Chapter 5
CHAPTER 5

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 (Frias 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/m$^2$, of which 36% of the population was live (Figure 5.1). At St-2, oyster bed harboured average of 948 specimens/m$^2$ 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% ± 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% ± 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% ± 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% ± 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

\[
\log y = -2.2264 + 2.0670 \log x
\]

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

\[
\log y = -1.1549 + 1.5390 \log x
\]

Its corresponding parabolic equation may be represented as

\[
y = 0.0700 \times 1.5390^{x}
\]

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

\[
\log y = -0.8008 + 1.4188 \log x
\]

Its corresponding parabolic equation may be represented as

\[
y = 0.1582 \times 1.4188^{x}
\]

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

$$\log y = -3.2903 + 2.0717 \log x$$

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

$$\log y = -1.9997 + 1.3906 \log x$$

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

$$\log y = -1.9485 + 1.4897 \log x$$

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

$$\log y = -1.2468 + 1.4655 \log x$$

Its corresponding parabolic equation may be represented as
\[ y = 0.0567 \times 1.4655 \]

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

\[ \log y = -0.7333 + 1.2449 \log x \]

Its corresponding parabolic equation may be represented as

\[ y = 0.1848 \times 1.2449 \]

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

\[ \log y = -0.6790 + 1.3432 \log x \]

Its corresponding parabolic equation may be represented as

\[ y = 0.2094 \times 1.3432 \]

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

\[
\log y = -2.0133 + 1.2439 \log x
\]

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

\[
\log y = -1.1524 + 0.7615 \log x
\]

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

\[
y = 0.0526x^{0.9452}
\]

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

\[
\log y = -0.7969 + 1.2974 \log x
\]

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

\[
\log y = -0.4473 + 1.1764 \log x
\]

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:

\[
\log y = -2.7798 + 1.7089 \log x
\]

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

\[
\log y = -1.6090 + 1.0613 \log x
\]

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

\[ \log y = -1.6968 + 1.2483 \log x \]

Its corresponding parabolic equation may be represented as

\[ y = 0.0201x^{1.2483} \]

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

\[ \log y = -2.1179 + 1.9946 \log x \]
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

\[ \log y = -1.1838 + 1.5219 \log x \]

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

\[ \log y = -0.6438 + 1.2938 \log x \]

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

\[
\log y = -2.130 + 1.2382 \log x
\]

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

\[
\log y = -2.0186 + 1.2710 \log x
\]

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.
5.2.3.2.6. 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

\[
\log y = -1.3787 + 0.9321 \log x
\]

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.

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

*** 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.

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

*** p < 0.001  ** p < 0.01  * p < 0.05
Figure 5.9. Allometric relationships in *Crassostrea madrasensis* at St-2.
Figure 5.10. Allometric relationships in Crassostrea gryphoides at St-1.
Figure 5.11. Allometric relationships in *Crassostrea madrasensis* at St-1.
Figure 5.12. Allometric relationships in *Crassostrea Gryphoides* at St-2.
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 *Pema 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: 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.