

An Analysis of the *Acanthaster* Control Programs in Guam and the Trust Territory of the Pacific Islands¹

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Abstract

The crown-of-thorns starfish, *Acanthaster planci*, has been subjected to extensive control programs in Micronesia in an effort to decrease population densities and to reduce probable reef destruction. The kill data from these programs were compiled for the years 1970 through 1972 and summarized and analyzed for important variable components. Detailed analyses were possible only for Ponape, Truk and Guam. Generally, within an island group, the total number of starfish killed or seen declined following an extended period of starfish control; however, the kill per unit of effort (man-hour in water) remained relatively stable, ranging from 4 in Palau to 18 in Ponape. The total kill per unit of effort (effort based on total man-hours worked) ranged from 1.4 in Palau to 5.2 in Truk. The areal and time patterns of control activities are discussed in relation to the monitoring programs and show with few exceptions good correlation between the results of the control program and the predictions and recommendations of the survey teams. Recommendations are made concerning the influence of certain variables and data keeping procedures in determining the effectiveness of control programs.

INTRODUCTION

The populations of *Acanthaster planci* in Micronesia are subsiding after reaching in the late 1960's what have been termed "plague" conditions on many of the islands (Chesher, 1969a, 1969b; Marsh and Tsuda, 1973). Because of the obvious damage that these large numbers of starfish could inflict upon the coral community of a reef, it was strongly recommended in the initial surveys that starfish control programs be established on islands hardest hit by *Acanthaster* in an effort to limit reef destruction (Chesher, 1969a). Control was first initiated in Guam in late 1968. Programs were subsequently established in the Mariana, Palau, Truk, Ponape and Marshall Islands Districts of the Trust Territory of the Pacific Islands.

Of these programs, only those in Truk and Ponape were still functioning in 1973. The other island groups possessed insufficient starfish for the maintenance of their control programs, as the populations had apparently generally reached

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"normal" levels. Additionally, concomitant monitoring surveys conducted throughout the 1969-1973 period produced evidence of declining or at least stable populations in all areas. With one minor exception where adequate control had not been carried out, there has not been a major starfish outbreak since 1969 (Marsh and Tsuda, 1973).

A large number of starfish were destroyed by the control teams. In the Trust Territory the number totaled more than 220,000 by mid-1972. On Guam nearly 70,000 were taken by paid and volunteer control teams from 1968 through 1972. Despite these figures, there is no conclusive evidence that *Acanthaster* control precipitated or accelerated the decline in overall starfish populations. Marsh and Tsuda (1973) employing monitoring data attributed this decline at least in part to control efforts, particularly in Guam, but also in Saipan and Palau. This conclusion is in line with the original assumption of Chesher (1969a) that starfish control will prevent undue destruction of coral reefs. Indirect evidence has also been gathered showing that the existence of cycling components in *Acanthaster* population dynamics are a function of various natural and man-induced factors independent of control activities (Branham, 1973).

This study is an attempt to achieve an objective evaluation of the control activities in Micronesia by compiling, summarizing and analyzing the kill data resulting from these programs. Peripheral data are included to provide information on some of the factors generally affecting the outcome of starfish control.

METHODS

The *Acanthaster* control efforts in Micronesia consisted of combined control-monitoring functions. Monitoring was originally directed by the University of Guam throughout Micronesia with support and logistic aid from the Trust Territory government and recently was conducted by fisheries specialists at the Trust Territory District Centers. The purpose of monitoring was to obtain quantitative information on the abundance and locations of *Acanthaster*. This information was used to assess and guide the control efforts. The surveillance technique was described by Marsh and Tsuda (1973).

Starfish located during surveys were killed by teams of divers by removal or multiple injection with ammonium hydroxide or formalin. Efforts were usually concentrated on expanding or migrating populations and populations located in major recreational diving areas, fishing grounds, and the like. Of secondary importance were isolated, small populations and very low-density populations.

Worksheets were provided to Guam (1972 only) and Trust Territory control teams to help standardize data recording. Each control point was plotted or located from landmarks or by the use of a numbered chart. These data were subsequently converted into a numerical form allocating coded values to the compass direction (from the center of the island) and reef site (seaward and lagoon side of barrier reef, etc.) for each control point. Additional data were gathered on the

depth, reef condition, sea condition, water visibility, estimated number of starfish per 100 m², total man-hours in the water, and total daily man-hours. Some data were obtained on the reproductive state of the starfish, abundance of *Culcita* or cushion starfish and size of the starfish. These data were then tabulated and compared with *Acanthaster* kills for the respective control points.

RESULTS AND DISCUSSION

Acanthaster control data have been gathered in Micronesia since late 1969. These data tended to be highly variable in both precision and accuracy and in many aspects were incomplete and superficial; however, they were the only data available for the Micronesia control effort. The most complete records existed for Truk, Ponape and Guam, although some information was available from other islands.

The yearly data for Guam and all Trust Territory districts excepting the Mar-

Table 1. Yearly totals, monthly averages, and kill per unit of effort of the *Acanthaster* control programs in the Trust Territory (excluding Majuro and Yap) and Guam (1972 only).

| Island | Year | | No. Starfish Seen or Killed (1) | No. Man- hours in Water (2) | No. Starfish per Unit of Effort (1)/(2) | No. Man- hours Worked (3) | No. Starfish per Unit of Effort (1)/(3) |
|-----------------------------|------|----------------------|--|--------------------------------------|--|------------------------------------|--|
| Ponape | 1970 | Totals | 22,176 | 1,057 | 21.0 | — | — |
| | | Mo. \bar{x} (n=4) | 5544 | 264 | | | |
| | 1971 | Totals | 35,058 | 1,997 | 17.6 | — | — |
| | | Mo. \bar{x} (n=12) | 2917 | 166 | | | |
| | 1972 | Totals | 13,598 | 936 | 14.5 | — | — |
| | | Mo. \bar{x} (n=5) | 2720 | 187 | | | |
| Grand Totals | | 70,832 | 3,990 | 17.8 | 19,143 | 3.7 | |
| Truk | 1970 | Totals | 47,270 | 4,599 | 10.3 | 8,560 | 5.5 |
| | | Mo. \bar{x} (n=7) | 6753 | 657 | | 1223 | |
| | 1971 | Totals | 65,098 | 4,197 | 15.5 | 10,856 | 6.0 |
| | | Mo. \bar{x} (n=12) | 5918 | 382 | | 987 | |
| | 1972 | Totals | 23,689 | 2,336 | 10.1 | 6,704 | 3.5 |
| | | Mo. \bar{x} (n=8) | 2961 | 292 | | 838 | |
| Grand Totals | | 136,057 | 11,132 | 12.2 | 26,120 | 5.2 | |
| Palau | 1970 | Totals | 9,617 | 2,101 | 4.6 | — | — |
| | | Mo. \bar{x} (n=8) | 1202 | 263 | | | |
| | 1971 | Totals | 1,411 | 542 | 2.6 | — | — |
| | | Mo. \bar{x} (n=4) | 352 | 136 | | | |
| Grand Totals | | 11,028 | 2,643 | 4.2 | 7,629 | 1.4 | |
| Saipan, Rota & Tinian | 1970 | Totals | 3,936 | 560 | 7.0 | 2,171 | 1.8 |
| | | Mo. \bar{x} (n=7) | 562 | 80 | | 313 | |
| Guam | 1972 | Totals | 5,896 | 362 | 16.3 | 2,541 | 2.3 |
| | | Mo. \bar{x} (n=10) | 590 | 36 | | 254 | |

shalls are given in Table 1. Truk and Ponape generally exhibited a progressive reduction in the numbers of starfish seen or killed per month. Because the effort also decreased however, kill rates declined at a slower rate. These data will be influenced by diver experience, training, motivation and working conditions, as well as the abundance of starfish and their location. These factors alone should account for the great between-island variability in kill per unit or in-water time (range 4.2 to 17.8). Kill rates based on total working time (usually an 8-hour day per man) were usually low, and reflect diver productivity, search time needed to locate starfish populations and various logistics problems.

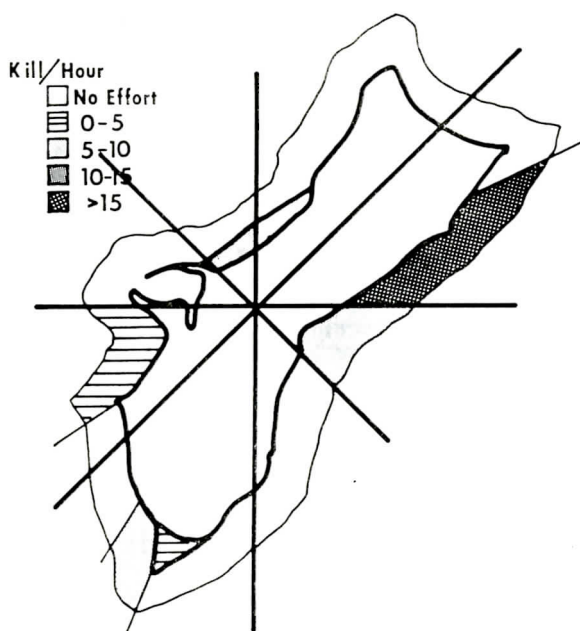


Fig. 1. Average starfish kill per unit of effort (man-hours in the water) for the island of Guam in 1972.

Control data from Truk, Ponape and Guam were subgrouped to assess starfish control activities on an areal basis against time. On Guam (Fig. 1) the high kill rate in the northeast sector was attributable to a discrete high density population located in a relatively small area where the starfish form aggregates of up to 200 per 100 m². Other areas where aggregates were found were on the seaward reefs of the southern and southeastern sectors. In all cases kill rates greater than 50 per hour were possible only when starfish aggregated. Thus where aggregates were not found such as inside the barrier or fringing reefs (density from 3 to 40 per 100 m), high kill rates were only possible because of the increased diver efficiency in taking starfish in shallow water.

Truk (Fig. 2 and Table 2) is a complicated system of lagoon islands and patch

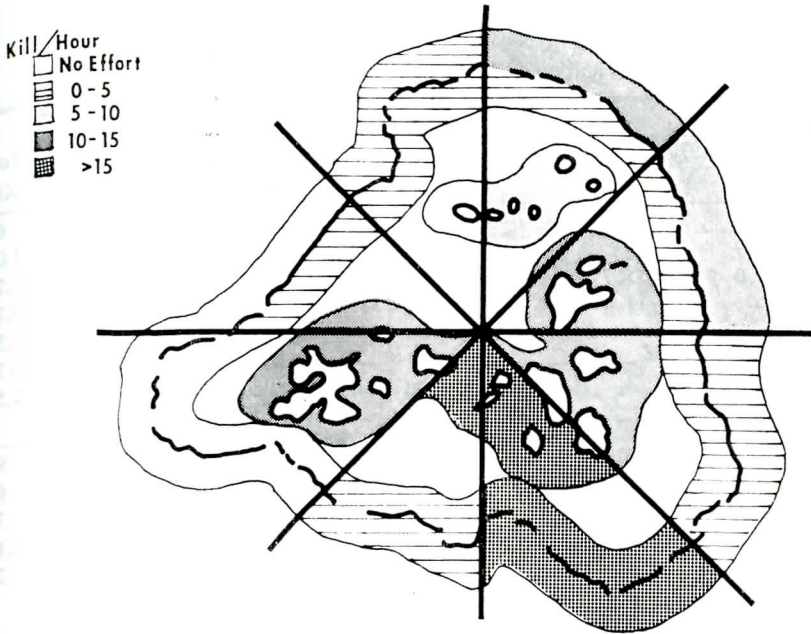


Fig. 2. Average starfish kill per unit of effort (man-hours in the water) for the island of Truk from the second quarter of 1970 through the third quarter of 1972.

reefs surrounded by a large barrier reef. The large number of starfish taken from Truk (136,057 through August 1972) gives some measure of the starfish carrying capacity of this island system. (Note: the sums of the figures in Table 2 and Table 3 will not always equal the totals given in Table 1 due to a lack of location information in some of the kill reports.) A major amount of effort (65 per cent of the total) was centered on the eastern and southeastern sectors. The lagoon islands and patch reefs alone yielded 86,900 starfish in the 1970-1972 period with an average kill per unit of effort of 13.2. For the same time period 8476 starfish were taken from the lagoon side of the barrier reef with a kill per unit of effort of 7.4 and 31,195 *Acanthaster* or 13 per hour were killed on the seaward side of the barrier reef.

The kill per unit of effort was location and time dependent. Control efforts in the Truk region were initiated on the seaward side of the barrier reef in the north sector late in 1970 (Table 2). Control efforts on the seaward slopes ceased through 1971 until 1972 when control was again initiated in the southeast sector. In both cases kill per unit of effort was high when control began but decreased rapidly thereafter. The lagoon side of the fringing and patch reefs showed a similar shift in effort from the northeast to the southeast sectors with kill rates declining somewhat in the former sector. Unfortunately, comparative data were not available for the barrier reef in the southwest and west sectors.

Ponape (Fig. 3 and Table 3) has a smaller reef area than Truk and most of the

Table 2. The number of starfish taken per unit of effort (man-hours in the water) from each of three major reef types on the island of Truk. The data is compiled on a quarterly basis and divided into eight equal circumferential sectors.

| Reef Location | Area | Date | | | | | | | | | Total Effort | Total Kill | |
|---------------------------|------|------|------|------|------|------|------|------|------|------|--------------|------------|--------|
| | | 1970 | | | 1971 | | | | 1972 | | | | |
| | | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | | | 3 |
| Fringing and Patch Reefs | N | — | 3.5 | — | — | — | — | — | 13.0 | — | — | 118 | 699 |
| | NE | 10.9 | — | — | — | — | — | — | — | — | — | 93 | 1,018 |
| | E | 6.0 | 9.7 | 15.7 | — | 11.1 | 0 | 5.4 | 17.6 | — | 3.7 | 2317 | 25,713 |
| | SE | — | — | 11.4 | 18.4 | — | — | 38.9 | 16.7 | — | 8.5 | 1935 | 29,781 |
| | S | — | — | — | 16.0 | — | — | — | 14.4 | 15.4 | 12.5 | 1084 | 16,392 |
| | SW | — | — | — | — | 4.2 | 24.1 | — | 9.8 | — | — | 844 | 10,781 |
| | W | — | — | — | — | — | — | 12.4 | — | — | — | 207 | 2,558 |
| | NW | — | — | — | — | — | — | — | — | — | — | 0 | 0 |
| Barrier Reef-Lagoon Side | N | — | 2.3 | 0.6 | — | — | — | — | 10.0 | — | — | 270 | 961 |
| | NE | — | 6.9 | — | — | — | — | — | — | 0 | — | 203 | 672 |
| | E | — | 3.1 | 0 | 1.1 | — | — | — | — | — | — | 193 | 383 |
| | SE | — | — | — | 2.4 | — | — | 28.0 | 7.9 | — | — | 298 | 6,127 |
| | S | — | — | — | — | — | — | — | 1.6 | 2.0 | — | 124 | 201 |
| | SW | — | — | — | — | — | — | — | — | — | — | 0 | 0 |
| | W | — | — | — | — | — | 0 | — | — | — | — | 7 | 0 |
| | NW | — | — | — | — | 4.4 | 0 | — | — | — | — | 50 | 132 |
| Barrier Reef-Seaward Side | N | — | 15.7 | 4.7 | — | — | — | — | — | — | — | 915 | 13,309 |
| | NE | — | 9.2 | — | — | — | — | — | 1.5 | — | 3.6 | 519 | 4,531 |
| | E | — | 5.6 | 0 | — | — | — | — | — | — | — | 411 | 2,183 |
| | SE | — | — | 0 | 0 | — | — | 31.8 | 14.3 | — | — | 375 | 10,430 |
| | S | — | — | — | — | — | — | — | — | 4.9 | — | 110 | 540 |
| | SW | — | — | — | — | — | — | — | — | — | — | 0 | 0 |
| | W | — | — | — | — | — | — | — | — | — | — | 0 | 0 |
| | NW | — | — | — | — | 4.2 | 0 | — | — | — | — | 70 | 202 |

effort has been concentrated in the lagoon side of the barrier reef and the fringing and patch reefs in the southwest sector. Control in the seaward side of the barrier reef has been primarily confined to the northern sector with lesser effort in the southwest. Survey parties did report starfish in the seaward reefs of the western sector, but there was no control within this region (Tsuda *et al.*, 1971). Otherwise, the results of the Ponape control activities concur closely with the survey predictions.

The yearly compilation of starfish taken per unit of effort presents several distinctive patterns and a few areas of nearly continuous effort (Table 3). There has been an apparent reduction in the kill per unit of effort in the lagoon side of the barrier reef in the northern to eastern sectors but in other sites the kills indicate continued high density populations. Some of these data were plotted in Fig. 4 where it can be seen that control on the seaward slope of Ponape lead to a highly variable kill rate with the upper ranges undoubtedly representing aggregated populations. While these kill rates have remained high, total numbers of starfish taken declined

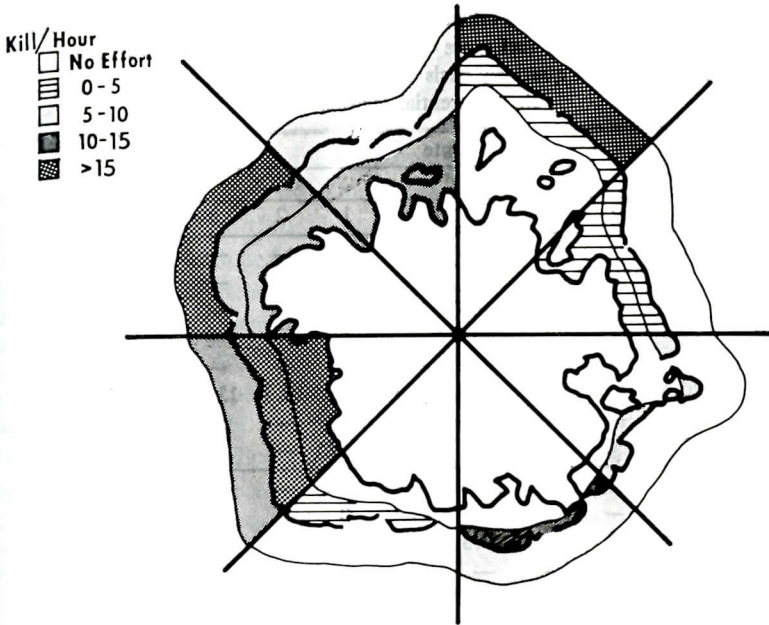


Fig. 3. Average starfish kill per unit of effort (man-hours in the water) for the island of Ponape from the fourth quarter of 1970 through the third quarter of 1972.

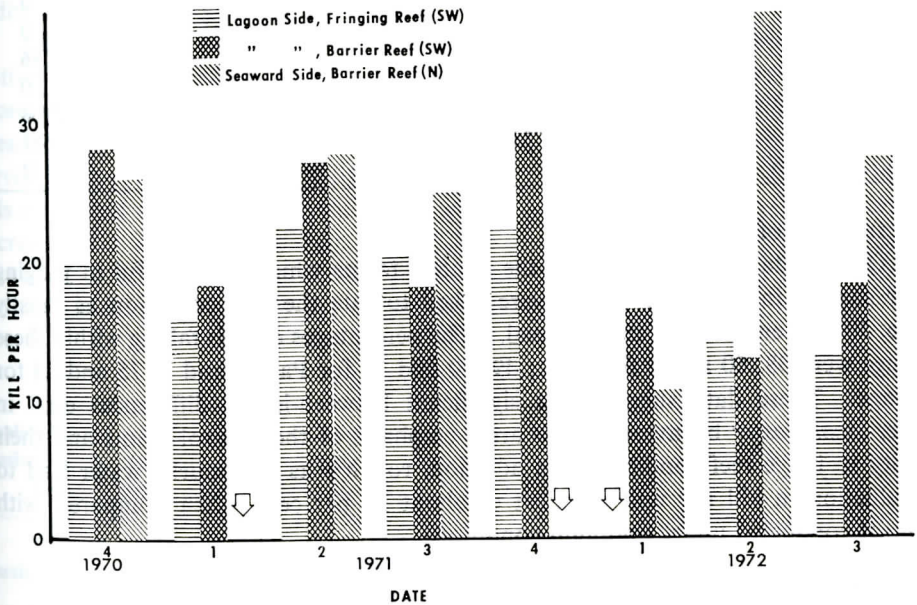


Fig. 4. The number of starfish taken per unit of effort (man-hours in the water) averaged on a quarterly basis from each of three major reef types on the island of Ponape.

Table 3. The number of starfish taken per unit of effort (man-hours in the water) from each of three major reef types on the island of Ponape. The data is compiled on a quarterly basis and divided into eight equal circumferential sectors.

| Reef Location | Area | Date | | | | | | | | Total Effort | Total Kill |
|---------------------------|------|------|------|------|------|------|------|------|------|--------------|------------|
| | | 1970 | | 1971 | | | | 1972 | | | |
| | | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | | |
| Fringing and Patch Reefs | N | 0 | — | — | — | — | — | — | — | 0 | 0 |
| | NE | 7.5 | — | — | 0 | — | — | — | — | 39 | 180 |
| | E | — | — | — | — | — | — | — | — | 0 | 0 |
| | SE | — | — | — | — | — | — | — | — | 0 | 0 |
| | S | — | — | — | — | — | — | — | — | 0 | 0 |
| | SW | 20.4 | 16.0 | 24.4 | 20.3 | 22.3 | — | 14.1 | 13.0 | 493 | 8401 |
| | W | 13.2 | — | — | 12.0 | 19.6 | — | — | 5.2 | 106 | 1496 |
| NW | 13.9 | 0 | 10.7 | — | — | 15.7 | — | — | 45 | 597 | |
| Barrier Reef-Lagoon Side | N | — | 1.5 | 0 | 14.3 | — | — | — | — | 89 | 299 |
| | NE | 4.8 | — | — | — | — | 0 | — | — | 45 | 192 |
| | E | 11.1 | — | 0 | 0.3 | — | 2.6 | — | — | 55 | 486 |
| | SE | 11.9 | — | — | — | — | — | — | — | 18 | 215 |
| | S | — | 4.9 | — | 0 | — | — | — | — | 54 | 178 |
| | SW | 28.1 | 18.6 | 26.8 | 18.0 | 28.5 | 15.9 | 12.8 | 17.7 | 1788 | 36,168 |
| | W | 13.6 | — | 0 | — | — | 17.3 | — | — | 119 | 1666 |
| NW | — | 5.1 | — | — | — | — | — | — | 30 | 154 | |
| Barrier Reef-Seaward Side | N | 25.8 | — | 27 | 24.3 | — | 11.2 | 37.9 | 26.7 | 574 | 15,183 |
| | NE | — | — | — | — | — | — | — | — | 0 | 0 |
| | E | — | — | — | — | — | — | — | — | 0 | 0 |
| | SE | — | 8.6 | 0 | — | — | — | — | — | 16 | 86 |
| | S | — | — | — | — | — | — | — | — | 0 | 0 |
| | SW | 9.3 | 11.8 | — | — | 21.3 | — | 5.4 | — | 249 | 2768 |
| | W | 23.2 | — | 0 | 11.4 | 22.7 | — | 20.0 | — | 125 | 2651 |
| NW | 0 | — | — | — | — | — | — | 22.4 | 17 | 112 | |

as a function of a decreased effort.

Other data were gathered by the control teams which were useful in judging their success in the field. They were asked to rate the reef condition as mostly alive, 50 per cent alive, or mostly dead. The percentages of kills falling within these ratings were 38, 60 and 2 for Truk; 49, 40 and 11 for Palau; and 1, 75 and 24 for Ponape. These data suggest that significant between-island differences exist in either *Acanthaster* behavior, or the areal emphasis of the control teams and their ability to judge reef condition. In addition, rough seas and murky water lead to a reduction in kill per unit of effort of about 30 per cent when compared with control conducted under optimum conditions.

CONCLUSIONS

At least 300,000 *Acanthaster planci* have been removed and killed *in situ* from

the reefs of Micronesia. The expenditure in time and money has been high; nevertheless, it must be concluded that the control programs have reduced the potential for the destruction of coral cover on reefs by this starfish. Control has not eradicated the starfish, but has changed the character of the existing populations. The programs have been effective in reducing the number of large dense aggregates and decreasing the heavy coral damage associated with these high density populations. It is also possible that under certain circumstances the likelihood of successful spawning was reduced by decreasing the concentration of starfish within the herds. On Guam, for example, the existing starfish aggregates appear to be remnants of a successful recruitment which probably occurred between 1966 and 1969. There appeared to be no reproductive recruitment in these population and control therefore simply prevented accelerated predation.

While starfish control programs were able to supply reliable abundance data within island groups, particularly when combined with local monitoring, kill rate data were not directly comparable between islands mainly due to variations in personnel training and experience. The observational and control techniques employed in Micronesia have been generally consistent and standardized; however, the data records particularly with respect to the Trust Territory generally reflect the difficulty of using individuals with little prior training to systematically compile data on a routine basis. Additional data are needed to provide information on recent recruitment which should include an estimate of population density such as number per unit area and the average range and standard error of diameters of individuals within population groups.

The evaluation of the starfish control programs in Micronesia remains a subjective one, for the actual percentage of *Acanthaster* reefs is unknown with the exception of a few heavily damaged reefs on Guam (Randall, 1973-this issue; in press). To this date the programs have been mainly conservation measures preserving in part the aesthetic qualities of relatively limited reef area. Nevertheless, it is clear that a program of continuous, intensive control will result in an overall decrease in a starfish population after a 2 to 3 year period. Therefore, it must be assumed that the general decline in populations of *Acanthaster* in areas where control has been applied are not entirely a reflection of natural limiting factors.

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