Community-based Coral farming for Reef Rehabilitation, Biodiversity Conservation, and as a Livelihood Option for Fisherfolk

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Abstract

The present condition of marine resources in the Philippines is critical and a majority of coastal communities live below the poverty line. If it continues, the progressive degradation of coral reefs and overexploitation poses a dangerous trend. Coastal resource management strategies are facing a new challenge: the integration of social, economic and natural sciences in future concepts to reverse the current status of ecosystem destruction and improvement of the people's living conditions. Hence, the primary objective of the coral farm is to provide alternative livelihood to fisher families from their resources on a sustained basis. The second objective is the rehabilitation of degraded reefs. Currently coral colonies of 64 species are taken through fragmentation from the wild. After 6-12 weeks (depending on the species) of grow-out in the farm, the fragments were deployed at the rehabilitation site at an average of 2 fragments per square meter (=12.5% cover). The survival rate of fragments is high at 84%, despite the fact that some coral colonies were placed in unsuitable substrates by the fisherfolk. More trainings have to be conducted to improve their knowledge of coral biology and community structure. The net cost of rehabilitating a one-hectare reef is U$2,100 for 12.5% cover. Additional profit from coral marketing is used for community projects identified by the fisherfolk. In this case, coral farming may be an option for livelihood and a cost-effective tool for reef rehabilitation.

Introduction

The persistent large-scale destruction of coral reefs worldwide as a consequence of pollution, overexploitation, natural calamities, and destructive fishing practices, among other perturbations, is well known (Wilkinson, 1993; Hodgson, 1999). Globally, it has been estimated that 10% of the world's coral reefs have already been seriously destroyed (ICRI, 1995). According to REEF CHECK data, there is no more pristine coral reef in the world (Hodgson, 1999). In the Philippines, host to one of the most diverse reefs on earth, surveys on the status of coral reefs at 14 sites revealed that only 2-4% could be considered in excellent conditions having 75-100% live coral cover while three-fourths were in the fair to poor category having 0-49% coral cover (Gomez *et al.*, 1994). Given the importance of coral reef ecosystems as a major source of dietary fish for coastal communities, as basis of tourism economy, as host to high level biological diversity, and as an effective coastal protection system against strong wave actions (White and Cruz-Trinidad, 1998), there is a sense of urgency to stop or even reverse the present situation and rehabilitate damaged reefs back to their normal productive condition. Two recognized problems that hinder large-scale reef rehabilitation are the cost and the source of coral colonies.

While in the past there have been efforts to rehabilitate degraded coral reefs, these were not cost-effective in terms of the methods employed and working time of scientists (Harriott and Fisk, 1988; Clark and Edwards, 1995; Kaly; 1995: van Treek and Schuhmacher 1997, Lindahl, 1998). To overcome these constraints, low-cost community-based coral farming was introduced. In 1998, the farm was established as a coral nursery until the fragments have attached to limestone substrates and ready to be transferred to any rehabilitation site. The coral farm maintains diverse coral species and serves as a source of income for the local community.

The most important factor in driving a change among coastal communities is the development of small-scale enterprises (Moffat *et al.*, 1998). In coral farming, the combination of reef improvement and the income potential for fisherfolk could be one way of raising responsibility of stakeholders through livelihood options. We believe that the success of any resource management effort is largely dependent on the level of community involvement. The coral farm is operated and managed with strong participation of the fisherfolk.

Materials and Methods

The coral farm site

The coral farm is located at the northeastern tip of Olango Island with an area of 20,000 m^2 (Fig. 1). The site is exposed to open water with occasional strong wave impacts during the rainy season and wave protection during the dry season. Tidal currents could reach up to 1 m per second. The seafloor at 5 to 10m depth is sandy with sparse seagrass beds and isolated coral heads. Water visibility ranges from ≤ 12m to 50m. The lowest water temperature recorded was 26°C and the highest 31.4°C; salinity is relatively stable at 1 m depth, ranging from 32.8 to 33.5ppt.

Collection and transport of coral fragments

Coral fragments were collected bi-weekly from four donor sites: Cordova reef, Gilutongan reef, Talima reef, and Tungasan reef in central Visayas, Philippines from January 1998 up to the present time (Fig. 1). Fragments of 64 scleractinian and 2 non-scleractinian coral species were taken using scuba. For most branching and delicate species, fragments were cut off manually using pliers, while massive, sub-massive, foliose, columnar and some encrusting species were cut with a hammer and chisel (Fig. 6a,b). To ensure continued growth of the donor colonies and maintain the good condition of the reef, only about 10-20% (from large colonies) of each donor colony were taken and in no case more than 50% (from small colonies). Since the start of the study, some donor corals were monitored for continued growth (Fig. 6c,d). The cut fragments were collected in 30-liter plastic baskets and transferred to styrofoam boxes or 80-liter barrels filled with seawater on board. During transport from the donor sites to the coral farm, which usually took less than an hour, all containers were covered to protect from direct and intense sunlight. Seawater was changed at 30 min intervals due to mucous secreted by the corals. The entire operation of fragmentation, transport, fixation to the substrate, and final placement into the Coral Nursery Units (CNU) at the farm site was a maximum of 4 h. At that time, the corals remained submerged in seawater, except during the fixation process, which took less than 5 min.

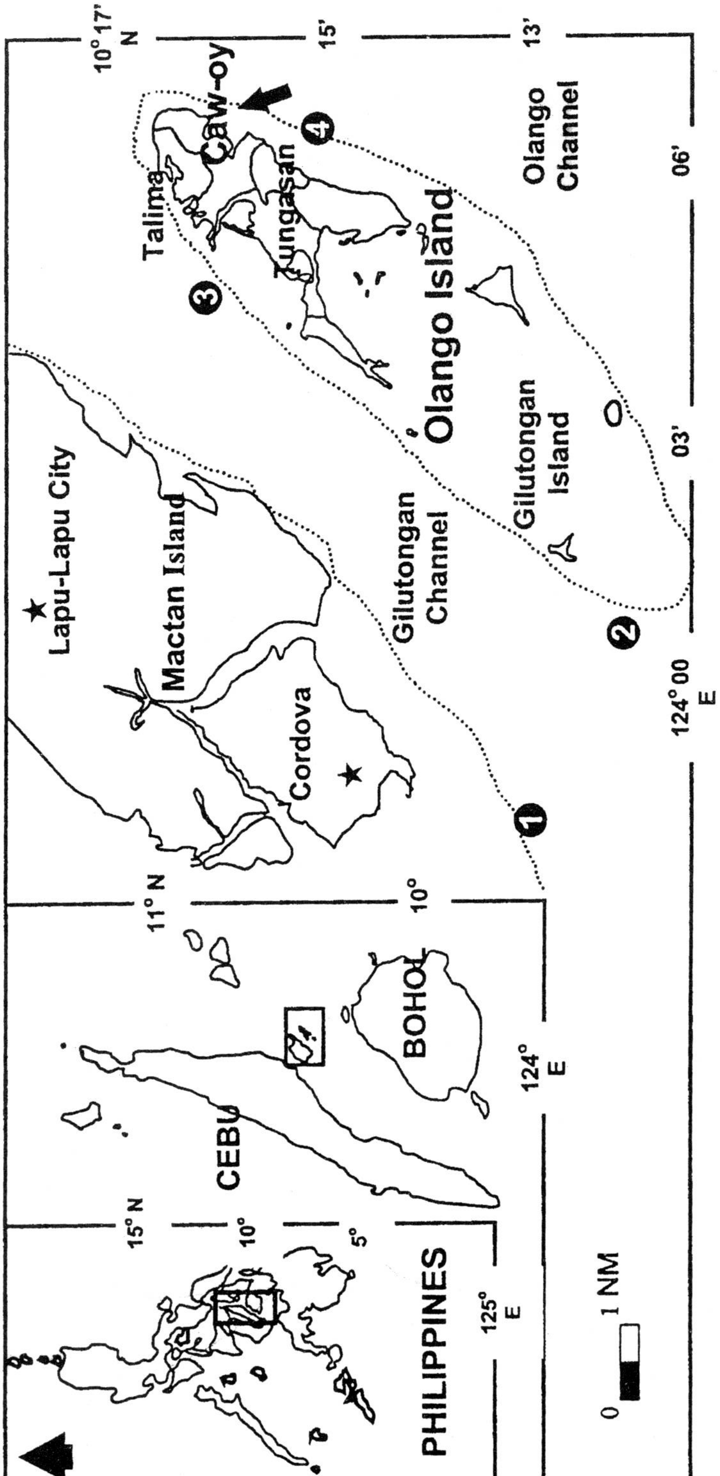

Figure 1. **Location of the coral farm site in Caw-oy (arrow), Olango Island, Cebu. Numbers indicate coral donor sites: Cordova reef (1), Gilutongan reef (2), Talima reef (3) and Tungasan reef (4)**

Substrate and fixation

After testing several substrates in a previous study (Heeger *et al.*, 1999), the results showed that customized-cut fossil limestone (20x5x1.3cm) was the most suitable. The individual limestone slabs were further subdivided to adjust to fragment size. Before the fragments were fixed, all substrates were washed with seawater and dried. At the farm site, the fragments were attached to the substrate using galvanized wire (1/16 and 1/18), tightened with pliers, and excess wire cut off (Fig. 6e). As much as possible, the fragments were always vertically positioned. Large polyps such as that of *Lobophyllia hemprichii* were fixed laterally to the substrate slabs.

Nursery technique

After attaching the fragments to the substrates, these were transferred to the CNU at depths of 6 to 9m using scuba (Fig. 6f). The CNUs are concrete frames of 1.2 x 10cm wide and 10cm high made by the fisherfolk (Fig. 6f, Fig. 7f). One bag of cement and a waterproofing substrate were used to produce one CNU. The seafloor inside the CNU was covered with plastic canvass to prevent the fragments from falling down and being buried in soft sediment after the intensive scavenging activity of infauna and fishes (Fig. 6f, Fig. 7d).

Reef rehabilitation

A 2,000 square-meter degraded reef located off Mactan Island is the site of the rehabilitation efforts. Before transferring the coral colonies, a survey of the site was conducted using scuba to assess the general condition of the reef and the coral community structure (e.g., dominant species and lifeforms) and to identify the most suitable spots in the reef to place the fragments. A series of line-intercept transects was made to obtain baseline data on coral cover (Fig. 8).

The coral fragments were collected from the CNUs with the help of fishermen using surface air-supplied compressor systems and then transferred to plastic barrels or styrofoam boxes filled with seawater on board. Only firmly attached and healthy colonies were chosen for rehabilitation. During transport, all containers were covered with canvass to protect the corals from direct sunlight. The transport of farm grown coral fragments to the rehabilitation site took less than an hour and, upon reaching the site, they were immediately deployed on the seafloor. On the average, 2 fragments per square meter were deployed, which is equivalent to a coral cover of 12.5% (Kaly, 1995).

Results

Community profile

The site of the Coral Farm Project (CFP) is Barangay Caw-oy located northeast of Olango Island, Lapu-Lapu City, Cebu, Philippines. Generally flat with limestone bedrock, it is the smallest of the eleven barangays in Olango Island with a total land area of 0.36 km^2 (Fig. 1). It has 200 households with an average family size of 5 persons. The population of Caw-oy is 1,002 with a population density of 2,783 persons/km^2. Caw-oy has a young population with more than 70% under 40 years old and only very few have finished high school and college education (Figs. 2 and 3). Although 95% own their house, only 68% own the lot where they are residing. Houses are predominantly made of light materials. A majority (71%) of the households have no toilets and the people use un-cultivated areas or the sea for human waste disposal. About 70% of the households are connected to the power line, which provides electricity from 12:00 noon to 11:30 pm.

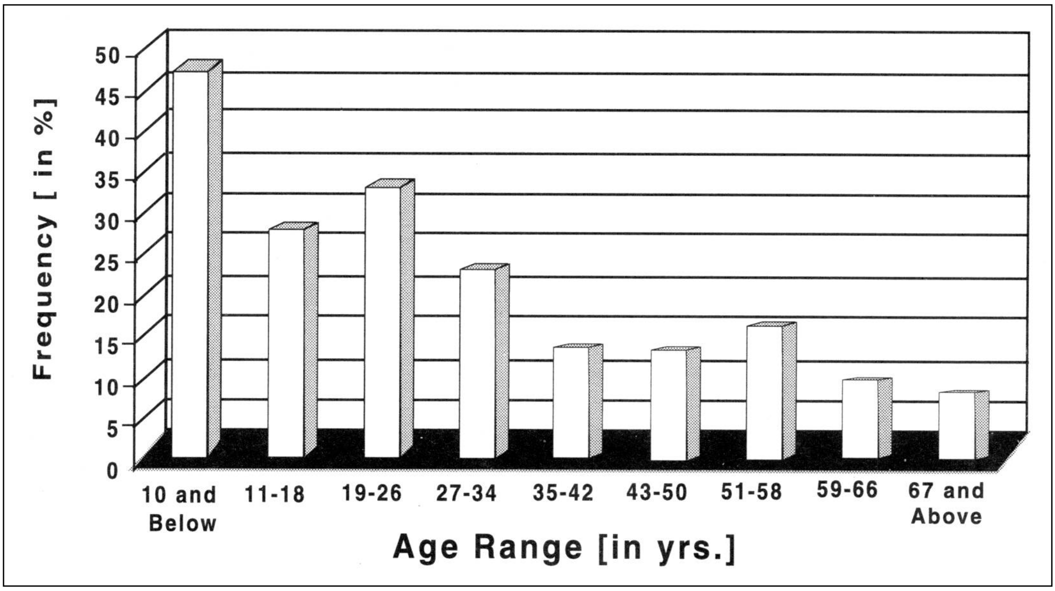

Figure 2. **Age profile of household members in Caw-oy, Olango Island, Cebu. Number of respondents = 42**

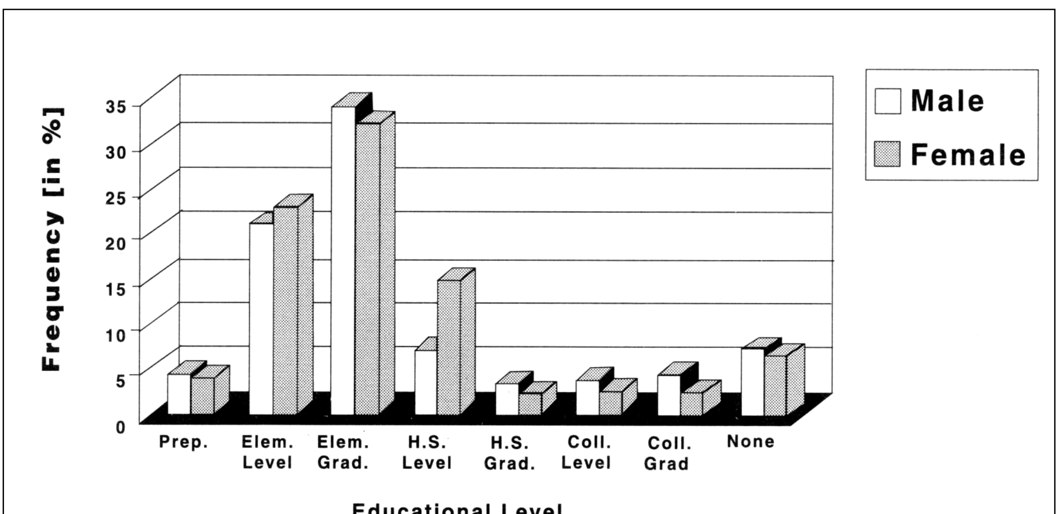

Figure 3. **Educational attainment of household members in Caw-oy, Olango Island, Cebu. Number of respondents = 42**

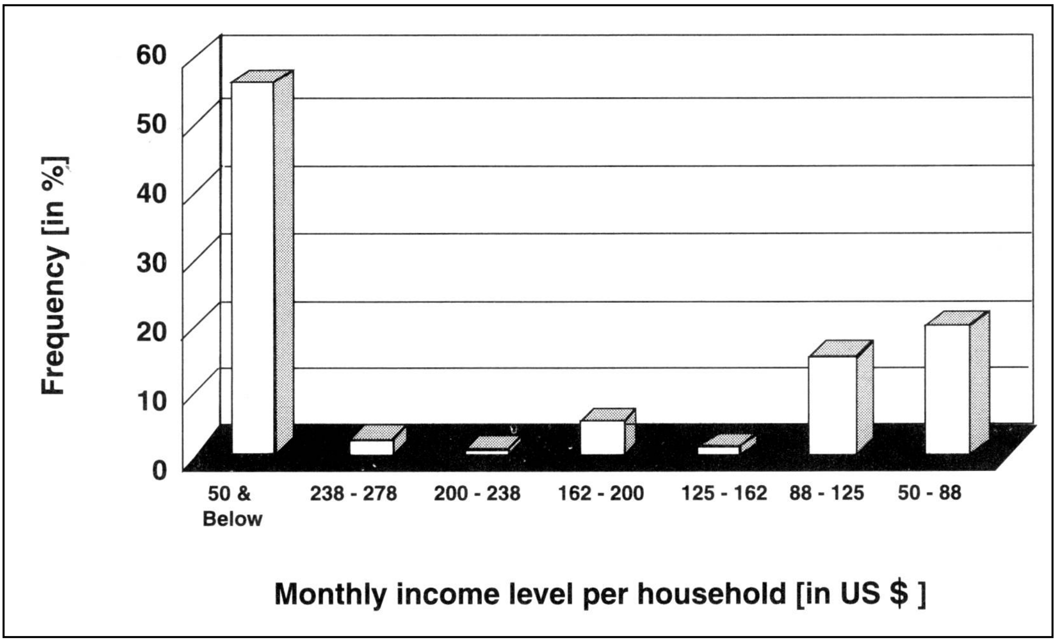

Figure 4. **Monthly income level (in US $) of families in Caw-oy, Olango Island, Cebu. Number of respondents = 42**

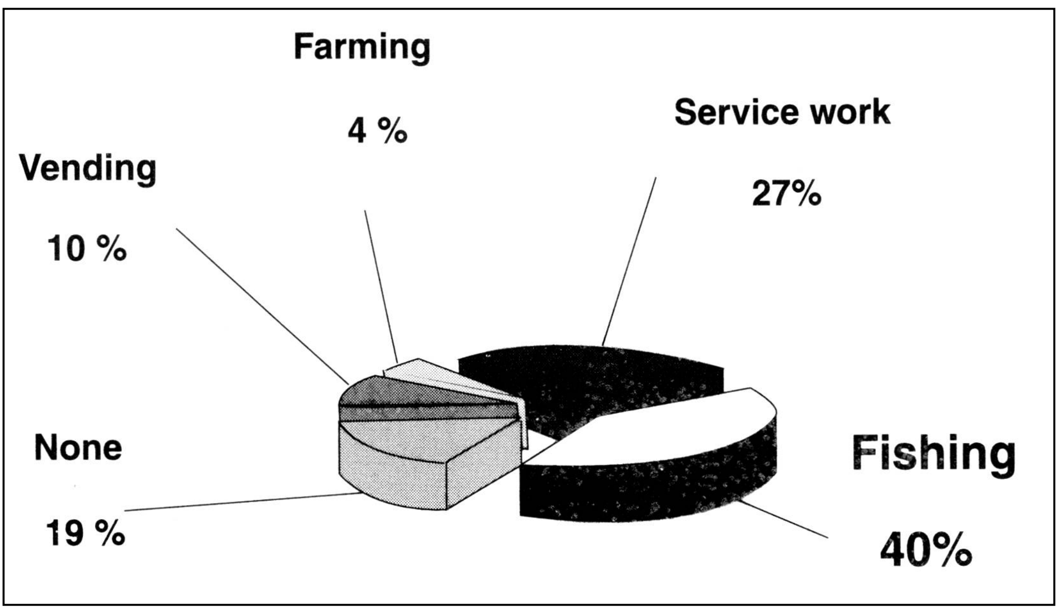

Figure 5. **Occupation of household members in Caw-oy, Olango Island, Cebu. Number of respondents = 42**

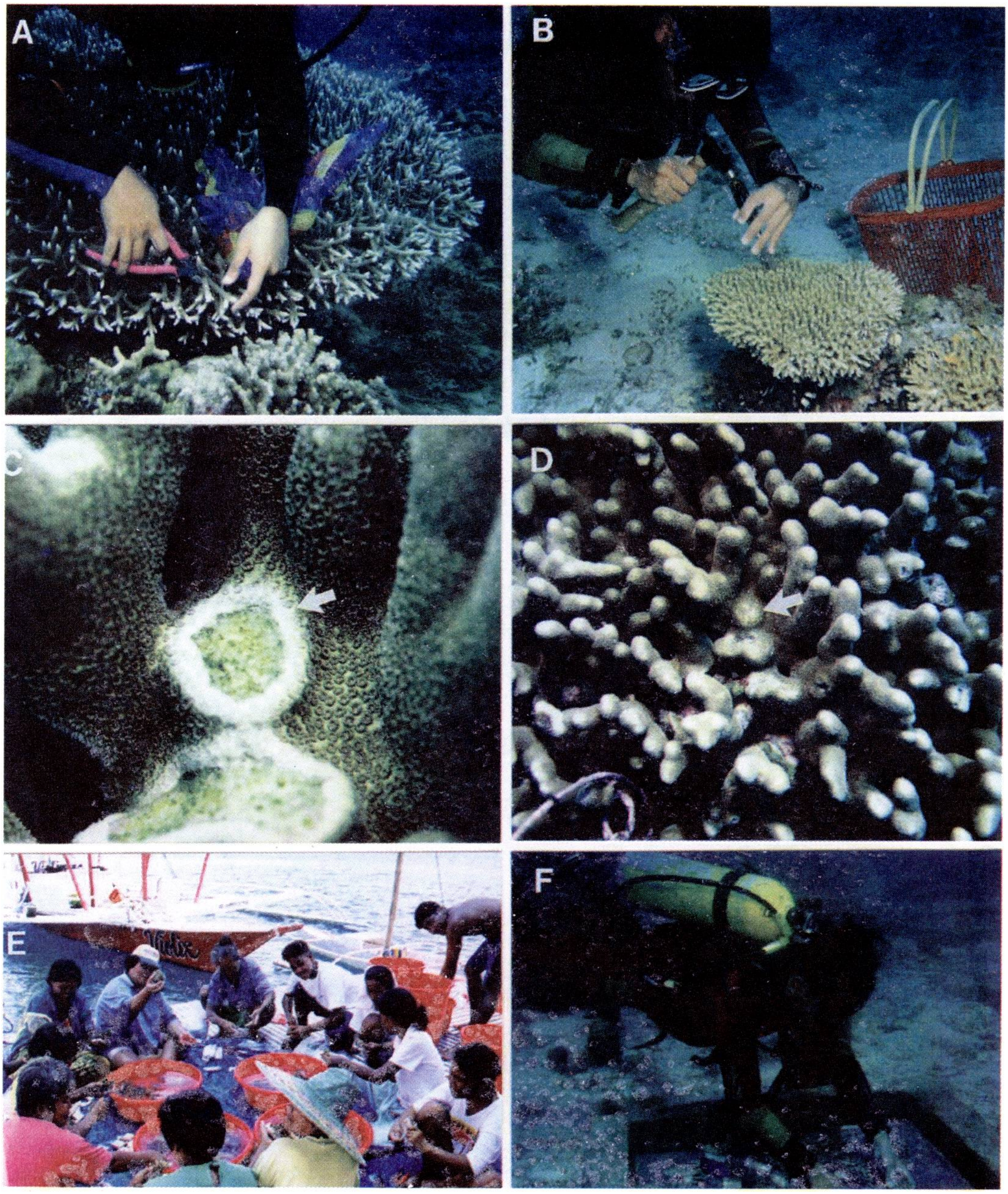

Figure 6. **A) A diver cuts off hard fragments of *Acropora valenciennesi* with pliers. B) Fragments of strong-built branching or other coral life forms are chipped off with hammer and chisel. C) One week after cutting off fragment, the margin of a *Porites* colony has already started to overgrow the scar (arrow). D) Five weeks after fragmentation, the area has been completely overgrown (arrow). E) The fisherfolks are trained in fixing the coral fragments to the hard substrate. F) All fragments are placed inside a concrete square (1 m^2 inner area), which defines the Coral Nursery Unit (CNU), at a density of 60 to 80 fragments. The CNU wards off predators and the plastic canvass prevents the fragments from falling down due to the intensive activities of infauna and fish.**

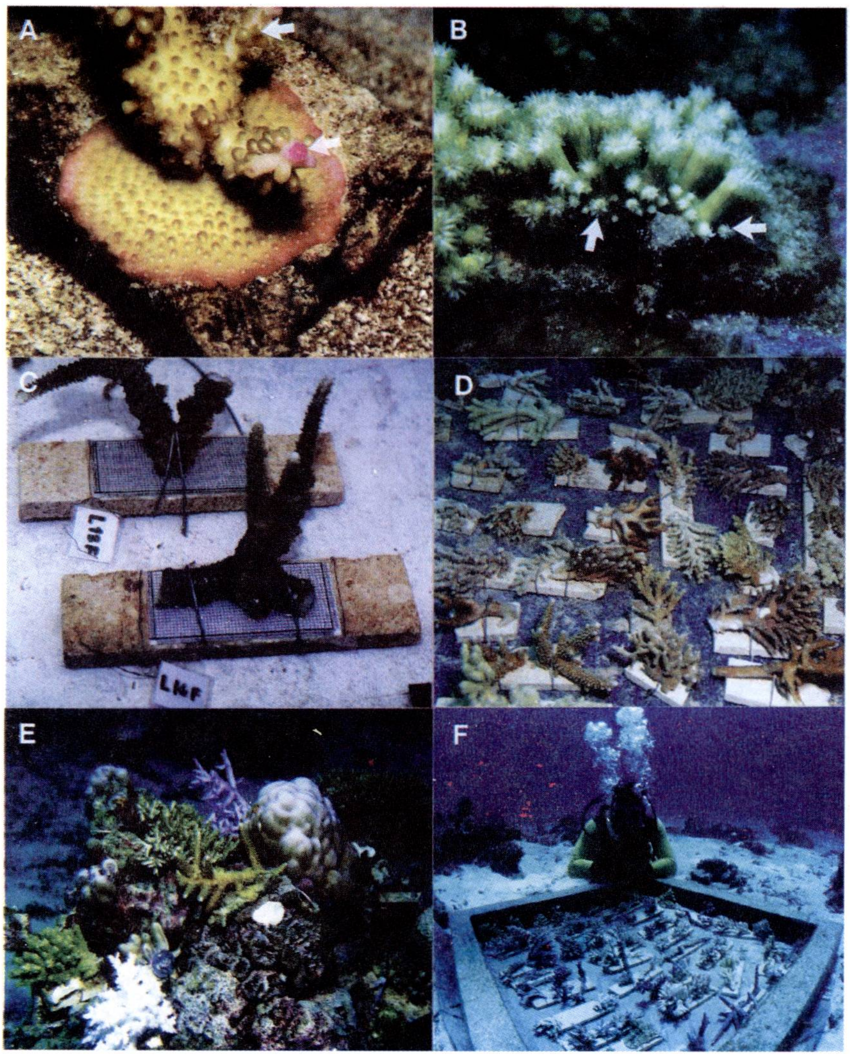

Figure 7. **A) A fragment of *Acropora divaricata* 12 weeks after fragmentation. The secondary basal disc stabilizes the fragments on the substrate. Newly formed branches (arrows) follow the natural symmetry of the coral colony. B) Numerous buds on the side of *Galaxea fascicualris* fragments document fast regrowth at the fragmented site. This species is quite aggressive and needs to be distanced from other species as extend it can extend its sweeper tentacles up to 15 cm at night and therefore harm other adjacent coral colonies. C) An experimental set up of *Acropora grandis* fragments fixed horizontally and vertically (background) on the substrate with laminated grids to document the area and time interval of secondary basal disc formation according to vertical or horizontal orientation of the fragment. D) A view inside a CNU showing some of the 60-80 fragments. The number of fragments, which can be placed together, is species- and initial fragment size-dependent. E) An area of a nearby reef, which have been rehabilitated with tagged fragments of 22 different hard and soft coral species. This experiment was conducted to acquire basic data on "reef scaping". F) A SCUBA diver checks the growth of fragments. At present the farm has 233 CNUs having a total of more than 18,000 fragments ready for marketing.**

The poverty threshold was pegged at U$110 per month in 1997 (NEDA). The survey of 42 households shows that 56% earn (Fig. 4) less than U$50, and another 25% of the households earn between U$87.50 and U$275 per month, showing that 75% of the households live below the poverty line with a monthly income of U$110. Among 42 respondents, 40% indicated fishing as their most significant livelihood (Fig. 5). Other livelihoods are service work (27%), vending (10%) and land-based farming (4%). About 19% of the respondents claimed to have no source of livelihood at all. Since the use of destructive fishing methods in Caw-oy has been totally banned in 1998, fishing is now dominated by fish trap, long line, hook and line, set net and compressor diving (hookah-hookah). Few fishers work on long distance trawlers or shell collectors, which usually last for up to four months at sea.

Reef rehabilitation efforts

A 15m outrigger boat and a team of at least 4 divers are capable of transplanting 1,000 coral colonies in a 500 m^2 of reef in a day. On the average, twelve 60-100 liter containers were required to transport 1,000 fragments submerged in seawater. The placement of the coral colonies on suitable areas was dependent on the type of substrate present. Hard substrate such as coralline rocks, dead table corals, sandy patches with underlying hard limestones and an open space versus resident corals are preferred, as these offered stability. Suitable spots for coral fragment placement in the rehabilitation site were patchy in distribution. The actual number of fragments deployed ranged from 0 to 8 colonies per m^2. Some fragments have grown to a size that caused instability when positioned vertically on hard substrate. In this case, the fragments were positioned so that the side having the largest surface area was in contact with the natural substrate. Whenever possible, the fragment's fixed substrate was firmly secured in the crevices of the reef. Aside from special requirements or adaptations of coral species, which were considered during deployment, the resulting community pattern through reef rehabilitation was at random.

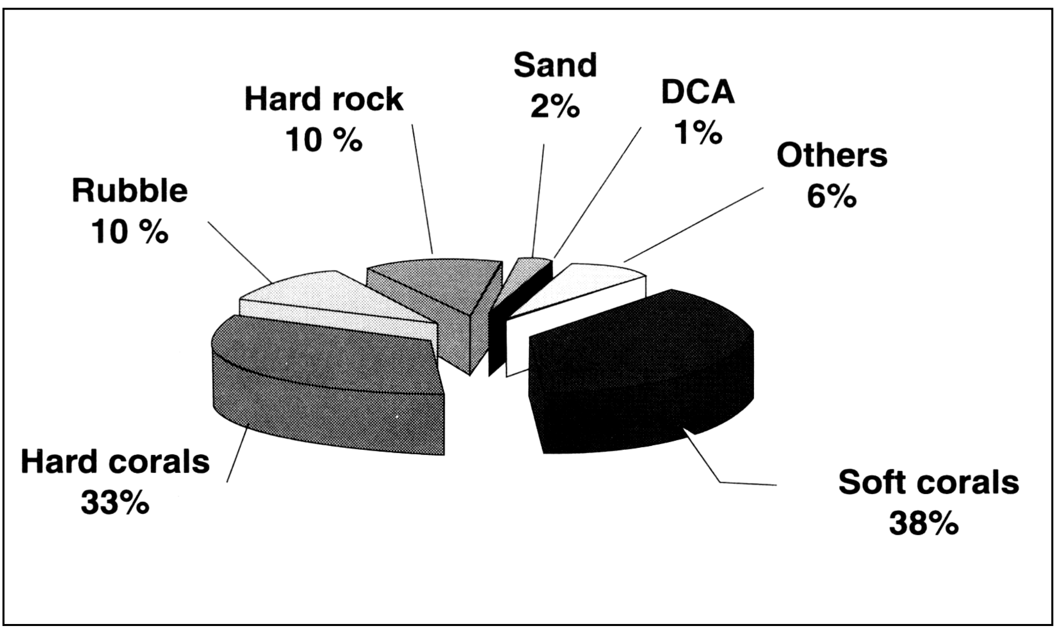

Figure 8. **The benthic community profile at the rehabilitation site**

Fast growing branching species like *Acropora muricata*, *A. nobilis*, and *Goniopora djiboutinensis* were placed on sandy substrate while slow growing plate-forming, encrusting or foliaceous colonies like *Montipora undata, Oxypora labra* and *Mycedium elephantotus* were placed on elevated hard substrate. *Galaxea fascicularis* was properly spaced with other scleractinians because it is known to extend its polyp tentacles during the night thus stinging other species with their nematocysts. Some species (*Acrhelia horrescens, Acropora echinata, A. grandis A. millepora, A. sarmentosa, A. valenciennesi, Echinopora lamellosa, Stylopora pistillata, Turbinaria peltata* and *Heliopora coerulea),* which were not recorded during the surveys, were introduced from the farm. At depths of 8-10m in the rehabilitation site, the soft coral, *Xenia* sp. was dominant at 38% coral cover compared with the other hard corals at 33% (Fig. 8). *Xenia* sp. colonies were luxuriant because of high inflow of particulate organic matter from public beaches near the rehabilitation site. Colonies of *Xenia* sp growing on hard substrate were removed and replaced with farm-grown corals. The average survival rate of coral colonies transferred to the rehabilitation site was 84%.

Table 1. **Cost of reef rehabilitation with 100 coral transplants (US$1 = Php 40)**

Item	Cost (US $)
Gathering	1
Fixing (including tie wire and limestone slab)	2.75
Tending	2
Transportation	2.5
Deployment	1
Overhead	1.25
Total	10.5

Overall cost of reef rehabilitation

The breakdown of expenditures of the entire rehabilitation process from gathering of fragments to monitoring of growth and survival rate of the deployed coral colonies appears in Table 1. The coral fragments were marketed at U$25 per 100 fragments, inclusive of rehabilitation efforts and monitoring of survival rate for 3 months. After deducting the expenses of U$10.5, a profit of U$14.5 was realized. This profit is used for the maintenance of the farm, the dive gears, boat etc. and for community projects, which the fisherfolk themselves proposed.

Income of fisher families through coral farming

Women did the fixing of coral fragments on the substrates and they are paid U$1.5 per 100 fragments. The daily income of women fixing fragments for less than 2 hours range from U$2 to U$4 while the fishermen were paid U$5 for 4 hours of coral farming per day. On the average, a couple earns U$7 to U$9 daily for a total 6 man-hours work, which could amount to U$180 monthly income. About 75% of a typical 5-member household in Caw-oy has an average monthly income of less than U$87.5 with more than 8 working hours.

Discussion

Reef degradation caused by natural events such as coral bleaching following a rise in seawater temperature (El Niño phenomenon), crown-of-thorns outbreaks or coral diseases may have detrimental effects on local coral reefs. Globally, this may be negligible compared to human impacts such as overexploitation and the use of destructive fishing techniques. Reef scientists agree that coastal communities generally lack the consciousness and the responsibility to stop the over-harvesting of their marine resources. But actually, fisherfolk have no option for environment-friendly, sustainable use of their resources. About 75% of Caw-oy residents in Olango Island, a few minutes by boat from tourist resorts in Mactan Island, involved in CFP live below the poverty monthly income of U$110.

The successful co-existence of coastal communities with the sea providing unlimited food resource has changed dramatically over the past decades. Too many fishers have been competing for dwindling resources (Pauly and Chua, 1988). Although strict law enforcement and regulations have tried to limit overexploitation, this strategy has generally not been successful. The vicious cycle of increasing population growth and dwindling resources has led to irreversible destruction of the reef ecosystem, and eventually the collapse of commercially targeted species. This trend of marine ecosystem degradation has to be reversed and requires a new strategy in managing coastal resources by integrating livelihood options and limiting the number of future resource users.

Alternative livelihoods should have a strong entrepreneurial component to trigger a change in the attitudes of coastal communities towards sustainable utilization of their resources (Moffat *et al.*, 1998). To date, implementable livelihood options are very limited. Small projects such as mat-weaving, poultry and livestock raising, variety store etc. are not viable in the long-term, probably because these ventures are not related to fishery or these are simply unprofitable. Future programs of coastal resource management should devise low-cost and income-generating sea ranching activities in consonance with their fishing tradition. Hence, the coral farming concept highlights the livelihood options for fisherfolk and at the same time contributes to the rehabilitation of degraded reefs. The economic benefits derived from farming corals increases the responsibility of stakeholders to manage their resources wisely.

The constraint identified so far is the limited experience of successful reef rehabilitation. Most efforts in reef rehabilitation have been confined only to “minor repair” after impacts of ship groundings (Precht *et al.*, manuscript submitted) or reef damage following construction activities. In such cases, the entire live coral colonies from adjacent reefs were transplanted to the damaged sites, resulting in loss of coral biomass *per se* since survival is less than 100%. Although methods of coral fragmentation and “nursery” maintenance need improvement, the time has come to undertake mass coral cultivation to provide enough coral colonies for large-scale rehabilitation. According to Salvat, (1995), urgently needed solutions will not be found through additional experimentation but through application of that which we already know.

The parameters set in “reef scaping” are based on coral biology, reef community structure, and cost-effectiveness. First, the rehabilitation site has to be checked for suitable conditions that support coral growth. If basic conditions are not present because of the use of destructive fishing techniques, pollution, sedimentation, high organic influx, etc., the impact of rehabilitation efforts would be nil. Second, a reef selected for rehabilitation should have a coral cover of at least 20% to provide sufficient protection for the newly transferred fragments against predators. An observed effect after rehabilitation was an increase in the number of microhabitats within the individual coral symmetry, lower mortality rate of coral recruits, and higher abundance and diversity of invertebrates. Fish population is expected to increase over time. The CFP supports the idea of rehabilitation to approximate natural species diversity similar to the coral community before the destruction. Priority in the selection of fragments is not focused on the fast growing species, but on those species tolerant to fragmentation. For instance, almost all branching corals are easy to fragment and grow fast (*Acropora*, *Porites, Pocillopora* etc.) while some massive species (*Lobophyllia*, *Diploastrea, Favia*, *Goniopora* etc.) need utmost care and experience if fragmented. On the alteration of the coral community structure due to rehabilitation, only coral species occurring abundantly in adjacent reefs of up 15 nautical miles from the site were selected. Thus, deployment of species not recorded during the pre-check of the rehabilitation site are not considered as introduced species, since these species may have been present in the site prior to rehabilitation.

Third, the actual placement on the reef for transplanting coral recruits by local fisherfolk must be closely supervised. In many instances, despite briefing before deployment, almost 30% of the fragments were placed in unsuitable or sub-optimal substrates. For example, slow-growing species have been placed on sand, while fast-growing species on elevated positions. Some fragments also were placed on top of resident colonies or too close to it. More “hands-on” training for local fisherfolk need to be conducted before deployment.

And, fourthly, *Xenia* sp., grows luxuriantly in the rehabilitation site, out-competing resident and transplanted scleractinians. The high inflow of organic particles near the rehabilitation site that favors the growth of this soft coral should therefore be mitigated to ensure the success of the rehabilitation effort.

Acknowledgements

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