Recruitment of Coral Reef Asteroids, with Emphasis on *Acanthaster planci* (L.)[1]

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Abstract

The paucity of juvenile asteroids and other echinoderms in the field has been recognized by a number of workers from various localities. Some authors have paid special attention to trying to locate such juvenile populations but have failed in most cases. This is true for the common asteroids of Guam such as *Linckia laevigata, L. multifora,* and *Culcita novae-guineae.* This fact is surprising because the adult populations are so conspicuous. *Acanthaster* represents a similar picture in population structure. The aggregating populations of *Acanthaster* from various localities in the Indo-West Pacific show a uniform unimodality in the size-frequency distribution of the animals, except for one from the Red Sea. Juvenile *Acanthaster* have seldom been located in the field. Field evidence suggests that recruitments of many echinoderms, which produce larvae of similar feeding requirements and similar life-spans, is very sporadic in intensity from year to year although they reproduce annually or semi-continuously. Their populations are maintained by occasional year-classes which settle at high intensity and their longevous nature may keep the populations superficially stable, although the exact longevity data in the animals are unknown.

Recruitment of sedentary animals to coral reefs has not been well documented. Frank (1969) indicated that settlement of many coral reef gastropods was a highly localized and sporadic phenomenon. He discussed the rather long life spans in reef gastropods. Frank (1968) speculated that this is favorable for population maintenance of the animals which might show variable spawning success or variable settlement success. High fecundities and dispersal pelagic stages are usually associated with animals' variable recruitment (Thorson, 1961).

Outbreaks of large populations of *Acanthaster planci* (L.) have occurred in certain coral reefs of the Pacific in recent decades. A number of hypotheses have been developed to explain the causes and mechanisms of this dramatic phenomenon (see review by Branham, 1973). It is evident that these hypotheses are based only on circumstantial evidence and that they are subject to controversy.

The following account is an attempt to understand the nature of population recruitment of the coral reef asteroids of Guam from observations on their population structures, and especially on the occurrences of juvenile forms in the field.

There are at least 23 species associated with the coral reefs of Guam (Table 1).

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Table 1. Asteroid species found in the shallow waters of Guam.

Astropectinidae	*Astropecten polyacanthus* Muller and Troschel
Oreasteridae	*Bothriaster primigenius* Doderlein
	Choriaster granulatus Lutken
	Culcita novaeguineae Muller and Troschel
	**Protoreaster nodosus* (Linnaeus)
Ophidiasteridae	*Cistina columbiae* Gray
	Fromia hemiopla Fisher
	Fromia sp.
	Gomophia egyptiaca Gray
	Leiaster leachi (Gray)
	Linckia guildingi (Gray)
	Linckia laevigata (Linnaeus)
	Linckia multifora (Lamarck)
	Linckia sp.
	Neoferdina cumingi (Gray)
	Ophidiaster granifer Lutken
	Ophidiaster lorioli Fisher
	Ophidiaster squameus Fisher
Asteropidae	*Asteropsis carinifera* (Lamarck)
Asterinidae	*Asterina anomala* H. L. Clark
	Asterina sp.
Acanthasteridae	*Acanthaster planci* (Linnaeus)
Mithrodiidae	*Mithrodia clavigera* (Lamarck)
Echinasteridae	*Echinaster luzonicus* (Gray)

* Probably not existing at present although this species was recorded from Guam by A. H. Clark (1954, Pac. Sci. 8: 254).

Three species of *Linckia* (*L. laevigata, L. multifora* and *L. guildingi*), *Culcita novaeguineae, Choriaster granulatus,* and *Echinaster luzonicus* usually occur in fully exposed habitats, as do aggregating *Acanthaster planci.* Adults of other species, as well as juvenile forms of all species studied, are usually cryptic in the daylight and active only at night, including non-aggregating *Acanthaster.*

Most of the common coral reef asteroids of Guam produce planktotrophic larvae. Larvae of *Linckia, Culcita, Choriaster, Acanthaster,* and probably *Leiaster leachi* develop in a similar manner through bipinnariae to brachiolariae and stay in the pelagic environment for at least three weeks. It has been assumed that larval forms of the common reef asteroids show a convergence in their structures, feeding requirements, life-spans, etc., presumably because of adaptation to a rather uniform pelagic environment (Yamaguchi, 1973). The post-metamorphosis juveniles of the above asteroids are less than 1 mm in total diameter at the beginning of their sedentary life.

Because of their small sizes and cryptic behavior, very young juveniles are difficult to find in the field. The survival of pelagic stages, as well as that of the very early juvenile stages of asteroids, may be highly variable but we have practically no substantial information concerning this point. Therefore, we may only be able to judge, at present, the over-all survival of the early stages from the appearance and abundance of sizable juveniles in the field.

I have not been able to locate any large number of juvenile asteroids around the reefs of Guam in the two years, from 1971 through 1973, although special attention was directed to this. Small specimens of the most common asteroid, *Linckia laevigata*, are among the hardest to find. A small number of juvenile *Acanthaster* and *Culcita* were found, but very occasionally. In short, I was very surprised at not finding juvenile forms, adults of which are abundant or common and very conspicuous on the reefs. Not only asteroids but also many species of other echinoderms and also molluscs showed a similar picture, i.e., paucity of juveniles but very conspicuous adult populations. Old naturalists, such as Clark (1921) and Mortensen (1937), recognized and noted this fact for various tropical echinoderms.

Dana and Wolfson (1970), Branham *et al.* (1971), and Nishihira and Yamazato (1972) reported the absence or scarcity of small juveniles in aggregating *Acanthaster* populations from the Gulf of California, Hawaii, and Okinawa, respectively. On the other hand, Pearson and Endean (1969) and Chesher (1969) found small numbers of juveniles during the peroid of the starfish infestations of the Great Barrier Reef and Guam, respectively.

The size-frequency distribution of *Acanthaster* has shown a consistent unimodal trend, not only in the above-mentioned reports but also in those by Owens (1971), Goreau *et al.* (1972), and Glynn (1973) for Fiji, Saipan, and Panama populations, respectively. The only exception is a population in the Red Sea reported by Ormond and Campbell (1971). There, they described a bimodal size distribution and speculated that the modes represented different age groups. Dana *et al.* (1972) suggested that the bimodal size distribution reported by Ormond and Campbell (1971) may reflect an artifact of their sampling and that the bimodality could be attributed to two different sub-populations with different modes in size distributions, which might be influenced by the environmental conditions such as nutrients. I agree with this view for various reasons. The growth rates in asteroids are highly dependent upon nutrient supply. Feder and Christensen (1966:107) stressed "As already found by Mead, the food factor acts in such a way that it is impossible to tell the age of a sea star from its size". Moreover, laboratory-reared *Acanthaster* juveniles showed a tendency toward determinate growth, that is, animals seemed to cease their size increases after reaching their ultimate individual size as adults (Yamaguchi, in press). The size of an animal does not reflect its age in this case, except for very small animals. No persistent increase in mean size was reported for an adult population of *Acanthaster* at Hawaii for about one year (Branham *et al.*, 1971).

What does the paucity of juveniles in the field and the existence of adult populations with unimodal size-frequency distributions mean? We can detect little evidence of sizable juvenile recruitment in many echinoderms and other marine invertebrates. Recruitment could easily be overlooked because of small sizes of juveniles and their cryptic behavior. Moreover, some asteroids show transformations in morphology and behavior from juvenile forms to adult forms. In the case of

Acanthaster the transformation is completed at the small size of about 10 mm in total diameter within five months after metamorphosis (Yamaguchi, 1973). On the other hand, *Culcita novaeguineae* transforms from a flat and pentagonal juvenile to the cushion form adult at an approximate size of 90 mm diameter. *Linckia laevigata* may transform into an adult form at a size of about 50 mm in arm radius. This phenomenon of juvenile-to-adult transformation makes it more difficult to observe juvenile recruitment.

It is doubtful, despite the above mentioned difficulties, that there is a constant juvenile recruitment to the adult populations, which is suggested for *Acanthaster* by Dana *et al.* (1972), Glynn (1973), and Branham (1973). For example, a long-term study on the populations of infaunal echinoderms near Northumberland, England by Buchanan (1967) revealed that three of five species studied, including an ophiuroid, a spatangoid and a holothuroid, showed very sporadic recruitment. Despite evidence of repeated breeding of the animals, sometimes five years would pass between appreciable larval settlements. Ebert (1968) reported that a sea-urchin *Strongylocentrotus purpuratus*, on the Oregon coast showed an exceptionally heavy settling in 1963, with poor settlement in most of the period from 1959 to 1967. Feder (1970) discussed the paucity of juvenile *Pisaster ochraceus* along the California coast. Large numbers of juveniles of the starfish were rarely reported by previous workers, but he did find a large juvenile population at Monterey Bay in 1954. The present author frequently dived to collect and to observe a sand-dollar, *Clypeaster japonicus*, near Misaki Marine Biological Station, Japan, for five years but could not detect any influx of juveniles to the adult-only population with an unimodal size-frequency distribution (Yamaguchi, 1970).

It is possible that the above-mentioned animals in general have a very sporadic recruitment and that their populations are maintained by occasional year-classes with heavy juvenile recruitment. Longevity of these animals is estimated to be fairly long, often ten years or more, although there are no substantial data on this point. Chesher (1969) stated that the longevity of *Acanthaster planci* at Guam is eight years but he presented no evidence to support his view. However, *Acanthaster* seems to have a long life-span, with the first two years spent as juveniles (Yamaguchi, 1973). The evidence of continual infestations by migratory starfish on the Great Barrier Reef (Pearson, 1972) over half a decade or more may well indicate the long life-span of the starfish rather than the continual recruitment of new generations alone.

It is well known that most marine organisms show a wide fluctuation in population recruitment from year to year; it is especially well documented for fisheries resources. Thorson (1950) indicated that those organisms that produce (longer life-span) planktotrophic larvae showed greater annual fluctuation in population sizes than those that produce (shorter life-span) non-planktonic larvae. Loosanoff (1964) have given direct evidence of wild fluctuation in larval settlement of *Asterias forbesi* at Long Island Sound, New England for 25 years.

Some authors have discussed and speculated on the case of *Acanthaster* infestations on the coral reefs as unique and a possible man-induced phenomenon. Others questioned this view and stressed natural causes instead. I believe that our knowledge is presently inadequate to solve this problem. The *Acanthaster* problem should be discussed after collecting more adequate data on the nature of recruitment and other ecological aspects related to population dynamics of the starfish.

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