the Mathamuhuri river estuary.

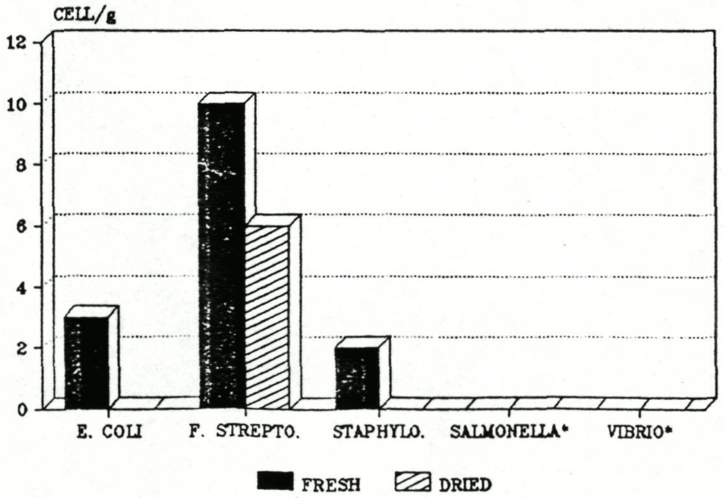


Fig.168. Showing different types of public health significance bacteria in the fresh *Acetes erythraeus* of the Mathamuhuri river estuary.

Table 25. Total bacterial counts ($x10^5$/g sample) of adult Acetes shrimps in the investigated area, Bangladesh.

Species		1992								1993				Yearly
		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average ($\bar{X}$)
Acetes indicus	Fresh	5.4	5.5	6	6	5.5	5.4	5	4.5	4	4.6	4.6	4.8	5.11
	Sun dried	NA	NA	NA	NA	NA	NA	4	3.8	3.2	2	3.8	3.5	3.38
Acetes erythraeus	Fresh	5.5	5.8	6	5.8	5.3	5.5	5	4.6	4	4.2	4.8	4.8	5.11
	Sun dried	NA	NA	NA	NA	NA	NA	3.5	3.2	3	2.5	3	3	3.03

Table 26.Qualitative and quantitative pathogenic bacterial counts of fresh and dry Acetes shrimps, Bangladesh.

Species	Condition	*E. coli*	Faecal *Streptococcus*	Coagulase positive *Staphylococcus*	*Salmonella*
Acetes indicus	Fresh	2.5	12	3	_
	Sun dried	_	8	_	_
Acetes erythraeus	Fresh	3	10	2	_
	Sun dried	_	6	_	_

Table 27. Pathogenic bacterial counts of fresh Acetes indicus/A. erythraeus of the Mathamuhuri river estuary, Bangladesh.

Sl. No.	Media	Cultural Characteristics	GS	MR	VP	Ind.	Fermentation of Sugars						Result	Remarks
							G	L	S	M	Ma	X		
1	Levin's E.M.B. agar	Colonies having green metalic sheen with a dark centre	[-ve] single	+	_	+	(+)	(+)	(+)	(+)	(+)	(+)	*E. coli*	*E. coli* presents only in fresh Acetes indicus & A. erythraeus
2	Blood agar	Non haemolytic deep colonies	[+ve] short chained	_	_	_	+	+	+	+	+	_	Faecal *Streptococcus*	Streptococcus faecalis present dry & fresh *Acetes indicus*
3	Tellurite Glycine agar	Colonies with black surface	[+ve] branches	_	_	_	+	+	(+)	_	+	_	Coagulase positive *Staphylococcus*	Present only in fresh Acetes spp., but absent in dry Acetes.
4	Brilliant dry agar	Slightly opaque colonies surro-unded by brilliant red color not found											No *Salmonella*	Totally absent in dry or fresh Acetes
5	Phosphate buffer medium	Suspected colonies not found											No *Vibrio parahaemolyticus*	Tottaly absent in dry or fresh Acetes

Abbreviations: GS=Gram staining, MR=Methyl Red test, VP=Voges-Proskeuer test, Ind=Indole test, G=Glucose, L=Lactose, S=Sucrose, M=Maltose, Ma=Manitol, X=Xylose, +=Acid production or positive reaction, (+)=Acid and gas production, _=Negative reaction or no change

Table 28(a). Morphological characteristics of the isolated of freshly caught Acetes indicus and A. erythraeus.

Sl. No.	Reaction to Gram Stain	Shape of cell	Grouping of cell	Reaction to acid fast	Spore formation	Motility
1	Gram-negative	Rod	Free	Not acid fast	No spore	Motile
2	Gram-positive	Spere	Free	Not acid fast	No spore	Non-motile
3	Gram-negative	Rod	Pair	Not acid fast	No spore	Non-motile
4	Gram-negative	Rod	Free	Not acid fast	No spore	Motile
5	Gram-positive	Sphere	Free	Not acid fast	No spore	Non-motile
6	Gram-negative	Rod	Pair	Not acid fast	No spore	Non-motile
7	Gram-positive	Sphere	Single	Not acid fast	No spore	Non-motile

Table 28(b). Culture characteristics of the isolates of freshly caught whole Acetes indicus & A. erythraeus.

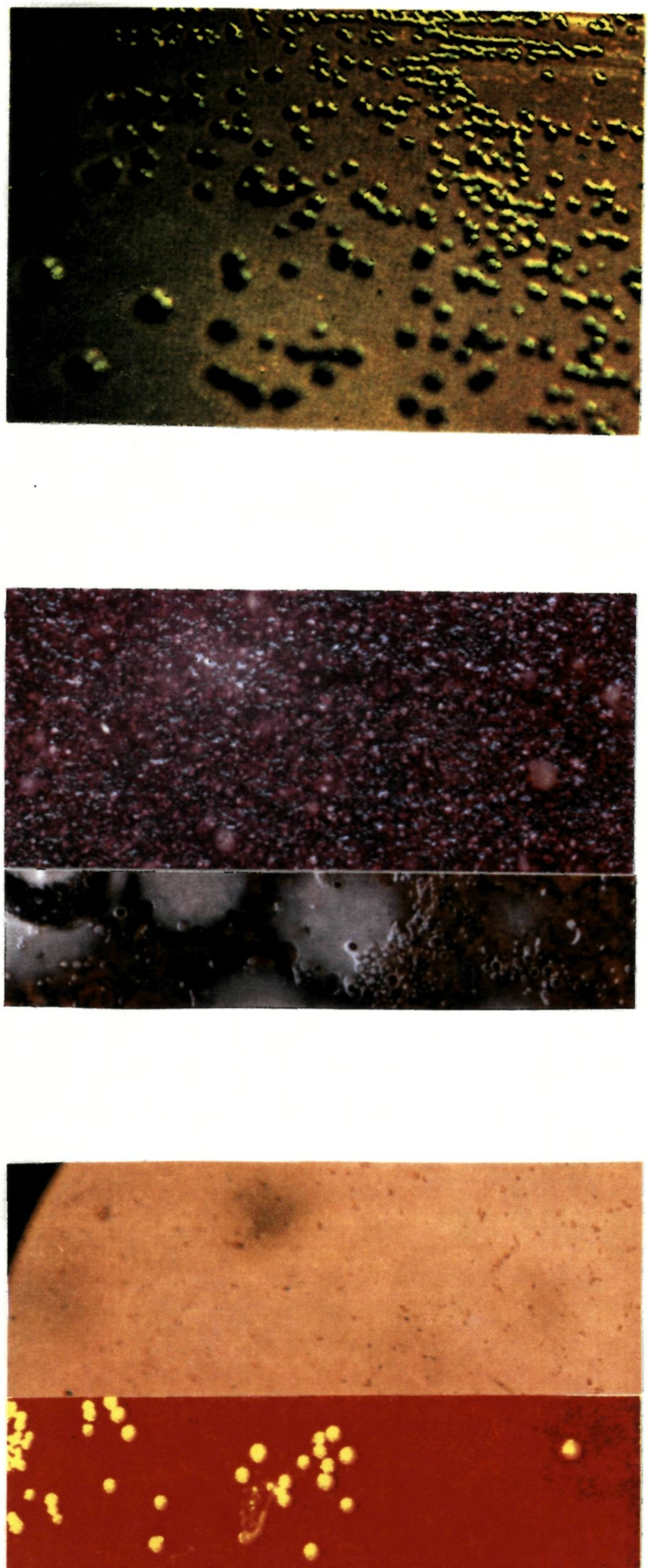
Sl. No.	AC	SWAS	SWB	FWB	Potato slant
1	Circular convex, entire blue-green, 1 mm	Filiform, heavy growth	Heavy turbidity, scanti sediment	Poor growth	No visible growth
2	Circular, convex, entire, no pigment 1.5 mm	Beaded, moderate growth	Slight turbidity, moderate sediment	Moderate growth	Heavy growth
3	Circular, lobate, convex, no pigment	Beaded scanty growth	Heavy pellicle, sufficient growth, flocculant	Very ppor growth	No visible growth
4	Flat, irregular edge, uneven surface, no pigment edge	Echinulate heavy growth	Heavy turbidity, moderate sediment, growth well	No visible growth	No visible growth
5	Circular, convex, entire, yellow 1.2 mm	Beaded, abundant growth	Heavy turbidity, slight sediment, growth along the wall	Moderate growth	Slight growth, potato darkened
6	Punctiform, convex, no pigment, 0.9 mm	Beaded, scanty growth	Heavy turbidity, flocculant, heavy pellicle	Very poor growth	No visible growth
7	Circular, entire, yellow, 1.2 mm	Beaded moderate growth	Evenly clouded, moderate viscid sediment	Good growth	Poor growth

Legends: AC=Agar colony, SWAS=Seawater agar slant, SWB=Sewater broth, FWB=Freshwater broth

Table 28(c). Biochemical reactions of the isolates of freshly caught whole Acetes indicus & A. erythraeus.

Sl. No.	Litmus Milk	Gelatin Liquification	Nitrate reduction	Amoonia production	MR test	VP test	Digestion of starch	Caesin digestion	Indole test	H_2S test	Fermentation of Sugars						Bacterial genus
											Gl	Su	La	Mal	Man	Xyl	
1	–	+	–	+	+	–	–	–	–	+	+	+	–	+	–	+	*Pseudomonus*
2	–	+	–	–	–	–	–	–	+	+	+	–	+	–	–	–	*Micrococcus*
3	–	+	+	+	–	–	–	+	–	–	+	–	–	–	–	–	*Achromobacter*
4	–	–	–	+	+	–	–	–	–	–	+	+	–	+	+	+	*Pseudomonus*
5	–	+	–	–	–	–	–	–	–	–	+	+	+	–	–	+	*Micrococcus*
6	–	+	+	+	–	–	–	–	–	–	+	–	–	–	–	–	*Achromobacter*
7	–	+	+	–	–	–	–	–	–	–	+	–	+	–	–	–	*Micrococcus*

Legends: Gl=Glucose, Su=Sucrose, La=Lactose, Mal=Maltose, Man=Manitole, Xyl=Xylose, +=acid production or positive reaction, -=negative reaction or no change, M.R.=Methyle Red, V.P.=Voges-Proskauer test



1

2

3

Fig.169. Showing photographs of three public health significance bacteria (*Escherichia coli*,[1] fecal *Streptococcus*[2] and coagulase positive *Staphylococcus*[3]) in the fresh *Acetes* shrimps.

10.4. Discussion

There is little information on microbial analysis on *Acetes* . Chung & Lee (1976) stated that marine bacteria of the genera *Acromobacter, Pseudomonus* and *Micrococcus* were isolated from fresh *Acetes chinensis* . Adnan & Owens (1984) reported that 4.2 x 10^6 cells/g in belacan (*Acetes* paste) of the microscopic bacteria count. Mulbagal *et al.* (1980) recorded 4.05 x 10^5 bacteria/g in oven dried (14°C, 24-28 hrs.) *Acetes* powder, and no coliform and *Salmonella* was determined by plate technique.They also recovered 3 x 10^5 bacteria/g, 20 cells of coliform/g, and no *Salmonella* were found in oven dried (40°C, 4-6 hrs.) in *Acetes* powder. Zachary and Colwell (1979) observed that 2.3 x 10^1-1 x 10^5 bacteria/g of copepods *Labidocera aestiva*). Ridley and Slabyi (1978) recorded 1.11 x 10^5 bacteria/g freshly caught shrimp (*Pandalus borealis*). From spones, Wilkinson (1978 a, b) calculated the bacterial numbers is 2.0 x 10^5 - 8.13 x 10^6/g. The present results of the bacterial analysis supports with the findings of Adnan & Owens (1984) and Mulbagal *et al* . (1980).

10.5. Conclusion and Recommendation

The microbial investigation is clearly indicated that *Acetes* is an ideal food. The concentration of total bacteria and also number of pathogenic bacteria are undoubtly acceptable.The highest cocentration and pathogen were found in the fresh *Acetes* than sun dried *Acetes* . So, dry *Acetes* is more useful in small-scale hatchery for larvae operation.

CHAPTER 11

GENERAL DISCUSSION AND CONCLUSION

Shrimps of the genus *Acetes* inhabit coastal and estuarine waters in tropical, sub-tropical and temperate parts of the world. They form an important component of coastal zooplankton communities (Young & Wadley, 1979; Chaitiamvong, 1980; Robertson & Duke, 1989; Zafar and Mahmood, 1989; Grabe and Lees, 1992, Zafar, 1992) and play significant role in the food webs of neritic waters, particularly mangroves and seagrass beds by linking vegetable materials, phytoplankton, zooplankton and animals of higher trophic levels (Job, 1940; Chacko, 1949; Tham, 1950; Xu, 1957; Venkataraman, 1960; Basheeruddin & Nayer, 1961, Omori, 1975). *Acetes* is preyed upon by widely diverse groups of animals that include ctenophores, cephalophods, crustaceans, fishes, crocodiles but also humans (Xiao and Greenwood, 1993). Zafar (1992) stated that *Penaeus monodon* and *Penaeus semisulcatus* showed significant relationship between *Acetes* in Kutubdia channel, lower delta of the Mathamuhuri river (Fig.143). In the Mathamuhuri river estuary *Acetes* is an important constituent of the shrimp communitiy and in the mangrove ecosystem of Chakaria-Sundarban *Acetes* was linked in the food webs with amorphous materials, phytoplankton, zooplankton and also with fishes. In the stomach of *Lates calcarifer, Therapon jarbua, Otolithoides pama, Glossogobius giuris* *Acetes* were found (personal observation).

Wood *et al.* (1992) stated that *Acetes* shrimp is a possible raw material for the manufacture of shrimp feed in India (Fig.170). Ali *et al.* (1984) have shown that frozen *Acetes* are ideal feeds for penaeid larvae, while Kungvankij *et al.* (1986) have used *Acetes* spp. as prime foods for the indoor and outdoor culture of *Penaeus monodon*. Nagabhushanam and Joshi (1986) have successfully cultured larval *Parapenaeopsis stylifera* using blended frozen *Acetes* and have forecast the great potential of *Acetes* feed for large-scale field aquacultural operations. Youguan and Jinglin (1989) reported that all essential amino acids in respect to nutritional requirements (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine) are presented in *Acetes chinensis* and *A. japonicus*. Generally 20-50% protein are the requirements for a fresh or saltwater shrimps. In *Acetes* 14% protein of wet weight and 64% protein of dry weight were found. Major elements especially high calcium content (about 1g/100g), low concentrations of radioactive elements (^{137}Cs 0.09, Bq/Kg, ^{40}K 9.83 Bq/Kg, ^{236}U 0.8 Bq/Kg and ^{232}Th 0.32 Bq/Kg) were recorded, and acceptable microbial limits (Total bacterial load 5 x 10^5/g in fresh *Acetes* and 3 x 10^5/g in sun dried *Acetes*) and below level of public health significance or pathogenic bacteria were found. *Salmonella* and *Vibrio* were totally absent in fresh and dry *Acetes* shrimps. The present study of biochemical and microbial analyses clearly shows *Acetes* shrimp is an ideal food material.

The annual world catch of *Acetes* is estimated to about 1,70,000 tons, or about 15% of the total shrimp catch in the world (Omori, 1975). The average annual catch of *Acetes* spp. from Indo-Asia during 1979 to 1989 exceeded 228850 tons and comprises about 50% of the annual shrimp (Natantia) catch in the Indo-West-Pacific region (473600 tons in 1970) and

25% of the world's annual total shrimp catch (930000 tons in 1970), FAO, 1971. *Acetes* fisheries operate mainly in Asia and to a muh lesser extent in Africa and South America (Omori, 1975). *Acetes chinensis, A. erythraeus, A. indicus, A. japonicus, A. serrulatus, A. sibogae* and *A. vulgaris* are used singly or in combination, in commercial fisheries in China, India, Indonesia, Japan, Korea and Thailand. Smaller amounts of *Acetes* are caught for consumption in Combodia, Myanmar, Vietnam (Isarankura, 1974), possibly Bangladesh, Pakistan and Srilanka (Mistakidis, 1973; Omori, 1974 & 1975). A limited amount of *A. erythraeus* is harvested in Madagascar (Crosnier & Fourmanoir, 1962; Le Reste, 1970) Mocambique (De Freitas, 1966; MacNae, 1974) and Tanzania (Mwaiseje, 1982) and only a small amount of *A. americanus* is consumed in Surinam and French Guiana in South America (Holthuis, 1959 & 1980). *Acetes* exists probably in potentially exploitable quantities in other tropical, sub-tropical and temperate regions such as coastal areas of the United States in the Gulf of Mexico, and coasts of Australia, but is not fished due to lack of appropriate technologies for harvesting and food processing, richness of other resources, and/or small size of local market.

In Bangladesh coastal waters, the genus *Acetes* is widely distributed. Mahmood (1984), Zafar and Mahmood (1989), Zafar (1992) and present observation). Only small-scale fishermen and penaeid fry catcher (Fig.146) exploit it for human food. A general model (Fig.171) is presented. This model could be useful for fishermen and aquaculturists, and to mitigate the protein deficiency of tropical and subtropical countries and helpful to the development of the hatchery and aquaculture.

The present study showed maximum densities of *Acetes* occurred during post-monsoon months (October-November) and pre-monsoon months (April-May) and minimum was in monsoon period, especially in rainy months (August-September). Lamboef (1987), Zafar (1992) stated that the geoclimatic environment of the Bay of Bengal, particularly the Bangladesh portion is dominated by wind direction, precipitations under the influence of the tropical monsoon climate, and river discharge. These factors have a strong influence on the marine environment as they affect, to a varying extent and varying time sequence, the water circulation, salinity, turbidity, productivity and bottom topography. In the Mathamuhui river estuary *Acetes* showed strong seasonality and that seasonality was correlated closely with arrival and departure of monsoons. During monsoon especially in rainy season (August-September) *Acetes* did not immigrate in the Mathamuhuri river of Chakaria sundarban area to adverse factor of monsoon. Correlation and CANOCO (RDA) analyses shows that *Acetes* abundance in the investigated estuary were correlated with salinity and sunshine, and apparently there is a insignificant positive correlation between phytoplankton and *Acetes* density of the investigated area. But in their diet about 50% of phytoplankton is found.The upstream station showed comparatively lower densities than down stream station and during night almost always higher densities were found at station 2. In the lower station of the studied estuary *Acetes* came (immigration) from offshore

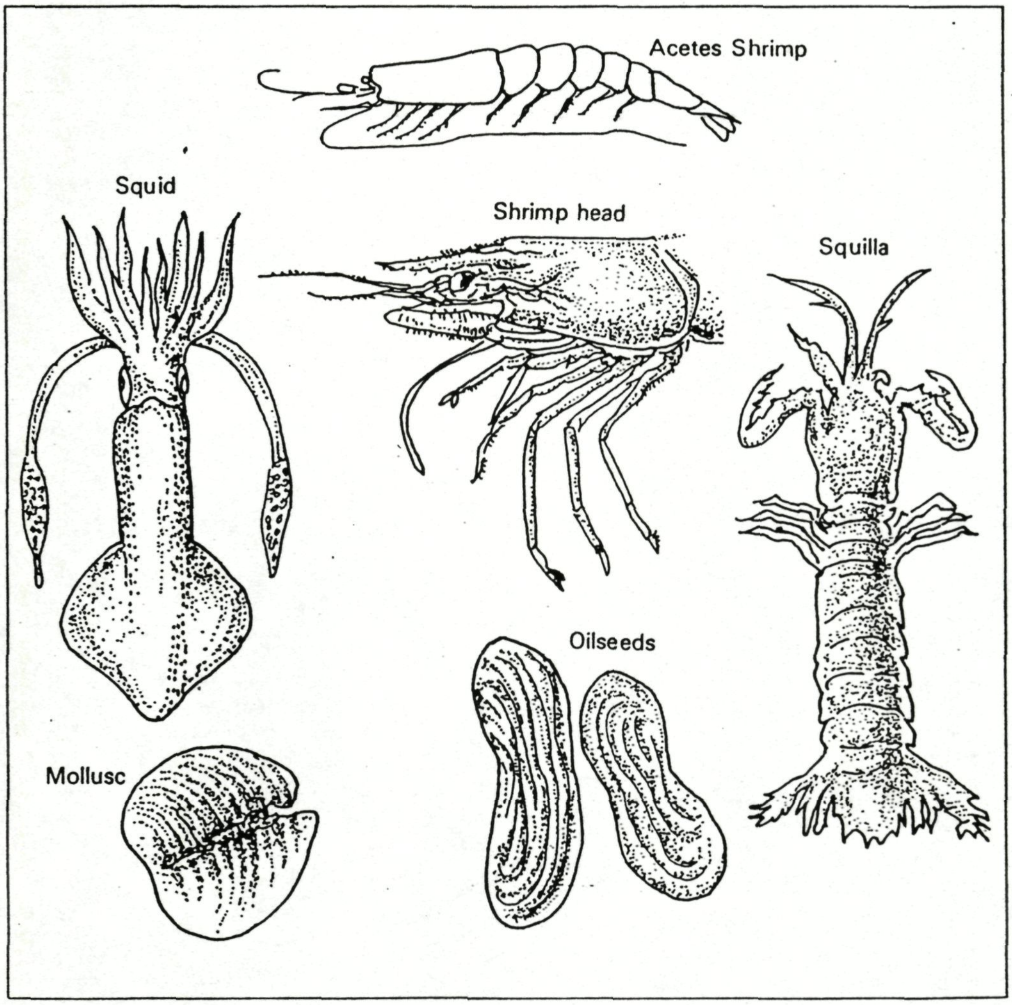


Fig.170. Showing possible raw materials for the manufacture of shrimp feed in India (Wood et al., 1992);

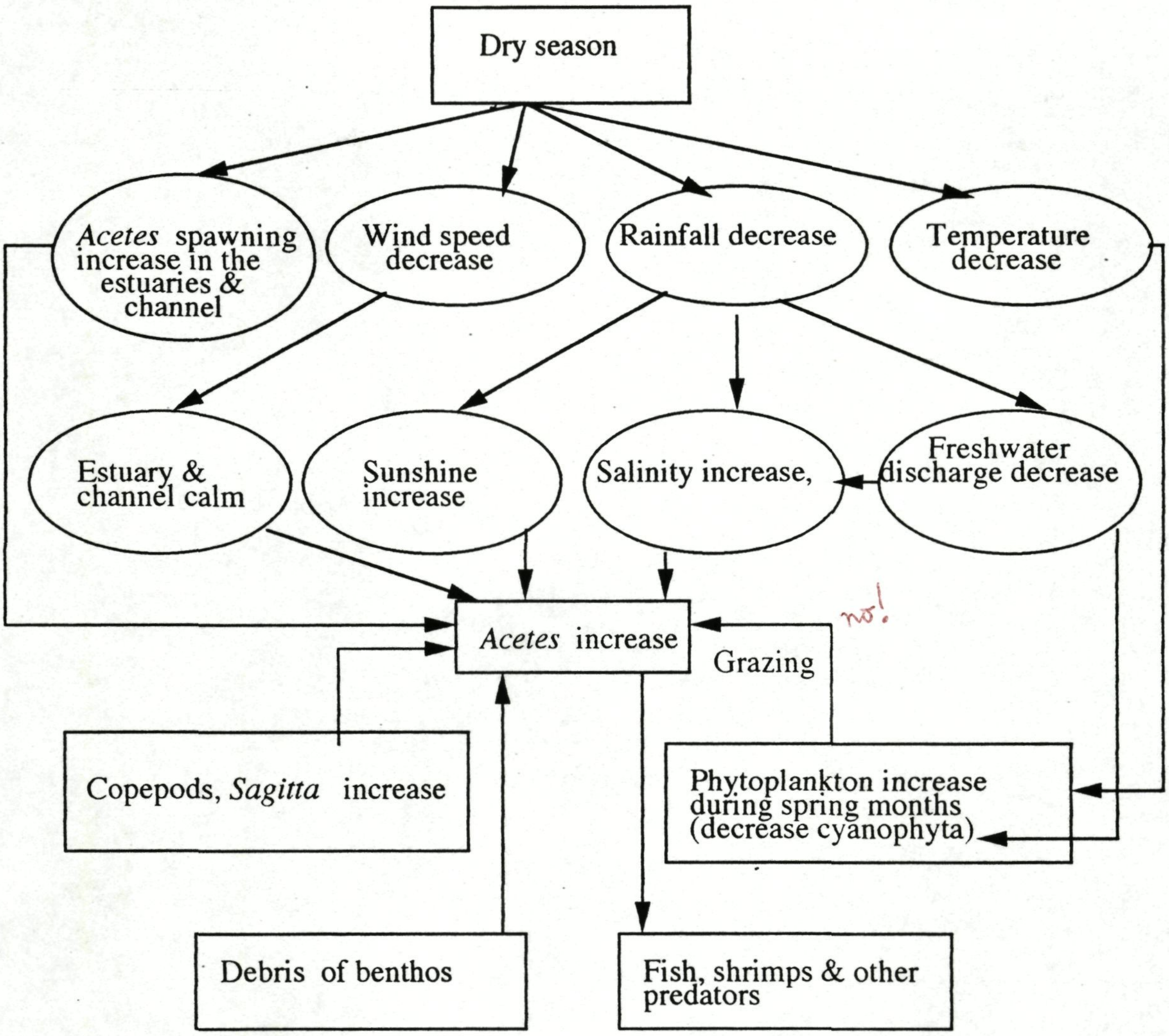


Fig.171. A general model during the peak occurrence of adult *Acetes* shrimps in the Mathamuhuri river of Chakaria mangroves ecosystem, Bangladesh.

Islands coastal waters Kutubdia and Moheskhali channel. Xiao and Greenwood (1993) stated that *Acetes* were mainly distributed near the mouths of estuaries. In the Mathamuhuri river of Chakaria sundarban area adults are entering with saline water.

Bottom densities were significantly higher in values than surface, and even in night bottom abundance were higher than surface samples in the Mathamuhuri river estuary. Zafar (1986) stated that bottom samples were higher in values than surface samples in the Satkhira estuarine system, southwestern coastal waters of Bangladesh. So, present investigation concluded that *Acetes* are hyperbenthic shrimps.

This results as well as other observations of Bangladesh coastal waters (Zafar & Mahmood, 1989; Zafar, 1992; Alam, 1995 and Chowdhury, 1995) indicated that mangrove tidal area, estuaries, channel and surrounding waters of offshore islands are suitable areas for breeding and nursery ground of *Acetes* and concluded that the lower delta of the Mathamuhuri river of Chakaria mangrove area off Bangladesh coastal waters is an ideal place for *Acetes* shrimps. Comparatively higher densities of *Acetes* shrimps were recorded when natural mangroves was not cleared or destructed. Eleven deltaic islands at the confluence of the Mathamuhuri river estuary once supported a luxuriant mangrove vegetation the Chakaria-Sundarbans, a well known mangrove ecosystem of Bangladesh. This forest reserve used to cover an area of about 8510 ha till 1977 and now about 75% of the area has been leased out, where mangroves have been removed for preparation of shrimps ponds. Anticipating threats to this productive ecosystem, and based on the result of this investigation, conservation measures are suggested and reminded not to forget its value as a natural nursery ground for important shrimps and other fisheries items.

It is possible for Bangladesh that large amount of *Acetes* shrimps are commercially harvested and utilized as food or feed for aquaculture and human consumption to fulfilment of protein defficiency of people.

This study has shown that:

1. Fluctuations of hydrometeorological factors are related to seasonal influences of the Mathamuhuri river estuary in the coastal waters of Bangladesh.

2. Six species of *Acetes* were recorded in the Mathamuhuri estuary. Three species (*A. intermedius, A. vulgaris* and *A. chinensis*) are new records for coastal waters of Bangladesh.

3. In the Mathamuhuri river estuary *Acetes* showed seasonality and that seasonality it is correlated closely with arrival and departure of monsoon. Two peak occurrence of *Acetes* shrimps were found (October- November) just after the monsoon months and (April-May) prior to the start of the monsoon. In the rainmonsoon months (August-September) almost *Acetes*

disappeared, due to adverse factors of monsoon, and during rainy season most of the *Acetes* shrimps did not immigrate for low salinity in the Mathamuhuri river of Chakaria sundarban from the lower coastal areas of Bangladesh coastal waters.

4.The density of *Acetes* in the Mathamuhuri river estuary was not related to only one factor, because monsoon is influenced by several factors. CANOCO & correlation analyses showed the abundance of *Acetes* was related to salinity and sunshine, and opposite to rainfall and dissolved oxygen (which themselves are related to the monsoon months).

5.Apprently there is no significant relation between phytoplankton and *Acetes* shrimps, and they only maintained parallel relationship with Bacillariophyta, which represent their main food.

6. *Acetes* spp has strong relationships with Alpheid shrimp PL, Squilla and also parallel correlation with Hydromedusae and *Parapenaeopsis* PL (these organisms are known as being the predators of *Acetes*).

7. This investigation clearly reflects that ingress of *Acetes* shrimps takes place more at night in comparision to that of the day and they migrate in higher densities through bottom waters which is reversed at night. At that time it was suggested that they could feed on plankton, their mean food (Diatoms & Copepods).

8. Bottom samples were higher in values than surface samples, even at night higher abundance of *Acetes* were recorded at lower station.

9. The genus of *Acetes* in the study area was dominated by four species (*Acetes indicus* 45.35%; *A. erythraeus* 33.22%; *A. chinensis* 7.46%; *A.japonicus* 6.80%). All species of *Acetes* occurred in large schools during northeastern monsoon, when the weather was fine, area of saline water increased and the estuary or sea calm; and higher abundance was observed in dense mangroves.

10. The delta of Mathamuhuri river and its adjacent area of the Kutubdia & Moheskhali channel is a good nursery and fishing areas of *Acetes* shrimps, especially in premonsoon and postmonsoon months.

11. High protein content (15% of wet weight and 65% of dry weight in sun dried *Acetes*), significant amount of calcium (1g/100g), 2.5-5.05 mg/100g of iron, 80- 100mg/100g of phosporous, 2-2.5g/100g of nitrogen; and low concentration of radionuclides {^{238}U (0.08 ± 0.02 Bq/Kg), ^{232}Th (0.32 ± 0.09 Bq/Kg) and ^{40}K (9.83 ± 0.79 Bq/Kg)}, and chitin (3.7-3.9g/100g) were found in *Acetes* .

12. Acceptable bacterial population (5 x 10^5 cells/g) in fresh *Acetes* , and 3 x 10^5 cells/g in sun dried *Acetes)* and lower concentration of pathogenic bacteria, no *Salmonella* and *Vibrio* were recorded in *Acetes* spp.

Comparatively dry *Acetes* is more acceptable food for larvae culture in a hatchery.

Recommendations

1. *Acetes* is an ideal food for fish, shellfish and humans.

2. This report will significantly contribute in higher catch of *Acetes* shrimps from the coastal water in Bangladesh and growing knowledge to increase the production of fish and shellfish and to mitigate the protein deficency of tropical and subtropical countries and helpful to the development of the shrimp hatchery and aquaculture.

3. Recognising the importance of the Mathamuhuri river estuary as a natural spawning & nursery ground for shrimp and others, conservative measures are essential for preventing rapid destruction of mangroves of the Chakaria-Sunderbans for saving shrimp ecology for long term economy of the related country.

4. Sewage, high water discharge with soil particles, untreated waste materials (oils, faecal) dumping from ships will a serious problem in future for shrimps spawning and nursery ground in the Chakaria Sundarban and its adjacent coastal waters. So initiative measures are necessery on those regards.

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Brussel, 7 mei 1996.

Aan Prof. P. POLK
ECOL

WE/U/4382/RDS

Geachte professor,

De Fakulteit WE heeft de examencommissie voor de promotie van de heer Zafar Mohammad als volgt samengesteld :

- Prof. P. Polk, voorzitter
- Prof. N. Daro, promotor
- Prof. C. Joiris
- Prof. N. Koedam
- Prof. N. Mahmood, University of Chittagong
- Dr. F. Redant, Instituut voor Zeevisserij
- Dr. J. Mees, RUG

De besloten verdediging zal plaatshebben op maandag 13 mei om 15u in lokaal 7F414.

Met de meeste hoogachting
en vriendelijke groeten,

i.o.

Prof. H. EISENDRATH,
Dekaan Fakulteit WE.

C.C. aan de leden van de examencommissie
aan de heer Zafar.

* $[O_2] \sim t^\circ$ cf. saturation.

RDA phytoplankton → no rel!

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reason to ~~believe~~ think radio-activity present?

MODEL

N.F.W.O. DOSSIER
I.I.K.W.
F.G.W.O.
F.K.F.O.
27 NOV. 1991
PARAAF

Academiejaar 1990-1991

Jaarverslag

Het ganse academiejaar werd doorgebracht aan de Universiteit van Calgary (Canada) in het laboratorium van Professor Kostas Iatrou, met als doel het aanleren van moleculair biologische technieken die ons zouden toelaten bepaalde problemen uit de fysiologie van insecten, o. a. hormonale regulatie van de reproductie, vanuit een nieuw gezichtspunt te benaderen. Er werd onderzoek verricht op een interessant ontwikkelingsbiologisch systeem : het ovarium van de zijdepop, *Bombyx mori* (Lepidoptera). Het ovarium van *Bombyx* bestaat uit 4 strengen van follikels (ovariolen). De differentiatie van de follikels in de ovariool gebeurt asynchroon ; elke 2-3 uren start een follikel die geproduceerd wordt in het germarium een ontwikkelingsprogramma dat de follikel voert doorheen de verschillende stadia van previtellogenese en vitellogenese tot de follikulaire cellen hun terminale differentiatie ondergaan. Dit laatste houdt voornamelijk de productie in van de eischaal of het chorion. Elke ovariool bestaat dus uit een reeks follikels die elk een welbepaald ontwikkelingsstadium vertegenwoordigen ; in een ontwikkelende ovariool aan het einde van het popstadium zijn alle stadia van follikulaire ontwikkeling (previtellogene, vitellogene, choriogene en geövuleerde follikels) vertegenwoordigd. Het onderzoek dat door ons werd uitgevoerd had betrekking op de hormonale regulatie van de productie van het chorion.
Het is bekend dat de ontwikkeling van het ovarium van *Bombyx* geïnduceerd wordt door het vervellingshormoon, 20-hydroxy-ecdysone, bij het begin van de verpopping. Het gevolg van de stijging van de concentratie van 20-hydroxy-ecdysone in de haemolymfe is, dat follikels om beurt hun ontwikkelingsprogramma zullen starten dat vijf dagen later zal resulteren in de productie van chorionproteïnen door de follikulaire cellen. Het is echter niet bekend of dit programma volledig follikel-autonoom is, dan wel dat bepaalde aspecten van het programma (choriogenese) afhankelijk zijn van factoren in de haemolymfe (hormonen). Hiervoor werden ovariolen van *Bombyx* in orgaancultuur gebracht en na 24, 48 en 72 uren werd er nagegaan welke prechoriogene follikels in staat waren de choriongenen tot expressie te brengen. Expressie van de choriongenen door individuele follikels werd onderzocht zowel op het niveau van mRNA (Northern blot analyse) als op het niveau van de proteïnen (SDS-polyacrylamide-gelelectroforese na pulse-labeling met radioactieve aminozuren). Deze experimenten hebben ons tot de conclusie geleid dat de laatste 17 (± 2) prechoriogene follikels in staat zijn om autonoom (d.i. in orgaancultuur) het ontwikkelingsprogramma van choriogenese te starten. Dit aantal is significant kleiner dan datgene wat waargenomen wordt *in vivo*, wat betekent dat de prechoriogene follikels proximaal van de 17de prechoriogene follikel afhankelijk zijn van extra-ovariële factoren opdat ze het programma van choriogenese zouden kunnen starten. Dit leidde tot de volgende werkhypothese : het programma van

Chapter 1. Review of literature?

Chapter 2. || Physiology of a river?
|| Physiography

(p3) Selection sampling stations??] cf.

Chapter 4: spatial pattern in PP along est. grad.
sc

31 species → what happened with these?? MVA?

Chapter 6: 6.1. Intro, last sentence???

Identification levels used??? Other???

* (Why use RDA???)

p66: higher in st 2. due to?. flushed out during monsoon?

p76 - p74: RDA with 4 species! nonsense!

p75: + rel with phyto??

p81: fig 143. relevance??

Chapter 7: p87, fig 145 relevance???

General: • phytopl. study more detailed than zoo.
||
background trying to explain Acetes distr??

Abstract: • sentence? immigration for feeding & spawning ?
↕
salinity tolerance.

• higher abundance ~ dense mangroves / no aquaculture?

Chapter 8: food comp: (numerical????) *

~~General - data analysis - length / growth / rel. food ??~~

~~(p83) spawning ... date??~~

~~[illegible]~~

(Chap 10) Discussion 1/2 p.

(p106) Copied!!

DIEPTE 5/10

Nr Station ____________ Plaats ____________ Datum ____________.

SOORT: ______________________________.

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OPMERKINGEN

INTERUNIVERSITY PROGRAM F.A.M.E.

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Geachte Dr. Mees,

Gelieve hier in bijlage een exemplaar te vinden van de Ph.D. thesis van Mohammad Zafar.

De private verdediging zal plaatsvinden op 13 mei in de VUB. Het juiste uur en lokaalnummer worden later nog doorgegeven.

Met vriendelijke groeten,

Prof. N. Daro

'APPENDANT THESIS'

By

Zafar Mohammad

PROTECT THE MANGROVE FOREST FROM DESTRUCTION FOR THE LONG-TERM ECONOMY OF BANGLADESH.