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CROWN OF THORNS (ACANTHASTER PLANCI) PLAGUES: THE NATURAL CAUSES THEORY

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by Peter J. Vine[1]

ABSTRACT

The history of research on Acanthaster planci prior to 1960 is briefly reviewed and the results of some more recent research are discussed. There is evidence that many "plagues" of A. planci have occurred prior to 1960. Predation by Charonia tritonis on A. planci is unlikely to have been a significant factor controlling its population in any area. The suggestion that artificial damage to coral reefs, by blasting or dredging, has created conditions for population explosions of A. planci is considered in relation to the known habits of larval and juvenile stages. It is suggested that many "plagues" have been aggregations which are a natural and necessary facet of the life of this species. There is some evidence that feeding starfish release a chemical attractant thus producing mini-aggregations. The likely results of destruction of corals by A. planci are briefly discussed and a possible measure to reduce populations is suggested.

INTRODUCTION

The crown-of-thorns starfish, Acanthaster planci, was known to science long before the recent focus of public attention on destruction of coral reefs which it is causing in the Indo-Pacific. Rumphius mentioned it in 1705 and it was described by Plancus and Gualtieri in 1743. The name Acanthaster planci was created by Linnaeus in 1758. Early knowledge of its widespread distribution can be gathered from the literature; Goa (Portuguese India), 1743; Java, 1793; Philippines, 1781; and Mauritius, 1885. It was recorded from Australia's Great Barrier Reef in 1913 (Clark, 1921) and at Low Isles, where the Great Barrier Reef Expedition was centred in 1928-29 (Livingstone, 1932). Other records such as those of Madsen (1955) indicate a widespread distribution throughout the Indo-Pacific. It has not been recorded from the Caribbean.

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OBSERVATIONS

Early records of large aggregations of A. planci are understandably scarce. The animal prefers a sublittoral habitat and is frequently hidden during the day. Many reef areas were seldom visited and very rarely dived upon. Indigenous people on atolls throughout the Indo-Pacific recognise the starfish, have remedies for stings caused by penetration of its spines, and in some cases are able to report large numbers which have appeared on their reefs in the past. Mortensen, who studied A. planci in the Java Sea in 1929, wrote in 1931: "This species was found rather commonly on the coral reefs at the little island of Haarlem off Batavia, near Onrust......". It was also reported as "common" in Port Galera Bay and Sabang Cove in the Philippines in 1938 (Domantay and Roxas, 1938), as "very common" in the Palaus (Hayashi, 1938) and "abundant" around Christmas Island (Edmonson, 1946). As Dana (1970) has pointed out it seems quite probable that these records might have been applied to the modest densities which are now said to constitute plagues (Endean, 1969; Pearson, 1970). I have spoken to fishermen in the Solomon Islands who recall large concentrations of them many years ago. It was said of Maringe lagoon, Santa Ysabel, that night-time fishing on the reef was especially hazardous about 40 years ago, because fishermen were afraid of treading on starfish which were present in large numbers. It has been widely held that Green Island experienced the first "plague" on the Great Barrier Reef in 1959 (Endean, 1969) but an experienced professional diver from Townsville, D. Tarca (personal communication and Sunday Mail, September 7, 1969) recalled that there were large numbers on the south-east side of Lodestone reef in 1954.

Attention was drawn to the feeding habits of A. planci by Goreau (1963) who discovered an aggregation in the southern Red Sea. He foresaw the likelihood that: "this species may, under certain conditions, be an important factor limiting the growth and development of coral reefs". At that time large numbers of A. planci were being reported from reefs near Cairns, on Australia's Great Barrier Reef, and destruction of corals had been noticed at the tourist resort of Green Island.

Pearson, the scientist employed by the Queensland Government to investigate the biology of Acanthaster and the damage which it was causing on the reef, reported further recent and massive destruction of corals in the Innisfail area, which had gone quite unnoticed by the press and public. This suggests that intense destruction of coral by A. planci may have occurred undetected throughout the range of the species many times in the past.

Recent research by Pearson and Endean in Australia, Chesher and a team of scientists at Guam and elsewhere in the

Pacific, Weber and Woodhead in the Pacific, the Cambridge Coral Starfish Expedition in the Red Sea and a large number of individual scientists, who have reported on its distribution, have added greatly to our knowledge of this species (see papers by Barnes, 1966; Branham et al, 1971; Chesher, 1969 and 1970; Dana, 1970; Dana and Wolfson, 1970; Elderedge, 1970; Roads and Ormond, 1971; Vine, 1970; Weber and Woodhead, 1970).

Endean (1969) suggested that removal by shell collectors of the giant triton, Charonia tritonis, which preys upon A. planci, may have removed the predator pressure controlling populations of this starfish. He believed that the larvae had a short planktonic life: "a matter of a few days", and that significant pressure could be exerted on the population by C. tritonis. Mortensen (1931), however, had shown that the larval development of A. planci takes two to three weeks. He succeeded in fertilising eggs and reared the larvae for sixteen days, by which time they had reached the brachiolaria stage. Recently Henderson and Lucas (1971) have shown larval life is 4-5 weeks, depending on temperature. Such animals normally produce great numbers of eggs and Pearson has estimated the egg production of a female Acanthaster of average size (30 cms.) to be 12-24 million. Thorson (1950) has shown how such invertebrates undergo great fluctuations in population size, depending on their breeding success and particularly the conditions met by their larvae in the plankton. Charonia tritonis is a somewhat scarce and sluggish predator. One was recorded as eating on average 0.7 Acanthaster per week when given an unlimited supply (Pearson and Endean, 1969). Experiments have indicated, moreover, that C. tritonis usually prefers to eat Linckia laevigata, a blue starfish which appears to be more abundant than A. planci on many coral reefs which I have visited in the Pacific (Vine, 1970).

Chesher (1969) suggested that A. planci larvae are heavily preyed upon by live coral polyps and that areas for safe settlement of larvae are severely restricted on a normal coral reef. He points out that mechanical damage to reefs, such as is caused by blasting or dredging, may have reduced predatory pressure on the larvae and increased the area suitable for settlement. Increased survival of larvae would produce localised dense populations of A. planci. These would increase the area of dead coral by their feeding activities and might thus further reduce predation on the larvae, simultaneously increasing the area suitable for subsequent settlement.

DISCUSSION

This suggestion, that recent mechanical damage may have been important, meets with the difficulty that coral reefs have long been subject to cyclone damage. Disturbance of coral by such a natural cause would presumably result in conditions similar to those postulated as favouring the development of *A. planci* plagues. Pearson (Pearson and Endean, 1969) has shown that larvae can in fact settle in areas of rich coral growth, especially among the basal stems of closely packed branching colonies of *Acropora echinata*. The larvae may indeed swim for a long time among the coral stems for it seems well established that echinoderm larvae can delay metamorphosis until they discover an area suitable for settlement (Mortensen, 1938). The older photonegative larvae (Thorsen, 1950) may thus be expected to visit the bottom repeatedly, while being carried by water currents for several days, but it is not clear that they would be vulnerable to predation by coral. If they are photonegative, it is probable that most of their searching is carried out during daylight, when the majority of coral polyps are not feeding. Shaded crevices of coral reefs offer many suitable surfaces, which are free from filter feeders and would provide for the attachment of brachiolaria larvae and the protection of young metamorphosed starfish. In most situations the coral cover of a flourishing reef is only 30-50 per cent (Talbot and Talbot, 1971) and the remainder is veneered with hard encrusting red coralline algae forming sheets or patches of cement-like pink calcium carbonate. Larvae reared in the laboratory settled in the presence of encrusting algae, algal detritus, serpulid tubes, fine siliceous sand, lithothamnion, live *Pocillopora damicornis*, spines and tube feet of *A. planci* and recently predated *P. damicornis* (Henderson and Lucas, 1971). Mechanical destruction of coral would seem to be unnecessary for survival and metamorphosis of *A. planci*, and might be unfavourable through reducing the available food. Moreover it does not necessarily follow that a "seed" population would reproduce locally and thus build up in the manner envisaged by Chesher, since the larvae have a planktotrophic life of considerable duration, during which they must be widely dispersed and are probably preyed upon heavily.

Several workers have recently suggested that the present situation regarding populations of *A. planci* is natural (Weber and Woodhead, 1970; Dana, 1970; Vine, 1970) and it appears likely that the recent outbreak of reports of "*A. planci*" reflects an increase in the number of divers aware of the starfish. There seems to be no need to postulate a real increase in the numbers of *A. planci* in the Indo-Pacific. As Pearson (1969) has pointed out, prior to 1964, starfish aggregations on the Great Barrier Reef had been overlooked by fishermen and skindivers. In the Red Sea I asked several fishermen, shell collectors and skindivers where we could find large numbers of *Acanthaster*. Nobody could direct us to a "plague", although we eventually discovered two reefs on which large numbers were found, both within several miles of Port Sudan (Roads and Ormond, 1971).

The fact that "plagues" have now been reported throughout the range of distribution of *A. planci* suggests that these are in fact natural facets of the life-history of Acanthaster. Work carried out by the Cambridge Coral Starfish Expedition in the Red Sea tends to support this view. Within the aggregations of A. planci which were discovered we identified "mini-aggregations"--many starfish huddled together, often with arms interlocked or discs partly overlapping, emerging at night time from their shaded situations under Acropora tables to feed together on the same tables. Although the majority were inactive and hidden in daytime, occasional individuals were observed moving over sandy areas between the hidden mini-aggregations. The presence of other A. planci did not appear to attract these moving starfish, but at night A. planci which had commenced feeding appeared to attract others. Thus the number feeding on a particular table increased, and it seems possible that some form of chemo-attraction may be exerted by feeding starfish. Research by Brauer, Jordan and Barnes (1970) suggests that A. planci may be attracted by particles of semi-digested coral tissue. They demonstrated reflex stomach eversion by injection of coral extract into the water. The degree of responsiveness of starfish to this stimulus was greater at night than during daytime. Chemo-attraction between individuals has not been conclusively demonstrated but seems likely to occur. Experiments carried out with Y tubes on A. planci in the Red Sea indicate that individuals are attracted to feeding starfish (R.F.G. Ormond, personal communication, October 1971). In a Red Sea area where Acanthaster was sparse, observed directions of movement of isolated individuals, in relation to the spacing of previous feeding scars, suggested the possibility that chemo-attraction from aggregations may attract starfish from one or two miles away. Thus massive aggregations may perhaps form by mechanisms similar to those which create mini aggregations.

The fact that feeding aggregations develop naturally suggests a mechanism by which massive sudden population increases may occur. A slight fluctuation in larval survival may result in an increased population density of starfish. Beyond a certain level a significant increase may occur in the number and size of feeding aggregations which develop. Greatly increased fertilisation within these aggregations could lead to a sudden increase in metamorphosed starfish. Thus the initial change in conditions may be quite small (giving rise to a slight increase in population). This triggers off a natural chain of events which may lead to sudden localised population explosions.

An advantage of aggregations is that they increase the chances of successful fertilisation of eggs. It is doubtful whether isolated individuals contribute at all to the planktonic population of larval A. planci (see Thorson, 1950). Epidemic spawning has been recorded in a number of asteroids: Asterias rubens (Gemmill, 1914; Bull, 1934); Asterias forbesi (Galstoff and Loosanoff, 1939); Solaster papposus (Gemmill, 1920); and Astropecten irregularis (Thorson, 1946). Pearson (Pearson and Endean, 1969) observed synchronous male spawning in A. planci and this seems to have triggered off spawning in at least one female a metre away from the nearest spawning male. Probably fertilisation is ensured through some ecto-hormone, as in Asterias (Chaet, 1961; Kantani et al, 1963; Stebbing, 1967), and the successful reproduction of A. planci may well rely upon the formation of aggregations.

A fortunate result of the aggregated feeding habits of A. planci is that the damage is localised and many large coral structures are left completely untouched. Where aggregations appear to have been abnormally large (such as at Guam and on a section of the Great Barrier Reef), there is less likelihood of any large coral structures remaining undamaged, except of those species not usually attacked by A. planci (see Pearson and Endean, 1969), but the majority of reported "plagues" have been of more moderate proportions. It is a characteristic feature of such areas that some coral structures survive undamaged. I have seen examples of this at Northeast Bay on Great Palm Island, where isolated outcrops of delicate staghorn Acropora remained untouched whereas at least 50% of the Acropora was killed (see also Endean, 1969; Pearson and Endean, 1969). Off Fiji and in the Red Sea I have observed similar examples. The corals which escape attack are likely to provide planulae for settlement and recolonisation of devastated areas. This is a slow process but it has been observed to occur (Pearson and Endean, 1969).

Suggestions that fishermen will lose their livelihoods, reefs will erode and atolls sink gradually beneath the waves must be treated with more than a little scepticism. Apart from destruction of corals, few faunistic changes in the ecology of reefs devastated by A. planci have been observed by Pearson and Endean. Pacific islanders appear to rely a great deal on bottom fishing from deep water off the edges of reefs, and from fishing for pelagic fish. Neither of these fish populations are likely to be affected by A. planci destruction. There has been little evidence of serious reef erosion following devastation by A. planci and indeed this seems unlikely to occur.

Cover by live corals on richly flourishing reefs is remarkably low (Talbot and Talbot, 1971) and many reefs consist mainly of dead coral material covered by calcareous algae. Indeed, this is a feature of areas most exposed to wave action, such as in shallow water on exposed sides of reefs. Rates of recolonisation and regrowth of coral appear more than enough to compensate for gradual sinking of some reefs. In view of the massive thickness of dead coral on most coral reefs, beneath the thin veneer which is alive, it is worth considering the possibility that, far from having a deleterious effect on the development of coral reefs, dense predation by A. planci may actually promote their development by killing protuberant colonies and thus encouraging firmer regrowth and cementation basally. As growth studies on scleractiniam corals have shown (Manton, 1932; Motoda, 1940; Abe, 1940) initial rapid growth rate of a colony, or individual in the case of *Fungia*, is followed by a slowing down, leading to almost complete cessation. Thus, by providing new surfaces for settlement of planulae and development and more rapid growth of young colonies, predation by *A. planci* may lead to an acceleration of reef growth.

CONCLUSIONS

Although predation on coral by *A. planci* may be a normal facet of the development of coral reefs, in the short view massive destruction of scleractinian corals is undesirable on reefs visited by tourists. The only practical solution so far suggested is to kill or remove *Acanthaster* from infested reefs (Endean, 1969). In view of the restricted breeding season of *A. planci* in several regions affected by plagues (Pearson and Endean, 1969) and the probability that recruitment takes place from aggregated stocks, where fertilisation is more likely to occur, it is suggested that efforts by skindivers to remove *A. planci* from reefs should be concentrated on aggregations in the period immediately prior to the breeding season. It is thus important to establish whether a regional population exhibits a restricted breeding season such as that reported by Pearson (1970) for *A. planci* on the Great Barrier Reef, and to discover the time of the main breeding period (December to January in Queensland waters). Given competent divers it would be considerably more efficient to collect starfish at night time when more are exposed on corals. Removal of aggregated starfish following the breeding season is unlikely to have a significant effect on the population in an area, whilst searching out and removing isolated individuals is probably never worth the effort.

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FIGURES

1 *Acanthaster planci* removed from hiding and placed in light during daytime soon moves back into shaded conditions. The long light-sensitive terminal podia can be seen.

2 Peter Goreau (son of the late Tom Goreau) studies an *Acropora* table in the Red Sea. The white region has been predated upon by *A. planci* and the peripheral darker region is still alive. Twelve *A. planci* were found under the table, mostly attached to the basal stem.

3 *A. planci* moving over sand.

4 Two *A. planci* revealed by removing an overlying slab of coral.