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First Indonesian record of Fungiacava eilatensis Goreau et al., 1968 (Bivalvia: Mytilidae), endosymbiont of Fungia spp. (Scleractinia: Fungiidae)

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The mytilid bivalve *Fungiacava eilatensis* Goreau, Goreau, Neumann & Yonge, 1968, previously mistakenly referred to as *F. eilatensis* Soot-Ryen, 1969, is reported for the first time from Indonesia. It lives as an obligate endosymbiont of mushroom corals, particularly *Fungia* spp., reef-dwelling corals restricted to the tropical Indo-Pacific. Notes are given on its assocation with different host species, its habitat, its biogeography, and its possible competition with endosymbiotic gastropods belonging to the genus *Leptoconchus* (Coralliophilidae).

Key words: Bivalvia, Mytilidae, *Fungiacava*, *Lithophaga*, Gastropoda, Prosobranchia, Coralliophilidae, *Leptoconchus*, endosymbiosis, host species, Anthozoa, Scleractinia, Fungiidae, *Fungia*, ecology, biogeography, Indonesia.

INTRODUCTION

While examining a collection of dried mushroom corals (Scleractinia: Fungiidae) from Komodo Island (Indonesia) for the occurrence of coral-inhabiting barnacles (Crustacea: Cirripedia), we encountered specimens of *Fungia* (*Cycloseris*) *fragilis* (Alcock, 1893) that were infested with endolithic molluscs. Apart from a few specimens belonging to the genus *Leptoconchus* Rüppell, 1835 (Gastropoda: Prosobranchia: Coralliophilidae), the sample of these disc-shaped coralla also contained empty bivalve shells of *Fungiacava eilatensis* Goreau, Goreau, Neumann & Yonge, 1968 (Bivalvia: Mytilidae), which formerly was erroneously referred to as *F. eilatensis* Soot-Ryen, 1969 (in Goreau et al., 1969).

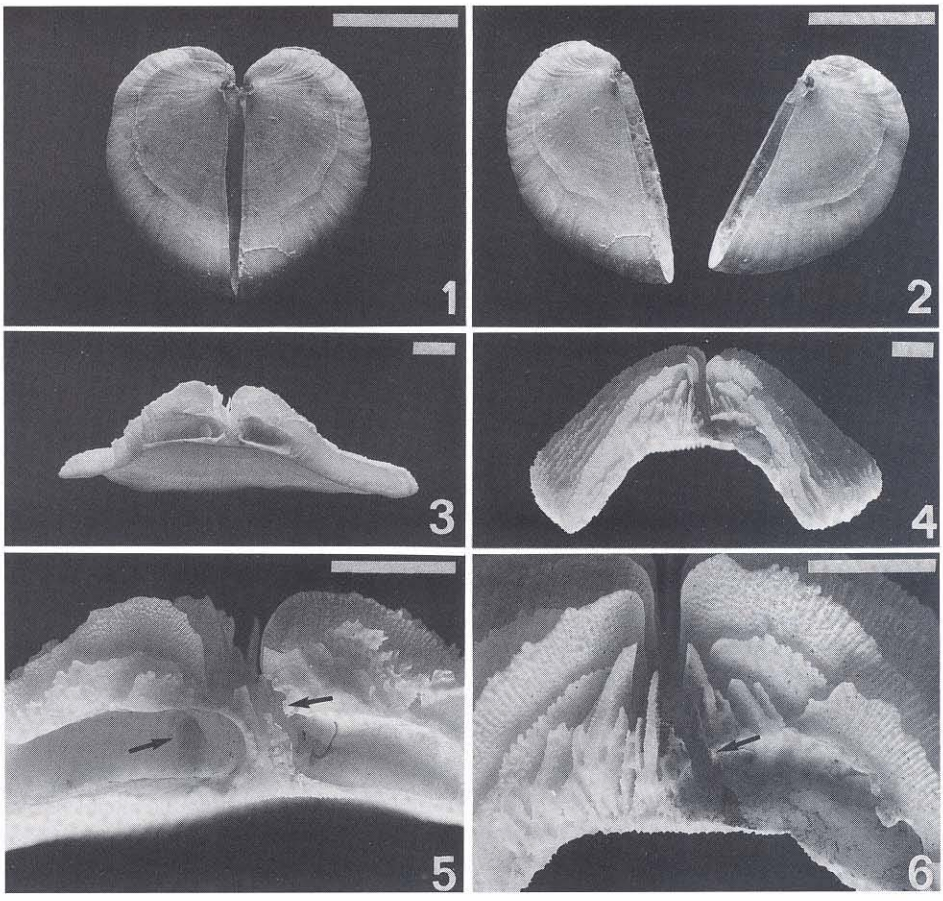
The biology of this species, which is known to occur exclusively as commensal inside solitary mushroom corals, has been studied in much detail at the Gulf of Eilat, Red Sea (Goreau et al., 1968, 1969, 1970, 1972). This is the first documented record of this species from Indonesia. Previously, it was only assumed that the species might occur in Indonesia (Goreau et al., 1969, 1976).

SYSTEMATICS

Fungiacava Goreau, Goreau, Neumann & Yonge, 1968

Fungiacava Goreau, Goreau, Neumann & Yonge, 1968 (= *Fungiacava* Soot-Ryen, 1969).

Type species (by monotypy): *Fungiacava eilatensis* Goreau, Goreau, Neumann & Yonge, 1968. Remarks on the nomenclature of the genus and its type species follow below.



Figs. 1-6. *Fungiacava eilatensis* infesting *Fungia* (*Cycloseris*) *fragilis*; specimens from Komodo Island, Indonesia (RMNH Coel. 21414); scale bars 0.5 cm. 1-2. A complete pair of empty shells (from the coral shown in figs. 3 and 5). The two host corals in cross-section showing the position of the cavities, one (3) with two cavities and another (4) with a single one. 5-6. The location of the siphon canals (arrows) in the same corals.

Fungiacava eilatensis Goreau, Goreau, Neumann & Yonge, 1968 (figs. 1-6)

Fungiacava eilatensis Goreau et al., 1968: 799 (type locality: Eilat, Israel); Soot-Ryen, 1969 (in Goreau et al., 1969): 174, figs. 1, 4, pls. I, III; Goreau et al., 1970: 160, figs. 1-2, pls. 1-2; 1972: 55, pls. 1-2; Yonge, 1974: 162, figs. 9-10, pl. 1 figs. f-g; 1976: fig. 1.3; Goreau et al., 1976: 245, pls. 36-39; Morton, 1980: 893, fig. 11; Morton & Scott, 1980: 200, fig. 11c; Bouillon et al., 1981: 554, fig. 2; Morton, 1983: 164, figs. 8c, 9; 1990: 18, 32.

Fungiacava eilatensis f. *gardineri* Goreau & Goreau, 1969 (in Goreau et al., 1969): 179.

Fungiacava gardineri; Goreau et al., 1972: 56, pl. 1a; Morton, 1990: 18.

Fungiacava cf. *gardineri*; Morton, 1983: 164; 1990: 32.

Material. — Two specimens from one host coral and one from another, *Fungia (Cycloseris) fragilis* (Alcock, 1893), RMNH Coel. 21414.

Locality. — Slawi Bay, NE. Komodo Island, Indonesia: Sta. 4.252 of the Indonesian-Dutch Snellius-II Expedition (see Hoeksema & Moka, 1989: fig. 5).

Nomenclature. — Until now, Soot-Ryen (1969) was considered the author of *Fungiacava* and its type species *F. eilatensis*. This author was given material by Prof. T.F. Goreau, who reported on the same new genus and species during the 65th Annual Meeting of the American Society of Zoologists. The abstract of the presentation was published prior to this meeting, and consequently the descriptions of the two taxa (Goreau et al., 1968) were published before those by Soot-Ryen (1969).

Although the description by Goreau et al. (1968) is short, it leaves no doubt about the identity of the species: "*Fungiacava eilatensis* is a mytilid bivalve commensal in free living fungiid reef corals of the genera *Fungia, Cycloseris* and *Diaseris*." Furthermore they commented on its way of excavating, its position in the host corals, and its anatomy: "*Fungiacava* lives entirely inside the coral, ..." and "*Fungiacava* burrows by chemical means. The exceedingly delicate and reduced shells are unsuitable for mechanical boring and are in any case covered entirely by the pallial envelope which represents the greatly hypertrophied middle fold of the mantle edge". At that time no other bivalve species was known to live inside mushroom corals, and also in recent reviews other associations between bivalves and mushroom corals are not mentioned (Kleemann, 1980, 1990; Morton, 1983, 1990). However, Dr. Cl. Massin (Brussels) wrote to us that he had found specimens belonging to the genus *Lithophaga* Röding, 1798 (Mytilidae), co-occurring with *Leptoconchus* specimens in the mushroom coral species *Fungia (Verrillofungia) repanda* Dana, 1846, *F. (Lobactis) scutaria* Lamarck, 1801, and *Herpolitha limax* (Esper, 1797).

The description given by Soot-Ryen (1969) is much more extensive than the one by Goreau et al. (1968), but it does not have priority. Therefore, Soot-Ryen cannot be considered the real author of the two taxa. Consequently, the holotype designated by Soot-Ryen (1969), which was selected from material first studied by Goreau et al. (1968), should be considered a lectotype instead: British Museum (Natural History), No. 196854W.

Description. — The present host corals of *Fungia fragilis* have a diameter of approximately 5 cm. One coral was infested by two specimens of *Fungiacava eilatensis* and another one by a single specimen, all about 1 cm long (figs. 1-6). The cavities of the three molluscs have a connection with the coral stoma (figs. 5-6). The thin shells are heart-shaped as in the specimens from Eilat (figs. 1-2). They are wider than the specimen from Papua New Guinea (Bouillon et al., 1981: fig. 2). Although the present host corals are smaller and deeper-living than those at Eilat, there is no indication that the bivalves from Indonesia belong to a different form of *Fungiacava eilatensis*. Goreau et al. (1969: 179) distinguished a form *gardineri* for bivalves infesting *Fungia (Cycloseris)* spp. at the Maldives, which were supposed to be smaller, flatter, and broader than those of the form *eilatensis*. Unfortunately, these authors do not present illustrations of such specimens, but only an X-ray photograph of their cavity outlines (Goreau et al., 1972: pl. 1a). The present specimens inhabiting *Fungia fragilis* do not differ distinctly in shape from the lectotype (1 cm long) described by Soot-Ryen (1969) and the paralectotype (1.5 cm long) illustrated by Goreau et al. (1969: pl. 1a). Differences in size are not significant since they may depend on the age of the individual and be limited by the dimensions of

the host coral. Therefore we assume that the Indonesian specimens belong to the same species as those from Eilat, despite the difference in coral host species.

ECOLOGICAL AND BIOGEOGRAPHICAL NOTES

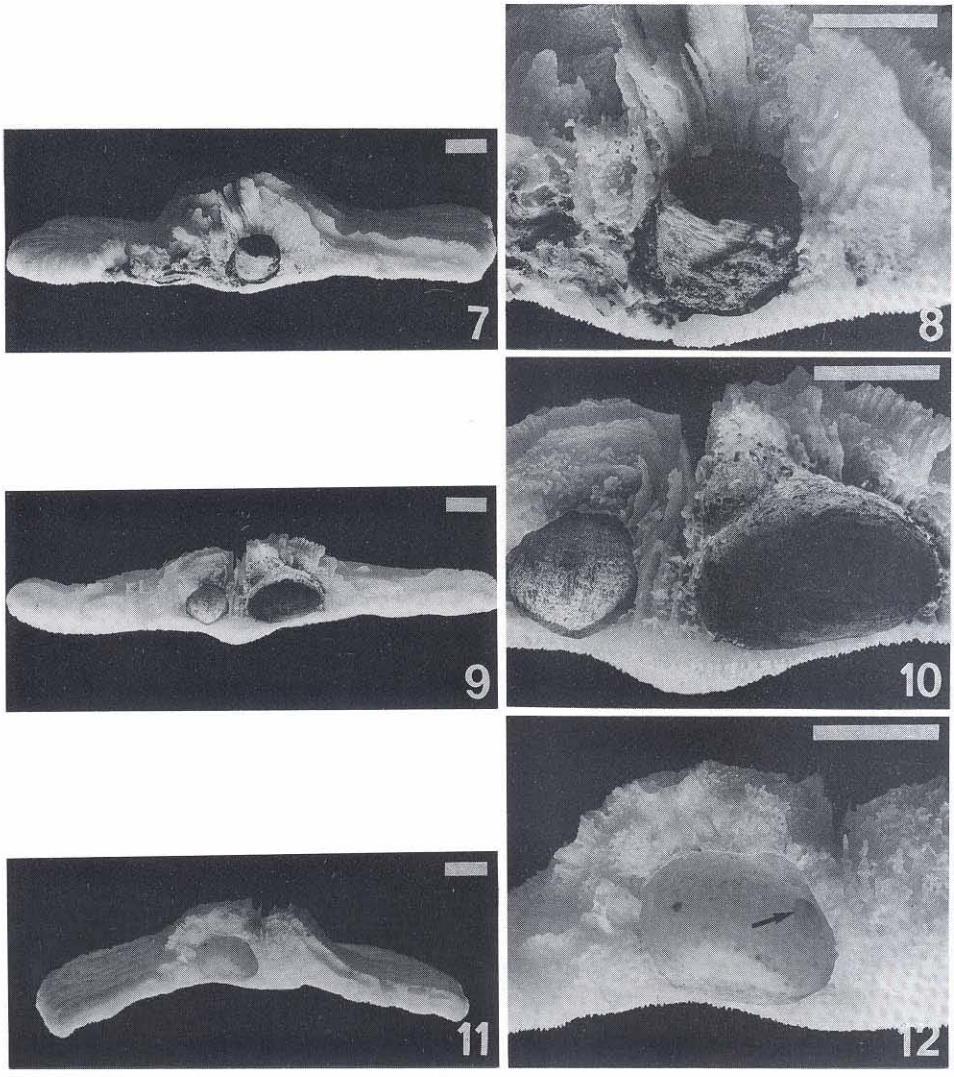
The sample (45 specimens) of the *Fungia fragilis* population was taken from a depth of 9-20 m on a declining bottom consisting of fine sand and silt at the SE. point of a small islet (Pulau Lasa) inside a sheltered bay (Teluk Slawi), NE. of Komodo Island (Hoeksema & Moka, 1989: fig. 5). The specimens were part of a typical soft-bottom assemblage of corals, consisting of mushroom corals, mainly *Fungia* (*Cycloseris*) spp. (Hoeksema & Moka, 1989; Hoeksema, 1989), and other free-living scleractinians (Best & Hoeksema, 1987; Best et al., 1989; Hoeksema & Best, 1991).

The sample also contained six *Fungia fragilis* specimens that served as host for the endosymbiotic gastropod *Leptoconchus* sp. (Coralliophilidae). One of these six corals was also inhabited by a single individual of the epibiotic barnacle *Megatrema oulastreae* (Utinomi, 1962). This is the first record of *Fungia fragilis* as host for a *Leptoconchus* species (cf. Massin, 1982, 1988, 1992). Since each mushroom coral species is always associated with one *Leptoconchus* species (Massin, 1992), the present sample of gastropod shells is monospecific. An updated overview of fungiid host species, partly based on mushroom coral collections from Indonesia, is in preparation by Dr. Cl. Massin.

The cavities of this gastropod (figs. 7-12) were located in positions inside the mushroom corals similar to those of *Fungiacava eilatensis*. At Hansa Bay, northern Papua New Guinea, this bivalve species was found in mushroom coral assemblages that likewise contained corals infested by *Leptoconchus* specimens (Bouillon et al., 1981). Some recently (1986) collected mushroom corals containing *F. eilatensis* specimens from this locality (deposited at the Royal Belgian Institute of Natural Sciences at Brussels), appeared to belong to *Fungia* (*Cycloseris*) *tenuis* Dana, 1846, which was previously unknown as host species for this bivalve. In addition, the mushroom coral assemblages at Hansa Bay also contained *Lithophaga* specimens (Massin, pers. comm.), which so far have never been reported to occur in fungiids.

All mushroom coral species known to act as host for *Fungiacava eilatensis* belong to the genus *Fungia* Lamarck, 1801. *Cycloseris* Milne Edwards & Haime, 1849, and *Diaseris* Milne Edwards & Haime, 1849, were mentioned as host genera by Goreau et al. (1968, 1969), but these were united as subgenus *Cycloseris* in *Fungia* (see Hoeksema, 1989). All host species in this fungiid genus have a relatively large central mouth, from which the bivalve collects food with the help of its large inhalant siphon (Goreau et al., 1970). Following the revision by Hoeksema (1989), seven fungiid host species belonging to five subgenera are presently recorded (table 1).

Unlike in *Fungiacava*, not all cavities of the *Leptoconchus* species necessarily have an opening into the mushroom coral mouth (Massin, 1982). In the present sample, only a few of the *Leptoconchus* specimens show a siphon canal opening inside the coral mouth; other openings can be observed in the area close around the coral mouth. Another difference is that the cavities of the bivalve are flatter than those of the gastropod (compare figs. 3-6 with figs. 7-12). The location of most *Leptoconchus* specimens in the relatively thick centre of these small mushroom corals is possibly related to the maximum available space there, whereas *Fungiacava eilatensis* specimens need to be there in order to live in connection with the mushroom coral mouth. Therefore, theoretically speaking, there is competition with regard to the availability of host corals between



Figs. 7-12. Three dried specimens (shown in cross-section) of *Fungia* (*Cycloseris*) *fragilis* from Komodo Island, Indonesia (RMNH Coel. 21414) infested by *Leptoconchus* sp.; scale bars 0.5 cm. 7-8. One gastropod shell is shown; another is still hidden inside the coral, more to the left. 9-10. One specimen of *Leptoconchus* sp. is shown (left) and two empty cavities (right), a small one (most probably a male) above a large one (most probably a female). 11-12. An empty cavity with an opening (arrow) to another one that is still occupied.

Table 1. Records of *Fungiacava eilatensis* with its fungiid host species, revised after Hoeksema (1989).

Locality	Host species	Reference
Eilat (Israel), Gulf of Eilat	*Fungia* spp.[1]	Goreau et al. (1968)
Eilat (Israel), Gulf of Eilat	*F. (Lobactis) scutaria*	Goreau et al. (1969)
	F. (Fungia) fungites	
S. Sinai (Egypt), Gulf of Eilat	*F. (Lobactis) scutaria*	Goreau et al. (1969)
Pleistocene at S. Sinai (Egypt)	*F. (Wellsofungia) granulosa*[2]	Goreau et al. (1976: fig. 4)
	F. (Verrillofungia) repanda	Goreau et al. (1976: fig. 6a)
Safaga (Egypt), Red Sea	*F. (Fungia) fungites*	Kleemann (1992)
Maldives, Indian Ocean	*F. (Cycloseris) sinensis*[3]	Goreau et al. (1969)
	F. (Cycloseris) fragilis[4]	
	F. (Lobactis) scutaria	
	F. (Fungia) fungites	
?	*F. (Cycloseris) fragilis*[4]	Goreau et al. (1972: pl. 1a)
East Indies or Australia?	*F. (Cycloseris) fragilis* (?)	Goreau et al. (1969)
Komodo I. (Indonesia), Flores Sea	*F. (Cycloseris) fragilis*	this paper
Hansa Bay (P.N.G.), Bismarck Sea	*Fungia* sp.[5]	Bouillon et al. (1981)
	F. (Cycloseris) tenuis[6]	this paper
Marshall Islands, Pacific Ocean	*F. (Lobactis) scutaria*	Goreau et al. (1969)

[1] Originally referred to as *Fungia, Cycloseris* and *Diaseris*, but only *Fungia* is specifically mentioned for the Red Sea.
[2] Previous identification *F. (Verrillofungia) repanda* (by J.W. Wells in Goreau et al., 1976).
[3] Previous identification *Diaseris distorta* (cf. Gardiner, 1905; see Hoeksema, 1989: 31).
[4] Previous identification *Cycloseris sinensis* (cf. Gardiner, 1905; see Hoeksema, 1989: 54).
[5] The mollusc (without the host coral) was given to Dr. Cl. Massin for identification.
[6] Two corals collected in 1968 by Dr. M. Claereboudt, each with two bivalves inside.

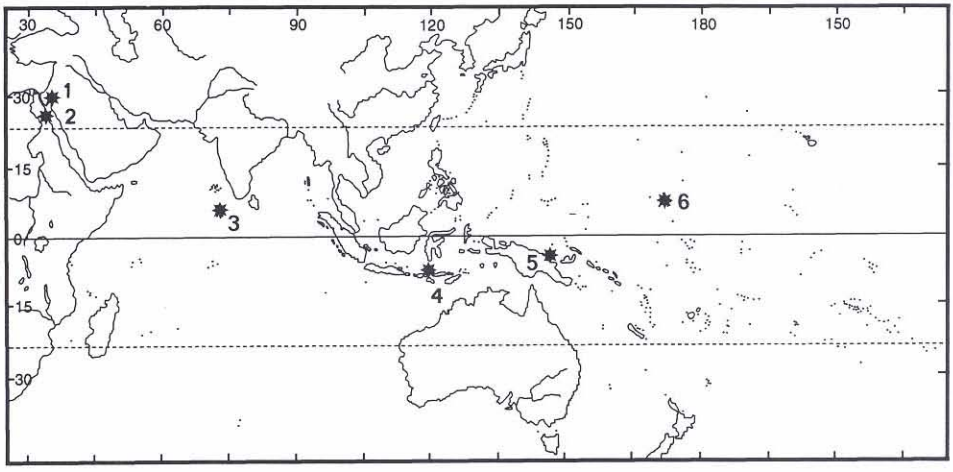


Fig. 13. The presently known range of *Fungiacava eilatensis* in the Indo-Pacific (references in table 1): 1. Gulf of Eilat (Israel and Egypt), 2. Safaga (Egypt), 3. Maldives, 4. Komodo Island (Indonesia), 5. Hansa Bay (N. Papua New Guinea), 6. Marshall Islands, exact locality unknown.

Fungiacava eilatensis and the *Leptoconchus* sp. (see also Bouillon et al., 1981). Since only a few of the mushroom corals in the sampled population were infested by either one of the two mollusc species, specimens of the two species could have excluded each other with regard to individual mushroom coral hosts but obviously not to the whole coral population.

The patchy distribution of *Fungiacava eilatensis* (table 1, fig. 13) has been commented on by some authors (Goreau et al., 1969, 1976; Bouillon et al., 1981; Morton, 1990). Specimens have rarely been found in the field or in the museum collections that were intensively searched by Goreau et al. (1969). There is probably a lack of data because only a few people have tried to look for the species in the field. Many specimens may still be present in collections, unnoticed like the present specimens were before.

Furthermore, the species may have specific habitat requirements. It apparently has a preference for quiet water, since it has been found at sheltered localities, but probably does not occur close to river outlets. However, it may tolerate diffuse terrigenous run-off, since it persists on bottoms that are rich in fine sediments. When additional studies are performed, focusing on the special environments in which the animal is likely to occur, and more locality data are obtained, we may eventually obtain a more precise picture of the species distribution.

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REFERENCES

BEST, M.B., & B.W. HOEKSEMA, 1987. New observations on scleractinian corals from Indonesia: 1. Free-living species belonging to the Faviina. — Zool. Meded., Leiden 61: 387-403.

——, ——, W. MOKA, H. MOLL, SUHARSONO, I N. SUTARNA, 1989. Recent scleractinian coral species collected during the Snellius-II Expedition. — Neth. J. Sea Res. 23: 107-115.

BOUILLON, J., C. MASSIN & J. VAN GOETHEM, 1981. Fungiacava eilatensis Soot-Ryen, 1969 (Bivalvia, Mytilidae) et Leptoconchus striatus Rüppell, 1835 (Gastropoda, Coralliophilidae), mollusques perforant des Fungia (Anthozoa, Fungidae) récoltés en Papouasie Nouvelle-Guinée. — Bull. Séanc. Acad. r. Sci. Outre-mer Cl. Sci. nat. med. 4: 549-570.

GARDINER, J.S., 1905. Madreporaria III. Fungida IV. Turbinolidae. In: J.S. GARDINER, ed., Fauna and geography of the Maldives and Laccadives Archipelagoes 2: 933-957, pls. 89-93. Cambridge.

GOREAU, T.F., N.I. GOREAU, T.J. GOREAU & J.G. CARTER, 1976. Fungiacava eilatensis burrows in fossil Fungia (Pleistocene) from the Sinai Pensinsula. — Proc. R. Soc. Lond. B 193: 245-252.

——, —— & Y. NEUMANN, 1970. On feeding and nutrition in Fungiacava eilatensis (Bivalvia, Mytilidae), a commensal living in fungiid corals. — J. Zool., Lond. 160: 159-172.

——, ——, Y. NEUMANN & C.M. YONGE, 1968. Fungiacava eilatensis n. gen., n. sp. (Bivalvia, Mytilidae), a boring bivalve commensal in reef corals. — Amer. Zool. 8: 799.

——, ——, T. SOOT-RYEN & C.M. YONGE, 1969. On a new commensal mytilid (Mollusca: Bivalvia) opening into the coelenteron of Fungia scutaria (Coelenterata). — J. Zool., Lond. 158: 171-195.

——, —— & C.M. YONGE, 1972. On the mode of boring in Fungiacava eilatensis (Bivalvia: Mytilidae). — J. Zool., Lond. 166: 55-60.

HOEKSEMA, B.W., 1989. Taxonomy, phylogeny and biogeography of mushroom corals (Scleractinia: Fungiidae). — Zool. Verh., Leiden 254: 1-295.

——, & M.B. BEST, 1991. New observations on scleractinian corals from Indonesia: 2. Sipunculan-associated species belonging to the genera Heterocyathus and Heteropsammia. — Zool. Meded., Leiden 65: 221-245.

——, & W. MOKA, 1989. Species assemblages and phenotypes of mushroom corals (Fungiidae) related to coral reef habitats in the Flores Sea. — Neth. J. Sea Res. 23: 149-160.

KLEEMANN, K., 1980. Boring bivalves and their host corals from the Great Barrier Reef. — J. moll. Stud. 46: 13-54.

——, 1990. Evolution of chemically-boring Mytilidae (Bivalvia). In: B. MORTON, ed., The Bivalvia: 111-124. Hong Kong.

——, 1992. Coral communities and coral-bivalve associations in the northern Red Sea at Safaga, Egypt. — Facies, Erlangen 26: 1-10.

MASSIN, C., 1982. Contribution to the knowledge of two boring gastropods with an annotated list of the genera Magilus Montfort, 1810 and Leptoconchus Rüppell, 1835. — Bull. Inst. r. Sci. nat. Belg. 53 (17): 1-28.

——, 1988. Boring Coralliophilidae (Mollusca, Gastropoda): coral host relationship. — Proc. 6th Int. Coral Reef Symp., Townsville, 1988, 3: 177-184.

——, 1992. Ecology of some Leptoconchus spp. (Gastropoda, Coralliophilidae) infesting Fungiidae (Anthozoa, Madreporaria). — Abstr. 11th Int. Malacol. Congr., Siena, 1992: 455.

MORTON, B., 1980. The mode of life and functional morphology of Gregariella coralliphaga (Gmelin 1791) (Bivalvia: Mytilacea) with a discussion on the evolution of the boring Lithophaginae and adaptive radiation in the Mytilidae. In: B.S. MORTON & C.K. TSENG, eds., The marine flora and fauna of Hong Kong and southern China: 875-895. Hong Kong.

MORTON, B., 1983. Coral-associated bivalves of the Indo-Pacific. In: W.D. RUSSELL-HUNTER, ed., The Mollusca 6. Ecology: 139-224. Orlando.

——, 1990. Corals and their bivalve borers — the evolution of a symbiosis. In: B. MORTON, ed., The Bivalvia: 11-46. Hong Kong.

——, & P.J.B. SCOTT, 1980. Morphological and functional specializations of the shell, musculature and pallial glands in the Lithophaginae (Mollusca: Bivalvia). — J. Zool., Lond. 192: 179-203.

UTINOMI, H., 1962. Studies on the cirripedian fauna of Japan VIII. Thoracic cirripeds from western Kyusyu. — Publ. Seto Mar. Biol. Lab. 10: 211-239.

YONGE, C.M., 1974. Coral reefs and molluscs. — Trans. R. Soc. Edinburgh 69: 147-166.

——, 1976. The 'mussel' form and habit. In: B.L. HAYNE, ed., Marine mussels: 1-12. Cambridge.