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CALCIBIOCAVITOLOGICAL INVESTIGATIONS

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1. Introduction

Several species of marine organisms are known to excavate cavities inside hard calcareous objects like shell, coral, lime stone etc. either by chemical or mechanical means or by a combination of both. Representatives of about 12 major taxa of marine algae and invertebrate animals are known to engage themselves in such destructive activities in the marine environment. A lot of information has already been amassed in the past century on the systematics, distribution, ecology and physiology of these organisms from different parts of the world. The biological, chemical and geological changes that these organisms would bring about in the marine environment are, by no way, insignificant as they cause bioerosion, influence calcium balance in the sea, and control the structure of calcium carbonate - producing communities.

Animals which excavate hard calcareous objects by mechanical means often remove the hard particles from the latter in chips or in any other form that is characteristic to the species, and such particles often form a sizable fraction of the sediment adjoining the respective environment. Boring sponges, which chip out minute calcium carbonate particles of more or less uniform size and shape by a combination of enzymatic and physical action, expel them through the oscula. Such particles often contribute about 2-30% of the total sediment load in the reef environment. These sponges, while removing such chips from the substratum, only 2-3% goes in dissolved form. It is estimated by earlier workers that in reef environment with high sponge concentration, the erosion rate may go up to 3 kg m^{-2} $year^{-1}$ or 1 mm per year. On the other hand, animals which resort to burrowing by chemeical means often dissolve calcium carbonate matter which may mix with sea water and this will, to a certain extent, alter the calcium balance in the environment.

Calcium carbonate penetration by marine organisms (calcibiocavitation) is a major poroblem in the marine environment. In areas where corals and economically important molluscan beds occur, precise information on the number of such deleterious species and the magnitude of damage caused by them to the calcium secreting animals are prerequisites for an efficient management of both natural and tended stocks. With this end in view, a detailed study on these aspects has been undertaken during the years 1980-'82, and the salient findings which emerged are presented here.

Gregarious molluscs such as the sacred chank *Xancus pyrum* (Lam.), mussels (both green and brown), rock oysters *(Crassostrea spp.)*, pearl oysters, *Thais rudolphi* (Lam.) and corals which inhabit the southwest coast of Kerala and the Gulf of Mannar have been investigated in detail for the various animals which destroy them by boring into their hard parts. It is found from the investigations that the major groups of animals which destroy them are 1) sponges, 2) molluscs, 3) polychaetes, and 4) sipunculids. When the sponge bores into a live molluscan shell the latter may exhibit both physical and physiological strain and this may result in a variety of pathological manifestations. A detailed account on 12 well recognised diseases which occur in molluscs due to the infection of sponges has been published by Thomas (1980, *Symp. Coastal Aquaculture, Mar. biol. ass. India)*

The various groups of boring organisms are dealt with below:

2. Sponges

2.1 As pests of Chanks (Figs. 4B, 5A, B, C)

2.1.1. Incidence of boring sponges

Every year a sizable fraction of the chanks exploited at each centre along the Indian coast is being discarded as 'wormed'. Detailed study made by Thomas (1979, *Indian J.Fish. 26, 1 & 2)* revealed that all such 'wormed' shells are bored by sponges and the percentage of worm attack on them is practically nil.

Examination of the data published elsewhere *(Bull.* C.M.F.R.I. No.25) shows that the incidence (infection per 100 shells collected at random) during the years 1961-1967 at Tuticorin fluctuated between 1.5 and 20.9 and this percentage, when compared with that seen in the beds off Sivaganga, Ramanathapuram, Tanjavoor and Kanyakumari, is very low. The rates of incidence noted at Tuticorin beds during the seasons 1980-'81 and 1981-'82 were 10.9 and 8 percent respectively (Fig.1A)

The chank beds off Thiruchendur are only occasionally fished as compared to those off Tuticorin; and

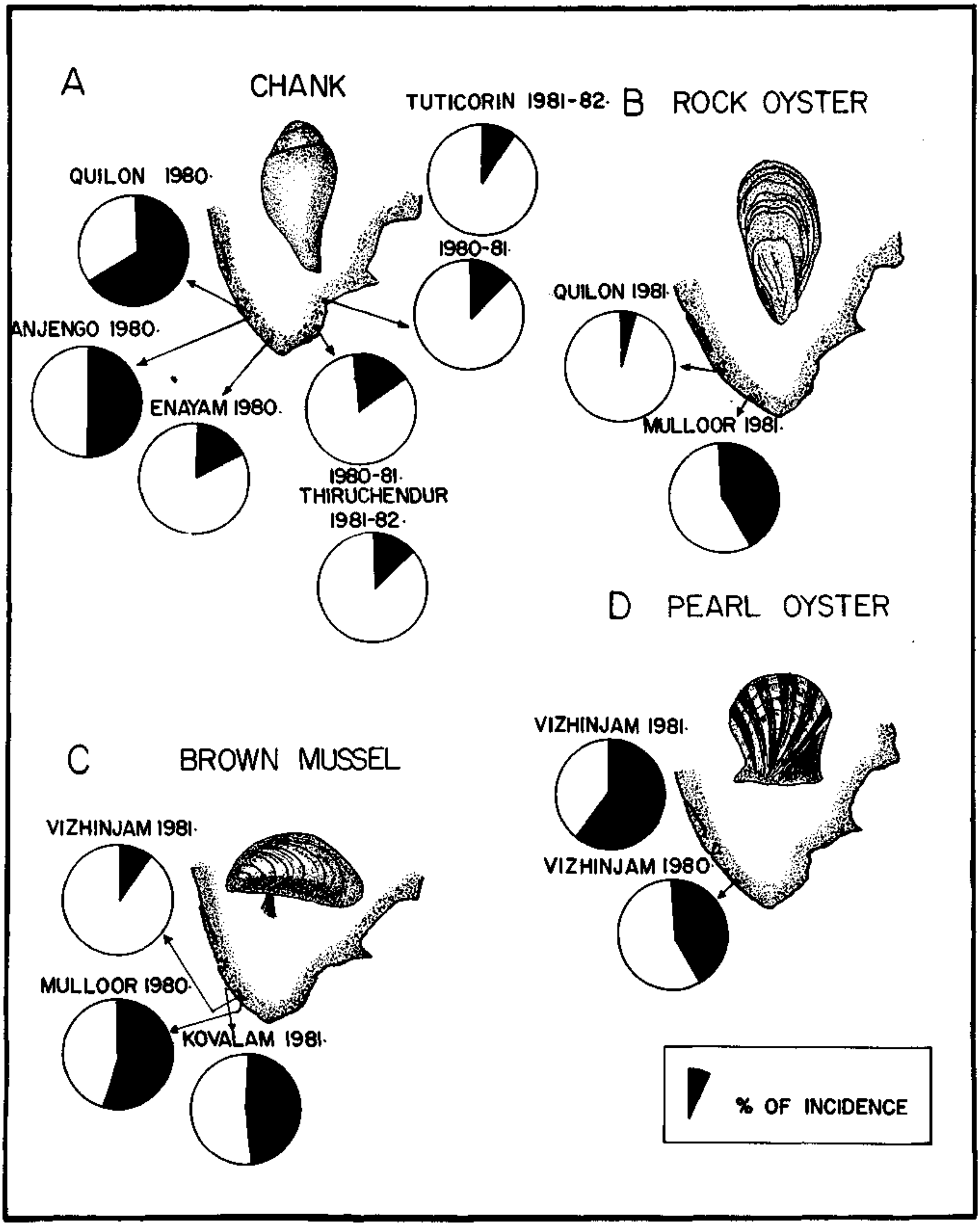

Fig. 1. A-D Percentage of incidence of boring sponges in chanks, mussels and oysters at different places.

recently when the fishing resumed in 1980-'81 season, the incidence was found to be quite high (17%). But during the ensuing season, i.e. 1981-'82, the incidence came down to 12.2% (Fig.1A).

The rate of incidence varied considerably from 'paar' to 'paar' as also from year to year. During 1980-'81 season, at Tuticorin, the maximum incidence of boring sponges was noted at Meleonbothu paar (30.57%) and the minimum at Siluvai paar (6.9%). A more or less similar pattern was noted at Thiruchendur beds also with the maximum at Thiruchendur Karai paar (34.2%) and the minimum at Karuwal paar (18.77%).

Investigations on the chank beds off the southwest coast of Kerala revealed a low incidence (10.15%) at the southern centre (Enayam), whereas the same increased abruptly towards the northern centres like Anjengo and Quilon. During 1980, the incidence recorded at Quilon was about 60% and at Anjengo, 50% (Fig.1A).

2.1.2. Species of boring sponges

Species of boring sponges which infect the chank shells, in the order of abundance, were *1) Cliona celata* Grant, *2), C.vastifica,* Hancock, *3) C.carpenteri* Hancock and *4) C.lobata* Hancock. An earlier study made by Thomas (1979, op. cit) revealed only the first three species in the chank beds of the Gulf of Mannar, and hence *C.lobata* may be considered to be the most recent intruder into the chank beds of the Gulf of Mannar.

2.1.3. Abundance and population structure

C.celata formed the most dominant pest of chanks in the Gulf of Mannar up to 1981. But subsequently, ie. in 1981-'82 season, this composition changed and *C.vastifica,* which had only a secondary role in the chank beds till 1981, dominated. Hence 1981-'82 season may be considered to be a transitional period when the dominance shifted from an established species *(C.celata)* to a less important one *(C.vastifica)* (Fig.2A)

Another important finding emerged during the present study is the infiltration of *C.lobata,* a dreadful pest of rock oysters of the Atlantic, into the Indian chank beds. Untill 1980-'81 season there were only three species of boring sponges in the chank beds of the Gulf of Mannar, and the presence of *C.lobata,* the 4th species, may pose a serious threat to the economically important molluscs of the Gulf of Mannar as a whole. At present this species is confined to the chank beds of Thiruchendur alone, but it is likely to spread throughout the Gulf of Mannar (for further details on the infiltration of this species into various other species of molluscs, refer the section 2.2.2)

In the chank beds extending along the southwest coast of Kerala the dominance of *C.vastifica* is noted only in the southern centre (Enayam) and here it practically co-exists with *C.carpenteri.* But towards the northern part of this zone its positition has been taken up by *C.celata.* In the chank beds off Vizhinjam, *C.celata* dominated (67%) among boring sponges during 1981, followed by *C.celeta* (33%). But in the northern centres like Anjengo and Quilon only *C.celeta* was noted. But this monospecific dominance of *C.celata* in the Quilon beds did not last long, and chanks collected during the next season, ie. 1980-'81, included *C.vastifica* in stray numbers (13.4% of the population). During the subsequent season, ie. 1981-'82, though *C.celata* still constituted the major component among the boring sponges, *C.vastifica* disappeared totally from the bed, and its place has been taken up by by *C.lobata,* a species unknown in the chank beds off the southwest coast of India till 1980-'81, constituting about 20% of the boring sponge population (Fig.2A).

The present infiltration of *C.lobata* into the chank beds of the southwest coast of Kerala is the first major attempt in colonishing the chank beds of this area. The infiltration period of this species into the Quilon chank beds exactly coincides with the infiltration of *C.lobata* into the chank beds of Thiruchendur during 1981-'82 season.

C.carpenteri, which is found wide spread in the chank beds off Tuticorin and Thiruchendur, is met with only in the southern centre (Enayam) and is totally absent from the northern centres.

2.2. As pests of pearl oysters (Figs. 4C, D, 5D)

2.2.1. Incidence of boring sponges

It was not possible to examine the pearl oysters from the natural beds of Tuticorin during the present investigation. The first report on sponges as the major enemy of the pearl oyster of Ceylon beds is that of Herdman (1905, *Rep. Pearl oyster. Fish.*) who had reported an incidence as high as 80% at the Cheval paar, Ceylon. Th only species reported by him was *C.margaritifera,* a new species. Subsequently Thomas (1979, op. cit.), based on study during the years 1969 and 1970, reported two species, *C.vastifica* and *C.celata* and the percentage of incidence reported by him was 8.5 in the natural beds of the Gulf of Mannar. No specimens of *C.margaritifera* were available in the Gulf of Mannar at that time.

Experiments on pearl culture were taken up at Veppalodai, near Tuticorin in 1972 and at Vizhinjam in

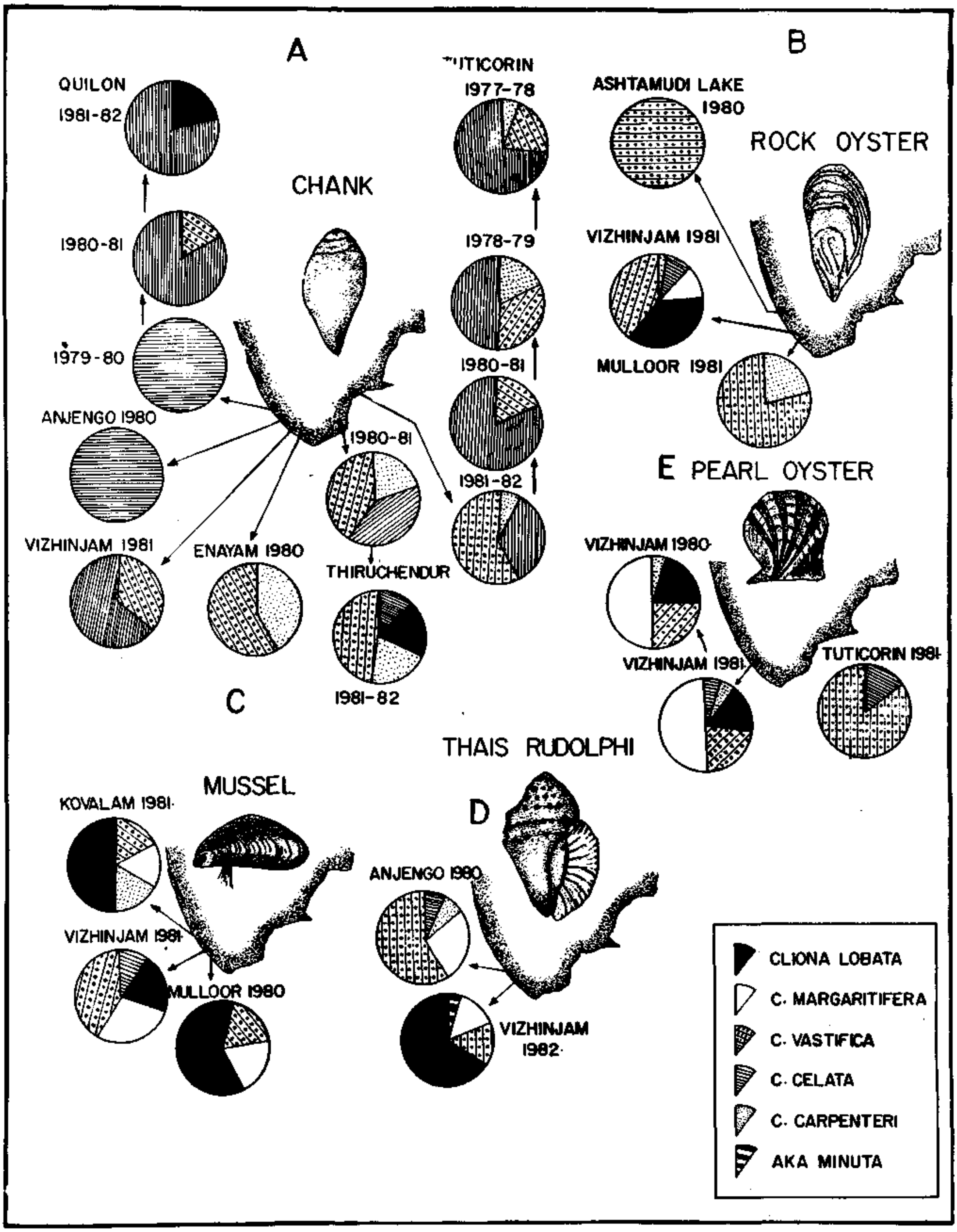

Fig. 2. A-E Abundance of different boring sponge species in chanks, mussels and oysters at different places.

1975. As a part of the investigations on the fouling and boring organisms that occur on culture rafts, Alagarswami and Chellam (1976, *Indian J. Fish.*, *23 (1 & 2)* made a preliminary study and reported polychaetes, sponges,molluscs and isopods to be the major pests on the culture rafts at Veppalodai, Tuticorin. They could record only one species of sponge *(C.celata)* from the cultured pearl oysters; and this made the oyster susceptible to further damages by polychaete and other infections. The rate of infection by *C.celata*, according to the above workers, was 20%. Subsequent studies made by Thomas (unpublished data) on farm grown pearl oysters from Tuticorin during 1978 revealed the presence of only *C.vastifica* at Tuticorin. Specimens of *C.vastifica* examined during February (1978) harboured as many as 5 gemmules per chamber indicating a very high rate of autoinfection in the culture system. During 1981, another collection of cultured pearl oysters was made from Tuticorin, and the same revealed the existance of two species, *C.vastifica* and *C.celata* (Fig.2 F). The former constituted the major pest while the incidence of the latter was rather negligible (12%).

The infection pattern of boring sponges on the cultured pearl oysters at Vizhinjam presents an altogether different picture. The incidence was found to be high at Vizhinjam when compared to that at Tuticorin: 41% of the cultured pearl oysters was found infected during 1980, whereas the same went up to 80% during 1981 (Fig.1D).

In order to study whether the pearl oyster or the flat oyster is more prone to sponge infection, analyses were made separately for these two species. These studies revealed that *P.fucata* (pearl oyster) is more vulnerable than the flat oyster and the incidence was found to be 47 and 37 respectively. Size frequency analyses also revealed that the infection rate, in *P.fucata*, increased abruptly in higher size groups unlike in flat oysters. Size frequency (%) distribution of the total population of cultured pearl oyster and flat oyster together with the same of infected shells and those with openings inside the shell are furnished in Fig. 3,D,E and F.

2.2.2. Species of boring sponges

Five species of boring sponges were found to infest the cultured pearl oysters at Vizhinjam, and they are, in the order of abundance, 1) *Cliona margaritifera* Dendy, 2) *C.vastifica* Hancock, 3) *C.lobata* Hancock, 4) *C.carpenteri* Hancock, and *C.celata* Grant. Cultured pearl oysters at Tuticorin were found infected with two species, viz. *C.vastifica* Hancock and *C.celata* Grant (Fig. 2E).

It may be mentioned in this context that *C. margaritifera* was first reported from Ceylon (Dendy, 1905, *Rep. Ceylon Pearl Oyster. Fish.*, Suppl. 18.) based on a collection made by Herdman from the pearl banks of Ceylon, in 1902. It is reported by Dendy that this sponge spread in the pearl banks almost like an epidemic and destroyed the pearl oyster beds either partly or completely. No other species of *Cliona* were reported by Dendy in his above cited report. There is sufficient ground to believe that *C.margaritifera* totally disappeared from the Ceylon beds after this great epidemic. Subsequent collections made from the Gulf of Mannar and other parts of the Indian seas in general also failed to record this species, though a few atypical or aberrent forms have been reported from widely separated areas and also from hosts other than pearl oyster. The reappearance of this highly destructive species on raft cultured pearl oysters at Vizhinjam, in 1980, hence is very interesting as it forms a major infiltration into the pearl oysters of India after a long lapse of about 80 years. Since 1980, the incidence of this species has generally been on the increase, and now a sizable fraction of the boring sponge population among the gregarious molluscs off Vizhinjam is composed of this species.

Similarly, *C.lobata* recorded from the cultured pearl oysters at Vizhinjam in 1980, also deserves mention in this context. This is a very common and wide spread oyster pest of the Atlantic and the first record of the same from the Indian seas is that of Burton (1937, *Bull. Madras Govt Mus.*, *1* (2) Pt. 4) from Pamban pas (Gulf of Mannar). But subsequent surveys failed to record this species from the Indian seas. The occurrence of *C.lobata* on cultured pearl oysters in alarmingly large numbers in 1980 (Fig. 2E) hence, pose a serious threat to the comercially important molluscan beds of Indian waters as a whole. As in the case of *C.margaritifera* mentioned above, the impact of this species is felt among all gregarious molluscs inhabiting the southwest coast of Kerala; and forms the major pest of mussel, rock oyster, and *Thais rudolphi* collected off Vizhinjam in 1982. The chanks collected from Thiruchendur beds during 1981-'82 indicate the infiltration of this species into the chank beds of the Gulf of Mannar (Fig. 2A)

2.2.3. Damage caused to the shell

When the sponge ramify the inner layers of the pearl oyster shell, it is likely to produce holes on the nacreous layer (Thomas, 1979, op. cit.), through which the sponge comes into contact with the soft parts of the animal producing lysis of the epithelial lining of the mantel. When the animal is in its actively growing phase such openings made by sponges are mended quickly by secreting nacreous substance over these openings. Such repairs, no doubt, may cause considerable physiological strain on the host. But this situation may get still aggravated when the mollusc becomes weak due to old age or other environmental stress; and at this stage the openings formed in the inner side of the shell remain permanently open. At Vizhinjam, during 1980, pearl oyster shells above 50 mm (height) often possessed such openings inside the shell. Among infected shells, 23% of *P.fucata* and 15% of the flat oysters were in this condition. A steep increase in the number of such shells was noted during the ensuing year (1981) when about 27% of the infected shells possessed openings in the inner side. It is actually not known to what extent the energy utilised in repairing such holes will affect the pearl-producing capacity of the pearl oyster.

In conclusion, it may be stated from the past observations that the boring sponges can cause mass mortality (Herdman, 1905 op. cit.), physiological strain (Alagarswamy and Chellam, 1976, op. cit.), and suppression of growth (Chellam, 1978, *Indian J. Fish.*, 25, (1 & 2) to pearl oysters of both natural and cultured stocks.

2.3 As pests of Mussels

2.3.1 Incidence of boring sponges

Mussels, both brown and green, occurring in fishable magnitude along certain areas of the south-west of Kerala as well as the brown mussels being cultivated at Vizhinjam were investigated in detail during the period 1980-'82 for boring sponges. Collections were made from the intensely fished shallow waters and also from the occasionally fished deeper beds to know the effect of fishing on the population structure and composition of the various boring communities. The maximum size of mussel from occasionally fished beds was considerably larger as against those in the intensely fished beds.

The incidence of boring sponges was found to be rather high in occasionally fished deeper beds. Collections made off Mulloor in 1980 (at 15 m. depth) recorded about 54% incidence for brown mussels and 50% for green mussels. A more or less similar figure (48%) was obtained in the case of brown mussel collected from the deeper parts of Kovalam also. Well fished beds off Vizhinjam, on the contrary, registered very low incidence (10.6%) during 1981 (Fig.1C).

2.3.2. Species of boring sponges

The following five species, in the order of abundance, were found to infest the mussels off the south west coast of Kerala during the period 1980--82: 1) *Cliona lobata* Hancock, 2) *C.vastifica* Hancock, 3) *C.margaritifera*, 4) *C.carpenteri* Hancock and 5) *C.celata* Grant.

2.3.3. Abundance and population structure

As in the case of cultured pearl oysters at Vizhinjam, the impact of the two new migrants viz. *C.margaritifera* and *C.lobata* was well seen among the mussel population also from 1980 onwards. *C.lobata* constituted the major pest in the deep water beds off Mulloor and Kovalam alike (Fig.2C), but *C.vastifica* formed the major pest in the shallow water areas off Vizhinjam. *C.margaritifera* was found to be the second largest component both in deeper as well as in shallow water beds. It is noted generally that the sponge infection starts at 60-64 mm size group onwards in green mussels. Infection by *C.celata* was rather negligible and occurred at the shallow water beds off Vizhinjam. Size frequency (%) distribution of the mussel samples analysed from different beds together with the same of infected shells in the population are presented in Fig. 3 A,B,C.

The infection of sponges was found to be nil among the farm cultured brown mussels at Vizhinjam. The reason is that the mussels are kept on rafts only for a short period (5 months on an average) and are harvested as they attain a size of 70-80 mm. In the natural condition also the infection rate is quite negligible in smaller size groups.

2.3.4. Damage caused to the shell

As in the case of pearl oysters, here also the borings are confined to the thickest parts of the shell. But in the case of those infected by *C.margaritifera* and *C.lobata*, the ramifications of the sponge, in advanced stages, may reach up to the margin of the shell. As in pearl oysters here also the tendency to pierce the inner part of the shell by the sponge was rather well pronounced, but unlike in pearl oysters no attempt by the mussel to repair these openings by nacreous material was observed. Blister formation was rarely noted among mussels.

2.4 As pests of rock-oysters (Fig. 4A).

Rock oysters *(Crassostrea* spp.) are abundantly distributed in the intertidal realms of the sea and the estuaries of the south west coast of Kerala. Specimens of rock oysters were examined from the shallow areas (0-2 m depth) off Vizhinjam, moderately deeper areas (10-15 m depth) off Mulloor, and also from the estuarine areas (Ashtamudi Lake, Quilon) for the incidence of boring sponges.

2.4.1. Incidence of boring sponges

There are no data on the overall incidence of boring sponges in the rock oyster population from the

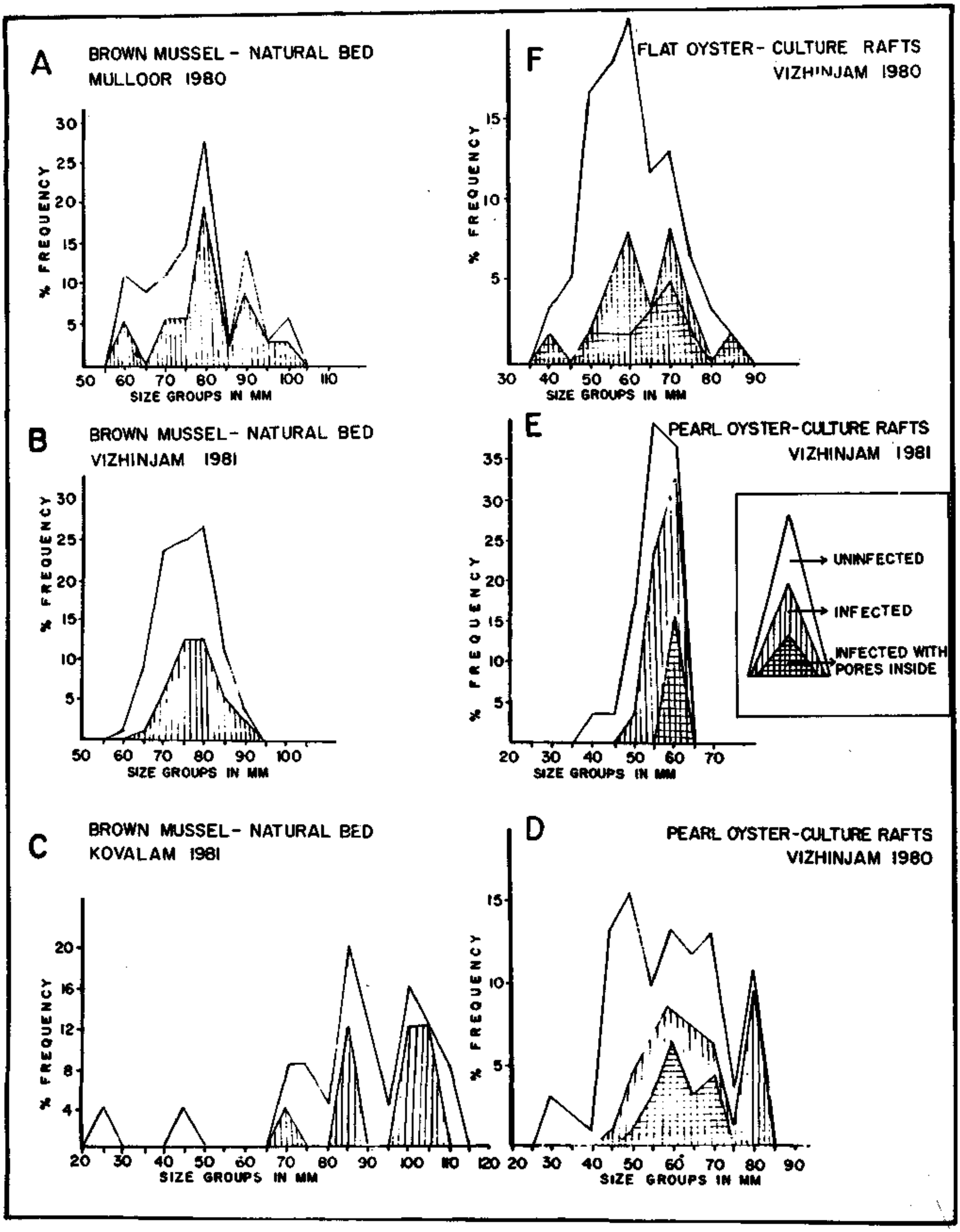

Fig. 3. A–F Percentage of infection by boring sponges in brown mussels in natural beds and in oysters in culture rafts.

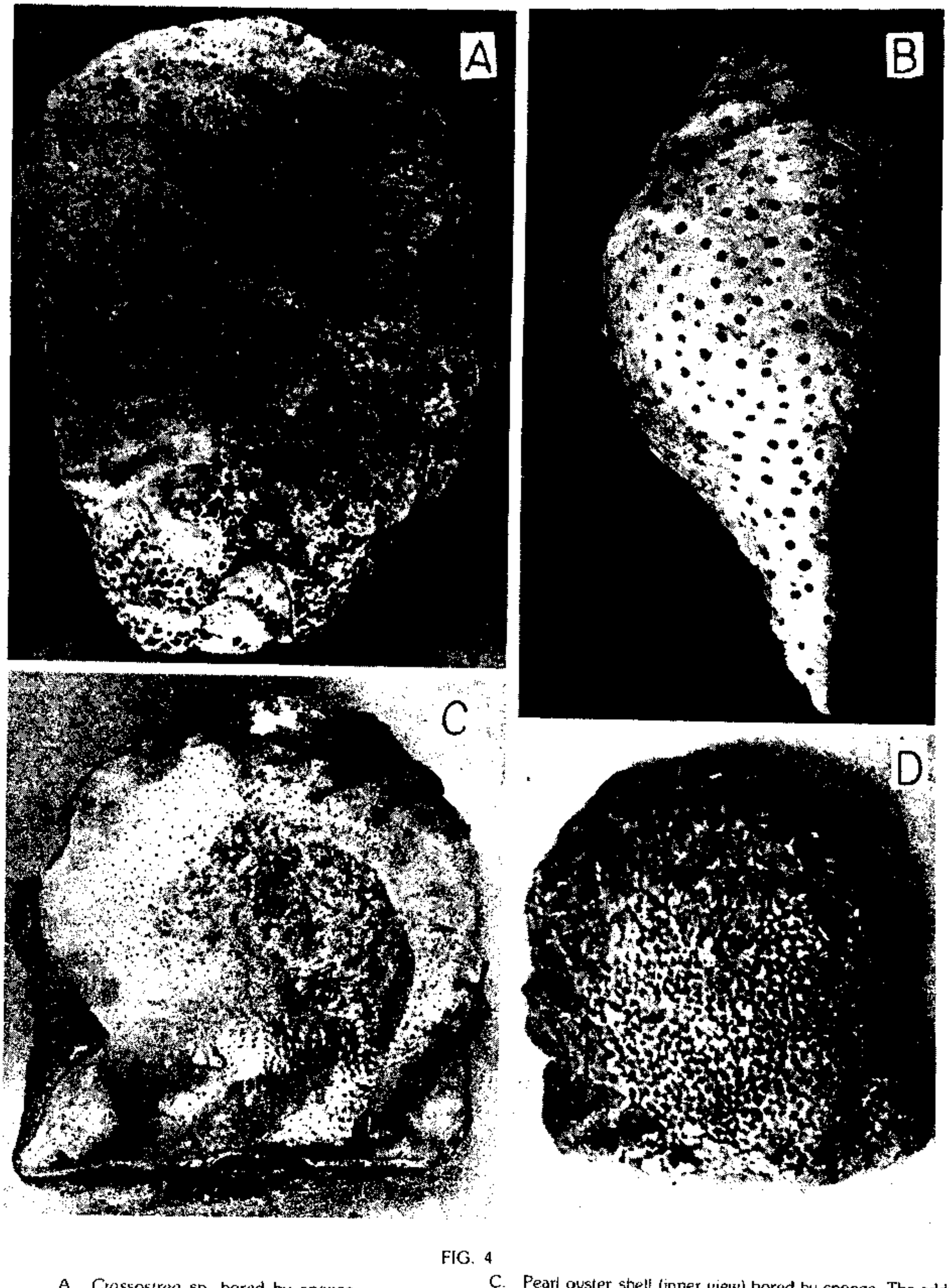

FIG. 4

A. *Crassostrea* sp. bored by sponge

B. *Xancus pyrum* bored by sponge.

C. Pearl oyster shell (inner view) bored by sponge. The adductor attachment zone is eroded much and the pores made by sponge in the inner part of the shell are also clearly visible.

D. Badly damaged pearl oyster shell (outer view).

shallow areas off Vizhinjam, but the data obtained from the moderately deeper areas off Mulloor (Fig. 1B) show that the incidence was rather high in these areas (41.6%). The estuarine areas investigated registered very low incidence (8%).

2.4.2. Species of boring sponges

Rock oysters of this area were found infected with five species of boring sponges. The various species, in the order of abundance, were: 1) *Cliona vastifica* Hancock, 2) *C.lobata* Hancock, 3) *C.carpenteri* Hancock, 4) *C.margaritifera* Dendy and *C.celata* Grant.

2.4.3. Abundance and population structure

The shallow areas off Vizhinjam exhibited rather a complex species composition (5 species) as against the deeper areas where it consisted only of 2 species (Fig. 2B). But this composition changes abruptly in the estuarine condition as there is much fluctuation in the salt content from time to time. The only species capable of tolerating wide fluctuations in salinity is *C.vastifica*, and hence this species enjoys a wider distribution in the Ashtamudi Lake.

The major pest of rock oyster in both shallow and moderately deeper areas was *C.vastifica* though its abundance varies from place to place (Fig.2B). In shallow areas off Vizhinjam *C.vastifica* accounted for about 40% of the population while in deeper areas off Mulloor it was about 80%. A similar pattern of abundance was noted in the case of *C.carpenteri* also; in deeper areas it was five times as abundant as in shallower areas. Species like *C.lobata*, *C.margaritifera*, and *C.celata* were commonly met with in the shallow water beds only.

2.4.4. Damage caused to the shell

It is generally noted that the attached valve is infected first and thence the infection spreads to the free valve by contact. In all cases, the sponge comes into contact with the soft parts of the mollusc and possibly no effort is taken by the latter to repair these openings made by sponge. Normally when such pores are distributed densely in localised areas on the inner side of the shell such areas present an undulated appearance. Damage to hinge area of the shell as well as to adductor attachment zone was also noted.

2.5 As pests of Thais rudolphi

This edible gastropod is rather common in the rocky areas and is exploited at random along this coast. Samples collected from Angengo, in 1980, as also off Vizhinjam in 1982 were utilised in the present study.

2.5.1 Incidence of boring sponges

No data are available on the incidence of boring sponges among *T.rudolphi* collected off Anjengo in 1980 as it was a sample consisting only of bored shells; but those collected off Vizhinjam in 1982 recorded a percentage of 9.7.

2.5.2 Species of boring sponges

The following five species of boring sponges were found to occur among *T.rudolphi* population in this area, in the order of abundance, 1) *Cliona lobata* Hancock, 2) *C.vastifica* Hancock, 3) *C.margaritifera* Dendy, 4) *C.celata* Grant and 5) *Aka minuta* Thomas. Of the above mentioned species, the last one is a common coral borer and is rarely met with in the molluscan shells.

2.5.3 Abundance and population structure

Samples obtained from Anjengo in 1980 were found infested with 4 species with *C.vastifica* as the major component accounting for about 60% of the population, followed by *C.margaritifera (Fig.2D). The other two species, viz. C.carpenteri* and *C.celata* were found to contribute only a minor share and comprised of only 6.6% each in the boring sponge population. The shells obtained from Vizhinjam, in 1982, presented a quite different combination of species with *C.lobata* as the major pest contributing to about 66.6%. Both *C.vastifica* and *C.margaritifera*, which occupied the first and second position respectively at Anjengo in 1980, had negligible part to play at Vizhinjam in 1982. The composition of *A.minuta* was quite negligible (4.4%).

2.5.4. Damage caused to the shell

Localised attack with more preference to the thickest area was rather a general feature with regard to the sponge infection on *T.rudolphi*. An exception to this general pattern was noted in the case of those shells which were infected by *C.margaritifera* since there was a tendency for this species to ramify the entire shell. The pores produced by this species of sponge on the surface of the shell were, as a rule, smaller when compared with those produced by the same species of sponge on the shells of other molluscs. Pores, in this case, are distributed on both surfaces of the shell alike, and invariably those made inside the shell are left unrepaired resulting in the lysis of the epithelial tissue of *T.rudolphi*.

3. Molluscs (Fig. 5A)

Molluscs play an important role in excavating calcareous objects such as shells, corals, lime stone, etc. Young (1963, *Amer. Ass. Adv. Sci. Publ.*, 75) while reviewing the studies on the boring molluscs, has given

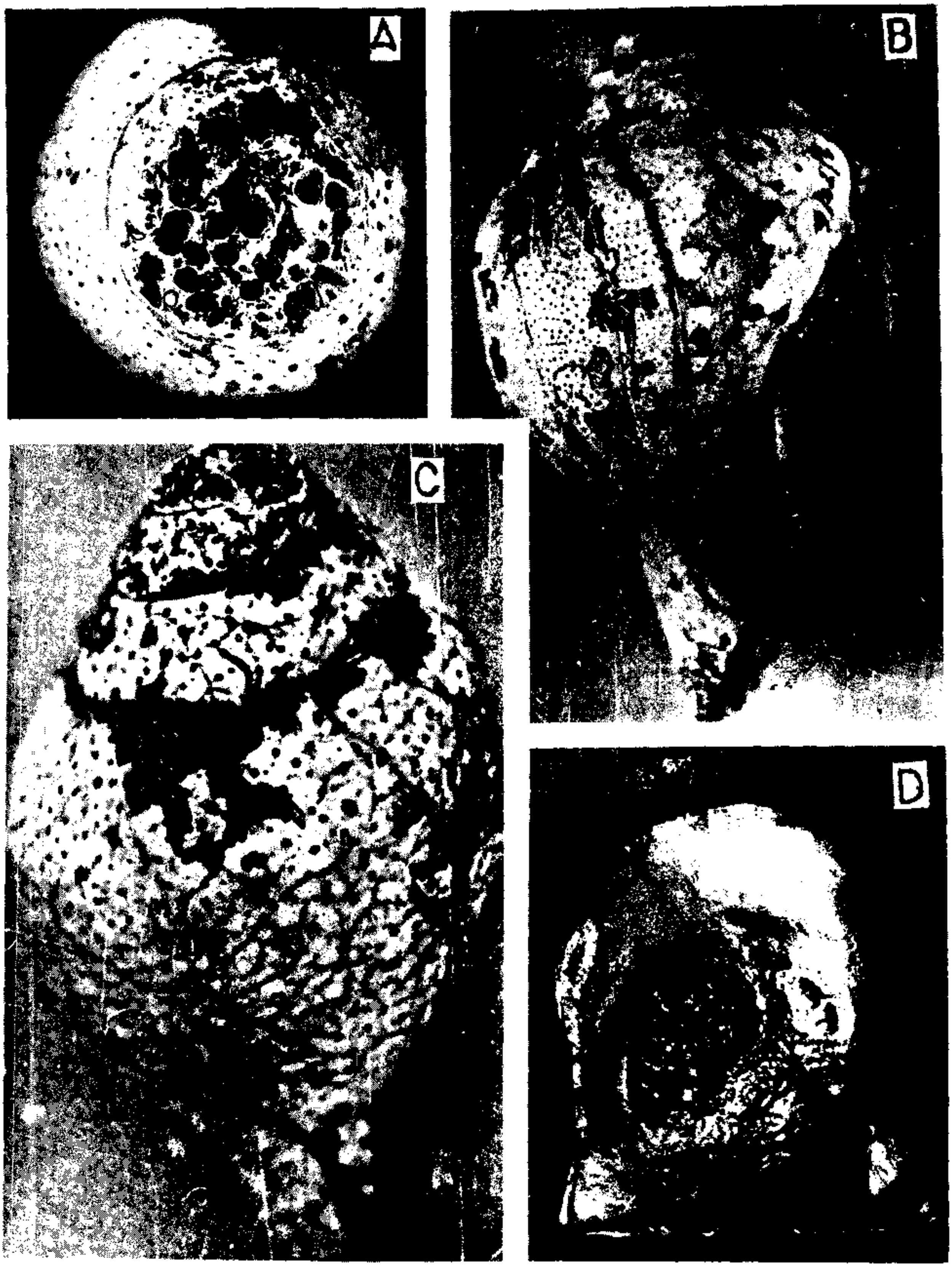

FIG. 5

A. Badly damaged apical portion of *Xancus pyrum*. Those larger openings are made by species of *Lithophaga*, while the smaller ones are made by sponge. B. *X. pyrum* bored by sponge, *Cliona carpenteri*. C. *X. pyrum* bored by *C. vastifica*. Those larger openings are made by boring mollusc, *Lithophaga*. D. Pearl oyster affected by sponge (inner view). Blisters are found at the adductor attachment zone of the shell. Pores made at the inner part are repaired at places by the secretion of nacreous substance.

sufficient details on 7 superfamilies, viz. Myacea, Adesmacea, Petricolidae, Saxicavacea, Gastrochaenacea, Cardiacea, and Mytilacea, and concluded that they have evolved independently of one another, though two major lines in their evolution - epifaunal and infaunal - could be well noticed. Appukuttan (1973, *Mar. Biol. Ass. India, 15* (1)) listed 22 species of coral boring bivalves from the Indian coast. This list was further supplemented by the addition of two more species (Appukuttan, 1974, *J. Malac. Soc. Australia, 3* (1); 1976, *Indian J. Fish., 23* (1 & 2)) making the total 24.

3.1 Species of boring molluscs

Recent investigations on the destruction caused by the molluscs, especially the bivalves, to the commercially important chanks as well as to the coral colonies have revealed the existance of the following 6 species on the south west coast of India, 1) *Lithophaga laevigata* (Q. and G.), 2) *L.bisulcata* d'Orbigny, 3) *Lithophaga* sp., 4) *Botula cinnamomea* (Lamarck), 5) *Venurupis macrophylla* Deshayes, and 6) *Diplothyra* sp.

Among these, the first 4 come under Mytilacea, the 5th under Veneridae and the 6th under Pholadidae. The first record of *L.bisulcata* from the Indian coast is that of Appukuttan (1976, *Indian J. Fish., 23* (1)) and all the other species are reported herein as shell borers for the first time. *L.bisulcata*, a common shell borer in the Indian waters, is also reported here as a pest of corals. The other two coral borers found commonly at Vizhinjam are *L.laevigata* and *V.macrophylla*.

3.2 Abundance and population structure

During the present study, bored chanks ranging in length from 76 to 205 mm from the Gulf of Mannar and 111 to 152 mm from the south east coast were examined. Boring bivalves were found to occur in great abundance among chanks of 125 to 205 mm, whereas those below this size group were seldom found infected. Among the various genera, the genus *Lithophaga* ranked first, dominated by the species *L.bisulcata* on chanks.

Though the rate of infection among the chank population in both the Gulf of Mannar and the south west coast of India varied considerably from place to place, the rate was more in shallower beds as compared with deeper beds.The number of boring bivalves, in individual shell, varied from 5 to 85 in shallow water beds.

3.3. Damage caused to the shell

Both chemical and mechanical methods are employed by the molluscs for boring into calcareous substrata. Lithophags are considered by some to be chemical borers while others attribute a chemical action initially, followed by mechanical means at a later stage. Species like *B. cinnamomea*, *V.macrohylla and Diplothyra* sp. bore mechanically by the rocking movement of their shell valves.

Burrows made by lithophags on shell are long and cylindrical in outline. The anterior part of the burrow, in cross section, is oval and the posterior, circular. The aperture of the burrow, in the case of *L.laevigata* varies from rounded to dumbbell shaped whereas in *L.bisulcata*, it is oval. The orifice of the burrows of the young lithophags reported herein, is as a rule round and the burrow is partly or completely devoid of any calcareous coating inside, unlike in adults where it is lined by a uniform coating of calcareous matter. The burrow made by *B.cinnamomea*, on the contrary, is pear-shaped, with a perfectly round orifice; rather shallow and devoid of calcareous lining. The burrow made by *Diplothyra*, which is otherwise similar to that made by *B.cinnamomea*, may be easily identified by its mid-vertical ridge inside. Here also no calcareous lining is noted inside the burrow.

The burrow made by lithophags in corals differs considerably from that made in shells. The burrow made by *L.laevigata* in coral is not lined by calcareous matter, while in the case of *L.bisulcata* the anterior part of the burrow may show traces of calcareous lining. *V.macrophylla*, often makes shallow burrows which are oval in shape and with round orifices. The posterior part of the shell, in this species, always projects beyond the general surface of the substratum.

The main target of the boring bivalves is the spire portion of the chank. Sponges, on the other hand, pierce the entire shell giving a honey-comb like appearance to the shell in the advanced stages of infection. The shells infected by bivalves, hence, could be utilised to a certain extent by curio-manufacturers for making buttons or rings, while those riddled by sponges are entirely discarded as no part is left free and intact. At Tuticorin alone 50,000 shells, at an average, are discarded every year due to the infection of various borers.

4. Polychaetes

Though several species of polychaetes belonging to families Nereidae, Terebellidae, Spionidae, and Syllinidae are known to bore into hard calcareous objects, the best known and wide-spread pests of the molluscs come under the family Spionidae and the genera *Polydora* and *Polydorella*. The common species from the Indian region are 1) *Polydora antennata* Claparede, 2) *P.hornelli* Willey, 3) *P.caeca* Oested and 4) *Polydorella prolifera* Angeuer.

4.1 Abundance and population structure

4.1.1. As pests of Chank

There is no account on the rate of infection of *Polydora* spp. on the Indian chank beds. A preliminary study made during the years 1980 to '82 showed that the infection rate of *Polydora* spp. varied considerably from place to place. At Tuticorin beds only 6.6% infection was noted during the 1977-78 season, but during the ensuing season, ie. 1978-'79, it went up to 33%. In 1980, when the chank fishery at Thiruchendur resumed after a long pause, the percentage of *Polydora* infection noted was as high as 40; but during the ensuing season it came down to 20%. The infection in the chank beds off Vizhinjam and Quilon registered 11.7% and 10% respectively during 1980-'81 season

4.1.2. As pests of cultured pearl oysters

The first authentic report on *Polydora* infection among cultured pearl oysters is that of Alagarswamy and Chellam (1976, op. cit.). They recorded an infection rate of 20.7% at Tuticorin initially, but the rate increased considerably after one year of planting the oyster on to rafts. According to above workers, about 78.4% of the infected oysters contained blisters inside the shell. Another major hazard noted is that the polydora ramifications inside the shell make it rather fragile in due course.

The polydora infection noted at Vizhinjam pearl culture rafts is considerably less when compared to that at Tuticorin. During 1980 only 10% of *Pinctada fucata* and 3% of flat oysters were found infected. But subsequently (in 1981) the rate of infection increased to 23%.

4.1.3 As pests of mussels

Cultured brown mussel from Vizhinjam as well as brown and green mussels obtained from the wild were examined during the present study. Natural beds off Mulloor revealed an infection rate of 8.5%, but the infection on the raft-cultured brown mussels at Vizhinjam was practically nil.

4.2. Damage caused to the shell

These small-sized worms (*Polydora* spp.) usually form minute tubes on the surface of the shell initially agglutinating sand and other arenaceous objects. While burrowing, the animal bent the body into a 'U' shaped structure, the arms of which are separated by a partition of sand or mud or both, mixed with mucus. The burrowing is effected, at least in part, by the help of enlarged dorsal setae of the 5th setigerous segment. Whether any chemical action is involved in this process or not is not fully known.

The worm enters into the shell through a small opening made on the surface of the latter, and the entry may take place at any part of the shell. Eventhough several species of polychaetes exhibit the habit of burrowing into shell, only some are capable of producing simple or compound blisters inside. All species of *Polydora* fall under the latter category, and the blisters formed inside the shell often press the soft tissue and this in turn may cause malfunctioning of the epithelial tissue. In rare instances it is noted that the burrow may establish contact with the mantle cavity producing local irritation. When such openings made inside are small, the same is repaired by the mollusc secreting nacreous layer over it. But when the mollusc become old or physiologically weak the worm becomes a permanent irritant to it.

In the case of the genus *Polydora*, normally only one specimen is noted inside each blister, but in the case of the genera like *Syllis* and *Terebella* as many as four specimens could be located inside each blister.

5. Sipunculids

Sipunculids form a major group which play an important role in the destruction of dead corals and are seldom encountered in the living parts of the coral. The common species found in the Gulf of Mannar is *Dendrostoma signifer* Selenka and de Man. The usual habitat of this species is the upper strata of dead corals up to a depth of about 4 cm. The burrows made by this species are oblong in outline and the maximum size attained by this animal is 3 cm.

Though not as common as the above mentioned one, another species, *Aspidosiphon elegans* (Chamisso and Eysenhardt) is also reported from the Gulf of Mannar and this too prefers the upper strata of dead corals. This species is easily distinguishable from the former by its smaller size, say 1-1.5 cm, and dark anterior shield.

It is not fully understood whether the sipunculids obtain all or a significant part of their food from the substratum. Here the cuticular plates act as the chief organ of boring.

General Remarks

The findings presented are based on the study of boring organisms infesting the coral reefs and economically important molluscan beds of the Gulf of Mannar and the southern coast of Kerala during the period 1980-'82. The wide fluctuations noted in the abundance and population structure of the various pests in the molluscan beds during the short period of two years clearly indicate that they are in severe competion for suitable substrata and the shells of gregarious molluscs which inhabit this area provide ample opportunities for the pests to flourish. The abundance and succession of these pests in the natural beds are always within the predictable limits for the conventional species. But on some occasions such a prediction become impossible, for the migration of unconventional species from nearby beds or the reactivation of any endemic quiescent species may totally alter the natural cycle of abundance at times. The infiltration of *C.lobata*, into Indian beds during 1980, as also the reappearence of *C.margaritifera* at Vizhinjam pearl culture rafts in 1980, may be cited as two examples denoting the two types of colonisation mentioned above. Both these species have, since then, migrated into other beds of a totally different species forming the major component in the respective beds. It is normally noted that any new infiltrant can cause a sudden spurt in the new bed, but gradually the percentage of incidence may come down and this reaction is due to the slackening in the activity of some other less competent species already existing in the bed. On the contrary, in some cases, the new migrant may multiply disproportionately resulting in epidemics. Hence it is essential to estimate the year--to-year fluctuations in the abundance of conventional species of any bed and also the impact of new infiltratant, if any, on a long-term basis.

The incidence of boring sponges is found to be rather high among raft-cultured pearl oysters both at Tuticorin and Vizhinjam. The sponge bores into the shell by chipping off the latter. When the chipping becomes intense the sponge tissue may establish contact with the soft parts of the mantle through the pores made at the inner part of the shell. The mollusc, in order to prevent such a contact, secretes extra quantities of nacreous material and repairs these holes immediately. This may, in turn, cause great physiological stress on the host. How far this stress affects the pearl-producing capacity of the oyster is not known at present and is worth investigating.

It is rather difficult to control the infection of boring animals in the natural beds, but the low rate of incidence recorded year after year under normal conditions suggests that the nature plays an important part in keeping the abundance of these deleterious agents at a lower level, when untampered by extraneous influence. The higher incidence of boring organisms on the culture rafts, on the contrary, is an indication that the ecological inhibition which is at play in the natural beds is no longer in operation in this artificial environment. Hence any management system which places more emphasis on ecological aspects would help in cutting down the incidence of boring organisms at least to a level noted in the natural beds.

Another important observation made during the present study was the wide distribution of the boring sponge *C.vastifica* in the Ashtamudi Lake, Quilon. This species has succeeded in colonishing the estuarine realms in many parts of the world by virtue of its euryhaline nature. Along the estuaries of India too, *C. vastifica* is wide spread and in estuaries like the Zuari estuary of Goa, the incidence of this species is as high as 63% (Thomas and Thanapathy, 1980, *Indian J. Fish.*, 27 (1 & 2) as against a low rate of 2-3% noted in the inshore areas of Goa. Such a high incidence of *C.vastifica* in the estuarine condition may, apart from its euryhaline nature, be due to the availability of the shells of *Crassostrea* spp. in plenty. Hence there is every possibility that this species *(C.vastifica)* may form a major threat to our future rock oyster farms along the estuaries.

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