

***ENVIRONMENTAL AND HYDROLOGICAL
CHARACTERISTICS INFLUENCING CRASSOSTREA BEDS
FROM SELECTED MANGROVE HABITATS***

4.1. Introduction:

Mangroves are complex and dynamic ecosystem, greatly influenced by interrelated environmental and climatic factors (Naskar and Mandal, 1999). Distribution and zonation of mangroves and its associates are usually influenced by various physical and chemical factors such as tidal gradients, temperature, salinity, rainfall, freshwater inputs and sediment characteristics (Jagtap, 1985; Tomlinson, 1986; Naskar and Mandal, 1999; Kathiresan and Qasim, 2006).

The characteristics, i.e. distribution and structure, of mangrove habitats govern the associated biotic communities including oyster population. Other associated parameters of these ecosystems constitute substrate, water movements, pH, water salinity, temperature and abundance of planktonic food (Rao and Nayar, 1956; Mahadevan and Nayar, 1987). The filtration rate of bivalves depends upon the temperature and speed of water current in ambience (Walne, 1972).

Formation and growth of oyster beds is greatly influenced by the prevailing ecological and environmental qualities. Therefore, it is necessary to understand various biotic and abiotic characteristics pertaining to the mangrove harbouring oyster areas.

In the present investigation, attempts have been made to study the physico-chemical parameters (temperature, salinity, pH, dissolved oxygen, particulate organic carbon and nutrients ($\text{NO}_3\text{-N}$, $\text{NO}_2\text{-N}$ and $\text{PO}_4\text{-P}$)) of the overlying water at the sites of oyster beds in the close vicinity of mangrove habitat. Climatology and environmental data relevant to study areas have been described in relation to oyster beds.

4.2. Results:

4.2.1. Climate:

The climate of Goa though remain equable, depending upon temperature, humidity and rain, it is broadly divided into three seasons, i.e. pre-monsoon (February to May); monsoon (June to September); and post-monsoon (October to January).

The atmospheric temperature varied from a minimum of 16.6 °C in December 2005 and January 2006 to a maximum of 37.3 °C in the month of February. The average of maximum temperature ranged between 34.1 °C in February 2006 and minimum of 29.6 °C in September 2005. The average

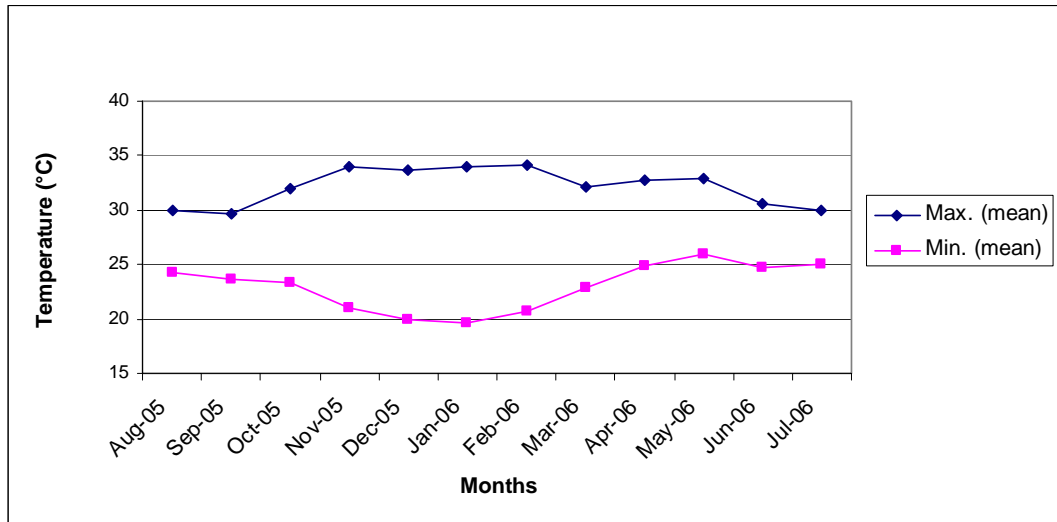


Figure 4.1. Seasonal average in air temperature in Goa during August 2005 – July 2006.

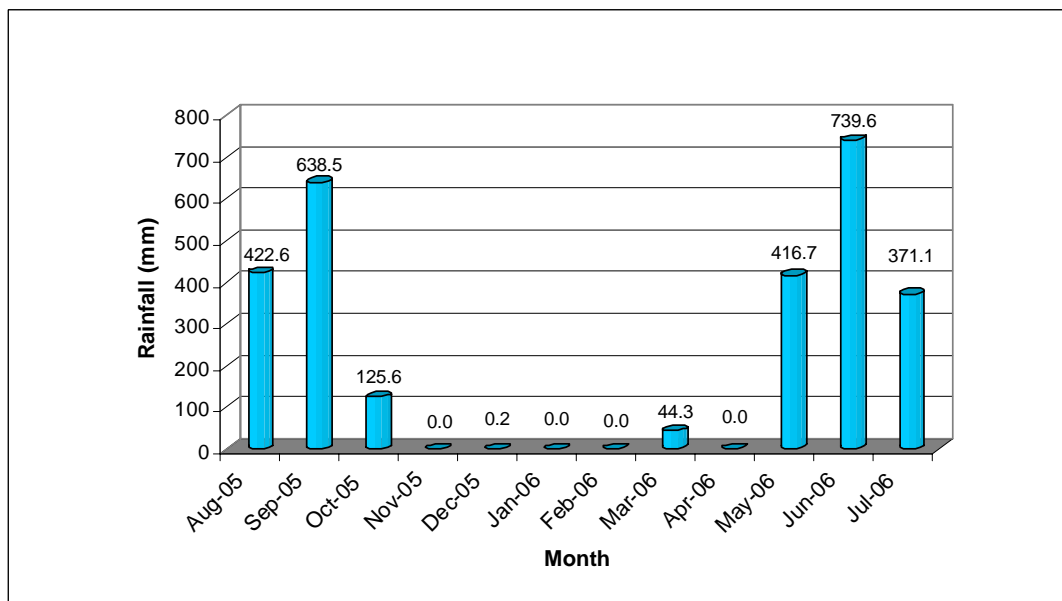


Figure 4.2. Seasonal variation in rainfall in Goa during August 2005 – July 2006.

of minimum temperature ranged between 19.6 °C in January and 26.0 °C in May 2006 (Figure 4.1).

The total rain fall during sampling period received in the state of Goa was about 2,758.9 mm. The major portion of rainfall is received from South-west monsoon during June to September. The highest amount of rains received during the months of September 2005 (638.5 mm) and June 2006 (739.6 mm). Occasional post and pre-monsoon showers also encountered in the months of October 2005 and May 2006, respectively (Figure 4.2). Except negligible precipitation in March, no rainfall was practically observed from November 2005 to April 2006.

The relative humidity ranged from 65.5 % during the month of January 2006 to 90 % during September 2005 with an annual average of 77.3 % (Figure 4.3). Wind speed varied from 3 to 13 km/h with an annual average of 6 km/h. The area experienced gusty winds during monsoon season with a peak value in July 2006 (Figure 4.4). Calm weather prevailed during post-monsoon and then started to increase in pre-monsoon towards the monsoon season.

4.2.2. Physico-Chemical Parameters of Water:

4.2.2.1. Temperature:

At St-1, water temperature varied from 25 °C in September 2005 to 34 °C in

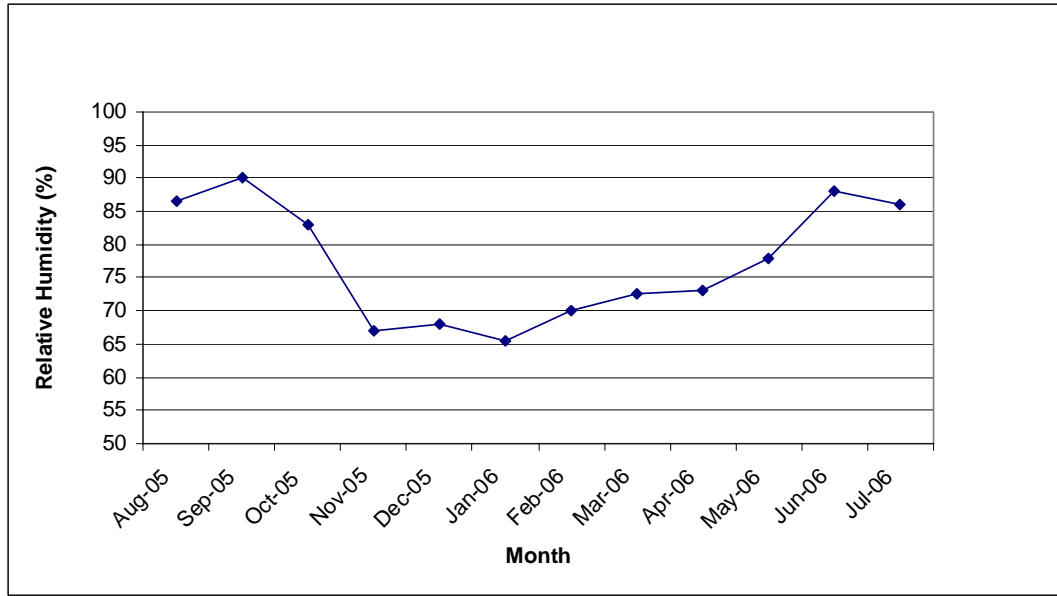


Figure 4.3. Seasonal variation in average relative humidity in Goa during August 2005 – July 2006.

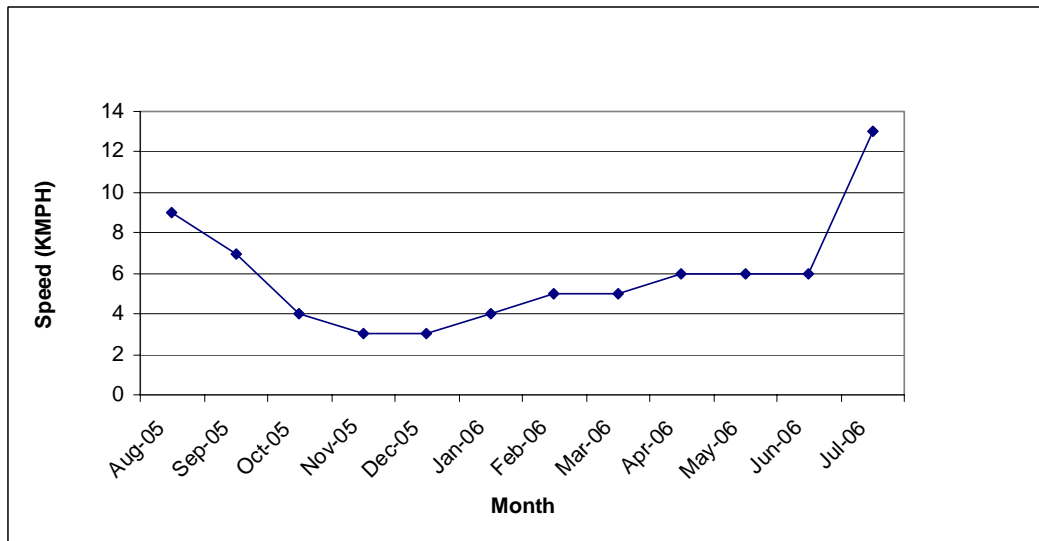


Figure 4.4. Seasonal variations in average wind speed in Goa during August 2005 – July 2006.

May 2006, while at St-2, it ranged between minimum of 25 °C in September 2005 and maximum of 36 °C in the month of May 2006. Generally, temperature was low during monsoon (June – September), and increased in October 2005, and then decreased in November. Thereafter, it gradually increased reaching its peak (34 °C and 36 °C at St-1 and St-2, respectively) in the month of May 2006. During monsoon period, the water temperatures from both stations were relatively low (Figure 4.5). The average water temperature recorded during the sampling period was 29.7 °C ± 2.4 and 30.8 °C ± 2.7 from St-1 and St-2, respectively.

4.2.2.2. Salinity:

Salinity of water ranged from 0.23 psu to 32.44 psu and 1.00 psu to 36.44 psu at St-1 and St-2, respectively. At St-1, water salinity was low during rainy season and it gradually increased in post-monsoon season (October – February). Minor variations then observed with salinity concentrations till the end of May 2006 (Figure 4.6). However, at St-2, there was a marked increase in salinity values between September and October 2005, and further increased until January 2006. Slight decline in salinity values was observed during March 2006, however, later increased to reach its peak in May 2006. Both stations showed a sudden decrease in salinity concentrations during monsoon season.

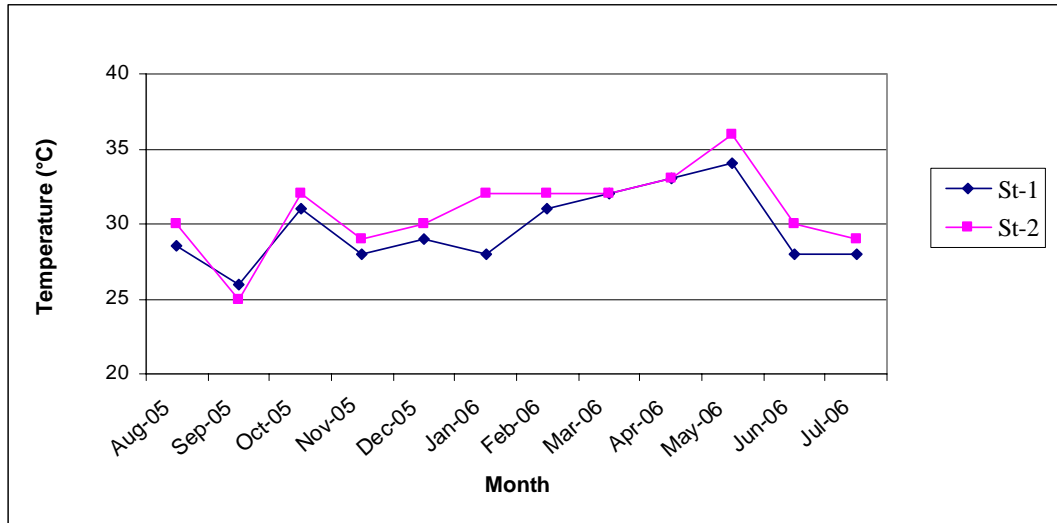


Figure 4.5. Seasonal variation in water temperature during August 2005 – July 2006.

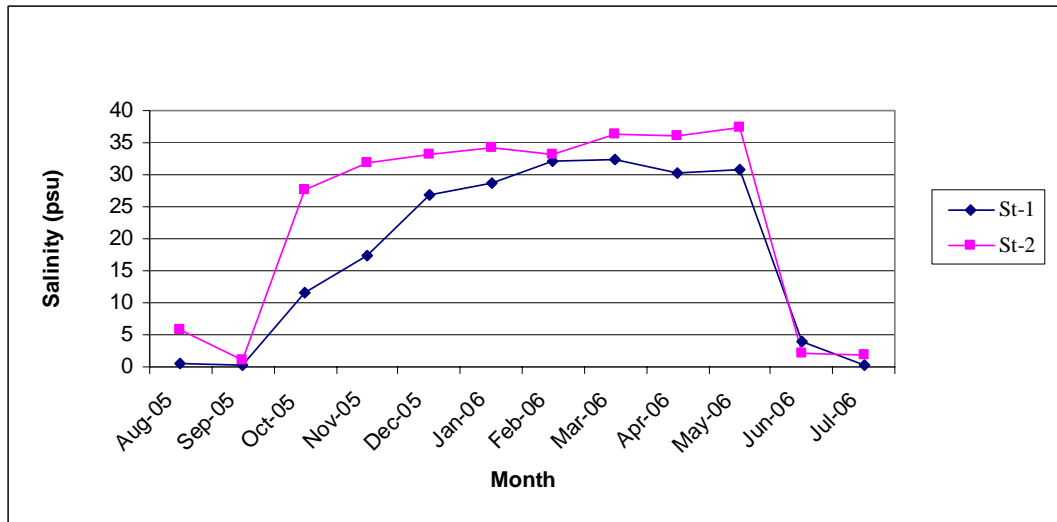


Figure 4.6. Seasonal variation in water salinity during August 2005 – July 2006.

4.2.2.3. pH:

Marked fluctuation was noticed in pH values at St-1 from 6.85 in June 2006 to 8.10 in November 2005. A gradual increase in pH was recorded from August to November 2005 followed by a decrease in December. However, pH remained slightly stable during January to March 2006, and it increased in April and May 2006, and later reduced during monsoon period (Figure 4.7). The similar trend was observed in pH values from St-2 (Figure 4.7) with low values during monsoon. The highest value (8.69) was recorded during November 2005, while it was lowest (7.03) in January 2006.

4.2.2.4. Dissolved Oxygen (DO):

Figure 4.8 depicts the seasonal variations in DO concentration during the sampling period. Dissolved oxygen values fluctuated in the range of 2.50 mg/l in February 2006 and 4.56 mg/l during September 2005 to July 2006 at St-1. The concentration increased from August 2005 and reached to its first peak (4.46 mg/l) in September 2005, and further fluctuated up to December 2005. Slight variations in DO values were observed from December 2005 to February 2006 and later it gradually increased to reach the concentration of 3.63 mg/l in April 2006. However, DO values declined from April onwards till June 2006. The concentration showed a sudden increase (4.65 mg/l) in the month of July 2006 with first monsoon showers.

At St-2, the DO concentrations ranged between 2.53 mg/l and 5.59 mg/l

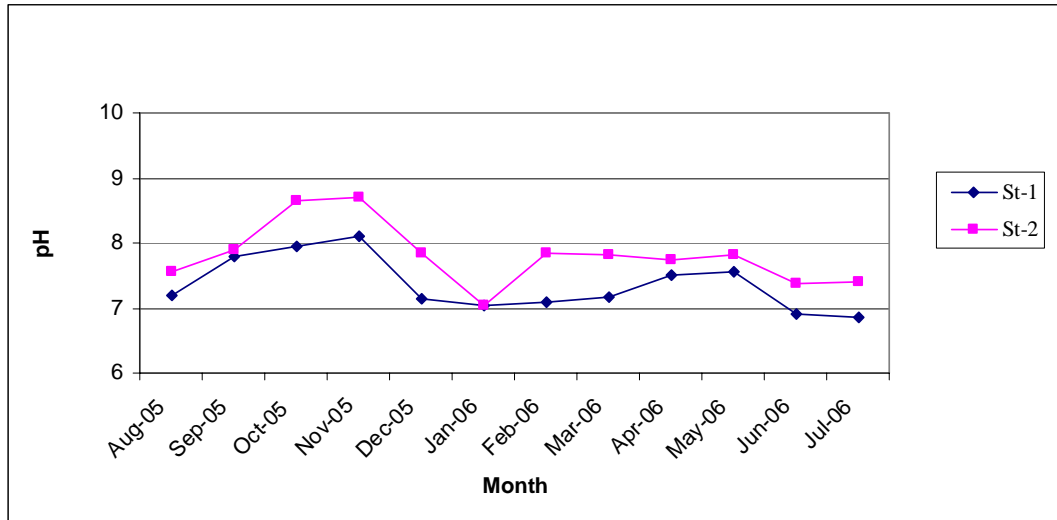


Figure 4.7. Seasonal variation in water pH values of water during August 2005 – July 2006.

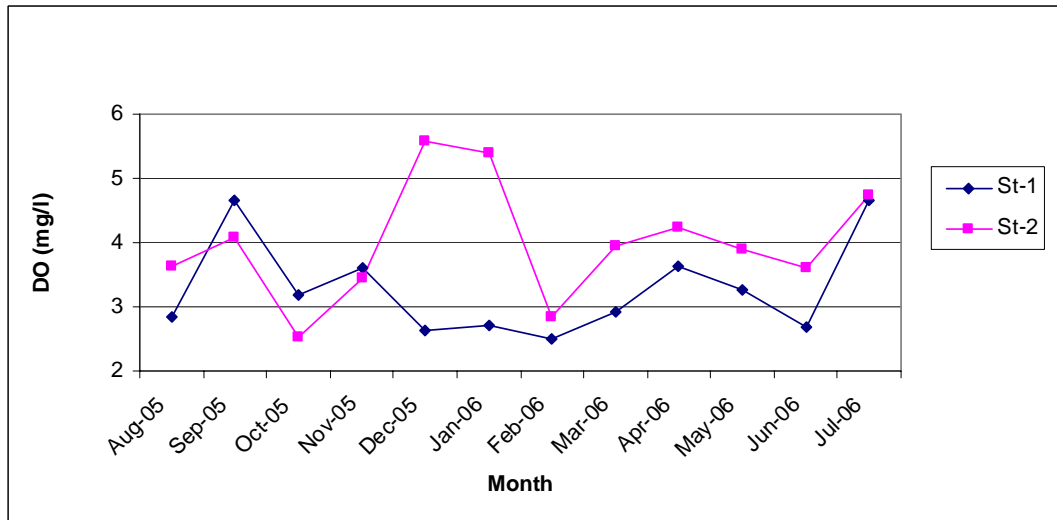


Figure 4.8. Seasonal variation in the concentration of dissolved oxygen in water during August 2005 – July 2006.

with minimum in October and maximum in December 2005, respectively. Slight increase was observed from August to September 2005, however, its concentration dropped in October 2005. A steep increase was recorded till it reached its highest values (5.59 mg/l) in December 2005. In February 2006, the DO content reached to its lowest (2.84 mg/l), and from March 2006 onward, it exhibited similar trend as observed at St-1 (Figure 4.8).

4.2.2.5. Particulate Organic Carbon (POC):

Particulate organic carbon (POC) values showed slight variations from August to November 2005 at St-1. It decreased drastically in December 2005 to its lowest value (475.25 $\mu\text{g C/l}$), later, it increased gradually from January (Figure 4.9) to April 2006. The highest value (2809.21 $\mu\text{g C/l}$) was observed in June 2006. Similarly, POC concentrations at St-2 showed slight decrease from August and reached to its lowest (357.26 $\mu\text{g C/l}$) in December 2005. It was increased in January 2006 to 936.81 $\mu\text{g C/l}$, however, it continued to decrease until April 2006. The highest value (2271.44 $\mu\text{g C/l}$) of POC was recorded in the month of June 2006 (Figure 4.9).

4.2.2.6. Nutrients:

Nutrient concentrations showed marked seasonal fluctuations at both stations during the period of study (Figure 4.10).

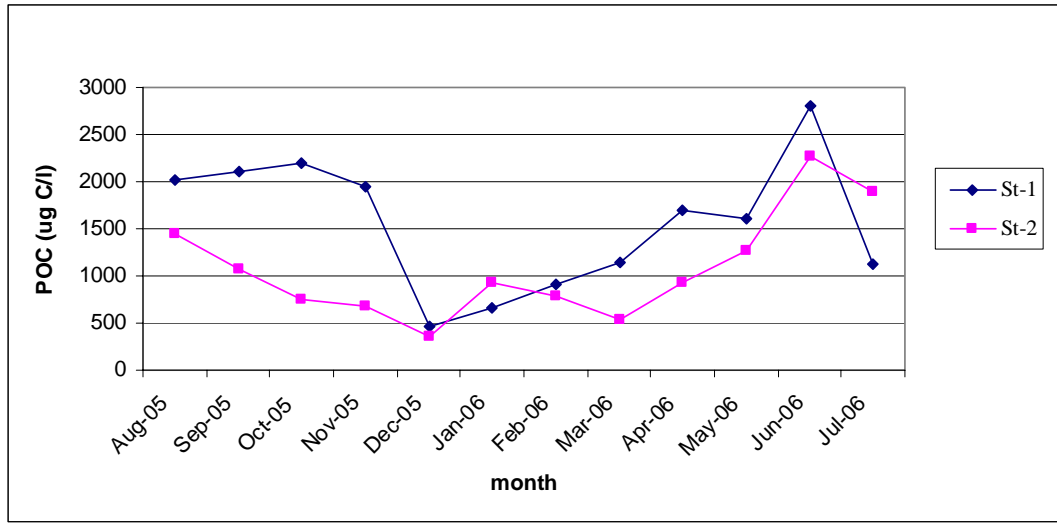


Figure 4.9. Seasonal variations in the concentration of particulate organic carbon of water during August 2005 – July 2006.

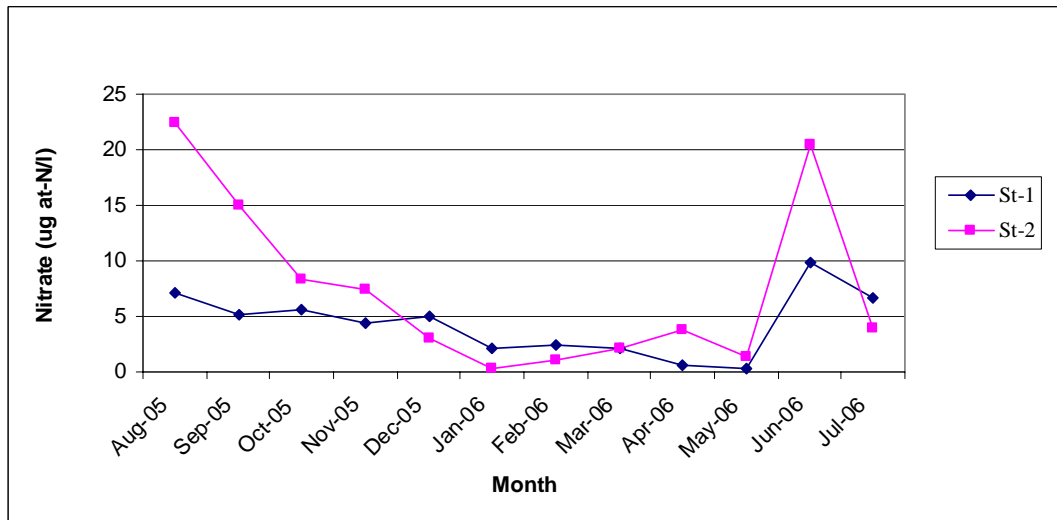


Figure 4.10. Seasonal variations in the concentration of NO₃-N in water during August 2005 – July 2006.

Nitrate-Nitrogen ($\text{NO}_3\text{-N}$) ranged between 0.24 to 9.82 $\mu\text{g at-N/l}$ in May and June 2006, respectively at St-1. Very little fluctuations were observed in $\text{NO}_3\text{-N}$ values from August 2005 to May 2006, and increased steeply reaching its highest peak value in June 2006 (Figure 4.10). However, the highest value of $\text{NO}_3\text{-N}$, at St-2, was observed during the months of August 2005 and June 2006 (22.49 and 20.47 $\mu\text{g at-N/l}$, respectively) i.e. during monsoon period. Gradual decrease was noticed from August 2005 to reach its lowest concentration value (0.30 $\mu\text{g at-N/l}$) during January 2006. From January 2006 onwards, there was slight increase in the $\text{NO}_3\text{-N}$ concentrations up to April 2006. However, it showed slight decrease in May 2006, before reaching to its peak in June 2006. However, $\text{NO}_3\text{-N}$ values were drastically decreased in July 2006.

Nitrite-Nitrogen ($\text{NO}_2\text{-N}$) values ranged from 0.06 $\mu\text{g at-N/l}$ in August 2005 and 2.21 $\mu\text{g at-N/l}$ in April 2006 at St-1. At St-2, $\text{NO}_2\text{-N}$ concentrations showed, more or less, similar trend to that from St-1 and ranged between minimum of 0.29 $\mu\text{g at-N/l}$ in January 2006 to the maximum of 2.78 $\mu\text{g at-N/l}$ in May (Figure 4.11).

Phosphate-Phosphorus ($\text{PO}_4\text{-P}$) quantum ranged between 0.40 $\mu\text{g at-P/l}$ in September 2005 and 3.30 $\mu\text{g at-P/l}$ in May 2006 from St-1, while it was observed to vary from 0.52 $\mu\text{g at-P/l}$ in August 2005 to 6.3 $\mu\text{g at-P/l}$ in May 2006 at St-2. Overall, very minor fluctuations in the $\text{PO}_4\text{-P}$ values at both the stations except the highest peak during May 2006 at St-2 (Figure 4.12).

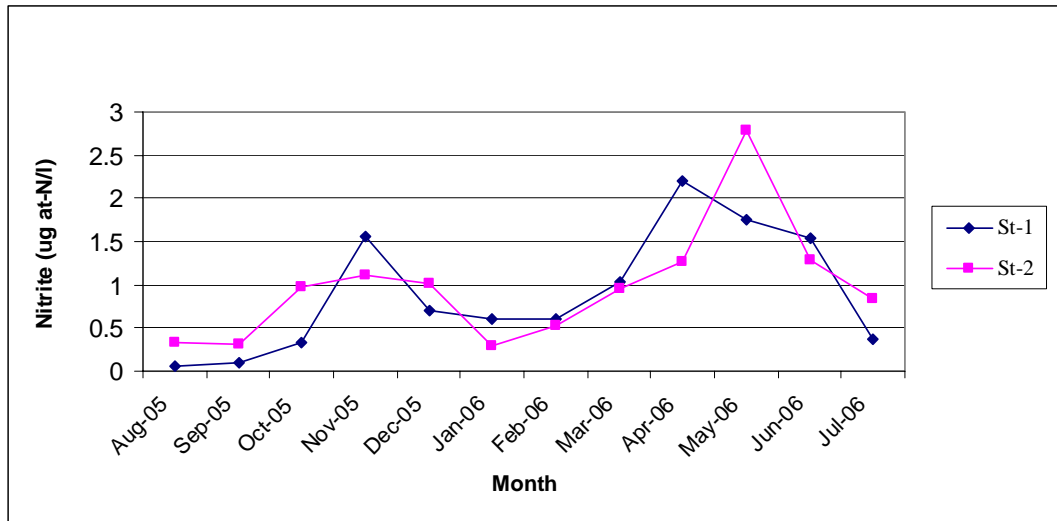


Figure 4.11. Seasonal variations in the concentration of NO₂-N in water during August 2005 – July 2006.

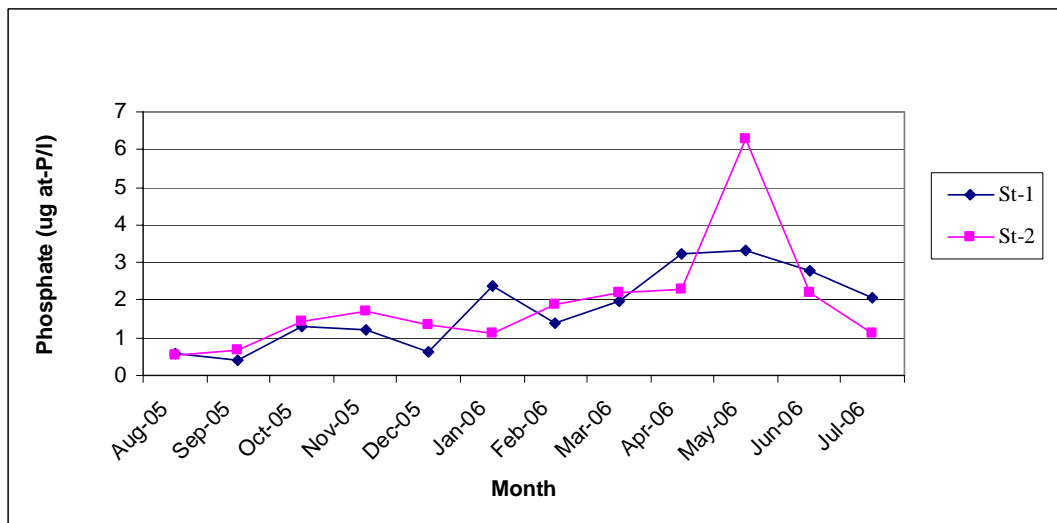


Figure 4.12. Seasonal variations in the concentration of PO₄-P in water during August 2005 – July 2006.

4.3. Discussion:

The greater extent and maximum diversity of mangroves occurs in the humid tropical and subtropical regions between 28° N and 32° S, though they extend in the latitudinal belt of 32° N and 38° S (Walter, 1977). Atmospheric average temperature in the present study ranged between minimum 19.6 °C and maximum 34.1 °C, which are the most suitable for mangrove formations. Cloud cover, precipitation as well as strong wind during monsoon decrease the summer high temperature, which leads to increase in the relative humidity to range between 83% and 86% during monsoon months. Humidity in the region though governed by precipitation and evaporation in summer, it is significantly correlated ($r= 0.8795$, $P < 0.001$) as shown in Tables 4.1 and 4.2. Mangrove seedlings normally prefer to grow in the temperature ranges of 20 °C and 31 °C at humidity range of 69 to 93% (Sidhu, 1974; Jagtap, 1985). However, species like *A. marina* known for its wide tolerance to salinity, temperatures and humidity could establish in the regions of arid climate such as gulf of Kutchchh (Jagtap & Nagle, 2007). The relative humidity increases during monsoon due to the cloud cover and heavy precipitation, which act like a blanket to restrict the water vapour near the earth's surface. The high humidity through out the year considered as a perfect for enhancing the establishment and growth of mangroves. The greater extent luxuriance and species richness of mangroves from the tropics to be certainly attributed to

Table 4.1. Correlations between various environmental components at St-1.

	<i>Rain</i>	<i>R.H.</i>	<i>Wind</i>	<i>Temp.</i>	<i>pH</i>	<i>Salinity</i>	<i>DO</i>	<i>Nitrate</i>	<i>Nitrite</i>	<i>Phosphate</i>	<i>POC</i>
Rain	1.0000										
R.H.	0.8795	1.0000									
Wind	0.5230	0.6605	1.0000								
Temp.	-0.3706	-0.2947	-0.1964	1.0000							
pH	-0.1390	-0.0409	-0.4137	0.0878	1.0000						
Salinity	-0.7299	-0.8374	-0.6018	0.6944	-0.0110	1.0000					
DO	0.3312	0.4565	0.5715	-0.2989	0.3174	-0.4976	1.0000				
Nitrate	0.5962	0.6335	0.3338	-0.6802	-0.2197	-0.8436	0.0741	1.0000			
Nitrite	-0.1458	-0.3393	-0.2978	0.5562	0.1497	0.4899	-0.1141	-0.4041	1.0000		
Phosphate	0.0220	-0.1212	0.0669	0.5748	-0.2308	0.3917	-0.0728	-0.3857	0.7518	1.0000	
POC	0.6574	0.6788	0.1161	-0.1428	0.3984	-0.6019	0.2057	0.5057	0.1690	0.0528	1.0000

D.F.= 10

* p< 0.05 0.576
 ** p< 0.01 0.708
 *** p<0.001 0.823

Table 4.2. Correlations between various environmental components at St-2.

	<i>Rain</i>	<i>R.H.</i>	<i>Wind</i>	<i>Temp.</i>	<i>pH</i>	<i>Salinity</i>	<i>DO</i>	<i>Nitrate</i>	<i>Nitrite</i>	<i>Phosphate</i>	<i>POC</i>
Rain	1.0000										
R.H.	0.8795	1.0000									
Wind	0.5230	0.6605	1.0000								
Temp.	-0.3721	-0.4002	-0.2424	1.0000							
pH	-0.2859	-0.1076	-0.4333	-0.0523	1.0000						
Salinity	-0.8221	-0.8577	-0.6971	0.7016	0.2897	1.0000					
DO	-0.1225	-0.2914	0.0836	-0.1127	-0.5891	0.0405	1.0000				
Nitrate	0.7224	0.7267	0.2751	-0.5166	-0.0412	-0.7700	-0.2996	1.0000			
Nitrite	0.1153	-0.0386	-0.1083	0.6379	0.1909	0.3548	-0.0907	-0.2570	1.0000		
Phosphate	0.0792	-0.1180	-0.1361	0.7344	0.0680	0.4450	-0.1243	-0.3566	0.9372	1.0000	
POC	0.8003	0.7060	0.6868	-0.1357	-0.5070	-0.7484	-0.0610	0.5510	0.1159	0.0642	1.0000

D.F.= 10

* p< 0.05 0.576
 ** p< 0.01 0.708
 *** p<0.001 0.823

humid and warm climate and adequate rains. During the year of the sampling period, Goa received about 2,758.6 mm of rainfall, which was considered to be less than what is normal rainfall of ~ 3,000 mm.

The hydrological parameters from the study regions appear to be highly influenced by the S-W monsoon, which led to a rhythmic seasonal pattern. The comparative study between the two stations influenced by Mandovi estuary showed that the temperature, salinity, pH, DO and nutrients followed similar seasonal trends with minor variations (Figures 4.5 – 4.12). However, POC contents in the water column exhibited independent behaviour from both the stations may be due to their geographical locations. The higher concentrations of POC from St-1 compared to the same from St-2 could be attributed to its location in the main stream (Figure 2.2), where mixing of seawater and freshwater usually remains higher.

Surface water temperature of the water column at ebb showed moderate fluctuations with a single peak in April (Dehadrai and Bhargava, 1972). Higher water temperatures have been observed during the pre-monsoon season from both stations, with a peak in May 2006, may be due to the high intensity of solar radiation, prolonged photo-period and higher salinity in comparison to the rest of the study period (Figure 4.6). However, higher water temperature during October may be the result of high atmospheric temperature and high humidity, the lower temperature during the monsoon could be attributed to the greater cloud cover, responsible for reducing solar radiation, as well as a result of precipitation and speedy winds.

Mandovi estuary has a relatively larger tributary system, and hence shows relatively lower salinity throughout the year, compared to other rivers from Goa (Jagtap, 1985). The freshwater discharge in estuaries in the state remains negligible during pre-monsoon and post-monsoon periods, and hence they are tidal dominated (Das *et al.*, 1972). Heavy precipitation during the monsoon season reduces the water salinity prevailing fresh water conditions in Mandovi estuary due to the drainage from its catchment area, resulting in wide salinity variations throughout the year. Salinity increases from October onwards as rainfall decreases and remain high until the next pre-monsoon showers during May and June. Significant negative correlation ($r = -0.7300$, $p < 0.01$ at St-1 and $r = -0.8221$, $p < 0.01$ at St-2, respectively) were observed between salinity and the rainfall (Table 4.1 and 4.2).

Lower salinity during monsoon is performed by mangrove seedlings to germinate (Jagtap, 1985) and establish themselves. Estuarine fauna, including oyster, are subjected to a wide salinity variations from time to time depending on the rainfall, tidal cycle and fresh water influx. The conditions at St-1 remain is more saline compared to the same at St-2 as it is located in the major path of the direct influx of tidal and riverine ways, whereas, St-2 lies in a semi-enclosed creek, having relatively lesser impact of the tidal and riverine influence.

The topography and drainage pattern strongly influences the pH of any aquatic body, and greatly influenced by the concentration of carbon dioxide

and acidic compounds. The lower pH from study areas during monsoon compared to the same during the rest of the period might be due to the reduced photosynthesis as a result of increased turbidity (Rao and Madhavan, 1964). Torrential runoff during monsoon contribute a greater amount of suspended matter including organic materials contribute in forming organic acids, which decrease the pH values. The cloud cover during monsoon season reduces the availability of the sunlight. Similarly, the increased turbidity too decreases the sunlight penetration in the water column and consequently reducing the primary productivity. The reduced photosynthetic activity leads to the increase in carbon dioxide in the water column lowering the pH values. In post and pre-monsoon season the carbon dioxide is utilized through the photosynthesis activities, which increase the pH values of the water (Sarma *et al.*, 2001). Negative correlation ($r = -0.507$, $p > 0.05$) was found between the pH and the concentration of POC in the water column of St-2. The highest values of pH occurred during October and November 2005, and similar results have also been reported by Rivonkar (1991). In General, pH values at St-1 are found to be lesser compared to pH values in St-2, probably because of the influence of turbidity, which was relatively more at St-1 than St-2.

Dissolved oxygen contents in aquatic environment depend on the abundance of phytoplankton, which increases oxygen concentration through photosynthesis process (Bhargava *et al.*, 1973). Singbal (1976)

reported that the solubility of oxygen remains more in fresh or brackish water than in the sea water.

The higher concentration of the DO from both stations in the monsoon season could be due to the freshwater runoff and precipitation. High values of DO from estuaries of Goa have also been reported earlier (Goswami and Singbal, 1974; Jagtap, 1985; De Souza and Sen Gupta, 1986). At both stations, DO exhibited similar trend, except during December - January at St-2 (Figure 4.8), with peak values of 5.59 and 5.39 mg/l, respectively were observed, which might be attributed to algal-phytoplankton blooms (Rivonkar, 1991). On the other hand, DO fluctuated in the narrow range during the remaining period with two peaks in September and April. Dehadrai and Bhargava (1972) reported inverse correlation between DO and temperature in ambience. The present investigations also confirmed a negative correlation between these two parameters from both stations, although it was not significant (Table 4.1 and 4.2).

Earlier studies (Jagtap, 1987) have reported high contents of POC ranging between 0.06 - 9.94 mg/l in the mangrove environment of Mandovi estuary. The present observations also confirm the high values of POC from estuarine system. Higher values of POC during the period of monsoon and post-monsoon, until the month of November, could be related to precipitation and increase in the freshwater runoff that carries organic matter, including planktonic fauna, from the hinter land regions. A significant correlation was found between the POC and the rainfall ($r= 0.6574$, $p < 0.05$

at St-1 and $r = 0.8003$, $p < 0.01$ at St-2). This explains also the higher concentration of POC at St-1 than what is recorded at St-2. The monsoon dynamics disturbs the bottom probably releasing the organic matter from the sediments. The weak wave action in the mangrove area during low tide results in depository environment (Jagtap, 1985). Due to the lack of vigorous water motion, suspended matter along with organic matter tends to settle down and accumulate at the bottom, and lower the particulate organic carbon in the water column.

Throughout the sampling period, marked variations occurred in POC contents from both stations. The POC from the estuarine habitats were reported to be highly positive correlated to chlorophyll-a (Rattan, 1994). Chlorophyll-a contents in estuaries have been reported to be lower at low tide compared to the same during high waters (Dehadrai and Bhargava, 1972).

Nutrients play vital role for the growth of mangroves as well as sustaining the productivity in mangrove influenced waters (Untawale *et al.*, 1973). In estuaries, nitrates are contributed via precipitation, land drainage and river runoff, while removed through biological productivity and denitrification (De Sousa *et al.*, 1981). Nutrients values tend to be higher where effects of land drainage remain more pronounced and depth is less (Goswami and Singbal, 1974). Qasim and Sen Gupta (1981) reported decrease of nitrate concentration in estuarine systems of Goa from head to mouth during the dry season, due to its utilization for photosynthetic activity.

The highest concentration of $\text{NO}_3\text{-N}$, from both stations, occurred in the period of monsoon when rainfall and runoff remain at their highest (Pai and Reddy, 1981; Sardessai and Sundar, 2007). The state is well known for mining of iron ore from hinter lands. Mining rejects form a source for nitrate in the estuaries of Goa, as the explosives used in mining operations contain nitrates (De Sousa, 1983). Mangrove litters play an important role in sustaining the nutrient budget of the Mandovi estuary (Wafar *et al.*, 1997). The increase of $\text{NO}_3\text{-N}$ in the estuarine waters during monsoon could also be attributed to the contribution by the fertilizers used in the low lying rice fields and horticulture (Sardessai and Sundar, 2007). The low values of $\text{NO}_3\text{-N}$ could be attributed to the removal of it by biological productivity in the area as denitrification process could be ruled out because the sampling sites are shallow and well oxygenated (De Sousa *et al.*, 1981). Two peaks of $\text{NO}_2\text{-N}$ values observed during post-monsoon (November 2005) and pre-monsoon months of April and May 2006 from St-1 and St-2, respectively, and very low concentrations in monsoon season.

Phosphate-phosphorus concentration at both stations, during monsoon and post-monsoon, exhibited similar trends of variations, with higher concentrations during the month of May. No significant temporal or spatial variations in $\text{PO}_4\text{-P}$ concentration were observed by Sardessai and Sundar (2007). Phosphate in estuarine water contributed from natural weathering processes and breakdown of polyphosphates used in detergents (De Sousa

et al., 1981), and could be released to the water by disturbances in substrates (Sankaranarayanan and Qasim, 1969).

The data during the present investigations indicated that there are marked spatial and temporal variations in the distribution of hydrographic parameters in the mangrove environment. Monsoon season plays a major role in influencing the environmental parameters in this ecosystem.

***DIMENSIONAL RELATIONSHIPS IN CRASSOSTREA
MADRASENSIS (PRESTON) AND C. GRYPHOIDES
(SCHLOTHEIM) IN MANGROVE ECOSYSTEM***

5.1. Introduction:

Mangrove habitats from the tropics harbour a great deal of fauna and flora of ecological socioeconomic values. Detritus rich and repository kind of environments sustain high benthic productivity and predominantly shell and bivalve fisheries including oyster beds. Mangroves and associated environmental features favour oyster and their larval settlement (Frías and Rodríguez, 1990). Such ecosystem supports a protection to oyster beds against strong wave action and speedy currents. Enrichment of organic carbon in the water column in mangrove regions possess adequate amount of nutrients for the production of plankton, which can support the growth and fattening of oysters.

Oysters form edible, cheap and feasible source of commercial importance. They contribute sediments to the marine environment by fragmentation of their shells and thus are of geological significance. Oyster species like *Crassostrea madrasensis* (Preston) and *C. gryphoides* (Schlotheim) from the mangroves and in the vicinity regions influenced by them, have been studied for their percentage edibility, condition index,

biometric relationships and their production. The Percentage Edibility and the condition indices may serve in evaluating the quality of the oyster population as food source and determining the population health (Lucas and Beninger, 1985).

The length-weight relationship in oysters helps in establishing the yield and converting one variable into the other. Of the two, length, width and height are easier to measure and can be converted into weight. Description of the relationship between shell and soft body characteristics are essential in understanding ecological variations and productivity of oyster population.

Very limited studies have been attempted on *C. gryphoides* from mangrove and in the vicinity regions of Goa (Chatterji *et al.*, 1985). However, *C. madrasensis* has been reported for the first time from the state. The present investigations, therefore, forms first hand information on this particular species.

5.2. Results:

During the period of investigations, the average density of oysters at St-1 was estimated to be about 969.6 specimens/m², of which 36% of the population was live (Figure 5.1). At St-2, oyster bed harboured average of 948 specimens/m² of oysters; however, the live (16.17%) were relatively much less compared to the same from St-1. (Figure 5.2).

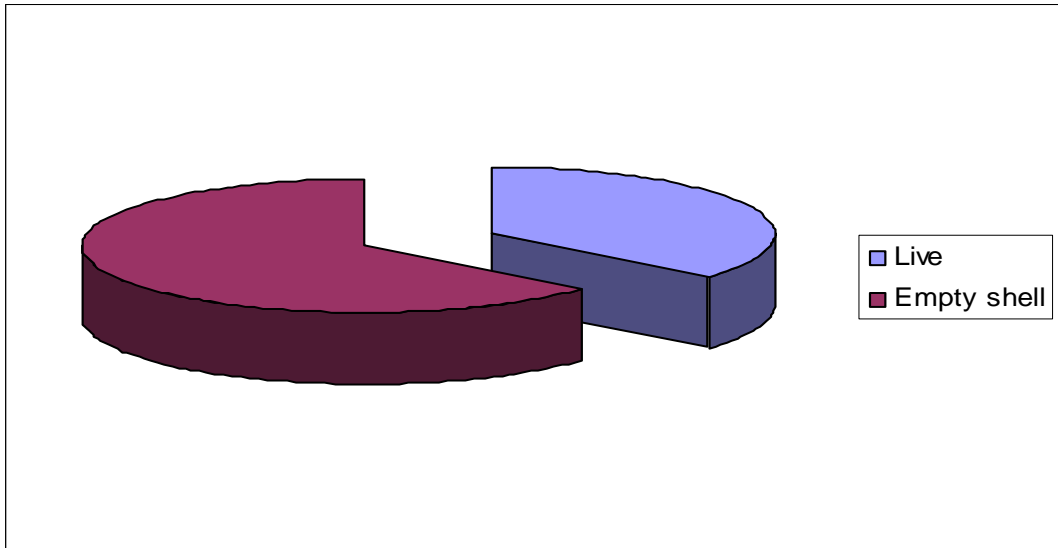


Figure 5.1. Percentage of live and empty shells in oyster beds from St-1.

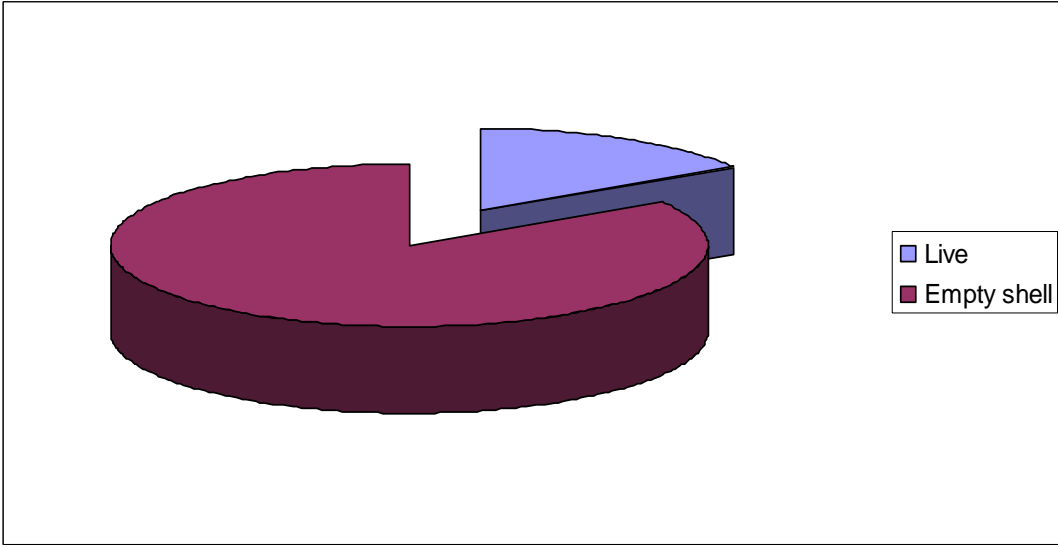


Figure 5.2. Percentage of live and empty shells in oyster beds from St-2.

A total number of 305 oyster specimens were collected from St-1 over the period of study from August 2005 to July 2006. The number of *C. madrasensis* found to be 221 specimens (72.46%), while only 84 specimens (27.54%) found to be *C. gryphoides* of the total number collected. The total number of oyster specimens collected from St-2 was 322, of which 205 (63.66%) was found to be *C. madrasensis*, while *C. gryphoides* amounted to 117 (36.34%). Figures 5.3 and 5.4 illustrate the monthly percentage occurrence of both the species collected from St-1 and St-2, respectively.

5.2.1. Percentage Edibility (PE):

The minimum value of percentage edibility (PE) of *C. gryphoides* at St-1 recorded was 7.13% during the month of August 2005, while the maximum of 10.13% in the month of February 2006 (Figure 5.5), with an average of $8.56\% \pm 0.76$. The annual variation in PE of *C. gryphoides* showed fluctuation between August and October 2005, and increased gradually to its maximum value in the month of February 2006. It decreased in the next month of March, and remained almost stable thereafter with a slight decrease in values ranging between 9.14 - 8.27% during the period of March and June 2006. However, it has increased again in July to 8.65%.

The PE of *C. madrasensis* at St-1 ranged between a minimum

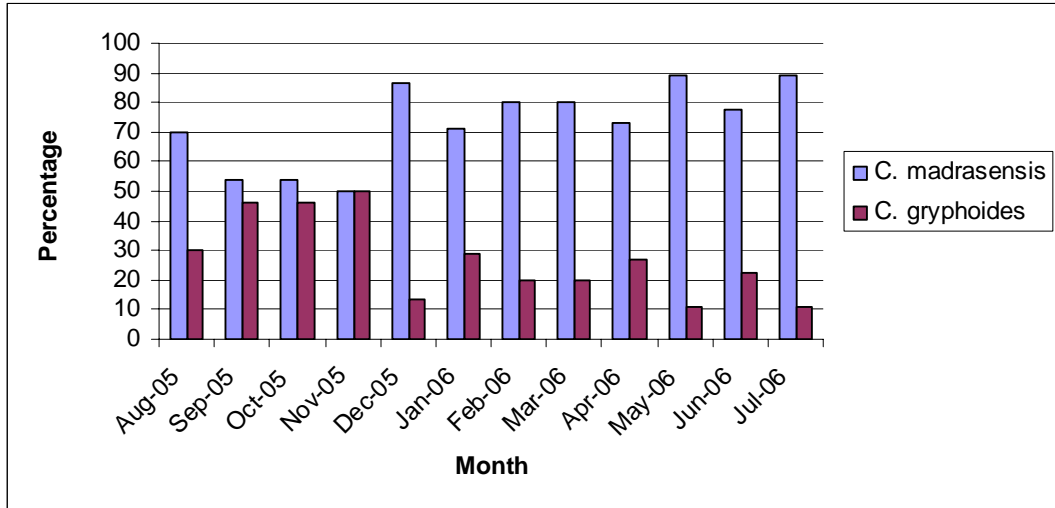


Figure 5.3. Seasonal percentage of species collected from St-1 during August 2005 – July 2006

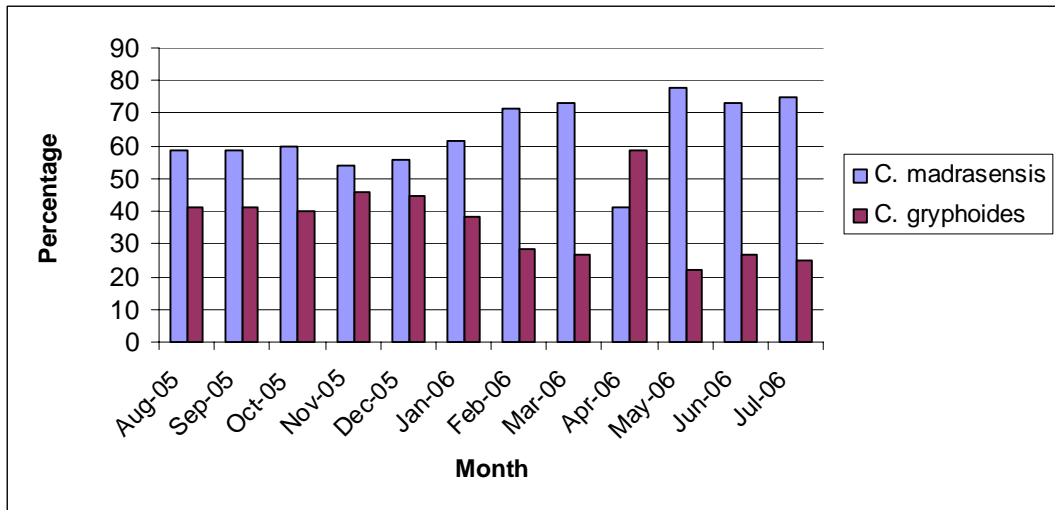


Figure 5.4. Seasonal percentage of species collected from St-2 during August 2005 – July 2006.

of 7.21% in December 2005 to a maximum of 10.98% in April 2006, with an average of $9.00\% \pm 1.28$. The PE values fluctuated between 8.35% and 7.21% from August 2005 to January 2006. These values showed sudden increase of 9.86% in February and continued to increase gradually reaching its peak (10.98%) in the month of April 2006, and later decreased gradually from April to July 2006 (Figure 5.5).

The PE values of *C. gryphoides* from St-2 ranged between a minimum of 4.44% in September 2006 to maximum of 9.58% in May 2005, with an average of $6.76\% \pm 1.49$ (Figure 5.6). The annual variations showed a decline in the values from August to its minimum in September 2005, and then increased from 4.44% to 7.91% in October. However, these values decreased in November and remained almost constant until January 2006, and later, increased gradually reaching its peak (9.58%) in May 2006. During monsoon months, PE values were generally low (Figure 5.6).

PE values of *C. madrasensis* ranged between 4.58% during September 2005 to 11.00% in the month of April 2006 (Figure 5.6), with an annual average of $7.37\% \pm 1.94$. The variations in PE of *C. madrasensis* exhibited similar trend as in case of *C. gryphoides*. The values decreased to its minimum value from August to September 2005 and increased to the value of 8.53% in October 2005. It decreased further in the next month until it reached a value of 5.66% in the month of January 2006, and

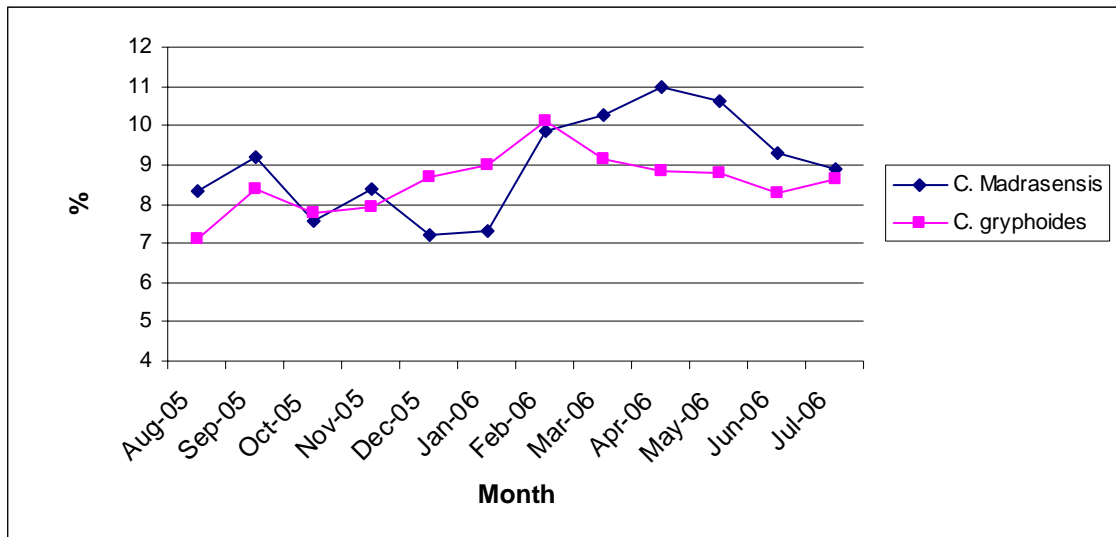


Figure 5.5. Seasonal average variations in Percentage Edibility of oysters in St-1 during August 2005 – July 2006.

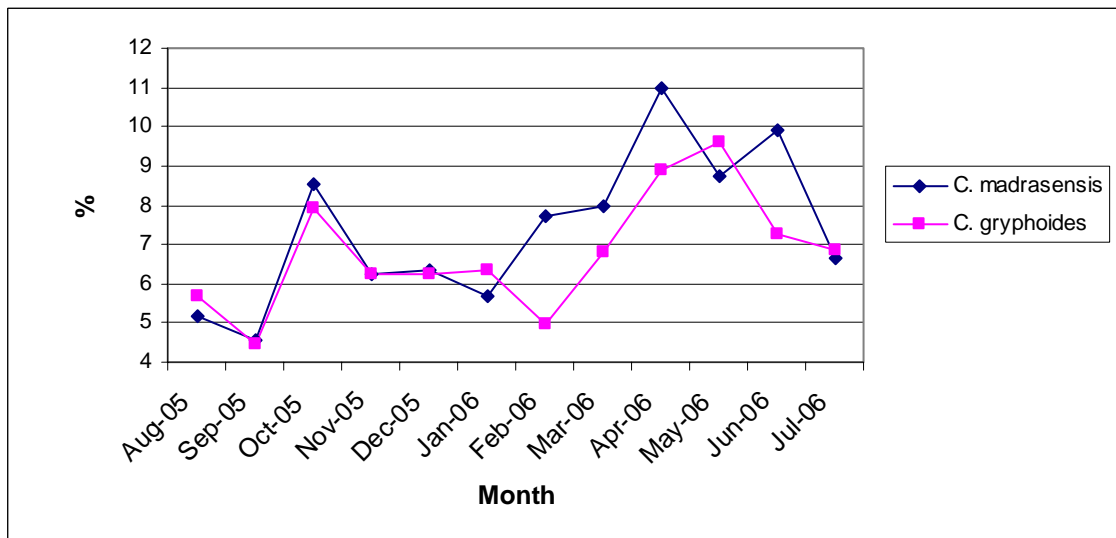


Figure 5.6. Seasonal average variations in Percentage Edibility of oysters in St-2 during August 2005 – July 2006.

later it increased gradually to its peak value in the month of April 2006. The PE values then showed a fluctuation between April and June 2006, and later it decreased in July to 6.65%.

5.2.2 Condition Index (CI):

The Condition Index (CI) values of *C. gryphoides* from St-1 varied from 48.54 in October 2005 to 153.35 in May 2006, with an average of 101.65 ± 32.58 (Figure 5.7). The CI gradually decreased from August to its minimum value in October 2005. It gradually increased from October to December 2005, however, it decreased to 75.35 in January 2006 and then increased in February to 120.01. The period between February and May 2006 showed minor fluctuations in the CI values, however, decreased in June to 87.85 and thereafter increased slightly in July 2006 to 98.15.

The CI values of *C. madrasensis* ranged between minimum of 54.53 in the month of October 2005 and maximum 142.93 in April 2006, with an average of 97.22 ± 29.06 (Figure 5.7). These values decreased gradually from August to October 2005, and then, with slight increase, remained almost constant during November 2005 to January 2006. The period between January and April 2006 showed a gradual increase until it reached its peak value in April, and remained almost stable in May 2006 before it gradually decreased in June and July.

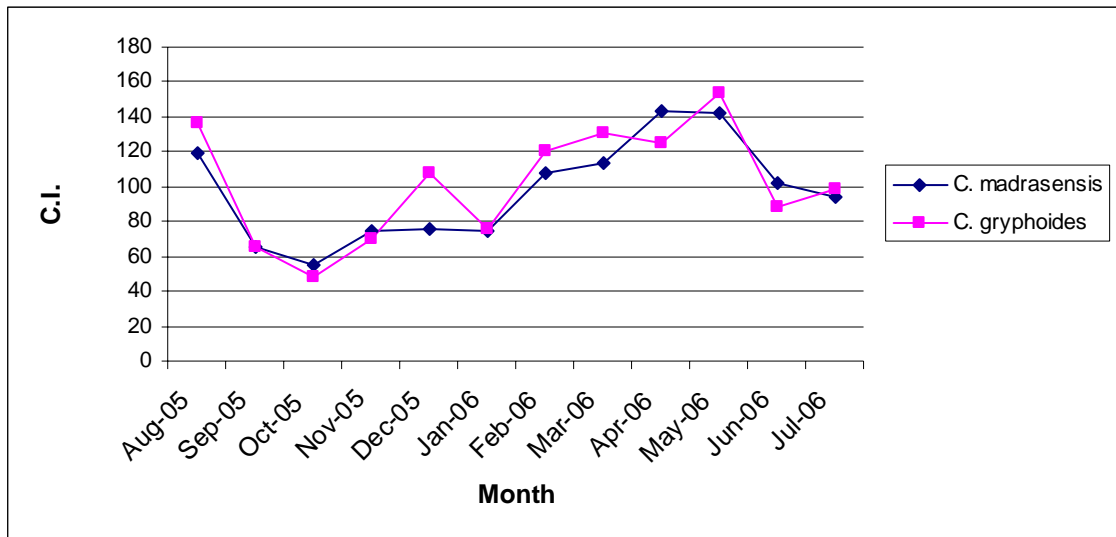


Figure 5.7. Seasonal average variation of condition index of oyster species at St-1 during August 2005 – July 2006.

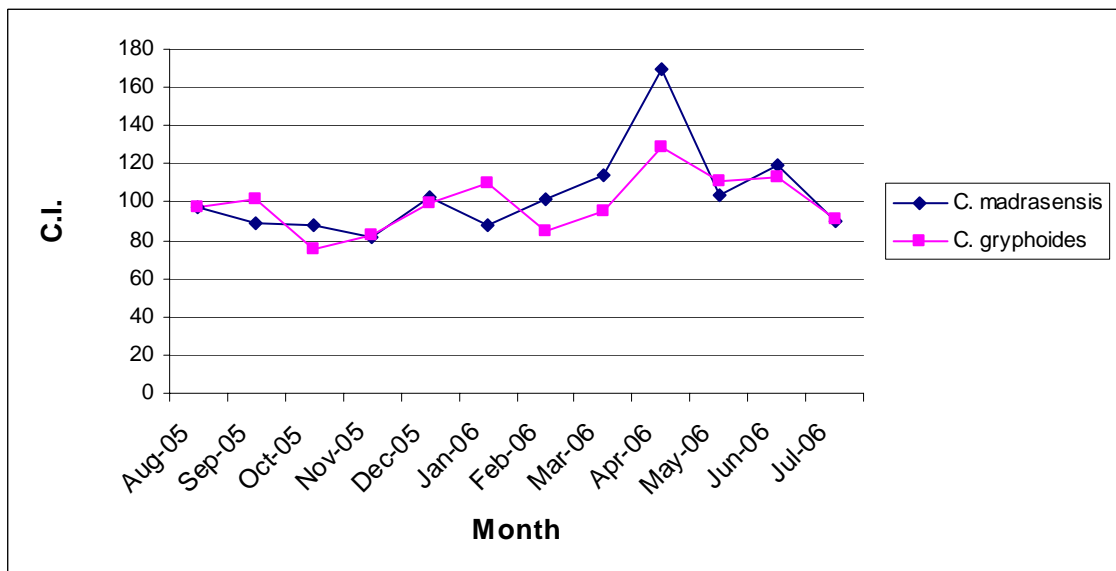


Figure 5.8. Seasonal average variation in condition index of oysters species at St-2 during August 2005 – July 2006.

The CI values in *C. gryphoides*, from St-2, showed a slight variations ranging from 75.02 in October 2005 to 128.40 in the month of April 2006, with an average of 99.05 ± 14.96 (Figure 5.8). These values increased slightly during August and September 2005, and decreased further to its lowest value in October. Values steadily increased from October onwards reaching 109.39 in January 2006, however, in February dropped to 85.09 and later increased gradually to its peak in April 2006. The period between April to July 2006, showed decrease in CI from 128.40 to 90.89 (Figure 5.7).

The CI of *C. madrasensis* ranged between minimum of 81.40 in November 2005 to maximum of 169.02 in April 2006, with an average of 103.51 ± 23.54 (Figure 5.8). The CI values showed gradual decrease from 97.16 in August to its minimum value in November 2005, and later fluctuated from November 2005 onwards up to January 2006. Later, values were gradually increased reaching its maximum in April 2006, however, in May 2006, CI dropped from 169.02 to 103.92. It increased to 119.54 in June but declined again to 89.65 in July 2006.

5.2.3. Allometric Relationships:

The statistical analysis of allometric parameters of the two species from St-1 and St-2 are summarized in Table 5.1. and 5.2., respectively, and described below:

5.2.3.1. Oysters from St-1:

5.2.3.1.1. Allometric Relationships in *C. madrasensis*:

A total number of 221 specimens of *C. madrasensis* collected from St-1 between August 2005 and July 2006 were used for study length-weight relationship. Data resulted was pooled and express on average basis. The length of specimens ranged between 25-65 mm, while width and height were found in the ranges of 17-41 mm and 12-35 mm, respectively. The total weight of the animal ranged between 3.37-37.18 g, and the fresh weight of meat ranged between 1.81-0.32 g. Following are the relationships obtained from the statistical analysis of the allometric data:

5.2.3.1.1.1. Shell length : Total weight relationship:

The relationship between shell length and total weight of the animal showed highly significant correlation ($r = 0.7828$, $p < 0.001$). It is expressed by the following logarithmic regression equation as

$$\text{Log } y = -2.2264 + 2.0670 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0059 x^{2.0670}$$

Where, y is the total weight and x is the shell length.

5.2.3.1.1.2. Shell width : Total weight relationship:

Shell width and total weight showed highly significant correlation ($r = 0.6727$, $p < 0.001$). The logarithmic regression equation obtained was

$$\text{Log } y = -1.1549 + 1.5390 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0700 x^{1.5390}$$

Where, y is the total weight and x is the shell width.

5.2.3.1.1.3. Shell height : Total weight relationship:

The shell height and the total weight also showed a highly significant correlation ($r = 0.6989$, $p < 0.001$). The logarithmic regression equation between them was

$$\text{Log } y = -0.8008 + 1.4188 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.1582 x^{1.4188}$$

Where, y is the total weight and x is the shell height.

5.2.3.1.1.4. Shell length : Meat wet weight relationship:

The two parameters were highly correlated ($r = 0.6469$, $p < 0.001$). The logarithmic regression equation, which expresses the relationship between the shell length and the meat wet weight, is as

$$\text{Log } y = -3.2903 + 2.0717 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0005 x^{2.0717}$$

Where, y is the meat wet weight and x is the shell length

5.2.3.1.1.5. Shell width : Meat wet weight relationship:

High correlation between shell width and meat wet weight ($r = 0.5012$, $p < 0.001$) was observed, and expressed by logarithmic regression equation as

$$\text{Log } y = -1.9997 + 1.3906 \log x$$

Whereas, its corresponding parabolic equation may be represented as

$$y = 0.0100 x^{1.3906}$$

Where, y is the meat wet weight and x is the shell width.

5.2.3.1.1.6. Shell height : Meat wet weight relationship:

The shell height and meat wet weight showed highly significant correlation between them ($r = 0.6051$, $p < 0.001$), and expressed as the logarithmic regression equation as

$$\text{Log } y = -1.9485 + 1.4897 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0113 x^{1.4897}$$

Where, y is the meat wet weight and x is the shell height.

5.2.3.1.2. Allometric Relationships in *C. gryphoides*:

A total number of 84 specimens of *C. gryphoides* collected from St-1 were pooled together and used for the study. The length of the specimens ranged between 25-51 mm, width 19-43 mm and height 9-32 mm. The total weight of the animal ranged between 4.39-27.12 g, and the meat wet weight ranged between 0.29-2.34 g. Following relationships were noticed:

5.2.3.1.2.1. Shell length : Total weight relationship:

The two parameters showed a highly significant correlation ($r = 0.6340$, $p < 0.001$). The logarithmic regression equation obtained was

$$\text{Log } y = -1.2468 + 1.4655 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0567 x^{1.4655}$$

Where, y is the total weight and x is the shell length.

5.2.3.1.2.2. Shell width : Total weight relationship:

The correlation between the shell width and total weight was highly significant ($r = 0.5552$, $p < 0.001$). The logarithmic regression equation obtained was as

$$\text{Log } y = -0.7333 + 1.2449 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.1848 x^{1.2449}$$

Where, y is the total weight and x is the shell width.

5.2.3.1.2.3. Shell height : Total weight relationship:

Shell height and total weight showed a highly significant correlation ($r = 0.7120$, $p < 0.001$). The logarithmic regression equation obtained was as

$$\text{Log } y = -0.6790 + 1.3432 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.2094 x^{1.3432}$$

Where, y is the total weight and x is the shell height.

5.2.3.1.2.4. Shell length : Meat wet weight relationship:

The correlation in this relationship was highly significant ($r = 0.4583$, $p < 0.001$). Following is the logarithmic regression equation obtained

$$\text{Log } y = -2.0133 + 1.2439 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0070 x^{1.2439}$$

Where, y is the meat wet weight and x is the shell length.

5.2.3.1.2.5. Shell width : Meat wet weight relationship:

The two parameters showed a highly significant correlation ($r = 0.2892$, $p < 0.01$). The logarithmic regression equation obtained was as

$$\text{Log } y = -1.1524 + 0.7615 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0704 x^{0.7615}$$

Where, y is the meat wet weight and x is the shell width.

5.2.3.1.2.6. Shell height : Meat wet weight relationship:

The correlation between the two parameters was highly significant ($r = 0.4267$, $p < 0.001$). The logarithmic regression equation was obtained as

$$\text{Log } y = -1.2791 + 0.9452 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0526 x^{0.9452}$$

Where, y is the meat wet weight and x is the shell height.

5.2.3.2. Oysters of St-2:

5.2.3.2.1. Allometric Relationships in *C. madrasensis*:

A total number of 205 specimens of *C. madrasensis*, were collected from St-2, and analyzed for allometric parameters. Data were pooled together and used for the study as one class. The length of the specimens ranged between 27-60 mm, width 17-49 mm and height 10-34 mm. The total weight of the animal ranged between 4.34-36.23 g, and the wet weight of meat ranged between 0.21-2.85 g. Following were the relationships obtained from the statistical analysis of allometric data.

5.2.3.2.1.1. Shell length : Total weight relationship:

Shell length and total weight showed highly significant correlation ($r = 0.7295$, $p < 0.001$), and is expressed by the following logarithmic regression equation

$$\text{Log } y = -1.6477 + 1.7236 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0225 x^{1.7236}$$

Where, y is the total weight and x is the shell length.

5.2.3.2.1.2. Shell width : Total weight relationship:

The relationship between shell width and total weight showed highly significant correlation ($r = 0.6038$, $p < 0.001$). The logarithmic regression equation was obtained as

$$\text{Log } y = -0.7969 + 1.2974 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.1596 x^{1.2974}$$

Where, y is the total weight and x is the shell width.

5.2.3.2.1.3. Shell height : Total weight relationship:

The correlation between the shell height and total weight was highly significant ($r = 0.5961$, $p < 0.001$). The logarithmic regression equation calculated as

$$\text{Log } y = -0.4473 + 1.1764 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.3570 x^{1.1764}$$

Where, y is the total weight and x is the shell height.

5.2.3.2.1.4. Shell length : Meat wet weight relationship:

The two parameters showed a highly significant correlation ($r = 0.4965$, $p < 0.001$). The logarithmic regression equation, which expresses the relationship between the shell length and the meat wet weight, is:

$$\text{Log } y = -2.7798 + 1.7089 \log x$$

Its corresponding parabolic equation may be represented as follow:

$$y = 0.0017 x^{1.7089}$$

Where, y is the meat wet weight and x is the shell length

5.2.3.2.1.5. Shell width : Meat wet weight relationship:

Shell width and meat wet weight showed significant correlation ($r = 0.3390$, $p < 0.001$). The logarithmic regression equation may be expressed as

$$\text{Log } y = -1.6090 + 1.0613 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0246 x^{1.0613}$$

Where, y is the meat wet weight and x is the shell width.

5.2.3.2.1.6. Shell height : Meat wet weight relationship:

The shell height and meat wet weight showed highly significant correlation ($r = 0.4342$, $p < 0.001$). The logarithmic regression equation may be expressed as

$$\text{Log } y = -1.6968 + 1.2483 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0201 x^{1.2483}$$

Where, y is the meat wet weight and x is the shell height.

5.2.3.2.2. Allometric Relationships in *C. gryphoides*:

The allometric data on 117 specimens of *C. gryphoides* collected from St-2 were pooled together and expressed on an average basis. The length, width and height of the specimens ranged between 24-55 mm, 18-40 mm and 11-32 mm, respectively. The total weight of the animal ranged between 3.27-28.87 g, and the wet meat weight ranged between 0.20-1.72 g. Following relationships were observed.

5.2.3.2.2.1. Shell length : Total weight relationship:

The two parameters showed a highly significant correlation ($r = 0.7436$, $p < 0.001$). The logarithmic regression equation was obtained as

$$\text{Log } y = -2.1179 + 1.9946 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0076 x^{1.9946}$$

Where, y is the total weight and x is the shell length.

5.2.3.2.2.2. Shell width : Total weight relationship:

Shell width and total weight showed a highly significant correlation ($r = 0.6430$, $p < 0.001$). The logarithmic regression equation obtained was as

$$\text{Log } y = -1.1838 + 1.5219 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0655 x^{1.5219}$$

Where, y is the total weight and x is the shell width.

5.2.3.2.2.3. Shell height : Total weight relationship:

The shell height and total weight showed a highly significant correlation ($r = 0.6678$, $p < 0.001$). The logarithmic regression equation was obtained as

$$\text{Log } y = -0.6438 + 1.2938 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.2270 x^{1.2938}$$

Where, y is the total weight and x is the shell height.

5.2.3.2.2.4. Shell length : Meat wet weight relationship:

The correlation between the two parameters was highly significant ($r = 0.4157$, $p < 0.001$). Following was the logarithmic regression equation obtained

$$\text{Log } y = -2.130 + 1.2382 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0074 x^{1.2382}$$

Where, y is the meat wet weight and x is the shell length.

5.2.3.2.2.5. Shell width : Meat wet weight relationship:

The two parameters showed a highly significant correlation ($r = 0.4836$, $p < 0.01$). The logarithmic regression equation obtained was as

$$\text{Log } y = -2.0186 + 1.2710 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0096 x^{1.2710}$$

Where, y is the meat wet weight and x is the shell width.

5.2.3.2.2.6. Shell height : Meat wet weight relationship:

The correlation between the two parameters showed a highly significant correlation ($r = 0.4333$, $p < 0.001$). The logarithmic regression equation obtained was as

$$\text{Log } y = -1.3787 + 0.9321 \log x$$

Its corresponding parabolic equation may be represented as

$$y = 0.0418 x^{0.9321}$$

Where, y is the meat wet weight and x is the shell height.

Parabolic and its corresponding linear relationships between various allometric parameters, described above, are depicted in Figures from 5.9 to 5.12.

5.3. Discussion:

The oysters are known to show large variations in their meat quality depending on their physiological conditions and associated environmental factors (Durve, 1964). In general, the PE values in *C. madrasensis* and *C. gryphoides* remained lower during the post-monsoon season, when temperature and salinity in ambience were at their low. The higher PE during pre-monsoon could be attributed to elevated temperature and salinity around oyster population. The PE values in oysters have been

Table 5.1. Summary of statistical analysis of allometric data on *Crassostrea madrasensis* collected from St-1 and St-2.

Sl. No.	x	y	a	b	SE of b	Regression equation	Parabolic equation	r	Significance
St-1, D.F. = 219									
1	length	Total weight	- 2.2269	2.0670	0.1110	Log y = -2.2269 + 2.0670 log x	Y = 0.0059 x ^{2.0670}	0.7828	***
2	Width	Total weight	- 1.1549	1.5390	0.1144	Log y = -1.1549 + 1.5390 log x	Y = 0.0700 x ^{1.5390}	0.6727	***
3	Height	Total weight	- 0.8008	1.4188	0.0981	Log y = -0.8008 + 1.4188 log x	Y = 0.1582 x ^{1.4188}	0.6989	***
4	length	Wet weight	- 3.2903	2.0717	0.1650	Log y = -3.2903 + 2.0717 log x	Y = 0.0005 x ^{2.0717}	0.6469	***
5	Width	Wet weight	- 1.9997	1.3906	0.1623	Log y = -1.9997 + 1.3906 log x	Y = 0.0100 x ^{1.3906}	0.5012	***
6	Height	Wet weight	- 1.9485	1.4897	0.1325	Log y = -1.9485 + 1.4897 log x	Y = 0.0113 x ^{1.4897}	0.6051	***
St-2, D.F. = 203									
1	length	Total weight	- 1.6477	1.7236	0.1134	Log y = -1.6477 + 1.7236 log x	Y = 0.0225 x ^{1.7236}	0.7295	***
2	Width	Total weight	- 0.7969	1.2974	0.1202	Log y = -0.7969 + 1.2974 log x	Y = 0.1596 x ^{1.2974}	0.6038	***
3	Height	Total weight	- 0.4473	1.1764	0.1112	Log y = -0.4473 + 1.1764 log x	Y = 0.3570 x ^{1.1764}	0.5961	***
4	length	Wet weight	- 2.7798	1.7089	0.2097	Log y = -2.7798 + 1.7089 log x	Y = 0.0017 x ^{1.7089}	0.4965	***
5	Width	Wet weight	- 1.6090	1.0613	0.2067	Log y = -1.6090 + 1.0613 log x	Y = 0.0246 x ^{1.0613}	0.3390	***
6	Height	Wet weight	- 1.6968	1.2483	0.1818	Log y = -1.6968 + 1.2483 log x	Y = 0.0201 x ^{1.2483}	0.4342	***

*** p < 0.001

** p < 0.01

* p < 0.05

Table 5.2. Summary of statistical analysis allometric data on *Crassostrea gryphoides* collected from St-1 and St-2.

Sl. No.	x	y	a	b	SE of b	Regression equation	Parabolic equation	r	Significance
St-1, D.F. = 82									
1	length	Total weight	- 1.2468	1.4655	0.1974	Log y = -1.2468 + 1.4655 log x	Y = 0.0567 x ^{1.4655}	0.6340	***
2	Width	Total weight	- 0.7333	1.2449	0.2059	Log y = -0.7333 + 1.2449 log x	Y = 0.1848 x ^{1.2449}	0.5552	***
3	Height	Total weight	- 0.6790	1.3432	0.1463	Log y = -0.6790 + 1.3432 log x	Y = 0.2094 x ^{1.3432}	0.7120	***
4	length	Wet weight	- 2.0133	1.2439	0.2664	Log y = -2.0133 + 1.2439 log x	Y = 0.0070 x ^{1.2439}	0.4583	***
5	Width	Wet weight	- 1.1524	0.7615	0.2783	Log y = -1.1524 + 0.7615 log x	Y = 0.0704 x ^{0.7615}	0.2892	**
6	Height	Wet weight	- 1.2791	0.9452	0.2213	Log y = -1.2791 + 0.9452 log x	Y = 0.0526 x ^{0.9452}	0.4267	***
St-2, D.F. = 115									
1	length	Total weight	- 2.1179	1.9946	0.1672	Log y = -2.1179 + 1.9946 log x	Y = 0.0076 x ^{1.9946}	0.7436	***
2	Width	Total weight	- 1.1838	1.5219	0.1690	Log y = -1.1838 + 1.5219 log x	Y = 0.0655 x ^{1.5219}	0.6430	***
3	Height	Total weight	- 0.6438	1.2938	0.1345	Log y = -0.6438 + 1.2938 log x	Y = 0.2270 x ^{1.2938}	0.6678	***
4	length	Wet weight	- 2.1297	1.2382	0.2526	Log y = -2.1297 + 1.2382 log x	Y = 0.0074 x ^{1.2382}	0.4157	***
5	Width	Wet weight	- 2.0186	1.2710	0.2145	Log y = -2.0186 + 1.2710 log x	Y = 0.0096 x ^{1.2710}	0.4836	***
6	Height	Wet weight	- 1.3787	0.9321	0.1808	Log y = -1.3787 + 0.9321 log x	Y = 0.0418 x ^{0.9321}	0.4333	***

*** p < 0.001

** p < 0.01

* p < 0.05

Figure 5.9. from Excel (allometric relationships graphs).

Figure 5.10. from Excel (allometric relationships graphs).

Figure 5.11. from Excel (allometric relationships graphs).

Figure 5.12. from Excel (allometric relationships graphs).

reported to be correlated with the sexual cycle of *C. gryphoides* during their spawning period (Durve, 1964). Nagabhushanam and Bidarkar (1977) have found that the highest values of PE in *C. cucullata* were obtained in oyster with length between 45 to 50 mm. However, the PE values in *C. madrasensis* and *C. gryphoides* remained constant to some extent in oyster that ranged in length between 50 - 70 mm, and these values decreased with increased length of organisms (Nagabhushanam and Bidarkar, 1977).

Crassostrea madrasensis had better condition of edible biomass than *C. gryphoides* from both the stations. Generally, oysters of St-1 showed higher values of PE, with an annual average of 9.00 and 8.56% in *C. madrasensis* and *C. gryphoides*, respectively. Whereas at St-2, the oysters showed an annual average of 7.37 and 6.76% of PE values, respectively. The increase in total weight, in oysters, has been observed to be mainly due to the increase in the size of shells (Nagabhushanam and Bidarkar, 1977). The biochemical constituents in oysters also have been correlated with the PE values (Durve, 1964), which will be discussed in relevance with *C. gryphoides* and *C. madrasensis*, from Goa, in the following chapter.

The CI of oysters is often routinely analyzed to provide estimates of factors such as meat quality and yield (Lawrence and Scott, 1982). Bivalves are sometimes called “fat”, which refers to plump animals, ones that fill the available internal shell cavity (Quayle and Newkirk, 1989). The CI is an important indicator of how well an oyster utilized its internal available volume for tissue growth. *Crassostrea madrasensis* and *C. gryphoides*,

during the present investigations, showed comparatively higher CI values in the pre-monsoon season and lower values during post-monsoon season. Higher CI value indicates that the oyster contain higher glycogen content (Gabbott and Stephenson, 1974).

The CI greater than 120 indicates a better healthy oyster, whereas CI of 70 and below suggests a thin oyster with poor health (Gabbott and Stephenson, 1974; Quayle and Newkirk, 1989). Poor values of CI in *C. madrasensis* and *C. gryphoides*, from both stations, were recorded between September and November 2005. *Crassostrea madrasensis* showed poor condition also in January 2006, while *C. gryphoides* showed this poor condition again in February 2006. These results match with the findings of the CI study on Pacific Oysters *C. gigas* done by Quayle (1988), and *C. gryphoides* by Durve (1964).

Physico-chemical variables such as salinity, wave action, water currents, nature of substrate, exposure to sun, turbidity, etc., in addition to food supply and predatory pressure will impose their specific patterns of productivity within the intertidal zone (Nascimento, 1990). A study on oyster *C. gigas* by Schumacker *et al.* (1998) and Austin *et al.* (1993) revealed that the CI could also be used for monitoring of condition and trends in an aquatic estuarine environment. The higher values of CI in *C. madrasensis* and *C. gryphoides* during the pre-monsoon period, therefore, could be attributed to the higher temperature and salinity in ambience.

Durve (1964) compared the methods of PE and CI, and found that the former has certain disadvantages as it does not account for the shell cavity. In case of thick-shelled oysters, the value of PE would be considerably disturbed due to their heavy weights. However, by CI method; the degree of fatness of the meat is objectively assessed irrespective of the shell thickness. Therefore, the CI seems to be more reliable than the method of PE in monitoring the health of oyster community.

The correlation between the PE and the CI of *C. madrasensis* was found to be highly significant at the 1% level from both the stations, with correlation coefficient of 0.7978 and 0.7628, respectively. On the other hand, non-significant correlation (0.2746 and 0.4112) at the level of 5%, was observed in *C. gryphoides* from St-1 and St-2, respectively. Beninger and Lucas (1984) found a very close correlation between CI and the biochemical constituents. Similar observations have been discussed with relevance to *C. madrasensis* in the following chapter.

The oyster colonies from the study area were generally overcrowded, covered with sediments, with irregular shape of individual with different sizes. However, shell cavities in both the species found to be deep, except in some organisms, it was narrow. Evaluation of the biometric characteristics and relationships in oyster provides better understanding of their relative growth of various body parts (Chatterji *et al.*, 1985). Shell height is considered to be effective in predicting biomass parameters (Dame, 1972; Ansari *et al.*, 1978). Oysters are irregular in shape, even

within the same species and they live in an overcrowded colonial pattern attached on to the hard substratum (Plate 5.1.). They are subjected to a process called xenomorphism in which their shape is determined by contour of the substrate where they grow (Quayle and Newkirk, 1989). The infestation by other specimens on the oyster shell along the colony compels in alteration of its shell growing pattern to accommodate itself within the colony. Therefore, dimensional relationships modifies by the environmental conditions under which the oyster grows (Seed, 1968; 1973; Jones *et al.*, 1979 and Hickman, 1979). Overcrowding results in the assumption of a variety of crooked forms (Rao and Nayar, 1956). Rivonkar (1991) suggested that the relationship in *Perna viridis* L. could indirectly be influenced by the local ambient environmental conditions, including food availability, feeding efficiency and population density.

Generally, positive allometric relationships have been reported in bivalves (Mohan, 1980). The relationships between the three dimensions of the oyster shells (length, width, and height) from St-1 and St-2, found to be significantly correlated with the total body weight than that of the flesh wet weight. However, the important of larger bivalves could easily be over estimated, if calculated from the total weight (Schaefer *et al.*, 1985). Overall, the relationships between length, width and height were found to be highly significant ($p < 0.001$), when correlated with total weight and meat wet weight in *C. madrasensis* and *C. gryphoides* from Goa. The width did

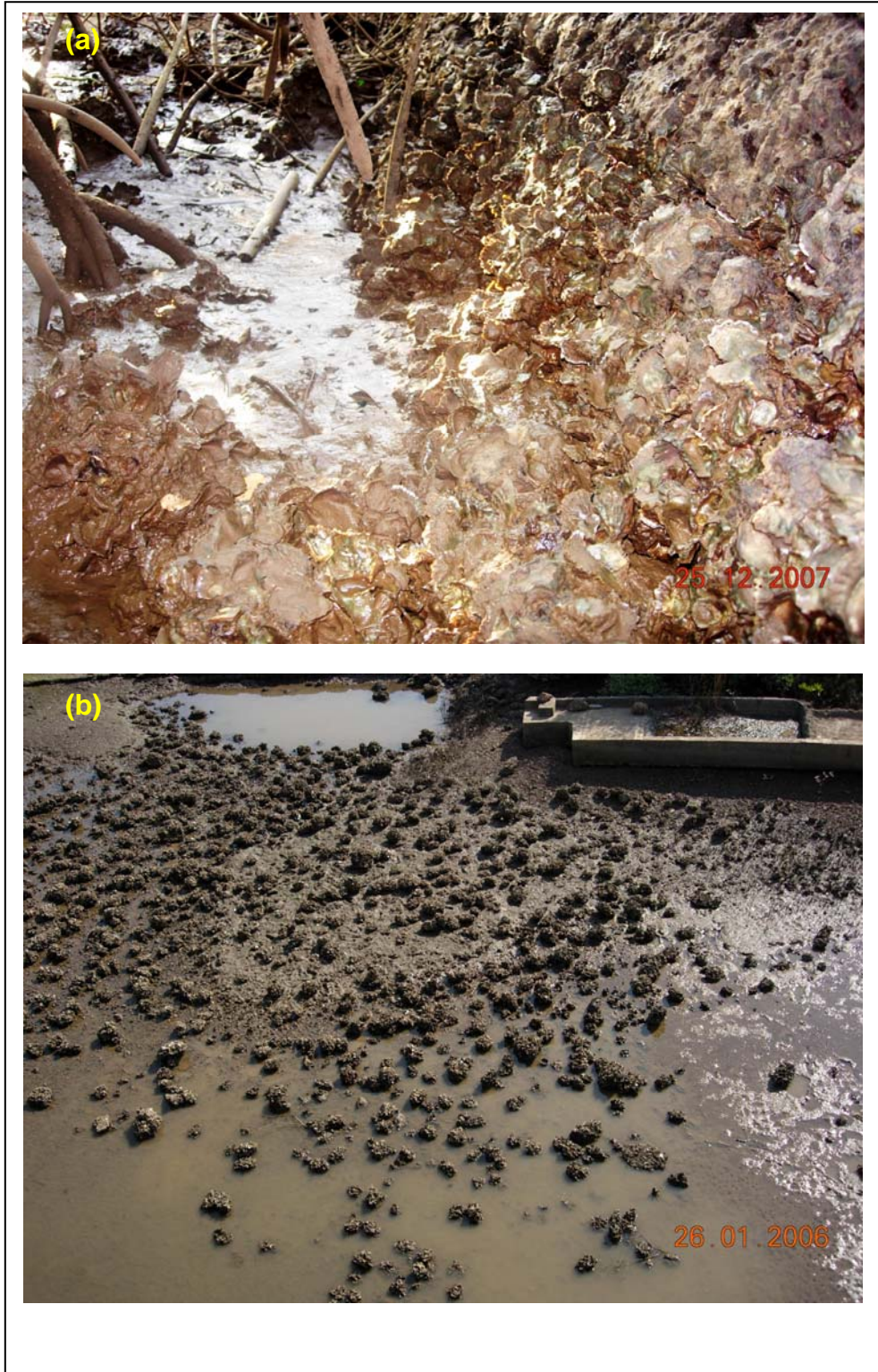


Plate 5.1. Oyster beds exist in the mangrove ecosystem of (a) St-1 and (b) St-2.

not exhibit correlation with most of the allometric parameters of oyster, except with flesh wet weight of *C. gryphoides* at St-1, which was found to be significant at $p < 0.01$.

The rate of conversion of energy to soft tissue remains higher in the cultured mussels compare to those occurring in natural habitats (Qasim *et al.*, 1977; Ansari *et al.*, 1978). The present findings revealed that the increase in total weight and meat weight are mostly dependent on the increase of the shell length of *C. madrasensis* and *C. gryphoides*. However, the increase in the total weight coincided with the increase in the flesh weight, indicating that contribution of soft tissue to the total weight was significant. The correlation coefficient between shell size and fresh meat weight was found to be 0.7615. The total weight found to increase faster than length to the tune of 2.07 and 1.72 times in *C. madrasensis* collected from St-1 and St-2, respectively. While in *C. gryphoides*, it was to the tune of 1.47 and 2.00 times from St-1 and St-2, respectively. The meat weight increased faster than length, which was 2.07 and 1.71 times in *C. madrasensis* collected from St-1 and St-2 respectively, whereas it was 1.24 time faster than length in *C. gryphoides*. Jorgensen (1976) and Hickman (1979) have reported that in larger mussels, the increases in size, growth rate decreases.

Oyster beds in the mangrove habitats of Goa have been continuously

subjected to heavy exploitation, with indiscriminate collection for daily consumptions, which has resulted in declining oyster population (Plate 5.2a). The oyster beds from Nerul creek (St-2) was observed to be relatively more stressed compared to the same from St-1 (Plate 5.2b). About 64% of the oyster bed has been exploited from St-1, while from St-2; it has been estimated to be about 83.83%. The lesser exploitation of oyster bed from St-1 could be attributed to the protection of mangrove habitats from the Chorao Island as it has been declared as a sanctuary protected area. However, the area remains accessible by locals, and the oyster's bed still uncontrolled.

The marketable size of oyster is considered to be when the shell height reaches 70 mm (Rao and Nayar, 1956), which is referred in the present study as length. However, the oyster size from St-1 in case of *C. madrasensis* ranged between 25-60 mm, however, in *C. gryphoides* it was ranged between 51-55 mm. The relatively smaller size compared to the marketable size might be due to the constant overexploitation, which does not allow the oyster to grow to the marketable size.

It could be concluded from these observations that the exploitation of those natural oyster beds is uncontrolled and would lead to total destruction of the oyster population and meat revenue from the area. Total destruction of oyster beds have been noticed at several locations from the estuaries of the



Plate 5.2. (a) Collection of oysters by fishermen from oyster beds adjacent to mangrove areas, (b) Selling of collected oysters by local ladies.

state. The optimum time for collecting the oysters found to be during pre-monsoon season between February and May, during which the CI and the PE values are higher. Regulation of oyster collection is required for the sustainable development of oyster fisheries in Goa.