# *Acanthaster planci* Population Survey on the North Coast of Moorea, French Polynesia

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**Abstract:**

Recent increases in observations of *Acanthaster planci* in lagoons on the North Coast of Moorea, French Polynesia have prompted a population survey on both the outer reef slope and inside the lagoon. Nine transects were performed along the coast between (S 17°28.971', W 149°54.130'; & S 17°28.65', W 149°50.75'). *A. planci* population was found to be very patchy. Timed surveys using SCUBA showed the population of stars on the outer reef slope to be concentrated in a depth range between 15-30m, with a high concentration 40/Ha near one of our transects. Measured density transects were performed at this site and the density was shown to be 4,000/km$^2$, higher than the 6/km$^2$ baseline for the western Pacific. Transects inside the lagoon were between 120-220/km$^2$ for three areas surveyed. The overall *A. planci* population appears slightly higher than normal when sampling difficulty, and error margins are factored in.

**Introduction**:

*Acanthaster planci*, the Crown-of-Thorns Sea Star (CoT), is a voracious predator upon sclaractinean corals. They feed by externally digesting the soft tissues from corallites in a colony. After feeding, a white bleached area referred to as a feeding scar is left behind. Feeding scars provide opportunity for algal settlement. At outbreak densities, *A. planci* kills substantial portions of the reef corals in localized areas of the tropics. As the bulk of the hard coral cover of a reef is destroyed, a switch from a coral-dominated to an algae-dominated community occurs. Increased surface cover by algae leads to decreased topographic complexity of the reef, and an increased carrying capacity of herbivorous fishes. This leads to a decrease in reef community species abundance, diversity, and loss of habitat. A study reef at Irimote Island, Japan was reduced to unstructured coral rubble within 4 years of an *Acanthaster* outbreak, (ENDEAN 1977, MADL 2002). In recent years, the sea star impact on reef ecosystems seems to have an additional detrimental effect on the already stressed coral communities (coral bleaching due to the rise in sea surface temperature) (MADL, 2002).

Fig. 1: Feeding scar.

Fig. 2: Adult *Acanthaster* with large feeding scars.

Primary infestations occur on reefs due to factors peculiar to those reefs, or the waters around those reefs. Many hypotheses have been proposed as to the cause of primary infestations, however, many are conflicting and the infestations continue to occur nonetheless. Secondary infestations occur due to large numbers of larvae from primary infestation centers being carried by currents, or by migration of adults from devastated reefs to other reefs. (Endean 1977).

According to Madl, outbreaks on the Great Barrier Reef, Australia (GBR) last for about 4-5 years (may differ from reef to reef) and end suddenly once food becomes scarce and/or the sea stars die of diseases. The time frame between these outbreaks has been roughly15 years, enough time to allow fast growing coral species to recover to pre-outbreak levels (MADL, 2002). The current conditions coupled with the typical time frame between outbreaks may indicate the onset of a new infestation.

Acroporids, (*Acropora* and *Montipora*), are the most common group of corals grazed upon by *A. planci*. *Acanthaster* has been shown to commonly graze on all species of *Acropora*, as well as on *Montipora, Porites, Favia*, and *Pocillopora.* In the case of *Pocillopora,* the central part of the largest colonies are generally void of feeding scars and alive, perhaps because of the difficulty for a sea star to insert gastric folds between central branches, or because of defense by crustacean symbionts (GLYNN 1981, cited by FAURE, 1989). *Acropora* and *Pocillopora* are relatively fast growing genera, though in areas of severe infestation, these corals cannot compete with fast growing algae. (FAURE 1989). *Acropora* and *Pocillopora* compose the bulk of the reef on the outer slope in Moorea. (CHANCERELLE, pers com).

Several studies have been conducted over the past 40 years on the presence of *Acanthaster* on the Great Barrier Reef, while relatively few studies have been published on *Acanthaster* in French Polynesia. The normal population density of adult *A. planci* is of the order of $6/km^2$ in the Western Pacific and $1/40\text{-}100m^2$ in the Eastern Pacific (CAMERON, 1977).

A study by Gerard Faure, published in 1989, describes the last major outbreak of *A. planci* at Moorea, French Polynesia. The last major infestation of *Acanthaster* at Moorea occurred between 1982 and 1986. Extensive field observations along with results of selective and past predation by *Acanthaster* suggest in retrospect that a large amount of coral destruction is attributed to this outbreak. In one area surveyed, near Taotoi Pass on the northwest coast of Moorea, the damage observed amounted to more than 35% of the 2500-3000 $m^2$ of living substrates being destroyed and a total of 30-50 *A. planci* counted in 20 minutes (FAURE, 1989).

Studies by Fagerstrom show that reefs on Moorea showed signs of recovery from 1987 to 1991. Median live coral cover within 28 $1/4m^2$ quadrats increased from 14% to 38% between 1988-91, and species diversity increased from 8-9 spp. to 15 corals. (FAGERSTROM, 1992).

Studies by the French Polynesia Coral Monitoring Network have shown present coral cover on Moorea to be highest since 1992. They have also observed a noticeable increase in the numbers of *A. planci* over the past two years (CHANCERELLE, pers com). This increase in the numbers of *Acanthaster* may indicate the beginning of a primary infestation, or may simply be a naturally direct correlation to this rich coral cover. The presence of both juvenile and adult *Acanthaster* in the lagoon may, at the very least, indicate a distinct change in the population or distribution.

One important thing to consider in the case of an outbreak is whether it is an episodic or an ongoing event. One way we will attempt to do this is to look for juvenile specimens and compare sizes of adults. Zann et al. (1987, cited in DOHERTY and DAVIDSON, 1988) showed that local outbreaks of *Acanthaster* might arise from a single strong recruitment of juveniles.  Juvenile *Acanthaster* 0-15 cm show strong nocturnal behavior and tend to inhabit shallow areas near the reef crest, hiding deep within the coral heads.  During the first 10-12 months of benthic development, juveniles range between 0-3cm.  Because of their small size, and cryptic behavior, there are large gaps in our understanding of the demographic and population dynamics of the species, most importantly the lack of information concerning the ecology of the juveniles (DOHERTY and DAVIDSON, 1988).  Due to these constraints, past studies have found destructive methods of surveying for juveniles on coral reefs in the GBR to be most successful. In this sampling method, all corals along a transect line are overturned and searched for the <3cm juveniles. This is a very labor and time intensive approach, and causes tremendous damage to the reef.

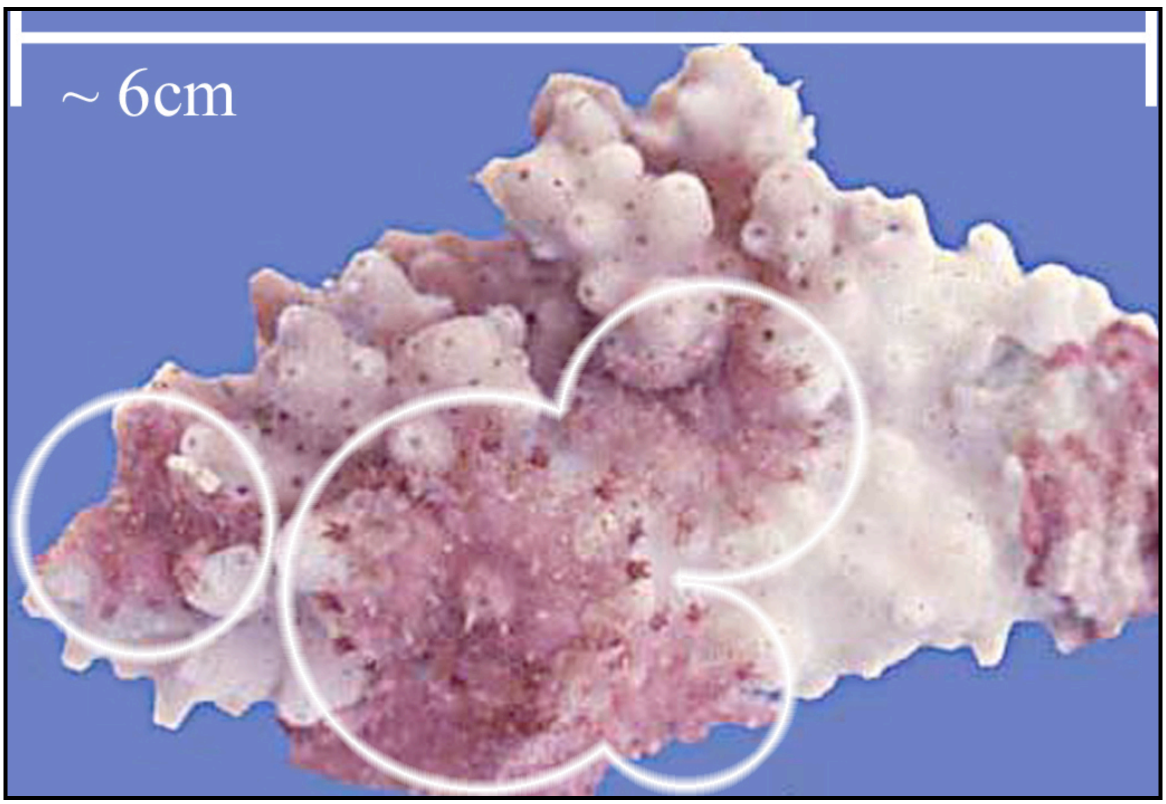


Fig. 3:  *Acanthaster* recruits; <3cm.

The goal of our study is:

- To determine if the number of *A. planci* on the north coast of Moorea is presently above the "normal" levels of $6/km^2$ for the Western Pacific
- To assess the local population in relative terms of high or low for the area.
- In addition, we intend to search for any patterns in spatial distribution in the population, both on the outer reef slope, and in the lagoon.

**Methods:**

A survey was conducted by way of nine transects, 100m apart, five on the West side of Opunohu Bay, and four on the East side.

**Transects outside the reef crest:**

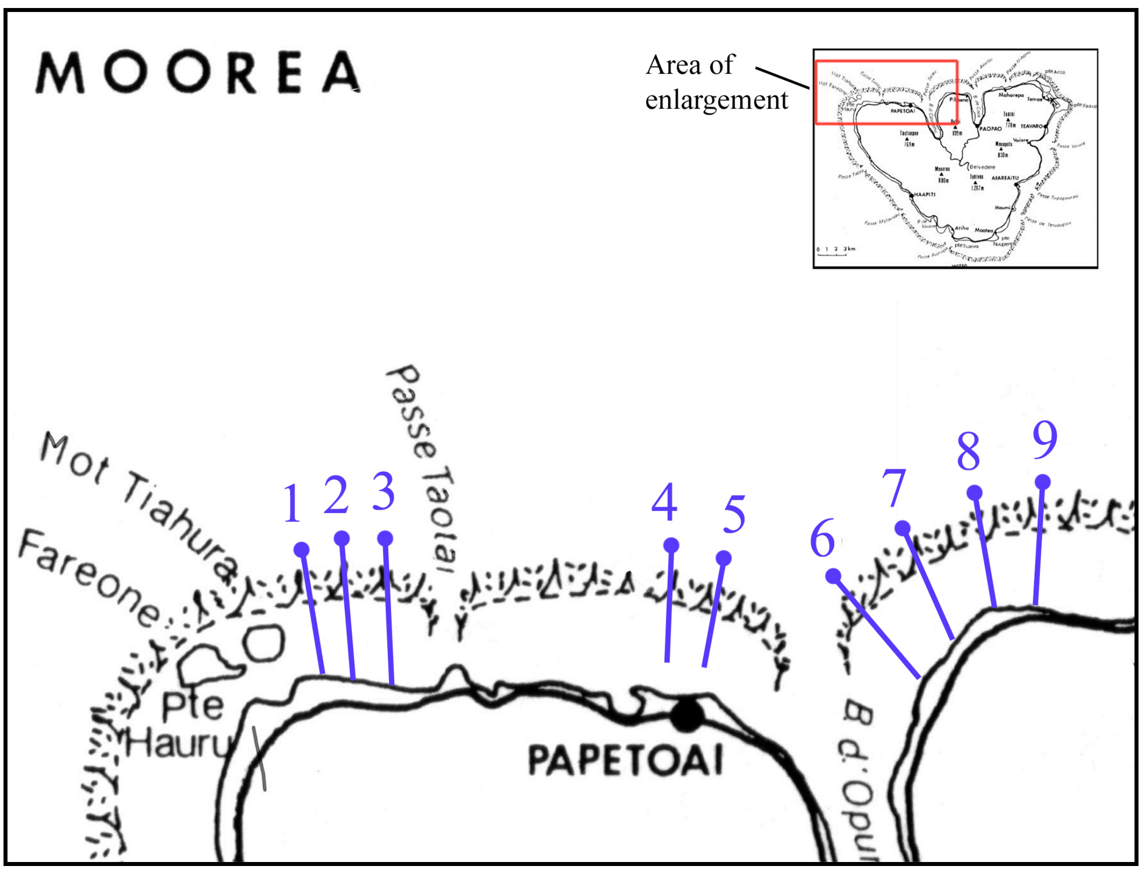


Fig. 4: Location of transects.

Transects on the outside of the reef began at a depth of 90ft and continued from the bottom of the nearest spur to the crest. Two divers on SCUBA performed a timed transect of the reef from ninety feet for twenty minutes, or until conditions became unsafe due to swell near the crest. The location of each star was denoted by depth for those found outside the crest. For each star found, the genus and shape of the coral the star is on, the amount of live coral cover within a 2m box around each star, and the presence or absence of a feeding scar within that 2m box around the star was documented.

On the west side of Opunohu Bay, the Tihura transect was surveyed (S 17°28.872'; W 149°53.891'), as well as two more transects to the west of the Tihura marker buoy (S 17°28.971', W 149°54.130'; & S 17°28.978', W 149°54.007'). Two additional transects were performed to include the West Opunohu site (S 17°28.864", W 149°52.651'; & S 17°28.963, W 149°52.114). Transect # 4 at West Opunohu was treated as two distinct transects because it was performed using two sets of divers. The westernmost transect # 4 is labeled as such in our data, and the easternmost is labeled as transect # 4-2$^{nd}$. On the east side of Opunohu Bay, four transects were performed beginning at Public Beach (S 17°28.697', W 149°51.041') and three more sites including the Viapahu transect, (S 17°28.648', W 149°50.860'; S 17°28.586', W 149°50.664'; S 17°28.65', W 149°50.75').

We included an additional dive to perform three area transects at the West Opunohu site as a comparison to the timed surveys. This site was chosen because of the occurrence of several stars on a single spur during one of the timed transects. Each of these area transects were 15m wide X 50m long, for an area of 750m. They were performed at 52ft, 67 ft, and 82 ft depth to cover a depth range from 45 ft to 90ft. Each transect was performed at a constant depth, parallel to shore. The transects covered roughly an entire spur.

**Transects inside the lagoon**

Transects inside the lagoon were performed by snorkeling. The same data were taken with the exception of depth and time, since depth was seldom more than two meters in most of the lagoon, and the transects were to determine density/m$^2$. Using maps of the lagoon, the distance between the crest and shore was calculated to determine the area surveyed. The locations of stars were also noted on the map to be analyzed for any spatial distribution pattern within the lagoon. Transects in the West Opunohu region were done from the crest to the boat channel. From the boat channel to shore, the lagoon was too shallow (<0.5m) and algal cover was too great to warrant sampling. In the Public Beach region, transects were done from the crest to the shoreline, where patch coral was found for the total length of the transects.

In an additional attempt to locate juvenile Crown-of-Thorns, we made two separate night surveys at White House Wall and Public Beach. These were not measured transects, but merely observations to see if there was a difference in the distribution of juveniles between night and day within the lagoon.

**Results**

Outside:

The outside transects are treated as three distinct areas or sites due to the patchiness of the *Acanthaster* population. From west to east, the sites are Tiahura (TIH), West Opunohu (WO), and Public Beach (PB). The site mean is presented as average number of adult stars per 20-minute dive for the site. Table 1 lists the number of adult *A. planci* found on each outside transect. The site mean was taken by dividing the number of stars found by the number of transects at each site.

| SITE | TRANSECT # | # ADULT *A. planci* | SITE MEAN |
|---|---|---|---|
| TIH | 1 | 5 | 3.3/20 min. |
| TIH | 2 | 3 | 3.3/20 min. |
| TIH | 3 | 2 | 3.3/20 min. |
| WO | 4 | 3 | 5.3/20 min. |
| WO | 4, 2nd transect | 13 | 5.3/20 min. |
| WO | 5 | 0 | 5.3/20 min. |
| PB | 6 | 0 | 0/20 min. |
| PB | 7 | 0 | 0/20 min. |
| PB | 8 | 0 | 0/20 min. |
| PB | 9 | 0 | 0/20 min. |

Table 1: Number of *A. planci* per twenty minute transect. Note: Site means are included to demonstrate the discrepancy between actual counted numbers, and statistical mean when sampling patchy population.

| DEPTH (m) | LENGTH (m) | WIDTH (m) | AREA ($m^2$) | # CoT | DENSITY (Ha) #/10,000$m^2$ |
|---|---|---|---|---|---|
| 16 | 50 | 15 | 750 | 0 | 0 |
| 20.4 | 50 | 15 | 750 | 4 | 53/10,000$m^2$ |
| 25 | 50 | 15 | 750 | 5 | 67/10,000$m^2$ |

Table 2: Density in $m^2$ for measured area transects, on second dive of transect # 4.

Table 2 lists the number of *Acanthaster* found per 750$m^2$ measured from transect # 4. Density per hectare was calculated by dividing the number of CoT's found per transect by 750$m^2$, and multiplying by 10,000$m^2$.

| TOTAL # STARS | TOTAL AREA ($m^2$) | #/Ha | #/$km^2$ |
|---|---|---|---|
| 9 | 2250 | 40/10,000$m^2$ | 4,000/$km^2$ |

Table 3: Extrapolation to $km^2$ from transect #4 density data.

Table 3 lists density per $km^2$ using the total number of stars counted on transect # 4. Measured density from all three depths at transect # 4 was found to be 4,000/$km^2$.

Lagoon:

The transects inside the lagoon were treated as two separate regions, separated by Opunohu Bay, West Opunohu and Public Beach**.**

| TRANSECT# | SITE | LENGTH (m) | WIDTH (m) | AREA ($m^2$) | # CoT | #/Ha | #/$km^2$ |
|---|---|---|---|---|---|---|---|
| 1 | WO | 380 | 5 | 1900 | 0 | 0 | 0 |
| 2 | WO | 380 | 5 | 1900 | 0 | 0 | 0 |
| 3 | WO | 380 | 10 | 3800 | 1 | 2.6/10,000$m^2$ | 260/$km^2$ |
| 4 | WO | 310 | 5 | 1550 | 1 | 6.6/10,000$m^2$ | 660/$km^2$ |
| 5 | WO | 472 | 10 | 4720 | 1 | 2.1/10,000$m^2$ | 210/$km^2$ |
| 6 | PB | 264 | 15 | 3960 | 0 | 0 | 0 |
| 7 | PB | 740 | 5 | 3700 | 1 | 2.7/10,000$m^2$ | 270/$km^2$ |
| 8 | PB | 264 | 5 | 1320 | 0 | 0 | 0 |
| 9 | PB | 800 | 10 | 8000 | 1 | 1.3/10,000$m^2$ | 130/$km^2$ |

Table 4: CoT Data for Lagoon Transects

Overall density of *Acanthaster* in the lagoon was determined to be 1.6/10,000m$^2$. Density at West Opunohu and Public Beach sites were 2.2/10,000m$^2$ and 1.2/10,000m$^2$ respectively.

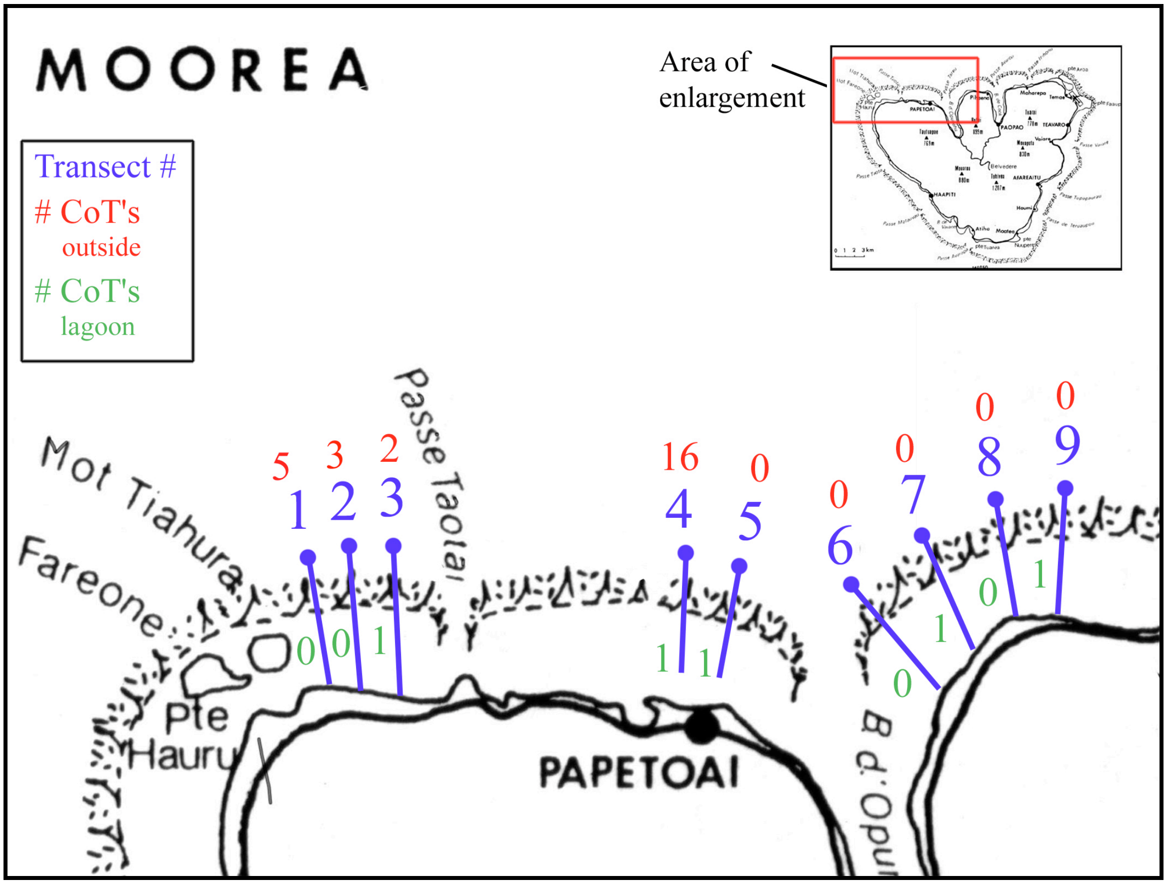


Fig. 5: #of *Acanthaster* on each transect.

**Discussion**

**Outside**

The naturally rare and patchy distribution of *Acanthaster* was probably the most difficult factor in this survey. Choosing random sample areas to statistically project the population would yield false results. In order to provide an accurate estimation of *A. planci* populations when they are not at obvious infestation levels (30-40/km$^2$, or 30-50 CoT/20 min.) (Faure 1989), each spur would have to be surveyed across the entire reef concerned. This point was made clear when the timed transect # 4 was performed. We had the opportunity to use two extra divers and treat it as two transects along neighboring spurs. The first spur chosen had 3 adult *A. planci*. The alternate spur was chosen by the fact that the other two divers descended along it. It was a neighboring spur, roughly 25m away from the first, at the base of the reef, and thirteen stars were surveyed during a 20 min. transect. Clearly this demonstrates a need for high resolution in studies of populations whose distributions are compounded by rarity and patchiness. Our first transect areas, Tiahura and Public Beach, were chosen following the reports from local researchers who had seen *Acanthaste*r in those areas recently. West Opunohu, where we found the highest concentration of stars, is between the other two areas, and was added later because more opportunities to survey the outside were made available to us well after our study began. Again, this demonstrates that this study would have yielded inaccurate results had we extrapolated population size from statistical data for a larger area than was actually surveyed.

Our study was constrained by resources and diving safety procedures. Most dives were performed using NAUI dive tables as a safety precaution. This allowed for a maximum of 20 minutes of diving at 90ft., including descent time. Many of our timed transects were shorter than 20 minutes. This complication may have been negligible in the amount of area surveyed because the stars on the outside reef slope were found within a depth range of 50-90 ft. Due to the tendency of juveniles (0-19 cm) to hide during daylight hours, the surveys may have yielded greater numbers of smaller stars by way of a more thorough search of the area, had safety constraints allowed for the use of computers in dive planning instead of tables. Greater time allowed at depth would have made the use of meter tape and a measurable density/area survey possible, as demonstrated by the three additional transects performed on transect # 4. Among other constraints were the availability of boats, staff, divers certified to 90ft, and time shared with the projects of other students. These resources were overextended already and could not be extended further for this study.

Small areas of transects # 5, # 6, and # 7 appeared to have minute feeding scars (white, structurally normal spots) on *Acropora*, and *Pocillopora* spp. We speculated that these might have been feeding scars from juveniles that were hiding during daylight.

Nighttime surveys were not logistically possible due to the threat of predation on divers by sharks. More thorough surveys for juveniles on SCUBA in shallow water near the reef crest were limited by the danger of injury from diving in unpredictable surge. These would also have required the physical removal of corals to search within and underneath for smaller stars. This method would have been fairly destructive. Due to the difficulties of surveying these animals, a high degree of error should be assumed for any statement of population size or density, to the effect that too few animals would have been counted.

The distribution of adult *Acanthaster* on the outer reef slope was limited to a depth range between 15-30m with the majority nearer the lower depths. The three areas surveyed, Tiahura (TIH), West Opunohu (WO), and Public Beach (PB), are separated by passes. Totoai pass, between TIH and WO is shallower than the pass at Opunohu Bay, which separates WO from PB. It is worth noting the possibility that adult stars may be walking west from the area near transect # 4. A significant amount of coral within the measured transects appeared covered in algae, though no effort was made at the time to quantify this.

**Lagoon**

Low densities reported by this study for individuals of *Acanthaster* inside the lagoon may not represent the true distribution of the species in this region of Moorea. Several sightings were made of individuals inside the lagoon at times outside of specified transects. These individuals existed both inside and outside of the transect lines surveyed in this study. At Public Beach, six individuals were observed in a relatively small area (roughly $2000m^2$). These sightings confirm the patchiness of individuals inside the lagoon and demonstrate that their distribution cannot be determined on statistical grounds alone. A more comprehensive sampling method should be employed for future studies; perhaps narrowing the distance between transects to allow for the patchiness of the sea stars, as well as a more thorough method for looking inside and beneath the crevices of branching and massive corals.

An interesting aspect of the distribution of *A. planci* in these study sites is the lack of individuals found on the outside crest at depths shallower than 16m. Compared to the number of stars found inside the lagoon, at much shallower depths, it seems improbable that distribution is limited by depth. From our observations, there is also an abundance of food sources (i.e. rich coral cover) in this region. One plausible explanation for this gap in distribution may be the high wave action on the upper slope of the outside crest. Individuals of *Acanthaster* may prefer the low wave action of the lower slope while those found inside the lagoon may have washed in as larvae and are inhibited from returning to the outer slope due to the high wave action breaking over the crest. Further research into this aspect of distribution is needed before further conclusions can be made.

There were also noticeable differences in the feeding patterns between the stars found on the outside and those found inside the lagoon. A feeding scar accompanied nearly all individuals of *Acanthaster* found on the outside, while those found in the lagoon were nearly all void of feeding scars. The feeding scars found on the outside were very conspicuous white patches on the coral, while the few we did see on the inside were smaller and subtler. This, along with differences in depth that individuals were sighted, may suggest a difference in the behavior or feeding pattern. Individuals found on the outside were only found at depths exceeding 45 ft and appeared to be avid feeders, while those found inside the lagoon existed in one to two meters and did not appear to be feeding at a rate that would cause noticeable damage to coral. More research would need to be done into this to make a distinction between the feeding behaviors and activity rate of individuals inside and outside of the lagoon.

In order for a recruitment of juveniles to be significant, it must be strong enough to overcome predation by filter feeding organisms, which passively feed on eggs and larvae. These are mainly Porifera, Bivalvia, and Tunicata. Unfortunately, in many tropical countries, shelled filter feeders have been extensively collected by the curio trade. Factors that influence a strong recruitment are nutrification and eutrofication of costal waters, which increase the growth of phytoplankton (a main food source of juveniles <1 year old). This nutrification comes from runoff during heavy rainfalls and can be compounded by anthropogenic factors such as costal development or runoff from agriculture.

Considering that the "normal" population of *A. planci* has not been previously surveyed, reports of increased sightings of adult stars by other researchers, and the difficulty in sampling methods, it appears that the current population of CoT's on Moorea is slightly high for the areas sampled in this study when compared to the baseline of $6/km^2$ for the West Pacific. The population observed may be the beginning of a primary infestation on the North Coast of Moorea; however, a complete survey of the island would be needed to determine if the population is limited to the area of outer reef near the West Opunohu site. If there is a larger population on another reef of the island, the West Opunohu site itself may be a secondary infestation, owing to an influx of larvae from a different reef on Moorea. Elevated populations of *Acanthaster* have been reported on other islands (Riatea, Bora Bora) in the Society archipelago as well (CHANCERELLE pers. comm.). In light of this, any increase in the population on Moorea is likely not the result of localized processes. This study was undertaken with the intent that the information it provides will be useful in future studies and in monitoring of the *Acanthaster* population on Moorea. Documentation of this population in its current state may provide an opportunity to study the transition of a small population into outbreak levels, should it grow significantly in the next few years.

A more comprehensive future study which includes: % coral eaten by CoT's, any change in coral composition, % coral covered by algae, measured density for high population areas, higher transect resolution for the whole island, and extensive search for juveniles, may prove useful in putting this current population into perspective, and monitoring its change. Future experiments to track larval dispersion, and testing/modeling of *Acanthaster* predation as a selective force in the evolution of hermatypic corals could be useful. In any case, we would strongly suggest that an annual monitoring study should be carried out concerning this population.

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