Larval Life Span of the Coral Reef Asteroid *Gomophia egyptiaca* Gray[1]

MASASHI YAMAGUCHI[2]

Abstract

The asteroid, *Gomophia egyptiaca* Gray, is widely distributed on the coral reefs in the Indo-West Pacific. Its larval development is of the lecithotrophic type. Reduced brachiolariae settle and metamorphose in ten days after spawning under laboratory conditions. The swimming period is extended about four weeks further when there is no substrate for settlement. This potential to prolong larval life span is not considered significant enough to account for the wide geographical distribution of *Gomophia*. Swimming behavior of the larvae does not seem to be adapted for long-distance transportation by surface currents. A hypothesis that transportation of the post-metamorphosis stage by means of drifting or migrating substrate, on which larvae settle, is proposed.

Introduction

Thorson (1950, 1961) and Mileikovsky (1971) indicated that production of pelagic larvae of either planktotrophic or lecithotrophic type is the dominant mode of reproduction in tropical inshore invertebrates and that length of pelagic larval life is three to four weeks in most species studied (seldom exceeding six weeks). However, Sheltema (1968, 1971a, b) demonstrated evidence of trans-oceanic larval transportation in tropical gastropods and several other shoal-water invertebrates. Taylor (1971) considered geographical distribution of coral reef molluscs in the Indian Ocean. He pointed out that there is a uniform molluscan fauna in the area and little endemism shown in the fauna on oceanic islands. This trend of uniform faunal composition appears to be true in coral reef asteroids in the tropical Pacific (Yamaguchi, in press). It is important to examine whether or not larval forms of such shoal water invertebrates are adapted to transportation by oceanic currents over great distances.

Distribution and Morphology

Most of the asteroids which are associated with coral reefs of the Indo-West Pacific have very wide ranges of geographical distribution. *Gomophia egyptiaca* was first described from the Red Sea by Gray in 1840 (Clark and Rowe, 1971) and subsequently reported from various localities in the Indian Ocean and the western Pacific, such as Samoa and Fiji (H. L. Clark, 1921), New Guinea (Clark

---

[1] Contribution No. 43, University of Guam Marine Laboratory.

[2] The Marine Laboratory, University of Guam, Agana, Guam 96910.

Micronesica 10(1):57-64. 1974 (June).

and Bayer, 1948), Gilberts (A. H. Clark, 1954), the Great Barrier Reef (Endean, 1965), Mauritius, Loyalty Islands and Christmas Island (Indian Ocean) (A. M. Clark, 1967), and Guam (Yamaguchi, in press). Marsh (1974) records this species from Tonga, Australs, Cook, and Society Islands in Polynesia. An old record from Hawaii is questionable (Ely, 1942), and *Gomophia* has not been recorded from the Philippines, where extensive collections of asteroids have been made (Fisher, 1919; Domantay and Roxas, 1938; A. H. Clark, 1949).

In spite of its wide geographical distribution, *Gomophia* has never been recorded as abundant in any locality. Only 12 specimens were located on Guam in a two-year period. Those collected from the other localities above were single or a few each. These collections were, however, made during expeditions of short periods in most cases. This species is usually cryptic in the day-light, and its maximum size is only about 60 mm in arm radius. Color in life of Guam specimens differs among individuals but is mostly dark purple on the aboral surface with orange conical tubercles in several somewhat irregular longitudinal rows on each ray. There are one to three nipples on the top of each of the conical tubercles. Many orange, non-conical tubercles are scattered among the conical ones. The madreporite is bright orange red. The number of rays is five, but there are a few specimens with four rays. The rays are cylindrical, tapering distally from the disc to the relatively large terminal plates (Fig. 1).

Larval Development

Four individuals of *Gomophia* collected at various sites in Guam, during February to April, 1973, have been kept alive in an aquarium with a sub-sand filter and an air-lift circulating system of 40-liter capacity. Various organisms had been tested as food for the asteroid. Solitary ascidians (such as *Ascidia*) and a sponge (genus *Tethya*) were found to be readily consumed by them. Compound ascidians, other sponges, actinians and corals have not been grazed upon. Occasionally *Gomophia* everted its stomach on the surface of aquarium and appeared to be digesting epiflora, such as diatoms, from the substrate.

On July 1st, 1973, I found many bright orange eggs floating near the surface water in the aquarium which contained the four *Gomophia*. The eggs were already cleaving and the beginning stage of embryonic development had been overlooked. The number of eggs was about 650 and their diameter was about 0.6 to 0.7 mm. The embryos hatched out of egg membranes later in the same day.

About 100 larvae each were held in 2-liter beakers and kept outdoors. Water temperature fluctuated between about 27 and 31°C daily. The eggs and developing embryos inside the egg membranes floated close to the surface in the beakers, presumably because of buoyancy by the rich yolk substances. The larvae, upon hatching, started swimming or rotating around their longitudinal axis. Many sank to the bottom of the containers on the 2nd day. Most larvae swam to the surface whenever transferred to fresh sea water. However, 10 to 30 per cent of the larvae were swimming near the surface most of the period until about

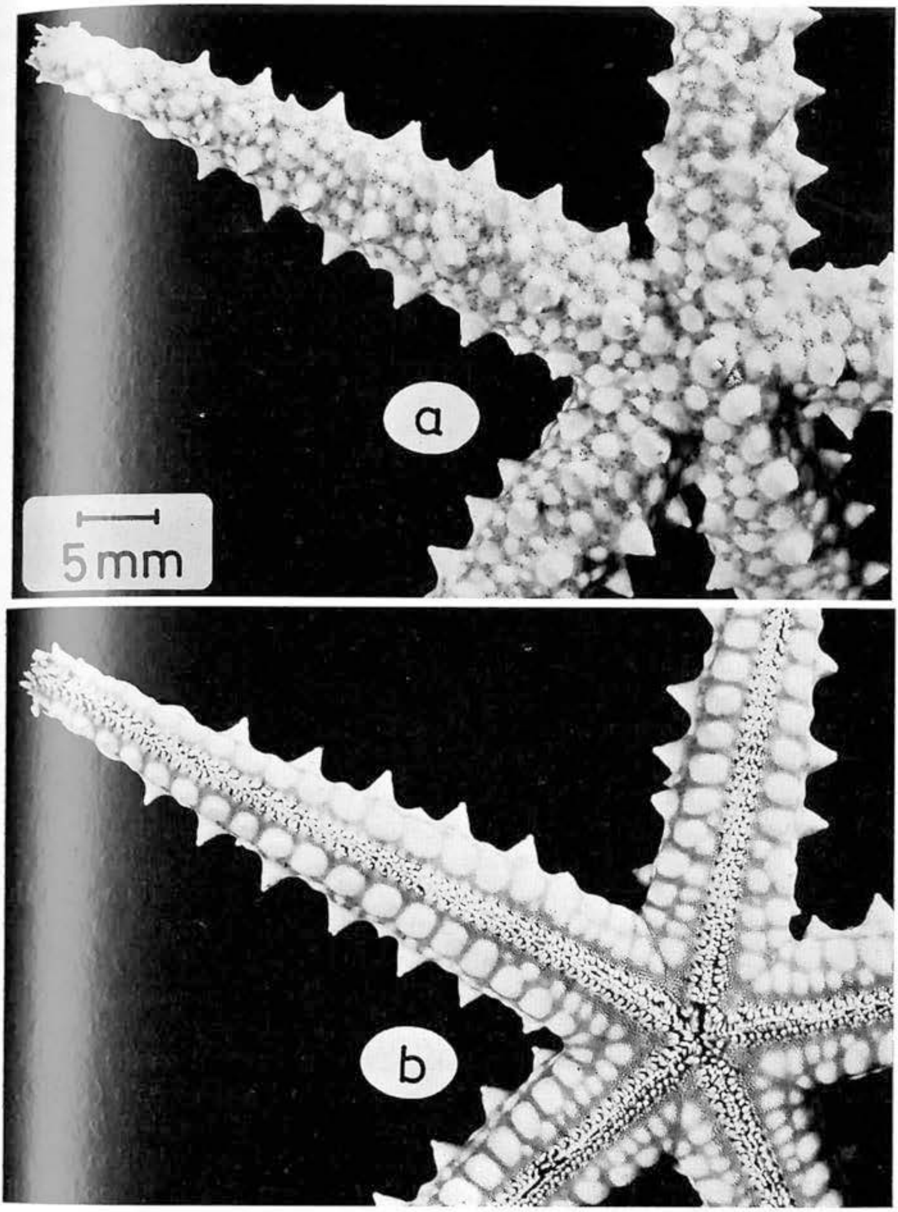

Fig. 1. *Gomophia egyptiaca*, dry specimen. a. Aboral surface. b. Oral surface.

the 30th day. Many larvae tended to swim posterior end forward. A similar swimming behavior was described for *Fromia* larvae by Mortensen (1938).

Nine species of small reef fishes, collected from the reef-flat pools in Pago Bay, were tested for predation on larval *Gomophia* in aquaria (*Abudefduf glaucus, A. amabilis, A. biocellatus, Acanthurus triostegus, Apogon* sp. (juv.), *Bathygobius fuscus,* *Canthigaster solandri, Chaetodon auriga*, and *Halichoeres hortulanus*). None of the fishes fed on the larvae. Although the conspicuous larvae attracted the attention of some fish, the larvae were expelled without swallowing. Most of the above fish species were also tested for predation on larval *Acanthaster* and other species of planktotrophic type asteroid larvae and none fed on any of the asteroid larvae. These observations suggest a chemical repellent substance in asteroid larvae, effective against fishes (Yamaguchi, in press).

The larva of *Gomophia* belongs to the lecithotrophic type which do not feed during larval development but subsists on yolk substances. The hatched larva is slightly oblong and possesses a single blastopore. Because of its orange pigment the larval body is not easily observed except for external characters.

Larval development appeared to be very rapid. In the second day, the larval body attained an oppressed peanut-shape and then brachiolar arms began to appear anterior part. In the fourth day, the larval body reached to full size of 1.2 to 1.3 mm in length, and the starfish primordium became distinct posterior part. The larva appeared to be very similar to that of *Fromia ghardaqana* described by Mortensen (1938). On the fifth day, the skeletal ossicles were evidently developing on the primordium, and a sucker was being formed among the three brachiolar arms which were by then movable.

Larval Settlement

The clean glass surface of the beakers did not elicit normal metamorphosis of the larvae when they were being transferred daily into the filtered sea water in cleaned beakers (during at least the first two weeks). However, some of the larvae, kept in the beaker in which the water was not changed and diatoms covered the glass surface, settled and metamorphosed, beginning on the ninth day. All of about 40 larvae which were separately kept in the aquarium with their parents settled and metamorphosed on dead coral skeletons or pebbles encrusted with algae during the ninth and tenth day. Juvenile starfish were formed by the 12th day after absorbing the larval body into the starfish primordium. Juveniles are mostly five-armed (a few four-armed) and carry on each arm two pairs of tube-feet and one terminal tentacle with a red eye spot on the basal part. Juveniles, just after metamorphosis, were about 0.9 to 1.0 mm across (Fig. 2).

Three different algae (*Porolithon*—coralline alga, *Gelidium* and *Polysiphonia*—bushy red algae) and the sponge *Tethya* sp. were tested for induction of metamorphosis or as settling substrates. *Porolithon* encrustation is a good settling substrate for larval *Acanthaster* and other species of the planktotrophic type (Yamaguchi, 1973). The bushy algae are known as an important settling substrate for larvae of temperate water asteroids such as *Asterias*. The sponge, *Tethya*, appeared to be the most favored food for adult *Gomophia* and is usually covered with diatoms and other microscopic organisms on its outside surface. The above four items were placed individually in four 2-liter beakers, along with 30 larvae. One beaker with filtered sea water and 30 larval *Gomophia* without algae, was maintained at the same time with the above four beakers. The larvae in this beaker were transferred to fresh conditions daily while others stayed in the same water during the observation from the 10th to 16th day.

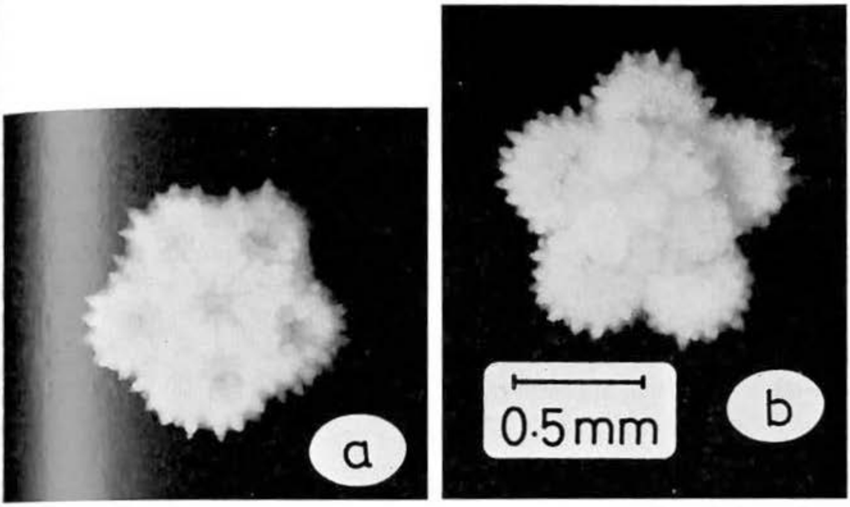

Fig. 2. *Gomophia egyptiaca*, preserved juvenile specimens. a. Juvenile just after metamorphosis, oral surface. Note opened mouth and two pairs of tube-feet each ray. b. Juvenile several days after metamorphosis, aboral surface. Note well-developed skeletal plates and numerous spinelets.

Table 1. Metamorphosis of *Gomophia* larvae in response to algae and a sponge on 16th day.

	Porolithon	*Polysiphonia*	*Gelidium*	*Tethya*	Without organisms
Swimming	7	11	19	19	29
Metamorphosing	3	4	2	5	0
Metamorphosed	20	15	8	6	1
Total No. Larvae	30	30	29*	30	30

* One larva ruptured on the surface of water.

More than half of the metamorphosed larvae settled directly on the surface of *Porolithon* encrustations or algal strands of *Polysiphonia* (Table 1). However, the remainder and metamorphosed larvae in other beakers failed to attach themselves to substrates. In the case of *Polysiphonia*, the algal strands worked as a trap in which the larvae were confined and then metamorphosed. It was evident that the algae and the sponge induced metamorphosis of *Gomophia* larvae at various rates while only one out of 30 larvae in the clean beaker metamorphosed.

Prolongation of Larval Life Span

On the 16th day, after the above settling experiments, 109 larvae were left unmetamorphosed. They were kept in clean beakers and transferred to fresh conditions every two to three days. The purpose was to test their ability to prolong larval life-span. On the 23rd day, the number of swimming larvae was reduced to 91, because 10 had metamorphosed and 8 had ruptured. On the 33rd day, the number of larvae was 63; 28 larvae had metamorphosed or showed signs of metamorphosis.

Six weeks after spawning, on the 42nd day, there were still 54 larvae swimming in the beakers, but not vigorously. They apparently shrank in size and seldom went near the surface of the water. All 54 surviving larvae were then placed on a plastic petri-dish encrusted with coralline algae and other organisms. The number of individuals successfully metamorphosed on the dish were counted five and ten days later, respectively. Only five larvae completed metamorphosis in five days, but 34 did complete ten days after, although some of these failed to attach on the substrate. The larvae which had not metamorphosed at this time were mostly inactive. Many juveniles, after this delayed metamorphosis, showed irregularity in external appearances and they were about 20 per cent smaller in diameter than those that metamorphosed normally.

Discussion

The reproductive strategies of coral reef asteroids diverge into two distinct stereo-types, if the sand-dwelling species are excluded. One is to produce planktotrophic larvae and the other, lecithotrophic larvae. Most of the rare species of coral reef asteroids have not been studied and are unknown as to their type of larval development. However, the majority of common species are known to produce planktotrophic larvae, and most of the rare ones are suspected to produce lecithotrophic larvae (Yamaguchi, in press). This difference in population size might reflect a fecundity difference between the two types. Small sizes (0.1 to 0.2 mm dia.) and large numbers of eggs (well exceed one million) in planktotrophic asteroids (for example, *Acanthaster*) are contrasted with large size (0.6 to 0.7 mm dia.) and small number (650 probably from a single female) of eggs in *Gomophia*.

Lecithotrophic larvae tend to have shorter life spans than planktotrophic ones in the same group of animals. However, there are asteroids that can prolong the swimming period under laboratory conditions. In the temperate water asteroid, *Mediaster aequalis*, onset of metamorphosis in some larvae was observed 38 days after fertilization of ova, and some larvae were still capable of metamorphosis at 14 months age under laboratory conditions (Birkeland *et al.*, 1971). The rate of larval development in *Mediaster* is much slower than that of *Gomophia*, although both species produce very similar lecithotrophic larvae. *Gomophia* larvae are ready to settle in ten days after spawning but are capable of metamorphosis at six weeks age. The lecithotrophic larvae of *Fromia ghardaqana* were observed in the Red Sea. Some *Fromia* larvae completed metamorphosis 16 days after spawning, but the majority of them went on swimming for an additional two to four weeks or more, reducing their size (Mortensen, 1938).

Both *Fromia ghardaqana* and *Gomophia egyptiaca* may have considerable potential in the larval stages to postpone metamorphosis when lacking suitable substrate to settle. However, this character itself may not significantly contribute to their wide-range dispersal. *F. ghardaqana* is confined to the Red Sea (Clark and Rowe, 1971). The wide geographical distribution of *Gomophia* in the tropical Indo-West Pacific, particularly on oceanic islands, may be related to causes other than larval transportation.

The potential for extending pelagic life in larval *Gomophia* may be too small to account for the hypothetical larval transportation among oceanic islands. Moreover, larval *Gomophia* tended to sink to the bottom during most of swimming period after two days, although the eggs and very early developmental stage were strongly buoyant. It is doubtful if *Gomophia* larvae could be successfully transported long distances by surface currents without sinking to deep water. However, it would be likely that larvae could settle on a floating substrate and then juveniles could be transported great distances. Juveniles may subsist on algae and other organisms which encrust such substrates.

Transportation by artificial substrates (*i.e.*, ships) and subsequent colonization of new localities by sessile organisms has been documented in some species, especially in fouling organisms (*e.g.*, Skerman, 1960; Doty, 1961). The wide geographical distribution is well recognized for many divergent groups of the tropical Indo-West Pacific marine animals (Ekman, 1953). Scleractinian corals, as well as many other sessile animals (*e.g.*, sponges and ascidians, etc.) produce lecithotrophic larvae of short pelagic life (*e.g.*, see Vaughan and Wells, 1943; Grave, 1936), but many of these animals are nevertheless widely distributed. Therefore, there might be a means of transportation for sessile forms, presumably by natural and man-made substrates which drift or travel on the surface current system in the tropical oceans.

ACKNOWLEDGEMENTS

I am grateful to Dr. Fu-Shiang Chia of the Department of Zoology, University of Alberta, for his criticism of my manuscript. I thank Miss A. M. Clark, British Museum (Natural History) and Mrs. L. M. Marsh, Western Australian Museum for their comments and information concerning the asteroid. I wish to thank all the staff of the Marine Laboratory, University of Guam, for their assistance and encouragement.

REFERENCES

Birkeland, C., F-S. Chia, and R. R. Strathmann. 1971. Development, substratum selection, delay of metamorphosis and growth in the seastar, *Mediaster aequalis* Stimpson. Biol. Bull. 141:99–108.

Clark, A. H. 1949. Collection of sea-stars from the Philippines. Proc. Biol. Soc. Wash. 62: 73–77.

———. 1954. Records of Indo-Pacific echinoderms. Pac. Sci. 8:243–263.

Clark, A. H., and F. M. Bayer. 1948. Some echinoderms from Biak, Schouten Islands (New Guinea). J. Wash. Acad. Sci. 38:143–144.

Clark, A. M. 1967. Notes on asteroids in the British Museum (Natural History) V. *Nardoa* and some other ophidiasterids. Bull. British Museum (Nat. Hist.) Zool. 15:169–198.

Clark, A. M. and F. W. E. Rowe. 1971. Shallow-water Indo-West Pacific echinoderms. Trustees British Museum (Natural History), London 238 p.

Clark, H. L. 1921. The echinoderm fauna of Torres Strait: Its composition and its origin. Carnegie Institution of Washington Pub. 214, 223 p.

Domantay, J. S., and H. A. Roxas. 1938. The littoral Asteroidea of Puerto Galera Bay and adjacent waters. Philipp. J. Sci. 65:203–237.

Doty, M. S. 1961. *Acanthophora*, a possible invader of marine flora of Hawaii. Pac. Sci. 15:547–552.

Ekman, S. 1953. Zoogeography of the sea. (Translation from the Swedish). Sidgwick and Jackson, London. 417 p.

Ely, C. A. 1942. Shallow water Asteroidea and Ophiuroidea of Hawaii. Bull. B. P. Bishop Mus. 176:1–163.

Endean, R. 1965. Queensland faunistic records VIII. Further records of Echinodermata (excluding Crinoidea) from southern Queensland. Pap. Dep. Zool. Univ. Qld. 2:229–235.

Fisher, W. K. 1919. Starfishes of the Philippine Seas and adjacent waters. Bull. U. S. Nat. Mus. 100:1–711.

Grave, C. 1936. Metamorphosis of ascidian larvae. Pap. Tortugas Lab., Carnegie Inst. Washington 29:211–291.

Marsh, L. M. 1974. Shallow-water Asterozoans of southeastern Polynesia. I. Asteroidea. Micronesica 10(1):65–104.

Mileikovsky, S. A. 1971. Types of larval development in marine bottom invertebrates, their distribution and ecological significance: A re-evaluation. Marine Biol. 10:193–213.

Mortensen, T. 1938. Contributions to the study of the development and larval forms of echinoderms. IV. K. Danske Vidensk. Selsk. Skr. (Naturv.-Math,), Series 9, 7:1–59.

Skerman, T. M. 1960. Ship-fouling in New Zealand waters: A survey of marine fouling organisms from vessels of the coastal and overseas trades. New Zealand J. Sci. 3:620–648.

Sheltema, R. S. 1968. Dispersal of larvae by equatorial ocean currents and its importance to the zoogeography of shoal-water tropical species. Nature 217:1159–1162.

———. 1971a. Larval dispersal as a means of genetic exchange between geographically separated populations of shallow-water benthic marine gastropods. Biol. Bull. 140:284–322.

———. 1971b. The dispersal of the larvae of shoal-water benthic invertebrate species over long distances by ocean currents. p. 7–28. *In* D. J. Crisp (ed.), Fourth European Mar. Biol. Symp.

Taylor, J. D. 1971. Reef associated molluscan assemblages in the western Indian Ocean. Symp. Zool. Soc. London 28:501–534.

Thorson, G. 1950. Reproductive and larval ecology of marine bottom invertebrates. Biol. Rev. 25:1–45.

———. 1961. Length of pelagic life in marine invertebrates as related to larval transport by ocean currents. p. 455–474 *In* M. Sears (ed.), Oceanography Pub. 67. Amer. Assoc. Adv. Sci.

Vaughan, T. W., and J. W. Wells. 1943. Revision of the suborders, families, and genera of the Scleractinia. Geol. Soc. America Spec. Pap. (44):1–363.

Yamaguchi, M. 1973. Early life histories of coral reef asteroids, with special reference to *Acanthaster planci* (L.). p. 369–387. *In* O. A. Jones and R. Endean (eds.) Biology and Geology of Coral Reefs. Academic Press. Vol. II (Biology 1).

———. (in press). Coral reef asteroids of Guam. Biotropica.