Research article

Coral Transplantation Technology for Sustainable Fisheries and Underwater Tourism

SAMUEL J. GULAYAN*
Bohol Island State University, Candijay Campus
Email: samgulayan@yahoo.com

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Abstract Application of coral transplantation technology was the project funded by Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (PCAARRD DOST). Implemented by Bohol Island State University – Candijay Campus in partnership with Provincial Government of Bohol, Municipality of Anda, and AMUN Ini Beach Resort. 30,000 coral fragments from dislodged coral colonies were transplanted in damaged reef areas in Anda, Bohol, Philippines. Coral fragments were attached in the nailed concrete nails, fixed with plastic cable ties, and tightened with aqua epoxy clay from 5 m to 12 m depth. After year of transplanting corals, it was found that the total mean average of survival = 37.1 percent, however, in term of significant difference of survived coral it was revealed that there is a significant different due to "p value = 0.367" which is higher than the p = 0.05". With regards to the influence of transplanted corals to fish, it was observed that there were 38 families with 52 species of fish, and thousands of individuals attracted and settled in the rehabilitated area. The dominant species of fish in both areas were Pomacentridae and Apogonidae with the occurrence of other attractive animals such as sea slugs, sea turtles, leopard anemone shrimp, whale shark and eagle ray.

Keywords coral, coral fragment, rehabilitation, reef fishes, transplantation

INTRODUCTION

Coral reefs are underwater structures formed as a result of the deposition of calcium carbonate by living organisms, predominantly by corals. Coral reefs are home to thousands of coral polyps which feed on planktonic organisms or photosynthesize by means of their symbiotic algae called zooxanthellae. Corals can only grow in shallow waters where light is not limited by depth. Corals are only found along the shallow coastlines of more than 100 countries worldwide (Moberg and Folke, 1999). Coincidentally, coral reefs attract wide range of organisms. In fact, there are up to 9 million of reef living animals and plants described up to date (Knowlton, 2001a) making it appropriate to call coral reef as the rainforest of the sea (Mulhall, 2008; Knowlton, 2001b). Coral reefs have also been considered as one of the most productive ecosystem on earth. In the Philippines, it provides livelihood for more than a million of fishers who contribute almost US$ 1 billion annually to the country's economy (White et al. 1998). Unfortunately, coral reefs are in serious deterioration-suffering massive, long term declines in abundance, diversity and habitat structure due to overfishing, pollution, tourism, and other anthropogenic and natural disturbances (Abelson, 2006).

Anda is considered one of the prime tourist destinations, next to Panglao, in Bohol and is now starting to experience surge of beachfronts developments to accommodate growing number of local and foreign tourists. Recreational services provided by these resorts are diving and island tours, thus increasing the number of boats anchoring directly on the shallow reef flats causing destruction within the area. To make matter worse, the sheer number of tourist divers with poor buoyancy control and lack of spatial awareness adds to the destruction of reefs in popular dive sites.

The result of the participatory coastal resource assessment (PCRA) conducted by Bohol Environment Management Office (BEMO) and Department of Environment and Natural Resources (DENR) last 2011 revealed that in all eight coastal barangays in Anda (Badiang, Linawan, Talisay, Bacong, Virgen, Candabong, Poblacion, and Suba), only Virgen and Bacong was at a good condition having 57.5% and 51.5% live hard coral cover (LHC), respectively, while the rests are found to be at poor condition with LHC ranging from 7.3-23.5%. Coral rubbles and dead corals covered with algae were predominantly dominated in the reef areas leading them to suggest previous dynamite fishing, and the use of poisonous and obnoxious substances were to blame. However, with the increased of boat use in the area, coral breakage due to anchors was also observed.

Transplanting coral fragments is one of the many ways of restoring damaged portions of reef. It has been observed that the use of coral fragments from donor colonies or from dislodged fragments (Monty et al. 2006), have the capacity to restart new colonies elsewhere when artificially attached to stable substrates (Thongtham and Chansang, 2008) as compared to waiting for new recruits to regrow (Fox et al. 2005). Several studies have shown the importance of coral nurseries in this endeavor (Shafir et al. 2006, Herlan and Lirman, 2008; Shaish et al. 2008). Nurseries provide a way to determine coral growth rates empirically as well as giving them a chance to heal before transplanting.

These techniques were pilot tested in the different parts of the Philippines, including Panglao, Bohol, through the national coral reef restoration program last 2012 and were found out to be effective. Amper J.A. et al. 2015 observed that the fragments attached to a nursery can grow up to 2.5 cm. in three months while according to the unpublished report by the University of San Carlos and Bohol Island State University (2013), same fragments transplanted in the area can grow up to 0.5 – 0.7 cm per month.

This coral transplantation was done in Anda, Bohol with funding support from Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (PCAARRD DOST), implemented by Bohol Island State University – Candijay Campus in partnership with the Province of Bohol, Municipality of Anda, Bohol, and AMUN Ini Beach Resort. The town is located in the eastern part of Bohol with coordinates 9˚45 N, 124˚34' E and a distance of 99 km from the City of Tagbilaran. The specific sites for coral reef restoration are strategically located in three barangays of Anda, Bohol, Philippines (Fig. 1). It was chosen because it passes the criteria of site selection.

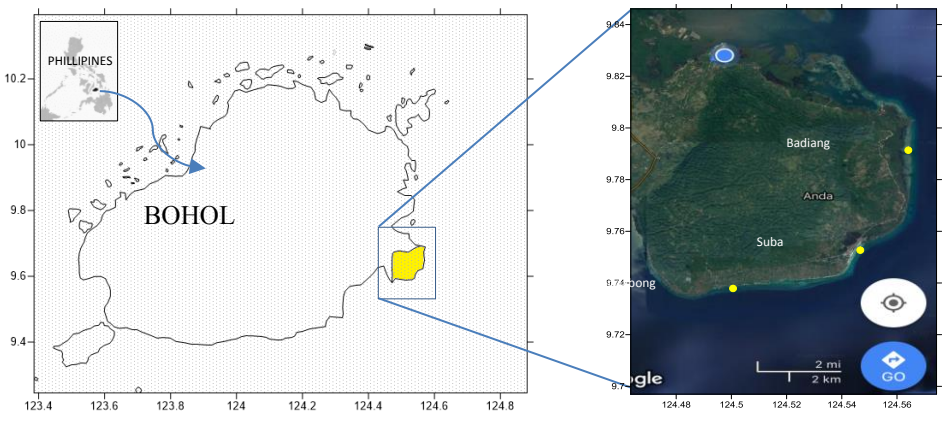

Fig. 1 Project sites

OBJECTIVES

The objective of the project was to transplant 30,000 dislodged coral fragments from colonies, monitor the survival rate of transplanted corals after year of transplanting in the damaged reef areas, count the

species of fish in the rehabilitated areas, and compare the population of fish before and after year of coral transplantation, and observe the environmental parameter on the aspect of temperature, and salinity. And, test the significant difference on the performance of coral transplantation after year of project implementation, and the fish abundance in the rehabilitated coral reef areas in the municipality.

MATERIALS AND METHODS

Dislodged corals from colonies were utilized as the planting materials. Damaged reef areas with live hard coral cover from 40-60 percent were chosen as the area for the coral rehabilitation. The method applied was the following.

Collection of planting materials: Detached corals from colonies were collected, placed in plastic crates, and transported to the project areas. Crate filled with coral fragments were carried out by the two divers to the rehabilitation areas where the other divers waiting the planting materials.

Rehabilitation of damaged reef areas: Coral rehabilitation was done in areas with water depth from 5 m to 12 m. Coral fragments were attached in the nailed concrete nails number 4, reinforced with cable plastic ties (36 mm X 6 mm), and tightened with aqua epoxy clay. One hundred coral fragments were transplanted in one quadrat. Estimated size per quadrat was 5 m X 5 m or 25 m^2. The distance between coral fragments was one foot to one meter, depending on the topography of the reefs.

Monitoring on the performance of transplanted corals: Transplanted coral fragments were monitored after year of coral transplanting. Ten sampled quadrats were monitored per project area. Transplanted live corals inside the quadrat were counted to determine the survival rate, to include counting of fishes by using fish visual census (FVC). Reef fishes were counted inside the 100 m transect line with 2.5 m side by side, at two replicate transects per project area, and aided by video.

Statistical treatment used: Simple mathematical computation was applied of understanding survival rate. Formula where: survive corals over 100 then times 10 to get the total mean average of the survived corals after year of transplanting. Kruskal Wallis Test was used of getting the significant difference of survival rate of transplanted corals, and Kolmogorov Smirnov Test was used to determine the fish abundance from before and after year of project implementation.

RESULTS AND DISCUSSION

Branching corals were used in the rehabilitation of damaged reef areas. The coral transplantation was started from February 2015 to January 2016. From one year period, the project team was able to transplant 30,000 corals in three areas (Table 1), from Badiang in the north, Suba in the east, and Candabong in the southern part of the municipality. 10,000 coral fragments were transplanted in per project area. Planting materials were taken from the dislodged coral fragments from colonies. This method differ on the method applied by Thongtham and Chansang, 2008, wherein they were utilized planting materials from the coral nursery. According to them, grown corals from the coral nursery have the capacity to start new colonies elsewhere when permanently attached in the stable substrates.

Table 1 Coral Fragments Transplanted in the Damaged Reef Areas

Reef Areas Rehabilitated	Number of Coral Fragments	Status
Barangay Badiang	10,000	Transplanted coral fragments
Barangay Suba	10,000	able to enhance the damaged
Barangay Candabong	10,000	reef areas in the project areas
TOTAL	30,000	

The following table describes the survival rate of transplanted corals after year of transplanting in the degraded reefs. It was found that the three project areas have great difference on the survival rate. Candabong was an excellent result of 87 percent, while the other two project areas were very low survival rates with 13.1 and 11.9 percent respectively. In term of the significant difference on the survival rate of the transplanted corals in three areas, it was disclosed after subjected to Kruskal-Wallis Test that p value = (0.368) which is higher than the p = 0.05 level of significance. Therefore, there is a significant difference on the survival rate among the three project areas. The result of Candabong area corroborate of the study conducted by Alasdair Edwards, 2010, that coral transplantation have delivered reasonable survival over a few years, just a first towards a trajectory of improving ecosystem structure and function.

Table 2 Survival of Transplanted Corals

Location	Number of Quadrats (100 corals/quadrat)										
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total Survival Rate (%)
Suba	6	12	8	9	6	23	10	14	11	20	11.9
Badiang	18	1	7	29	11	16	14	5	7	23	13.1
Candabong	98	78	73	89	87	92	85	93	95	80	87.0
Total Ave. Mean	40.67	30.33	29.33	42.33	34.67	43.67	36.33	37.3	37.7	41	37.33

There were 38 families with 52 species of fish found in the rehabilitated areas after year of transplanting corals. Pomacentridae and Apogonidae were dominated in the rehabilitated areas with present of some commercial fishes, species of sea slugs, sea turtle, seahorses and its relatives, leopard anemone shrimp, and the occurrence of whale shark and eagle ray. According to Feary et al. 2007 fish abundance, biomass and number of species are closely correlated with the condition of the coral community. A potential positive effect of coral transplantation on the fish community has been widely stated, only few studies have been published that included observations on this connection (Alfeche, 2003). This study describes that there is a positive connection of coral transplantation and attraction of fish. From very poor to very high fish condition was observed in barangay Candabong and Suba, if it is based of fish condition index published by Hilomen et al. 2000, however, barangay Badiang remains very poor condition.

It was perceived that one of the factors that contribute in the increased of fish individuals in two rehabilitated areas was the strict implementation of no-take zone policy. The significant difference of fish abundance in coral transplantation areas, revealed after subjected to Kolmogorov Smirnov Test that there is a significant difference from before with p = 0.910 and p = 0.998 after year of transplanting corals in degraded reef in three areas, which is higher than the significance level of $p < 0.05$.

Table 4 shows the surface temperature and salinity, and perceived cause of mortality of transplanted corals in project areas. It was observed that water salinity start to change from the month of September to December of same year. It was happened due to continuous rains and flooding. The perceived cause of high mortality rate of the two project areas (Badiang and Suba) was due to the changed of water salinity and weak of protection of transplanted corals. Fishermen sometimes engage fishing in the rehabilitated reef areas.

Table 3 Number of Fish Individuals Found After Year of Coral Transplantation (1,000 m^2/project area)

Project Area	Name of Families	No. of Ind./Family Before (Feb 2015)			No. of Ind./Family After (Jun 2016)		
		T1	T2	Total	T1	T2	Total
Barangay Suba	Acanthuridae	0	0	0	1	0	1
	Apogonidae	7	51	58	880	930	1,810
	Blennidae	0	0	0	1	1	2
	Caesionidae	0	0	0	8	8	16
	Chaetodontidae	1	1	2	5	2	7
	Gobiidae	0	0	0	3	2	5
	Labridae	2	3	5	31	27	58
	Mullidae	1	2	3	0	0	0
	Nemipteridae	0	0	0	2	1	3
	Ostraciidae	0	0	0	1	0	1
	Pomacanthidae	0	0	0	1	0	1
	Pomacentridae	9	63	72	415	259	674
	Serranidae	1	0	1	1	0	1
	Siganidae	0	1	1	2	0	2
	Scorpaenidae	1	0	1	1	0	1
	Synanceiidae	0	0	0	1	0	1
	Tetradontidae	1	1	2	2	0	2
TOTAL	17	23	122	145	1,355	1,230	2,585
Barangay Candabong	Acanthuridae	2	2	4	2	7	9
	Amphiprionidea	3	3	6	0	0	0
	Apogonidae	3	4	7	0	0	0
	Blennidae	0	0	0	9	0	9
	Batrachoididae	0	0	0	0	1	1
	Caesionidae	0	2	2	0	0	0
	Callionymidae	1	1	2	0	0	0
	Chaetodontidae	1	3	4	5	2	7
	Epinephelidae	1	2	3	0	0	0
	Haemulidae	0	2	2	0	0	0
	Labridae	5	9	14	5	0	5
	Lutjanidae	0	1	1	4	0	4
	Mullidae	1	2	3	0	0	0
	Muraenidae	1	1	2	0	0	0
	Ophichthidae	1	1	2	0	0	0
	Pomacentridae	5	5	10	4,311	1,530	5,841
	Pinguipedidae	1	1	2	0	0	0
	Scaridae	1	1	2	0	0	0
	Serranidae	0	0	0	324	0	324
	Siganidae	1	2	3	3	1	4
	Sphyraenidae	0	1	1	0	0	0
	Syngnathidae	2	2	4	0	0	0
	Tetraodontidae	1	1	2	0	0	0
TOTAL	22	30	46	76	4,663	1,539	6,204
Barangay Badiang	Acanthuridae	1	1	2	0	0	0
	Amphiprionidae	2	2	4	2	4	6
	Apogonidae	7	7	14	24	15	39
	Balistidae	1	1	2	0	0	0
	Caesionidae	1	1	2	1	1	2
	Chaetodontidae	1	2	3	1	1	2
	Centriscidae	1	1	2	0	0	0
	Haemulidae	0	2	2	2	2	4
	Holocentridae	1	1	2	1	1	2
	Labridae	4	8	12	5	11	16
	Lethrinidae	1	1	2	1	1	2
	Lutjanidae	1	3	4	2	2	4
	Monacanthidae	1	1	2	0	0	0

	Mullidae	1	1	2	2	2	4
	Ostracidae	1	1	2	1	1	2
	Ogcocephalidae	0	1	1	0	0	0
	Nemipteridae	1	0	1	0	0	0
	Pempheridae	1	1	2	1	0	1
	Plotosidae	0	1	1	1	0	1
	Pomacanthidae	1	1	2	2	1	3
	Pomacentridae	5	6	11	40	103	143
	Scaridae	1	1	2	0	0	0
	Scorpaenidae	1	1	2	0	0	0
	Serranidae	1	1	2	0	0	0
	Siganidae	0	2	2	2	4	6
	Synodontidae	1	1	2	0	0	0
	Tetraodontidae	1	1	2	0	0	0
	Zanclidae	0	1	1	0	0	0
TOTAL	28	37	51	88	88	149	237

Legend: 0 – 200 very poor; 201 – 676 poor; 677 – 2,267 moderate; 2,268 – 7,592 high; 7,593 above very high

Table 4 Environmental parameters

Period	Project Areas					
	Badiang		Suba		Candabong	
	Temp ˚C & Time	Salinity (Ppt)	Temp ˚C & Time	Salinity (Ppt)	Temp ˚C & Time	Salinity (Ppt)
Feb 6, 2015	24 (08:00AM)	33	24 (08:20AM)	35	24 (08:40AM)	35
Mar 6, 2015	23 (08:00AM)	33	23 (09:00AM)	35	23 (09:20AM)	35
Apr 3, 2015	26 (08:00AM)	34	26 (08:40AM)	35	26 (09:00AM)	35
May 8, 2015	28 (08:00AM)	35	28 (08:20AM)	35	28 (08:40AM)	35
Jun 5, 2015	29 (08:00AM)	35	29 (08:30AM)	35	29 (08:50AM)	35
Jul 10, 2015	26 (08:00AM)	35	26 (08:30AM)	35	26 (08:50AM)	35
Aug 7, 2015	32 (11:00AM)	35	32 (11:30AM)	35	32 (11:50AM)	35
Sep 4, 2015	29 (08:00AM)	30	29 (08:20AM)	31	29 (08:40AM)	35
Oct 9, 2015	31 (11:00AM)	30	31 (11:30AM)	32	31 (12:00NN)	35
Nov 6, 2015	32 (11:00AM)	30	32 (11:20AM)	30	32 (11:40AM)	35
Dec 4, 2015	28 (08:00AM)	29	28 (08:40AM)	30	28 (09:00AM)	35
Jan 8, 2016	26 (08:00AM)	30	26 (08:30AM)	31	26 (08:50AM)	35

CONCLUSION

After year of transplanting corals in the degraded reef areas, it was concluded that the corals transplanted in the cliff/wall area with water depth from 5 to 15 m has excellent survival rate than the coral fragments transplanted in rolling substrates with water depth from 4 to 5 m during lowest tide. Another was, the rehabilitated areas with strict enforcement of no-take zone policy was able to improve the fish population from very poor to high fish condition if based on the standardized fish condition index, and with the occurrence of different species like sea slugs, seahorse, sea turtle, leopard anemone shrimp, eagle ray, and whale shark.

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