

# Invertebrates, Communities, and Reef Health in Airai, The Republic of Palau

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## Abstract

During 2006 to 2008, a women's group studied the distribution, densities, sizes and harvest rates of edible invertebrates in southeast Babeldaob. Replicate transect lines, mobile GPS tracking units and traditional harvesting methods were used. Women covered a mean area of 2,520 m<sup>2</sup>h<sup>-1</sup> or 0.25ha h<sup>-1</sup>. The mean CPUE for weight for all invertebrates collected was 2.4 kg w<sup>-1</sup>h<sup>-1</sup> and the mean CPUE for weight for all invertebrates per hectare was 6.2 kg w<sup>-1</sup>h<sup>-1</sup>ha<sup>-1</sup> and differed significantly between sites. Low densities of *Hippopus hippopus* and *Holothuria scabra* were found. Low densities of *Tripneustes gratilla* may indicate a potential collapse in this fishery. Spawning of wild *Tripneustes gratilla* was observed in April 2007. Small and patchy populations were measured at finer spatial and temporal scales with input from resource users to better estimate and detect change in populations. One market sold a mean weight 1345 kg of selected invertebrates between 2000 and 2007. Airai State conservation officers are working with research, enforcement and community partners to manage these resources. Key invertebrates are potential indicators of reef health. These results can be used to set size limits, threshold densities of specific species and seasonal and site closures for specific sites.

**Key words:** Invertebrates, women, harvest, effort, management.

## Introduction

Overfishing, pollution, habitat loss and global warming threaten fisheries worldwide. *Tridacna* clams are on the UN's red list of endangered species (IUCN 1983). *H. hippopus* is sensitive to elevated seawater temperature; mass mortality occurred in the Philippines during the 1998 ENSO event (Blidberg et al. 2000). *Holothuria scabra* is one of several prized sea cucumbers used as food, medicine and as an aphrodisiac. All *Tridacna* species and the sea cucumbers, *H. scabra* and *Actinopyga miliaris* are banned for export in Palau; *Tridacna* spp. are produced in hatcheries in Palau and the region (Heslinga et al. 1990). The gonads of *Tripneustes gratilla* were over harvested and the fishery collapsed in the Philippines (Juninio-Meñez et al. 1998). *Stichopus vastus*, an edible sea cucumber with regenerative properties and *Lambis lambis*, the culturally significant spider shell are declining in numbers. Women play a critical role in nearshore fisheries (Matthews and Oiterong 1991, Lambeth 1999). Our objectives were to work with a women's group in Airai to determine relative abundance, distribution, size and catch efforts for populations of key invertebrate species; share the results in the community; and discuss management options.

## Materials and Methods

The Republic of Palau is the westernmost archipelago of the Caroline Islands in Micronesia that lies within latitudes 8°12' to 2°48' N and longitudes 131°07' to 134°44' E The study site is located in Airai State in southeast Babeldaob, the largest island in Palau (Fig.1).



Figure 1: Study sites (West, South, East) in Airai State, Southeast Babeldaob, Republic of Palau (Source: PALARIS).

Three sites along the West, South and East coasts of Airai (Fig. 1) were surveyed over a 34 day period from November 2006 to April 2008. At least three 50m transects were set 100m apart and parallel to the reef covered a minimal area of 750m<sup>2</sup> at each site for the key invertebrates optimizing overlapping habitats. Seagrass density and canopy height was measured within 0.25m<sup>2</sup> quadrants at either 4m, 5m or 10m intervals along the transect line; invertebrates were quantified within 5m of the transect line. The line intercept technique was used to quantify coral cover at the West site. Invertebrates were counted, measured to the nearest 0.1cm, and all but the unharvested embedded clams were weighed to at least the nearest 0.1 kg. The wet weight of harvested clam meat and the shell length were measured. Weight and lengths for *Tridacna crocea* and *T. maxima* where combined as embedded clams for this study as women did not distinguish between them in the field. Sea cucumber measurements are complicated because they change shape and retain water and sediment (Preston 1993). In this study, sea cucumbers were weighed and measured after sand and excess water was removed and if contracted, they were left few minutes before length was measured. The taxonomy of the Genus *Actinopyga* is under revision: the local name “cheremrum” represents several species. However we are referring to the smallest species in this genus with a variable coloration. The total weight of sea urchins was measured because they are sold unprocessed. Photodocumentation was conducted during the study.

The area covered during traditional harvesting was quantified using an “in-water” tracking device designed by Coral Reef Research Foundation which was a modified PVC waterproof casing that can a small GPS unit can be inserted and sealed with an screw top, airtight lid. An extended PVC pipe is attached to the device that has a foam float for buoyancy. A Garmin GPS unit was set to track position at 15 sec intervals. The device was either tied onto a person or a collecting basin. Data was downloaded, analyzed and mapped using ©Arcview software. Women searched a mean width of 4m and harvested singly or in groups. Individual and group catches were quantified. The non-parametric Kruskal-Wallis Test was used to test the null hypothesis that the CPUE for numbers (ct w<sup>-1</sup>h<sup>-1</sup>), the CPUE for weight (kg w<sup>-1</sup>h<sup>-1</sup>), the CPUE for weight per hectare (kg w<sup>-1</sup>h<sup>-1</sup>ha<sup>-1</sup>), size and densities, did not differ significantly between the 3 sites. The Rank Sum Test was used to compare 2 sites (Ambrose, Ambrose 1987). Results were presented to over 250 people in the Airai community in a series of power point presentations. Concerns and comments were recorded and summarized.

## Results

### *Seagrass Density and Substrate Cover*

A total of 189 0.25m<sup>2</sup> quadrants were placed along transects at the West (n=72) South (n=73) and East (n=44) sites. The mean density for all seagrass species (plants 0.25/m<sup>2</sup>) at each site was as follows: East: 3.1 (sd=4.4); South: 1.3 (sd=2.8) and West: 1.1 (sd=2.1). For all seagrass species, the mean height (cm) at each site was as follows: West: 13.9 (sd=12.3, n=134); South: 12.4 (sd=11.2, n=262); East: 9.2 (sd=5.3, n=381). The mean densities (plant 0.25/m<sup>2</sup>) for each species at each site were as follows: West: *E. acoroides* 1.5 (sd=1.9), *T. hemprichii* 2.7 (sd=2.9); *C. rotundata* 0.3, (sd=1.1); South: *E. acoroides* 1.4 (sd=1.7), *T. hemprichii* 3.2 (sd=4.6); *C. rotundata* 6.4 (sd=6.1); and *Syringodium isoetifolium* 0.2 (sd=0.8); East: *Enhalus acoroides* 4.1 (sd=3.2); *Thalassia hemprichii* 1.5 (sd=2.2); *Cymodocea rotundata* (6.4, sd=6.1); and *S. isoetifolium* 0.2 (sd=0.8). Substrate cover at the West site along 4 transects included live coral 54.6% (sd=36.1), dead coral 6.4% (sd=2.8), coral rubble 15.0(sd=7.0) and sand 25.8% (sd=6.2). An estimated 36% of the live coral was of the genus *Porites*. *T. crocea* and *T. maxima* were found in habitats with high *Porites* sp. coral cover.

### *Track Paths*

The mean speed obtained from the mobile GPS units was 630m w<sup>-1</sup> h<sup>-1</sup> (sd=198, n=24). Based upon a mean search width of 4m, women covered a mean area of 2,520m<sup>2</sup>h<sup>-1</sup> or 0.25ha h<sup>-1</sup>. When in deeper water, women swam 91% of the time (sd=6%, n=13) and stopped 9% (sd=6%, n=13). When in shallow or exposed reef areas women walked 70% of the time (sd=11%, n=9) and stopped 30% of the time (sd=11%, n=9). Women stopped to either harvest, process, or rest; they swam or walked to either search or reach a harvest area.

### *Total Biomass and Catch per Unit Effort*

The mean CPUE for weight for all invertebrates collected was 2.4 kg w<sup>-1</sup>h<sup>-1</sup> and the mean CPUE for weight for all invertebrates per hectare was 6.2 kg w<sup>-1</sup>h<sup>-1</sup>ha<sup>-1</sup>. The CPUE in total wet weight for all invertebrates collected (H=10.14) and the CPUE for total wet weight harvested per hour per hectare (H=14) significantly differed between sites (X<sup>2</sup>.05[2] value=5.99) as shown in Table 1.

Table 1. Catch per Unit Effort (CPUE) in wet weight (kg w <sup>-1</sup> h <sup>-1</sup> ) and CPUE of wet weight per hectare (kg w <sup>-1</sup> h <sup>-1</sup> ha <sup>-1</sup> ) for all invertebrates (sd=1) and the number of samples (n).		
Site	kg w <sup>-1</sup> h <sup>-1</sup>	kg w <sup>-1</sup> h <sup>-1</sup> ha <sup>-1</sup>
West	2.1 (2.0) n=10	7.3 (13) n=10
South	2.4 (2.2) n=12	6.9 (9.8) n=12
East	2.8 (2.2) n= 6	4.3 (4.9) n= 6
Mean	2.4 (2.0) n=28	6.2 (9.8) n=28

#### *Tridacna crocea* and *Tridacna maxima*

The mean clam size for *Tridacna crocea* and *Tridacna maxima* combined for all transects was 7.0cm (sd=3.5, n=208). Women harvested clams ranging from 6.5 to 15cm with a mean size of 10.2cm (sd=1.8, n=130). For all sites, the mean CPUE for the numbers of *T. crocea* and *T. maxima* was 11.8 (sd=11.9, n=37) and the mean CPUE for weight was 0.62kg (sd=0.51, n=32). The CPUE significantly differed between sites for numbers (H=42) and weight (H=204) with an X<sup>2</sup>.<sub>.05[2]</sub> value of 5.99 (Table 2). The mean density of clams was 0.07(sd=0.06, n=14) compared to 0.03(sd=0.05, n=78) in 2003. Clam densities, harvest sizes and sizes along the transects showed no significant difference between sites. The percent of clams that were less than the minimum harvestable size (>6.5cm) at each site were as follows: West: 11%, South: 42% and East: 50%.

Table 2. The mean CPUE for counts (ct w <sup>-1</sup> h <sup>-1</sup> ) and weight (kg w <sup>-1</sup> h <sup>-1</sup> ) for <i>Tridacna crocea</i> and <i>Tridacna maxima</i> (sd=1) and sample number (n). X <sup>2</sup> . <sub>.05[2]</sub> value = 5.99.		
Site	ct w <sup>-1</sup> h <sup>-1</sup>	kg w <sup>-1</sup> h <sup>-1</sup>
West	17.7 (14.4) n=18	0.66 (0.52) n=18
South	5.8 (3.7) n=12	0.26 (0.15) n=10
East	7.1(6.5) n=7	0.15 (0.11) n=4
Mean	11.8 (11.9) n=37	0.62 (0.51) n=32
H	*42	*204

#### *Hippopus hippopus* and *Tridacna squamosa*

The mean size for all harvested *H. hippopus* was 22.6cm (sd=6.4, n=43) ranging from 8cm to 45cm. The mean CPUE for numbers of *H. hippopus* was 1.7 (sd=1.45, n=35). The mean CPUE for weight was 1.0kg (sd=0.9, n=26). The mean CPUE for the numbers and the mean CPUE for weight and mean size of harvested *H. hippopus* were significantly different between sites. (The H statistic was 28, 27.6 and 56 respectively; all values were greater than the X<sup>2</sup>.<sub>.05[2]</sub> value of 5.99). Mean sizes for each site were

as follows: West: 23.3cm (sd=12.7, n=3); South: 22.6cm (sd=6.4, n=43) East: 31.7cm (sd=16.2, n=10). Mean CPUE for counts for each site were as follows: West: 0.83 (sd=0.59, n=6.3); South: 1.81(sd=1.5, n=17) East: 2.16(sd=1.86, n=11). Mean CPUE for weight for each site were as follows: West: 0.76kg (sd=0.79, n=6); South: 0.82kg (sd=0.65, n=11) East: 1.29kg (sd=1.14, n=9). The mean density of *H. hippopus* was 0.011/m<sup>2</sup> (sd=0.007, n=5) compared to 0.002/m<sup>2</sup> (sd=0, n=7) in 2003. The CPUE for *T. squamosa* at the South site was 3.5/w/h.

#### *Tripneustes gratilla*

The mean size for all harvested *T. gratilla* was 6.3cm (sd=1.0, n=233) ranging from 4.3 to 11cm. The mean CPUE for the number was 34 (sd=20, n=11). The mean CPUE for weight was 5.6kg (sd=1.3, n=11). The mean CPUE for number and weight significantly differed between the South and West sites (T =18) with a critical value for Rank Sum Test =20 at  $\alpha=0.05$ . The East site is not a known site for *T. gratilla*: only dead tests and a few urchins were found. At the South site the mean CPUE for numbers was 47 (sd=13, n=4) during November 2006 and 91 (sd=63, n=3) during March 2007 which was the highest CPUE recorded in this study; the mean CPUE for weight was 4.7kg (sd=1.0, n=5) in November and 18 kg (sd=9.5, n=3) in March; the mean diameter was 6.2cm (sd=0.85, n=95) in November and 6.0 cm (sd=0.54, n=109) in March. During April 15, 2007, *T. gratilla* were observed spawning in the seagrass at 4pm at the South site. At the West site, the mean CPUE for numbers was 27.6 (sd=9.3, n=6), the mean CPUE for weight was 6.4kg (sd=1.1, n=6) and the mean harvest size of 7.6 cm (sd=1.1, n=40) in December 2006. At the East site, 24 empty tests were found along the transect line with a mean diameter of 6.0 cm (sd=0.8, n=24) and a mean density was 0.03/m<sup>2</sup> (sd=0.05, n=3) in June 2007. The mean density for all sites was 0.06/m<sup>2</sup> (sd=0.05, n=3) compared to 0.005/m<sup>2</sup> (sd=0.004, n=10) in 2003.

#### *Actinopyga* sp.

The mean CPUE for numbers of *Actinopyga* sp. was 25 (sd=25, n=12) and the mean CPUE for weight was 2.8kg (sd=2.8, n=17). The mean size was 11.1cm (sd=3.5, n=124). This species was not found at the South site. The West and East sites significantly differed for mean CPUE for numbers and weight. At the West site, the mean CPUE for counts was 8.2 (sd=16.6, n=6) compared to 38.5 (sd=24.7, n=6) at the East site. The mean CPUE for weight was 0.53kg (sd =0.7, n=6) at the West site and 3.2kg (sd=3.0, n=14) at the East site. The mean size was 9.8cm (sd=2.3, n=28) at the West site and 11.5cm (sd =3.8, n=96) at the East site. The mean density was 0.003

(sd=.006, n=6) at the West site and 0.10 (sd=.006, n=6) at the East site. The mean density for both sites was 0.05/m<sup>2</sup> (sd = 0.11, n=12) and lower than the mean density of 0.07/m<sup>2</sup> in 2003.

#### *Stichopus vastus*

For all sites, the mean CPUE for numbers was 22.4 (sd=23.8, n=40) and the mean CPUE for weight was 3.2kg (sd=3.8, n=18). The mean CPUE for numbers, significantly differed (H=41) between sites as follows: West:30.2 (sd=25.7, n=29); South: 4.8 (sd=16.9, n=6); and East:11.9(sd=6.1, n=5). The mean CPUE for weight significantly differed (H=19) between sites as follows: West:3.8kg (sd=4.3,n=12); South:2.0kg (sd=3.0, n=3); East:1.2kg(sd=0.6, n=3). Densities significantly differed (H=31) between sites as follows: West: 0.05(sd=0.07, n=6); South: 0.92 (sd=0.86, n=6); and East: 0.009(sd=0.008, n=6). The more accessible areas of the West site had lower mean CPUE for numbers 1.0 (sd= 0.9, n=3) and weight 0.2kg (sd=0.09, n=3) than less accessible areas with a mean CPUE for counts of 19.9 (sd= 18, n=8) and a mean CPUE for weight of 7.0kg (sd=4.6, n=6). Higher mean densities of *S. vastus* were also found at the South site in the 2003 survey (Table 3). The mean size for all harvested *S. vastus* was 17.9cm (5.0, n=17) compared to 14.7cm (sd=2.3, n=1,388) in 2003.

	2006-2008(ct/m <sup>2</sup> )	2003 (ct/m <sup>2</sup> )
West	0.01(0.01) n=2	0.05(0.07) n=6
South	0.94 (0.93) n=3	0.80(0 .76) n=3
East	0.01(0.003) n=2	0.02(0.003) n=2)
Mean	0.41(0.73) n=7	0.24(0.48) n=11

#### *Holothuria scabra*

For all sites, the mean CPUE for numbers of *H. scabra* was 6.7 (sd=5.8, n=10) and the mean CPUE for weight was 1.3kg (sd=1.2, n=10). The CPUE for numbers (H=16) and weight (H=15.7) significantly differed (the Kruskal-Wallis critical value<sub>0.05[2]</sub>= 5.25) between sites. The mean CPUE for numbers at each site was as follows: West: 10.7 (sd=4.7, n=5); South: 5.0 (sd=5.7, n=2); and East: 1.1 (sd=0.6, n=3). The mean CPUE for weight at each site was as follows: West: 2.1kg (sd=0.9, n=5); South: 1.2kg (sd=1.4, n=2); East: 0.2kg (sd=0.1, n=3). The mean density for all sites was 0.009/m<sup>2</sup> (sd=0.009, n=8) compared to 0.005/m<sup>2</sup> (sd=0.008, n=12) in 2003. The mean length was 14.5cm (sd=2.4, n=29) compared to 14.9cm (sd=13, n=6) in 2003 and 16.8cm (SE=0.6, n=17) for the 2007 SPC survey.

#### *Lambis lambis*

*Lambis lambis* had a mean size of 12.4cm (sd=2.3, n=13) and a mean weight of 0.3kg. The mean CPUE was 0.8 (sd=1.2, n=22). The CPUE for counts significantly differed (H=10, X<sup>2</sup><sub>0.05[2]</sub> value=5.99), between sites as follows: South: 1.4 (sd=0.9, n=8); East: 1.2 (sd=0.7, n=4); and West: 0.6 (sd=0.3, n=4). The mean density of 0.004/m<sup>2</sup> (sd=0.003, n=3) was similar to the mean density of 0.005/m<sup>2</sup> (sd=0.004, n=10) in 2003. The mean size was similar to the 2007 PROCFish study by SPC.

#### Market Value

The mean purchase price for several invertebrate species between 2000 and 2007 was \$6.00/kg at a local market. The mean annual sales were as follows: *Actinopyga* sp.: 1098kg, *T. crocea* and *T. maxima*: 148kg and *S. vastus*: 99kg. The retail values in 2008 were as follows: *T.crocea* and *T. maxima* meat: \$10kg<sup>-1</sup>, *S.vastus*: \$10.80kg<sup>-1</sup>; *H. scabra*: \$10.50kg<sup>-1</sup>; *T. gratilla*: \$11kg<sup>-1</sup>; sliced *Actinopyga* sp.: \$6.50kg<sup>-1</sup> and minced: \$4kg<sup>-1</sup>. The time required to harvest 1kg of these species based upon the mean CPUE for weight (not including transport and processing time) is as follows: *T.crocea* and *T. maxima* meat: 1.6h, *S.vastus*: 0.33h; *H. scabra*: 0.75h; *T.gratilla*: 0.18h and *Actinopyga* sp.: 0.3h. Revenues generated from hourly harvest ranged from \$13 for *Actinopyga* sp. to \$61 for *T. gratilla*. Commercial production showed an increasing trend for Yano's market (Evelyn Yano, unpublished data, 2008). Increased local demand for these delicacies by residents and visitors puts pressure on this fishery and some are illegally exported. Currently there are no national regulations for *S.vastus* or *T. gratilla*.

#### Discussion

The harvest rates of selected invertebrates showed high percent declines compared to a qualitative survey 17 years ago (Matthews and Oiterong 1991). The percent declines in harvest rates compared between 2007 and 1991 were as follows: embedded *Tridacna* species (60%), *H. hippopus* and other *Tridacna* species (75%), *S. vastus* (50%) and *H. scabra* (80%). The Belau Mariculture Demonstration Center (BMDC) produces clams that reach maturity within 5 years and have recommended minimum sizes to harvest wild clams. The size at first maturity of cultured clams and the recommended harvest sizes for wild clam populations in Palau are as follows: *T. crocea* (8cm; 12cm), *T. maxima* (10cm; 12cm), *H. hippopus* (12cm; 18cm), *T. squamosa* (18cm; 18cm) and *T. derasa* (30cm; 35cm) (Lawrence Sumer-BMDC supervisor, pers comm. 2008). Jameson (1976) observed *T. maxima* spawning at sizes ranging from 11cm to 13cm. The mean size of harvested *T.*

*crocea* and *T. maxima* in this study were lower than the recommended harvest size. The mean harvested size for *H. hippopus* was within BMDC's recommended size range and similar to the mean size in the 2007 SPC study. *Tridacna crocea* and *T. maxima* clams are good indicator species of reef health for *Porites* spp. dominated reefs because they are common and accessible, have a colorful mantle, and leave a depression after extraction, enabling easy detection and measurement. *Hippopus hippopus* is a potential early indicator species of overharvesting because women prefer it because it is easier to harvest and has larger meat than the embedded clams. However it is found in lower densities. Women transplanted smaller *H. hippopus* to depleted areas.

In the Philippines, densities of *T. gratilla* dropped from 0.11-2.14/m<sup>2</sup> to 0.02 to 0.07/m<sup>2</sup> prior to the collapse of the urchin fishery in 1992 (Juninio-Meñez et al. 1998). In this study, the mean density was 0.06/m<sup>2</sup> and 0.005/m<sup>2</sup> in 2003, which were similar to the threshold densities in the Philippines prior to its collapse. The mean diameter of harvested *T. gratilla* was similar to sexually mature cultured *T. gratilla* (6cm) in the Philippines and wild populations in other regions (Juninio-Meñez et al. 1998). In Palau, sea urchins were more abundant from November 2006 to March 2007 and were observed spawning in synchrony during April 2007. Breeding peaks were between September and November in the Philippines and Taiwan, (Chang-Po and Ku Hsiung 1981). Algal food availability (Conan and Sloan 1989) and macroalgae preferences (Stimson et al. 2007) were correlated to *T. gratilla* abundance and distribution. Temperature and photoperiod changes acted as cues to induce spawning in *T. gratilla* (Väitölä et al. 2005). Coral (Penland et al. 2004), plants (Borchert 2005, Kitalong 2008), *Acanthaster planci* (Idip 2003) and *Siganus fuscescens* (Kitalong et al. in prep) exhibited reproductive peaks that correlated with annual spring and fall maxima in solar insolation. Fisherfolk have observed that *T. gratilla* become buoyant and move in masses from reef to reef. They believe that urchins live in deep water and emerge to the shallows to breed. We found only empty tests in June at the East Site. During extensive surveys during May 2007 and the summer of 2003, only 4 and 3 urchins were found respectively (SPC 2007, Kitalong 2003), suggesting seasonality for this species in Palau.

*Actinopyga* sp. used coral as a refuge during daylight and emerged at night at the West site. *Actinopyga* sp. harvest rates were similar to estimated rates 17 years ago (Matthew and Oiterong, 1991). The mean size of harvested *Actinopyga* sp. in this study was 11cm which was smaller than the size of mature *Actinopyga echinites* (12cm) found by

Conand (1982). In this study, *Actinopyga* sp. were common at the East site however women limited their harvest effort for *Actinopyga* sp. because it required several hours to process its edible endodermis. Women preferred to collect *H. hippopus*, *T. gratilla* and *H. scabra* which were easier to process.

The mean size of *S. vastus* decreased from west to east in this study and in 2003. Women said they preferred harvesting *S. vastus* at the West site because it "tasted better" than at the other sites. Their preference is reflected in the high CPUE rates yet lower densities at the West site compared to the South site. The author and fishers have observed a decline in populations at accessible sites. Women traditionally slice *S. vastus* into 2 or 3 sections and scatter them onto the depleted areas. *Stichopus vastus*(?) spawned during April 2003 at a southern reef.

The mean size of harvested *H. scabra* in this study compared to other countries indicates that they have not reached sexual maturity. *H. scabra* are known to emerge from the sediments on incoming tides at dusk. Juveniles burrow during sunrise and emerge during sunset to feed (Mercier et al. 1999). We observed similar behaviour in this study. The decline in *H. scabra* has been attributed to overharvesting and pollution from land based sediments and other pollutants. Golbuu et al. (2003) found high rates of sedimentation in Airai Bay.

Small patchy populations require measurement at fine spatial and temporal scales with input from resource users to better estimate and detect population change. Fishers are observing more restricted habitats and smaller sizes for most invertebrates. Mobile GPS tracking units locate specific habitats for targeted species for future monitoring. Experienced gleaners showed the less experienced gleaners the proper harvest sizes and how to harvest embedded clams without damaging corals. Sustainable harvesting skills must be taught in the field. Teamwork between managers and fishers enhanced implementation of this study and the exchange of valued information which provided more management options. These results can be used to educate the community; set size limits, threshold densities, seasonal harvest periods and site closures of important pre-spawning and spawning grounds. These key invertebrates can serve as potential indicators of reef health. Their functional roles as grazers, aerators of sediment and processors of organic matter are essential in maintaining a healthy reef.

During village meetings, the community recommended the following actions: stop dredging the inner reef areas, protect important areas for each

village, restrict boat traffic, reduce or stop sources of pollution, conduct more studies, develop sustainably, involve communities in activities and employ more conservation officers. Currently protected areas are being demarcated and Airai conservation officers are monitoring and enforcing marine laws with their local research, enforcement and community partners.

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