INVESTIGATIONS OF ACANTHASTER PLANCI
IN SOUTHEASTERN POLYNESIA DURING
1970-1971

by Dennis M. Devaney and John E. Randall
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INTRODUCTION

In recent years considerable interest has been aroused by the damage to reefs in the tropical Pacific caused by large populations of the crown-of-thorns starfish (Acanthaster planci), a coral predator. Survey teams have made starfish counts and assessed the damage to reefs at a number of islands. Most of this activity has taken place in the western Pacific, particularly the Trust Territory and Great Barrier Reef. Very little information has been obtained on the relative abundance of this starfish and the condition of the coral reefs in southeast Oceania.

The opportunity to visit a number of islands in this remote part of the Pacific was provided by a marine biological expedition carried out during the period December 1, 1970 to May 20, 1971 on the 99-foot schooner "Westward" owned and operated at that time by the Oceanic Foundation. During the expedition, Bishop Museum marine biologists Dennis M. Devaney and John E. Randall conducted a reconnaissance for the crown-of-thorns starfish at the various islands visited. When the starfish were present in numbers, an assessment was made of their damage to the coral reefs. At several places, measurements, gonad samples, and color notes were taken of A. planci (Table 1).

The expedition was financed by a grant to the Bishop Museum from the National Geographic Society, augmented by funds from the Oceanic Foundation for operation of the vessel. Support for the surveys of A. planci was provided by the Sea Grant Program of the University of Hawaii.

Surveys for the starfish were carried out at the following groups of islands (number of islands visited within groups shown in parentheses): Tuamotu Archipelago (4), Gambier Group (4), Pitcairn Group (4), Rapa (2), Austral (3), southern Cook (3), Society (3), and the Marquesas (6). In addition, Devaney visited two islands in American Samoa. The itinerary of the "Westward" is shown in Figure 1. Names of the islands visited are underlined.

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Text figures in this report of the islands at which surveys for Acanthaster planci were carried out are based on maps in Pacific Islands Volume II, Eastern Pacific, 1949, Geographical Handbook Series, Naval Intelligence Division, Cambridge.

DUKE OF GLOUCESTER GROUP, TUAMOTU ARCHIPELAGO

1. Anuanuraro Atoll

On December 6, 1970, the "Westward" anchored off the northwest side of Anuanuraro (20° 25' S; 143° 33' W), a small uninhabited atoll which lacks a pass (Fig. 2). A boat was carried from the seaward side, across the reef flat to the lagoon. A search for Acanthaster was carried out in the western lagoon (Fig. 2, A) with SCUBA and by skin diving. Considerable live coral was present along the sides and top of coral knolls as well as in isolated patches on the sandy lagoon bottom (maximum depth, 40 feet). At one knoll, extending from a depth of approximately 30 feet to near the surface, a large Acanthaster was collected in mid-afternoon along the side of the knoll at a depth of 20 feet. Color notes taken at the time of capture revealed the starfish to have the aboral side greyish to tan with the spines reddish. No recent feeding scars were seen, and the animal was not feeding when taken. Further survey of the knoll and adjacent knolls failed to reveal additional Acanthaster. Measurement data concerning this specimen are presented in Table 1.

Two SCUBA dives were made by Randall and the "Westward" crew off the seaward side of the reef along the northwestern side of the atoll. The first dive (Fig. 2, B) revealed a rather steep slope with live coral and coral rubble; no Acanthaster was seen nor was there any sign of feeding by starfish. The second dive, (Fig. 2, C) which was made farther south, revealed even richer coral growth and more varied topography with caves, etc.; again, there was no sign of Acanthaster nor evidence of coral predation.

GAMBIER OR MANGAREVA GROUP, TUAMOTU ARCHIPELAGO

On December 9, "Westward" anchored at Port Rikitea on Mangareva (Figs. 3 and 4), the principal settlement of the Gambier Group. On December 11 our survey for Acanthaster commenced. Observers included Devaney, Randall, Dean B. Canno, and Jean-Pierre Bablet, fishery biologist with Centre d'Expérimentations du Pacifique (C.E.P.). Prior to our arrival we had been informed by personnel of Service de la Pêche and the Institut de Recherches Médicales in Papeete that numerous A. planci had been found along the southwestern side of Mangareva Island (apparently first noted in October, 1969).
Our first station (1 of Fig. 3) was carried out in the lagoon a few hundred yards southeast of Ile Tenoko (23° 4' 30" S; 135° 2' W). Patch reefs were investigated with the use of SCUBA and by skin diving. The majority of the coral was alive; there was no evidence of Acanthaster.

On the afternoon of the same day the second station (2 of Fig. 3) was run outside the barrier reef just southwest of Ile Tenoko at a depth of 20 to 60 feet. Some towing was carried out in the vicinity. Coral growth was lush. No starfishes were seen.

On December 12 a series of seven tows were made (alternating observers) along the southwest shore of Mangareva Island. These constituted Station 3. The first two began at Atitutiti and the last ended three miles beyond near the western end of the island. No Acanthaster were sighted until the end of the fifth tow when several were seen. Two specimens were collected, as were the corals (Acropora) on which they were feeding. With the sixth tow the numbers of starfish increased, and the coral damage as well. We had found the A. planci concentration that had been reported to us (X of Figs. 3 and 4). It is a relatively restricted area centered on 23° 7' 20" S; 135° 0' 30" W between Pte. de Ganoa and Pte. Terimuroa at an average depth of 20 feet. Two divers collected 22 starfish in 95 minutes. While towing in the area of greatest density, about one starfish was seen per minute. This certainly does not qualify as an infestation, but this number of starfish is well above the normal occurrence. The coral growth in this area is rich; it is dominated by table and branching Acropora. Estimates of the percentage of live coral by the observers ranged from 65 to 80% (most of the dead coral appeared to have been killed recently, probably by A. planci). About half of the starfish were actively feeding during this time (1300-1435 hours), mainly on species of Acropora. Samples of the coral being eaten were saved. The dominant table acroporan was identified as A. reticulata (Brook) by Dr John W. Wells at Cornell University. Measurements and determinations of sex were made of the sample of A. planci (Table 1). The starfish were bluish-grey aborally, the tips of the spines orange-red.

During the seventh tow the numbers of starfish diminished (eight counted in 13 minutes). By the time Pte. Terimuroa was reached, no more A. planci or white feeding scars on the coral were seen.

On the following day at 1500-1600 hours we returned to the site of concentration mainly for underwater photography (Plates I-III). A strong current (about 2 knots) was flowing in a SE direction, against the prevailing wind.

On December 14 Devaney and Cannoy investigated the lagoon
area by towing between Ile Taravai and Ile Agakuitai (4 of
Fig. 3). Live coral was found throughout the area but no
Acanthaster was noted.

In a conference with Dr Raymond Bagnis of the Institut de
Recherches Médicales on March 20, 1971 we learned that surveys
for starfish were made in 1969 along the lagoon off Ile
Totegegie where the airstrip has been completed and off Ile
Kamaka. No significant numbers of Acanthaster were seen.

PITCAIRN GROUP

1. Oeno Atoll

On December 18-20, 1970 "Westward" anchored off the north
shore of the uninhabited atoll of Oeno (23° 55' S; 130° 45' W)
(Fig. 5). Two days of intensive snorkeling, diving, and some
towing failed to reveal any Acanthaster or any sign of recent
coral damage that might be attributed to it. The lagoon is
shallow (nearly all less than 10 feet deep) and dominated by
sand and coral rubble. The occasional patches of coral rock
did not have a heavy cover of live coral. The only area out-
side the reef which was explored was in the vicinity of the
small boat passage on the north shore (this passage, by the
way, is shallow and would not be safe with even a moderate
swell running from the north). Although there were more reef
areas outside the reef than in the lagoon, the bottom was still
dominated by sand—even to the outer edge of the shelf at 100
feet or more where the slope of the bottom steepened. Dives
on outer reef areas were made to depths of 120 feet. Coral
growth was richer than in the lagoon, but still sparse by
usual atoll standards.

2. Pitcairn Island

A total of 23 days were spent diving and towing around
Pitcairn Island (25° 04' S; 130° 06' W) during the period
December 21, 1970 to January 21, 1971. This rugged high island
is only about 2 miles long and 1 mile wide; consequently, it
was not difficult to explore its marine environment thoroughly
in the time available. Inshore, the bottom is dominated by
boulders, often of large size, heavily carpeted with brown
algae (particularly Sargassum). Very little live coral may be
found in this zone. In the deeper sectors (below about 40
feet), sand or low-profile rock, either covered with brown
algae or a thin veneer of sand, account for most of the bottom.
With the help of Pitcairn fishermen the few well developed reef
areas were located. These were found mainly at depths greater
than 80 feet. The most luxuriant patch reef, known to the
islanders as "The Bear", occurs off Gannet Ridge on the north
side of the island. It is about 400 square meters in area and
rises from a sand bottom with a little rubble in 145 feet to a
height of about 30 feet above the base level. It is almost completely live coral. A more extensive reef (about 100 meters in length and about 1/3 this in average width) may be found off Adamstown on the north side in 70 to 100 feet of water. In contrast, this reef is composed of dead coral rock about half covered with colonies of live coral (usually no more than 18" in diameter and mostly Porites). In six dives on this reef, (X in Fig. 6) two adult Acanthaster were found at 90 feet one of which was preserved and data taken (Table 1). The bottom temperature when one starfish was collected was 24.8° C. Later the same area was subject to a thermocline effect. The water at 90 to 100 feet was roily and at least 2 to 3 degrees C cooler (no thermometer was on hand at this time and when one was brought the following day, the water no longer felt as cool at the 100-foot depth). Very little coral damage was apparent on the reef off Adamstown. One of the two starfish had been feeding, and a sample of the coral on which it fed was taken. No other Acanthaster was seen at Pitcairn.

3. Henderson Island

On January 11 and January 17-18 a total of two days were spent on the north and west side of Henderson Island (24° 20' S; 128° 20' W) (Fig. 5). The island is elevated coral limestone, with cliffs along most shores 50 feet or more in height, the central region of the island being at most 100 feet high and relatively flat. Henderson is 5 miles long and nearly 3 miles wide. It is uninhabited except during rare visits by Pitcairn islanders seeking miro wood (Thespesia populnea). The shelf region offshore is relatively narrow, but the reefs are more extensive than those of either Oeno or Pitcairn. Dives were made to depths of 160 feet. No Acanthaster was seen nor was any damage noted to the coral which might be attributed to this asteroid.

4. Ducie Atoll

For a period of 2-1/2 days beginning January 13, 1971 a marine biological survey was made of Ducie (24° 40' S; 124° 47' W), the easternmost atoll of Oceania. It is small (1.3 miles in greatest diameter) and uninhabited. It is certainly one of the least visited islands of the globe. There is a shallow channel on the SW side to the lagoon which can be negotiated by a ship's boat, except during low tide, providing one is alert for the numerous small coral heads. This small channel is the main exchange for the lagoon, although some water passes over at high tide between two islets on the east side. The deeper part of the lagoon is about 50 feet in depth (53 feet at deepest sounding). The lagoon is interlaced with irregular coral heads, many interconnected at their bases, and many reaching nearly to the surface. The coral on these coral heads is nearly all completely dead. The water of the lagoon had a dark greenish cast, and the visibility was only about
75 feet at the maximum, probably reflecting a low level of flushing. Eight hours were spent in towing, snorkeling, and diving in criss-cross pattern throughout the lagoon. Only one adult Acanthaster was seen, on the SW side of the lagoon just north of the small boat passage, in about 10 feet (Fig. 5, X). This was preserved in formalin (Table 1 for data). Temperature in the lagoon at the bottom and surface was 26.5°C and the salinity 38 o/oo.

In contrast to the lagoon, a moderate amount of live coral was seen in the small boat passage—nearly all as small colonies.

Outside the reef from the small boat passage to the NW corner of the atoll, from the reef edge to at least 100 feet, the bottom was predominantly dead coral encrusted with coralline red algae. It was evident that all of this coral had been killed at approximately the same time. Without a knowledge of the succession of benthic life on dead coral, it is difficult to guess how long the coral had been dead, but it would seem to be at least a year. The nullipores had nearly bridged the gap between adjacent terminal branches of some heads of closely branched Acropora. No Acanthaster was seen outside the reef (dives were made to 180 feet). Time did not permit investigation of the northern or eastern sides of the atoll, but the almost complete disolation of corals in the areas examined did not suggest that the picture would be different elsewhere. Concomitant with the paucity of corals was the dearth of fishes, both in number and individuals; this was all the more evident in view of the total lack of fishing pressure.

In view of the level of devastation of coral by Acanthaster in certain areas such as Guam and the Great Barrier Reef, it would seem plausible that the starfish could be responsible for Ducie's mass mortality of corals. The lack of starfish could be explained by their mortality following decimation of the food supply. Possibly there is some other reason, such as mortality due to intrusion of cold water from more southern latitudes. At almost 25° S, Ducie is near the southern limit of distribution of reef corals. However, reconnaissance at Rapa and Ilots de Bass (see below) even farther south, revealed a proliferation of coral, including acroporans, without evident thermal destruction.

The presence of Acanthaster planci at Ducie extends the known eastern limit of this species and together with the specimens found at Pitcairn represent new distributional records.
RAPA AND ILOTS DE BASS

A period of 25 days between January 26 and February 21, 1971 was spent at the island of Rapa (27° 35' S; 144° 20' W) (Fig. 7) during which time a number of diving stations were worked all around the island. Several sea surface temperatures were taken; they ranged from 23.5 to 25° C. On no occasion was Acanthaster found nor was there any indication of coral predation by the starfish. Although the local residents were familiar with the crown-of-thorns (known throughout the French Polynesian area as Taramea) via radio descriptions from Tahiti and most recognized this starfish from our photographs, all denied its existence in their waters.

Around most of Rapa coral growth is poor, at least in depths less than about 50 feet. There are, however, well developed fringing reefs in Haurei (Ahurei) Bay and luxuriant patch reefs off the entrance to the bay. Table and branched acroporan as well as many other scleractinian corals were noted and collected. For the most part, the corals are vigorously growing and well developed in this area.

On February 20 a visit of one day was made to Ilots de Bass (Marotiri) (27° 57' S; 143° 26' W), about 50 miles SE of Rapa. Short survey dives were made between NE and SE Rocks in depths from 0 to 150 feet. The deeper areas showed a bottom covered with lush, vigorously growing acroporan and other corals, interspersed with sandy areas. No Acanthaster was noted.

THE AUSTRAL ISLANDS

Three of the Austral Islands were visited between February 25 and February 28, 1971. At Raivavae (23° 52' S; 147° 40' W) we heard from a school teacher that the crown-of-thorns had been seen within the lagoon on the SW side but not in great numbers. On February 25, together with this man, Devaney, Randall, and two members of the "Westward" crew examined the area where Acanthaster had been noted (Fig. 8, 1). Over an hour's survey in the shallow part of the lagoon failed to reveal any Acanthaster or evidence of coral damage which might be attributed to this starfish. SCUBA diving outside the lagoon beyond Motu Haa (Haha) and off the southern boat passage in depths from 20 to 175 feet revealed considerable live coral but no Acanthaster.

Dives at selected sites around the islands of Tubuai and Rurutu failed to demonstrate any Acanthaster or evidence of coral depredation. At Tubuai, the dives were made within the lagoon near the NW side and off Motu Moturoa by Devaney and out beyond the barrier reef on the north side, west of the boat passage by Randall during the afternoon of February 26. At
Rurutu, diving was conducted off Avera Bay and more extensively off Moerai Bay on the NE side of the island during February 27 and 28. Local residents and officials of the French government at both of these islands had not seen or heard of the crown-of-thorns in their waters.

SOUTHERN COOK ISLANDS

1. **Manuae (Hervey)**

On March 6, 1971 between noon and 1800 hours, Devaney examined the lagoon and one seaward site of Manuae (Fig. 9, insert) for Acanthaster. A small boat was dragged through the shallow channel along the NE side of Manuae Islet (19° 21' S; 158° 58' W). The lagoon was crossed between Manuae and Te Au O Tu Islets. Very little coral appeared in the shallow parts of the lagoon (depths 2-6 feet). Many black sea cucumbers, primarily Holothuria atra, were seen on the white sand bottom. Later in the afternoon a dive was made in the deeper portion of the lagoon near the south central part where the bottom depth is 16 feet. Several coral knolls rise very near the surface. The coral was alive and extensive, especially along the upper margins of the knolls. Several underwater photographs were taken of coral along such edges. No evidence of Acanthaster nor coral damage from the starfish was noted.

In the late afternoon, on the seaward side of Manuae Islet just SE of the small boat channel (Turakina Passage) (Fig. 9, X), Devaney and Rhett McNair made a SCUBA dive from 40 to 180 feet. The deeper zone from 120 to 180 feet is nearly vertical. The bottom here was dominated by large sheetlike terraced colonies of live Porites. Very few other live corals were present, but there was considerable dead coral covered with coralline algae. Leading into this steep sector is a canyon which appears to be an erosion channel. This was examined from a depth of 40 to 100 feet. The bottom of the canyon, which averages about 20 feet in width, is clean sand and boulders, some cemented by nullipores. The walls are between 10 and 15 feet in height. Above the walls, on the south side, 80 to 90% of the bottom was covered with dead coral. Most of this coral, especially the branching forms of Acropora and Pocillopora, was cemented in place by nullipores. In some areas a scum of blue-green algae covered much of the surface. Although there was no sign of Acanthaster in this area, the high percentage of dead coral condition of the bottom was reminiscent of the reefs killed by the starfish in Guam. Possibly the dead coral was a result of an infestation of A. planci.

2. **Aitutaki**

Beginning at noon on March 7, 1971 the lagoon of Aitutaki (18° 53' S; 159° 47' W) was surveyed by Devaney, Rich Costello,
and James Haywood. The path of the survey is shown by the dotted line of Fig. 9 beginning just south of the main village of Arutanga. Numerous coral knolls (most about 15 to 30 feet in diameter) occur in the zone between A and B Fig. 9. Ten of these knolls were examined completely by two or more divers. Up to 90% or more of the branching corals (mostly Acropora and Pocillipora) were dead. Much of the dead coral was covered with brown, green, and coralline red algae. Soft corals and the blue starfish Linckia laevigata were common (3 to 8 starfish per knoll). Approximately at point B the first coral heads with live branching acroporan corals were noted. The depth to the sand bottom here is 10 to 12 feet. Each of these knolls had several adult Acanthaster on them. Most of the starfish were concealed near the lower part of the knolls (one of six starfish on a knoll was on the sand bottom beneath a ledge). None of the starfish were feeding, but fresh feeding scars were evident on the corals.

Moving toward Maina Islet from point B the knolls had a higher percentage of live coral and fewer A. planci. On these heads with more live coral Linckia laevigata was not common. The direction of survey was then altered toward Tekoutu Point, and random knolls were investigated. The greatest concentration of A. planci was noted on knolls near Tekoutu Point. Here several of the starfish were seen actively feeding on coral along the edges of knolls near the surface. Underwater photographs were taken in this area and starfish were collected from three of the knolls.

Towing over the sandy bottom between knolls there are small heads of Acropora (probably formosa) which were mainly dead, with indication of not having died too recently. Only a few had the usual commensal invertebrates and the pomacentrid fish Dascyllus aruanus associated with them.

Proceeding SSE from Tekoutu point we entered an area so shallow with numerous coral heads (Fig. 9, D) that it was impossible to continue towing. The coral here was alive, and there was no evidence of Acanthaster.

We conclude from this survey that there was an active zone of predation by A. planci in the lagoon of Aitutaki between the wreck of the Alexander and Tekoutu Point (approximately B-C of Fig. 9). We believe that the starfish have advanced in a southerly direction from Arutanga and are responsible for the dead coral. That they have crossed areas of bare sand is suggested by the high percentage of dead stands of Acropora between the knolls. The absence of small or even medium-sized starfish is also indication that a single relatively small population of A. planci has moved as a progressive front in the Aitutaki lagoon.

Mr Val Hinds, the Fisheries Officer of the South Pacific
Commission, made a brief survey for Acanthaster in the lagoon of Aitutaki in the summer of 1970. He failed to find any starfish at that time. Iopa Marsters, a Rarotongan fisherman who accompanied Mr Hinds during his survey, was also with our team at Aitutaki. He does not recall seeing the many knolls of dead coral during the 1970 investigations. He stated, however, that the survey group had little experience with Acanthaster and its damage to corals.

On March 8 between the hours of 0830 and 1105 a survey was made of the seaward side of Aitutaki from Arutanga Passage south to Maina Islet (the dotted line of E-F, Fig. 9), a distance of about 4 miles. An observer was towed behind a small boat and spot checks were made by skin and SCUBA diving. Devaney was assisted in this survey by Haywood and David Bryant of the "Westward" crew.

The seaward shelf of this area, from a depth of 10 to 100 feet, consisted mainly of dead coral. A few encrusting corals were alive as were occasional small heads of Acropora and Pocillopora, and there was live Millepora and soft alcyonarian corals. Approximately 80 to 90% of the scleractinian corals, including massive heads of Porites, were dead. No evidence of Acanthaster was noted. Underwater photos were taken and samples of dead coral taken. The samples revealed much encrustation by coralline red algae (up to 1 mm in thickness). It is very possible that Acanthaster is responsible for the extensive coral mortality of this sector of Aitutaki.

Cook Island government officials informed us that there has been heavy use of chlorinated hydrocarbon insecticides at Aitutaki in recent years. They also mentioned that several 55-gallon drums of DDT had been dumped in or just outside Arutanga Passage after World War II.

3. Rarotonga

When Devaney went on "Westward" to Manuae and Aitutaki, Randall remained at Rarotonga (21° 13' S; 159° 46.5' W) with Dean B. Cannoy for a survey of Acanthaster there. Devaney returned for the investigations on Rarotonga on March 10.

On March 6, 1971 Randall was towed from Avaavaroa Pass on the south side of Rarotonga for a distance of 300 meters to the east over an average depth of 40 feet (Fig. 10, A). Away from the pass the water was clear enough to reveal a bottom nearly completely covered with live coral with no trace of Acanthaster. A dive was then made in 50 feet with SCUBA in the company of Walter Hambuechen, the Agriculture Officer of the Cook Islands. Toward the end of the dive, the deeper portion of the reef was investigated. At about 80 to 90 feet some dead coral was observed. At 100 to 125 feet fresh feeding scars from Acanthaster were seen; the coral here was 90% dead. Two
adult Acanthaster were observed in this area, one of which was brought to the boat (398 mm in diameter, 1315 gms; see Table 1), along with two kinds of coral on which it was feeding. After a return to shore for fresh tanks, a second dive was made (with Dean B. Cannoy) in an attempt to find the same deep area of heavy coral destruction. The exact area was not located, for no fresh feeding scars and no Acanthaster were seen, but the coral was at least 90% dead at 100 feet and below, with some dead coral apparent at the 80- to 90-foot level.

The south shore of Rarotonga is subject to consistent heavy swell. On only a few days of the year is it calm enough to venture through the pass in a small boat for diving as we did on March 6. We believe that the heavy surge may be responsible for Acanthaster avoiding coral in the shallower sectors of the southern Rarotongan reef.

On March 7 two dives were made off the oil tanker buoys near the harbor entrance on the north shore of Rarotonga (Fig. 10, B). In one half hour, at a depth of 50 to 80 feet, Randall counted 26 Acanthaster. Of these, 18 were feeding, mostly on Porites. The bottom in this area is about 3/4 coral, as viewed from above. Of this, 60 to 70% was dead. Most of the surviving coral is Porites, some of which stands in large heads 10 to 15 feet above the base level of the bottom. One cannot help but feel that the starfish have avoided Porites initially, but now are forced to feed on it in view of the paucity of more favored kinds. Samples were taken of three species of coral on which the starfish were feeding.

The second dive began at the easternmost of the two buoys (depth 45 feet), and moved toward shore to a depth of 30 feet. There was more live coral in this zone, but still about half was dead. In ten minutes no Acanthaster were found and no very recent coral damage was seen. However, we believe the older damage was due to the starfish, particularly since it involved mainly species other than Porites.

A third dive on March 7 was made off the laundry, 1 kilometer west of the oil tanker buoys (Fig. 10, C). The depth was 45 to 80 feet. In a dive of 30 minutes three adult Acanthaster were counted, one of which was feeding on coral (sample taken). This area had more sand bottom than the previous areas (about half sand and rubble, and half coral). Half of the coral at this locality was dead, seemingly from Acanthaster. Most of the surviving coral was Porites. No towing was possible from this area to the harbor because of turbidity of the water.

An attempt was made on the morning of March 8 to launch the small green fiberglass skiff through an alleged boat passage near Black Rock, NW Rarotonga. This proved impossible and the morning was lost. In the afternoon towing was attempted directly off the wreck of "Yankee" on the reef of Avarua (Fig. 
It was not possible to see the bottom well enough because of dirty water, so a dive was made in 45 to 55 feet. In 30 minutes 38 adult Acanthaster were counted. Of these, 18 were feeding, seven on Porites. Samples were saved of four coral species other than Porites on which the starfish were feeding. In this area the bottom is about 85% coral, about half of which is dead. Again, most of the surviving coral is Porites.

The starfish were detached from the bottom to determine whether they were feeding or not. When detached, they fold their arms ventrally, thus forming a nearly complete spinous ball which tends to roll in sand channels with surge. One such detached starfish rolled back with the surge to strike Randall's wrist and one finger and inflict seven deep spine wounds.

A second dive was made on March 8 off Pue, 1.3 kilometers east of the wreck of "Yankee" (Fig. 10, E). The dive covered a depth range of 30 to 100 feet in an area where the bottom was about 50% coral. Coral damage was nearly as heavy as off "Yankee" but only eight Acanthaster were sighted in 30 minutes; all but one of these were in the depth range of 80 to 100 feet. Because of disconcerting pain from the spine wounds, Randall was probably not as alert in counting as he would otherwise have been.

That evening the pain was still mainly confined to the wrist and hand, although there was some radiation up the arm. The next morning pain had subsided in the limb but an overall illness prevailed which necessitated bed rest. Among the symptoms were backache, headache, joint pain, malaise, and loss of appetite.

The wounds were slow to heal, particularly three of them around which necrotic tissue developed to a radius of about 3 mm. A week later there was still soreness around these three wounds and severe itching of those more fully healed.

On March 10, 1971 Devaney was towed along the northwest side of Rarotonga between Motu Toa and Black Rock for a period of 10 minutes (Fig. 10, F). During this period 57 Acanthaster were sighted over a distance of approximately 500 yards. Individual starfish were scattered over the bottom in depths from 30 to 55 feet. It was noted that in several cases more animals aggregated along edges of coral ridges next to shallow sand grooves. A check dive in this area showed considerable dead branching coral but with the large scattered heads of Porites still mainly alive. A few fresh white feeding scars were evident. At the end of the tow the water was becoming turbid, but there was no sign that the number of Acanthaster had decreased.

Later in the morning of March 10th, Devaney, Randall, and Hambuechen made a SCUBA dive just south of Black Rock (Fig. 10,
G) at a depth of 90 to 100 feet. Our location was approximately 3/4 mile SW of the end of the earlier tow (Fig. 10, F). We noted that most of the branching Acropora and Pocillopora coral was dead, well covered with low algae and in some cases had a covering of coralline algae. Live heads of Porites remained. No Acanthaster was noted in the small area circumscribed during this dive (approximately 100 yards in diameter).

In the afternoon of the same day a SCUBA dive was made between the two oil line buoys about 200 meters west of Avatiu Harbor at a depth of 40 to 50 feet (Fig. 10, B). Massive live Porites heads with rubble and sand patches dominate the area with smaller less abundant heads of branching corals present. These branching corals, mostly Acropora spp. and Pocillopora spp. were found to be dead and overgrown. No Acanthaster was sighted; however, a dive to the same area two days later resulted in the sighting of three adult starfish, one of which was feeding on Porites.

On March 11, 1971 Devaney, accompanied by Mr Hambuechen, surveyed the north side of Rarotonga, east of Avarua Harbor. Towing commenced west of the wreck of the "Yankee" at a depth of 50 feet and proceeded parallel to the coast for 100 yards; no Acanthaster was evident although the bottom appeared to be dead coral. We turned seaward into deeper water. At a depth of 100 feet we noted the first Acanthaster traveling over sand between coral ridges; immediately thereafter a large number of starfish was observed in a concentrated band about 50 yards wide extending eastward. A SCUBA dive at a depth between 100 and 120 feet was made. We counted 23 adult individuals covering an area about 50 yards in diameter next to a sand groove. Several starfish were feeding on Porites. Only a small percentage of the branching corals were observed to be alive; the rest were covered with low algae and nullipores, the latter filling in the crevices between branches. Underwater photographs were taken with Nikons and flash. Seven of the smaller Acanthaster were collected for size and sex measurements (see Table 1), and gonad samples taken. A portion of two individuals collected was retained for later examination (one which was yellowish colored with numerous pedicellaria). The color of most of the specimens appeared greenish, greyish, or bluish at 100-foot depth but were red in the flash pictures and red upon bringing the starfishes to the surface, the difference in color being due to the extinction of red color with depth.

In the time available we were unable to survey the entire coastal area of Rarotonga, but the numerous A. planci and extensive coral damage observed at widely separated areas suggests that the starfish might be expected in abundance all around the island.

Rarotonga with about 13,000 people is the most populous of the Cook Islands. Agriculture is important, and the use of
chlorinated hydrocarbon insecticides--first DDT and now mainly dieldrin and lindane--is excessive (Hambuechen, personal communication).

SOCIETY ISLANDS

1. Bora Bora

On March 18, 1971 two teams of divers examined the coral and bottom environment on both sides of Teavanui Pass on the west side of Bora Bora (16°30' S; 151°45' W) (Fig. 11). One team (Devaney, McNair and Bryant) worked along the northern rim of the pass and seaward as far as the northern end of Ile Teveiroa. With the exception of a small area off the middle of Ile Teveiroa which revealed dead coral, the pass and seaward region appears to support considerable live coral. No Acanthaster was observed. The one small area with dead coral shows a westward projection of the reef and appears to receive heavy surf. The dead coral probably resulted from wave action. At a depth of 40 feet, and deeper off this area, live coral was abundant.

The second team of divers (Randall and Cannoy) was towed along the south side of the Teavanui Pass and south as far as the middle of Ile Tupua (Toopua) about 1.2 miles from the pass on the seaward side. No signs of coral damage due to the crown-of-thorns could be detected. The bottom was mostly live coral. A few heads of Acropora with white areas were noted, but diving failed to reveal any starfish.

A SCUBA dive including both Devaney and Randall on the seaward side outside the reef (Fig. 11, X) showed a moderately steep drop from 60 to 155 feet. A considerable amount of live coral was seen on this slope. The bottom was mainly sand between 155 and 175 feet. There was no evidence of Acanthaster activity.

According to an informant in Bora Bora, Erwin Christian, who operates a glass-bottom boat and has a SCUBA facility, there has been no evidence of an increase in the number of Acanthaster at this island. Only an occasional individual is sighted. He mentioned having recently seen one or two in the southwestern part of the lagoon south of Ile Tupuaiti. We towed an observer in this sector of the lagoon during the afternoon of March 18 but failed to find any A. planci or coral damage.

2. Huahine

On March 19, 1971 several hours were spent along the northwest side of Huahine (16°45' S; 151° W).

A tow was made from inside Avamoa Pass to Avapeihi Pass along the seaward side (Fig. 12, A). There were no signs of
Acanthaster: the mouth of the Avamoa Pass on the south side is a scoured pavement bottom with isolated heads of live Porites and Pocillopora coral. Along the seaward side between the two passes, the bottom is also hard with a few shallow sand grooves and pockets. It is mostly covered with live coral, including Pocillopora eydouxi, P. meandrina and Acropora spp.

A second tow was made on the seaward side south of Avapeihi Pass for a distance of 200 yards to a point just opposite Mt. Tavahi (Fig. 12, B). Some dead coral and rubble was noted and a SCUBA dive by Rhett McNair off a steep slope to 80 feet revealed a considerable amount of dead coral; however, no Acanthaster was observed nor were there any fresh feeding scars.

SCUBA dives were made north of Avamoa Pass (Fig. 12, C). Live coral banks separated by shallow rubble and sand grooves were noted in depths from 20 to 100 feet. There was no sign of Acanthaster.

Several persons familiar with the waters of Huahine, both at the island and in Tahiti, informed us that they knew of no indication of an abundance of A. planci there.

3. Tahiti

As early as May 1969, evidence of Acanthaster predation on Tahitian coral reefs was known. By October 1969 the Service de la Pêche in Papeete with volunteer help began a control program in the lagoon areas at Punaauia and Paea, 17 and 21 kilometers SW of Papeete, respectively. A resume of the control program through October 1970 is available in a 9-page mimeographed report of the Service de la Pêche, dated December 1970.

Through the kindness of Dr. Raymond Bagnis of the Institut de Recherches Médicales at Papeete and Dr. S. Stein, Chef du Service de la Pêche, we were able to examine several of the most affected areas, especially Punaauia and Faone.

On March 22, 1971 the lagoon of the district of Punaauia was visited (Fig. 13, A). The devastating effect on the lagoon corals, particularly near the barrier reef, was noted. Over 10,000 A. planci had been removed from this sector. We were able to find only 12 adult specimens in a period of three hours. A special effort was made to find juvenile starfish, but none were seen. A few small white feeding scars were observed near basal portions of staghorn Acropora, but diligent searching for young A. planci in the vicinity of these scars failed to yield any specimens. Our smallest specimen from the area was of medium size (1100 grams).

On March 23, 1971 Devaney joined Mr. Francis Nanai from the Institute de Recherches Médicales and Mr. Phillip Tsu and three
other divers from the Service de la Pêche for a starfish control mission in the lagoon of Faone on the eastern side of Tahiti (40 kilometres from Papeete). We were informed by Tsu that as recently as March 9, 1971 several hundred Acanthaster had been removed from this area. Four divers of our group collected 40 specimens of A. planci in about two hours. The starfish were thrown into a small boat, taken to shore, and placed on land for 48 hours before being dumped. No chemical injection or other methods of eradication have been employed in Tahiti.

On the outside of the fringing reef an examination was made of the bottom parallel to the reef edge along a transect of 200 yards. Dives were made from the reef edge to depths of 50 feet at a distance of about 100 yards from the reef edge. There is a heavy cementation of the coral and rubble with coralline algae. This often obliterates the branches of the corals, making it difficult to determine the amount of previous live coral cover. There is partial coral recolonization over the cemented substratum at Faone. No small A. planci were found, in spite of careful search.

On March 28 and 29 SCUBA dives were made by Randall and Cannoy on the outer reef outside Papeete Harbor off the middle of the concrete breakwater in the vicinity of a wreck of a large iron-hulled sailing vessel. Depths ranged from 20 to 250 feet. The coral growth was good. A few whitish patches on the coral suggestive of Acanthaster damage were seen in the depth range of 60 to 100 feet, but no starfish could be found. The water was too turbid for towing; also there was an oil slick on the surface.

On March 29, the sea was moderately clear NE from the end of the breakwater, and it was possible to see the bottom in 30 to 40 feet. A tow was made for 1.5 miles over this depth from the NE end of the breakwater toward Tau-noa Pass. The bottom was dominated by small heads of Pocillopora meandrina. No Acanthaster were seen.

It is perhaps no coincidence that Tahiti and Rarotonga, the only islands of heavy infestations of Acanthaster planci of the 27 we visited in SE Oceania, are the ones of the greatest human habitation and heaviest agriculture. One of us has already suggested that there may be a connection between the use of chemical pesticides and the outbreaks of the crown-of-thorns starfish (Randall, Biotropica, 4, 1972, 132-144).

NORTHERN TUAMOTU ARCHIPELAGO

1. Rangiroa

Rangiroa is the largest atoll in the Tuamotus. Its eastern
end lies at $15^\circ 17'\ S; 143^\circ 13'\ W$. There are two passes, both on the north side, about 5 miles apart. In 1957 there were 700 inhabitants, mostly in two villages, one at the eastern side of each pass.

On April 6, a dive was made from 40 to 100 feet on the outer reef 200 yards east of Tiputa Pass, the easternmost of the two passes. The coral growth was extremely rich. No Acanthaster were seen, nor was any damage to the coral suggestive of the starfish noted.

On April 7 and 8, dives from 20 to 60 feet were made on groups of coral heads in the lagoon of Rangiroa about 1 mile east of Avatoru Pass. Less than 50% of the hard bottom consisted of live coral. There was no sign of Acanthaster.

On April 8, a tow was made from the western side of the pass 1/2 mile to the west, the tow commencing at the outer half of the pass. At the edge of the pass in 15 to 40 feet there was considerable dead and broken coral, but not suggestive of Acanthaster damage. On the outer reef in the region of the tow (30 to 40 feet) the bottom was monotonously flat coral rock studded with small heads of Pocillopora, Porites, and Millepora (coral about 1/3 of bottom area). The water was somewhat turbid by atoll standards (evidently the discharge from the pass moves mainly westward). At the outer edge of the reef the slope steepens and the coral growth is richer. No Acanthaster were seen.

A tow was then made from the outer part of the pass on the eastern side for one mile in the easterly direction, at an average depth of 50 feet. Because the water was very clear, it was possible to see over a depth range of at least 20 to 80 feet. Except at the outer part of the pass and the first 200 yards or so to the west, which was flat coral rock bottom with scattered small heads of coral, the bottom was almost totally covered with coral in the 20 to 80 foot depth range. A dive was made to 150 feet at the end of the tow. The following day sporadic brief tows were made from one mile to slightly more than two miles to the east of the pass, with no change in bottom type. Two dives were made from a range in depth of 15 to 140 feet. There is a steep drop-off of 60 to 70 degrees with sand, coral rock, and some live coral beginning at about 70 to 80 feet. Only a very few small white dead areas on coral were noted, and no Acanthaster were seen. The dominant coral is Pocillopora. In several broad areas in the depth range of about 30 to 70 feet in the vicinity of one to two miles east of Avarua Pass, about one third of the Pocillopora is dead and very heavily encrusted with coralline algae and other marine growth. If such damage were caused by Acanthaster in abundance, one can only wonder why no starfish could be found at this time in the area of partially dead coral.
In the afternoon interviews were made with local divers with the help of Dr Pierre Fourmanoir, ichthyologist of O.R. S.T.O.M., New Caledonia, who was visiting Rangiroa at the time. One man recalled finding seven Acanthaster about six months ago on the east side of the pass between the concrete dock and outer reef. A tow was made over this area the next day (day of departure). As on the other side of the pass, there was considerable dead coral but very little of recent origin. Most was Pocillopora. Very little Acropora was seen, dead or alive, and this in deeper sections. Moderate heads of Porites are common. A few small patches of white on the coral were visible. One adult Acanthaster was seen.

2. Manihi Atoll

The atoll of Manihi (western extremity 14° 27' N; 146° 05' W) has a single passage, Tairapa Pass, to its lagoon on the SW side. A village (200 inhabitants in 1948) lies on the SE side of the pass. The Lagoon is shallow, the NW end of the pass with soundings of as little as 1.2 to 2.2 meters across it. The pass is only 246 feet wide and the dock has less than 10 feet of water. With no suitable anchorage, "Westward" stayed at Manihi only during the daylight hours of April 11.

Tows were made in the outer half of the pass in either direction for about 1/4 mile. The water was very clear, and the coral growth was rich and diverse in both directions from the pass (at the edges of the pass Pocillopora dominated). The outer reef is narrow, so it was possible to see the bottom from the shore to the drop-off in about 60 to 70 feet. No Acanthaster were observed. Only a few white patches were observed on the coral; these were mainly on Acropora and appeared to be the result of feeding by fishes.

Dives were made to 100 feet 1/4 mile NW of the pass and to 180 feet SE of the pass for selective fish collecting. No starfish were observed at this time.

Late in the day before departure an interview was held with about 20 adults of the village on the incidence of Acanthaster. They reported that a moderate number could be found at places in the lagoon. When asked how many one diver might count in two hours of swimming, the reply (after some hesitation and comparing of opinions) was 10 to 12. Unfortunately there was then no opportunity to make any reconnaissance of the lagoon.

3. Takaroa Atoll

Takaroa is one of two atolls of the King George group (the other, Takapoto lies 5 miles SW). The SW extremity is located at 14° 31' S; 145° 4' W. The atoll is about 15 miles long and 5 miles wide. There is a single pass, Teavaroa, on the SW side.
The village of Teavaroa, with about 140 inhabitants today, is on the north side of the pass. Takaroa is one of the more valuable atolls with respect to its resource of blacklip pearl oysters. The taking of pearl shell was forbidden during our stay at the atoll. In fact, it was necessary to obtain permission to dive in the lagoon.

Interviews were carried out with several natives who were divers. All stated that the "taramea" (Acanthaster) is very rare at Takaroa, both in the lagoon and outer reef (though they would know the lagoon better, for toxic fishes are known to occur outside the reef whereas the lagoon fishes are reportedly safe; thus fishing, plus pearl diving, takes place principally in the lagoon).

The pass and lagoon were very turbid while "Westward" was at Takaroa. Towing for Acanthaster was carried out only on outer reef areas.

On April 12 a tow was made over an average depth of 40 feet for a distance slightly greater than two miles south from the pass. A near-vertical discontinuity of perhaps 10 feet was apparent along much of the outer reef a short distance from the reef front where the surf was breaking. Seaward of this there was often a depression of a few feet. Then a broad outer coralliferous terrace to a drop-off in about 60 to 70 feet. Coral growth was rich and diverse on this terrace. No starfish or starfish damage were noted.

On the following day a tow of about two miles was made in the northern direction. The bottom was similar to that south of the pass, but about a mile to the north it was noted that an increasing amount of the bottom was covered with light pink coralline algae. A dive was made from near shore to 220 feet. From one third to one half of the bottom consisted of long-dead coral overgrown with coralline algae, new coral, and Millepora (but primarily coralline algae). The existing live coral is mainly in small heads. On the outer part of the reef at this area in 40 to 50 feet, the coral growth was better and by the edge of the drop-off, the bottom was almost completely coral-covered. Most of the coral in the 15 to 40 foot zone, both live and dead, is Pocillopora. No Acanthaster were seen.

On the morning of the 14th, the day of departure, a dive was made on the north side of the pass from the dock to the entrance. A few white patches were found on Pocillopora, but no starfish could be found.

MARQUESAS ISLANDS

The period between April 18 and May 19, 1971 was spent visiting the six principal Marquesas Islands. All six islands
were examined for the presence of *Acanthaster* or effects of its predation on the coral fauna. There was no indication of the starfish nor any damage to coral which could be attributed to it.

Two persons in Tahiti had mentioned that the "taramea" was known from the Marquesas, but we still have no verification of the species there.

**AMERICAN SAMOA**

1. **Tutuila**

Devaney arrived at Tutuila (14° 20' S; 170° 40' W) on March 25, 1971 and spent three days on the island and the small adjoining island of Aunu. During this period a conference with the Governor, John Haydon, was arranged. He expressed his concern about the possibility of *Acanthaster* infestation but stated that there was no evidence of a population increase at that time.

Two areas along the southwest coast of Tutuila, Coconut Point and Pagaoto, were examined for signs of *Acanthaster*. A dive was also made along the west side of Aunu Island. No crown-of-thorns were seen. At Coconut Point the cushion starfish (*Culcita*) was observed feeding selectively on small heads of *Pocillopora damicornis*.

**Resumé**

1. A small population of *Acanthaster* occurs off the southwestern side of Mangareva Island in the Gambier Group. Little coral damage was noted and the population has apparently remained relatively stationary for at least 2 years.

2. The distribution of *Acanthaster planci* is extended as far east as Ducie Atoll (Long. 124° 47' W) and new records for the species are from Ducie, Pitcairn, and Amururo Atoll.

3. Ducie Atoll appeared to have a considerable amount of dead coral. A paucity of marine life is attributed to geographic position and possibly isothermic conditions. The cause of the dead coral was not determined.

4. *Acanthaster* apparently has not reached Rapa and only one island in the Austral group (Raivavae) was reported second-hand to have had "taramea" (*Acanthaster*). Rapa and the Australs support a fairly rich coral fauna including acroporan corals.

5. In the southern Cook Islands, coral predation due to *Acanthaster* was evident at Aitutaki in a portion of the lagoon.
The presence of up to 90% of dead scleractinian coral along a 4 mile seaward stretch of Aitutaki suggests Acanthaster activity in the past. Little recruitment of new coral was noted and coralline algae cementation was conspicuous. A single dive on the seaward side of Manuae revealed a similar condition but further work there is required to verify the cause(s). Rarotonga shows a considerable concentration of Acanthaster, and coral predation is extensive, especially to the east and west of Avatiu and Avarua Harbours. Additional Acanthaster and dead coral was noted near Avaavaroa Passage off the south side in depths from 100 to 125 feet.

6. In the Society Islands, only Tahiti has large concentrations mainly affecting the lagoon areas. Since 1969, and continuing presently, a control program has been underway by the Service de la Pêche.

7. In the Northern Tuamotus only one atoll, Rangiroa, was reported second-hand to have had a small concentration of the "taramae". The survey found only a single specimen of the starfish and no appreciable coral death which could be attributed to A. planci.

8. In the Marquesas Islands, no Acanthaster was found and only second-hand reports which could not be verified suggested that this starfish occurs in these islands. There is a definite reduction in the number of coral species, especially acroporan types, in these islands.

9. In American Samoa, although Acanthaster is known around the main Island of Tutuila, discussions with the Governor indicate that there has not been extensive Acanthaster predation nor have any large concentrations been noted.
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* Gonad Condition: U-unripe, R-ripe, S-spent

** Number of arms regenerating
Plate I, figure A. *Acanthaster planci* upon Acroporan coral after feeding. Freshly eaten area on left. Mangareva Island, Station 3, depth 1 1/2 m. Dec. 12, 1970. Photo by D.M. Devaney.

Plate I, figure B. Acroporan coral showing fresh feeding scar (upper left), previously eaten, algal covered area (lower right), and living part (center left). Mangareva Island, Station 3, depth 2 m, Dec. 12, 1970. Photo by D.M. Devaney.
Plate II, figure A. *Acanthaster planci* on underside of recently eaten *Acroporan* coral. Mangareva Island, Station 3, depth 2 m, Dec. 12, 1970. Photo by D.M. Devaney.

Plate II, figure B. *Acanthaster planci* among branches of *Acroporan* coral. Older dead algal covered portions (right) and live coral (foreground, left). Mangareva Island, Station 3, depth 3 m, Dec. 12, 1970. Photo by D.M. Devaney.
Plate III, figure A. Fresh feeding scar on *Porites* coral and surrounding dead branching corals. Rarotonga, Cook Islands, depth 30 m, Mar. 11, 1971. Photo by D.M. Devaney.
Figure 2. Anuanuraro Atoll, Tuamotu Archipelago
Figure 3. Gambier Islands, French Polynesia

Figure 4. Mangareva Island
Figure 5. The islands of Oeno, Henderson, and Ducie

Figure 6. Pitcairn Island
Figure 7. The island of Rapa

Figure 8. Raivavae, Austral Islands
Figure 9. Aitutaki Island and Manuae (Hervey Islands), Cook Islands
Figure 10. Rarotonga, Cook Islands
Figure 11. Bora Bora, Society Islands

Figure 12. Huahine, Society Islands
Figure 13. Tahiti, Society Islands