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Low-cost artificial reef program in the Philippines: an evaluation in the management of a tropical coastal ecosystem**

Ein Programm für preisgünstige künstliche Riffe auf den Philippinen: eine Evaluierung des Managments eines tropischen Küsten-Ökosystems

by

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Abstract

This paper evaluates a 15-year program on low-cost artificial reefs (LCAR) in the Philippines resulting in an eco-economic analysis of reefs. The most common and popular materials used in the construction of artificial reefs are discarded tires and bamboos. Concrete cement is rarely used due to the high cost of its materials. Available data reveals that there is a low biological productivity in bamboo and tire artificial reefs with an average of 0.154 $kgm^{-3}wk^{-1}$ and 0.010 $kgm^{-3}wk^{-1}$, respectively, compared with the natural reefs having 0.256 $kgm^{-3}wk^{-1}$. Likewise, findings show that fishermen earn a lower income of PHP 6.16 $kg^{-1}m^{-3}wk^{-1}$ from using bamboo reefs and PHP 0.40 $kg^{-1}m^{-3}wk^{-1}$ from tire reefs in comparison with the earnings from natural reefs which is PHP 10.24 $kg^{-1}m^{-3}wk^{-1}$. Preliminary researches on the ecology of artificial reefs (i.e., bamboo and tires) showed that the substrates of such reefs are not conducive to reef organism encrustation, and as rubber tires decay they produce toxic chemicals adding more problems to the ecosystem. Recommendations for the tropical coastal ecosystem management are presented.

Zusammenfassung

Diese Arbeit evaluiert ein 15-Jahres Programm an preisgünstigen künstlichen Riffen auf den Philippinen auf der Basis einer ökologisch-ökonomischen Riffanalyse. Die häufigsten und beliebtesten Materialien, die für den Bau von künstlichen Riffen verwendet werden, sind alte Autoreifen und Bambus; Beton ist durch seine hohen Materialkosten selten. Mit Mittelwerten von 0.154 $kgm^{-3}wk^{-1}$ bzw. 0.010 $kgm^{-3}wk^{-1}$ ist die biologische Produktivität in künstlichen Bambus- und Autoreifen-Riffen im Vergleich zu natürlichen Riffen (0.256 $kgm^{-3}wk^{-1}$) gering. Ebenso ist das Einkommen der Fischer mit PHP 6.16 $kg^{-1}m^{-3}wk^{-1}$ aus Bambus-Riffen und PHP 0.40 $kg^{-1}m^{-3}wk^{-1}$ aus Autoreifen-Riffen geringer als jenes aus natürlichen Riffen mit PHP 10.24 $kg^{-1}m^{-3}wk^{-1}$. Vorläufige Untersuchungen zur Ökologie dieser künstlichen Riffe zeigen, daß sie der Inkrustation von Rifforganismen nicht dienlich sind und daß Gummireifen toxische Zerfallsprodukte bilden, die dem Ökosystem zusätzliche Probleme bringen. Vorschläge zum Management von tropischen Küsten-Ökosystemen werden gemacht.

1. Introduction

In the Philippines, 70% of the 34,000 km^2 coral reefs were found to have been badly damaged in the middle of the 1980s. Extensive documentation on the rate and causes for the degradation of the reef resources are given by GOMEZ et al. (1981), CORPUZ et al. (1983), WHITE (1984, 1987), YAP & GOMEZ (1985), MEÑEZ et al. (1991), and HILLMER (1991). The reasons for the destruction are as follows: 1) intensive and destructive fishing methods such as blasting, use of cyanide, muro-ami trawling, gleaning, and spearing; 2) sedimentation due to deforestation and poor land use practices; 3) all kinds of boat anchorage; 4) pollution caused by improper disposal of domestic, agricultural and industrial waste products, and 5) tourism. These conditions were also observed in neighboring Southeast Asian countries.

The country has been experiencing economic difficulties aggravated by natural calamities, thus tapping indigenous and low-cost materials for development and management of the resources is the priority thrust of the government. This thrust includes the preservation of natural reefs and the establishment of artificial reefs to conserve and increase fish production in order to help alleviate the plight of poor fishermen. These reefs, through time, will be col-

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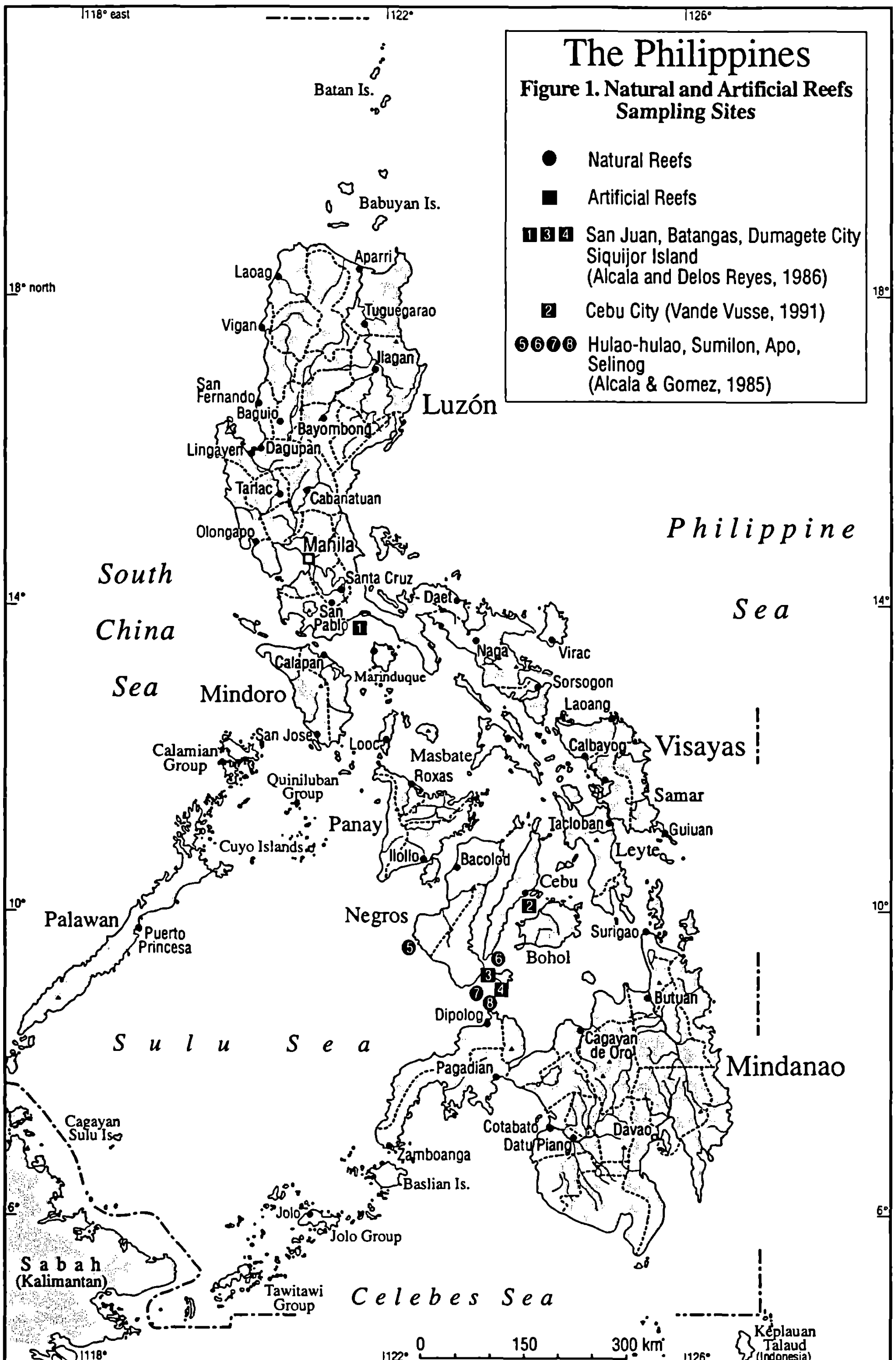

Cartographic Sources: Knaurs Großer Weltatlas, 1980, Rand McNally International Atlas, 1978
Dirk Bronger: Die Philippinen, 1987
Cartography: K. Reich '94

Figure 1: The Philippines: natural and artificial reefs sampling sites.

onized by coral organisms which will develop into coral communities and serve as fish sanctuaries, which are important links to the food chain.

The low-cost artificial reef program launched by the Philippine government through the Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) has the general aim of saving one of the biggest coral reef resources in the world from total degeneration by regulating the exploitation of this important type of ecosystem where commercially important fishes and invertebrates thrive.

This study presents the evaluation of the artificial reef program in the Philippines using locally available low-cost materials such as bamboos and discarded tires as well as the construction and development of such reefs, fish yields, cost and return analysis, problems and recommendations.

2. Materials and Methods

Information necessary for the preliminary analysis of the low-cost artificial reefs program in the Philippines were gathered from published and unpublished literature and from the monitoring, coordination, and evaluation work experiences of the first author at the Department of Science and Technology-Philippine Council for Aquatic and Marine Research and Development (DOST-PCAMRD). Unpublished literature (manual and handout) from the (DA-BFAR) were used for the general description and construction of artificial reefs. The analysis of the biological productivity in natural and artificial reefs was taken from a 10-year study on fish yields. Yield (Y) was computed from the observed catch divided by the number of sampling days multiplied by the number of fishing days in one year over the reef area as given by ALCALA & GOMEZ (1985). Estimation of cost and return analysis were based on methods presented in the brochure entitled, "Technology on Philippine Artificial Reef", PCARRD Vol. 8, No. 6 co-authored by the first author. The results of both analyses are included in this paper. Data were organized, figures and values for the biological and economic productivity were obtained through the methods of conversion and standardization. Note that US$ 1.00 = PHP 27.60 (Philippine Peso) in December 1993. Fig. 1 shows the map of the Philippines and the natural and artificial reefs sampling sites.

3. Site and construction of low-cost artificial reefs

Based on ALCALA & DELOS REYES (1986) and BFAR (no date), artificial reefs are best located in protected embayments with sandy or sandy-muddy substratum at depths of 15–20 m. These places pose no hazards to navigation and are least affected by the movements of waves.

Artificial reefs in the Philippines are constructed from discarded tires and bamboos which are the two most common low-cost materials. They are placed in a jumbled state or are assembled into geometric forms. Tires last 3–4 times longer than bamboos, which stay intact only for about three years. Citing the government launched artificial reef models, the constructed one-module tire and bamboo reefs are shown in Figs. 2a and 2b, respectively.

4. Development of low-cost artificial reefs

In the last 15 years, low-cost artificial reefs have been used for coastal management in the Philippines. According to the survey, the first low-cost artificial tire reefs were built by the Silliman University Marine Laboratory in Dumaguete City in 1977. In the early 1980s, the Central Visayas Regional Project (CVRP) based in Cebu City adopted the technology by promoting the use of bamboo reefs in the shallow coastal waters off Negros, Cebu, Siquijor, and Bohol Islands. The CVRP, after the first four years of implementing this technology, deployed 26,000 modules (33,800 m^3) of bamboo artificial reefs along the 67 km coastline project sites. The Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) launched a nationwide artificial reef development program in early 1985 as one of its fishery management tools. The target beneficiaries of the program were the sustenance/artisanal fishermen. In 1987, 63 small-scale artificial reefs in various parts of the country were established. The full implementation of the program started in 1989 by the government through the DA-BFAR soliciting discarded tires from the public and private citizens for this purpose. Cooperation between the government and local fishermen was promoted wherein

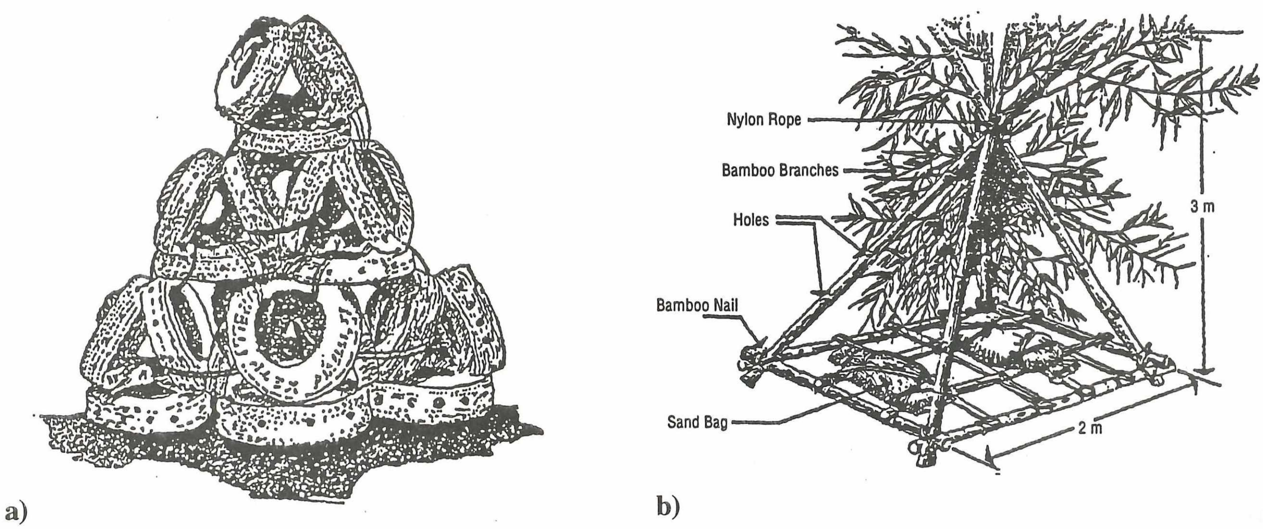

Figure 2: a) Tire artificial reef; b) Bamboo artificial reef.

the government took the responsibility of providing the materials such as bamboos, discarded tires and other materials needed while the fishermen rendered free labor for the construction of the artificial reefs. The Philippine Business for Social Progress (PBSP), a non-governmental organization (NGO) composed of businessmen also disseminated artificial reef technology in the southern Philippines (Mindanao) in the late 1980s with the aim of uplifting the socio-economic conditions of the poor fishermen in that area.

5. Fish yields and species harvested

Common fishing gears used are traps, gill nets, handlines and hook and lines which are set at 20 m depth. Harvesting usually begins in about 6 months after artificial reefs have been dropped into the sea.

Based on the data shown in Tab. 1, biological productivity or harvest yields in natural and artificial reefs range from 0.087 to 0.639 and from 0.009 to 0.154 $kgm^{-3}wk^{-1,}$ the former having a difference of 0.552 and the latter, 0.144 $kgm^{-3}wk^{-1}$. The reason for the difference in terms of yields in natural reefs is, perhaps, due to the conditions of their respective locality. According to ALCALA and GOMEZ (1985), the difference in fish yields in natural reefs (such as Hulao-hulao, Apo, Selinog and Sumilon) could be associated to their varying reef environments, intensity of fishing, the dominant species consisting the fishery, and the degree of protection given to that environment. Hulao-hulao is the least productive since it suffered the highest degree of physical damage, has a relatively flat and shallow profile, and is the most exploited area (Fig. 3a). Generally, the yields from artificial reefs are much lower than yields from natural and even damaged reefs where bamboo reefs reached 60.0% and 4.0% for tire reefs as shown in Tab. 1.

However, as these conditions worsen (intensity of human impact), the productivity of natural reefs falls 6-7 times and in severe cases, it may equal to or less than the yields in bamboo artificial reefs. On the other hand, low productivity of bamboo and tire reefs (with an average of 0.154 $kgm^{-3}wk^{-1}$ and 0.010 $kgm^{-3}wk^{-1}$, respectively) in comparison to natural reefs (0.256 $kgm^{-3}wk^{-1}$) are caused by the low population of reef building organisms which are important links to the food chain. This reveals the limited efficiency of these kind of artificial reefs in imitating the natural reefs (Fig. 3b). The poor encrustation of reef organisms are due to the instability of material and unsuitable substrates as reported by HILLMER (1991). Tire reefs are much less productive than bamboo reefs. Chemical analysis of tires shows that as the tires decay in water, they produce toxic compounds that cause problems to the aquatic ecosystem. This could be a significant factor in addition to the above mentioned reasons for halting the settlement of coral organisms and hindering fishes and marine organisms from using artificial reefs as their permanent habitat. This means that the use of industrial wastes such as tires has an adverse effect on the ecosystem.

Some of the fishes that thrive and caught in artificial reefs are the barracudas (Sphyraenidae) and Spanish mackerel (Scomberomoridae), surgeon fishes (Acanthuridae), fusiliers (Caesionidae), jacks (Carangidae), sweetlips (Haemulidae), wrasses (Labridae), snappers (Lutjanidae), goatfishes (Mullidae), groupers (Serranidae), and rabbitfishes (Siganidae).

Natural Reefs		Artificial Reefs		
Location	Productivity	Location	Productivity	
			Bamboo	Tire
Hulao-hulao ***	0.087	Dumaguete City	–	0.009
Selinog ***	0.100	Siquihor	0.154	
Apo **	0.197	Cebu City	0.154	
Sumilon *	0.639	Batangas		0.010
Average	0.256		0.154	0.010
Percent	100.0		60.2	4.1
Range	0.087–0.639		0.009–0.154	
Difference	0.552		0.144	

Legend: ***–high human impact, **–intermediate human impact, *–low human impact.

Calculations based on ALCALA & GOMEZ, 1985; ALCALA & DELOS REYES, 1986: VANDE VUSSE, 1991.

Table 1: Biological productivity of natural and artificial reefs in the Philippines (in kg m^{-3} wk^{-1}) (No. of Cases 838).

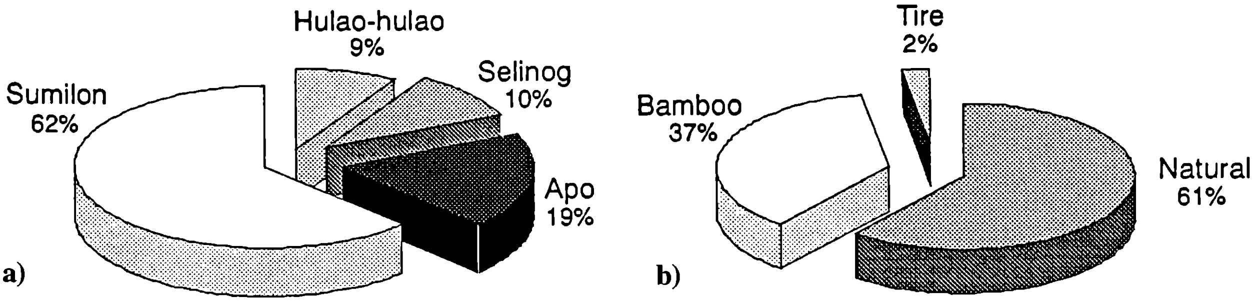

Figure 3: a) Biological productivity of natural reefs; b) Biological productivity of natural and artificial reefs.

Natural Reef			Artificial Reef				
Location	Income		Location	Income			
				Bamboo		Tire	
	Per Week	Per Year		Per Week	Per Year	Per Week	Per Year
Hulao-hulao	3.48	180.96	Dumaguete City	–	–	0.36	18.72
Selinog	4.00	208.00	Siquilhor	6.16	320.32	–	–
Apo	7.88	409.76	Cebu City	6.16	320.32	–	–
Sumilon	25.56	1329.12	Batangas	–	–	0.44	22.88
Average	10.24	532.48		6.16	320.32	0.40	20.80

Table 2: Monetary productivity from natural and artificial reefs in the Philippines (in Pesos kg^{-1} m^{-3}) (No. of Cases 838).

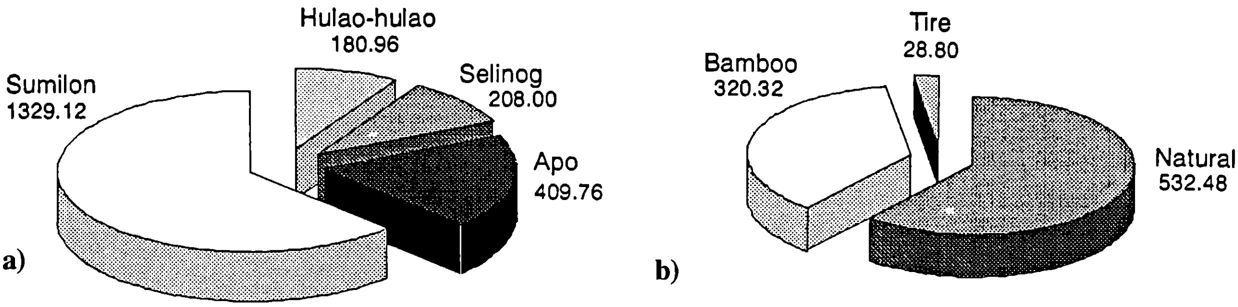

Figure 4: a) Monetary productivity of natural reefs; b) Monetary productivity of natural and artificial reefs.

6. Cost and return analysis

Based on fish yields, monetary productivity and cost and return analysis were estimated comparing natural and artificial reefs.

Figure 4a shows that among the natural reefs, Sumilon yielded 62% while Apo, Selinog and Hulao-hulao contributed 19%, 10% and 9%, respectively. Natural reefs provide earnings to the fishermen and his family amounting to PHP 10.24 $kg^{-1}m^{-3}wk^{-1}$ or PHP 532.48 $kg^{-1}m^{-3}yr^{-1}$. On the other hand, fishermen earn PHP 6.16 $kg^{-1}m^{-3}wk^{-1}$ or PHP 320.32 $kg^{-1}m^{-3}yr^{-1}$ using bamboo artificial reefs and PHP 0.40 $kg^{-1}m^{-3}wk^{-1}$ or PHP 20.80 $kg^{-1}m^{-3}yr^{-1}$ for tire reefs (Tab. 2 and Fig. 4b). Tab. 3 shows comparisons between natural and artificial reefs considering the volume of operation. These volumes represent the DA-BFAR smallest (29.0 m^3) and biggest (1,500.0 m^3) artificial reefs operations. With a constant volume of 1,500.0 m^3, natural reefs provide an income of PHP 798,720.00 per year while fishermen earn PHP 36,300.00 per year utilizing bamboo artificial reefs. However, the use of tire artificial reefs results to a loss of PHP 594,750.00 per year. This indicates that the construction of tire artificial reefs are not profitable as compared to bamboo artificial reefs which are more beneficial to poor fishermen.

In general, earnings from artificial reefs are considered by the government as supplementary income to the regular gain from fishing.

Income			
	Natural Reef	**Artificial Reef**	
		Bamboo	Tires
Volume (m^3)			
1.0	532.48	320.32	20.80
29.0	15,441.92	9,289.28	603.20
1,500.0	798,720.00	480,480.00	31,200.00
Cost			
1.0	–	296.12	417.30
29.0	–	8,587.48	12,101.70
1,500.0	–	444,180.00	625,950.00
Returns			
1.0	+532.48	+24.20	−396.50
29.0	+15,441.92	+701.80	−11,498.50
1,500.0	+798,720.00	+36,300.00	−594,750.00

Table 3: Cost and return analysis of natural and artificial reefs in the Philippines (40 Pesos kg^{-1} in 1993) (in Pesos yr^{-1}).

7. Recommendations

From these biological and economic investigations, some recommendations for the tropical coastal management of coral reefs are the following:

1. Stop the construction of tire artificial reefs and if possible remove the already dropped tires for ecological reasons.
2. Continue the construction of bamboo artificial reefs as a means of supplementary income for fishermen until such time that other alternatives and more economical means have been developed.
3. Carry out experimental studies using other available natural coastal materials such as carcar limestone for artificial reefs or the "geo-artificial reefs" as suggested by HILLMER (1991).
4. Use of concrete cement as an artificial reef is not recommended due to its expensive cost of material.
5. Encourage community involvement for the management and development of coastal resources.
6. Strict implementation of laws regarding the protection, maintenance and management of coral reef ecosystem.

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