

BIOCHEMICAL COMPOSITION OF CRASSOSTREA

MADRASENSIS

6.1. Introduction:

Aquatic, particularly tidal influenced, ecosystems are increasingly being looked at as a great potential food source for human being. Bivalves are considered as a low cost subsistence food of the coastal people (Stephen, 1980a). Among shellfishes, oysters are considered to be a valuable food items as they constitute rich source of many of the elements, essential for providing a balanced diet (Nagabhushanam and Bidarkar, 1978). Generally, the quality of biochemical composition of a whole body is an indication of animal quality, determining its nutritional value in comparison to other organisms (Rattan, 1994). These (Protein, Carbohydrates and lipids) constituents form an important tool to assess the condition index of the oyster, which provide a valuable indication of reaching its peak nutritive value, and as a source of nutritious seafood.

Goa is the only state in the Indian territories where the meat of oysters is popular and has got prominent market (Santhanam *et al.*, 1990). Oysters from mangrove influenced ambiance represent major source of potential nutrition for human consumption in Goa. Therefore, it is more desirable to understand the most important facts relating to its nutritive value by

determining the normal fluctuations in biochemical composition of the species. The present work was, therefore, undertaken to get an insight on the seasonal variation of water content (moisture), proteins, carbohydrates, and lipids levels in the flesh of the edible oyster, *Crassostrea madrasensis* (Preston), which is growing in association with mangroves habitats from estuaries and creeks of Goa.

6.2. Results:

6.2.1. Water Contents (Moisture):

Among the biochemical composition of the animal, water forms the main bulk of the oyster tissue with an annual average of $83.89\% \pm 3.23$ and $83.44\% \pm 2.14$ from the samples at St-1 and St-2, respectively, during the period of study. The water contents in *C. madrasensis* growing at St-1 ranged between 78.76% in May 2006 and 88.87% in October 2005, while at St-2, it ranged between 79.48% and 86.86 % with the lowest value observed in April 2006 and the highest in November 2005 (Figure 6.1).

The tissue maintained higher contents of moisture in the samples from St-1 during monsoon and post-monsoon, and later it decreased gradually reaching to its lower values in the pre-monsoon period. The samples from St-2 showed slight fluctuations in their moisture contents during monsoon and post-monsoon (August 2005 to January 2006) and reached its peak

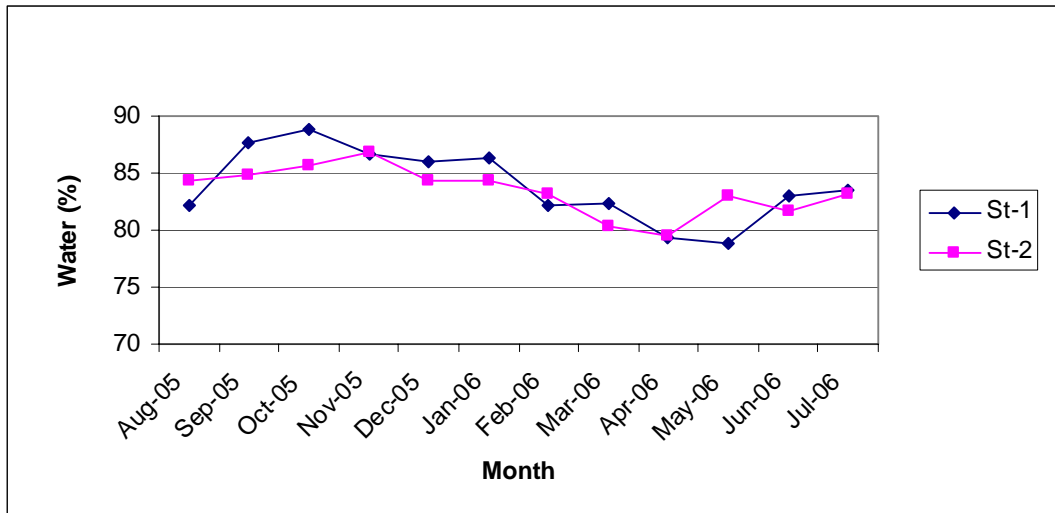


Figure 6.1. Average variation of water content (moisture) in oyster samples during August 2005 – July 2006.

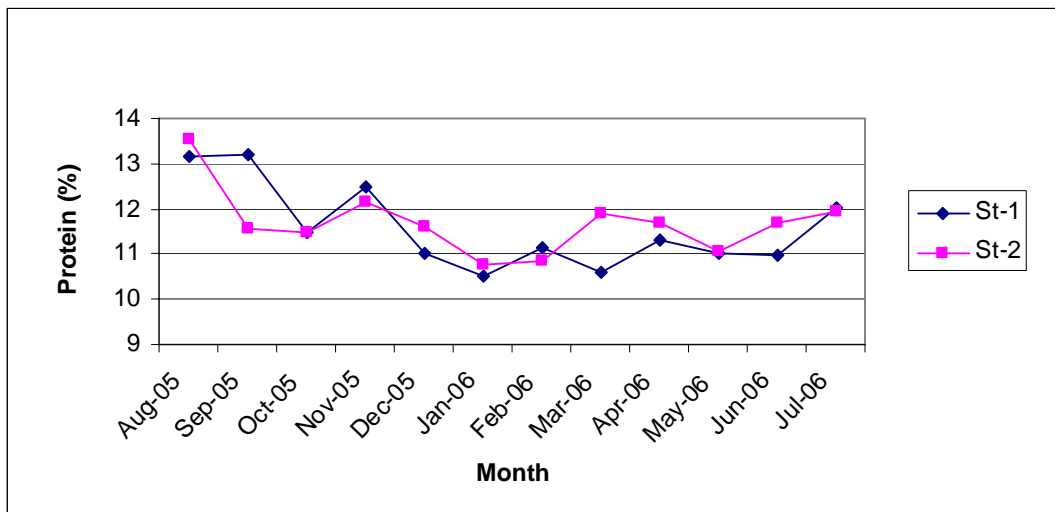


Figure 6.2. Average percentage of protein content in oyster samples during August 2005 – July 2006.

during November 2005. However, it reached to its minimum values in March and April 2006 and further increased in May 2006 and fluctuated thereafter until July (Figure 6.1).

6.2.2. Protein Contents:

Protein contents of *C. madrasensis* from St-1 ranged between 10.53% and 13.18%, while it ranged between 10.78% and 13.55% at St-2 (Figure 6.2). During monsoon period protein contents remain almost constant at its highest (13.14% and 13.18%, in August and September 2005, respectively). It decreased slightly in October (11.49%), and further increased in November (12.46%). Later it gradually decreased from November 2005 until it reached its lowest value in the month of January 2006 (10.53%). Protein contents increased in February, and thereafter fluctuated until April 2006. It decreased to 11.01% in May and remained almost stable in the month of June (10.99%), and later increased in July to 12.01%. The annual average of protein content in samples from St-1 was observed to be $11.57\% \pm 0.92$.

Protein contents in the samples from St-2 showed highest value in August 2005 (13.55%). However, it drastically reduced to 11.57% in September as well as in October (11.50%). Later it was increased in November to 12.17%, thereafter, gradually declined reaching its lowest value (10.78%) in January 2006. During March and May 2006, protein contents though showed

gradual decrease, it gradually increased from June 2006 onwards (Figure 6.2). The annual average of protein contents in oysters from St-2 was calculated to be $11.69\% \pm 0.72$.

6.2.3. Lipid Contents:

Percentage of lipid contents, in the oyster *C. madrasensis*, from St-1, varied from 2.10% in February 2006 to a maximum of 4.35% in July 2006, with an annual average of $2.93\% \pm 0.69$. Higher values of lipids were observed during monsoon season and gradually decreased in the post-monsoon reaching 2.50% in October 2005 (Figure 6.3). During October 2005 – January 2006, the values fluctuated slightly and then dropped down to its lowest value in February 2006 (2.10%). The lipid contents gradually increased from March to reach its maximum level (4.35%) in July 2006.

Tissue of *C. madrasensis* samples from St-2, followed similar trend of those collected from St-1. It showed higher lipid values during monsoon and decreased gradually to reach its minimum value (2.15%) in January 2006. It increased from February onwards and continued with slight fluctuations until May 2006. Thereafter, It exhibited sudden increase to 3.45% in June and July (Figure 6.3). The average of lipid contents in the samples from St-2 were also found to be very close ($2.95\% \pm 0.36$) to the average of lipid contents in the samples from St-1.

6.2.4. Carbohydrate Contents:

Carbohydrates in the flesh of *C. madrasensis*, from St-1, found in the range of 1.64% to 4.19% with an annual average of $2.80\% \pm 0.86$, while in the samples from St-2, it was recorded from minimum of 1.52% to maximum of 3.73%, with an average of $2.37\% \pm 0.67$.

The higher carbohydrates values, in the samples from St-1, recorded during monsoon and pre-monsoon seasons. Its values remained constant in August (2.58 %) and September (2.56 %) 2005. However, it showed relatively lower values during post-monsoon season, which ranged from 1.64% in October and November 2005, to 2.16% in January 2006 (Figure 6.4). The maximum value of carbohydrates (4.19%) encountered in February 2006, and later dropped to 2.72% during March, however, again increased in May (3.93%). During monsoon of 2006, values fluctuated slightly showing higher values in June and July (3.36% and 3.55%, respectively).

Slight fluctuations in carbohydrate values, from August to December 2005, were noticed in the samples from St-2, which ranged between 1.84% and 1.52%, respectively. It gradually increased until February 2006 (3.02%), and fluctuated, thereafter, until May and further increased gradually to reach its maximum value (3.73%) in the month of July 2006 (Figure 6.4).

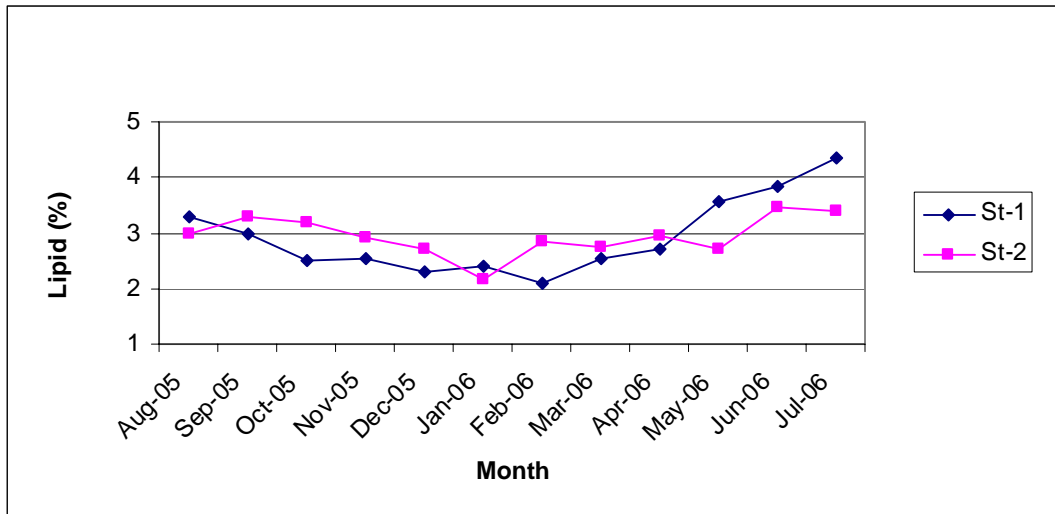


Figure 6.3. Average percentage of lipid content on oyster samples during August 2005 – July 2006.

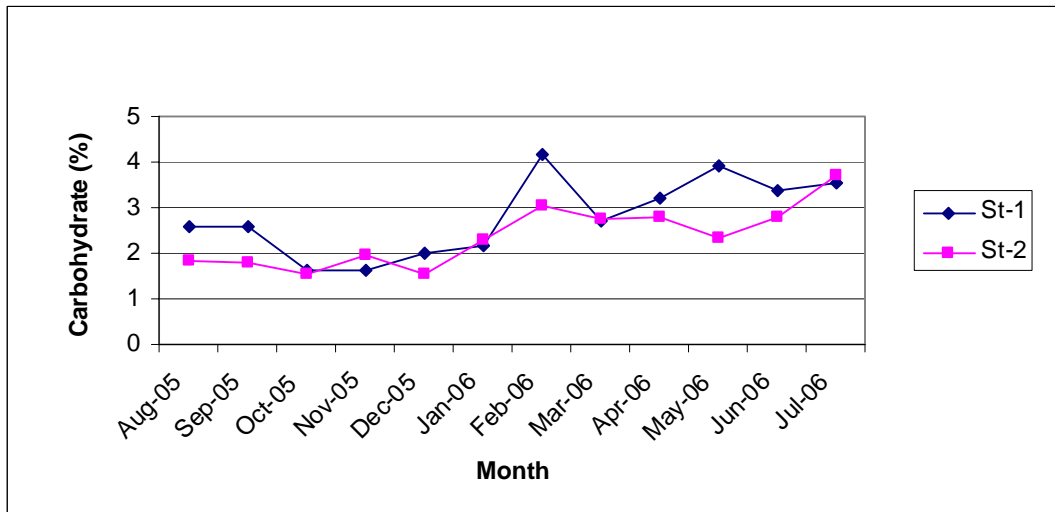


Figure 6.4. Average percentage of carbohydrate content in oyster samples during August 2005 – July 2006.

6.2.5. Caloric Values:

Maximum caloric value of protein (744.74 cal/g), in *C. madrasensis*, was recorded in September 2005 from St-1, and the minimum (594.86 cal/g) during January 2006 (Table 6.1), with an annual average of 653.86 cal/g \pm 52.13. Samples from St-2 showed the maximum value of 765.74 cal/g in August 2005, and the minimum value of 608.86 cal/g was recorded in January 2006 (Table 6.2), with an average value of 660.61 cal/g \pm 40.84.

Lipids caloric value ranged between maximum 408.90 cal/g during July 2006 and minimum 197.40 cal/g in February 2006 in samples from St-1. The same values in samples from St-2 ranged between 324.30 cal/g in June 2006 and minimum 202.10 cal/g in January 2006. The average of caloric value of lipids was calculated to be 275.34 cal/g \pm 65.14 and 276.91 \pm 34.21 cal/g in the samples from St-1 and St-2, respectively (Table 6.2).

Caloric value of carbohydrate contents found to range from a maximum of 175.84 cal/g in February 2006 to a minimum of 68.99 cal/g in November 2005 in the samples from St-1 (Table 6.1). The samples collected from St-2 showed a range between 156.49 cal/g in July 2006 and 63.94 cal/g in December 2005 (Table 6.2). The averages of caloric value from carbohydrate content were calculated to be 117.51 cal/g \pm 35.99 and 99.35 cal/g \pm 28.27 in the samples from St-1 and St-2, respectively.

The total caloric value in the samples from St-1 ranged from 911.32 cal/g in

Table 6.1. The calculated caloric values in oyster *Crassostrea madrasensis* at St-1.

Month	Proteins (cal/g)	Lipids (cal/g)	Carbohydrates (cal/g)	Total caloric content (Cal/g)
August 05	742.41	310.20	108.53	1161.14
September 05	744.74	282.00	107.69	1134.43
October 05	649.10	235.00	68.99	953.09
November 05	705.08	239.70	68.99	1013.77
December 05	622.85	216.20	84.13	923.19
January 06	594.86	225.60	90.87	911.32
February 06	628.68	197.40	175.84	1001.93
March 06	597.78	239.70	114.42	951.90
April 06	638.60	253.80	135.46	1027.86
May 06	622.27	333.70	164.90	1120.87
June 06	621.10	361.90	141.35	1124.35
July 06	678.84	408.90	148.92	1236.66

Table 6.2. The calculated caloric values in oyster *Crassostrea madrasensis* at St-2.

Month	Proteins (cal/g)	Lipids (cal/g)	Carbohydrates (cal/g)	Total caloric content (Cal/g)
August 05	765.74	282.00	77.40	1125.14
September 05	653.76	310.20	74.88	1038.84
October 05	649.68	300.80	64.78	1015.26
November 05	687.59	272.60	82.45	1042.64
December 05	655.51	253.80	63.94	973.25
January 06	608.86	202.10	95.91	906.87
February 06	614.10	267.90	127.04	1009.05
March 06	673.01	258.50	115.26	1046.77
April 06	660.18	277.30	117.79	1055.27
May 06	625.77	253.80	98.44	978.01
June 06	659.59	324.30	117.79	1101.68
July 06	673.59	319.60	156.49	1149.68

January 2006 to 1236.66 cal/g during July 2006. The values decreased gradually from 1161.14 cal/g in August to 953.09 cal/g in October 2005. During October 2005 and March 2006, the caloric values fluctuated and further increased steadily reaching its peak (1236.66 cal/g) in July 2006 (Figure 6.5). The annual average caloric value was 1046.71 cal/g \pm 105.82.

The total caloric value in the samples from St-2 ranged between maximum 1149.68 cal/g in July 2006 and 906.87 cal/g in January 2006, with an average of 1036.87 cal/g \pm 67.99. The values decreased gradually from August to October 2005, and increased slightly in November (Figure 6.6). However, It decreased to lowest value (906.87 cal/g) in January 2006. During January and April 2006, values increased to reach 1055.27 cal/g in April 2006, however, it went down to 978.01 cal/g in May. Thereafter, it increased gradually to reach its maximum value in the month of July 2006.

6.3. Discussion:

Various kinds of marine organisms, from different tidal influenced habitats, forms vital and renewable source of food and pharmaceuticals. Marine molluscs provide highly nutritious food for human consumption as they store large quantities of glycogen and fat (Nagabhushanam and Bidarkar, 1978; Kumari and Nair, 1988). Oysters and other bivalves form low-cost subsistence food of the coastal people, especially the local fishermen

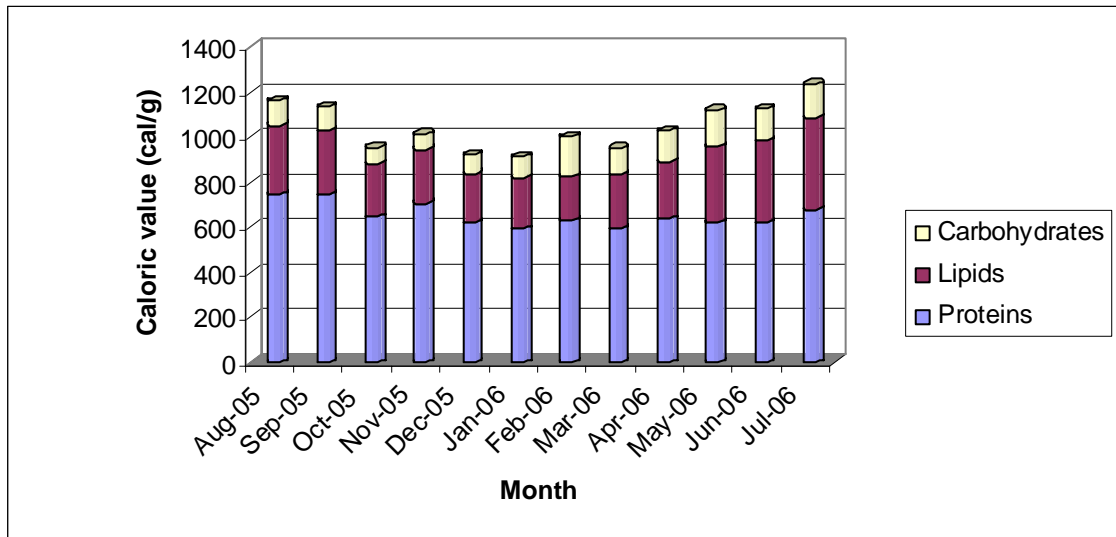


Figure 6.5. Seasonal variation in total caloric values of oyster *C. madrasensis* from St-1 during August 2005 – July 2006.

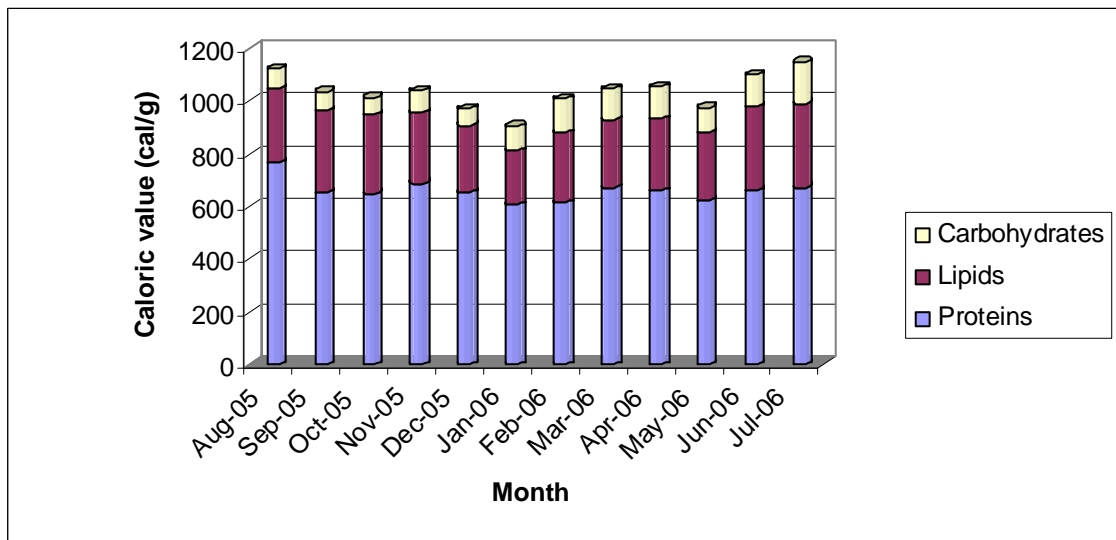


Figure 6.6. Seasonal variation in total caloric values of oyster *C. madrasensis* from St-2 during August 2005 – July 2006.

communities (Stephen, 1980a). The nutritive value of molluscs is governed by the various ecological and environmental parameters in ambience (Ruiz *et al.*, 1992).

The understanding of biochemical composition in various marine organisms plays a very important role in providing their nutritive value (Qasim *et al.*, 1977; Parulekar *et al.*, 1982; and Mohan and Kalyani, 1989). Seasonal variation in the biochemical composition of *C. madrasensis* may be correlated with various biological and environmental factors. The biochemical composition has been reported to be influenced by the salinity concentration in the surrounding water column (Durve and Bal, 1961; Saraswathy and Nair, 1969; Stephen, 1980b).

Average annual variations of moisture contents, in the tissue of *C. madrasensis* from St-1 and St-2 were estimated to be $83.89\% \pm 3.23$ and $83.44\% \pm 2.14$, respectively. These variations could be attributed to the salinity concentrations around oyster beds (Galstoff, 1964; Nagabhushanam and Bidarkar, 1978). During unfavorable conditions of salinity (higher or lower concentrations), molluscs, particularly oysters, might lose salts and gain water into their tissue when salinity reduces. During monsoon, salinity of the water drops down, leading water to enter into the body tissue increasing water contents in their body. The moisture contents of *C. madrasensis* exhibited negative correlation with the water salinity ($r = -0.3675$ and -0.13074 at St-1 and St-2, respectively). During summer, these contents were relatively low in the tissue due to higher of

salinity in ambient water. The above views could be further strengthened as low water contents were reported in bivalves during summer (Parulekar *et al.*, 1982; Rivonkar and Parulekar, 1995). Mussels develop an appropriate compensatory mechanism to counteract the increasing salt content in the surrounding environment during summer season (Parulekar *et al.*, 1982). It has been reported that the water contents in Indian bivalve increased after their spawning period (Venkataraman and Chari, 1951; Durve and Bal, 1961; and Saraswathy and Nair, 1969). Stephen (1980b) suggested that this increase is probably exaggerated by the simultaneous decrease in the salinity of the water column.

The protein values were higher whenever adequate food was available to the surroundings. During monsoon season, higher values of proteins in *C. madrasensis* could be attributed to richness of POC in ambience. Protein contents found to be positively correlated with POC ($r = 0.4437$, $P < 0.1$, at St-1 and $r = 0.2093$, $P > 0.1$ at St-2), although it was insignificant (Table 6.3 and 6.4). Protein contents have been reported to increase during pre-spawning season (Rivonkar, 1991), which could be a mechanism for storage of reserve to meet the spawning requirements. The richness of protein in oyster was also been related to the period of maximum ripeness during May and July (Dridi *et al.*, 2007), as well as attributed to the better metabolic conditions prevailed in the ecosystem (Qasim *et al.*, 1977).

The lowest value of protein in *C. madrasensis* in winter (January 2006) might be due to poor POC contents in the surroundings. The low protein

Table 6.3. The correlation between the biochemical composition and different components in oyster collected from St-1.

	Water content	Total proteins	Total lipids	Total carbohydrates	Total caloric content	Condition index	Percentage edibility
Water content	1						
Total proteins	0.2711	1					
Total lipids	-0.3054	0.2617	1				
Total carbohydrates	-0.7717	-0.2131	0.4192	1			
Total caloric content	-0.3169	0.5812	0.8870	0.4931	1		
Condition index	-0.9916	-0.2080	0.2755	0.7096	0.3085	1	
Percentage edibility	-0.7955	-0.1276	0.2200	0.7324	0.3216	0.7978	1

Table 6.4. The correlation between the biochemical composition and different components in oyster collected from St-2.

	Water content	Total proteins	Total lipids	Total carbohydrates	Total caloric content	Condition index	Percentage edibility
Water content	1						
Total proteins	0.1010	1					
Total lipids	-0.0308	0.3527	1				
Total carbohydrates	-0.6048	-0.1744	0.2062	1			
Total caloric content	-0.2064	0.7061	0.8009	0.4148	1		
Condition index	-0.8484	-0.0179	0.0478	0.3202	0.1464	1	
Percentage edibility	-0.6769	-0.2635	0.1708	0.3760	0.0839	0.7628	1

contents values could also be attributed to spawning. Durve and Bal (1961) and Stephen (1980a) indicated that *C. madrasensis* has a well defined semi-annual breeding pattern. The major spawning activity occurs during the period from April to June, and a minor spawning process occurs during the month of November with the rising salinity condition. Decrease in protein contents during post-spawning period could be an indication of the utilization of energy during active spawning period was contributed by protein (Galstoff, 1964; Wafar *et al.*, 1976; Nagabhushanam and Mane, 1978; Rivonkar and Parulekar, 1995). Proteins serve as an energy reserve during the gametogenesis process (Gabbott and Bayne, 1973; Ruiz *et al.*, 1993). Protein contents increased gradually in *C. madrasensis* from May at St-2 and from June at St-1. The reserves could be used to compensate the protein excess consumption during the period of spawning. On contrary, Nagabhushanam and Bidarkar (1978) found that protein contents of *C. madrasensis* were higher during pre and post-monsoon seasons, and lower values during the monsoon months.

The higher values of lipids in the tissue during monsoon could also be attributed to the higher concentrations of POC in waters influencing oyster beds and may be due to the increase in feeding efficiency (Rivonkar, 1991). Lipid contents showed positive correlation ($r = 0.4044$, $P < 0.1$ at St-1 and $r = 0.5774$, $P < 0.05$ at St-2) with POC. These results were very close to the earlier observations on *C. madrasensis* by Nagabhushanam and Bidarkar (1978). Widdow and Bayne (1971) and Bayne (1973) stated that presence

of large quantum of planktons in the water column allows the accumulation of lipid as well as carbohydrate reserves.

Negative correlation was found between water contents and lipids ($r = -0.3054$ and -0.0304 at St-1 and St-2, respectively). Such inverse relationship was reported in *C. gryphoides*, *Nausitora hedleyi*, *C. madrasensis*, and in *P. viridis* by several authors (Durve and Bal, 1961; Saraswathy and Nair, 1969; Stephen, 1980b; Rivonkar, 1991). Lowest levels of lipid contents were observed in the tissue samples during winter, particularly in February 2006 (2.10%) from St-1 and in January 2006 (2.15%) from St-2. The decline in lipids during post-monsoon (winter) was found to be consistent with low contents of POC (Widdows and Bayne, 1971; Rivonkar and Parulekar, 1995). The lower levels of lipids in the samples could also be attributed to the utilization of lipid reserves for building-up of tissue material (Rivonkar, 1991). Decrease in fat contents could also be attributed to initiation of gametogenesis and for development of gametes (Qasim *et al.*, 1977; Zandee *et al.*, 1980). Decrease of lipids and proteins during winter was reported in temperate species, i.e. *C. corteziensis* (Hertlein) by Páez-Osuna *et al.* (1993). The fat contents in *C. madrasensis*, however, were reported to be low in July and have been attributed to the growth and maturation of gonads of the oyster (Venkataraman and Chari, 1951), and higher levels in October – November, in the same species, was correlated to their intensive feeding.

Carbohydrates in the tissue of *C. madrasensis* from the study region of Goa ranged from 1.52% to 4.19%. Carbohydrate contents showed lower values during post-monsoon season, and increased during pre-monsoon and monsoon seasons. Oysters have been reported to be rich in glycogen during the period of monsoon (Stephen, 1980b). Nagabushanam and Bidarkar (1978) observed highest contents of glycogen in *C. cucullata* in the months of April – May and lowest during December. During present investigations, a negative correlation was found between contents of protein and carbohydrates, though insignificant. The same relationship has been observed by Lakshmanan and Nambisan (1980) in *Villorita cyprinoids* var *cochinensis* and *Meretrix casta* (Chemnitz).

High values of carbohydrates and low values of protein and lipids during winter indicate accumulation of carbohydrates in the tissue and greater reliance of organism on proteins and lipids. It has been reported that, in *Mytilus edulis*, the food shortage between January and April caused a significant loss of protein (75%) and some of lipid reserves (15%), while carbohydrate contributed 10% of the total energy loss (Dare and Edwards, 1975).

High carbohydrate values could be attributed to intense breeding and reproduction activities as reported in case of *C. gryphoides* and *M. meretrix* (Durve and Bal, 1961; Nagabushanam and Deshmukh, 1974; Balasubrahmanyam and Natarajan, 1988). On the other hand, Páez-Osuna *et al.* (1993) reported a decline in carbohydrate contents in both *C.*

corteziensis (Hertlein) and *C. iridescens* (Hanley) during the stage of gametogenesis.

Glycogen has been considered to be the principal energy reserve of adult marine bivalves, especially under nutrient stress (Beninger and Lucas, 1984). It has long been known that molluscs contain a large amount of glycogen and annual cycle in oysters has been studied (Galstoff, 1964; Robert *et al.*, 1993). During summer, carbohydrate reserves build-up in the tissue (William, 1969). Carbohydrate serves as an index of high glycogen metabolism and a bioindicator during the period of environmental stress (Parulekar *et al.*, 1982 and Patrick *et al.*, 2006). During spawning season, energy requirements are met by proteins and lipids to a greater extent as compared to carbohydrates (Rivonkar, 1991). Some of the glycogen gets converted into lipid and forms an energy reserve for the larvae (Quayle and Newkirk, 1989).

The major biochemical constituents have been found to be stored during summer and pre-monsoon season for subsequent utilization of these resources during monsoon for body maintenance (Mohan and Kalyani, 1989). Generally, these constituents play an important role as a gametogenesis fuel and support the basic metabolic maintenance cost under the stress of food shortage (Dridi *et al.*, 2007).

As stated in the previous chapter, Beninger and Lucas (1984) found a very close correlation between the CI and the biochemical constituents.

Changes in body weight are mainly due to changes in carbohydrates content (Gabbott and Bayne, 1973). Carbohydrates in *C. madrasensis*, from St-1, showed highly significant positive correlation with the CI and the PE (Table 6.3 and 6.4). The highly significant correlation coefficient ($r = 0.7096$ at 1% level) was observed between the carbohydrates contents and the CI. Whereas, the correlation coefficient between carbohydrate contents and the PE was also found to be significant ($r = 0.7324$ at 1% level). These parameters also exhibited positive correlation in the samples from St-2, however, values found to be insignificant (0.3202 and 0.3760) in these between carbohydrates and CI, and carbohydrates and PE, respectively.

Water contents in the tissues of samples from both the stations showed a highly significant but negative correlation with the CI ($r = -0.9916$, $p < 0.001$ at St-1 and $r = -0.8484$, $p < 0.001$ at St-2), as well as PE ($r = -0.7955$, $p < 0.01$ and $r = -0.6769$, $p < 0.01$ at St-1 and St-2, respectively). Protein contents showed insignificant negative correlation with the CI and the PE, while lipids contents showed insignificant positive correlation in the samples from both stations (Table 6.3 and 6.4).

Present data revealed higher caloric values in *C. madrasensis* during monsoon season with an average of 1046.71 cal/g at St-1 and 1036.87 cal/g at St-2. The lowest caloric values (911.32 cal/g at St-1 and 906.87 cal/g at St-2) were recorded during the month of January 2006, during which the protein and lipid contents were at their lower levels. The caloric

value was positively correlated to proteins, lipids and carbohydrates (Table 6.3 and 6.4). Among these biochemical constituents, the total caloric value showed highly significant correlation with the lipid contents ($r = 0.88701$, $p < 0.001$ at St-1 and $r = 0.8009$, $p < 0.01$ at St-2). Caloric values also showed significant correlation with protein contents ($r = 0.5812$, $p < 0.05$ and $r = 0.7061$, $p < 0.05$, at St-1 and St-2, respectively), whereas it was insignificantly correlated with the carbohydrate contents ($r = 0.4931$, $p < 0.1$ at St-1 and $r = 0.4155$, $p < 0.1$ at St-2). These caloric values may be attributed to the concentrations lipids and proteins, which directly influence the energy contents (Rivonkar, 1991).

As mentioned before, the best time to harvest bivalves, including oysters, remains during monsoon season, which coincide with the higher caloric values as reported in the present investigation. Kumari *et al.* (1977) observed that higher values of protein content in clam *M. casta* from the back water during monsoon, indicating harvest season. Wafar *et al.* (1976) observed higher nutritive value in *M. viridis* (Linné) from April – August, which he also suggested to be the best time for harvesting. During the present investigations, the data revealed that during this period, particularly April and May, the CI was at its highest values.

The environmental conditions appear to influence the metabolic level and reproduction cycle within the oyster population (Stephen, 1980a; 1980b; Gabbott, 1983). The reduction in biochemical contents of *C. madrasensis* could be related to unfavorable temperature, salinity and other abiotic and

biotic environmental conditions prevailing at that time. Negative environmental and nutritive stress adversely influences the biochemical composition in marine organisms (Widdows and Bayne, 1971; Bayne, 1973; Gabbott and Bayne, 1973).

It may be concluded that, the oyster *C. madrasensis* associated with mangrove habitat showed seasonal variations in biochemical composition. The present study indicates that major biochemical constituents in oyster *C. madrasensis* are significantly influenced by the conditions of ambient environment such as quantity of food available, temperature and salinity. The high contents of lipids, proteins, carbohydrates, and relevant calorific values, during monsoon, are indicating this season as the best for harvesting this particular oyster species.

**BIOINDICATION POTENTIAL OF CRASSOSTREA
MADRASENSIS FOR TRACE METALS IN MANGROVE
ECOSYSTEM**

7.1. Introduction:

Accumulation of most of the heavy metals from the particular habitat is closely related to biogeochemical cycle in the environment (Sen Gupta *et al.*, 1978). Rapid alteration and development during recent times, has increased the heavy metal pollution discharge ultimately emptying in the marine environments. It has led to deteriorating the quality of the estuarine and related habitats.

Some bivalve species have been extensively used as a biological indicator organisms or flag species for identifying areas of pollution and monitoring the progress of measures to encounter pollution (Phillips, 1976b; Phillips, 1977a; Popham *et al.*, 1980; Gordon *et al.*, 1980; Udaybhaskar *et al.*, 1983). Various biological resources form natural and inexpensive tools for monitoring of industrial effluent standards, and thus enables monitoring and maintenance of the environment quality.

The waters of Mandovi-Zuari-Cumbarjua estuarine complex are intensively used for the transportation of manganese and iron ores. The major

mangrove formations from the state exist in the regions influenced by this estuarine complex (Chapter 3 of this thesis). Mining activities in the hinterlands and transportation of the same have been intensified during last four decades, contributing heavy inputs of rejects to the estuarine and mangrove regions in the state. The estuaries also receive discharge of waste water arising from anthropogenic and industrial activities.

Concentrations of trace metals in mangrove foliage have been studied by Gulati *et al.* (1979); Bhosale (1979) and Untawale *et al.* (1980). The trace metal concentrations have been evaluated in bivalves from estuaries and creek water regions of west coast of India to a little extent (Sankaranarayanan *et al.*, 1978; Rivonkar, 1991; Rivonkar and Parulekar, 1998). The present investigations are aimed at determining the concentrations of trace metals in the mangrove ecosystem and associated oysters *Crassostrea madrasensis*, and to evaluate their bioindicator ability for trace metal pollution.

7.2. Results:

7.2.1. Water Samples:

7.2.1.1. Iron (Fe):

The concentration of Fe from St-1 ranged between maximum of 126.7 ppm in August to minimum of undetectable levels in January and February

(Figure 7.1). The average concentration during the study period was found to be $44.3 \text{ ppm} \pm 41.2$.

Iron concentration of estuarine water from St-2 ranged between maximum of 79.6 ppm in September and minimum of undetectable levels during the months of October to February (Figure 7.1). The average concentration value during the study period was estimated to be $35.9 \text{ ppm} \pm 23.1$.

7.2.1.2. Zinc (Zn):

The average value of Zn was recorded to be $0.8 \text{ ppm} \pm 0.6$ from waters of St-1, while it was $0.8 \text{ ppm} \pm 0.7$ in the waters from St-2. The maximum concentration in St-1 during the study period was found in the month of September (1.6 ppm), while the minimum of undetectable levels were recorded in June. Waters from St-2 showed maximum of 1.8 ppm in August, and minimum of undetectable levels during the period between May and July. The concentrations of Zn in the estuarine water samples from both stations are depicted in Figure 7.2.

7.2.1.3. Manganese (Mn):

The concentration of Mn from St-1, during the period of study, varied from undetectable values in the months of August, January, May and July, to a maximum of 0.5 ppm in the month of June (Figure 7.3). The average value is found to be $0.1 \text{ ppm} \pm 0.2$.

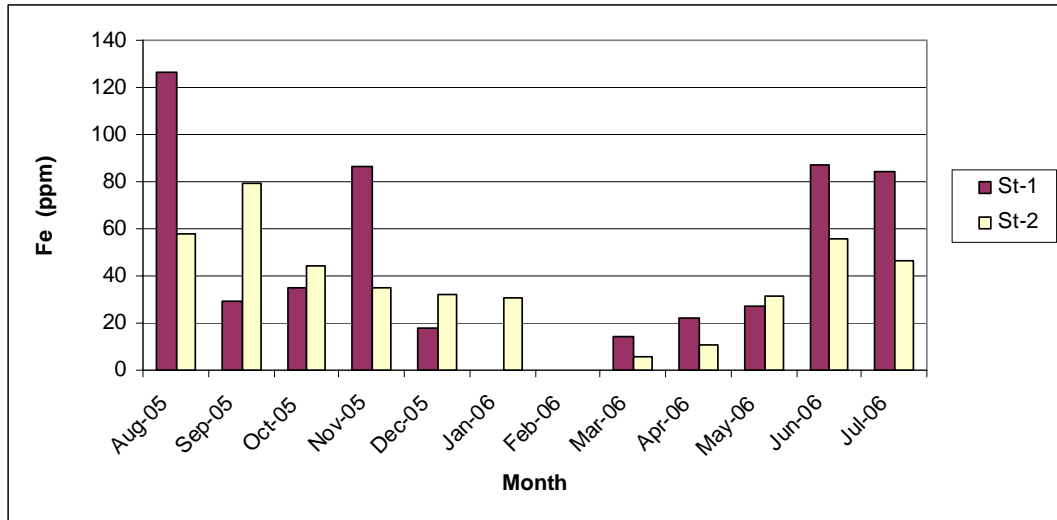


Figure 7.1. Seasonal fluctuations in Fe concentrations of water samples during August 2005 – July 2006.

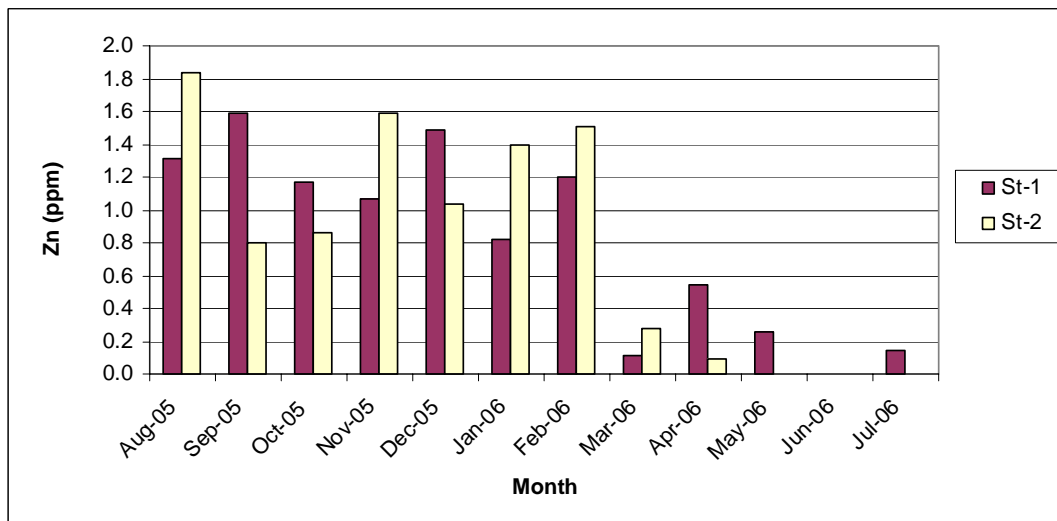


Figure 7.2. Seasonal fluctuation in Zn concentrations of water samples during August 2005 – July 2006.

Mn concentrations from St-2 ranged from undetectable concentrations in the months of September, February and March, and a maximum of 0.5 ppm in April (Figure 7.3). The average value of the Mn concentrations at St-2 was found to be 0.1 ppm \pm 0.2.

7.2.1.4. Lead (Pb):

Concentrations of Pb during the study period at St-1 varied from minimum 0.02 ppm in January to a maximum of 5.3 ppm in July, with an average of 1.4 ppm \pm 1.8, While at St-2, it fluctuated between maximum 1.291 ppm in July to minimum of undetectable levels in March and June, with an average value of 0.259 ppm \pm 0.37. The variations in Pb concentrations in the water samples collected from both stations during the study period are shown in Figure 7.4.

7.2.1.5. Chromium (Cr):

Concentrations of Cr in the water samples from St-1 ranged between maximum 4.7 ppm in March to minimum of undetectable levels in May (Figure 7.5). The average value during the study period found to be about 1.3 ppm \pm 1.6. At St-2, the Cr concentration fluctuated between maximum 3.069 ppm in July and minimum value of undetectable levels in March, May and June (Figure 7.5). The average value of Cr during the study period was found to be 0.6 ppm \pm 1.0.

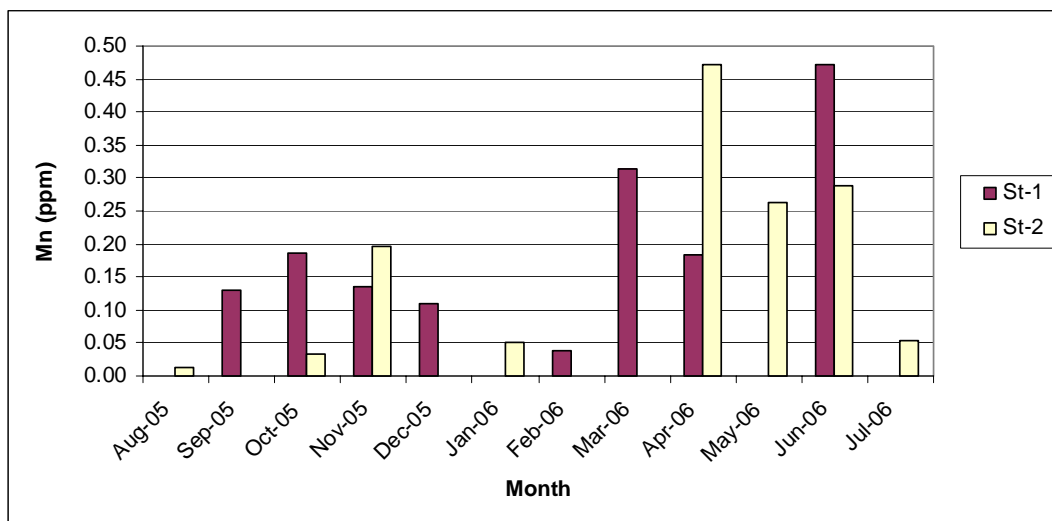


Figure 7.3. Seasonal fluctuation in Mn concentrations of water samples during August 2005 – July 2006.

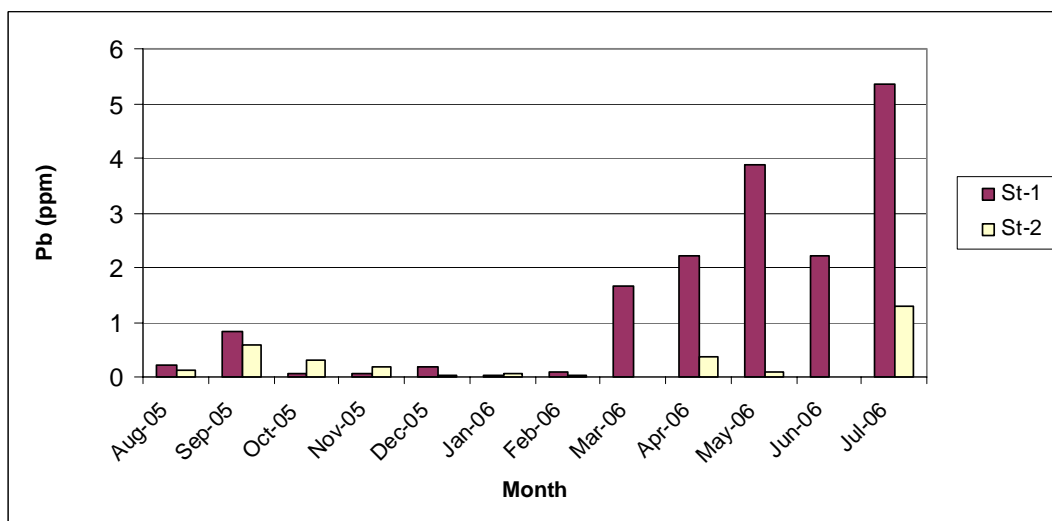


Figure 7.4. Seasonal fluctuation in Pb concentrations of water samples during August 2005 – July 2006.

7.2.1.6. Nickel (Ni):

Ni concentrations in the water samples from St-1 varied from 5.6 ppm in June to the minimum value of undetectable concentration in the months of August and September (Figure 7.6), with an average value of 2.9 ppm \pm 1.8. At St-2, the same concentrations fluctuated from maximum of 5.4 ppm in January and minimum concentrations of undetected range in the month of September (Figure 7.6). The average value of Ni concentration at St-2 was found to be 2.8 ppm \pm 1.8.

7.2.2. Tissue Samples:

7.2.2.1. Iron (Fe):

Concentrations of Fe in the tissue of oyster *C. madrasensis* from St-1 was observed in the range of 2534.9 ppm during March to minimum of 435.7 ppm in July (Figure 7.7), with an average value of 1215.7 ppm \pm 619.8. At St-2, the Fe concentration fluctuated between 1976.7 ppm in the month of November to minimum value of 483.840 ppm during July, with an average of 1015.8 ppm \pm 461.0 (Figure 7.7).

7.2.2.2. Zinc (Zn):

Zinc concentrations in the tissue of *C. madrasensis* from St-1 ranged from

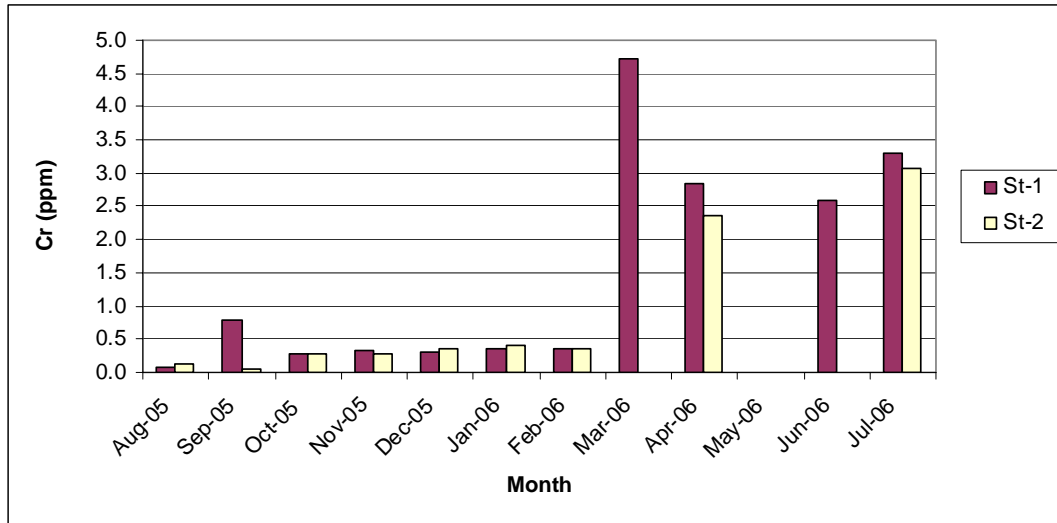


Figure 7.5. Seasonal fluctuation in Cr concentrations of water samples during August 2005 – July 2006.

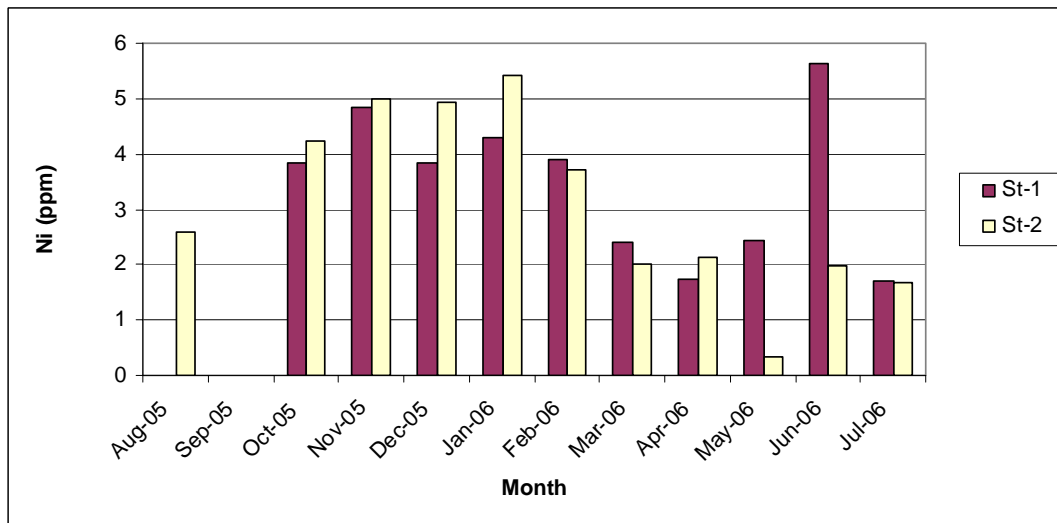


Figure 7.6. Seasonal fluctuation in Ni concentrations of water samples during August 2005 – July 2006.

1033.7 ppm in December to minimum of 626.2 ppm during March (Figure 7.8), with an average of 847.0 ppm \pm 146.9. The concentrations of Zn, in the samples from St-2, ranged between 1034.9 ppm during August to minimum of 428.7 ppm in March (Figure 7.8), with an average of 836.0 ppm \pm 183.1.

7.2.2.3. Manganese (Mn):

Mn concentrations in the oyster tissue from St-1 ranged from 33.3 ppm in November to undetected levels in February and May (Figure 7.9), with an average value of 17.5 ppm \pm 9.9. At St-2, these values fluctuated from 58.5 ppm in November to below detection levels in October, February and March (Figure 7.9), with an average value of 12.1 ppm \pm 17.1.

7.2.2.4. Lead (Pb):

Lead concentrations in tissue samples from St-1 was found to be varying between 41.670 ppm in October to the minimum of undetectable levels in April (Figure 7.10), with an average value of 22.0 ppm \pm 14.6. However, these values were relatively higher at St-2, ranging from 86.4 ppm in the month of July to 6.4 ppm in January (Figure 7.10), with an average of 30.6 ppm \pm 23.7.

7.2.2.5. Chromium (Cr):

Concentrations of Cr in the tissue of *C. madrasensis* from St-1 varied from

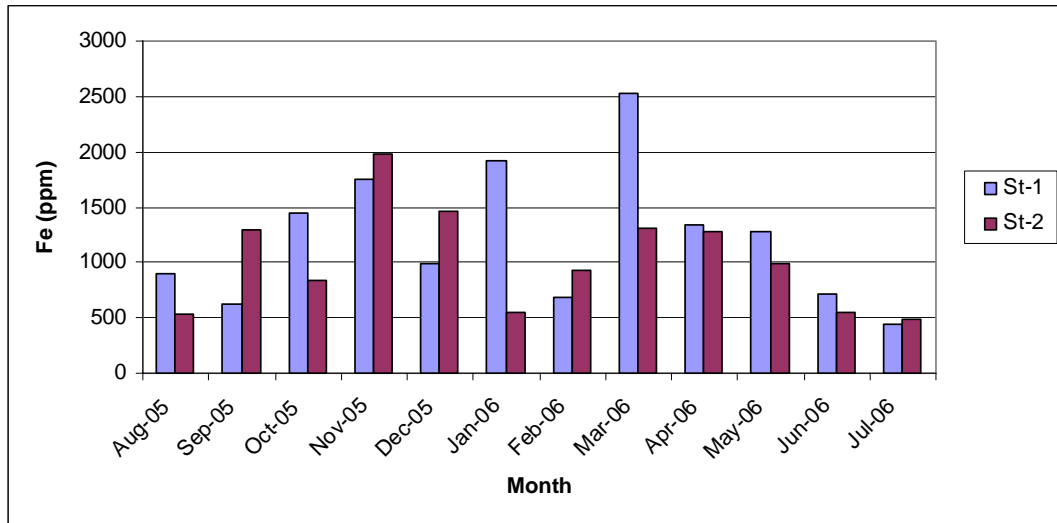


Figure 7.7. Seasonal fluctuation in Fe concentrations of oyster samples during August 2005 – July 2006.

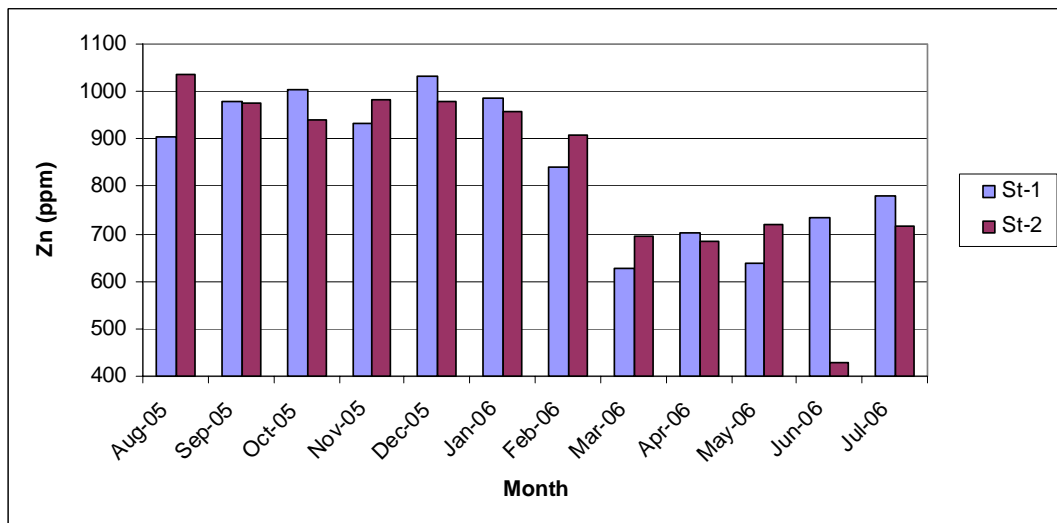


Figure 7.8. Seasonal fluctuation in Zn concentrations of oyster samples during August 2005 – July 2006.

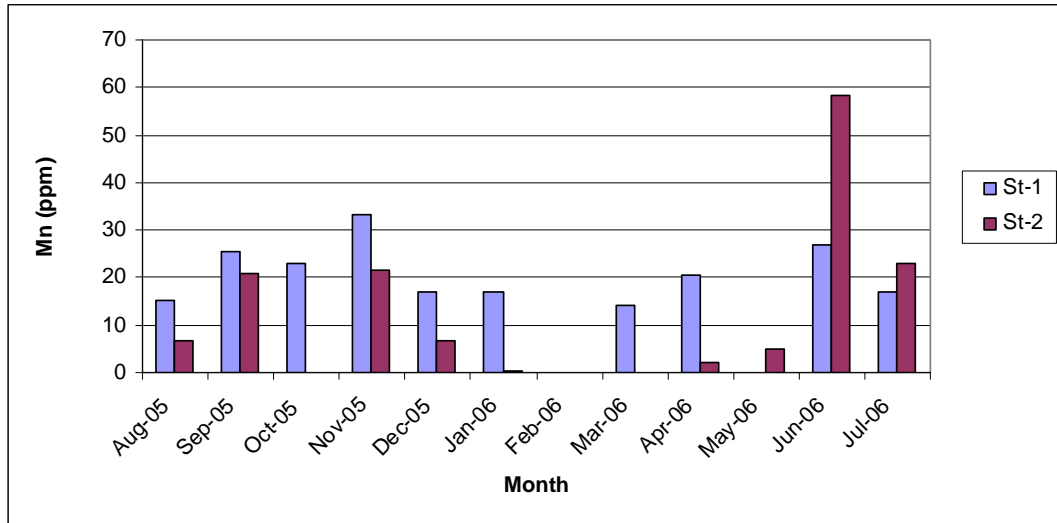


Figure 7.9. Seasonal fluctuation in Mn concentrations of oyster samples during August 2005 – July 2006.

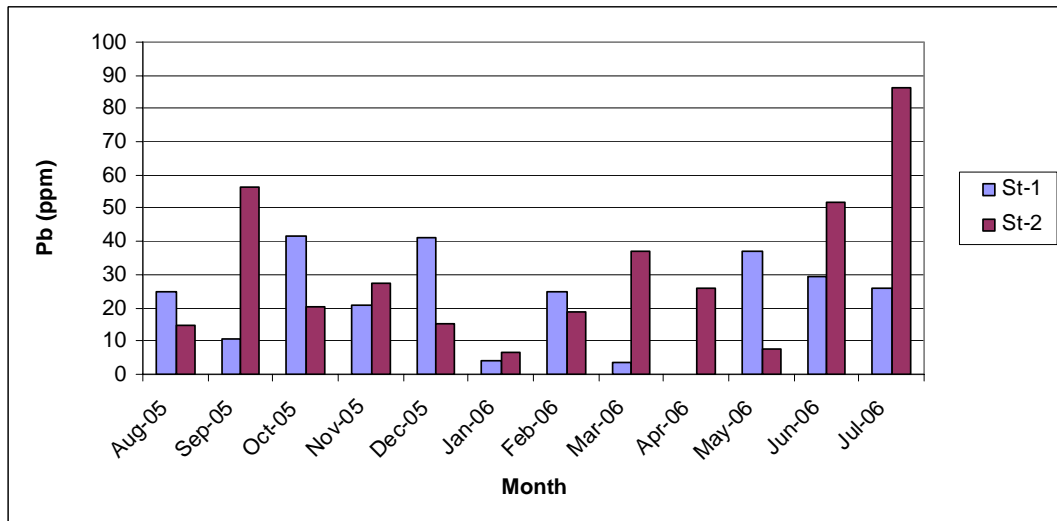


Figure 7.10. Seasonal fluctuation in Pb concentrations of oyster samples during August 2005 – July 2006.

maximum of 16.1 ppm in April and minimum of below detection levels in March and May (Figure 7.11), with an average of 7.4 ppm \pm 5.5. However, *C. madrasensis* from St-2 exhibited, relatively, higher concentrations of Cr ranging from 25.1 ppm in August to undetectable levels during March and May (Figure 7.11), with an average value of 10.2 ppm \pm 7.3.

7.2.2.6. Nickel (Ni):

The average value of Ni concentrations in the tissue samples was estimated to be 48.1 ppm \pm 7.4 at St-1, while at St-2, it was 40.0 ppm \pm 8.8. The maximum Ni concentration (65.1 ppm) from St-1 was recorded in February, and the minimum value (41.6 ppm) was during the month of March. The maximum value, at St-2, was found to be 53.9 ppm in December, while the minimum value (17.9 ppm) was observed in July (Figure 7.12).

7.2.3. Mangrove Samples:

Seasonal (monsoon, pre-monsoon and post-monsoon periods) concentrations of trace metals in the mature foliage of different mangroves species have been represented in Table 7.1 and 7.2 from St-1 and St-2, respectively.

7.2.3.1. St-1:

Quantum of Fe contents were observed to be close in different mangrove

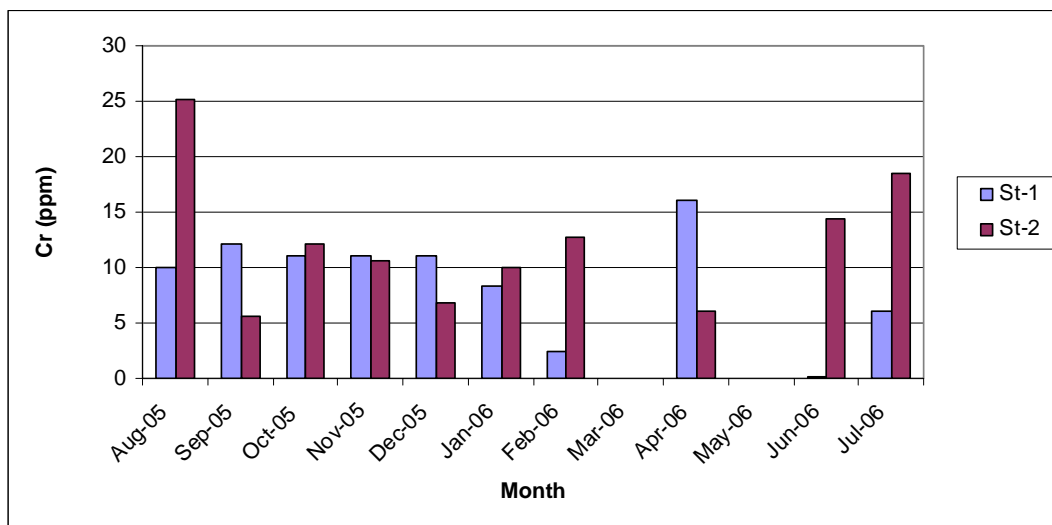


Figure 7.11. Seasonal fluctuation in Cr concentrations of oyster samples during August 2005 – July 2006.

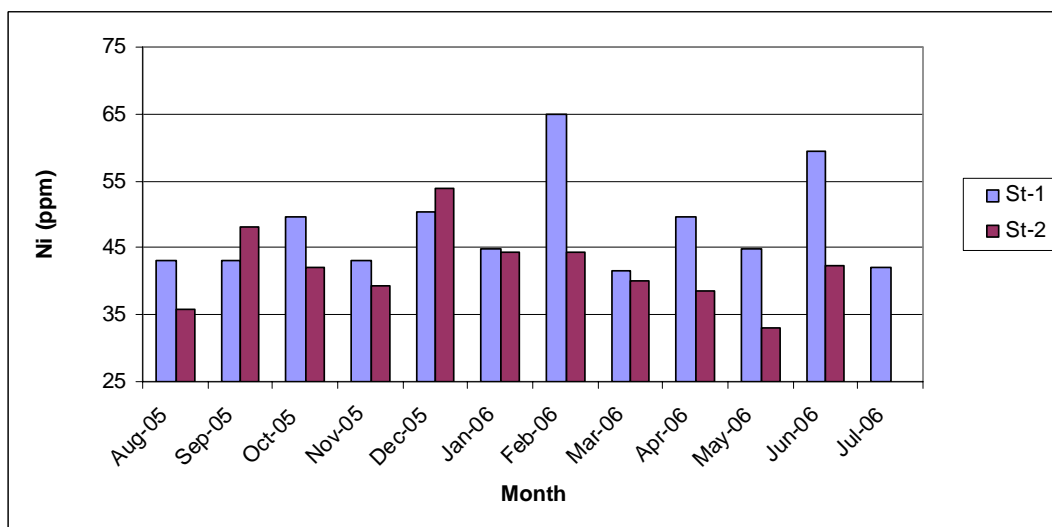


Figure 7.12. Seasonal fluctuation in Ni concentrations of oyster samples during August 2005 – July 2006.

Table 7.1. Concentrations of trace metals in mangrove leaves collected from St-1.

Sample	Fe (ppm)	Zn (ppm)	Mn (ppm)	Pb (ppm)	Cr (ppm)	Ni (ppm)
Pre-monsoon						
<i>R. mucronata</i>	270.34	ND	335.28	59.04	51.5	ND
<i>A. marina</i>	385.54	ND	89.54	11.12	72.72	ND
<i>A. illicifolus</i>	250.6	ND	329.42	51.86	66.66	ND
Monsoon						
<i>R. mucronata</i>	364.62	ND	1100.24	131.46	115.82	ND
<i>A. marina</i>	353.84	ND	246.3	108.92	152.18	13.94
<i>A. illicifolus</i>	214.62	2.48	111.22	103.28	156.22	5.98
Post-monsoon						
<i>R. mucronata</i>	151.46	ND	692.81	ND	101.23	46.42
<i>A. marina</i>	203.27	ND	69.63	ND	256.79	46.43
<i>A. illicifolus</i>	122.6	ND	119.89	ND	553.09	43.18

(ND): Not Detected.

Table 7.2. Concentrations of trace metals in mangrove leaves collected from St-2.

Sample	Fe (ppm)	Zn (ppm)	Mn (ppm)	Pb (ppm)	Cr (ppm)	Ni (ppm)
Pre-monsoon						
<i>R. mucronata</i>	952.28	ND	166.38	18.52	18.18	ND
<i>A. marina</i>	186.98	13.14	165.2	19.74	ND	ND
<i>A. illicifolus</i>	279.52	ND	293.06	18.52	12.18	ND
Monsoon						
<i>R. mucronata</i>	412.3	ND	17.18	52.58	67.34	22.88
<i>A. marina</i>	320.76	ND	62.52	111.74	148.14	15.92
<i>A. illicifolus</i>	353.08	2.48	97.86	63.84	196.64	23.88
Post-monsoon						
<i>R. mucronata</i>	258.03	ND	116.86	15.3	293.83	43.21
<i>A. marina</i>	235.83	ND	203.54	34.97	353.09	43.18
<i>A. illicifolus</i>	505.21	ND	146.33	17.49	197.53	49.67

(ND): Not Detected.

species. *R. mucronata* showed highest values (364.6 ppm) of Fe in the monsoon season compared to the same during pre-monsoon (270.3 ppm) and post-monsoon (151.5 ppm) seasons. However, *A. marina* and *A. ilicifolius* showed highest values (385.5 ppm) during the pre-monsoon. These values decreased gradually in monsoon and post-monsoon seasons. Zn concentrations were found below detectable levels in all the species in different seasons, except a very small concentration (2.48 ppm) of the same in *A. ilicifolius* during the monsoon. However, Mn and Pb contents were showed highest values during monsoon season in all the three species (Table 7.1). Pb concentrations were below detectable levels during the post-monsoon season. Cr and Ni values during the pre-monsoon were reported to be lowest (66.7 ppm and undetected level, respectively). However, the same were increased gradually during the monsoon and post-monsoon periods.

7.2.3.2. St-2:

Fe contents in *R. mucronata* showed highest value (952.3 ppm) during the pre-monsoon, and decreased gradually during the remaining periods. On the contrary, *A. ilicifolius* showed exactly opposite trend in Fe contents i.e. during the pre-monsoon concentrations were lowest and gradually increased during the rest of the season. *A. marina*, however, showed the highest value (320.8 ppm) of Fe during monsoon. Zn concentrations in all the three species were beyond detection limits from both stations, except a concentration of 13.1 ppm was recorded in *A. marina* during pre-monsoon

and 2.48 ppm in *A. ilicifolius* during monsoon. All the species were recorded to have lowest concentrations of Mn during monsoon, however, highest concentrations of Pb were observed during the same season. Cr and Ni followed the same trend as observed in mangrove foliage at St-1. The lowest values detected during pre-monsoon season and it increased gradually during the monsoon and post-monsoon seasons.

7.3. Discussion:

The rapidly and constantly increasing anthropogenic activities and industrial developments, particularly close to the marine coastal environment has encouraged baseline data banks on various biological, chemical and physical features and related monitoring to mitigate adverse impacts of these pressures on marine habitats (Gordon *et al.*, 1980). Metal Pollutants are added to sea as a result of atmospheric and anthropogenic pathways (Sen Gupta and Qasim, 2001). Discharge of effluents enriched with different trace metals from industries and municipalities finds its way to various aquatic systems, finally reaching to the marine environment. Freshwater aquatic bodies transport trace metals to the oceans in dissolved, colloidal and particulate forms (George, 1989).

Due to the considerable amount of input of riverine particulate matter to the low lying tidal zones has resulted in the formation of extensive mudflats sustaining mangroves and associated habitats. Intertidal mudflats are continuously prograding towards water fronts in the estuarine region.

Several localities from Mandovi estuary represent rich mangrove formations and associated flora and fauna. Mangroves with its associated biota are of vital importance as they form spawning, nursery and breeding grounds for a variety of invertebrates, fishes, reptiles and birds.

Fang and Wang (2006) opined that fine-grained sediments are the major carriers of heavy metals based on the significant correlations between concentrations of heavy metals and the clay contents. Mangrove regions being repository environment rich alluvial soils are rich in clay, silt and humus (Jagtap, 1985). It is therefore, these habitats possess a great potential sink of the trace metals brought by the runoff to the estuarine regions. Contribution of trace metals being a continuous process, the regular monitoring of estuarine and their associated biota would help in understanding the quality of environment.

Better knowledge of existing levels of trace metals in the aquatic environment play a major role in pollution studies (Rajendran *et al.*, 1987). Baseline data conformation on various aspects of habitats or monitoring the same often focuses upon marine biota. These organisms contain elevated concentrations of trace metals relative to polluted water, which assist detecting the changes in trace metal concentrations. Bivalves, among molluscs, are considered to be the sentinel organisms for studying and monitoring metal pollution in the marine environment (Phillips, 1977a; Popham, 1980). Due to their bio-accumulative properties, they play a key important role as indicator organisms in pollution monitoring programs

(Phillips, 1976a; 1976b; Talbot, 1987; Lannig *et al.*, 2006). *Saccostrea spp.* may be the tropical counterpart for temperate mussels of the genus *Mytilus* in assessing trace metal status in the world oceans (Phillips, 1979).

Coastal waters off Goa have been reported to be rich in Fe and Mn as their rich deposits in the hinterlands ore being constantly mined and transported via estuaries (Patel *et al.*, 1980). Mining activities of iron ore form the major economic support to the state. Heavy rains (~ 3000 mm/yr) in the state help in transporting Fe contents from hinterland mining deposits and rejects by the runoff to the marine waters. Iron contents in coastal water of Goa have been reported to be influenced by the runoff of riverine water (Braganca and Sanzgiri, 1980). Water higher values of Fe during the monsoon season could be attributed to the excessive input through runoff from the mining zones. Dissolved and particulate Fe in the nearshore coastal water were observed to be three times greater than those from the off-shore water, indicating presumably that Fe is largely contributed by the river runoff (Qasim and Sen Gupta, 1980). Another possible reason for high Fe content could be the terrestrial pollution and anthropogenic local inputs (Kremling and Petersen, 1984; Danielsson and Westerlund, 1984). Anthropogenic activities such as electroplating plants, iron works and waste are point sources of Fe pollution (Phillips, 1979).

Iron contents have been generally found to be associated with large amount of organic matter in the water column (Kremling and Petersen, 1984; Qasim and Sen Gupta, 1980; Rivonkar, 1998). The present data also revealed a

significant correlation with the particulate organic carbon in the water column ($r= 0.6264$, $p < 0.05$) at St-1. Rivonkar (1998) found that, the iron in the estuarine water column is mainly contributed through the suspended load.

In general, tissue of *C. madrasensis* found to have high concentrations of Fe. Higher concentrations of Fe in tissue of *C. madrasensis* from St-1 compared to the same from St-2 could be attributed to location of oyster beds along mean stream of Mandovi River, which is subjected to higher concentrations of iron loaded waters (with an annual average of 44.3 ppm during the study period) compared to the water (with an average of 35.9 ppm) surrounding the oysters beds of Nerul creek (semi-closed location).

Difference in concentrations of metals could also be due to the metal availability, physico-chemical factors, size and physiological condition of the organisms (Rajendran *et al.*, 1987). The high values of Fe in marine fauna could be attributed to the inflow of mine drainage (Zingde *et al.*, 1976). Walting and Walting (1976) stated that, Fe accumulation in marine organisms is regulated by other factors such as sex, salinity, season, turbidity and depth.

Zinc enters the aquatic ecosystem from deterioration of galvanized iron pipes and dezincification of brass, industrial waste, terrestrial contamination and anthropogenic local inputs (Kremling and Petersen, 1984). However,

metal corrosion, tires, road salt, and paint form major sources of Zn in the urban runoff (Novotny, 2003). Rivonkar (1998) observed low concentrations of Zn in the monsoon season, which was attributed to the colloidal and adsorbed forms of Zn in the suspended matter. Fowler and Oregioni (1976) reported that, Zn content in nearshore waters correlated with high precipitation and runoff.

The average of Zn contents in the tissue samples of *C. madrasensis* was found to be 847.0 ppm and 835.0 ppm in the animals collected from St-1 and St-2, respectively. Fowler and Heyraud (1980) reported that Zn, which has passed through biological cycle may be less available for bioaccumulation than Zn, which has been directly introduced in the marine environment in inorganic forms. Boyden (1974) found a positive correlation between the increase in Zn content and the body weight of the animal.

Manganese usually found to be associated with iron minerals. It is used in steel alloys, batteries and food additive, and finds its way to water bodies through waste disposal. Higher values of Mn in the monsoon season could be attributed mainly to mining and transportation of ore in this area, as Mandovi River is one of the major routes of barges transporting mining ore (Plate 7.1). On contrary, earlier studies, (Braganca and Sanzgiri, 1980; Rivonkar and Parulekar, 1998), have reported lower values of Mn during monsoon, which indicated that riverine input does not enhance the Mn concentrations in the water body. Qasim and Sen Gupta (1980) attributed



Plate 7.1. Transportation of Iron ore through the Mandovi River.

the low concentrations of Mn in both dissolved and particulate forms in the water to the gradual increase in DO and changing redox conditions, which gets Mn precipitated (Awadallah *et al.*, 1996). An inverse correlation was found between Mn concentrations in water and the DO during the present investigations.

The Mn contents in the oyster *C. madrasensis* collected from St-1 are found to be richer than those collected from St-2, which could be attributed to the locations of the collection sites. Low levels of Mn concentration in *C. madrasensis* indicate its poor accumulating ability (Zingde *et al.*, 1976; Sankaranarayanan *et al.*, 1978), while high concentration of Mn in the oyster tissues could be attributed to a greater rate of pollution from automobiles, small crafts and substrate composition (Rivonkar and Parulekar, 1998). Shells of fresh water molluscs such as *Anodontal sp.* were reported to have higher contents of Mn compare to the same in marine molluscs (Segar *et al.*, 1971). This indicates that Mn is from terrestrial origin and reaches estuarine system by the land erosion.

The present data revealed higher concentrations of Pb during the monsoon season. Concentration of Pb greater than 1.27 µg/l in sea water is considered to be harmful and indicative of polluted environment (Talbot, 1987). Pb could get released to the environment by erosion and weathering of mineral deposits and also through emission during volcanic activities. Industrial revolution during the recent past, including municipal waste, have enhanced the contribution of Pb into the marine environment. Pb is used in

batteries, solder, piping, pigments, insecticides and alloys industries. Its input to the aquatic environment also contributed from the dissolution of plumbing and plumbing fixtures. However, the major source of Pb in environment may be from automobiles, which use Pb as an anti-knock additive (George, 1989).

Excess accumulation of Pb greater than 2.5 mg/kg in tissues of animals leads to health hazards in human through ingestion of contaminated marine products. The edible meat should contain Pb concentrations less than 2.5 mg/kg wet weight (13.75 ppm dry weight), according to food standards for human consumption (Talbot, 1987). Excess intake of Pb through contaminated food, in human, leads to rising blood pressure, kidney and brain damages, as well as disruption of nervous system. The oysters during present investigations were found to be highly contaminated with Pb, as the values of metal in their tissue have been estimated in the range of 20.1 to 30.6 ppm (dry weight). Sediments from Mandovi estuary of Goa have been reported to be rich in Pb concentrations (Alagarsamy, 2006; Anon, 2007). Similarly, *Paphia malabarica* (clam) from estuarine regions of Goa have also been found to contain high (up to 68.5 ppm) amount of Pb (Kumari *et al.*, 2006). Since the lead concentrations in *C. madrasensis* from Goa exceed the recommended standard of edible meat, hence unfit for human consumption. However, large population in the state is regularly consuming oyster meat. Navigation (boating and transportation) activities may be responsible for the elevated concentrations of Pb in ambiance and the

oyster tissues (Fowler and Oregoni, 1976; Phillips, 1976b). A study by Talbot *et al.* (1976) revealed that oysters do not concentrate Pb in their tissue to the same extent as *Mytilus spp.*

Cr and Ni contents, however, are found in lower concentrations in the monsoon season, and comparatively higher concentrations during the post-monsoon and pre-monsoon seasons. The main sources of Cr in the marine environment are metal corrosion, paints and electroplating (Novotny, 2003). Sen Gupta *et al.* (1978) reported very low concentrations of Cr and Ni in water and in particulate matter. However, Morris (1974) found very high concentrations of both these metals along with a phytoplankton bloom from the same estuarine regions. Decaying of phytoplankton blooms releases trace elements taken up by it during its growing period (Jones *et al.*, 1986). Sen Gupta *et al.* (1978) also suggested that organisms might concentrate Ni at the surface, which can be released at depths.

Mangrove species from study regions did not show similar trend in variation of trace metals during the three seasons. For instance, *R. mucronata* showed higher values of Fe during monsoon at St-1, whereas at St-2 it showed higher values in Fe during pre-monsoon season. On the other hand, *A. marina* showed higher values of Fe during the pre-monsoon season at St-1, while it showed higher values of the same during monsoon season at St-2. Higher values of Fe in *A. ilicifolus* at St-1 were observed during pre-monsoon, while at St-2 during post-monsoon. Mangrove foliage of some species from Goa has been reported to be rich in Pb

concentrations (up to 66.1 ppm) during monsoon season (Untawale *et al.*, 1980). Similar findings have been observed during the present investigations (Table 7.1 and 7.2).

Silker (1964) found that as the river flow increases, concentrations of metals like Zn, Mn, Cu, etc. also increases, which were attributed to contribution of the elements to the main stream by tributary flows. On the contrary, Valenta *et al.* (1983) and Elbaz-Poulichet *et al.* (1987) observed low concentrations of some metals during rainy season and high flood, which diluted the waste during high water discharge.

George (1989) pointed out several mechanisms, which contribute to the distribution of trace metals in any estuary. These are: 1) Desorption from riverine suspended sediment as higher salinity waters are encountered; 2) Release due to dissolution of particulate phase; 3) Remobilization of metals from estuarine sediments; 4) Contamination from a chemical outfall in the area; and 5) Pollution from shipping activities in the area.

Considerable variations in concentrations of trace metals can be found among animals of the same species from the same area or habitat (Segar *et al.*, 1971, Popham *et al.*, 1980). In estuarine conditions, the amount of metal taken up by organisms from the water is greater than that in more saline waters (Phillips, 1976a). Popham *et al.* (1980) reported that mussels *Mytilus edulis* close to the outfall have very high concentrations of Zn and

Pb, and these metals decrease at very fast rate with distance from the point source.

Food chain and diet most probably play an important role in accumulation of trace metals as compared to its surrounding waters (Bryan, 1973). There are characteristics of organisms that may be used as biological indicator. Butler *et al.* (1971) and Haug *et al.* (1974) as cited by Phillips (1976b) suggested certain characteristics in an organism to be used as biological indicator. These include a sedentary or sessile living, abundance in the region of study, longevity, ease of sampling, ability to tolerate brackish water and accumulate pollutants with a high concentration factor. However, present investigations revealed insignificant correlations between metal concentrations in the oyster *C. madrasensis* and from its ambient waters and mangroves, except significant correlation between the concentration of Mn in the oyster collected from St-1 and their surrounding waters ($r = 0.6755$, $p < 0.05$). This insignificant correlation could be attributed to the metal bioaccumulation kinetics in oysters, which may be slow relative to short-term fluctuations in metal concentrations occurring in the water (Fowler and Oregioni, 1976). Therefore, metal concentrations measured in oyster at particular period need not exactly reflect the concentrations of these metals in water sampled at the same period.

A concentration factor more than 10^3 is one of the conditions which indicator species should fulfill (Shimizu and Tsuji, 1980). Reaching the high value of condition factor in animal tissues is suggestive of its bioindication

potential for metal contamination in the marine environment. Generally, the average concentration factor in *C. madrasensis* during the study period was found to be low and lesser than 1000 for all the trace metals. Only Zinc showed average concentration factor of 1763 and 1450 in St-1 and St-2, respectively. Similarly, trace metal concentrations in the ambient water and of that in the oyster tissue did not exhibit significant correlation. Earlier studies (Rivonkar, 1991), confirm to a certain extent that trace metals contents in *P. viridis* tissues is unregulated by the composition of the medium.

Since oyster accumulates quite high concentrations of metals, it might be harmful to the animal as well as its predator including human being. Therefore, it is essential that concentration of pollutants should be kept under continuous observations to ensure the unacceptable increase does not occur. The above results and statistics, suggest that the oyster *C. madrasensis* does not have indicator potential for pollution by trace metals. However, it is suggested that the indication ability of oyster *C. madrasensis* for different trace metals should be further studied in the laboratory before drawing conclusion concerning its suitability as indicator organisms. High concentration of Pb in estuarine environment and regular consumption of associated contaminated oysters warrants for the detailed investigations on Pb contamination and health hazards in the state.