

BIVALVE GASTROPODS OF THE INDIAN SEAS

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Three species of bivalved gastropods, *Berthelinia (Tamanovalva) limax*, from Visakhapatnam coast and *Berthelinia (Tamanovalva) schlumbergeri* and *Julia* sp. from Port Blair, Andaman Islands, Bay of Bengal, are described. The known bivalved gastropods are listed. The world distribution of bivalved gastropods along with their algal habitat is given. The possibility of a wider distribution of this interesting group of gastropods with a more intensive search among the seaweeds is indicated.

INTRODUCTION

The 'Bivalve Gastropods' are a peculiar group of Opisthobranch shells, which were previously placed in the family Julidae Dall, 1898 (Prasinidae Stoliczka 1871) in the Pelecypods or Clams. The discovery of *Tamanovalva limax*, 'a curious sea slug having two-valved shell and a small helicoid shell at the apex of the left valve' from Bisan Seto, Inland Sea of Japan, by Kawaguti and Baba (1959), startled the malacological world. The above authors have established the true identity of them as 'bivalved gastropods' with two thin and fragile lenticular green shell valves, the left valve bearing the larval helicoidal shell and with a single subcentral adductor muscle scar on the interior of the shell. Soft part of the body is slug-shaped, with distinct head and rhinophores and with a uniseriate radula of the sacoglossan type. Since the original discovery by Kawaguti and Baba (1959) of living bivalved gastropods in Japan, there have been over thirty publications which elaborated the original find, transferred species previously referred to the class bivalvia to the class gastropods, and described new species. The result was the recognition of the family Julidae, long referred to the Bivalvia as a family of sacoglossan opisthobranchs of the class Gastropoda. A perusal of the published accounts of the bivalved 'univalves' would reveal that at present there are as many as 15 named recent species belonging to four recent taxa viz., *Tamanovalva*, *Edentellina*, *Midorigai* and *Julia* which exist in different parts of the world. In addition to these named species, three more species are known to exist, one from Puerto Rico (Warmke Germaine 1966) and two from India (Ganapati and Sarma 1968).

The earliest fossil records date from the Eocene of the Paris Basin. The fossil taxa are *Berthelinia* with two fossil species described from the Eocene of the Paris Basin by Crosse (1875), and *B. burni* Ludbrook and Steel (1961), described from the upper Pliocene of South Australia; *Anomalomya* Cossmann; and *Ludovicica* Cossmann; which are monotypic, from the Eocene of the Paris Basin. A list of the recently published named and unnamed species of bivalved sacoglossans occurring in different parts of the world is given in Table I along with their habitat, locality and author.

There is some doubt as to the validity of the generic and subgeneric groupings of these bivalved gastropods. Reviewing these named groups and noting the general similarity of form among both the fossil and the recent genera Keen and Smith (1961) recognised *Julia* Gould (1862) *Berthelinia* Crosse (1875) and *Midorigai* Burn (1960 *b*) as genera. They regarded the fossil taxa *Anomalomya* Cossmann (1888) and *Ludovicica* Cossmann (1888) and the recent taxon *Edenttellina* Gatliff and Gabriel (1911), (*Tamanovalva* Kawaguti and Baba 1959, as argued by Burn 1960) as subgenera of the fossil genus *Berthelinia*. Baba (1961 *b*) and Boettger (1963) followed this generic and subgeneric arrangement, albeit Baba (1961 *a*) considered all the Keen and Smith (1961) subgenera as genera. Burn (1965, 1966, 1969) recognised three recent genera of Bertheliniids, *Midorigai*, *Tamanovalva*, and *Edenttellina*; in addition to the fossil genus *Berthelinia* which he restricted to fossil species with two whorled protoconchs. Kay (1968) in her review of the bivalved gastropods indicated that she followed Keen and Smith (1961), recognising *Berthelinia* as the genus and *Tamanovalva* as a subgenus of *Berthelinia*; thus *Berthelinia* (*Berthelinia*) is restricted to fossil forms on the basis of two whorled protoconch (Boettger 1963), and *Berthelinia* (*Tamanovalva*) is a recent group; but she considered *Midorigai* as a subgenus of *Berthelinia*. We follow the precedent of Kay (1968) recognising *Tamanovalva* and *Edenttellina* as distinct subgenera of *Berthelinia*; and Boettger (1963) and Kay (1968) restricting *Berthelinia* S. S. to the fossil forms. We, however, consider *Midorigai* as a distinct genus following Keen and Smith (1961) and Burn (1965, 1966, 1969). The recent bivalved sacoglossans are distributed throughout the Indo-West-Pacific to Victoria, (Australia), the west coast of the Americas and the Caribbean.

There are so far only two previous descriptions of living bivalve gastropods from the Indian seas, one by Prabhakara Rao (1965) of *Berthelinia* (*Tamanovalva*) *limax* from Mandapam, Gulf of Mannar on the south-east coast of India and the other by Ganapati and Sarma (1968) of two undescribed species of *Tamanovalva* from Visakhapatnam coast. We have since collected *Berthelinia* (*Tamanovalva*) *limax* from the local coast and two other species of bivalved gastropods, *Berthelinia* (*Tamanovalva*) *schlumbergeri*, Dautzenberg (1895) and *Julia* sp. from Port Blair, Andaman Islands, which are described in the present paper.

Berthelinia (*Tamanovalva*) *limax* (Kawaguti and Baba 1959)

(Figs. 1-3)

Tamanovalva limax Kawaguti and Baba (1959), p. 179; Baba (1961 *a*), p. 40.

Berthelinia limax Baba (1961 *b*), p. 390; Prabhakara Rao (1965), p. 404.

B. (Edenttellina) limax Keen and Smith (1961), p. 51.

B. (Edenttellina) limax Boettger (1963), p. 417.

Material—Two specimens were collected from *Caulerpa racemosa*.

Locality—Visakhapatnam foreshore.

Description—Two small juvenile preserved specimens were encountered while analysing the caulerpan microfauna. The shell valves are very thin, fragile and transparent and are light yellow in colour except for the brownish liver that shines through the shell valves. The shell valves measured 0.6 mm long and 0.4 mm high. The diameter of the protoconch is 0.1 mm. The shell valves (Figs. 1, 2) are small

TABLE I
The available records of bivalved gastropods along with their algal habitat throughout the world-seas

Name of the species	Algal habitat	Author(s)	Locality
<i>Berthelinia (Tamanovalva) limax</i>	<i>Caulerpa okamurai</i>	Kawaguti and Baba (1959)	Bisan Seto, Inland Sea of Japan
<i>B. (Tamanovalva) limax</i>	<i>C. racemosa</i>	Prabhakara Rao (1965)	Mandapam Camp (Gulf of Mannar, India)
<i>B. (Tamanovalva) limax</i>	<i>C. racemosa</i>	Ganapati and Sarma, (present record)	Visakhapatnam coast, (Bay of Bengal, India)
<i>B. (Tamanovalva) babai</i> (= <i>B. typica</i> Burn 1960 b)	<i>C. scalpelliformis</i>	Burn (1965)	Torquay, (Victoria, Australia)
<i>Midorigai australis</i>	<i>C. brownii</i>	Burn (1960 b)	-do-
	<i>C. scalpelliformis</i>		
	<i>C. simpliciuscula</i>		
<i>Midorigai australis</i>	In plankton tows made through <i>Posidonia</i>	Wisely (1962)	Port Hacking, Australia
<i>B. (Edentellina) typica</i>	<i>C. brownii</i>	Burn (1965)	Flinders, Victoria, Australia
<i>B. (Tamanovalva) chloris</i>	<i>C. sertularioides</i>	Keen and Smith (1961)	Puerto Ballandro Bay, Baja California
	<i>C. racemosa</i>		
<i>B. (Tamanovalva) pseudochloris</i>	<i>C. racemosa</i>	Kay (1964)	Koloa, Kauai, Hawaii
<i>B. (Tamanovalva) caribbea</i>	<i>C. verticellata</i>	Edmunds (1963)	Port Royal, Jamaica
<i>B. (Tamanovalva) caribbea</i>	<i>C. verticellata</i>	Germaine L. Warmke (1966)	Puerto Rico
	<i>C. racemosa</i>		
<i>B. (Tamanovalva) caribbea</i>	<i>C. verticellata</i>	John Grahme (1969)	Port Royal, Jamaica
<i>B. (Tamanovalva) fijiensis</i>	<i>C. racemosa</i>	Burn (1966)	Viti Levu, Fiji
<i>B. (Tamanovalva) sp.</i>	<i>Caulerpa</i> sp.	Legendre (1963)	Tulear, Madagascar

<i>B. (Tamanovalva) sp 1</i>	<i>C. taxifolia</i>	Ganapati and Sarma (1968)	Visakhapatnam coast, Bay of Bengal, India
<i>B. (Tamanovalva) sp 2</i>	<i>C. racemosa</i>	Ganapati and Sarma (1968)	-do-
<i>B. (Tamanovalva) schlumbergeri</i>	<i>Halimeda opuntia</i>	Ganapati and Sarma (present record)	Port Blair, Andaman Islands
<i>Julia japonica</i>	<i>Microdictyon japonicum</i>	Kawaguti and Yamasu (1962, 1966)	Mishia, Off the Coast of Hagi-shi, Yamaguchi prefecture, Japan
<i>Julia sp</i>	Algal mat of <i>Caulerpa</i> sp. and <i>Sargassum</i> sp	Ganapati and Sarma (present record)	Port Blair, Andaman Islands
<i>Julia exquisita</i>	On an algal mat of <i>Laurencia</i> , <i>Gracilaria</i> and <i>Gracillariopsis</i>	Kay (1962)	Koloa, Kauai, Hawaii

and elongately oval and equal in size. The anterior end is broadly rounded and the posterior end is narrowly rounded. The left valve bears the protoconch (Fig. 3) having one and one-half whorls situated just behind the anterior one-third of the shell length and is gently inclined. The adductor muscle impression is a rounded scar in the anterior half of the shell valve. There is a very thin transparent leathery periostracum on the shell valves which gets peeled off in the course of preservation.

The head and foot are withdrawn into the two shell valves which are tightly closed. The adductor muscle is firmly attached to the left valve and is easily detached from the right valve. Rhinophores are auriculate and externally grooved; and are speckled with white dots. Oral tentacles small and lobiform; two black eyes are situated close to each other on a prominence of the neck. Foot is narrow and the sole is medially grooved. Tail very short, does not extend behind the shell.

This very small specimen appears to be a recently metamorphosed form. It very closely corresponds to the developmental stages of *T. limax*. (Baba 1961 a). Hence we identified this specimen as *T. limax*.

Discussion—As already indicated, there is some disagreement as to the validity of the generic taxa of bivalved gastropods *Tamanovalva* and *Berthelinia*. Keen and Smith (1961) Baba (1961 b) and Taylor and Sohl (1962) synonymised the genus *Tamanovalva* Kawaguti and Baba (1959) with the Eocene Paris Basin fossil genus *Berthelinia*. Crosse (1875) included it under the subfamily *Bertheliniinae* Beets (1949) of the family Julidae Dall (1898). Burn (1965, 1966, 1969) recognised *Tamanovalva* as a recent genus having one and one-half whorls in the protoconch and *Berthelinia* as a fossil genus having two complete whorls in the protoconch. Kay (1968) recognised (*Tamanovalva* as a subgenus of *Berthelinia*, restricting *Berthelinia* (*Berthelinia*) to fossil forms with two whorled protoconchs. We follow Kay (1968) recognising *Tamanovalva* and *Edentellina* as the subgenera of *Berthelinia*, but we consider *Midorigai* as a separate genus. The shell valves of the fossil and recent species are conchologically so identical in shape and size that they are inseparable except for the difference in the number of whorls in the protoconch. The difference of half a whorl in the protoconch appears to be subgenerically significant. Prof. Myra Keen in a personal communication dated April 23, 1968 informs us that "To accept *Berthelinia* as the general name for the modern species would be a testimony to the very interesting past history of the stock which originated in the warm Tethyan Sea of Europe, radiated outward from there, and is now distributed in the Caribbean, the Indian, the entire Pacific, and south to Australia."

The present known distribution of *Berthelinia* (*Tamanovalva*) *limax* is from Bisan Seto (inland sea of Japan), Mandapam (Gulf of Mannar) on the south-east coast of India, and Visakhapatnam on the east coast of India.

Berthelinia (*Tamanovalva*) *schlumbergeri* Dautzenberg (1895)

(Figs. 4-6)

Berthelinia schlumbergeri Dautzenberg (1895) p. 37-38.

Berthelinia (*Berthelinia*) *schlumbergeri* Keen and Smith (1961) p. 50.

Berthelinia (*Edentellina*) *schlumbergeri* Boettger (1963) p. 416.

Material—Two left valves and two entire specimens from *Halimede opuntia*.

Locality—Port Blair, Andaman Islands, Bay of Bengal.

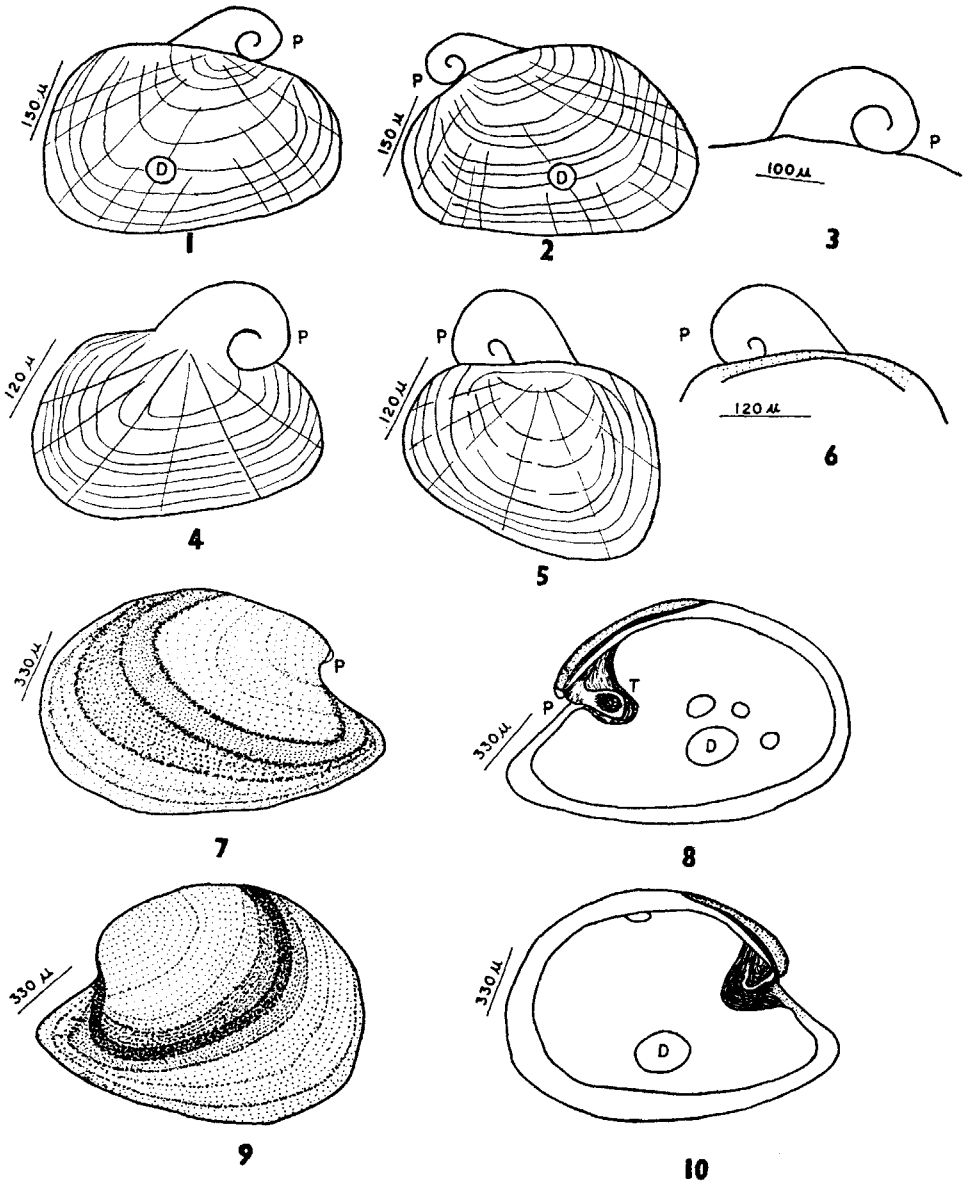
Description—Two small left valves and two small entire specimens were encountered among the siphonous alga *Halimeda opuntia* while investigating its microfauna. The shell dimensions of the four specimens are given in Table II.

TABLE II

Specimen No	Length (mm)	Height (mm)	Spire diameter (mm)
1	0.38	0.25	0.15
2	0.46	0.31	0.16
3	0.31	0.19	0.18
4	0.39	0.27	0.16

The shell valves (Figs. 4, 5) of the two entire specimens are thin, transparent, fragile, equivalve, inequilateral and light greenish yellow in colour. The sculpture of the valves consists of very fine concentric lines of growth and transversely radiating light yellow rays from the umbones to the ventral margin. The dead beach-worn shell valves were greyish white in colour with concentric lines of growth traversed by very fine radiating lines which might be the remains of colour lines. Adductor muscle scar was quite indistinct. The dark-brown liver radiates through the thin transparent shell valves. Protoconch having one and one-half whorls is conspicuous, elevated, erect and is situated at the latter one-third of the shell length of the left valve. The protoconch is transparent and gently inclined. The shell valves are oval, nearly trapezoid. The anterior side of the shell valve is high, dilated and subtruncate. The posterior side of the valve is rounded but shorter than the anterior side. The dorsal margin is convex and the ventral margin gently curved. The hinge (Fig. 6) is narrow and edentulous.

Discussion—*B. schlumbergeri* Dautzenberg (1895) is originally known only from a single tiny left valve described from Nosibe (Madagascar), measuring 0.5 mm umbo-ventral diameter; and 0.6 mm antero-posterior. This is the first publication of a recent species of Bertheliniids. Prof. Myra Keen in her letter dated April 8, 1968 informed us that she had seen a specimen from the Maldives. Apart from the original description and publication by Dautzenberg (1895) from the Western Indian Ocean, there are no published accounts of its occurrence in the rest of the Indian Ocean. The present record from Port Blair extends its distribution into the Eastern Indian Ocean. Dautzenberg (1895) pointed out the close similarities of the shell body of the fossil species *Berthelinia elegans* Crosse (1875) to that of his recent *Berthelinia schlumbergeri*. Dautzenberg (1895) differentiated *B. schlumbergeri* from *B. elegans* in that the protoconch of the latter is much larger in proportion, more coiled and less detached. It might have seemed to him that the difference in the number of whorls was only of specific importance in view of the closest similarities of shell body of his recent species with that of the Eocene Paris Basin fossil species *B. elegans*. Keen and Smith (1961) included the recent *B. schlumbergeri* in the fossil genus *Berthelinia* S. S. along with three other fossil species.



FIGS. 1-10. 1-3, *Berthelinia (Tamanovalva) limax*. 1, preserved shell from the left ; 2, preserved shell from the right ; 3, detail of protoconch on umbo of the left valve. 4-6, *Berthelinia (Tamanovalva) schlumbergeri*. 4, preserved shell from the left ; 5, preserved shell from the right ; 6, detail of hinge-line of the left valve. 7-10, *Julia* sp. 7, left valve of shell ; 8, inside view of the left valve showing muscle scars and hinge structure ; 9, right valve of shell ; 10, inside view of the right valve showing muscle scars and hinge structure.

(P, protoconch ; D, adductor muscle scar ; t, hinge tooth)

Boettger (1963) included *B. schlumbergeri* in the recent subgenus *Edenttellina* of the fossil genus *Berthelinia* restricting *Berthelinia* S. S. to fossil species with two whorled protoconchs. Concerning the specific status of *B. (T) schlumbergeri* Kay (1968) comments that "although the protoconch resembles that of the fossil subgenus, it may be a juvenile specimen, and adults would resemble other recent species." The specimens collected at Port Blair ranged from 0.31 to 0.46 mm in length. These shells are closely akin to Madagascar shells and closely agree with the description of *B. schlumbergeri*. Its specific status cannot be fruitfully discussed until more material of fully grown specimens is collected. It would be premature to synonymise this species with any other recent species until more material is studied.

Julia sp.

(Figs. 7-10)

Material—A single small preserved specimen from *Sargassum* weed mixed with *Caulerpa*.

Locality—Port Blair, Andaman Islands, Bay of Bengal.

Description—A single minute preserved specimen (Figs. 7 and 9) was encountered while investigating the microfauna of the *Sargassum* weed. The shells measured 1.5 mm long and 1.0 mm high and the diameter of the protoconch 99 μ . The shells are cordate, solid, equivalve, inequilateral, porcellaneous and dark brownish green in colour with a heavy 'hinge', leaving a prominent tooth-like knob on the left valve (Fig. 8) and a deep socket in the right valve (Fig 10). A minute, fragile, heterostrophic protoconch of about one and one-fourth whorls is laterally situated at the apex of the left shell valve. Both valves close up tightly when the animal is contracted completely. In this animal the position of the adductor muscle scar cannot be observed from the outside of the shell. The shell valves are sculptured with concentric lines of growth. A very thin, transparent periostracum of brownish-green tinge is present, which gets peeled off in the course of preservation. The umbones are prominent convex and beak-like. The shell valves are broadly oval in form, and moderately anterior margin rounded; the posterior margin deeply excavated. The dorsal margin more strongly convex than the ventral. The interior of the shell valves bear asymmetrical muscle scars (Figs. 8, 10). When examination for soft parts of the slug was made by removing the animal from the valves, the gross anatomy of *Julia* was akin to that figured for *Tamanovalva*.

The single small specimen examined and described above cannot be identified with any of the recent species of *Julia* so far described from the Indian and Pacific areas. As this specimen belongs to an undescribed species of *Julia*, a detailed account of it, along with information concerning soft parts will be described and published elsewhere.

Discussion—The bivalved gastropods of the genus *Julia* Gould (1862) (synonym, *Prasina* Deshayes 1863) can very easily be identified by the characteristics of the shells which are solid, broadly oval in outline with the anterior margin rounded and the posterior margin deeply excavated. The hinge bears a prominent tooth-like ridge in one valve and a fossette-like fold in the other. Thus the shell shape of *Julia* varies widely from that of *Berthelinia*, but their internal anatomical organisation is more strikingly similar to each other except for a few minor differences. Keen and

Smith (1961) maintained these two groups of bivalved 'univalves' in two subfamilies; Juliinae and Bertheliniinae of the family Julidae, because of their similarities in the possession of a 'Two-valved shell and a helicoid protoconch at the apex of the left valve, a sub-central adductor muscle scar that may be partially or completely divided.' The geologic range of *Julia* is from the Miocene (Europe, the Caribbean and the East Indies) to the recent. *Julia* now ranges in the tropics, from East Africa to Polynesia (Beets 1944). Up-till now the species of *Julia* are known only from shell valves and are classified as Pelecypoda. Living animals of *Julia* have been reported from Japan (Kawaguti and Yamasu 1962) and Hawaii (Kay 1962). Morrison (1961) reported on a preserved specimen of *Julia* at the United States National Museum. Maes (1967) reported the occurrence of *Julia borbonica* from Cocos-Keeling Islands (Indian Ocean). These reports described the animals of *Julia* as possessing typical gastropod features in their internal organ systems and with an external bivalved shell similar to that figured for *Tamanovalva*. These reports confirm Keen's contention (1960) that when living animals of *Julia* were discovered they would turn out to be bivalved gastropods like Berthelinids.

DISCUSSION

Two groups of bivalved gastropods have been known to exist in the fossil record, as well as in the recent fauna. One group of these tiny animals was characterised by the simpler 'hinge' structure and was included in the subfamily *Bertheliniinae* (Beets 1949). The other group was characterised by small cordate shells with heavy 'hinge' structure and was included in the sub-family Juliinae (Keen and Smith 1961). Both these groups of animals are distributed in the Indo-Pacific from the region of Madagascar to Japan to Australia and to the western shores of America. In the Indian Ocean, *Julia* has been recorded from Reunion, Mauritius, Seychelles, Ceylon, New Caledonia, the New Hebrides, the Kermadecs, Lord Howe Island, the Marshall Islands and from Cocos-Keelong Islands. But *Berthelinia* has been recorded in the Indian Ocean from Madagascar (Dautzenberg 1895) and from Mandapam, Gulf of Mannar on the south east coast of India (Prabhakara Rao 1965), and from Visakhapatnam shore on the east coast of India only (Ganapati and Sarma 1968). Beets (1944) distribution map shows that the range of *Julia* can overlap the range of *Berthelinia* at only a few places. Port Blair (Andaman Islands) is, therefore, strategically situated in the Indian Ocean like La Paz area of Keen (1960).

With the present discovery as many as five species of bivalved gastropods belonging to two genera are known to exist in Indian seas. They are : *Berthelinia* (*Tamanovalva*) *limax* (Kawaguti and Baba 1959), *B. (Tamanovalva) schlumbergeri* Dautzenberg (1895), *B. (Tamanovalva) sp. 1* and *B. (Tamanovalva) sp. 2* (Ganapati and Sarma 1968), *Julia* sp. (present report). In addition to these species two other species *Julia borbonica* (Deshayes 1863) and *Julia cornuta* (DeFolin 1867) are known to exist from Reunion and Mauritius Islands in the Indian Ocean.

The existing literature shows that all the Bertheliniids have been recorded from the siphonous green algal genus *Caulerpa*, but *Julia* has been recorded from small rocks covered with *Laurencia*, *Gracilaria*, *Gracilariopsis* (Kay 1962), and from *Microdictyon japonicum* (Kawaguti and Yamasu 1962). Kawaguti and Yamasu (1966) reported *Julia japonica* feeding on *Caulerpa ambigua* and depositing its eggs

on *C. okamurai*. The present report is from *Sargassum* and *Caulerpa* mixed vegetation.

Although there are only a few reports of the occurrence of the bivalved gastropods from the Indian Ocean, a more intensive search of the Caulerpan vegetation from other parts of the world bordering the Indian Ocean may perhaps bring to light a wider distribution of these most interesting 'living fossils'.

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