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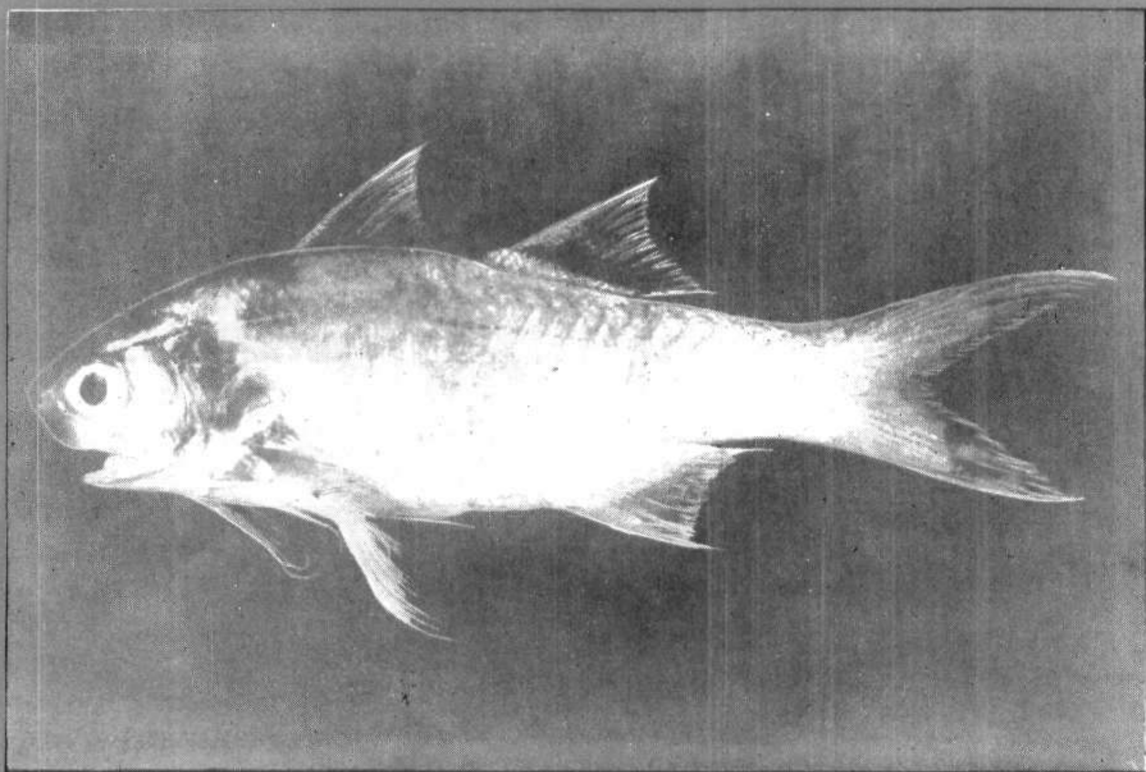

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SPONGE-GENERATED BIOEROSION IN LAKSHADWEEP

P. A. Thomas

Vizhinjam Research Centre of CMFRI, Vizhinjam

Introduction

The discovery of *Cliona celata* by Grant in 1826 from characteristic galleries made inside the oyster shell triggered off a long-lasting debate on the role played by sponges in bioerosion. Subsequent investigations on this species as well as its congeners have proved beyond doubt that not only species belonging to the genus *Cliona* but also species belonging to the genera such as *Thoosa, Spirastrella, Halina* and *Samus* are capable of excavating into calcium carbonate material such as shell, coral, calcareous algae *etc*. The part played by sponges in the destruction of gregarious molluscan beds and coral reefs has been well documented in the past, and as understood at present, the sponges constitute a major group among 12 different taxa of marine plants and animals that cause considerable damage in the marine environment.

Calcibiocavitological investigations made in the past indicate that various borers resort to various methods in gaining entry into the hard calcareous substrate. In some it may be by chemical means and in others, by mechanical means. In yet others it is effected by a combination of both the above means. The present article gives an account of the author's findings on sponge generated bioerosion in the coral islands of Lakshadweep.

Factors influencing bioerosion

It has been shown that when a coral piece infested with boring sponge is cut into two bits it will stimulate the boring activity in the resultant bits considerably. Boring animals and also human intervention by way of cutting channels across the reef *etc.* in Lakshadweep may accelerate the boring activity of sponges already existing.

Illumination plays an important role in the boring activity of sponges. It has been experimentally proved that calcite blocks infested with *Cliona* sp., when illuminated by low voltage microscope lamp started producing calcareous chips at a higher rate. The clarity of water in the various lagoons of Lakshadweep is exceptional (euphotic zone is about 90 m) when compared with any other coastal areas of the mainland and this may be taken as one of the reasons for the abundance of boring sponges in Lakshadweep. Besides the factors mentioned above, water movement and also the temperature conditions have some effect on the activity of boring sponges.

Structure and composition of the boring sponge population in Lakshadweep

An interesting aspect noted with regard to the sponge fauna of the various islands in the Lakshadweep is the abundance of boring species over nonboring species. This is not only with regard to the total number of species represented in each island but also with the number of species collected from each collection site along the various morphozones investigated. In some collection spots only boring species were represented. The percentage distribution of boring species in relation to the total number of species collected from each island is given in Table 1.

Table 1. *Distribution of boring sponges in the various islands surveyed (in %)*

Island	Boring sponges
1. Kavaratti	46.4
2. Kalpeni	36.1
3. Suheli	48.3
4. Androth	66.6
5. Minicoy	50.0
6. Amini	38.4
7. Kiltan	20.0
8. Agathi	60.0
9. Kadamath	58.3

The total number of boring species recorded from the various islands in Lakshadweep is 18 and these may be classified under 4 orders, 5 families and 9 genera of the Phylum Porifera. The genera represented and the number of species under each may be summarised as follows: *Rhabderemia* (1); *Spirastrella* (4); *Amorphinopsis* (1); *Aka* (2); *Cliona* (6); *Thoosa* (1); *Jaspis* (1); *Halina* (1) and *Samus* (1). Of the above 18 species those falling under the genus *Cliona* are widely distributed in the coral reefs of Lakshadweep and is followed by the genus *Spirastrella*.

In order to get a clear picture of the abundance of each species the total incidence by various species in each island was calculated for five islands. From this the percentage incidence of each species was found out and the same is furnished below graphically (Fig. 1).

The graphs indicate that *Cliona celata* is the dominant species in two islands (Kavaratti and Suheli), *C. ensifera* in Kalpeni and *C. mucronata* in Androth. The Minicoy Island offers an altogether different picture since both *C. celata* and *C. vastifica* are equally abundant.

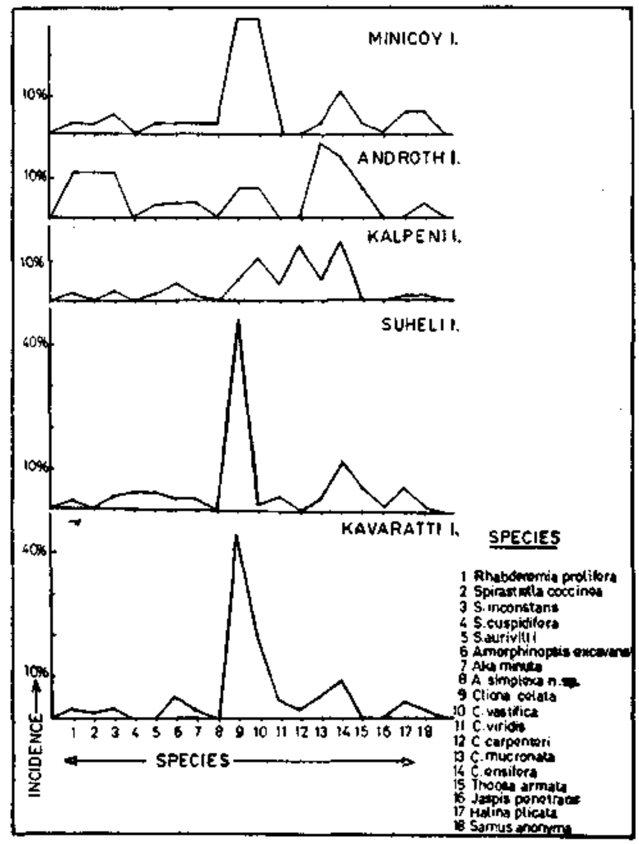

Fig. 1. Incidence indices (%) of 18 species of boring sponges from five islands in the Lakshadweep.

Four species of the genus *Spirastrella* are found to occur in the different islands surveyed, of which two *viz. S. inconstans* and *S. cuspidifera* show the tendency to overgrow the substratum after disintegrating it totally. These two species usually infest massive corals; both dead and alive, which may not project out much from the sea floor. When the substratum is totally disintegrated the upper part of the sponge grows into massive lobate structure bearing excurrent and incurrent openings. This overgrowth may be compared with the gamma stage in the growthform of *C. celata*. (But this growthform is never seen for *C. celata* in Indian waters.)

S. inconstans exhibits the habit of producing asexual bodies from the surface as well as from the tip of tubular branches in advanced stages. These asexual bodies get nipped off from the parent sponge and float in water indefinitely. On reaching a suitable substratum these bodies may get anchored to it and form new colonies.

The abundance of coralline sand in lagoons is an added advantage to this species for its spreading in the various lagoons surveyed.

Summarising the distribution of *C. ensifera* and *C. mucronata* it may be stated both in the light of present investigation as also from the data amassed in the past from the coral reefs of the Gulf of Mannar, Palk Bay and southwest coast of Kerala that these two species are typical coral boring species and are seldom encountered in molluscan shells. In Lakshadweep lagoons also these species are widely distributed and in Androth *C. mucronata* forms the dominant species incidence-wise, while in Kalpeni *C. ensifera* dominates. In these two lagoons the activity of *C. celata* and *C. vastifica* is seen at a lower level. It is not sure whether the activity of *C. mucronata* and *C. ensifera* is checking the activity of *C. celata* and *C. vastifica* or not, but a careful examination of the incidence pattern for various islands presented in Fig. 1 clearly indicates that there is severe competition for space between these two groups of species.

The other boring species represented in Fig. 1 are of no significance at present from the point of incidence. But judging from the behaviour pattern of boring sponges in general it is possible that any species can enter into a quiescent stage after an outburst and as such any species which is inactive today can prove to be dangerous after a few years.

It is quite interesting to note that both *Cliona margaritifera* and *C. lobata*, which have reappeared in the molluscan beds of the southwest coast of India around 1980 after a very long quiescent stage, have not yet made their appearance in the Lakshadweep group of islands. Since their first appearance at Vizhinjam around 1980, these two species have migrated to almost all the important gregarious molluscan beds of that area (Thomas *et al.*, 1983. *Mar. Fish. Infor. Serv., T & E Ser.*, **49**, 1-13). Both these species are potentially dangerous as they can cause wide spread depletion of the molluscan beds as has been reported from Ceylon (Sri Lanka) around 1902. There is every possibility that the larvae of these species may get swept off to Lakshadweep through the currents prevailing off the west coast of India. But such a migration will be very slow and hence is not a matter of immediate concern. On the contrary any attempt on the part of man to transport a few infected live specimens of pearl oyster, edible oyster, mussel or any other molluscan species to Lakshadweep for cultivation can cause immediate and far reaching repurcussions in the ecological equilibrium which is prevailing there at present. Hence, any consignment of cultivable mollusc from mainland or elsewhere to Lakshadweep must be screened properly before it is despatched.

Damage caused to corals

Details pertaining to the rate of mortality of corals in five islands (Kavaratti, Suheli, Kalpeni, Androth and Minicoy) were collected on a transect/morphozone basis and are furnished elsewhere in this paper. Examination of the sample collected from different lagoons indicates that sponge plays an important role in the death of corals everywhere.

It has been found that sponges can bore into both dead and living corals. Since boring sponges obtain their food from sources other than the host, the death of coral (host) will never affect the sponge adversely. And as such the chipping of calcium carbonate matter can go on incessantly even after the death of coral. The galleries formed inside the coral by the removal of calcareous particles weaken the entire reef framework making it more susceptible to the wear and tear caused by waves. Such a weakened substratum may also accelerate the activity of secondary borers such as polychaetes, molluscs, sipunculids and echinoderms.

Boring sponges make extensive galleries inside the substratum, but the upper stratum of corals and both upper and lower strata of shells remain practically untouched and more or less intact except for a few pores for the incurrent and excurrent papillae to project out. Hence the actual damage caused to shell or coral cannot be assessed by external examination alone. When the inroads of *Cliona* reach the climax stage the interior of the coral becomes practically hollow except for a few pillars of calcium carbonate matter stretching across the cavities. In branching corals a continuous cavity running length-wise, may even be seen (Fig. 3 E, F.) inside every branch infected.

Continuous chipping of calcium carbonate matter from the substratum can cause a decrease in the total weight of the substratum. It has been experimentally shown that in new colonies the boring activity of sponge will be quite intense but subsequently the substratum limitation and competition for food retard the activity considerably. Besides these, the sponge will have to set apart some energy for nutrient storage and reproduction also. It is calculated that in such cases the calcium carbonate removed from the original calcareous object is only about 50% of the total. In such species the question of disintegrating the substratum totally does not arise, but in species such as *Cliona celata*, *Spirastrella inconstans* and *S. cuspidifera*, the sponge at a later stage, becomes massive and overgrow the substratum (gamma stage) just like any other sponge. Hence, the capacity to disintegrate the substratum fully or partly in the early stage of its life history is a factor which governs its future morphology.

In order to evaluate the damage caused to coral colonies by boring sponges, data were collected separately for branching and massive forms. In the case of branching species boring intensity, in both stalk portion and branches, was assessed and the conclusion arrived at may be given as follows:

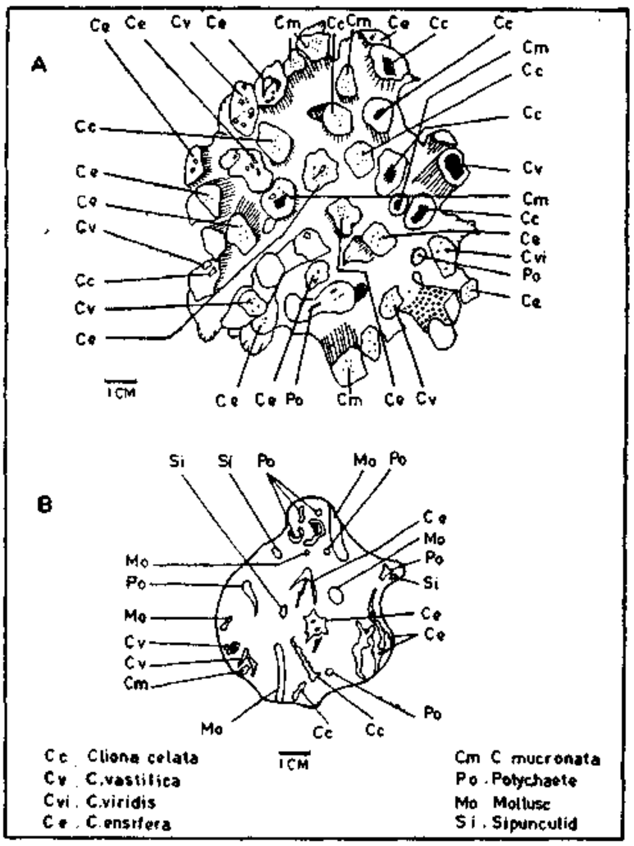

Fig. 2.

A. Diagramatic representation of a branching coral *(Acropora* sp.) collected from morphozone E3 of Kavaratti Island to show the distribution and boring pattern of the various boring organisms.

B. Diagramatic representation of the stalk of a branching coral *(Acropora* sp.) collected from morphozone J5 in Kavaratti reef system to show the distribution and boring pattern of the various boring organisms.

A. **Branching coral** *(Acropora* sp.)

(a) *Branches of* Acropora *sp.*

An *Acropora* colony (Fig. 2A) weighing 600 g with a maximum diameter of 15 cm bearing 48 upright branches arising from a flat basal portion was collected from Kavaratti (E_3) and was studied in detail for the species composition and intensity of boring. Branches were in a partly dead condition and when broken it was noted that most of them harboured boring sponge inside. Out of 48 branches, 34 (70.8%) were found infected with boring sponges. Other borers, mainly polychaetes and sipunculids, could also be noticed on some of these branches. The total number of boring organisms occupying the cut end of each branch was calculated and from this the incidence index of each species/group was prepared (*i.e.* percentage in total incidence). Sponge represented belonged to five species, and the distribution of various species/groups is given in Table 2.

Table 2. *Incidence indices of various boring organisms on the branches of* Acropora *sp.*

Species/groups	Number		% of incidence	
Sponge				
C. ensifera	12	34	30.7	87.2
C. celata	11		28.2	
C. mucronata	6		15.4	
C. vastifica	4		10.3	
C. viridis	1		2.6	
Polychaete	2		5.1	
Mollusc	2		5.1	
Sipunculid	1		2.6	
Total	39*			

* Multiple infection in some

The above Table indicates that sponge, as a group, dominated (87.2%) among the various groups of boring organisms that destroy coral colonies in Lakshadweep. The above Table also shows that the incidence noted for different species of boring sponges on this coral colony is not in full agreement with that seen for the whole island (compare Fig. 1 giving the incidence index for the island Kavaratti). In the projection for the entire island *Cliona celata* and *C. vastifica* ranked first and second respectively, while in the coral colony now investigated, species such as *C. ensifera, C. celata* and *C. mucronata* occupied the first three ranks respectively.

Based on the area occupied by different species of sponges on coral branches it may be stated that the etchings of *C. celata* occupy a larger area when compared to those made by other boring sponges. This species can fully fill the interior of any branch with its tunnels and chambers, and in this respect the damage done to coral is much more intense than that caused by any other species of sponge. The cavities made by both *C. mucronata* and *C. ensifera* assume the shape of an irregular tunnel inside the branch with little or no ramification sideways. Hence, the branches of coral infested by these two species of sponges may live for a comparatively longer period.

Pattern of boring

Based on the data collected from branching corals the pattern of boring seen in the case of *C. celata* has been studied in detail. The larva, soon after its settlement on the coral, flattens to form an encrusting mass. This is followed by the etching out of calcium carbonate particles to form an initial chamber. Further spreading of the sponge inside the coral is effected through chambers originating from the initial chamber and thus a mass of chambers is formed just inside the point of larval entry. These chambers may be seen filling the entire thickness of the branch and may open out at the other side (sometimes at several points) of the branch through the excurrent and incurrent papillae (Fig. 3A). The number of papillae increases gradually on all sides of the branch. The death of branch actually occurs from this point onwards and as a result the polyps above this point get decayed gradually. Algae may get attached to such dead branches and grow. It is noted that in all islands surveyed some filamentous algae of black colour usually colonise these dead branches giving a black, furry appearance to the branches underwater.

Further spreading of the sponge inside the coral branch takes place in a characteristic pattern. From the mass of chambers formed inside the coral (at the point where the larva gained access into the coral branch) some actively growing branches are formed by the sponge (usually 3 to 8 numbers). These branches are usually located at the periphery of the branch (of coral) very close to its outer surface. These branches (Fig. 3 B, C) usually take a linear course through the periphery of the coral possibly because of the added advantage of communicating with the surface through incurrent and excurrent papillae. Such branches of sponge may come closer to each other at a point where the diameter of the branch becomes less or at a point where the branch of coral divides to form a branchlet. Partial or total fusion of one or more of such branches of sponge may also be seen (Fig. 3 D). In an advanced stage of boring, all the peripheral branches (of sponge) become enlarged (Fig. 3 D, E) resulting in the breakdown of the calcareous material separating adjacent canals. This will produce a peripheral cavity filled with sponge encircling a central core of calcareous material (Fig. 3 E). This central core also may get disintegrated gradually resulting in a continuous central cavity filled with sponge (Fig. 3 F). At this stage the number of openings which lodge incurrent and excurrent papillae may also increase to meet the additional requirement of water for the entire colony of sponge. Since dimentional growth is not impossible inside the coral branch the sponge overcomes this situation by increasing its surface area in the following ways.

a) Papillae of similar function growing close by will fuse together forming a compound and more conspicuous structure.

b) After attaining this stage all the papillae irrespective of function get interconnected by a plate of sponge.

Further growth in this line may give rise to a massive growth outside the substratum (gamma stage). But the gamma stage is never attained in the Indian seas.

It is noted that *C. celata* prefer to grow upwards (negatively geotropic), that is, towards the distal end of each branch. The larva, when enters at the middle of any branch the disintegration and death of the branch occur from that point onwards, while the part of branch below this point remains unaffected. Coral colonies bearing distally dead branches further corroborate this point.

(b) Stalk of Acropora *sp.*

In order to get a clear picture on the magnitude of damage caused to the stalk portion of branching corals, the stalk of a branching coral *(Acropora* sp.*)* collected from Kavaratti (J_3) was studied in detail. The average diameter of the stalk is 5 cm, and the distribution of the various boring species/groups at the cut end of the stalk is diagramatically represented in Fig. 2 B. It is found that nearly 40% of the area of coral (in cross section) is being damaged by an array of boring organisms drawn up from different phyla of animal kingdom. Four species of sponges were present. The percentage incidence of various species/group is indicated in Table 3.

Table 3. *Incidence indices of various boring organisms on the stalk of* Acropora *sp.*

Species/groups	Number		% of incidence	
Sponge				
C. ensifera	3	8	13.6	36.4
C. celata	2		9.1	
C. vastifica	2		9.1	
C. mucronata	1		4.5	
Polychaete	6		27.4	
Mollusc	5		22.7	
Sipunculid	3		13.6	
Total	22			

The above Table and Fig. 2B indicate that in assessments, both incidence-wise and area-wise, sponges dominate among the various groups of boring organisms.

Species-wise analysis of sponges indicates that *C. ensifera* outnumber others in total incidence in the stalk portion followed by *C. celata*. In terms of total area excavated by each species it may be seen that *C. ensifera* ranks first at this portion. The data obtained on total incidence for the entire island Kavaratti (Fig. 1) show that *C. celata* is the dominant one followed by *C. vastifica*. While comparing the incidence and excavating capacity of the various species of boring sponges in both branches and the stalk portion of a branching coral (here *Acropora* sp.) it becomes evident that *C. ensifera* and *C. celata* are in severe competition for space and in this competition *C. celata* has succeeded in colonising the interior of branches while *C. ensifera*, inside the stalk portion.

B. Massive coral

A massive coral collected from Kavaratti (C_3) having an average diameter of 7 cm has been studied in detail for the various organisms that cause damage to them in the island. The various boring species/groups and their percentage of incidence are given in Table 4.

Table 4. *Incidence indices of various boring organisms on a massive coral*

Species/groups	Number	% of incidence
Sponge		
C. celata	3	33.3
Polychaete	2	22.2
Mollusc	1	11.1
Crustacea	1	11.1
Sipunculid	1	11.1
Alga	1	11.1
Total	9	

The above Table indicates that sponge forms a major group among the various groups that cause damage to massive corals in Lakshadweep and is followed by polychaete. Incidence-wise all the other groups of boring organisms represented here are of no significance. It could also be noted from Fig. 3 G that *C. celata* is responsible for the breakdown of a sizable part of the massive coral presently investigated, and the larva prefer the under surface of massive coral to settle and grow. Their growth, as seen from Fig. 3 G, is always upwards inside the coral block (negatively geotropic) and in this respect it is quite similar to that noted inside the coral branch (Fig. 2 A).

Conclusion

Damage caused to corals by boring sponges is rather wide spread in all the morphozones of the reefs investigated. In many cases it could even be noted that sponge infection may kill the colony either partly or fully. Any localised death of a colony may not produce far reaching results unless considerable damage occurs to the stalk portion. In a branching colony, that too when it occupies the reef front zone, a partially dead and disintegrated stalk can result in the sliding away of the entire colony into deeper areas where it will be buried by sediments. Branching colonies that occupy level bottom will never experience such a fate since the interlocking of the branches of adjacent colonies will keep them in position even after the total disintegration of the stalk. And in such cases colonies which do not have such interlocking, the tilting to one side will produce a result comparable to that seen in colonies growing along the reef front zone. Goreau and Hartman (*Am. Ass. Advmt. Sci. Publ.*, **75**: 25-54, 1963), who made extensive survey of the reefs off Jamaica, came to the conclusion that too much accumulation of fouling

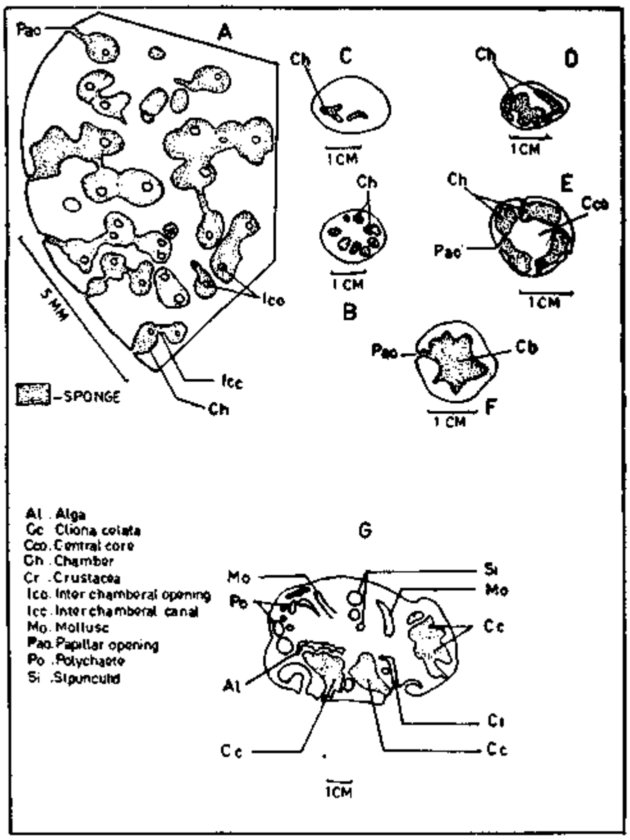

Fig. 3.

A. Cross section of a coral branch (in part) to show the nature of chambers formed inside after the penetration of larva *(C. celata)*. At this point the chambers formed inside (Ch) are more compact and fill the interior almost completely. Icc-Inter chamberal canals, Ico-Inter chamberal openings, Pao-Papillar opening.

B. Cross section of a coral branch infected with *C. celata*. Eight branches are seen originating from the mass of chambers marked in A.

C. Cross section of a coral branch with two branches (of sponge) originating from the mass of chambers marked in A.

D. Cross section of a coral branch. Canals enclosing the branches of sponge are getting widened and partly fused.

E. Cross section of a coral branch. Canals enclosing boring sponge is getting widened due to increased boring activity. These canals, at a later stage, fill the peripheral part of the coral (Ch) leaving a central core of calcareous material (Cco). These canals communicate with theexterior through papillar-openings (Pao).

F. Cross section of a coral branch. The central core of calcareous material (Cco) is completely destroyed resulting in a wide central cavity filled with sponge.

G. Section of a massive coral collected from morphozone C3 of Kavaratti Island. Diagramatic representation of the coral showing the various species/grounds of boring organisms and their distribution.

organisms may cause considerable strain on the coral colony in which the stalk has already been weakened by borers. But they have suggested that such situation often turn out to be a blessing for corals because massive sponges that grow across adjacent colonies will help to keep any coral colony, which is in distress, in position. In the case of massive corals the question of getting themselves dislodged in such a manner, is quite remote. In such cases partial death is only possible and at Kavaratti lagoon it is seen that boring algae flourish in the upper, well lighted side of massive corals killing the polyps totally. But the coral colony compensates for the situation by accelerating its growth along the periphery producing a circular rim around the zone of dead polyps. In some cases it could even be noted that this overgrowing outer rim may curl in and completely cover the central area of dead polyps. If this is not possible it is seen that sedentary organisms attach themselves and grow in this area of dead polyps. *Tridacna* sp. may be seen attached to this area generally.

Goreau and Hartman (1963 *op. cit.*) concluded that mass transport of loosened corals and coarse detritus from the upper reef to the deep fore-reef slope is due to (a) talus fall, (b) slides and avalanches and (c) reef subsidence and slump. The fore-reef slope which is often covered with soft sediments becomes more stable and well drained when coarse coral bits get deposited over it. This situation will indirectly encourage the colonisation of corals. The minute calcium carbonate particles etched out from coral by the activity of boring sponges constitute a major ingredient of the sediment fraction in any reef system. These particles have important lubricating and fluidizing properties which speed up the drainage of skeletal sediments from the reef.