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Coral farming as means of sustaining livelihoods and promoting resource management

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Abstract. With the ongoing transition between the barter and the cash economy in Papua New Guinea (PNG), traditional resource production and exploitation must adapt to the changing markets. The increasing demands for goods and services have resulted in coastal and marine resources in PNG showing signs of overexploitation. Andra Island in Manus Province is one of many islands whose inhabitants are highly dependent on the sea for sustenance and livelihoods. Ecological studies by the Wildlife Conservation Society have revealed that the surrounding reefs are denuded of branching *Acropora* corals compared with similar sites in Manus and elsewhere. This is likely to be due to the island's economic dependence on the harvest of *Acropora* corals for the coral lime trade. Lime (calcium hydroxide) is chewed with betelnut (*Areca catechu)* throughout most coastal regions of PNG, and Andra has a monopoly on the lime trade in Manus. A coral farming project was implemented with the aim of providing a sustainable means of maintaining the coral lime trade. Unlike other coral farming projects in the Pacific, this project operates completely at the local scale and is not reliant on overseas markets; nor does it face the logistical challenges of the aquarium trade. We assess here the degree to which the coral farming activities contribute to livelihoods while relieving extractive pressure on reefs. The project has potential to expand throughout other regions of PNG where corals are harvested for lime.

Key words: Coral farming, Betel nut, *Acropora*.

Introduction

In the majority of Papua New Guinea (PNG), coastal communities practice some form of traditional management over their natural resources in a complex system involving customary tenure and access rights. Within Andra Island in Manus Province, fishing can take place anywhere within the community's tenure area unless the family or clan that owns that area declares a closure, while coral harvesting can only take place within family-owned reefs. Through the wider North Manus region, the Andra Island community has a traditional monopoly on the production of coral lime for betel nut (*Areca catechu*) consumption, with Andra lime sold in both local markets and Lorengau, the provincial capital. Lime production is an important income generating activity for the community (Cinner et al. 2005).

Betel nut chewing is ubiquitous in PNG, practiced by an estimated 88% of the population, forming an intricate part of social and cultural customs and rituals (Gupta & Warnakulasuriya 2002). In PNG, betel nut is chewed with the leaf or flower of *Piper betel* and lime (calcium hydroxide). There are various sources for this lime; in coastal areas lime is primarily produced by baking (locally referred to as burning) the shells of shellfish and coral skeletons so that they break down into a fine, white powder (Gupta & Warnakulasuriya 2002). The harvesting of live coral for use in the production of lime has the potential to contribute substantially to the degradation of coral reef systems unless sustainable management practices are put in place.

In 2002, the Wildlife Conservation Society (WCS) conducted ecological and socioeconomic assessments in Manus Province and elsewhere in PNG, and found that the reefs of Andra were relatively denuded of branching Acroporid corals. The community's economic dependence on the lime trade is thought to have contributed significantly to the selective depletion of *Acropora* spp. (Cinner et al.

2005). Subsequently, as *Acropora* corals became increasingly scarce in the inshore reefs, Andra islanders resorted to harvesting less preferred and slower growing corals (e.g. *Porites* sp.) (Lahari 2007). In an effort to promote sustainable coral harvesting, WCS initiated a study to assess the viability of farming coral for the lime trade at Andra Island and to determine the potential contribution of coral farming to livelihoods in the Andra community, while relieving extractive pressure on the surrounding reefs.

Material and Methods

Study site

Andra Island is a small island located off the north coast of the main island of Manus in Manus Province, PNG (01°56.298 S, 147°00.271 E), approximately 25 nautical miles northwest of Lorengau, the provincial capital. Andra's land area covers an estimated 0.26 km^2 with the immediate reef and lagoon covering a further 5.6 km^2. The community claims customary fishing rights over resources in the surrounding lagoon and reef, on a neighbouring atoll, and on patch reefs between Andra and the mainland. As of January 2008, there were approximately 450 Andra residents, divided into two main clans, Rai and Paluwaha, and six sub-clans (Hartley et al. 2008).

A reef ecosystem assessment was conducted at Andra and Ahus in 2007 to compare with the 2002 WCS surveys. Ahus was chosen as a comparison as it has a similar reef system which is not subject to heavy coral harvesting. Six randomly selected sites were surveyed on the leeward reefs at each island, selected so as to be relatively similar in depth, current regime, and level of exposure to wave action. A socioeconomic assessment including coral harvests was conducted at Andra Island to accompany the ecological survey. Due to lack of SCUBA equipment, the deeper (6-8m) transects were not re-surveyed.

Coral reef assessments

At each site, substrate composition was assessed through two 50 m point intercept transects laid parallel to the reef crest. Three were laid on the reef flat, three on the reef crest and three on the reef slope (2-4 m in depth). The benthos was recorded at intervals of 0.5 m along each transect and placed into one of the following categories: hard coral, soft coral, coralline algae, turf algae, macroalgae and cyanophyta.

Reef fish abundance was estimated for all major non-cryptic reef fish families along belt transects at the same locations as the substrate transects on the reef flats and reef slopes. Two passes were made, the first surveying large fish (>10 cm) in a 5 m wide strip, and the second surveying small fish (<10 cm) in a 2 m wide strip. Fish size was estimated to the nearest 5 cm. Fish biomass was calculated using published length-frequency data (Froese and Pauly 2008). Species were assigned to one of four trophic groups: piscivores, herbivores, invertivores, or planktivores, based on the primary components of their diets. Local species richness of reef fishes was estimated using the Coral Fish Diversity Index (CFDI) method developed by Gerald Allen for PNG fish assemblages (Allen 1998). The mean local species richness was calculated for each island. No data transformations were required prior to analyses.

Coral harvest and socioeconomic assessment

Information on the productive activities within Andra was ascertained through recording seasonal calendars and conducting systematic household surveys (every second household), key informant interviews, and resource mapping with the aid of the Foundation of the People of the South Pacific International (FSPI). For the household surveys, interviews were conducted with the head of the household when available, or the next most senior person. Productive activities were classed as fishing, gleaning, marketing marine products, production of lime, agriculture, tourism, other services (e.g. salaried jobs or remittances), and other (e.g. informal business activities such as island trade stores).

Interviews with coral sellers provided information on the frequency of harvest and burning events, the amount of return from each harvest period, where in the reef area the harvests took place, and the type of corals harvested. Participatory observation techniques were also used to gain a contextual understanding of the lifestyle and issues associated with resource use and management. We estimated the volume and species composition of all coral piles ready to be burnt between September – November 2007 (n = 20). Volume of coral removed from the reef was calculated using the mean volume of a coral pile on Andra, the total number of piles burnt per year on Andra estimated from household surveys, and the coral volume loss ratio in Cinner et al (2005).

Coral farms

Following the ecological assessment of the coral reefs surrounding Andra Island, two coral farms were established in an effort to relieve extractive pressure on the reefs. The coral farms, consisting of five brood-stock and eight harvest-stock tables each, were situated in the lagoon at depths of ~2 m and in areas of low turbidity and current to reduce sedimentation. The tables were fabricated from metal rods and wire mesh and coral cuttings were attached using cable ties. Two hundred 15 cm cuttings of branching *Acropora* spp. (predominantly *A. intermedia*, *A. hyacinthus* and *A. formosa*) were taken from nearby reefs to seed

brood-stock tables between November 2007 and February 2008. These were left to grow for six to eight months before coral nubbins were harvested from brood-stock tables and transplanted to harvest-stock tables, which were subsequently harvested in May 2009.

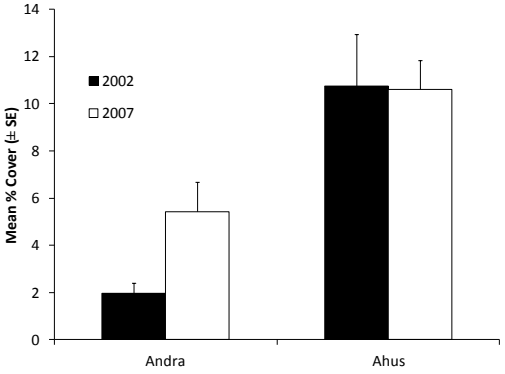

Figure 1: Percent cover of branching Acroporid corals at Andra and Ahus in 2002 and 2007 (± 1 SE).

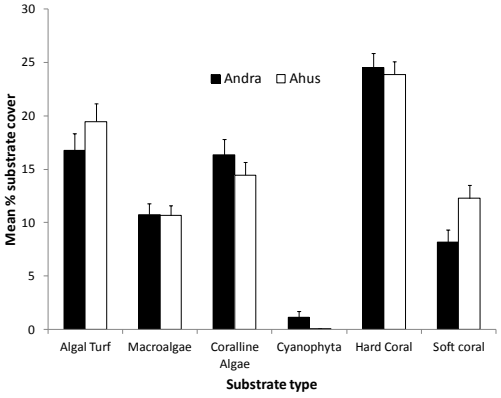

Figure 2: Percent cover of selected substrate categories at shallow reef sites at Andra (filled) and Ahus (open) islands in 2007.

Results

Coral reef assessment

Ecological surveys in 2002 and 2007 found that there had not been any significant change in hard coral cover in the shallow reefs of Andra and Ahus. Branching *Acropora* cover increased from 2% in 2002 to 5% in 2007 at Andra but there was little to no change in overall coral cover on the reefs of Ahus (Fig. 1). Total hard coral cover was still relatively low with 25% at Andra and 24% at Ahus in 2007. Macroalgal cover was similar between Andra and Ahus at ~10% of all benthic cover. There was notably higher cover of soft corals at Ahus than Andra, while coralline algae were significantly more abundant at Andra (Fig. 2).

Reef fish species richness was not compared between 2007 and 2002 since we were unable to survey the deeper parts of the reef in 2007; however, there was no notable difference found in reef fish species richness between Andra (34.11 species ± 7.63 (SD)) and Ahus (35.64 species ± 7.28 (SD)) in 2007. Similarly, mean reef fish density (no. of fishes per hectare) was 16752.22 ± 5797.33 (SD) for Andra and 17799.50 ± 5437.30 (SD) for Ahus; mean biomass was not found to be different between the two islands (Andra 331.59 kg/ha ± 5.85 and Ahus 345.59 kg/ha ± 178.03 (SD).

While the similarity in density and biomass of fishes between the two islands suggests that fish communities were relatively similar, when mean trophic group biomass was analyzed, a greater biomass of piscivores (Andra 6.41 kg/ha ± 8.97 (SD); Ahus 23.50 kg/ha ± 85.84 (SD)) and invertivores (Andra 33.54 kg/ha ± 18.48 (SD); Ahus 48.55 kg/ha ± 25.69 (SD) were found at Ahus Island (Fig. 3).

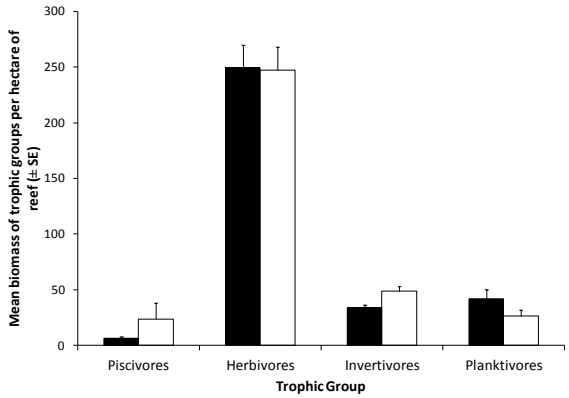

Figure 3: Mean biomass of fish trophic groups at Andra (filled) and Ahus (open) islands in 2007.

Socioeconomic assessment, coral harvests and coral farms

The primary activities within Andra's coastal zone were found to be fishing for domestic consumption or trade at local markets, and the harvesting of corals for the lime trade. Secondary activities were the collection of *Trochus* spp. and béche-de-mer (sea cumbers) to sell to local buyers in Lorengau, and gleaning of shellfish for domestic consumption. Figure 4 shows the percentage of households engaged in each of these activities and their dependence on them. A household was deemed dependent on an income or food generating activity if it was ranked first or second in importance by the head of the household.

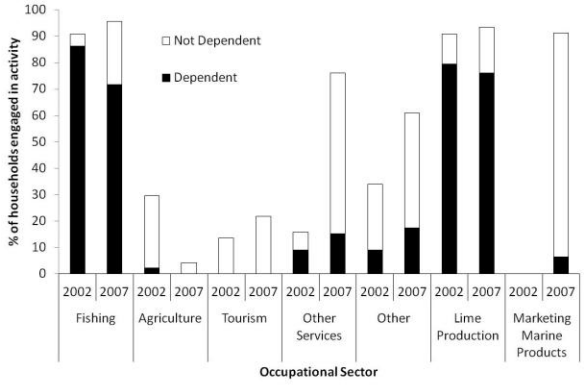

Figure 4: Percentage of Andra households participating in selected occupational sectors, highlighting the percentage of households that are dependent upon them. N = 44 in 2002 and 46 in 2007.

The Andra community is heavily reliant on its marine resources, with over 70% of households ranking themselves as heavily dependent on either fishing or lime production, a slight decrease from 2002 (Fig. 4). Fishing pressure, measured in fishing trips per week for each household was relatively low, at 1.75 in 2002 and 1.96 in 2007. Nearby Ahus Island reported 1.2 fishing trips per week per household in 2002. Spear-gun fishing and hook and line fishing were found to be the primary fishing gears used on Andra reefs with a variety of fishes targeted.

	2002	2007
Burns per year (by Household)	1.65 ± 0.19	1.65 ± 0.39
Burns per year (Community)	152 ± 26	137 ± 32
Value of lime/year/household (PNG Kina)	1113 ± 301	1208 ± 143

Table 1: Amount of coral removed and burnt and income per household on Andra in 2002 and 2007.

Examination of the extent and frequency of coral burning for lime production found that, on average, lime producing households burned coral 1.65 times in 2007, the same as in 2002 (Table 1). However, the total number of households in Andra decreased from 92 in 2002 to 83 in 2007, of which 77 had participated in burning corals in 2007. Therefore, the total number of times coral was burned in a year in the community reduced from 152 in 2002 to 137 times in 2007. The mean size of the coral pile burned had a mean volume 1.15 m^3 in 2007, which is equivalent to a volume of approximately 189 m^3 ± 23 of corals removed from the reefs surrounding Andra in the period 2006-2007 (Table 1).

In 2002 the coral lime producing industry was valued at USD102,000 ± 28,000 (SE) per year (Cinner et al. 2005). The 2007 survey of Andra lime producers reported a similar value for the industry of USD100,413 ± 13,367. At a household level this works out as USD1,208 ± 143 per household in 2007, compared with USD1,113 ± 301 per household from the 2002 study (Table 1) (Hartley et al. 2008).

Acropora intermedia was the primary coral species harvested in 2002 and accounted for about 90% of all corals in piles to be burned for lime. The 2007 study revealed that the proportion of this species in piles had fallen to approximately 20%, with other *Acropora* species making up a larger proportion of the piles. *Porites* spp. which had accounted for less than 1% of the pile in 2002 had risen to over 12% by 2007. Other coral species that contributed to the piles in 2007 were *A. formosa* (27%), *A. hyacinthus* (~12 %), *A. millepora* (~12 %), *A. robusta* (~10%), *A. vileda* (3%), and *Pocillopora spp.* (<1%).

The coral farms proved to be relatively successful, with post-transplantation mortality rates at ~15% for the first three months, decreasing to between 5 and 8% in each subsequent quarter. The first harvest was made in May 2009 and produced 1.23 m^3 of corals from a total of 11 tables, five of which had been overturned during extreme high swells experienced in December 2008.

Discussion

As with many coastal communities, the Andra community is heavily reliant on its marine resources. Economic demands, population increase, immigration, and the promotion of development activities all have varying impacts on resource utilization (Cinner & Mcclanahan 2006).

Ecological data indicate that the fish and coral communities at Ahus are in a healthier state than at Andra although there is no difference in fishing pressure. A likely explanation could be that coral harvesting at Andra is reducing refugia for fishes post-settlement, as indicated by Andra's lower biomass of piscivores and invertivores which are preferentially targeted by fisheries. Further to this, ecological data showed no difference in fish species richness or biomass and density between the two islands. Research has indicated that reef fish species richness is an important indicator of changes that can occur on coral reefs from both natural and anthropogenic disturbances, and that the loss of coral cover can be an important factor in loss of species richness (Jones et al. 2004). Furthermore, the number of species of reef fishes within a site is an indication of the biodiversity value of the location (Bellwood et al. 2004).

The coral lime trade is economically important to the Andra Island community and the majority of households have a heavy dependence on it as a source of income. Much of the community also

indicated a heavy reliance on fishing for income generation as well as for food. Thus, the Andra community is faced with a scenario where active degradation of reef habitat is required to maintain livelihoods, which further erodes the sustainability of other resources upon which they rely.

The slight increase in the cover of branching *Acropora* corals within the shallow parts of Andra's reefs is a promising sign that the reef system is capable of recovery if extractive pressure is lifted. It was established that the production from the experimental farms (1.23 m^3) is approximately equivalent to the mean coral volume for each burn by each household within the community (1.15 m^3), and is produced at roughly the same rate that coral is harvested. Once established, these coral farms can be maintained with little to no input from technical experts, and local communities can easily be trained to establish more similar farms. As the corals produced by the farms are consumed locally, many of the issues that are problematic to other coral farming projects, such as those that provide for the aquarium trade, are avoided; these problems include both logistical challenges (i.e. the transportation of live corals) and aesthetic requirements (i.e. the appearance of the corals). Further work on the capital costs of establishing and maintaining farms for each family harvesting coral is needed, but there is great potential for this project to be integrated into a comprehensive management plan. Through knowledge and information exchange with interested communities, such an initiative can be replicated throughout coastal PNG and perhaps the wider region where corals are harvested.

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