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**POPULATION LEVELS OF ACANTHASTER PLANCI
IN THE MARIANA AND CAROLINE ISLANDS
1969-1972**

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POPULATION LEVELS OF ACANTHASTER PLANCI IN THE MARIANA AND CAROLINE ISLANDS 1969-1972¹

by James A. Marsh, Jr.^{2/} and Roy T. Tsuda^{2/}

INTRODUCTION

The presence of large numbers of the crown-of-thorns starfish Acanthaster planci (Linnaeus) and its devastating effect on live coral reefs around certain Micronesian islands was first documented by a large-scale survey carried out by Westinghouse Electric Corporation in July and August, 1969 (Chesher 1969a). The survey indicated that there was, indeed, an abnormal population explosion of this animal on several islands, that the population explosion was of widespread occurrence, and that large areas of reef were being destroyed in certain islands beyond what could be considered a normal situation. There were, however, a number of islands which apparently had completely normal, healthy reefs.

Control efforts were subsequently organized in the Mariana, Palau, Truk, Ponape, and Marshall Island Districts of the Trust Territory of the Pacific Islands. The Yap District was not included at that time, because no abnormal Acanthaster populations were discovered in these islands by the Westinghouse survey. Control efforts consisted of divers injecting formalin into large numbers of individual starfish where the animals were found in aggregations.

Questions naturally arose as to whether or not there was a numerical increase or decrease in the starfish infestations after the original survey, and whether or not the reefs of new geographic areas were being invaded. There was also a desire to assess the effectiveness of the Trust Territory control program.

On May 3, 1970, a meeting of persons interested in the Acanthaster problem in Micronesia was held at the University of Guam. The primary objective of this meeting was to discuss a continuous starfish-monitoring program for Guam and the Trust Territory. A program was designed that would provide biologists from the University of Guam Marine Laboratory to resurvey certain islands for further information about the starfish.

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The monitoring program had a fourfold approach: 1) to assess population levels and general movement of starfish in newly infested areas, 2) to locate additional reef damage incurred since the 1969 survey, 3) to assess the control teams' efforts in each district, and 4) to observe any recolonization of corals in previously killed areas. A continued surveillance program was also expected to provide information on population dynamics and spawning cycles of starfish as well as other information of biological significance (e.g. potential fisheries, pollution, or such general abuse as overfishing, dynamiting, or poisoning fish). The Trust Territory Marine Resources Division provided travel, per-diem, and logistic support; the University of Guam Marine Laboratory provided expertise. Travel and logistic support was also kindly provided by the U. S. Coast Guard and the U. S. Navy.

During the period from June, 1970, to May, 1972, personnel from the University of Guam and the Trust Territory resurveyed the island of Guam (Tsuda, 1970) and 13 of the 16 Trust Territory islands previously visited by the ten Westinghouse teams. The islands included Rota (Tsuda et al., 1970c), Saipan and Tinian (Tsuda et al., 1970b) in the Marianas; and Truk (Jones et al., 1970a), Nukuoro and Kapingamarangi (McDonald et al., 1970), Yap (Tsuda et al., 1970a), Palau (Tsuda et al., 1971a), Ponape and Ant (Tsuda et al., 1971b), and Lamotrek, Woleai and Ifalik (Bryan and Struck, 1971) in the Carolines. Also, Aguijan (Tsuda et al., 1970b), Kayangel (Tsuda et al., 1971a), and eight atolls in the Carolines (Bryan and Struck, 1971) were surveyed for the first time. In addition, a second resurvey was conducted a year later in Guam (Cheney, 1971), Saipan and Tinian (Marsh et al., 1972), Palau (Marsh and Bryan, 1972), Ponape (Wass, 1972a) and Truk (Wass, 1972b). During this latter period, Aguijan was resurveyed for the first time (Marsh et al., 1972).

The purpose of this paper is to summarize our findings on the population levels of Acanthaster planci and their resultant damage to coral reefs on 27 islands and atolls in the Mariana and Caroline Islands between 1969 and 1972. The information is based on the surveys and resurveys conducted thus far in this area, as well as on information reported at an Acanthaster workshop (Tsuda, 1972) held at the University of Guam in March, 1972.

METHODS

The basic field technique used in the original surveys and the resurveys was to tow two observers behind or alongside a boat at a speed of approximately two knots. The boat usually followed a zigzag pathway so as to provide a broader swath of coverage than would be the case if it travelled in a straight line. This allowed observations in both the shallower and

deeper portions of an outer reef slope, and gave a more complete coverage within a given area. Thus, large areas of reef could be examined in a relatively short period of time.

Observers scanned the bottom on their side of the boat and counted the Acanthaster and fresh feeding sites seen. Fresh feeding sites were identifiable as distinct white spots standing out in marked contrast to the darker surrounding bottom. These white spots represented recent coral kills where the starfish had eaten away the soft tissues and exposed the skeletal remains of the coral. Early experience indicated that whenever white spots were seen from the surface, starfish could usually be found by divers in the immediate vicinity even if the animals were not obvious from the surface. They were often found in crevices or under tabulate growth forms of corals or in other shaded areas.

It was at times difficult to distinguish white spots left by Acanthaster from those left by other reef organisms (e.g. the pillow star Culcita novaeguineae). However, Culcita feeding sites usually have a more regular rounded appearance. Furthermore, Culcita are incapable of climbing onto the staghorn and tabulate Acropora which are the preferred food coral of Acanthaster.

The fresh surfaces are soon colonized by filamentous algae and other organisms, and take on a drab appearance which merges with the appearance of the surrounding substrate. According to Chesher (1969a), white spots indicate a coral kill within the past 48 hours.

An area was designated as "infested", or considered to have abnormal numbers of Acanthaster, when more than 20 animals and/or white spots were seen by two observers in 20 minutes (the usual duration of a towing period). Hence, counts of white spots and Acanthaster were lumped together in these considerations, and an average count of more than one per minute of towing was the threshold value. On some occasions, only one person was towed by the boat; thus, an average count of more than .5 starfish or white spots per minute would then be the threshold value. This also allowed standardization of tow periods of shorter or longer duration, as well as the swims made in areas of extremely rugged terrain or shallow water. Spot checks, usually lasting a minute, were made in "sharky" areas. The techniques did, however, lead to difficulties in converting counts into numbers per unit of reef surface or numbers per linear unit of reef face. Hence, data were usually recorded as counts per minute of towing or swimming time.

Reef conditions reported in Table 1 were assigned according to the classification of Chesher (1969a). This provided a more extensive evaluation than simply designating an area "infested" or "not infested". A brief description of Chesher's classification scheme follows.

Condition 1 is considered a normal situation, with few A. planci and the reefs healthy and undamaged. This condition was assigned when fewer than one starfish per minute of towing (two observers) was found.

Condition 2 exists when concentrations of starfish and feeding sites are found in localized areas, with only slight damage to surrounding reef areas; there are no extensive dead reef areas. Chesher (1969a) considered this a "seed" population preliminary to a more extensive infestation. However, here we designate some reefs as Condition 2 without implying that we expect this to necessarily lead to larger aggregations of starfish or widespread reef damage.

Condition 3 denotes large populations of A. planci found with an extensive depth distribution; many of these are aggregated into herds. Damage to the reef is fresh and extensive, and patches of completely dead reef are interspersed with live reefs. Chesher considered this to be an intermediate stage of short duration.

Condition 4 represents a situation where large populations of starfish are aggregated into one or more fronts, leaving behind almost completely dead reefs. There may be thousands of individuals in these fronts.

Condition 5 describes extensive reef areas of all or part of an island composed primarily of dead coral, with the damage attributable to A. planci. According to Chesher, there may still be large numbers of starfish present, or most of these may have dispersed. In this paper we have been extremely careful in attributing dead reefs to A. planci unless we have evidence from at least one resurvey that damage can be definitely attributed to starfish infestations previously observed. We believe that it is assuming too much to attribute dead reef areas to starfish activity unless there is some documentation of such activity.

Condition 6 is Chesher's designation for a postulated condition in which there was a minor population explosion, apparently to the level of Condition 2, followed by dispersal. Chesher considered this condition as a hypothetical case which required further documentation.

Like Chesher (1969a) and Goreau *et al.*, (1969), we believe that the towing technique is effective for locating and defining the limits of major infestations of A. planci, for gaining an overview of general reef conditions, and for making a reasonable qualitative judgement of the effects of the predator on the reef. Large areas of reef can be covered. However, the technique is not effective for a precise population census; and our numbers of starfish and white spots recorded are approximate indicators of the total population.

RESULTS

Results of all surveys and resurveys conducted in the Mariana and Caroline Islands are elaborated below and also summarized in Table 1.

MARIANA ISLANDS

Guam: Information on the distribution of populations and migrations of A. planci on Guam from early 1967 to May, 1969, was presented by Chesher (1969b). The infestation began in 1967 on the leeward (western) side and spread over most of the leeward coast. One population rounded the northernmost point and continued down the windward coast. Much of this population has now been killed, but remnants of it still remain near Catalina Point. Scattered individuals have appeared further south on the windward coast. Some remnants of a second population are still found along the southern part of the leeward coast. Starfish and feeding sites can also be found commonly in the southern lagoon. There appears to have been a stabilizing trend in the last 18 months or so.

Saipan: Goreau et al. (1969) reported large numbers of starfish in the summer of 1969, concentrated primarily on the leeward (western) coast inside and outside the barrier reef. By August, 1970, almost all these starfish had disappeared, but the numbers reported in 1969 could not be accounted for in the records of the control team. In 1970 there was a small remnant population left on the western barrier. By October, 1971, the numbers of starfish and feeding sites were completely within normal limits, although there were extensive areas of mostly dead reef attributable to A. planci. Most coral areas on the windward side remain live and luxuriant.

Tinian: This island was reported as primarily dead in 1969, with above-normal populations of A. planci in several areas. Most dead areas were attributed to past starfish activities. Starfish worked both sides of the island, mostly on the outer reef slopes but with some coral kill on the reef flat areas. In 1970 expanded dead coral areas were noted in the localities of the 1969 infestations. There was a further decline in starfish numbers between August, 1970, and October, 1971, with only one small population found on a reef top inside the western fringing reef in 1971.

Rota: This island was reported as infested in 1969, with large numbers of A. planci and extensive reef damage. Further reef damage was found in 1970, but the starfish were declining in numbers. Apparently the situation was near stabilization in 1970.

Aguijan: This small island (less than 5 km long) was

surveyed for the first time in 1970 and found to have a major infestation in progress. The number of starfish was conservatively estimated at 4,000-5,000, and there was extensive coral damage. By 1971 all A. planci had disappeared, and almost all coral was dead. This island originally had only scattered corals colonizing a rock platform; there was never a true infrastructure formed by reef-building organisms.

WESTERN CAROLINE ISLANDS

Palau: Four localized areas with infestations were pinpointed in 1969; all of these had extensive dead coral when surveyed in 1970. There was a marked decline in A. planci numbers between 1969 and 1971, and the situation in 1972 was similar to that seen a year previous. Starfish and white spots can still be found commonly in the Seventy Islands, although this area is mostly dead now. No starfish have ever been seen outside the barrier reef, despite extensive surveys in 1971 and 1972.

Kayangel: Only nine fresh feeding sites and no Acanthaster were observed on this atoll near Palau. The reefs appeared normal and healthy.

Yap: Only a few starfish and feeding sites were seen in 1969 and 1970. Reports by local residents of increasing numbers of A. planci led to the establishment of a control team in 1971. This team reportedly killed over 5,000 starfish, apparently from widely scattered areas. There is no evidence of any major concentrations.

Woleai: A small population of A. planci and scattered coral damage was reported on the inner side of the barrier in both 1969 and 1971, but the animals were apparently well dispersed. The 1969 survey team felt that this was a situation which would bear watching, but there was essentially no change in the next 22 months after their survey.

Ifalik: Only three starfish were found in 1969. No starfish, but 41 feeding sites, were found in 1971. The reefs were healthy, and the status did not change in 22 months.

Lamotrek: Only one starfish was reported in 1969. A minor infestation appeared to be in progress in 1971, with four Acanthaster and 96 feeding sites reported. The reefs generally were reported as "lush, normal, and healthy" both times.

Eauripik, Elato, Faraulep, Olimarao and Satawal: These islands were surveyed for the first time in 1971. There were signs of minor infestation at Faraulep; but, in general, all reefs appeared normal and healthy.

CENTRAL CAROLINE ISLANDS

Truk: Areas of major infestation were found in 1969. In 1970 these areas had more extensive dead reef. Apparently a major infestation continues to this day, even though large numbers of Acanthaster have been killed. Starfish have been found outside the barrier reef and on numerous patch reefs inside the lagoon. They have been more common on lagoon patch reefs than outside the barrier in recent months. Truk has the largest lagoon in Micronesia, and its barrier and patch reefs have not been thoroughly surveyed since 1969.

Kuop: This small atoll near Truk had only one specimen of A. planci in 1969, but all its reefs appeared to have been substantially killed off at some time in the past. There is no convincing evidence that the kill was due to Acanthaster.

Puluwat, Pulap, and Pulusuk: These islands were also surveyed for the first time in 1971. Only 25 starfish were seen on these three islands. A minor infestation was observed on the outer western reef of Pulusuk, but all reefs examined appeared normal and healthy.

EASTERN CAROLINE ISLANDS

Ponape: This island was rated Condition 4 by Chesher, who believed that it had recently passed from Condition 3. We rate it Condition 3 for 1971 and 1972 and believe that Condition 3 may have been a better assessment of the 1969 situation. Large numbers of starfish have been reported killed by the control team. There has been significant Acanthaster activity both inside and outside the barrier reef.

Ant: This small atoll near Ponape was reported as essentially dead by the 1969 survey team. However, the 1971 team found large areas of exceedingly luxuriant reef in localities where the 1969 team had not surveyed. The 1971 team also corroborated the 1969 team's findings of large areas of dead coral but did not feel that these could necessarily be attributed to Acanthaster. Both teams saw small numbers of starfish.

Mokil: This island was surveyed briefly in 1969. There were scattered A. planci along the entire western coast but not enough to prevent the reefs being classified as normal.

Pingelap: The entire barrier reef and lagoon were surveyed in 1969. There was some question as to whether this should be classified as Condition 2 or Condition 6. Along the southern and western coasts there were relatively large numbers of A. planci and numerous freshly killed corals, as well as much algae-covered coral. Elsewhere the reefs appeared normal.

Chesher believed that Pingelap had a seed population that had not had enough recruitment to continue rapid expansion. Pingelap has not been resurveyed.

Nukuoro: There was a fairly large A. planci population in 1969 and some dead coral areas. The atoll was resurveyed in 1970, and a team member who went on both surveys estimated that there had been a population increase of 30-40% over the 1969 condition. He still considered the starfish population to be within normal limits, however.

Kapingamarangi: Small numbers of A. planci were seen in 1969 and 1970, but the reefs were considered normal and healthy both times.

DISCUSSION

The resurveys show that there has been a definite overall decrease in Acanthaster planci populations since the original survey in the summer of 1969. In no case has there been a major new starfish outbreak since that time, with the probable exception of Aguijan. There has not been a major advance of an outbreak from Condition 2 to Condition 3 or from Condition 3 to Condition 4.

Of the islands reported as Condition 4 in 1969 (Guam, Saipan, Rota, Truk, and Ponape), there has been a marked decrease in starfish numbers on three islands (Guam, Saipan, and Rota) and a slight decrease on two islands (Truk and Ponape). Hence, Guam, Saipan, and Rota are now listed in Condition 5 because they have passed beyond Condition 4, even though these islands still have extensive areas of healthy reef. Truk and Ponape apparently still have large numbers of A. planci but have much live reef remaining as well; hence, they are downgraded to Condition 3.

Of the other islands surveyed and resurveyed from 1969 to 1972, two larger islands (Yap and Palau) and a number of smaller islands have not experienced a major Acanthaster infestation. Palau apparently passed from Condition 2 to Condition 6 without having a large-scale outbreak, and there is no evidence that Yap ever had higher than normal starfish counts.

We attribute the marked overall decline in A. planci infestation on these islands at least in part to control efforts, which have resulted in the killing of approximately 280,000 starfish (as of February, 1972)--63,000 in Guam, 14,000 in the Mariana District, 16,000 in the Palau District, 5,000 in the Yap District, 113,000 in the Truk District, and 69,000 in the Ponape District. The case is most clearly documented for Guam, where control efforts obviously broke up the large migrating herds reported by Chesher (1969b). This situation probably

applies to Saipan as well. We also suspect that control efforts in Palau prevented the infestation there from advancing beyond the level of Condition 2.

An exception to the suggestion of control activities as the cause of population decline is the situation that occurred on Aguijan, a small uninhabited high island in the Marianas. Personnel on the August, 1970, survey counted 3753 Acanthaster on the upper terrace and seaward slope around this island. In contrast to our original observations, only a single starfish and three feeding sites were seen during the resurvey in October, 1971. No control efforts were ever carried out on Aguijan. This is also the only case where the starfish simply migrated elsewhere on their own after killing almost all of the corals around the island.

CONCLUSION

Based on our three-year surveillance of the population levels of Acanthaster planci in the Mariana and Caroline Islands, we conclude that this organism is definitely on the decline and currently poses no widespread threat to the remaining reefs of Micronesia. This conclusion is based on repetitive field observations of the same areas, in contrast to the speculation which has characterized much of the discussion of the Acanthaster problem.

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Table 1. Summary of results of surveys and resurveys, 1969-1972.

ISLAND	DATES SURVEYED	CONDITION	TOTAL MAN-HOURS	TOTAL A. PLANCI	TOTAL FEEDING SITES	LOCATION OF POPULATIONS
MARIANA ISLANDS						
Guam (High island)	Nov. 68- Aug. 69	4	-	-	-	Outside W & N fringing reef
	Sept. 70	5	46	418	956	Outside NE & W fringing reef; southern lagoon
	April 71	5	-	-	-	Same as Sept. 70
Saipan (High island)	July 69	4	ca 25	1880	-	Outside & inside western barrier; NE tip
	Aug. 70	5	16.9	53	355	Western barrier
	Oct. 71	5	13.6	2	20	None
Tinian (High island)	July 69	5	29.7	324	-	Outside eastern fringing reef; outside western fringing reef; northern tip
	Aug. 70	5	13.5	189	258	Same as July 69
	Oct. 71	5	5.3	34	37	Inside western fringing reef

ISLAND	DATES SURVEYED	CONDITION	TOTAL MAN-HOURS	TOTAL A. PLANCI	TOTAL FEEDING SITES	LOCATION OF POPULATIONS
Rota (High island)	July 69	4	13.0	2926	-	Outside southern fringing reef; outside N fringing reef
	Oct. 70	5	16.0	369	392	Outside SE fringing reef; outside N fringing reef
Aguijan (High island)	Aug. 70	4	4.3	3753	ca 5000	Continuous around island
	Oct. 71	5	4.0	1	3	None
WESTERN CAROLINE ISLANDS						
Palau (Group of high islands surrounded by barrier)	April 69	2	-	-	-	N fringing reef inside barrier; patch reefs inside lagoon; reef tops near harbor entrance
	Jan. 71	6	63.0	179	1079	Patch reefs inside lagoon
	Jan. 72	6	69.8	201	889	Patch reefs inside lagoon; inside W barrier
Kayangel (Atoll)	Jan. 71	1	3.3	0	9	None

ISLAND	DATES SURVEYED	CONDITION	TOTAL MAN-HOURS	TOTAL A. PLANCI	TOTAL FEEDING SITES	LOCATION OF POPULATIONS
Yap (High islands surrounded by barrier)	July 69	1	-	20	-	None
	Nov. 70	1	36.4	11	173	Outside W barrier
	May 71-Feb. 72	1	-	5270	-	Scattered individuals inside & outside barrier
Woleai (Atoll)	July 69	1	17.0	ca 20	-	Inside W barrier
	May 71	1	2.7	1	76	Same as July 69
Ifalik (Atoll)	July 69	1	ca 17.5	3	-	None
	May 71	1	3.7	0	41	None
Lamotrek (Atoll)	Aug. 69	1	31.5	1	-	None
	May 71	1	10.0	4	161	Outside SW & N reefs
Eauripik (Atoll)	May 71	1	2.7	2	27	Outside S reef
Elato (Atoll)	May 71	1	.3	0	7	None
Faraulep (Atoll)	May 71	1	2.0	1	82	Scattered outside reef
Olimarao (Atoll)	May 71	1	4.0	0	30	Scattered outside reef

ISLAND	DATES SURVEYED	CONDITION	TOTAL MAN-HOURS	TOTAL A. PLANCI	TOTAL FEEDING SITES	LOCATION OF POPULATIONS
Satawal (Island with fringing reef)	May 71	1	1.7	0	24	None
CENTRAL CAROLINE ISLANDS						
Kuop (Atoll)	July 69	5	-	1	-	None
Truk (Group of high islands surrounded by large lagoon and barrier reef)	July-Aug. 69	4	125.5	463+	-	N outer edge of barrier; outside barrier near NE pass; patch reefs inside lagoon
	June 70	3-4	-	-	-	Same as July 69
	July 72	3	11.7	35	321	Patch & fringing reefs inside lagoon
Puluwat (Atoll)	May 71	1	2.7	1	12	None
Pulap (Atoll)	May 71	1	5.3	6	83	Outside NW reef
Pulusuk (Island with fringing reef)	May 71	1	1.7	18	36+	Outside W & SW reef
EASTERN CAROLINE ISLANDS						
Ponape (High island with barrier reef)	July-Aug. 69	4(3)	28.0	477+	-	Inner portion of S barrier reef; inner portion of NE barrier; inner & outer portions of N barrier

ISLAND	DATES SURVEYED	CONDITION	TOTAL MAN-HOURS	TOTAL A. PLANCI	TOTAL FEEDING SITES	LOCATION OF POPULATIONS
	April 71	3	30.4	298	ca 2400	Outside entire W, N, & NE barrier; scattered localities on inner portion of barrier
	Feb-Mar. 72	3	39.0	353	1792	Inside & outside SW barrier & patch reefs inside SW lagoon; outside NE barrier; inside & outside reef near E pass
Ant (Atoll)	July 69	5	11.2	54	-	Inner portion of reef; lagoon side of SE pass
	April 71	2	2.0	1	133	Outside NE tip of reef; outside NW tip of reef
Mokil (Atoll)	July 69	1	-	-	-	None
Pingelap (Atoll)	July 69	2	29.0	38	-	Outside S & W reef
Nukuoro (Atoll)	July-Aug. 69	6	-	-	-	Outside S reef
	July 70	6	-	-	-	None
Kapingamarangi (Atoll)	July 69	2	-	-	-	Inside SW reef; outside SW reef
	July 70	1	-	-	-	None