Age and growth of fungiid corals of Andaman and Nicobar Islands, India

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Two species of free-living and solitary corals such as Fungia paumotensis Stuchbury, 1833 and Fungia repanda Dana, 1846 under the family Fungiidae were examined inside in situ condition for 2 years to correlate and compare the age and growth relationship in Andaman Sea. Quarterly analysis of data revealed that, Fungia paumotensis showed higher growth rate \((0.323 \pm 0.028 \text{ cm (mean ± SD)})\) while Fungia repanda showed lower growth rate \((0.236 \pm 0.045 \text{ cm (mean ± SD)})\). Fungia paumotensis registered lower correlation co-efficient \((R^2 = 0.422)\) with the age whilst Fungia repanda shown higher correlation co-efficient \((R^2= 0.857)\) with the age. The ratio of morphological attributes remained same during the course of aging for both the species. Mass of dry skeletal amplified exponentially with the length of the polyps for both the experimental species. Fungia paumotensis attained more skeletal mass than Fungia repanda during the size increment. Growth rings at the aboral sides of the coralla indicated a maximum age of 7 years i.e. post-tsunami recruitment of Andaman and Nicobar Islands.

[Key words: Age and growth, fungiidae, scleractinian corals, Andaman and Nicobar Islands]

Introduction

Most of the scleractinian corals are restricted to tropical waters of the globe in its species content. Some of the scleractinians are adapted towards the temperate waters for their survival\(^1\). Growth rate of scleractinian coral species is the main component for reef formation. Larger corals have higher reproductive success and also have superior competitive advantage\(^2\). The pattern of coral growth is closely related to rate of calcification controlled by a number of factors such as light, temperature, feeding and the saturation state of the sea water. The calcium-carbonate saturation state is the ratio of the ion concentration product to the solubility product for the mineral deposited during a given time. Rate of chemical precipitation is proportional to calcium-carbonate saturation. Greater the concentration of ions, the greater is the formation of mineral\(^3\). The rate of growth pattern and sometimes depends on the growth of zooxanthallae by the animal host via nutrient limitation, which is known as a paradox\(^4\). Process of calcification in hard corals is a biogenic action firmly maintained via an organic matrix\(^7\), it is strongly affected by the energetic status of the coral. The activity is regulated both by the photosynthetic activity of the endo-symbionts and by the feeding command of the host\(^8,9\). The presence of light and type of food availability has a species-dependent consequence on rate of calcification. Life of scleractinian corals starts from the settlement of planula larvae. Larval survival, recruitment of juveniles, growth of somatic, reproduction through sexual process and the mortality of scleractinians is variable in wide state from species to species which monitor the development of reefs through the way of succession\(^10,11\). Some scleractinian corals follow \(r\)-strategy as they produce large number of propagules during the reproductive season of each year. The growths of those are very rapid and take pioneer role to settle recently formed space on reef\(^10\). Other scleractinians follow \(k\)-strategy as they reproduce during a short period each year and the growth rate is slow. Though the corals take several years to make settlement of fresh substrata, the successful establishments are able to dominate the reef through the effective defense of living space\(^10,15,16\). Growth patterns of the corals are
variable according to species and that hardly ever experience fission or fuse while partial mortality can be noticed by distortions of the usual growth appearance among stony corals with compact branching colonies, massive hemispherical and free-living fungiids etc. If process of fractional mortality and fragmentation of the corals do not take any part as interference, normal growth can take place indeterminately. Age is a linear purpose of individual length, according to von Bertalanffy (1938), the growth pattern of reef building corals are actively associated or related with the age of the corals. Age and size have a close relationship. Changes in stony corals and pattern of turnover are explicable with the growth model which can be expressed by age-size relationship. Fungiidae is the most important family of scleractinian corals due to presence of solitary appearance among the others with the unique form of free-living coral polyps. These corals are susceptible to overexploitation. With the presence of mobile activity, the only free-living fungiids move off the reef and settle down in sandy areas of reef associated environment. These settlements of corals in new areas serve as the nuclei for the formation of new reef patches. Formation of any reef area can be initiated with the presence of mushroom corals at reef flats and slopes. Asexual reproduction helped the coral for rapid recovery after disturbance though sexual reproduction is also a significant event for the survival. The asexual activity accelerates the formation of large patch reefs during a short period with only the fungiidae corals. Present paper dealt with the analytical description of growth pattern on two species of fungiidae corals of Andaman and Nicobar Islands.

Material and Methods

The study was carried out at Pongibalu Jetty (Lat. 11°30.956’N and Long. 92°39.206’E) of South Andaman at the depth of 7 m. Fungia paumotensis Stuchbury, 1833 and Fungia repanda Dana, 1846, the two species under the same genus were selected for the study. Undersea growth studies and regular monitoring were made by SCUBA diving. Undersea morphological measurements on growth were made with the help of Vernier calipers (Aerospace, 074 15376) and centimeter scale. Growth data were collected at 3 months interval following the procedure of Chadwick-Furman et al. Data were collected on the length of fungiids along their mouth axis and width which is perpendicular to the mouth axis. All the experimental specimens were kept in a net made enclosed area of reef slope to restrict their movement to control missing data. Observation was made for a period of 24 months to document the growth rate of the fungiids. After the completion of study period 30 live samples of Fungia paumotensis and Fungia repanda were collected and kept in freshwater for one week with 2-3 changes of water. After that the specimens were thoroughly washed in freshwater to get the calcareous skeleton structure of calcium carbonate and kept for sun drying for a period of 10 days. Dry mass of all the samples were measured by using pan balance (Docbel, BARUN). The ring structure at the ventral side of the fungiidae corals were studies as those correspond to the annual growth. Length frequency method was applied to demonstrate the multimodal length distribution of a population of different age groups. Growth rate of the fungiidae corals were also determined by von Bertalanffy’s growth curve and Ford-Walford method, computerized non-linear regression method using SPSS software.

Results

30 live specimens of Fungia paumotensis and Fungia repanda were selected to get quantitative data of their growth rate. There was no report of mortality of the experimental animals during the study period. The data of growth rates were analyzed at 3 months interval for the period of 2 years.

Fungia paumotensis Stuchbury, 1833:

Quarterly mean growth rate of Fungia paumotensis was 0.323 ± 0.028 cm. The width of the corals varied linearly with the length of the corals (Fig. 1). Dry mass of the individual coral samples was analyzed in accordance with the length of those. Mass of the samples increased exponentially with the length (Fig. 2). A total of 120 coral polyps were measured to study the morphometric growth pattern of the fungiids. Morphology of the 120 coral polyps were elongated or slightly oblong in shape which can be justified with the ratio of width and length (0.707 ± 0.167). Relationship of width and length in morphological character i.e. width and length ratio of the polyps were constant (Fig. 3). The constancy of the ratio indicates the regularity of their structure plane without any changes in future of their life span. This is the isometric growth pattern of life. The size of the corals increased with the time. It depends on the initial stage. Growth rate of this species decreased linearly with the increased coral size (Fig. 4). As the
documentation was recorded quarterly, it was observed that maximum growth (0.37 cm) was noticed during the 3 months periods of June to August 2011 whereas minimum (0.28 cm) was recorded during March to May 2012. Physical observation of the coral polyps indicated the 7 years maximum age of the corals depending on their ventral growth rings (Fig. 5).

*Fungia repanda* Dana, 1846

Quarterly mean growth rate of *Fungia repanda* was 0.236 ± 0.045 cm. The polyps of this species are circular shaped mostly. Depending on the shape of this species, only diameter was documented to observe and analyze the growth pattern. Dry mass of all the 30 individual coral samples were recorded and analyzed in comparison with the diameter of those. It was observed that the mass of this species increased exponentially with the diameter (Fig. 6). As two species were considered to carry out experiments, diameter was described as length to make comparative analysis during inter-species relationship.

![Fig. 1. Coral length and width linear relationship of *Fungia paumotensis*](image1)

![Fig. 2. Exponential relationship of coral length and dry skeletal mass of *Fungia paumotensis*](image2)

![Fig. 3. Graph showing polyp width: length ratio of *Fungia paumotensis*](image3)
Coral showed a same morphological structure i.e. circular shaped during the entire lifespan. The size of the corals increased depending on the age. Growth rate of this species decreased linearly with the increased coral size (Fig. 7). It was also observed that maximum growth (0.3 cm) was seen during the 3 months periods of June to August 2011 whereas minimum (0.19 cm) was seen during the two periods such as September to November 2012 and December 2012 to February 2013. Growth rings were observed on the ventral sides of the polyps. It was seen that the maximum age of this species was 6 years (Fig. 8).

Non-parametric methods ELEFAN

Optimized growth parameters ($L_\infty$ and $K$) and the goodness of fit index ($R_n$) was obtained for growth parameters of Fungia paumotensis and Fungia repanda by ELEFAN I method in the FISAT II package. The non-seasonalized length frequency histograms with growth curves for F. paumotensis and F. repanda are shown in Figs. 9 and 10. Automatic search routine in FISAT package derived the $L_\infty$ and $K$ values of 16.28 mm and 1.50 yr$^{-1}$ for F. paumotensis and 17.85 and 0.51 yr$^{-1}$ for F. repanda respectively, whereas the K-Scan routines gave the values of 16.28 mm and 0.340 yr$^{-1}$ for F. paumotensis and 19.85 mm and 0.690 yr$^{-1}$ for F. repanda respectively.
Fig. 7. Size dependent coral growth rate of *Fungia repanda*

Fig. 8. Aboral view of growth rings of coral polyps as indicator of annual growth (a. *Fungia repanda* - age 6 years; b. *Fungia repanda* - age 6 years; *Fungia repanda* - age 5 years; *Fungia repanda* - age 6 years). Each ring corresponds to a year of growth. Scale is in cm.

Estimation of growth parameters from length at age data - The results of fitting growth parameters $L_\alpha$, $K$ and $t_0$ to von Bertalanffy growth equation for obtaining length at age are given in Table 1 for *F. paumotensis* and Table 2 for *F. repanda*.

Table 1. Fitting of von Bertalanffy growth equation for *Fungia paumotensis*

<table>
<thead>
<tr>
<th>t (yr)</th>
<th>t-to</th>
<th>k(t-to)</th>
<th>$e^{K(t-to)}$</th>
<th>$1-e^{K(t-to)}$</th>
<th>$L_t = L_\alpha [1-e^{K(t-to)}]$</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>1.489</td>
<td>0.5062</td>
<td>0.9307</td>
<td>0.0693</td>
<td>1.12</td>
</tr>
<tr>
<td>2</td>
<td>2.489</td>
<td>0.8462</td>
<td>0.7290</td>
<td>0.2710</td>
<td>4.41</td>
</tr>
<tr>
<td>3</td>
<td>3.489</td>
<td>1.1862</td>
<td>0.6053</td>
<td>0.3947</td>
<td>6.42</td>
</tr>
<tr>
<td>4</td>
<td>4.489</td>
<td>1.5262</td>
<td>0.5173</td>
<td>0.4827</td>
<td>7.85</td>
</tr>
<tr>
<td>5</td>
<td>5.489</td>
<td>1.8662</td>
<td>0.4147</td>
<td>0.5853</td>
<td>9.52</td>
</tr>
<tr>
<td>6</td>
<td>6.489</td>
<td>2.2062</td>
<td>0.2901</td>
<td>0.7099</td>
<td>11.55</td>
</tr>
<tr>
<td>7</td>
<td>7.489</td>
<td>2.5462</td>
<td>0.0833</td>
<td>0.9167</td>
<td>14.92</td>
</tr>
</tbody>
</table>
The value of $L_o$ was deduced by employing the following equation:

$$L_o = \frac{a'}{1-b'}$$

The estimated $K$ values for *F. paumotensis* and *F. repanda* by Ford–Walford method were 0.340 yr$^{-1}$ and 0.690 yr$^{-1}$ for *F. paumotensis* and *F. repanda* respectively.

The estimated $L_o$ values were 16.28 mm and 19.85 mm respectively.

**Graphical depiction of Lt+1 on Lt** is shown in Fig. 11 for *F. paumotensis* and Fig. 12 for *F. repanda* to estimate the asymptotic length. The regression line fitted to the points showed the following equation for *F. paumotensis* $Y=0.7121x + 4.69$ and $Y=0.5013x + 9.89$ for *F. repanda*. The functional regression slope, $b'$, and intercept, $a'$ were 0.7121 and 4.69 in the case of *F. paumotensis* and 0.5013 and 9.89 in the case of *F. repanda* respectively. As the slope of the line ‘$b$’ is related to the growth coefficient ‘$K$’, the value of ‘$K$’ was deduced using the following equation:

$$K = -\ln [b']$$

The estimated $K$ values for *F. paumotensis* and *F. repanda* with the von Bertalanffy plot were 0.340 for *F. paumotensis* and 0.248 for *F. repanda*. Slope $b$, which is equal to the $K$ value, was 0.340 yr$^{-1}$ for *F. paumotensis* and 0.390 yr$^{-1}$ for *F. repanda*. The ‘$t_o$’ values estimated for *F. paumotensis* and *F. repanda* were -0.489 yr and -0.360 yr respectively.

**Fig. 11.** Ford-Walford plot for *Fungia paumotensis*

**Fig. 12.** Ford-Walford plot for *Fungia repanda*
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Discussion

The selected animals for the study were free-living during adult stage, solitary in nature. There was no report of mortality during the study periods indicate the experimental site is environmentally stable. As most of the reefs building corals are colonial, growth can be seen as long unlimited process depending on the body size. Previous experimental data shows that several hard corals are known for reducing their growth rate parallel to their age. Among the free-living fungiids several corals such as Ctenactis echinata, Diaseris distorta, Fungia actiniformis, Fungia fungites and Fungia granulosa showed age dependent the growth rate which reduced gradually. Present study supports the previous work after Bablet 1985 regarding age and growth rate relationship and also depicts that the growth pattern of Fungia paumotensis and Fungia repanda is age dependent and reduced gradually as they aged. Though the growth rates of both the species are dependent on same variables, but Fungia paumotensis shows comparatively higher quarterly growth \((0.323 \pm 0.028 \text{ cm} \text{ mean} \pm \text{ SD})\) with lower correlation co-efficient \((R^2 = 0.422)\) with the age and Fungia repanda shows lower quarterly growth \((0.236 \pm 0.045 \text{ cm} \text{ mean} \pm \text{ SD})\) with higher correlation co-efficient \((R^2 = 0.857)\) with the age. The Fungia paumotensis is elongated in shape \((\text{width: length}=0.707)\). The species shows a gradual continuation in the same ratio. Polyps of the Fungia repanda are circular and show the same structural plane according to age. Dry skeletal mass of both the fungiids increased exponentially with the length of the polyps. Fungia paumotensis gains more skeletal mass during the size increment than Fungia repanda. Thus Fungia repanda shows relatively flat \((R^2 = 0.863)\) exponential length-dry skeletal mass growth curve than the stiff \((R^2 = 0.878)\) curve of Fungia paumotensis. In the present study a total of 120 polyps of Fungia paumotensis and 30 polyps of Fungia repanda, it was seen that the maximum age was 7 and 6 years respectively depending on the annual growth rings on their aboral surface.

Growth rings are used as unique feature for the non-destructive aging of corals. The extensive analysis of growth pattern depending on the growth rings, it can be said that the growth of the corals continued from the centre to the perimeter for both of the species. Though these are solitary free living corals, but the recruitment of the juveniles occur through the natural process of larval settlement. In 2004, Tsunami resulted the destructive mode of life in every aspect of the coral through the alteration of sea water environment as well as by direct tremendous powerful wave action. Corals of all the families were damaged due the natural calamity. As of Fungia paumotensis and Fungia repanda are free-living and solitary corals under the family fungiidae, it can be predicted that wave action of Tsunami destroyed the low weight fungiids (Fungia paumotensis and Fungia repanda) most. Settlement of juvenile corals needs solid, concrete substratum and dead reef, lower siltation rates, oligotrophic condition or lower algal biomass, lower light intensities, favourable temperature and salinity. The physical environment of the sea came in biogenic state after this massive alteration during the periods of next one year tentatively. Recruitment of the experimental species was
occurred after the period of environmental settlement as the post tsunami recruitments. The maximum age of 7 years support the statement that the all the experimental animals were recruited after the tsunami in study areas of Andaman and Nicobar Islands. The present paper implies the growth pattern of the two funguïds as an initial frame work to understand the parts of development process of their life cycle. The study will be helpful to understand the life pattern of funguïds for their sustainable development and conservation of scleractinian corals in their own niche.

**Conclusion**

The experimental studies on two species of free living funguïd corals were carried to document their age and growth pattern in Andaman and Nicobar Islands at the depth of 7 m. *Fungia paumotensis* exhibited higher degree growth in comparison with *Fungia repanda*. The growth of the corals were proportion with the structural attributes of the specimens. Age of the said species were analyzed with the help of growth ring at the aboral surface and resulted as with the maximum age of 7 years.

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**References**


