

NOTES ON THE CROWN-OF-THORNS STARFISH: ITS DISTRIBUTION IN PAPUA AND NEW GUINEA (ECHINODERMATA : ASTEROIDEA : ACANTHASTERIDAE)

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ABSTRACT

The crown-of-thorns starfish, Acanthaster planci, until recently regarded as a rare nocturnal marine animal, is now menacing the reef-building corals in many Indo-West Pacific areas. Notes on the taxonomy, distribution, habitat, feeding, movement, breeding, growth rate and age at maturity, natural enemies and regeneration are discussed and current methods of control are outlined.

INTRODUCTION

THE facts are now beyond dispute and reality has replaced the once general reluctance to accept the evidence. The possible dangers of *Acanthaster planci*, commonly known as the crown-of-thorns starfish, appear greater than many researchers believed. Marine life on the reefs of many Indo-West Pacific islands is threatened by the 'population explosion' of this starfish, which was, prior to 1960, regarded as a rare nocturnal prickly starfish of no real scientific interest.

To halt predation by the crown-of-thorns starfish, scientists must first know how it lives, how rapidly it grows, how fast it moves, how it reproduces, what its spawning period is, what it feeds on, what type of coral it prefers, and what attacks it—predators and parasites. At present there is no way of predicting the silent movement of the starfish, and the reason behind the population explosion. Will it be in Papua and New Guinea that the starfish plague is reported next?

BRIEF HISTORICAL REVIEW

A. planci first became known to science in 1705 when it was described by Rumphius. It is a Linnean species. Prior to the 1960's little was heard about this species throughout the

world and only few specimens were to be found in museums. An extensive collecting expedition around Mer and Murray Islands (northern end of the Great Barrier Reef, Australia) by Clark (1921) reported only three specimens being found at Mer Island, the largest being 400 mm in diameter. The Young Expedition (1928-1929) to the Great Barrier Reef reported only one specimen (Clark 1931). Clark (1931) gave the distribution of the crown-of-thorns starfish in Australian waters as, 'just enters the Australian region at the northern end of the Barrier Reef, specimens having been taken at Warrior Reef, at the Murray Islands, and at the Low Islands—apparently it may be found anywhere from Zanzibar to Hawaii.' Between 1950 and early 1960's only a small number of *A. planci* were collected on the Great Barrier Reef despite numerous expeditions to the area.

In 1963, Dr T. F. Goreau put forward the theory that predation by *A. planci* was responsible for the impoverished coral growth in the Red Sea. In 1963, destruction of corals by the crown-of-thorns starfish on the Great Barrier Reef was first noticed. In 1969, 16 islands in the U.S. Trust Territory of the Pacific Islands were visited by American scientists. At the same time the University of Hawaii surveyed the Hawaiian Islands, Johnston and Midway Islands, and three Marshall Island atolls—Kwajalein, Arno and Majuro. As a result of these surveys, serious crown-of-thorns starfish infestations were

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found at Guam, Rota and Saipan in the Marianas Islands and Palau, Truk and Ponape in the Caroline Islands.

THE BIOLOGY OF *ACANTHASTER* *PLANCI*

Taxonomic Description

Class ASTEROIDEA Burmeister

These are free-living echinoderms characterised by a star-shaped body, composed of a central disk and usually five arms. The arms are hollow, each arm containing a prolongation of the coelom and its contained organs. The oral and aboral surfaces are distinct, the oral surface bearing the mouth and ambulacral grooves, while the aboral surface bears the anus and madreporite.

Family ACANTHASTERIDAE

'This is a monogeneric family which Fisher considers a relic of an old and at one time a more extensive group' (Clark 1946). Due to their large size, the multiplicity of rays and madreporites, and the large articulated spines, this family is distinct from all other groups of living starfishes.

Genus *ACANTHASTER* Gervais

Acanthaster planci (Linnaeus) Plate I.

Asterias planci Linnaeus, Syst. Nat. ed. 10, 823, 1758.

Acanthaster planci Verrill, Smithsonian Inst., Harriman Ser. 14: 364, 1914.

Acanthaster echinites Doderlein 1896a. Semon's Ast., in Jena Denkschr., Vol. 8, p.320, pl.21, figs 2 to 7.

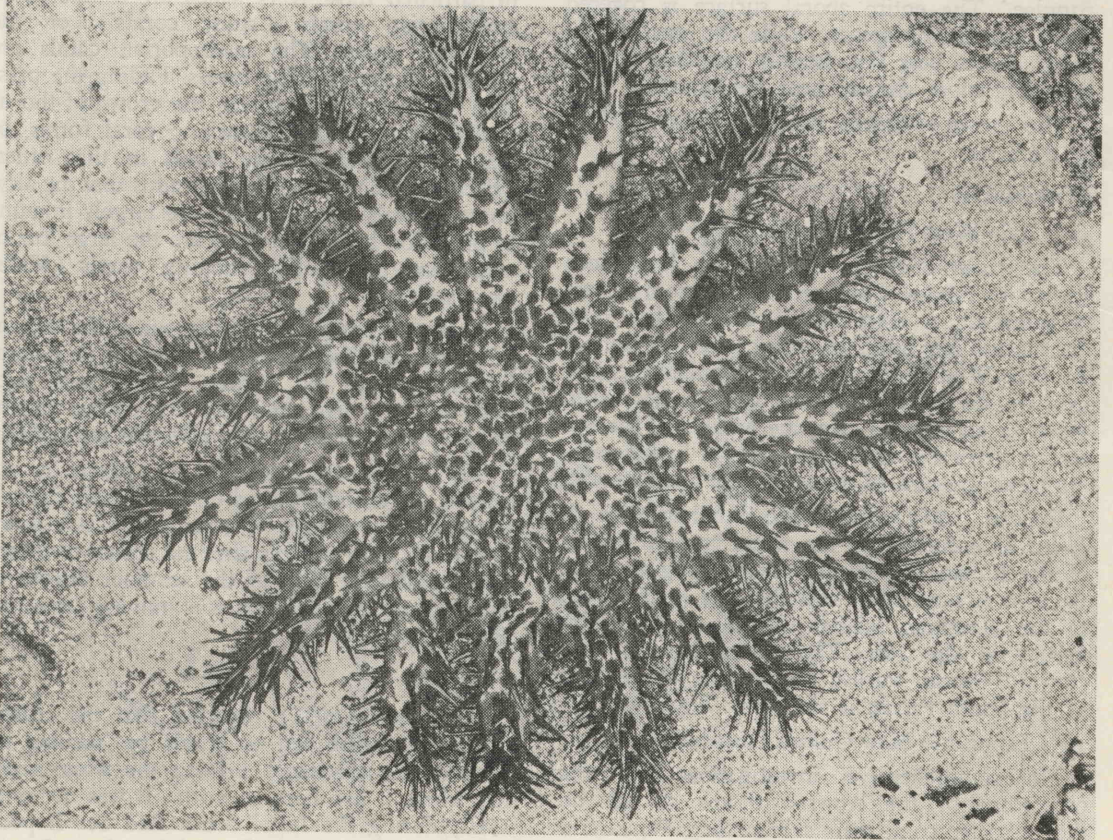


Plate I.—Crown-of-thorns starfish, *Acanthaster planci* (Linnaeus).

[Photo: D.I.E.S.]

The central disk is relatively large and flat, from which radiate many rays (13 to 18). The rays are short, approximately half the width of the disk, tapering only slightly to a blunt end. Clark (1931) gives a description of the colour in life as, 'bluish-gray with spines reddish at tips; the change from gray to red is not abrupt but gradual, apparently due to increasing amounts of rusty-red pigment in the skin. In some specimens the tips of the spines only are red, but in others the colour extends downwards towards, or even to, the base; if it spreads further into the dorsal skin, we should have red individuals, such as those Doderlein records from the Riu-Kiu Islands. The spines of the lower surface are dull reddish-purple, and the feet are white or pale yellowish. The disk, sides and upper surface of the arms basally are covered by dull reddish-purple or brownish papulae.' The entire aboral surface is covered with long thorny spines, while the small inter-radial spaces bear flat, heavily spatulate spines, becoming more slender near the mouth.

The crown-of-thorns starfish reaches 70 cm in diameter.

Distribution

(a) Indo-West Pacific Distribution

The crown-of-thorns starfish has long been known to inhabit coral reefs. In a normal reef environment, a diver would observe less than one starfish per hour. In recent years throughout the Indo-West Pacific Region a population explosion of the crown-of-thorns starfish has taken place. In an infested area, the number of starfish seen is generally more than five per hour, reaching concentrations of more than 600 per hour.

Endean (1969) defines the distribution of *A. plani* as occurring in the warm tropical waters of the Indian and Pacific oceans, ranging from the east African coast and Red Sea in the west, to the Hawaiian Islands and Tuamotu Archipelago in the east. The distribution of the crown-of-thorns starfish throughout the islands of the South Pacific is shown in Figure 1.

(b) Papua and New Guinea Distribution

No comprehensive investigation into the occurrence of the crown-of-thorns starfish on the extensive coral reefs surrounding Papua and New Guinea has been conducted. Reports of sightings and concentrations have been collated

from Field Officers' Journals of the Department of Agriculture, Stock and Fisheries, and communications from interested persons (Table and Figure 2).

Commencing in June 1970 a small concentration of *A. plani* in close proximity to Port Moresby has been visited regularly by the Division of Research and Surveys, D.A.S.F. A total of 47 starfish has been collected in two visits.

Details of reported concentration are given in the Appendix.

Habitat

The destructive feeding habit of the crown-of-thorns starfish affects the thin mantle of living coral covering the complex and relatively stable reef structure.

A. plani is found living on live coral reefs, in particular those reefs which are composed of madreporian corals ('stony corals') of the *Acropora* group. The madreporian corals are the typical reef-building corals. Failing the presence of madreporian corals, the crown-of-thorns starfish, 'selects small branching coral forms, or plate, shelf and boulder corals in that order' (Barnes 1966). Barnes further adds that the alcyonarian corals ('soft corals') are largely immune to predation by *A. plani*, as are the large 'brain' corals and the smaller 'stinging' corals (*Millepora* spp.).

Against a contrasting background, the crown-of-thorns starfish is easily seen, but in its natural habitat among the various forms and hues observed on a live coral reef, the colour pattern of *A. plani* forms a very effective camouflage.

The bathymetric range of *A. plani* is not known. It has been found on coral reefs covered by only a few inches of water at low tide down to 100 ft. It is unlikely that the crown-of-thorns starfish inhabits areas of the sea-floor devoid of living corals, except when it is moving from one area to another.

Feeding

Mortensen (1931) reported that the crown-of-thorns starfish fed on corals by 'sucking off all the soft substances, leaving the white skeleton where it had been at work.' It was not until 1962, during the Israel South Red Sea Expedition (March to April 1962), that Goreau (1963), when reporting on the nature of the

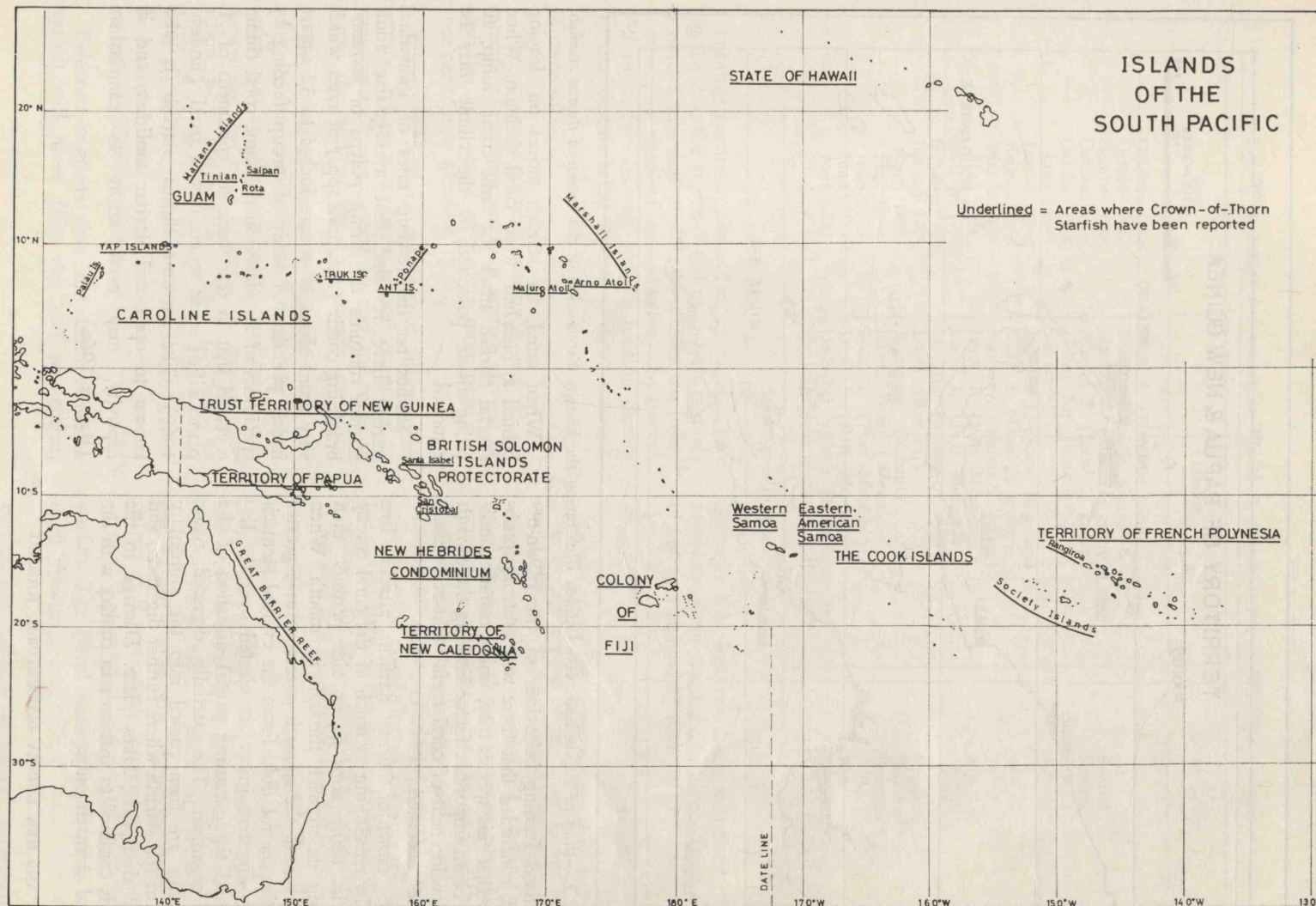


Figure 1.—Areas of reported crown-of-thorns infestation throughout the Islands of the South Pacific.

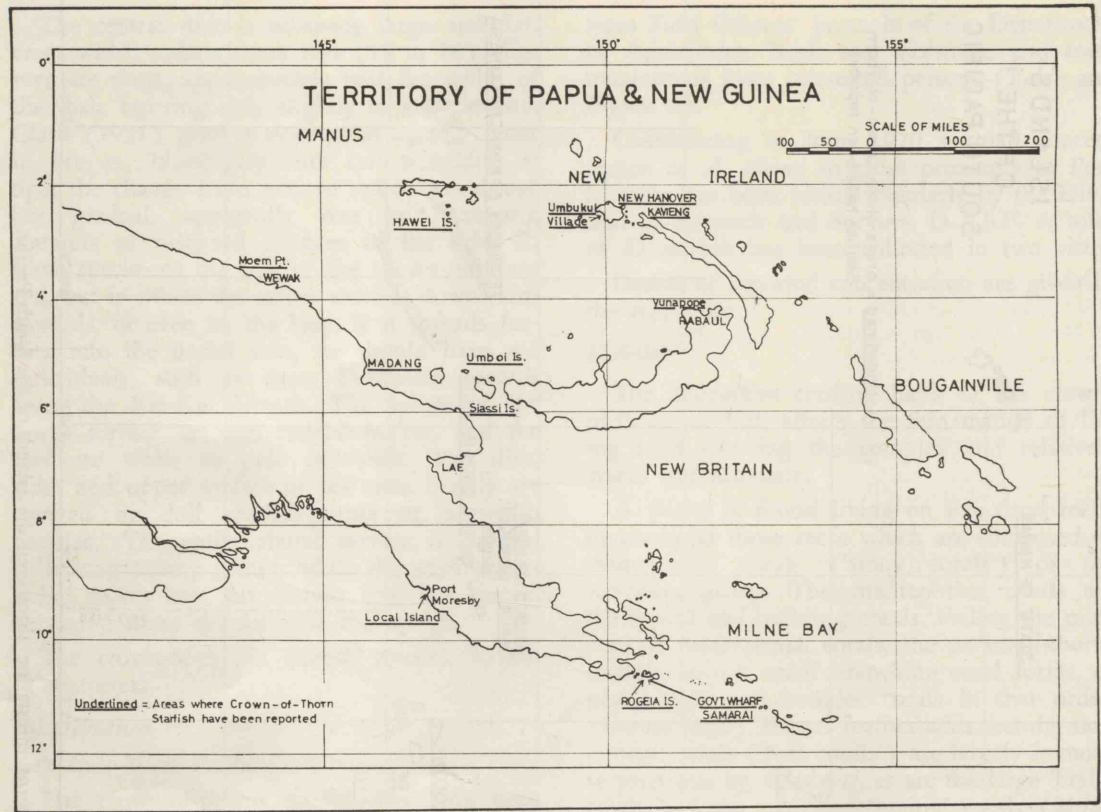


Figure 2.—Map of Papua and New Guinea illustrating the known distribution of the crown-of-thorns starfish.

specialised feeding behaviour of the crown-of-thorns, concluded that there was a 'strong probability that this species may, under certain conditions, be an important factor limiting the growth and development of coral reefs', that researchers became concerned.

The crown-of-thorns starfish attacks live coral by enveloping as much of the coral colony with its many arms as its size permits, then everting its stomach through its mouth. When fully everted, the stomach covers an area greater than the central disk. From the everted stomach lining, digestive juices are ejected over the living coral tissue causing partial digestion of the coral organism. The partially digested tissue fragments are then passed into the alimentary canal of the starfish where further digestion, and finally absorption, takes place. Damage to the coral is confined to that area in contact with the everted stomach only.

When sated, the starfish moves on, leaving behind a 'bleached' white coral skeleton. When several starfish attack the same coral clump, all living tissue possessed by the clump may be removed.

'Studies on the feeding rates of individual starfish have revealed that average-size adult starfish consume the living polyps of common branching corals (*Acropora* spp.) at rates which vary from about 17 square inches to 32 square inches per day. A study of group feeding by specimens of *A. planci* on the same coral clump revealed that in one week six specimens of *A. planci* killed seven square feet of coral' (Endean 1969). The crown-of-thorns starfish is also known to open and devour molluscs, and in captivity, may even resort to cannibalism (Barnes 1966).

Table.—Sightings and concentrations of *A. planci* in Papua and New Guinea.

Date	Location	Number Sighted
October 1966	Noru I. (Siassi Is group)	3
October 1966	Por I. (Siassi Is group)	2
October 1966	Mandok I. (Siassi Is group)	Several
October 1966	Aramot I. (Siassi Is group)	Several
October 1966	Luther Bay (Umboi I.)	Several
June 1967	Samarai	46*
January 1968	Mandok I. (Siassi Is group)	1
August 1968	Tuam I. (Siassi Is group)	32*
March 1969	Hawei I. (Manus I. group)	54*
May 1969	Local I. (Port Moresby)	12*
September 1969	Local I. (Port Moresby)	1
October 1969	Madang Harbour	1
January 1970	Logea (Samarai)	Reported
April 1970	Vunapope (Rabaul)	Reported*
May 1970	Moem Point (Wewak)	Reported*
June 1970	Local I. (Port Moresby)	27*
June 1970	Local I. (Port Moresby)	20*
June 1970	Umbukul Village (New Hanover)	Reported*
June 1970	Kavieng/New Hanover, 1968-1969	5*

*Details given in Appendix.

Feeding normally takes place at night. During the day, the crown-of-thorns starfish normally retreats into dark crevices away from the light; however, in areas of concentration, the starfish will often be observed actively feeding during the day, despite being exposed to direct sunlight.

Movement

The crown-of-thorns starfish is said to be capable of moving across a surface devoid of obstacles at a speed of slightly more than one foot per minute (Endean 1969).

When observed in numbers of plague proportion, there is a tendency for *A. planci* to congregate on one area of the reef and to move across the reef as the food supply dwindles.

'Depth was no barrier to movement, but soft substrate was avoided. Sand moved by surge action, was an effective obstacle since patch reefs surrounded by sand in areas of strong wave action were not infested. Sand provided no gripping surface for the tube feet and the sea-stars are easily overturned by water movement. In protected areas or during calm seas, sand is no barrier' (Chesher 1969).

Evidence suggests that the crown-of-thorns starfish will move from one reef to another,

although this has not been witnessed. Prawn fishermen have trawled *A. planci* from depths of 100 feet on mud bottom.

Breeding

In *A. planci* the sexes are separate and there is an even sex ratio of one male to one female. On Australia's Great Barrier Reef the breeding season is short and well defined, lasting for one month from mid-December to mid-January. 'A ripe female of average size (35 cm in diameter) is estimated to contain between 12,000,000 and 24,000,000 eggs' (Endean 1969). Prior to spawning, the gonads increase in size and occupy the major part of the body cavity. Fertilisation is external, the sexual products (eggs and sperm) being shed into the surrounding water.

The fertilised eggs develop into free-swimming planktonic larvae, capable of being carried long distances, depending on prevailing currents and wind systems. It is interesting to note that, during the planktonic phase of the life cycle, the starfish larvae are preyed upon by coral polyps. It is particularly interesting and unusual, as coral polyps are later preyed upon by the starfish. The larval starfish finally settle on the coral growths.

Growth Rate and Age at Maturity

'The mean growth rate (described in terms of increase in diameter) of specimens of *A. planci* during their first two years is approximately one cm/month (just under $\frac{1}{2}$ in./month). Thus a specimen 6 in. in diameter is approximately 1 year old and a specimen 12 in. in diameter is about 2 years of age. Presumably this rate of growth will decrease in older specimens' (Endean 1969). Endean further believes that a breeding specimen of starfish must be at least 2 years old.

The life-span of the crown-of-thorns starfish is not known, but very large specimens are considered to be at least three years old. Chesher (1969) has estimated the maximum life span

of adult starfish as eight years, but, when deprived of living coral, they starve in about six months.

Natural Enemies

(a) Eggs of *A. planci*—*Abudefduf sexfasciatus* or Damsel fish has been observed by Endean (1969) to feed on the eggs of *A. planci* soon after they were released. No other marine organism has been seen to prey on the drifting eggs, but it can be assumed there are many, either on the reef or in adjacent waters.

(b) Larval *A. planci*—perhaps the greatest mortality of the crown-of-thorns starfish takes place in the larval phase of the life history, the coral polyps being regarded as one of the main predators. Corals are zooplankton feeders, and

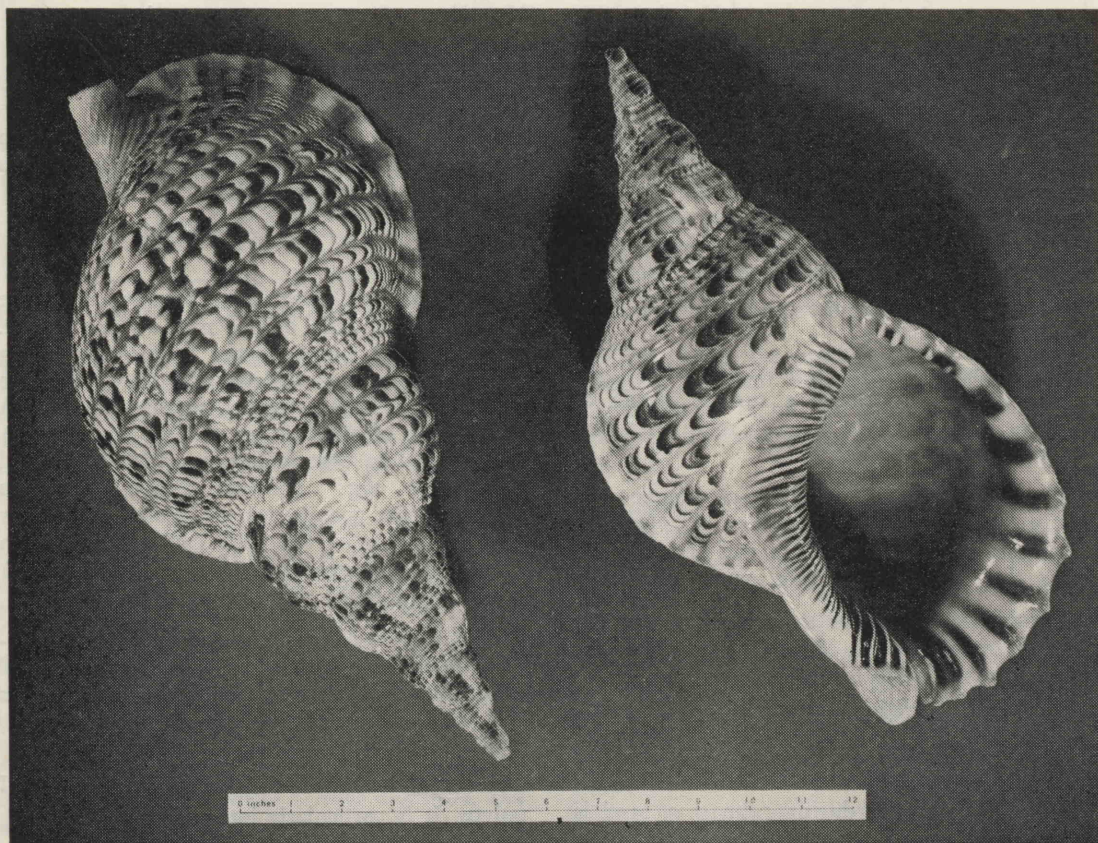


Plate II.—Giant Triton, Trumpet shell or Conch, *Charonia tritonis*.

[Photo: D.I.E.S.]

would include the larval stages of *A. planci* in their diet. Clams which are also zooplankton feeders are regarded as potential predators.

(c) Small juvenile *A. planci*—Endean (1969) has reported no potential predators of the small juvenile crown-of-thorns starfish as a result of investigations on the Great Barrier Reef.

(d) Large juveniles and adult *A. planci*—

(i) Giant Triton; Trumpet Shell; Conch Shell (*Charonia tritonis*), Plate II, is the second largest gastropod known in the Indo-West Pacific, reaching a length of 40 to 46 cm when fully grown.

C. tritonis is the only well known predator of the large juvenile and adult crown-of-thorns starfish. When feeding on *A. planci*, *C. tritonis* uses the outer lip of the shell to keep the starfish pinned to the substratum. With its radula (a flexible file-like structure bearing numerous teeth which can be protuded through the mouth) *C. tritonis* cuts the starfish into pieces. After the ingestion of the pieces of *A. planci* the sharp spines are usually regurgitated. Between 12 and 24 hours are required for an adult triton to consume an adult specimen of *A. planci* (Endean 1969). Under normal circumstances one adult triton will consume one adult crown-of-thorns starfish per week.

(ii) Giant Helmet Shell (*Cassia cornuta*), a gastropod reaching a length of up to 35 cm. When feeding, the Helmet shell envelopes the starfish in its voluminous foot, which crushes the starfish, after which the Helmet shell proceeds to eat the soft body parts. Apparently the Helmet shell is not bothered by the sharp spines of the crown-of-thorns starfish, some of which break off and become embedded in the foot of the Helmet shell.

(iii) The Hump-head Wrasse has been observed eating the crown-of-thorns starfish; however, it is not regarded as an important predator (Endean 1969).

(iv) As a result of recent research at Magnetic Island (Brown 1970), a small crustacean (approximately 8 cm in length), tentatively named *Neaxius* sp., has been found to prey on the crown-of-thorns starfish. Seven starfish ranging in size from 21 to 44 cm were killed by this small crustacean.

(v) Painted Shrimp (*Hymenocera elegans*), has also been shown to prey on large juvenile and adult crown-of-thorns starfish (Time, May 25 1970). Oblivious of the poisonous spiny armour, the Painted Shrimp immobilizes the starfish by causing it to retract its tube feet. The shrimp then turns the starfish onto its back, cuts away the underside tissue with its sharp pincers, and devours the internal organs. In little more than a day of feeding, this small crustacean reduces the starfish to a small pile of gelatinous debris.

Regeneration

Most starfish have great powers of regeneration, some species being able to regenerate completely from portions of an arm. Endean (1969) expected that the crown-of-thorns starfish would be able to regenerate arms from the central disk. However, after conducting experiments in the field involving the severing of arms from the central disk, he showed that, although the wounds healed rapidly, no obvious regeneration of even a portion of an arm had occurred after a period of one month. Further, there was negligible regeneration of spines removed from areas of the central disk.

Whilst conducting feeding experiments with *C. tritonis*, Chesher (1969) reported that half a starfish escaped from being eaten and lived to regenerate all its lost parts. He stated that, 'regeneration of small functional arms required about 2 months.'

Of 47 crown-of-thorns starfish examined from a small reef off Port Moresby, more than 50 per cent of those examined showed definite signs of regeneration, up to five arms in one individual. One specimen was collected alive with only five arms present; the remainder of the arms and half of the central disk were severed. There was no evidence of regeneration in this specimen, but the cut edge of the wound was completely healed over.

Venomous Spines

The multitude of prominent orange or reddish coloured spines present on the dorsal or aboral surface of the crown-of-thorns starfish can easily inflict a painful wound when handled carelessly or trodden upon. In a specimen of approximately 12 cm in diameter, the spines average 16 mm in length and approximately 1

mm in diameter. The pedicle in such a specimen would average 3 mm in height. In general, the length of spines on any 1 specimen is nearly uniform, although, in all specimens that I have examined, there is a tendency for those near the base of the arms to be slightly larger.

The rigid calcareous core of the spine is covered with an epidermal skin, bearing fine granules and the orange and reddish colour pigments. There is no obvious venom gland associated with the spine, and it is generally regarded that the toxic symptoms which result from the penetration of a spine are a result of local reaction to the epidermis, or even a secretion from the epidermis. It has even been suggested that the toxins may be contained in the colour pigments.

Injury caused by skin punctures can result in severe local pain and numbness and may, in severe cases, be followed by protracted vomiting for several days. Medical advice recommends the wound to be bled immediately, thus releasing the poison.

METHODS OF CONTROLLING THE CROWN-OF-THORNS STARFISH

Numerous methods have been suggested as a means of controlling the crown-of-thorns starfish; some of these have already been tested, others are still in the experimental stage. No one method has yet been found effective over a large area.

(a) Collecting by hand—although tedious, slow and very expensive, this method is regarded as the most practical, particularly in localised areas. Once collected, the starfish can be destroyed on land, either by sun-drying, burning or burying. Merely spearing or cutting a starfish in half is ineffective because the spear wound will often heal, and the starfish cut in half may regenerate and become two complete individuals.

(b) Injection of various chemicals (e.g., 5 per cent Formalin) into the body of the starfish will kill it. However, every starfish must be treated individually.

(c) Although involving considerable expense and death of the associated corals as well, the use of granular quicklime dropped on the body surface of the starfish will kill within 12 to 24 hours. The use of a quicklime barrier has met

with some success; however, a hard surface coating soon forms on the quicklime which then renders it ineffective.

(d) The use of copper sulphate has been suggested, but its use would have an adverse lasting effect on the reef environment.

(e) Tests are currently being conducted by Japanese researchers on the feasibility of using an electric gun. Again this method requires treating individual starfish.

(f) United States researchers have suggested the use of suction dredges in heavily infested areas. The feasibility of this method has not yet been tested.

(g) Biological control—researchers in Australia have suggested the possibility of increasing the population of the most commonly known predator, *C. tritonis*. However, before such a task can be undertaken, the biology of *C. tritonis* and its habits must be thoroughly investigated, and secondly, one must take into consideration what is going to happen once the population of starfish has been removed. Will researchers be faced with another plague, this time *C. tritonis*?

CONCLUSION

No single theory offered to date has explained the reason behind the starfish plague. Some researchers believe the population explosion has no unusual cause, regarding it as a natural periodic phenomenon and a passing nuisance.

Destruction of living coral reefs, however, would mean possible economic disaster for many island populations throughout the Indo-West Pacific area. The majority of inhabitants throughout this area derive almost all their protein from marine resources, and the destruction of living coral reefs would result in drastic reduction, and possible destruction, of these fisheries. Eventually, loss of living corals would allow severe land erosion by storm waves.

Many Australian researchers believe that over-collecting of the Giant Triton shell, *C. tritonis*, was the cause of the crown-of-thorns starfish population explosion on the Great Barrier Reef. United States researchers discount this theory in their area, as starfish infestations have been found in remote island areas where no serious shell collecting has taken place. 'Killing coral

in the process of blasting channels or dynamiting for fish, man has perhaps altered the underwater environment in favour of the sea-stars survival', has been suggested (Sugar 1970).

Many factors are involved in the growth and development of corals, and at this stage in our knowledge it is very difficult to predict just how long it will take for devastated reefs to recover completely, if indeed they ever do. Estimates range from 10 to 50 years.

Algal growth on dead corals may contribute substantially to the diet of herbivorous fish, and could be the origin of ciguatera-type neurotoxin now present in the flesh of some species. The eating of ciguatera-bearing fish causes a distressing illness in man.

Until more is known about the biology of the crown-of-thorns starfish, it is difficult to predict where the depredation will end or what will end it. Researchers are not too hopeful that artificial control methods are sufficient to halt devastation by the starfish. It has been suggested (Dickenson 1970) that the principal hope of starfish control lies in rallying islanders throughout the areas of known infestation to protect their own reefs. On the island of Palau in the Caroline Islands, school children were led on afternoon collecting expeditions at low tide and shown how to catch and handle the crown-of-thorns starfish without being injured. Killing the starfish could become part of the islanders' educational system.

Information concerning infestations in other areas of Papua and New Guinea is urgently needed, and people sighting the starfish are requested to notify the author. Reports of normal populations as well as abnormal concentrations of starfish and the degree of coral damage are very important. Your co-operation is requested.

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Appendix

DETAILS OF REPORTED CONCENTRATIONS OF *A. planci* IN PAPUA AND NEW GUINEA

(a) June 1967 (R. R. Pyne and A. G. Hinton)—on a small reef running in a south-west direction from and adjacent to the Government wharf, Samarai, 46 crown-of-thorns starfish were counted in an area 200 x 10 m, at a depth of 1 to 4½ m, in 1 hour's diving. Specimens ranged from 20 to 30 cm in diameter. Very little living coral was observed in the area surveyed.

(b) August 1968 (A. G. Hinton)—off Tuam Island (Siassi Is group) 32 crown-of-thorns starfish were sighted in a 100 m area of narrow fringing reef at a depth of 4½ m. Several specimens were observed feeding. Three unidentified coral species were seen to be bleached white directly beneath the feeding starfish.

(c) March 1969 (B. Withrington)—off Hawei Island (Manus Island group) 4 divers counted 54 crown-of-thorns starfish during a 60 minute dive over a wide area of reef. The starfish were found either under or alongside coral outcrops. No *C. tritonis* were seen in the area examined.

(d) May 1969 (P. Beaven)—at Local Island (Port Moresby), 12 starfish were collected in 10 minutes' diving in depths ranging between 1 and 1½ m. The starfish ranged from 20 to 30 cm in diameter.

(e) April 1970 (Catholic Mission, Vunapope)—a small breakwater, constructed of volcanic rock in the 1900's, was taken over by coral growth after 1945 when it fell into disuse. In 1967-1968 a plague of crown-of-thorns starfish was reported to have devastated the coral growth. About the end of 1968 the starfish disappeared and coral regeneration is reported to have commenced. Many spiny sea-urchins of the genus *Diadema* have moved into the area.

(f) May 1970 (B. Withrington)—an unconfirmed report that on the west side of Moem Point, Wewak, the density of crown-of-thorns starfish, on what was described as dead fringe reef, was approximately 100 starfish per acre.

(g) June 1970 (R. R. Pyne)—on a small reef off Local Island (Port Moresby), 4 divers in approximately 1 hour collected 27 crown-of-thorns starfish in depths ranging between 1 and 1½ m. Five starfish were observed feeding on coral (*Acropora* spp.) fully exposed to direct sunlight.

(h) June 1970 (R. R. Pyne)—on a small reef off Local Island (Port Moresby, 20 crown-of-thorns starfish were collected in approximately 180 minutes by 8 divers in depths ranging between 1 and 1½ m. One starfish was collected at 6 to 8 m moving across dead broken 'stag-horn' coral. All starfish were concealed beneath coral clumps. One specimen collected exhibited very marked red colouration over the entire aboral surface.

(i) June 1970 (E. C. Tarr)—an unconfirmed report from Umbukul Village (New Hanover) related by a village councillor stated that in 1955 a plague of *A. planci* devastated the reef off the village. A Fisheries Supervisor, diving in the area in 1969, reported finding only 4 crown-of-thorns starfish, but stated that he found no living coral.

(j) June 1970 (E. C. Tarr)—in the Kavieng/New Hanover area, a Fisheries Supervisor, after spending many hours diving during the 1968-1969 year, reported seeing only 5 crown-of-thorns starfish.

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