CHAPTER IV

INTERNAL MORPHOSTRUCTURE,
GROWTH RATE AND MECHANICAL STRENGTH
OF CORAL REEFS

4.1 Introduction

There are many a literature regarding the aspects of coral growth and the basic mechanisms of skeleto genesis. Most of them are of modern coral reef framework and the major structural component of scleractinian corals and are descriptive on skeletal structures and micro structures (Wells 1956, Sorauf 1972, Wise 1972, Jell 1974). The coral reef's massive structures are eroded and converted into rubble, sand and silt by organisms. These activities by organisms are broadly classified as external bioeroder (visible on reef surface) and internal bioeroder (living organisms that are within calcareous skeletons). Most of the bioeroders weather the coral reef by making holes into the corals. The diameter varies from 0.5mm to 15mm and the penetration ranges from 2cm to 10 cm. Since many of the bioeroders of the calcareous skeletons are minute they require microscopical methods for the study (Golubiz et al. 1975, Macintyre 1984, Birkeland 1997). Few studies give dynamics of skeletal morphogenesis. An detailed study on spatial and temporal patterns of mineral accretion of corals and bioerosion found in corals reef growth are like Acropora Cervicornis, Acropora formosa, Montipora folisa, Pocillpora damicornis, Montastrea annularis, Tubipora, Tubipora aurio, Porites poriter/divaricata, Diploria clivosa, Porites lutea and Agaricia fragilis in Gulf of Mannar. These studies were done through Scanning Electron Microscopy and Petrographic thin sections to reveal internal skeletal arrangement and skeletal alternative in modern scleractinian corals. These studies characterize coral reef environment. Many of the carbonate budget studies have demonstrated that constructive and destructive processes are closely balanced on many reef net accumulation, barely ahead of net reef loss.
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4.2 METHODOLOGY

The first part of this chapter is devoted to describe the internal arrangement of the coral skeletons through thin section study and the second part describes the ultrastructures through SEM. The third part deals about the patterns of the microborer and macroborers in the coral skeletons. The fourth and fifth parts deals with the Growth rate and Mechanical properties respectively.

4.2.1 Petrographic studies

Petrographic thin sections were prepared to study the internal arrangement of structures and calcium carbonate accretion in the coral skeletons and biological alterations including encrustation, bioerosion and destruction of coral skeletons by the organism having specific distribution pattern. The corals of massive and branching type corals, collected from reef area of Tuticorin group Islands' at a depth ranging from 2 to 5 meters. In each species, a cross and transverse sections were made using diamond cutting machine. The sectioned thin slabs were polished by grinding machine and pasted on glass plate and again polished to 1 mm thickness. By using the polished section as negative, positive photo printing is done to study the internal structural arrangement and pattern of bioerosion. Petrographic thin section studies on *Tubastra aurea*, *Montastrea annularis*, *Tubipora*, *Porites lutea*, *Agaricia fragilis*, *Porites divaricata* and *Diploria clivosa*.

4.2.2 Scanning Electron Microscopic studies

SEM analysis is done on the selected species of *Tubastra aurea*, *Acropora formosa*, *Montastrea annularis*, *Pocillopora clamicorms*, *Tubipora* and *Montipora foliosa*.

The principle of the Scanning Electron Probe (JSM-5300) scans the specimen surface and the secondary and back scattered electrons, etc are emitted from the specimen surface. These signals are then detected and are fed to a
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synochronously scanned CRT as an intensity modulating signal and thus displays a specimen image on the CRT screen. The CRT raster width divided by the electron probe scanning width, determined the image and can be observed in standard.

**Specimen preparation:**

The specimen should be shaped to fix the specimen holder and should be secured firmly on the specimen stub and specimen holder. The specimen fixed on the stub is examined in vaccum and is subjected to electron beam irradiation. Conductive paints such as silver and carbon is used to secure the specimen to the specimen mount. Gold foil is used as electrode material for sputtering.

**Ion sputtering device:**

The sputtering system is double pole horizontal electrode discharge system, with working pressure as \(10^{-1} \times 10^{-3}\) atms. High tension power supply either DC/AC current is used, the power supply may vary, the power used is 0~1KV. The specimen stand used is having eight holders in which 10mm diameter Av disk. The ion sputtering device of JFC-110E is placed on a table, the etching cap is removed and the target Av disk is attached. Fix the O ring for the base in the position, place the specimen stand at the center of the base. Then install the bell jar and set up rotary pump. Vacumm coating or gold coating is done for four minutes in 15mA, per minute 750A.

**Camera:**

The camera of MP-35051 (5300-CSI3) is attached to JSM 5300 to record SEM on CRT images of 35mm, high speed film of Nova Fp4 124 roll. An auto film winder is provided for this camera. The 35mm single lens of reflex type lens (F2,F=50mm). The apreature F2,2.8,4,5.6,8,11,16,22 and shutter is automatically
controlled. The image recording or photography speed is 6.4 seconds to record one image from CRT screen.

4.2.3 Types of Bio-Eroders

Microscopic examinations of thin section of coral specimens like *Tubastrea aurea, Montastrea annularis, Porites lutea, Diploria clivosa, Agaricia fragilis, Porites divaricata* reveal distinct channel in their micro structure. A wide range of studies on skeletal histology of coral specimen gives the difference in skeletal arrangement and pore spaces.

Thin sections of transverse and cross sections were prepared from the specimen of coral samples collected from the study area.

The total porosity and boring bioerosion by organisms were estimated from the cross and transverse sections. The sections were projected by petrological projectors at constant magnification. The projected images were photographed and from these photographs, the area of pore spaces and open spaces developed by boring organisms were measured.

The geometrical features of the cavities in the skeletons left by boring organisms and skeletal infillings were counted. The percentage of the cavities by bioerosion from the total areas of the coral skeletons were determined from the specimens from tip, middle and base of the colony. For each sample the pore space and open spaces developed due to boring of organisms were examined. The number of pore spaces and their dimensions were thus obtained. It is assumed that the number of open spaces or cavities and boring spaces represent the number of skeletal infilling in the coral. Hence the total area of pore spaces examined in the section was determined by totalling the area of all pore spaces (Table 4.1)
Table 4.1. Percentage of pore spaces and borings in coral samples.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Sample No</th>
<th>Boring percentage (openings or cavity)</th>
<th>Pore Space Percentage</th>
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<tr>
<td>1</td>
<td>C1</td>
<td>3.62</td>
<td>7.56</td>
</tr>
<tr>
<td>2</td>
<td>T2</td>
<td>21.33</td>
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<tr>
<td>3</td>
<td>C3</td>
<td>10.33</td>
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<td>5</td>
<td>T5</td>
<td>7.91</td>
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<td>C6</td>
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</tr>
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</tr>
<tr>
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<td>T8</td>
<td>12.03</td>
<td>19.17</td>
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<tr>
<td>9</td>
<td>C11</td>
<td>15.61</td>
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</tr>
<tr>
<td>10</td>
<td>C12</td>
<td>8.64</td>
<td>58.91</td>
</tr>
</tbody>
</table>
A mere count and dimensions of individual cavity would not have permitted meaningful comparison between different coral species. Since relative skeletal thickness vary from species to species and even within the species. A measure of percentage occupied by pore spaces was considered to be a better measurement.

4.2.4 Growth rate studies on coral skeletons

The coral growth is based on the morphology of their colony. Stony corals are used to study the growth rate with respect to physical and chemical environmental conditions (Hudson et al. 1976; Wellington and Glynn 1983). By the retrospective method of coral sclerochronology, the earlier growth rate of coral obtained from the skeletal bands, is used to study the paleoenvironmental conditions (UNESCO 1986). For detailed study, X-radiograph is used to measure seasonality of density bands within the skeleton and the skeletal bands of high and low bands alternatively arranged will provide us the winter and summer seasons of skeletogenesis (Klein et al. 1990).

The massive corals like Montastrea annularis and Porites lutea were selected for the growth study. These samples were collected from Kariyashuli island, located about 20 Km NE of Tuticorin town. In the reef area of this island, different types of massive corals like Diploria strigosa, Diploria clivosa, Diploria libuttu, Montastrea and branching corals like Acropora cervicornis, Acropora palmata, Acropora herbs, Acropora formosa (Ramanujam et al. 1992). The selected species of M. annularis and P. lutea were collected at a depth of 1.5 to 2.0m depth. The specimens were washed and air dried and by using rock cutting machine the corals specimens were sliced longitudinally parallel to their axes of growth into slabs of even thickness of 4 to 5mm. The slabs of even thickness were X-rayed
(Elpro - SRD 300) for about 4 to 6 seconds at 44 KV and 100 MA with slabs to film distance of 1m. The X-radiograph films clearly indicate the growth stage of the corals. X-radiograph of section of massive corals reveal a density banding pattern (Knutson et al. 1972) and it has generally been assumed that one dense band and lesser dense band together is equal to one year's growth. The density pattern of Low density (LD) and High density (HD) constitute one year growth.

4.2.5 Mechanical properties and compressive strength

In order to study the properties such as mechanical adaptation, a series of cross and transverse thin sections were made from the base to tip of the species by using a rock cutting machine. Each section of 2.5cm thickness is noted to determine the CaCO3 accretion. The species is grouped into four divisions, from bottom to top as A,B,C,D (Table 4.2).

Due to the boring of organisms well interconnected pore spaces are formed at the base. At the centre of the cross section the corallum is absent. The dimensions of the pore spaces increase from the centre to the tip. A section at the branching of two axial corallites exhibit linearity of the pore spaces between them. In transverse section, the central corallite remains open from the base to tip and growth pattern of apical corallites are seen clearly at an angle from the axial corallite. The pore spaces were determined and the percentage of porosity and mineralization for each specimen were calculated from the projected photographs of the sections.

The species is cut into uniform length of 2.5cm and diameter of 1.5cm. These specimens were subjected to compressive force by Universal Testing Machine.
Table 4.2. Porosity and compressive strength of Acropora cervicornis.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Porosity %</th>
<th>Compressive strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1. SAMPLE</td>
</tr>
<tr>
<td></td>
<td>Cross section from bottom to top</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>9.33</td>
<td>22.46</td>
</tr>
<tr>
<td>B</td>
<td>6.86</td>
<td>43.24</td>
</tr>
<tr>
<td>C</td>
<td>8.24</td>
<td>42.6</td>
</tr>
<tr>
<td></td>
<td>Transverse section from bottom to top</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>13.56</td>
<td>22.46</td>
</tr>
<tr>
<td>B</td>
<td>5.1</td>
<td>43.24</td>
</tr>
<tr>
<td>C</td>
<td>9.82</td>
<td>42.6</td>
</tr>
<tr>
<td></td>
<td>2 SAMPLE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cross section from bottom to top</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>9.01</td>
<td>33.5</td>
</tr>
<tr>
<td>B</td>
<td>5.81</td>
<td>64.38</td>
</tr>
<tr>
<td>C</td>
<td>9.23</td>
<td>65.29</td>
</tr>
<tr>
<td>D</td>
<td>10.6</td>
<td>25.47</td>
</tr>
<tr>
<td></td>
<td>Transverse section from bottom to top</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>22.62</td>
<td>33.5</td>
</tr>
<tr>
<td>B</td>
<td>7.65</td>
<td>64.38</td>
</tr>
<tr>
<td>C</td>
<td>7.33</td>
<td>65.38</td>
</tr>
<tr>
<td>D</td>
<td>5.81</td>
<td>25.47</td>
</tr>
</tbody>
</table>
Compressive strength of the material is calculated from the following equation

\[
\text{Compressive Strength} = \frac{\text{Compressive force}}{\text{Area}} \text{ N/mm}^2
\]

where \( \text{Area} = \frac{\pi d^2}{4} \)

and 'd' is the diameter.

The mechanical properties of the specimens depend mainly on the porosity and compressive strength. Generally high porosities are noted in the basal and tip of the specimens, whereas the middle portions reveal low porosity.

The porosity changes within a single colony may be due to rapid accretions of the initial skeletal frames at the growing periphery of the colony at its tip. The increase of porosity at the basal section of the colony is attributed to the action of boring organisms. The progressive infilling of calcium carbonate mineralisation reduces the porosity in the middle part of the colony.

**4.3 RESULTS**

**4.3.1 Internal Morphostructure of corals (Petrographic Studies)**

i) *Tubastrea aurea*

Thin section study on this species shows a well developed corallite, septa in two cycles and are found clear and steeply descending of uniform width throughout the section. The corallum morphology is thamnasterioid. The columella is spongy and endothecal dissepiment is also noticed. In transverse section, the wall of each chamber is thick and the septal arrangement is clearly visible (Plate Xa,b).
a) T.S. of Tubastrea aurea

b) C.S. of Tubastrea aurea

c) T.S. of Montastrea annularis

e) T.S. of Tubipora
PLATE X

e) C.S. of Tubipora

f) C.S. of Porites lutea

g) C.S. of Diploria clivosa

h) T.S. of Agaricia fragilis
ii) *Montastria annularis*

In *Montastrea annularis* is found with small corallite with endothecal separation, all corallites are interconnected to each other. Corallum is plocoid. Septa well developed, septal and costae margins feel rough to touch. The columella is broad and spongy in appearance. In the transverse section *Montastrea annularis* (Oome) shows very small corallite with endothecal dissepiments. No thick walls found, growth radiations are found from bottom to top. All corallites are interconnected to each other (Plate Xc).

iii) *Tubipora*

In the cross section of *Tubipora* the corallum are arranged in plocoid shape. Septal arrangement is of highest cycle, but curved columella is absent. In transverse section the theca found to be strong and many divisions of chamber is found along the organ pipe. Endothecal arrangement is also found. In between each organ pipe a horizontal platform of soft cementing material is found (Plate Xd,e).

iv) *Porite lutea*

The cross section of *Porite lutea* shows the polygonal corallite with septa perforated and their margins granular and armed with uneven tubercles. Corallum shows a cerioid morphology and columella is absent (Plate Xf).

v) *Diploria clivosa*

*Diploria clivosa* show an meandroid corallum and narrow valley. Septa are clearly visible as parallel lines running over the walls. It is found interrupted in some place, each canal is separated by a thin narrow wall. The columella is continuous and form plate like formation. In transverse section the septa are found in both the sides of the columella (Plate Xg).
vi) *Agaricia fragilis*

Agaricia fragilis is vase shaped. In thin section very small colonies are found as rounded and acute. Growth radiation is very fine projecting from the calice centre. The outer wall is thicker than the calice (Plate Xh).

vii) *Porites divaricata*

In the cross section it is clear with plocoid corallum. Septal arrangements are more than 5 and the arrangement is of highest cycle, short and not curved. Columella is of solid and some found to be absent. Corallite with endothecal separation is clear. In the centre of species, many boring holes are found. In transverse section, it is cylindrical, the axial corallite is porous in nature. Corallite are found radiating with endothecal dissepiments. In the base, septa are visible and found more than five in number and form solid columella (Plate XI a,b,c,d)

4.3.2 Internal morphostructure (SEM)

i) In *Tubastrea aurea*, the theca is thick, many division of chambers arranged alternatively. In each chamber the endothecal separation is ranging from 4 to 6mm. The detrital material trapped under the dissepiment of a corallite is seen in the chamber of larger view (Plate XIIIa).

ii) In *Acropora formosa*, infillings are noticed in between the septal arrangement and porous skeletal elements. Internal columella and spines are connected tangentially by bars. The surface texture is due to fasciculi. Porous opening is found in every section (Plate XIIa-f).

iii) In *Montastrea annularis*, the chambers are arranged straightly and endothecal separation is also found. Chambers of effluent size are found and particulates are also found deposited throughout skeletal cavities. Interconnected
PLATE XI

a) C.S. of *Porites Divaricata*

b) T.S. of *Porites divaricata*

c) C.S. of *Porites Divaricata*

d) T.S. of *Porites Divaricata*
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PLATE XII

a) Surface features of *Acropora formosa*
b) Surface features of *Acropora formosa*

c) Surface features of *Acropora formosa*
d) T.S. of *Acropora formosa*

e) C.S. of *Acropora formosa*
f) C.S. of *Acropora formosa*
CHAPTER IV

PLATE XIII

a) T.S. of Tubastrea aurea

b) C.S. of Montastrea annularis
c) C.S. of Montastrea annularis

d) T.S. of Montastrea annularis
e) T.S. of Montastrea annularis

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septal arrangements are seen in the cross section. The septal margin is found to originate from the middle towards the outer edge Calicoblastic ectoderm is found in broad scale. Porous infilling is also noticed (Plate XIII b-f)

iv) The corallites are uniformly arranged in *Pocilliopora damicornis*. Septa are well developed. In the upper surface small spine like projections are noticed. In each corallite, small formations of spine like septae are noticed. The septa are not fused. In transverse section, the arrangement of chamber is found to be aligned in fiabellate form. The endothecal wall is thicker than theca (Plate XIVa-c).

v) In *Tubipora* the septal formation is found in the order of highest cycle and they are short and united at inner ends. The corallum morphology is plocoid in nature and corallite is cylindrical. Porous spacing is not found. In transverse section the columella and endothecal arrangement are found devoid of deposition and each chamber is arranged alternating to reach the calics (Plate XVa,b,c)

vi) In *Montipora foliosa* the tip of the species shows many corallite formation and porous spacing around the corallite. In each coralite, septal formation is improper. Progressive infilling of skeletons with pore spaces with increasing distance from tip is seen (Plate XVIa,b)

4.3.3 Micro borers

i) *Porites divaricata*

It shows very small size opening and some with irregular shape. In the middle stem, boring holes are found to numerous. In the base very small rounded holes are noticed, in the tip portion large openings are found. In the cross section many boring holes are found in rounded or elongated form. The clubbed branch
a) Septal region of *Pocillopora damicornis*

b) Septal region of *Pocillopora damicornis*

c) Septal region of *Pocillopora damicornis*
PLATE XV

a) C.S. of Tubipora

b) C.S. of Tubipora

c) T.S. of Tubipora
PLATE XVI

a) Septal region of Montipora foliosa

b) C.S. of Montipora foliosa
with fine opening at base in large number and larger rounded or elongated opening at the top in the middle stem (Plate XIIa-d).

**ii) Diploria clivosa**

Inside the chamber, there are many openings made by boring of algae of rounded shape. The size varies from 4 to 8mm (Plate XIb).

**iii) Tubastrea aurea**

Boring holes of rounded and sometimes with larger opening with irregular shape with a size range of 2mm to 9mm (Plate Xa,b).

**iv) Agaricia fragilis**

Minute boring holes are found at the base than tip. In either side walls, there are numerous openings of smaller size as well (Plate XIc).

**v) Montastrea annularis**

In this, the side wall shows many small openings. At the base, the curved shape of the species is marked due to the boring of organisms. The maximum size of bore space is 4cm (Plate Xc).

**vi) Porites lutea**

In this species, very small rounded openings are found. The development of this is due to boring organisms. The size varies from 1 to 3.5mm (Plate XIa).

### 4.3.4 Macro borers

**i) Hydropora exesa**

In this species nearly about 13 boring holes are found at the base, each of them is 1mm to 2mm in diameter and the depth of penetration is 0.4 to 1.9cm (Plate XVIIa).
PLATE XVII

a) Base boring found in *Hydropora exesa*

b) Algae boring at the base of *Montastrea annularis*

c) Boring in *Montastrea annularis*

d) Boring in *Montastrea annularis*
ii) *Acropora tabular*

In this species boring is found at the base of the species. The size boring ranges from 0.4 mm to 0.6 mm diameter and 0.9 to 1.5 cm depth. Many minute bore holes are also found (Plate XVIIb).

iii) *Montastrea annularis*

At the base many boring holes are found ranging in diameter of 0.3 cm to 1.5 cm and depth of 1 cm to 3 cm (Plate XVIIc,d).

iv) *Acropora formosa*

*A. formosa* shows bores of tube-like formation ranging of 0.3 cm and 0.4 cm depth. About 6 to 9 tube borings are noticed.

v) *Platygyra Lamellina*

Base of the coral is fully bored. Two types of bores are noticed. Some of the holes are found inside the body and others form as tube-like outward projection. In this species the bottom is fully bored by the borers. In this Molluscan shell was also found embedded into the coral skeleton (Plate XVIIIa,b).

vi) *Platygyra* (Brain Coral)

Boring of 1.7 to 2.2 cm of diameter and depth above 5 cm are noticed (Plate XVIIIc,d).

vii) *Agricia fragilis*

At the base of the species many tube-like formations inside the body are found. The tube formation range from 2 to 4 cm in size (Plate XVIIIe).
PLATE XVIII

a) *Platygyra lamellina* with tube like formation

b) *Platygyra lamellina* with tube like formation

c) *Platygyra* with large sized base boring

d) *Agaricia fragilis* with many borings at base
4.4 GROWTH RATE STUDIES

The growth rate of corals has been noted as one of the best indicative measures to assess the "stress" due to disturbance because this parameter integrates different physiological processes (Birkeland et al. 1976; Hocuk et al. 1997; Neudecker 1983; Brown and Howard 1985). It is however, widely accepted that coral growth rates may be inherently variable (Buddemeier and Kinzle 1976; Barner and Crossland 1982) within the reef zone both for a single species (Gladfelter et al. 1978) and also for individual colonies (Rogers 1979; Brown et al. 1983).

It is well known that there is considerable variation in coral growth measurements (Buddemeier and Zanzu 1976). This variation may be attributed to the position of the measured growth on the coral colony.

The growth rate of low and high density bands are directly measured from the X-ray negative (Plate XIXa-d). From the measurements linear growth, surface area, volume, weight and growth rate were tabulated (Table 4.3). In order to estimate the bulk density (d), a cube of 3.0 cm and 1.5cm (v) of selected specimens of both *M. annularis* and *P. lutea* were weighed (w) and correct density was calculated by using the formula $d = w/v$. From the coral species *M. annularis* and *P. lutea* it is clear that the calcification rate, surface area, volume and weight of the specimens increase with time and remain constant with space and time (Fig. 4.1a-d).

The relationship between the annual rainfall and growth rate and high and low density bands of the coral species over a year is constructed by a diagram with co-ordinates axes of x,y and y' which represent the year, growth rate and rainfall the values were plotted (Fig 4.2 a-e)
PLATE XIX

X-ray photographs showing low and high density bands

a) Montastrea annularis
b) Porites Lutea
c) Porites Lutea
d) Porites Lutea
Table 4.3. Relationship between Radius (R), Surface Area (A), Volume (V) and Weight (W) in years.

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Year</th>
<th>Linear Growth</th>
<th>Surface Area</th>
<th>Volume</th>
<th>Weight</th>
<th>Growth Rate (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(R) A=2πr² (cm²)</td>
<td>V=2/3πr³ (cm³)</td>
<td>W=V/d (gm)</td>
<td></td>
<td>High Density</td>
</tr>
<tr>
<td>I</td>
<td>1995</td>
<td>0.4</td>
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<td>0.132</td>
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Data on weight were computed from Radius and bulk density value for M. annularis (1.1841) and P. lutea (1.422)
Fig 4.1. Line graph depicting relationship between year and a) Surface area b) Growth Rate c) Volume and d) Weight.
Fig. 4.2 Relationship between growth rate and annual rainfall with respective to year
4.5 MECHANICAL PROPERTIES AND COMPRESSIVE STRENGTH

To study the mechanical adaptation of the corals to the hydrodynamic conditions, the coral species *Acropora cervicornis* was selected. To know the hydrodynamic effects, and the adaptivity, skeletal strength and growth directions of corals. The corals have been collected from the windward side of the Kariyashulli island at a depth of 1.5 to 2.5m. *Acropora cervicornis* forms a colony and its maximum height varies from 0.5 to 1.5m with bar like branches and its average diameter is from 1.3 to 2.5cm with a thick central axial corallite and short radial corallites growing from it. Mechanical properties of bones, shells and other supporting materials developed by the organisms have been studied in detail (Wainwright et al. 1976). It is assumed that coral skeletons do not alter their mechanical properties when dried and cleaned as do bores which contain considerable amounts of colleangen and other elastic organic materials (Schuhmancher and Plewka 1981a, 1981b).

Mechanical properties such as porosity and compressive strength reveal that the porosity pattern and compressive strength varies significantly within the same colony. The adaptability not only depends on mineralization and mechanical properties of the species, but also other properties such as wave resistance and growth pattern. In the study area, the corals like *Acropora palmata* and *Acropora cervicornis* have a marked zonation. *Acropora palmata* is mainly confined within the breaker zone and in wave resistant zone by adaptations in growth from rather than by adaptations in the mechanical properties of the skeletons.

The growth direction of the branches is aligned to the current direction. But in *Acropora cervicornis*, the basal portions are weak due to the attack of diseases and boring organisms. Though the material strength of the *Acropora Cervicornis* is
higher, it has not been able to withstand the hydrodynamic forces concentrated at the base of the colony.

4.6 DISCUSSION AND CONCLUSION

The nature and extent of alteration of modern scleractinian coral skeleton can help to explain the biological and geological factors. Much of the skeletal alteration takes place while the colony is still alive. The extent of skeletal alteration depends on the reef habitat, the coral grows or environment to which it is transported after death. In turn the habitat determines both in distribution of processes responsible for coral. Skeletal alteration and the amount of time that the coral skeleton are exposed to these elements of destruction. The mechanical destruction of the coral colonies depend upon the biological alteration and original arrangement of chambers during the growth condition. So the study was planned to calculate the original pore spaces of the species and volume of internal spaces developed by the bioerosion.

Bioeroders are abundant and diverse in number. These borers are broadly classified as microborers and macroborers. In the study, the activity of the macroborers are studied through thin section. The macroborers are of varietal in nature. The microborers are mostly in the form of siliceous sponges (*Clino, Anthosigmella* and *Spheresco* sponges) infesting the coral reef colonies. The presence of clionid sponges are identified by the patches of brown, yellow are orange lining in the corroded interior of the coral colonies. Abundance of polychaete marks in the coral colonies identified through the circular holes of 0.5 - 2mm in the coral skeletons. In many of the living coral colony, green bands of algae are noticed on the under side of the living colony in the study area. This green algae are called as Ostreobium.
But due to the bioerosion the base of the colony is infected to quite a high degree. Number of open cavities and holes of both by microborers and macroborers and attachment of barnacles destroy the coral colony. Measurement of percentage of pore spaces from the species varies from 7.56 (C_1) to 58.95 (C_{11}). In the same section the percentage of open spaces by erosion counted and the percentage is ranging from 3.62 (C_1) to 24.58 (T_4). Though the number and percentage of pore spaces are inheritants of the species. It is found more often than not there are greater number of pores and voides due to bioerosion. The mechanical stability of the colony is susceptible to damage as a result of weathering and weakening of reef base by boring bioeroders. Through the removal of carbonate materials relatively a small but critically attack the supporting structure. As bioerosion increases the volume of internal spaces (porosity) of coral skeletons increases, less mechanical force is required for breaking, toppling and overturning. Apart from these bioerosion encrustation of reef are also noticed on the base of the coral colonies.

The thin section study of transverse and cross section made from the Montastrea annularis, Tubipora, Porite lutea, Diploria clivosa, Agaricia fragilis, Porite divaricata indicate that growth patterns, internal arrangement of chambers with interconnected open spaces. Scanning Electron Microscope (SEM) studies from same species also reveal the nature of the chambers, endothecal separation and minute arrangement of skeletal elements. In every species it was found that sufficient amount of open spaces exist. SEM studies also exhibit incorporation of particulates in between the chambers of the coral colonies.
Standardisation of pore spaces in the skeletal elements varies from species to species and from the same species the percentage of porosity is higher in the tip of the colony than the middle and base of the colony.

Reef destruction by bioerosion is comparatively larger than reef damage caused by violent storms, surges etc. But in literature contributory effects of bioerosion are seldom mentioned. Bioerosion initiates the weathering processes of reef structures. Boring organisms that weather the colony are also diverse in India. There are 32 species of boring sponges in Indian waters. Palk bay and Gulf of Mannar have 20 species of coral boring sponges. The most common sponge is Cliona celata.

The accretion of biogenic carbonate is one of the most remarkable global biogeochemical processes. The reef builds up the frame and it depends on geomorphological elements of the sea floor in this region. The ability to extract calcium carbonate on calcification and form as calcite, aragonite, dolomite and vaterite depends on the number of factors like photosynthesis, pH of sea water, diurnal variation, temperature, turbidity and wave stress (Dodge et al. 1984). There is a controversy about the exact cause of the variation in density of the skeleton, but the above factors play a major role in influencing the metabolism of corals and in turn affect calcification rate also. The earlier reports show that high and low density bands together are equivalent to one year growth (UNESCO 1986). The growth bands of *M. annularis* and *P. lutea* clearly depends on the seasonal changes indicated by wide low density bands deposited during summer and narrow high density bands during winter (Klein et al. 1990).

The growth rate of coral species *M. annularis* ranges from 6mm to 18mm per year, whereas *P. lutea* varies between 4mm to 22mm per year. These species are
having more or less similar values of growth rate with reported growth rates in
literatures (Sorokin 1993). Growth rates for different types of corals have been
reported that, growth banding is attributed to lunar and seasonal cycle (Goa and
Copper 1996), growth rates varies from 2 to 9 mm per year. Tabulate type of corals
give 4.3 to 27.2 mm per year for rugosans and 0.8 to 3.1 mm per year for
stromatoporids. The growth rate of *Acropora palmata* is determined as 5.2 cm ± 1.3.
The maximum growth rate is observed in dry season (Garcia, Alvarado *et al.* 1996).
In massive *Porites* the growth rate range between 17.2 to 0.9 mm per year.
Generally the high density bands formed during warm season and low density
during cold season (Guillaume and Hecde 1996). Davies (1996) studied the growth
rate of *Porites* and *Montastrea annularis* by using buoyant weighing techniques.
From the coaxial diagram near positive relationship is noted between high density
bands with the annual rainfall data over the year, so rainfall is also a controlling
factor for the enhanced growth rate. In the coral species *P. lutea* phosphorous
concentration is less than 50 ppm. The higher value of phosphorous in the high
density bands is by the pollution from surrounding places, like run off from
agricultural farms, local shrimp farms and spilling of chemical materials from the
harbour while loading and unloading.