CORAL-BORING BIVALVES OF GULF OF MANNAR AND PALK BAY

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ABSTRACT

Among coral boring animals the bivalves are the most destructive. The present account deals with the coral-boring bivalves of the Gulf of Mannar and Palk Bay with observations on their effect on the reef.

INTRODUCTION

Among coral-boring organisms, bivalve molluscs cause considerable destruction to coral reefs. They act as biological agents in the erosion of hard coral stones. The bivalves bore deep into their core and reduce them to a honeycomb-like structure, leading to their easy and quick destruction. Stray accounts of the coral boring bivalves of the Indian region were given by Melvill (1909), Hornell (1922), Gravely (1941), Ray (1949), Satyamurti (1956), Ganapati and Nagabhushanam (1958), and Kundu (1965). The major works relating to other areas on rock-boring bivalves are those of Gardiner (1903), Lindsay (1912), Otter (1937), Hunter (1949), Purchon (1955*a*, 1955*b*), Yonge (1955, 1963), Hodgin (1962) and Turner and Boss (1962).

The fringing reefs boardering Mandapam in Gulf of Mannar and Palk Bay have a significant role in protecting this area from wave action and erosion. The destruction of corals by biological agents and human exploitation adversely affects the reefs. Gardiner (1903) and Otter (1937) pointed out the importance of coral borers in the destruction of reefs. It is well known that the rate of growth of corals is very slow. The rapid destruction of corals by boring bivalves is of considerable importance, since there is very poor growth of corals around Mandapam. The present account deals with 17 species of bivalves and their method and pattern of boring.

MATERIALS

Material for the present study has been collected from the fringing reefs of the Palk Bay near Mandapam, Krusadi Island, Pulli Island and Manauli Island in Gulf of Mannar. (Lat 9°16' N to 9°18' N and Long 79°3' E to 79°11' 3" E). Collections were made during March 1967—October 1968. Live specimens were

brought to the aquarium for observation on their boring habits. The present collection includes 17 species, under ten genera of six families. Out of these *Lithophaga levigata* (Quoy and Gaimard) *Pholadidea cheveyi* Lamy, *Diplothyra* sp. and *Parapholas quadrizonata* Spengler are new records to Indian region. The occurrence and abundance of various forms in the Palk Bay and the Gulf of Mannar have been presented in Table 1. A classified list of the genera and species is presented below. The classification followed here is mainly that of Thiele (1935).

TABLE 1. *Distribution of Coral- Boring Bivalves of Gulf of Mannar and Palk Bay Genus and species are listed in order of their preference in the text.*

Sl. No.	Species	Gulf of Mannar	Palk Bay
1	*Lithophaga nigra* (d' Orbigny)	+++	++
2	*L. gracilis* (Philippi)	++	++
3	*L. teres* (Philippi)	++	+
4	*L. stramineus* (Dunker)	+	R
5	*L. levigata* (Quoy and Gaimard)	+	0
6	*Botula cinnamomea* (Lamarck)	++	0
7	*Venurupis macrophylla* (Deshayes)	+	+
8	*Petricola lithophaga* (Retzius)	+++	++
9	*P. divergens* (Gmelin)	+	+
10	*Aloides sulculosa* (H. Adams)	0	—
11	*Gastrochaena gigantea* (Deshayes)	+++	++
12	*G. impressa* (Deshayes)	++	+
13	*G. apertissima* (Deshayes)	R	—
14	*Pholadidea cheveyi* Lamy	++	+
15	*Parapholas quadrizonata* Spengler	+	R
16	*Diplothyra* sp.	+	R
17	*Jouannetia cumingii* (Sowerby)	++	+

+++Abundant ++Very common +Moderately common
0 Occasional R Rare —Not recorded.

Class BIVALVIA
Order ANISOMYARIA
Series MYTILACEA
Family MYTILIDAE

Genus *Lithophaga* (Bolten) Roding, 1798.

L. nigra (d' Orbigny), 1845

L. gracilis (Philippi), 1847.

L. teres (Philippi), 1846.

L. stramineus (Dunker), 1816.
L. levigata (Quoy and Gaimard), 1818

Genus *Botula* Morch, 1853.
B. cinnamomea (Lamarck), 1819.

Order EULAMELLIBRANCHIA
Series VENERACEA
Family VENERIDAE

Genus *Venurupis* Lamarck, 1818.
V. macrophylla Deshayes, 1853.

Family PETRICOLIDAE
Genus *Petricola* Lamarck, 1801.
P. lithophaga (Retzius), 1787.
P. divergens (Gmelin), 1790.

Series MYACEA
Family ALOIDAE

Genus *Aloides* Megerle von Mohlfeld, 1811.
A. sulculosa (H. Adams), 1870.

Series GASTROCHAENACEA
Family GASTROCHAENIDAE

Genus *Gastrochaena* Spengler, 1783
G. gigantea (Deshayes), 1830.
G. impress (Deshayes), 1854.
G. apertissima (Deshayes), 1854.

Series ADESMACEA
Family PHOLADIDAE

Genus *Pholadidea* Turton, 1819.
P. cheveyi Lamy, 1927.

Genus *Parapholas* Conrad, 1848.
P. quadrizonata Spengler, 1792.

Genus *Diplothyra* Tryon, 1862.
Diplothyra sp.

Genus *Jouannetia* Des Moulins, 1828.
J. cumingii (Sowerby), 1849.

SYSTEMATICS

Key to the identification of coral-boring bivalves in the vicinities of Mandapam.

I		Shell globular or elongate with accessory plates over the shell ..	I Pholadidae
		Shell without accessory plates	II
I		Apophysis present	A
		Apophysis absent	B
A i		Single dorsal mesoplax present	*Pholadidea*
	—	Mesoplax cap-like;posterior end of the shell duck bill shaped	*P. cheveyi*
		Two dorsal plates present	Aii
A ii	a)	Valves divided in to three regions with overlapping chitinous plates	*Parapholas*
	—	Laminated overlapping chitinous plates in the posterior end of the shell; single strong apophysis	*P. quadrizonata*
	b)	Valves divided into two regions; bifid metaplex and hypoplax ..	*Diplothyra*
	—	Shell small, posterior end with overlapping non-laminated chitinous plates; branching apophysis.	*Diplothyra* sp.
B i		Globular shell, almost spherical, right valve produced into rostriform appendage.	*Jouannetia*
B	—	Left valve deeper than right, prolongation of right valve without teeth like structures	*J. cumingii*
II		Shells small inequivalve	Aloidae
		Shells elongate equivalve	III
II	i)	Shell small, right valve being slightly large; hinge margin angular	*Aloides*
	—	Shell with concentric striae; front end beak like; an oblique keel present over the shell	*A. sulculosa*
III		Umbo generally placed near the front end; shell elongate	Mytilidae
		Umbo generally in the middle, shell oblong, ovate or rectangular	IV
III	a)	Shell subcylindrical with subterminal umbones; perpendicular striation present	*Lithophaga*
	—	Shell with dark chestnut blackish brown periostrucum..	*L. nigra*
	—	Shell dark brown with perpendicular striation on the ventral half and postero-dorsal margin.	*L. gracilis*
	—	Shell yellowish brown, perpendicular striation only on the ventral half of the shell	*L. teres*
	—	Shell brown with thin calcareous incrustation in the posterior end; concentric striae prominent	*L. stramineus*
	—	Shell cylindrical with thick calcareous incrustation, which extends beyond the posterior shell margin	*L. levigata*

	b)	Shell non-cylindrical with ultraterminal umbones; perpendicular striation absent.	*Botula*
		Shell small, chestnut brown colour with concave ventral margin	*B cinnamomea*
IV		Ventral margin of the shell gaping, only concentric striae present	Gastrochaenidae
		Shells with concentric and perpendicular striate	V
IV	a)	Shell ovate with anterior end pointed; closely set concentric striae over the shell	*Gastrochaena*
	—	Shell large, outline of the ventral margin convexly round; concentric striate strong and uniform; posterior end rounded	*G. gigantea*
		Shell thin with fine concentric striate; posterior end truncate	*G. impressa*
	—	Shell small with raised dorsal margin; anterior end cuneated; hiatus broad and elongate	*G. apertissima*
V		Oblong shells with three cardinal teeth in each valve	Veneridae
VI		Shells with two cardinal teeth in right valve and three in the left valve	Petricolidae
V	a)	Shell oblong or ovate; widely spaced concentric laminated striae often present	*Venurupis*
	—	Laminated concentric striae with fine perpendicular striae in between	*V.macrophylla*
VI	a)	Raised radial ribs present, sometimes oblique; nonlaminated concentric striae.	*Petricola*
		Shell thick, posterior end pointed; concentric striae prominent towards ventral margin	*P. lithophaga*
		Shell rectangular; oblique striae diverging from the point of origin, 4-6 raised radial incrustation at the posterior end	*P. divergens*

Genus LITHOPHAGA Roding

The genus is characterised by the elongate, subcylindrical shell. Umbones subterminal, surface of the shell sculptured with concentric and perpedicular striation, periostrucum thick, deep brown or black: shell sometimes with calcareous incrustation, thick towards posterior margin; hinge teeth absent; inner surface of the valves pearly or lusturous.

Remarks: The members of this genus are the foremost among boring bivalves both in number of species and in abundance. They are capable of causing greater destruction to corals than any other group. Five species of *Lithophaga* are represented in the present collection.

Lithophaga nigra (d'Orbigny), 1845

(Pl. I, fig. 1.)

Lithodomus nigra d'Orbigny, 1845, p. 331, pl. 28, figs. 10 and 11.

Lithodomus antillarun Reeve, 1857, pl. ii, fig. 7. Hornell, 1921, p. 161

Lithophaga nigra Satyamurti, 1956, p. 40, pl. 4, fig. 8. Kundu, 1965, p. 92, pl. 6, figs. 22a and 22b .

The presence of a chestnut blackish brown periostrucum is the striking feature of the species. Shell long with posterior end pointed; perpendicular striation prominent towards anterior end; radical sculptures conspicuous in the posterior terminal end; length-width relationship of the shell 3.6:1.

Occurrence: Krusadi Island, Pulli Island, Manauli Island in Gulf of Mannar and the reefs in Palk Bay near Mandapam.

Distribution: Indo-Pacific, Carribean, Cuba and Florida.

Remarks: Most common species in reefs. Maximum length of the specimen collected is 79 mm. and minimum 17 mm.

Lithophaga gracilis (Philippi), 1847.

(Pl. 1, fig. 2)

Modiola (Lithophagus) gracilis Philippi, 1847, p. 117.

Lithodomus gracilis Reeve, 1858, pl. 1, fig. 4.

Lithophaga gracilis Satyamurti, 1956, p. 39-40, pl. 4, figs. 7a, 7b.

Shell with dark brown periostrucum, posterior end broader than anterior; perpendicular striation confined to the ventral half and the posterodorsal part of the shell; radial striation strong towards posterior end. Length-width relationship is 3:1. Dorsal margin of the shell little raised. Shell whitish internally.

Occurrence: Manauli Island (Gulf of Mannar) Palk Bay near Mandapam.

Distribution: India; Andamans Islands; Ceylon and Malaya.

Remarks: The largest specimen collected was 82 mm in length and smallest 17 mm.

Lithophaga teres (Philippi), 1846

(Pl. 1, fig. 3)

Modiola teres Philippi, 1846, p. 148.

Lithodomus teres Reeve, 1858, pl. iii, fig. 13. Hedley, 1899, p. 492. Melvill, 1909, p. 124.

Lithphaga (Lithophaga) teres Prashad, 1932, p. 77

Lithophaga teres Satyamurti, 1956, p. 39, pl. 4, figs. 6a, 6b. Kundu, 1965, p. 92 pl. 6, fig. 21a, 21b. Maes, 1967, p. 15o.

Shells of medium size, periostrucum with golden yellow colour, posterior end more pointed and flat; anterior end rounded, very fine cosely set perpendicular striation

over the shell; no perpendicular striae in the posterodorsal part; the length-width relationship of the shell 3.25:1.

Occurrence: Krusadi Island and Manauli Island in the Gulf of Mannar; Palk Bay near Mandapam.

Distribution: South Africa; Madagascar; Indian Peninsula; Andamans and Laccadives; Ceylon; Philippines, Celebes; New Guinea and Queensland.

Remarks: Not very common. Largest specimen collected was 67 mm in length and smallest 17 mm.

Lithophaga stramineus (Dunker), 1857

(Pl. 1, fig.4)

Lithodomus stramineus Dunker, MS., Reeve 1857 pl. 2, fig. 11. Hornell, 1921, p. 101.

Lithophaga stramineus Satyamurti, 1956, p. 40-41, pl. 4, fig. 9.

Shell subcylindrical, concentric striae prominent towards posterior margin; perpendicular striation feebly developed, often not visible. A thin calcareous incrustation over the posterior half of shell often present; length-width relationship 2.5:1; umbo very near to the anterior end.

Occurrence: Pulli Island, and Manauli Island in Gulf of Mannar; Palk Bay near Mandapam.

Distribution: India; Cambodia and Japan

Remarks: Not common. Maximum length of specimen collected was 57 mm.

Lithophaga levigata (Quoy and Gaimard), 1835

(Pl. 1, fig. 5)

Lithodomus levigata Quoy and Gaimard, 1818, p. 464, pl 78. figs. 17, 18. Hedley, 1988, p. 492.

Lithophaga (Lithophaga) levigata Prashad, 1932, p. 78-79, pl. 2, figs. 42, 43

Shell almost cylindrical; calcareous incrustation present over the shell, projects beyond the shell margin, no concentric striate visible; perpendicular striation feebly developed; umbo almost near anterior end; length-width relationship 3:1.

Occurrence: Manauli Island in Gulf of Mannar; Palk Bay near Mandapam.

Distribution: Red Sea; India; Java, Celebes and New Guinea.

Remarks: Rare form, occurs in sand stones too. Maximum length of the shell obtained 35 mm.

Genus BOTULA Morch, 1853

Shells slightly arculate, flattened and moderately thin, covered with dark chestnut brown periostrucum, only concentric lines present over the shell; ultraterminal umbones.

Botula cinnamomea (Lamarck), 1819.

(Pl. 1, fig. 6)

Mytilus cinnamomea	Lamarck, 1819, p. 114 to 115.
Lithodonus cinnamominus	Reeve (ex parte) 1858, pl. i, figs. 5a and 5b
Lithophaga (Botula) cinnamomea	Prashad, 1932, p. 79
Lithophaga cinnamomea	Ray, 1948, p. 112 Satyamurti, 1956, p. 41, pl. 4, figs. 10 a and 10 b. Kundu, 1965, p. 91, pl. 5, figs. 19a and 19b.

Shells small, more or less 'D' shaped, concentric striation prominent towards the posterior margin, chestnut brown periostrucum. Ventral margin slightly concave towards the middle part; hinge margin short but deep. Length width relationship is 2:1. Internally shell purplish white.

Occurrence: Krusadi Island and Manauli Island (Gulf of Mannar); Palk Bay near Mandapam.

Distribution: West Indies; India; Cambodia, New Guinea and Australia.

Remarks: This species has been referred to by Prashad (1932) under subgenus *Botula* Morch of Genus *Lithophaga*. Satyamurti (1956) and Kundu (1965) referred if to Genus *Lithophaga*. Soot-Ryen (1955) gave *Botula* a generic status. The species described here agrees with the description of the genus *Botula*. Very few specimens were collected from the reefs of Palk Bay. The largest specimen collected measured 17 mm in length and smallest 6 mm.

Genus VENURUPIS Lamarck

Shell oblong, rectangular or ovate; sculptures consist of widely spaced concentric lamina with fine vertical striation in between them. Umbo at the anterior end of the hinge line. Hinge with three teeth.

Venurupis macrophylla Deshayes, 1853

(Pl. 1, fig. 7)

Venurupis macrophylla	Deshayes, 1853, pl. 16, fig. 8. Sowerby in Reeve, 1874, pl. 4. fig. 23. Prashad, 1932, p. 263. Gravely, 1941, p. 52. Satyamurti, 1956, p. 127 to 128, pl. 19, figs. 5a, 5b. Kundu, 1965, p. 216, pl. 21, figs. 67a, anp 67b.

Shell longer than high, anterior region angular and pointed, general shape extremely variable. The raised concentric laminae much foliaceous towards the posterior region; fine perpendicular striation present. Byssus present in adults.

Occurrence: Pulli Island, Manauli Island (Gulf of Mannar) Palk Bay near Mandapam

Distribution: India and Philippines.

Remarks: Very common form. Collected from sand stones too.

Genus PETRICOLA Lamarck, 1801.

Shell longer than high, front margin always round, sculptures consist of raised radial ribs, sometimes oblique. The pallial sinus deep.

Petricola lithophaga (Retzius), 1786

(Pl. 1, fig. 12)

Venus lithophaga	Retzius, 1786, pp. 11 and 14, figs. 1 and 2.
Petricola lithophaga	Sowerby in Reeve, 1874, pl. 2, figs. 11a and 11b. Satyamurti, 1956, p. 135, pl. 20, figs. 8a and 8b.

Shell thick with posterior end pointed, radial ribs strong and become zig-zag in nature towards ventral margin; radial lines are closely set in the anterior region, concentric striae prominent in the ventral part. Hinge area curved and hinge teeth occupy the anterodorsal region.

Occurrence: Krusadi Island and Pulli Island (Gulf of Mannar); Palk Bay near Mandapam

Distribution: Widely distributed in Indo-Pacific.

Remarks: Common form, occurs in sand stone too.

Petricola divergens (Gmelin), 1790

(Pl. 1, fig. 13)

Venus divergens	Gmelin, 1790, p. 3269.
Petricola divaricata	Sowerby in Reeve, 1874, pl. 3, fig. 22.
Petricola (Choristodon) divergens	Prashad, 1932, p. 264 to 266. Habe, 1951, p 96 to 98
Petricola divergens	Satyamurti, 1956, p. 134-135, pl. 20, fig. 7a and 7b.

The shell almost rectangular in outline; umbo terminal; ventral and dorsal margins parallel; surface of the shell with oblique radial striae, which diverge

from place of origin; concentric striae widely spaced, not strong as the preceding species; six raised radial calcareous incrustation, at the posterior end, lunule obsolete.

Occurrence: Krusadi Island and Manauli Island in Gulf of Mannar and reefs in Palk Bay near Mandapam.

Distribution: Indo-Pacific.

Remarks: Not as common as preceding species. Occurs in sand stone too.

Genus ALOIDES Megerle von Muhlfeld, 1811.

Shell small inequilateral; with hinge margin angular or beaklike, umbo situated near the middle of the shell, left valve smaller than the right; concentric striae prominent.

Aloides sulculosa (H. Adams), 1870

(Pl. 1, fig. 8)

Corbula sulculosa Adams, H. 1870, p. 6.

Aloides sulculosa Satyamurti, 1956, p. 161, pl. 25, figs. 5a and 5b

Shell small and concentrically sculptured, periostrucum thick, front part angular and beak-like, no radial striae present; oblique keel begin from the umbo and terminate a little behind the posterior end. A single hinge tooth of the right valve fits into the pit on the left valve.

Occurrence: Krusadi Island and Manauli Island, (Gulf of Mannar)

Distribution: Red Sea and India.

Remarks: Not very common, collected from live corals

Genus. GASTROCHAENA Spengler, 1783.

(Syn. *Rocellaria.* Blainville, 1828)

Shells of small to medium size, ovate with anterior end pointed and ventral margin strongly gaping; umbo situated near the anterior end; surface of the shell with closely set concentric striae; ligament external, hinge line straight.

Gastrochaena gigantea (Deshayes) 1830

(Pl. 1, fig. 10)

Fistulina gigantea Deshayes, 1830, p. 142.

Gastrochaena gigantea Sowerby in Reeve, 1878, pl. 3, figs. 15a and. 15b.

Rocellaria gigantea Smith, 1903, p. 626.

Gastrochaena gigantea Gravely, 1941, p. 65. Satyamurti, 1956, p. 163, pl. 24, figs. 6a and 6b.

Shell with anterior prolongation well in front of umbo; ventral gape wide, beginning a little posterior to umbo; dorsal margin straight, ventral margin convex and round towards posterior end; concentric sculpture strong; specimens examined were from 20 to 30 mm in length in the anteroposterior axis.

Occurrence: Krusadi Island, Pulli Island, Manauli Island (Gulf of Mannar) Palk Bay near Mandapam.

Distribution: India, Ceylon, Malaya; Burma, Cambodia; Philippines; Japan. Fiji Island;

Castrochaena impressa (Deshayes), 1854
(Pl. 1, fig. 11)

Gastrochaena impressa Deshayes, 1854, p. 327. Sowerby in Reeve, 1878, pl. 4, fig. 23 Satyamurti, 1956, p. 165, pl. 24, figs. 10, 10b and 10c.

Shell small, oval and thin; surface finely striated; a distinct depression extends from the umbo to the posteroventral margin; ventral margin convex and round towards the middle; umbo very near to the anterior end; shell length varies from 10 to 17 mm.

Occurrence: Manauli Island in Gulf of Mannar and reefs in Palk Bay near Mandapam.

Distribution: India and Philippines.

Remarks: Not very common.

Gastrochaena apertissima (Deshayes), 1854

(Pl. 1, fig. 9)

Gastrochaena apertissima Deshayes, 1854, p. 326. Sowerby in Reeve, 1878, pl. 1. fig. 4.

Rocellaria apertissima Gravely, 1927, p. 108.

Gastrochaena apertissima Satyamurti, 1956, p. 164, pl. 24, figs. 7a, 7b, 7c and 7d.

Shells elongated, finely striated, delicate or fragile; anterior end cuneated and posterior end roundedly subacuneated; hiatus broad and elongate and dorsal margin elevated, length of shell varies from 8 to 12 mm.

Occurrence: Manauli Island (Gulf of Mannar).

Distribution: India and Philippines.

Genus PHOLADIDEA Turtion, 1819.

Shell thick with a single dorsal mesoplax and an umbonal ventral sulcus, which demarcate the anterior and posterior region of the shell; callum present only in adults, undulating radial striation from umbo to the ventral sulcus; umbonal reflextion strong; apophysis prominent.

Pholadidea cheveyi Lamy, 1927

(Pl. 1, fig. 14)

Pholadidea cheveyi Lamy, 1927 p. 180.

A caplike dorsal mesoplax covers the antero-dorsal region of the shell. Umbonal ventral sulcus strong and prominent; anterior radial ribs delicate and undulating. Posterior-most part of the shell flat and duckbill-shaped, without any striae; shell internally with strong apophysis originating from below the umbo; chondrophore developed; pallial sinus deep.

Occurrence: Krusadi Island, Pulli Island and Manauli Island (Gulf of Mannar) Palk Bay near Mandapam.

Distribution: Recorded here for the first time from Indian territory.

Remarks: Very commonly seen among the corals of Manauli Island. Only a few specimens were collected from Palk Bay. This species differs from *Pholadidea* sp. described by Satyamurti (1956) in the absence of middle and posterior rudimentary plates and the horny process near the hind margin of each valve.

Genus PARAPHOLAS Conrad, 1848

Medium sized shells with three well-remarked regions; umbonal ventral sulcus present; posteriormost portion with chitinous overlapping plates; umbo with a pair of vaulted cavities in front; two dorsal plates present; single ventral hypoplax.

Parapholas quadrizonata Spengler, 1792

(Pl. 1, fig. 15)

Pholas quadrizonata Spengler, 1792, p. 93. Sowerby, 1872, sp. 38.

Parapholas quadrizonata. Gray, 1851, p. 383. Taki and Habe, 1955, p.12.

Anterior region of the shell provided with callum and dorsal mesoplax. Middle portion demarcated by the umbonal ventral sulcus and the posterior obliquely raised ridge; posteriormost part is with chitinous overlapping laminated plates; mesoplax thin, embedded in the periostrucal tissue; hypoplax single; internally a strong apophysis present; chondrophore well developed, with periostrucal tissue filled in; deep pallial sinus present. The siphonal tube bifurcates into exhalent

and inhalent siphon, each terminating in a siphonal aperture. Maximum length of shell collected is 34 mm.

Occurrence: Manauli Island, Palk Bay near Mandapam.

Distribution: India; Queensland; North Australia and Japan.

Remarks: This is the first record of the species from Indian coast. Very few specimens were collected from both Gulf of Mannar and Palk Bay.

Genus DIPLOTHYRA Tryon

Shell small, pyriform; umbonal reflection closely pressed; callum extending in between and on either side of mesoplax; metaplax and hypoplax bifid; posterior region has thick non-laminated chitinous plates.

Remarks: Bartch and Rehder (1949) have included *Diplothyra* as a sub genus of *Martesia.* Turner (1955) has given *Diplothyra* a generic status. This is the first record fom the Indian region.

Diplothyra sp.

(Pl. 1, fig. 16)

Shells very small ranging from 9 to 15 mm in length; a pair of mesoplax present; single bifid metaplax; embedded in periostrucal tissue; posterior region of the shell with chitinous plates, sometimes calcareous incrustations also present; internally chondrophore well developed; apophysis has 3 to 5 delicate branches; pallial sinus deep; siphons united and long; openings of siphons surrounded by non-pigmented tentacles.

Occurrence: Krusadi Island and Manauli Island, Palk Bay near Mandapam.

Remarks: This species differs from *Diplothyra smithii* in the presence of non-laminated chitinous plates in the posterior portion of the shell and the branching apopysis inside the shell. (Bartsch and Rehder, 1945) Both hypoplax and metaplax bifid. Rather rare as only a few specimens were collected.

Genus JOUANNETIA Des Moulin

Shell almost globular; right valve being produced into a rostriform appendage; ventral furrow divides the shell into an anterior large portion and posterior smaller portion; the former with oblique laminated striae; pallial sinus angular and pointed.

Jouannetia cumingii (Sowerby), 1849

(Pl. 1, fig. 17)

Triomphalia cumingii Sowerby, 1849, p. 161.

Jouannetia cumingii Gray, 1851, p. 382, Gravely 1927, p. 108. Satyamurti, 1956, p. 170-171, pl. 25, fig. 4- Kundu, 1965, p. 223, pl. 26, figs. 91a, 91b, and 91c.

The shell with two valves together presenting almost a spherical outline; a flat tongue-like appendage present in the right valve; left valve considerably deeper and the edges overlap those of right valve; left valve with an obliquely raised ridge, a little beyond the anterior furrow; appohysis absent; siphon bifurcating terminally into exhalent and inhanlet openings encircled by pigmented tentacles.

Occurrence: Krusadi Island, Pulli Island and Manauli Island (Gulf of Mannar) Palk Bay near Mandapam.

Distribution: India; Philippines; North Australia; South Australia and Japan.

Remarks: Common form. In the young ones the callum and the angular prolongation of the right valve are absent, but a small rudimentary spot is noticeable.

Method and Pattern of Boring

The intensity of destruction caused by borers to coral reefs in Maldives was pointed out by Gardiner (1903). The actual mechanism of boring into calcareous matter by borers is still not clearly understood. Hunter (1948) discussed the methods of boring by *Hiatella gallicana* and *H. arctica*. Hodgkin (1962) and Turner and Boss (1962) critically reviewed the theories put forward by various authors on the boring habit of *Lithophaga* and concluded that the boring in that genus was not mechanical but of a chemical nature. Otter (1935) and Yonge (1955, 1963) have also paid much attention to this interesting problem.

In Gulf of Mannar and Palk Bay there is no species specificity displayed by the borers, but in most cases massive corals are more susceptible to their attack The borers can broadly be divided into two groups, based on the nature of boring viz. chemical borers and mechanical borers (Otter, 1937; Yonge, 1963). Chemical borers are more destructive than the mechanical borers, since the former is generally in greater numbers and make deeper burrows.

Chemical Borers

Lithophaga: The evolution of boring habit in *Lithophaga* was discussed in detail by Yonge (1955). Otter (1937), Hodgkin (1962), Turner and Boss (1962) and Yonge (1963) have envisaged the method of boring in *Lithophaga* as chemical. The absence of abrasion over the shell surface, great reduction and localisation of the byssus, the calcareous nature of substratum and the presence of specialised glands in mantle show that *Lithophaga* are chemical borers.

The pattern of the burrow made by various *Lithophaga* is almost similar. The opening of the burrow is either slit-like, dumb- bell-shaped or of the shape of

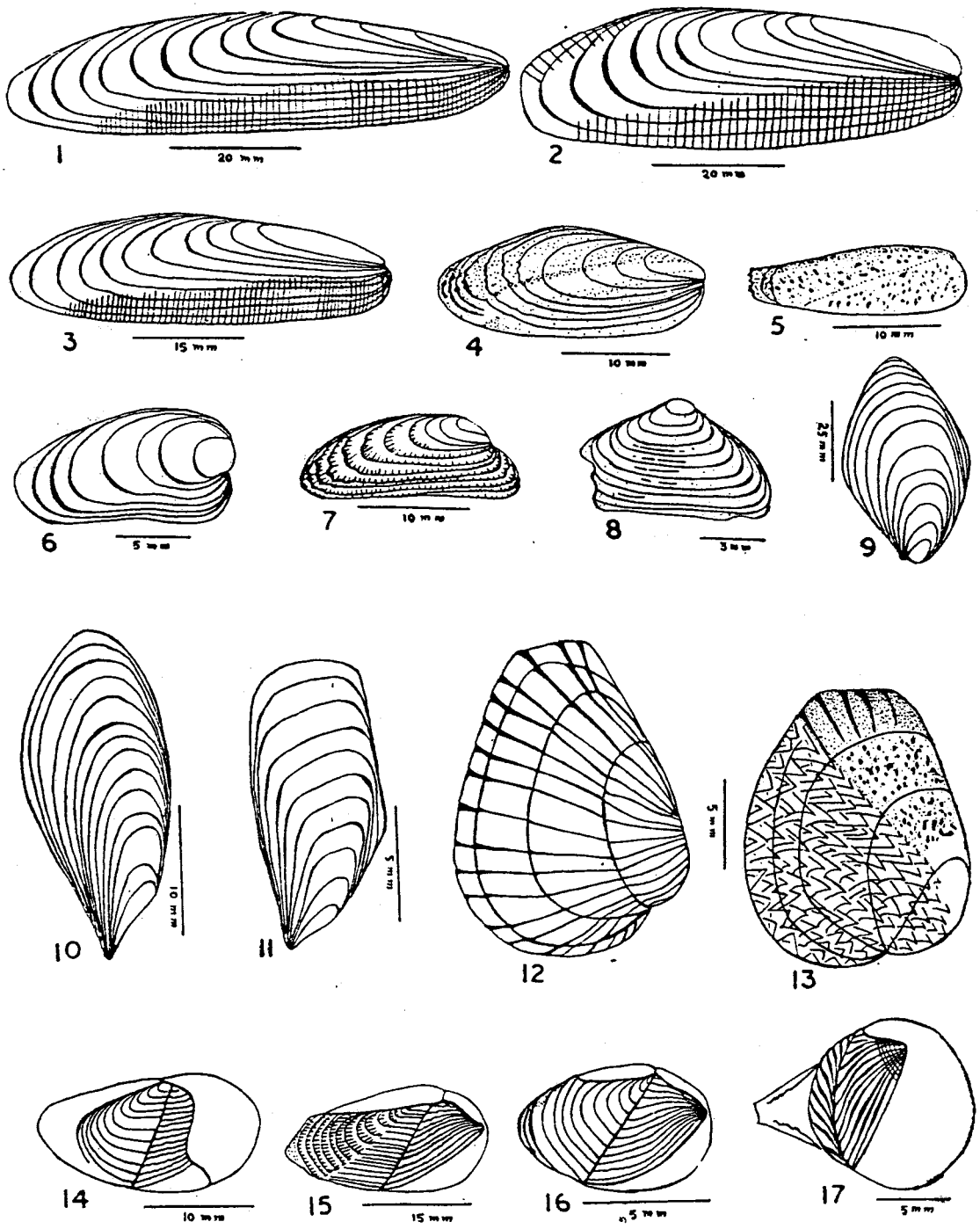
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PLATE 1.

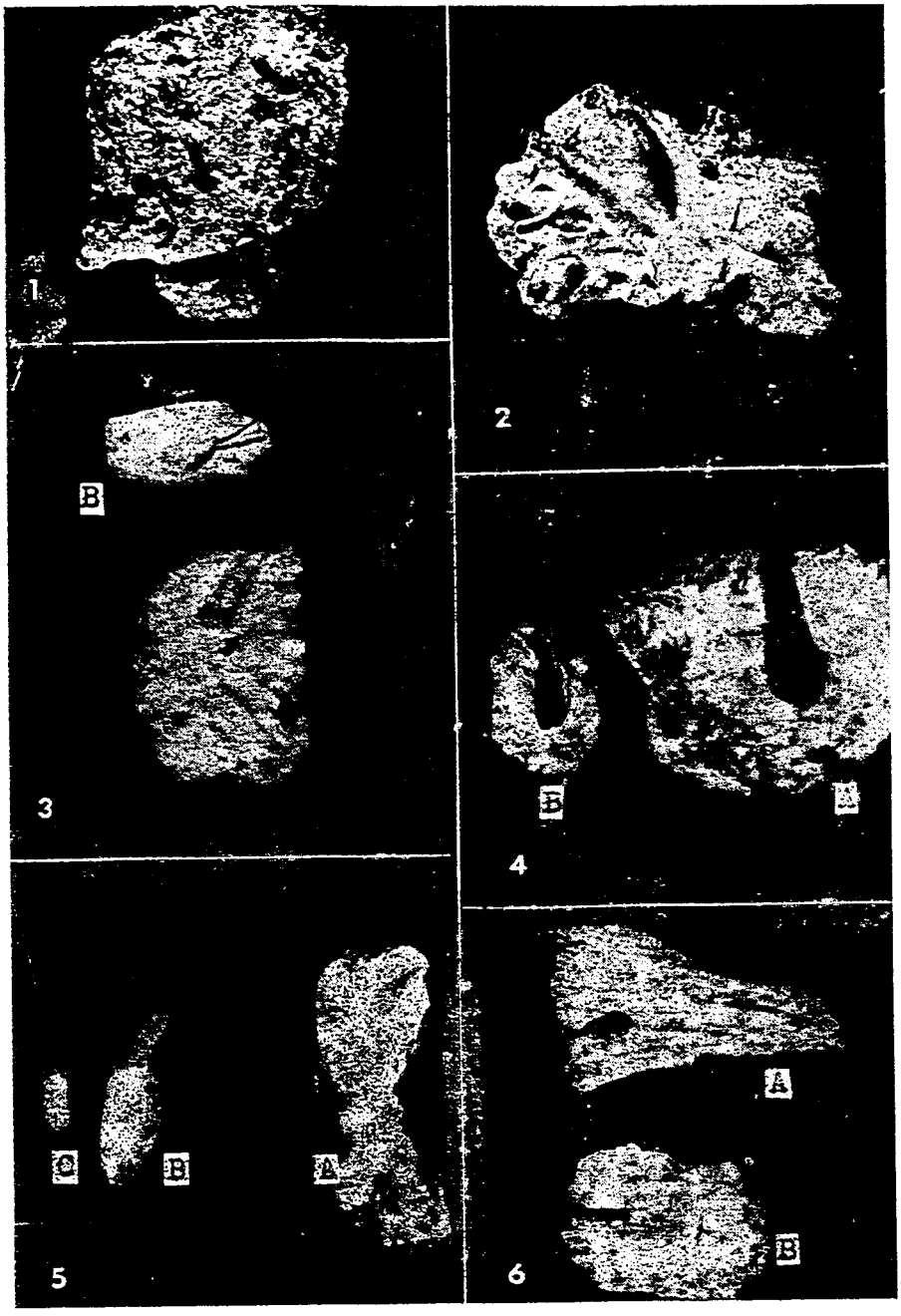

PLATE 2.

EXPLANATION TO PLATE 1

1. *Lithophaga nigra* (d'Orbigny)
2. *Lithophaga gracilis* (Philippi)
3. *Lithophaga teres* (Philippi)
4. *Lithophaga stramineus* (Dunker)
5. *Lithophaga levigata* (Quoy and Gaimard)
6. *Botula cinnamomea* (Lamarck)
7. *Venerupis macrophylla* Deshayes
8. *Aloides sulculosa* (H. Adams)
9. *Gastrochaena apertissima* (Deshayes)
10. *Gastrochaena gigantea* (Deshayes)
11. *Gastrochaena impressa* (Deshayes)
12. *Petricola lithophaga* (Retzius)
13. *Petricola divergens* (Gmelin)
14. *Pholadidea cheveyi* Lamy
15. *Parapholas quadrizonata* Spengler
16. *Diplothyra* sp.
17. *Jouannetia cumingii* (Sowerby)

EXPLANATION TO PLATE 2.

1. Opening of the burrow *Lithophaga*
2. Burrows of *Lithophaga*

3a. Burrow of *Gastrochaena gigantea*

3b. Burrow of *Gastrochaena impressa*

4a. Burrow of *Pholadidea cheveyi*

4b. Burrow of *Parapholas quadrizonata*

5a. Burrow of *Diplothyra* sp.

5b. *Gastrochaena gigantea*

5c. *Gastrochaena impressa*

6a. Burrow of *Petricola*

6b. Burrow of *Jouannetia cumingii*

figure of "eight" (Plate II, fig. 1). The burrows are long and almost cylindrical and scarcely any space exists between the shell and the wall of the burrow. Internally the burrow is lined by a calcareous coating which varies in thickness in different species (Plate II fig. 2). The common species of *Lithophaga* observed in Gulf of Mannar and Palk By are *L. nigra*, *L. gracilis* and *L. teres*. They are capable of ma-making deep burrows in corals. In the same block of coral all the three species are seen boring. The calcareous lining is either thin or even absent in the burrow made by *L. nigra* in the corals. In *L. gracilis* the lining is much thicker towards posterior end. The burrows of *L. stramineus* and *L. levigata* are smaller when compared with the previous species. The calcareous lining is uniformly thick. In *L. nigra* rotatory movement of the shell inside the burrow is noticed. The depth of the burrow varies greatly. In the case of younger specimens the burrow is of the same length of the animal, but in the older ones it reaches double the length of the shell. The burrows examined varied from 20 to 170 mm. Byssus threads are retained throughout life. The mantle edges are capable of protruding through the opening of the burrow. Foot is long and slender.

Because of the larger size of the shell and their presence in greater numbers in the coral blocks *Lithophaga* cause greater destruction than others. They are more common in corals such as *Porites*, *Favia*, *Favites* and *Goniastrea*.

Live specimens of *Lithophaga* were kept in the acquarium along with corals for observing their boring habits. They were moving forward and backward within the burrow, but they did not deepen the burrows during the period of observation.

Mechanical Borers

Botula cinnamomea burrows in the superficial layers of corals. With the opening almost round, the burrow is shallow and kidney shaped having dorsal and ventral ridges. There is no internal calcareous lining for the burrow. The method of boring being mechanical the forces responsible for this act are the opening and closing of the shell valves with the help of contraction of the byssal and pedal retractors (Yonge, 1955). The marks of erosion on the periostrucum is susggestive of mechanical boring. The burrow varies from 10 to 25 mm in depth. The destruction caused by this species is considerably less than by the *Lithophaga*.

Venurupis macrophylla makes shallow burrow, mostly in highly porous corals such as *Favia* and *Goniopora*. The opening is round and the burrow is without an internal calcareous coating. The shell is capable of moving forward and backward inside the burrow, which is almost round in cross section. Shell is highly erroded in the anterior region. It causes a good amount of destruction to corals. Burrow ranges from 6 to 15 mm in depth.

Petricola lithophaga and *P. divergens* are fairly abundant in corals of this area. They are also seen boring into sandstones. The burrow is oval in shape with circular openings (Plate II, fig. 6a). Internally there is no calcareous lining. Otter

(1937) and Purchon (1955b) suggested *Petricola* as a mechanical borer, boring by means of the opening and closing of the shell valves on the hinge line as an axis. The strong radial ribs and the thick shells assist in the mechanical boring. The depth of the shell varies from 20 to 35 mm. The destruction is of higher magnitude because of the greater number of specimens in corals.

Aloides sulculosa which is not common, has a shallow oval burrow. with one dorsal and ventral ridge. There is no internal lining. The opening of the burrow is circular. The boring in this species is comparable with that of *Platydon concellatus* described by Yonge (1963). The destruction caused by them is negligible as very few specimens have been found to be occurring in the reef.

Gastrochaena is a more specialised mechanical borer. The burrow is almost oval in shape with an internal thin calcareous lining. The burrows are deeper than the shell length. The mechanical means of boring is possible by the forward and backward movement of the shell within the burrows. The absence of hinge teeth helps in the opening and shutting of the shell valves (Otter, 1937). In *G. gigantea* the burrow is deeper and the external opening of the burrow is single and round (Plate II, fig. 3a.) There is an internal thick calcareous lining inside the burrow. Depth varies from 30 to 50 mm. In *G. impressa* the burrow is less deep than the preceding species and has two external orifices (Plate II, fig. 3b). Exhalent and inhalent siphons protrude through different orifices, which are seperated by a septum runing a short distance downwards. The burrow is lined by a uniformly thick calcareous coating. The length of the burrow varies from 15 to 30 mm. *G. apertissima* makes small burrows similar to that of *G. gigantea.* Only one exhalent opening is present. Burrow length varies from 10 to 20 mm.

The abundance of *Gastrochaena* in coral reefs shows that destruction is considerably high, next to *Lithophaga. G. gigantea* occurs commnonly along with *Lithophaga* in such corals as *Porites* and *Favia.*

The gastrochaenids were not able to make fresh burrows under laboratory condition. But some specimens were capable of secreting a thin layer of calcareous coating over the siphon within three days when exposed.

Pholadids are represented in the collection by four species. All of them are considered as active mechanical borers. The special adaptations noticed for mechanical boring are absence of hinge teeth, ligament getting reduced or absent and the presence of dorsal and secondary ventral articular surface, which helps in the rocking movement of the shell. The alternate contraction of anterior and posterior adductors help the shell valves to rock on the fulcrum of the dorsal articulation (Yonge, 1963).

Pholadidea cheveyi makes long and oval burrow with a narrow upper tubular part through which the siphons extend out (Plate II, fig. 4a.). The opening of the burrow is circular. The burrow except at the posteriormost part is internally

lined by a thick calcareous coating. The burrow ranges from 30 to 50 mm in length. *Parapholas quadrizonata* has a long oval burrow with a tubular part, which is divided into two at the terminal end by means of a calcareous septum, allowing for the passage of the exhalent and inhalent siphons (Plate II, fig. 4b). The burrow is completely lined internally by a calcareous coating. The depth of the burrow varies from 35 to 60 mm. *Diplothyra* sp. makes shallow burrows of depth ranging 15 to 25 mm. (Plate II, fig. 5a). The opening of the burrow has two closely situated small circular orifices through which the exhalent and inhalent siphons protrude. *Jouannetia cumingii* makes spherical burrows with an upper tubular part (Plate II, fig. 6b). The opening is dumb-bell-shaped. No calcareous lining inside the burrow is noticed. The burrows vary from 30 to 65 mm in depth.

Among pholadids *Pholadidea cheveyi* and *Jouannetia cumingii* are most abundant; causing good amount of destruction to corals, boring deep into them by mechanical means. *Diplothyra* sp. and *Parapholas quadrizonata* are not common. They cause lesser degree of destruction to coral reefs. Young ones of these pholadids also are collected from coral blocks. They are without callum and other accessory plates.

The pholadids kept in aquarium tanks were not able to make fresh burrows in corals. Certain specimens of *Parapholas quadrizonata* were able to secrete a thin coating of calcareous matter over the siphon, within three days, when exposed.

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DISCUSSION

MCCLOSKEY: Did you find any indication that some of the species of boring molluscs were occurring on the dead part of the corals or were they also occurring in the living corals?

APPUKUTTAN: I have seen *Corbula suleulosa* in the living corals

BARTHEL: Does *Lithophaga* bore in hard objects other than corals?

APPUKUTTAN: It bores into Sandstones also.

SERENE (COMMENT): I have observed them boring into concrete blocks.