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Survival and Growth Rate of *Acropora* Species in Coral Nursery Units

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Abstract – *Successful coral restoration is done by putting corals of opportunities (COPs) into coral nursery units (CNUs) before transplantation. This study determined the survival percentage and growth rate of Acropora species namely A. nobilis, A. digitifera, and A. valida in the CNUs. It was conducted at Clave Island of Hundred Islands National Park, Alaminos City, Pangasinan. It employed the quasi-experimental research design. All data gathered were tabulated and statistically treated using mean, percentage, growth rate and ANOVA. The results showed that Acropora nobilis have the highest average survival percentage among the three species with 95.74 %. However, Acropora valida have the highest average growth rate among the three species with 5.53 %. It is concluded that Acropora nobilis has the highest tendency to survive, which makes it suitable coral transplantation. Acropora valida has the highest growth rate, which will ensure fast building of reefs. The hypothesis there is no significant difference among the survival percentage of the different Acropora species in the coral nursery units, is accepted. The second hypothesis there is no significant difference among the growth rate of the different Acropora species in the coral nursery units, is rejected. It is recommended that the three Acropora species be used in the coral transplantation for its high growth rate and survival percentage. Prolonging the time of this study is suggested to see the long-time effects of putting corals in nurseries and including other parameters such as water temperature, density, and salinity. Other species of corals is also suggested to be used in this study.*

Keywords – *Acropora species, branching coral, coral nursery units, growth rate, survival percentage*

INTRODUCTION

Corals are marine invertebrates that typically live in compact colonies of many identical polyps. Its polyps secrete calcium carbonate from its calcioblast cells acting as giant carbon sinks. Calcium carbonate deposits and forms the main substance of a coral reef which is limestone. Hermatypic corals or reef-building corals live in the photic zone of relatively stable tropical marine environments with high water clarity, primarily on islands and along the edge of some continents (Castro, 2010).

One of the reef-building corals is the genus *Acropora*. It literally means a porous stem or branch. *Acropora* species have great variety of growth forms. Colonies can resemble antlers (staghorns) and be up to two meters tall, or can form delicately engineered plates and tables that may be up to three meters across (Pechenik, 2010).

Rain forests are to tropical land areas as coral reefs are to tropical seas. Coral reefs are equivalent to the rain forests in terms of productivity and biodiversity. It merely covers 0.17 % of the total ocean floor, providing 12 % of the global marine fish catch (Rana, 2010). It also functions as wave absorber lessening the impacts of waves on the shores. It also protects communities against typhoons and hurricanes by acting as buffer zones. These are only some of the benefits that humans get from the coral reefs.

Unfortunately, these reefs are being destroyed at an alarming rate and is rampant all over the world. According to the World Wide Fund (WWF) for Nature, within 25 years the world will lose 60 % of its coral reefs if strict actions will not be taken. Human activities such as pollution, illegal fishing, and recreational activities like diving and snorkelling are major threats. Global warming is also contributing to coral reef demise by raising seawater temperatures above the narrow range in which corals thrive. Hence, consequently, resulting to mass coral bleaching whose extent and severity have increased worldwide over the last decade. Also included as one of the many threats, are natural calamities like typhoons and earthquakes which may also contribute to the destruction of reefs.

The Philippines is an archipelagic country surrounded by 26,000 square kilometers of coral reefs that provide different natural resources to the people and beneficial economic uses to the government. Aside from fishing off the coral reefs, it serves as tourist sites that provide diving spots and snorkelling sites. These economic benefits created new jobs and profitable opportunities for the country (McManus, 2002).

In the Philippines, coral reefs have been slowly dying over the past 30 years (Tacio, 2015). The United Nations Environment Program (UNEP), reported that 97 percent of reefs in the Philippines are under threat from destructive fishing techniques, including cyanide poisoning, over-fishing, or from deforestation and urbanization that result in harmful sediment spilling into the sea.

Bolinao is a coastal municipality in Pangasinan. It is highly dependent on the bounty that the sea can offer. The existence of coral reefs that fringe its coasts attributes to the high productivity in Bolinao. However, Bolinao coral reefs have experienced degradation and decline in recent years because of natural and man-made stressors.

The above-mentioned scenarios somewhat mirror the situation in Hundred Islands National Park, Alaminos City. Coral sanctuaries are already set up in the area, but destruction of the reefs continues and seem not to be halted. To help its coral reef recover from the loss, transplanting coral fragments from branching corals is suggested.

Coral fragments when artificially attached to stable substrates have the capacity to restart new colonies (Monty et. al., 2006). This technology is far better than waiting for new recruits to grow that will take years to build a reef. Transplanting coral fragments involves the construction of coral nursery units. Several studies show the importance of coral nurseries in the transplanting of coral fragments (Shafir et. al. 2006; Herlan and Lirman, 2008; Shaish et. al.; 2008). It provides a way to determine coral growth and survival rates as well as providing time for the coral fragments to recuperate before transplanting.

The researchers in collaboration with the RVS Four Star came up with this study to determine the survival and growth rates of coral fragments of Acropora species (branching corals) in coral nursery units for possible transplantation. This endeavor is to help restore and conserve the coral reef of Hundred Islands National Park.

OBJECTIVES OF THE STUDY

The study determined the survival percentage and growth rate of different *Acropora* species fragments namely *A. nobilis* (Staghorn coral), A. digitifera (Plate coral), and *A. valida* (Tri-color coral) in the coral nursery units.

Specifically, it answered the following sub problems:

1. What are the survival percentages of the following *Acropora* species fragments in the coral nursery units
   1.1. *Acropora nobilis*,
   1.2. *Acropora digitifera*, and
   1.3. *Acropora valida*?
2. What are the growth rates of the above-mentioned *Acropora* species in the coral nursery units?
3. Is there a significant difference among the survival percentages of the different *Acropora* species in the coral nursery units?
4. Is there a significant difference among the growth rates of the different *Acropora* species in the coral nursery units?

MATERIALS AND METHODS

Quasi-experimental research design was used to estimate the causal impact of an intervention on its target population. This method was used because the study made use of two parameters which are survival percentage and growth rates.

Sources of Data

This study was conducted at the Hundred Islands National Park, Alaminos City, Pangasinan. Specifically, coral fragments or coral opportunities (COPs) were collected at three different sites namely Coral Island, Scout Island, and Virgin Island. COPs were planted on coral nursery units (CNUs) situated at Clave Island.

Instrumentation and Data Collection

Two sites were selected, one for collection of coral fragments or COPs and another for the CNU. There were three areas for the collection of COPs namely Coral Island, Scout Island, and Virgin Island. These islands were chosen for the abundance of disturbances like fishing, anchors, snorkeling, and diving. Due to these different disturbances, corals are damaged thereby producing coral fragments.

The area for the coral nursery units was in Clave Island. This island was chosen because it is within the five-meter depth which is suitable for the growth of corals. This area is also protected from tourists and has wave action which makes it suitable for the CNUs to be placed.

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The construction of the CNUs was the next concern. This was done in collaboration with the RVS Four Star, which provided all the needed materials. The dimensions of the CNUs were 3 meters by 1 meter. It was made of metal platforms which were custom built. At the middle of the platform is a metal white tray. Each platform can accommodate three trays, which totals 330 coral fragments per platform. Three platforms were used in this study representing the three replicates. These platforms were deployed on the seabed of the coral nursery site which is the Clave Island. Platforms are lighter when not yet filled with COPs, thus easier to deploy.

The next step was the collection of COPs. These are coral fragments or nubbins that are 80 % viable. In this study the collection focused on the three *Acropora* species (*A. nobilis, A. digitifera, and A. valida*) which were collected in three sites namely Coral island, Scout island, and Virgin island. Through snorkeling or diving, COPs were collected and put into crates. The COPs were maintained underwater at all times until brought to the CNUs site which is the Clave Island.

The COPs were placed on clay discs using underwater cement. This procedure was done close to the water to make sure of the viability of the COPs. After attaching the COPs on the clay discs, it was placed on the CNUs using nylon wires securing the COPs on the metal wire tray. The COPs were evenly spaced apart from one another, leaving a distance of 2-3 inches.

As mentioned above each platform accommodated three trays. Each tray was filled with the three *Acropora* species. There will be 110 *A. nobilis* fragments, 110 *A. digitifera* fragments, and 110 *A. valida* fragments per platform. There were three platforms representing the three replicates. These made a total of 990 COPs. The CNUs were maintained. Plastic brushes were used to get rid of sand, nuisance algae and fouling organisms.

In measuring the growth rate of the three *Acropora* species, a plastic caliper was used to measure the linear extension of the coral fragments or from tip to tip. This was done once a month for a period of three months. Data were written in slates and later transferred in spreadsheets.

After randomly picking samples, the corals were tagged using Dymo^{TM} tapes with embossed numbers attached to coral fragments using cable ties.

Percent survival of the different three *Acropora* species were gathered by counting the initial number of COPs per *Acropora* species deployed and counting the number of COPs that remained alive after the three-month (28 days per month) period.

Analysis of Data

In order to analyze and interpret the data gathered in this study, the following statistical techniques and method were utilized:

The data gathered from the survival of the three *Acropora* species fragments were tabulated and statistically treated using percentage, growth rate formula, and mean.

To determine if there is a significant difference among the survival percentages and growth rates of the different *Acropora* species fragments in the CNUs, the Analysis of Variance (ANOVA) was employed separately.

RESULTS AND DISCUSSION

Survival Percentage

The survival percentage of the different Acropora species in the CNUs were computed by getting the number of corals that survived and dividing it with the total number of samples which is 180. Presented below are the survival percentages of the three *Arcopora* species.

Table 1.a. Survival Percentages of *A. nobilis* in the Coral Nursery Unit for Three Months

Months	Number of Survival per Replicate			Average	Survival Percentage (%)
	R_1	R_2	R_3		
1st	57	58	60	58.33	97.22
2nd	57	58	60	58.33	97.22
3rd	56	54	57	55.67	92.78
Total Average				57.44	95.74

Table 1.a shows the survival percentage of *A. nobilis* in the CNUs observed for three months, done in three replicates. The average survival percentages of the replicates per month were observed to have an average of 97.22 % for both the first and second month and only a very slight decline of 4.44 % for the third month with a value of 92.78 %. The decline may be due to the decrease in temperature, for the month of January to February. The optimum temperature for corals to grow is about 23^{0}C (Reece, 2011).

Table 1.b. Survival Percentages of *A. digitifera* in the Coral Nursery Unit for Three Months

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Months	Number of Survival per Replicate			Average	Survival Percentage (%)
	R_1	R_2	R_3		
1st	59	57	59	58.33	97.22
2nd	59	52	56	55.67	92.78
3rd	54	50	54	52.67	87.78
			Total Average	55.56	92.59

Table 1.b shows the survival percentage of *A. digitifera* in the CNUs observed for three months, prepared in three replicates. The average survival percentage of the replicates for the first month was 97.22 %. For the second month the average survival percentage lowered by 4.44 % with a value of 92.78 %. The average survival percentage for the third month with a value of 87.78 % continued to lower with a difference of 5 % from the second month.

Table 1.c. Survival Percentages of *A. valida* in the Coral Nursery Unit for Three Months

Months	Number of Survival per Replicate			Average	Survival Percentage (%)
	R_1	R_2	R_3		
1st	57	58	57	57.33	95.56
2nd	56	57	53	55.33	92.22
3rd	56	54	53	54.67	91.11
			Total Average	55.78	92.96

Presented in Table 1.c are the survival percentages of *A. valida* in the CNUs observed for three months, done also in three replicates. The average survival percentage of the replicates for the first month has a value of 95.56 %. The second month average survival percentage dropped by 3.34 % with a value of 92.22 %. The average survival percentage for the third month also dropped with a value of 91.11 %, having a minimal difference of 1.11 % from the second month.

Table 1.d. Average Survival Percentages of the Different *Acropora* species in the Coral Nursery Unit for Three Months

Acropora Species	Survival Percentage (%)
A. nobilis	95.74
A. digitifera	92.59
A. valida	92.96

Reflected on Table 1.d. above is the average survival percentages of the different *Acropora* species for the three-month observation period. *A. nobilis* have the highest survival percentage of 95.74 %. Comparing the results with the study conducted by Amper et. al. using A. nobilis which have a result of 88.7 %, the result of this study has a higher survival percentage. Moreover, the result of this study is not different when compared to the 94.8 – 95.8 % survival percentage of A. nobilis in the Andaman Sea (Putchim et. al., 2007).

Growth Rate

The growth rate of the different *Acropora* species in the CNUs were computed by getting the present length of each coral minus the past length, then divided by the past length multiplied by 100. Presented below are the average growth rates of the three *Acropora* species.

Table 2. Growth Rates of the Different *Acropora* Species in the Coral Nursery Unit for Three Months

Acropora Species	Average Growth Rate per Month (%)			Total Average (%)
	1st	2nd	3rd	
A. nobilis	4.06	4.96	4.52	4.51
A. digitifera	4.34	4.66	4.57	4.52
A. valida	4.94	6.28	5.36	5.53

Table 2 shows the average growth rates of the three Acropora species in the CNUs for three months. It is observed that for the three species, all obtained its highest growth rate on the second month, with values of 4.96 % for *A. nobilis*, 4.66 % for *A. digitifera*, and 6.28 % for *A. valida*. However, *A. valida* recorded the highest growth rate among the three species for the three different months with an average of 5.53 %. The lowest growth rates were all observed also for the three species on the first month with values of 4.06 % for *A. nobilis*, 4.34 % for *A. digitifera*, and 4.94 % for *A. valida*. *A. nobilis* recorded to have the lowest growth rate among the three species for the three different months. The low growth rates on the first month can be due to the stress and injury endured by the corals from being fragmented and transferred to the CNUs. The first month of the corals in the CNUs was their time for recuperation, therefore spending their energy for healing and not for growing. On the second month of the corals in the CNUs, they already coped up with their situation and started growing properly, thus recorded the highest growth rates.

Differences in the Survival Percentage

The average survival percentages of the different *Acropora* species in the CNUs were analyzed using ANOVA and are shown in the following tables:

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Table 3.a. Differences in the Survival Percentages of the Different *Acropora* Species in the Coral Nursery Units

(I) Species	(J) Species	Mean Difference (I-J)	Sig.
A. nobilis	*A. digitifera*	3.14667	.297
	A. valida	2.77667	.353
A. digitifera	*A. nobilis*	-3.14667	.297
	A. valida	-0.37000	.898
A. valida	*A. nobilis*	-2.77667	.353
	A. digitifera	0.37000	.898

Shown in Table 3.a. is the difference in the survival percentages of the three *Acropora* species. Based on the results there is no significant difference among the survival percentage of the different Acropora species in the CNUs therefore, the survival percentages of the three species are comparable. However, it is observed that *A. digitifera* got a negative mean difference value with *A. nobilis* and *A. valida*, having values of -3.14667 and -0.37000 respectively. These values suggest that *A. digitifera* has a slightly higher survival percentage than the two species. *A. valida* also got a negative mean difference of -2.77667 with *A. nobilis*. These means that *A. valida* has a slightly higher survival percentage than *A. nobilis* but not with *A. digitifera*. The sequence of the species having the highest to the lowest survival percentage is A. digitifera, followed by *A. valida* and *A. nobilis*.

Table 3.b. Differences in the Survival Percentages of the Different *Acropora* Species in the Coral Nursery Units per Month

(I) Month	(J) Month	Mean Difference (I-J)	Sig.
1st	2nd	2.59333	.204
	3rd	6.11000*	.015
2nd	1st	-2.59333	.204
	3rd	3.51667	.102
3rd	1st	-6.11000*	.015
	2nd	-3.51667	.102

* The mean difference is significant at the 0.05 level

Presented in Table 3.b is the difference in the survival percentages of the three *Acropora* species per month. The results show that there is no significant difference in the survival percentages of the three *Acropora* species per month except between the first and third month. It was observed that the cause of death of the corals was bleaching.

Death of the corals in the CNUs were also attributed to the technology applied. Most of the recorded deaths in the first month is because of the detachment of the corals from the clay discs. The detachment may be due to the improper drying of the clay discs before the corals were placed underwater.

Differences in the Growth Rate

The average growth rate of the different *Acropora* species in the CNUs were analyzed using ANOVA and are shown in the following tables:

Table 4.a. Differences in the Growth Rate of the Different *Acropora* Species in the Coral Nursery Units

(I) Species	(J) Species	Mean Difference (I-J)	Sig.
A. nobilis	*A. digitifera*	1.5715*	.000
	A. valida	0.9069*	.000
A. digitifera	*A. nobilis*	-1.5715*	.000
	A. valida	-0.6646*	.000
A. valida	*A. nobilis*	-0.9069*	.000
	A. digitifera	0.6646*	.000

* The mean difference is significant at the 0.05 level

Presented in Table 4.a is the difference in the growth rate of the three *Acropora* species in the CNUs. Based on the results, there is a significant difference among the growth rates of the three species. It is noted that *A. digitifera* got negative mean difference values with both *A. nobilis* and *A. valida*, having the values of -1.5715 and -0.6646 respectively. These values suggest that *A. digitifera* has a higher growth rate than the two species. *A. valida* also got a negative mean difference of -0.9069 with *A. nobilis*. This means that *A. valida* has a higher growth rate than *A. nobilis* but not with *A. digitifera*. *A. digitifera* has the highest growth rate followed by *A. valida* and the one which has the lowest growth rate is *A. nobilis*.

The difference in growth rate may be attributed to the nature of the three corals. The three coral species belong to Genus *Acropora*, which are branching corals, but grows differently. *A. digitifera* with a common name of Plate Acropora does not branch much unlike the two other species, but instead it forms a plate. The growth length is much more concentrated than branching in *A. digitifera* explaining why it has the highest growth rate.

Table 4.b. Differences in the Growth Rate of the Different *Acropora* Species in the Coral Nursery Units per Month

(I) Month	(J) Month	Mean Difference (I-J)	Sig.
Initial	1st	-0.1658	.158
	2nd	-0.4322*	.000
	3rd	-0.6672*	.000
1st	Initial	0.1658	.158
	2nd	-0.2664*	.025
	3rd	-0.5015*	.000
2nd	Initial	0.4322*	.000
	1st	0.2664*	.025
	3rd	-0.2351	.052
3rd	Initial	0.6672*	.000
	1st	0.5015*	.000
	2nd	0.2351	.052

* The mean difference is significant at the 0.05 level

Table 4.b presents the difference in the growth rate of the three *Acropora* species per month. Results showed that there is a significant difference among the growth rates of the three *Acropora* species per month except between the initial and first month and between the second and third month. This suggests that in the first month of the corals in the CNUs, they were still stabilizing due to the stress and injury after being fragmented and transferred. On the second month, growth started to peak because the corals already adjusted to the CNUs. On the third month, growth was comparable with the second month because the corals are stabilized in the CNUs and grows normally as they do in their natural environment.

CONCLUSION AND RECOMMENDATION

Conclusions

Based from the findings of the study, the following conclusions were generated:

1. *Acropora nobilis* has the highest tendency to survive, which makes it suitable for coral transplantation.
2. *Acropora valida* has the highest growth rate, which will ensure fast building of reefs.
3. There is no significant difference among the survival percentage of the *Acropora* species in the coral nursery units, hence, the three species are comparable with each other.
4. There is a significant difference among the growth rate of the different *Acropora* species in the coral nursery units.

Recommendations

Based from the findings of the study and the conclusions generated, the researchers recommend the following:

1. The three *Acropora* species are recommended to be used in the transplantation for its high growth rate and survival percentage. This ensures success and fast building of coral reefs.
2. Prolong the duration of this study to see the long-term effects of putting corals in nurseries and include other parameters such as water temperature, density, and salinity.
3. Other coral species should be utilized in similar studies.

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