**INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCE AND ENGINEERING (IJESE)**
**Vol. 6: 93 - 103 (2015)**
**http://www.pvamu.edu/research/activeresearch/researchcenters/texged/international-journal**
**Prairie View A&M University, Texas, USA**

# Transplantation and cultivation of some coral species on a reef of Breakah Bay, Ras Muhammad, Egypt.

**Mohammed A. Abdo[1] and Muhammad M. Hegazi[*2]**
1- EEAA, Ras Muhammad National Park, South Sinai, Egypt.
2- Marine Science Department, Faculty of Science, Suez Canal University, Egypt.

**ARTICLE INFO**
***Article History***
Received: Sept.30, 2015
Accepted: Oct. 24, 2015
Available online: Feb. 2016

***Keywords***:
Coral species,
Transplantation,
Red Sea,
Ras Muhammad,
Cultivation,
Egypt.

**ABSTRACT**

Seven coral species of the genus *Acropora* and two species of the genus *Pocillopora* were studied in Ras Muhammad National Park (south Sinai) during the period from August 2011 to May 2013 to know their suitability for transplantation and to test the effects of temperature and size of fragments on their survival and growth rate. Coral fragments were collected and transplanted onto trays made from PVC connected by plastic strap to rectangular frame-tables. Mortality and growth rates were assessed; more than 37% of the fragments survived after 14 months. Overall growth rate was 0.864 ± 0.0392 mm/month. The regression lines displayed for those species showing a highly significant increase in mortality rate with decrease temperature. All *Acroporids* and some *Pocilloporids* developed a strong holdfast at their bases. Some trays have been suffered from predation by the corallivorous snail *Drupella cornus*.

In conclusion *Acropora eurystoma*, *A. humilis* and *A. gemmifera* were the fastest growing transplanted species, and they offer the best combination of life-history characteristics, especially in moderate temperature. However, *A. hemprichii* and *A. pharaonis* showed significantly greater mortality than other species, so they are not suitable for transplantation in Ras Muhammad site.

## 1. INTRODUCTION

Coral reefs are one of the most valuable and threatened ecosystems on the planet (Connell, 1978). They fulfil a range of ecological functions, such as shoreline protection, maintenance of biodiversity, genetic diversity, nutrient cycling and provision of habitat for a large number of organisms (Done, 1995;Costanza, *et al.* 1997 and Shutler, *et al.* 2006). The Coral Reef Task Force estimates that 70 % of the world's coral reefs are threatened and 10 % have been destroyed. Portions of Caribbean coral reefs have lost up to 80 % of coral species and continue to be under increasingly destructive pressures from various sources (Goreau, *et al.* 2000; Westmacott, *et al.* 2000; Cesar, 2002 and Burke, *et al.* 2002). There are many factors pushing reefs being in danger and threats to coral reefs are mainly regarded to human activities (Sebens, 1994; Rajasuriya, *et al.* 1995 and Burke, *et al.* 2004).

**Corresponding author:** *hegazi16054@yahoo.com
ISSN 2156-7530

Coral reefs in the Red Sea are exceptional in not being bordered by deforested land with heavy run-off into the sea or by densely populated coastlines; they are-enclosed by deserts-rather unaffected by perturbations such as sedimentation and eutrophication that deteriorate most other reefs in the world.

During high season, up to 200 dive boats invade this area and leave their traces in the reefs. Trampling by reef walkers and snorkelers, poorly trained divers and ship groundings cause mechanical damages resulting in increasing areas of dead rubble (Riegl & Velimirov, 1991). Additionally, big passenger and cargo ships occasionally hit the reefs in the Straits of Tiran.

There is a general thought that natural reefs cannot rebuild themselves fast enough to meet human demands (Grigg & Dollar, 1990 ; Hughes, 1994) and requires human assistance. Thus, there is a concern to identify management option to protect and restore coral communities. One of those management options proposed is the establishment of effective methodologies for coral propagation through human activity.

The approach we chose in this article is to study using of coral fragments for developing rehabilitation measures for mechanically degraded reef areas, particularly those of the *Acropora* sp., because these are known to grow or extend faster than most other corals (Yap & Gomez 1981), with a minimum of environmental harm and interference with living resources.

## 2. MATERIAL AND METHODS

Branching coral fragments used for transplantation were collected from a healthy area with about 65-68 % of coral cover between August 2011 and May 2013 from the north of Breakah Bay, Ras Muhammad National Park (N 27° 46.275′, E 34° 12.989′) (Fig. 1).


Fig. 1: Donor area and Experimental site

The site for rehabilitation experiments was Cony Bay, where the seabed is gently sloping down to about 13 m depth followed by a steeper slope down to a terrace in 40 m dropping further to more than 100 m in the middle of the bay. Experimental site is near from donor area (about 3 Km) to prevent stress-free transport of coral fragments. Nursery construction also in a depth similar to the depth of the donor site and water clarity allows adequate light penetration for good coral growth at the depth where the corals cultured.

### *2.1 Experimental design:*

Fixed modular tray nurseries technique was based on Shaish, *et al.* 2008 (Fig. 2).Trays were made from 3.6 cm diameter PVC (1 m × 1.2 m) connected by plastic strap to rectangular frame-tables (2.5 m × 1 m). The frame-table area allows a few

centimeters gap between trays for ease of working. The frame-tables were made of 3 cm wide angle iron hammered 20 cm into the seabed. A few small holes into the PVC pipes were made to reduce buoyancy. Trays holding coral fragments were located in the experimental site in 4.8 m depth and up to about 1 m from the bottom.

Fig. 2: Design for a fixed modular tray nursery (based on Shaish *et al.*, 2008).

***2.2 Fragmentation of donor colonies:***

Coral fragments used for transplantation were derived from South Breakah dive site using SCUBA diving, For *Acropora* sp., branching coral broken fragments from tourism activity used for transplantation were collected in different sized ranging from finger size to large heads, 2-9 cm long. For *Pocillopora* sp., side-cutting pliers were used to cut fragments from the donor healthy colonies. Clean plastic gloves were used and cutting was done from the side of the colony to prevent breakage of a bigger portion than required. Coral fragments were placed in plastic bags of seawater before being transferred to shore for transplantation to study area. Each genotype was placed in a separate plastic bag to avoid harmful interactions.

***2.3 Making coral fragments for nursery rearing:***

PVC pipes were used as trays because they are suitable primarily for branching and sub massive species (e.g. *Acropora, Montipora, Pocillopora, Stylophora*); the coral fragments was inserted into the hole of a PVC pipe. Further, having part of the skeleton inserted into the substrate reduces detachment. This speeds up the nursery stocking process and reduces its cost.

***2.4 Arrangement and spacing of corals in the nursery:***

The sessile life-styles and the growth forms of corals can lead to tissue contacts between adjacent colonies.

***2.5 List of coral tested for transplantation:***

In total nine scleractinian coral species, mainly branching Acroporids and Pocilloporids were tested for transplantation (Table 1).

**Table 1: List of coral species used for transplantation**

| Species | % of all colonies |
|---|---|
| *Acropora eurystoma* | 17.3 |
| *A. humilis* | 9.3 |
| *A. pharaonis* | 2.7 |
| *A .digitifera* | 10.6 |
| *A. hemprichii* | 2.7 |
| *A. squarrosa* | 8.1 |
| *A. gemmifera* | 6.6 |
| *Pocillopora verrucosa* | 29.3 |
| *P. damicornis* | 13.4 |

Detailed growth patterns were taken by a Vernier caliper, which involved measuring length, width and base diameter of the developing fragment. Percent live cover was estimated for each coral and the type of damage was recorded.

***2.6 Sedimentation:***

Three sediment traps were set up at iron Table. After collection the sediment was washed with fresh water to remove salt and the water was then removed by decantation before drying the sediment in the oven at 100° C for 24 h. The dry sediment was weighed on an analytical balance with a precision of 0.001 g (Clark and Edwards, 1995).

## 3. RESULTS

***3.1 Mortality rates of transplanted colonies:***

Overall approximately 62.6% of coral colonies died *in situ* over the study period, with mortality ranging from 41.8% at Acroporidae to 90.6% at Pocilloporidae and had significantly higher exponential mortality rates than Acroporidae with a mean of 6.474 (SD 7.091) as opposed to 2.99 (SD 3.583). Mortality rates were individually estimated for nine coral species. Intra-family variation is apparent with *Acropora hemprichii* and *A. pharaonis* having a significantly higher mortality rate than either *A. gemmifera* or *A. squarrosa* (Fig. 3).

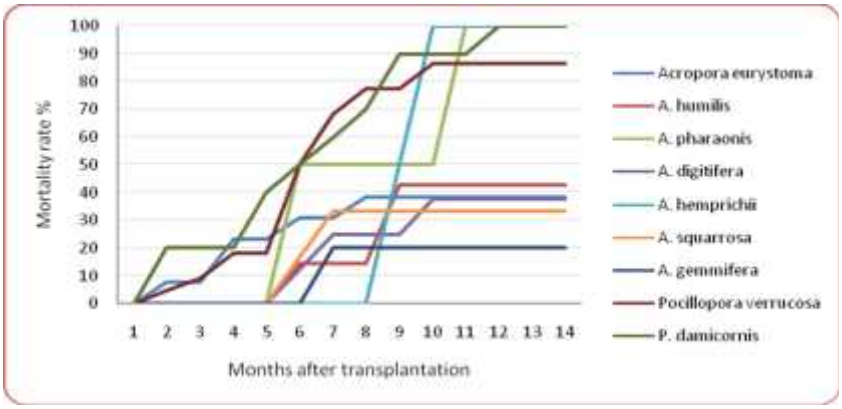


Fig. 3: Mortality rate of transplanted fragments of different coral species.

***3.2 Percentage of survival rate by size class:***

All coral fragments were classified to three groups of size, small (20-50 mm), medium (50.5-70 mm) and large (> 70.5 mm) to know the best fragment size to transplant (Fig. 4). There was no significant difference between percentage survival and size for either Acroporidae (P = 0.689) or Pocilloporidae (P = 0.827).

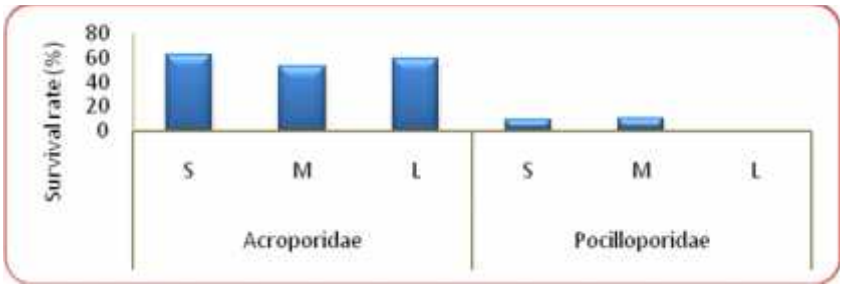


Fig. 4: Survival rate of the Acroporidae and Pocilloporidae in different size classes.

***3.3 Monthly and Annual axial growth rates of transplanted colonies:***

Overall average growth rate was 0.864 ± 0.0392 mm/month. Growth rates varied

widely between colonies within one species and between congeneric species (P-value <0.05) as well as between families (Table 2). The fastest monthly growing species were *Acropora eurystoma* (1.699 ± 0.1213 mm/month), followed by *Pocillopora damicornis* (1.033 ± 0.1380 mm/month). The slowest growth rates were found in *A. Squarrosa* (0.533 ± 0.0756 mm/month) and *P. Verrucosa* (0.538 ± 0.0536mm/month) (Fig. 5).

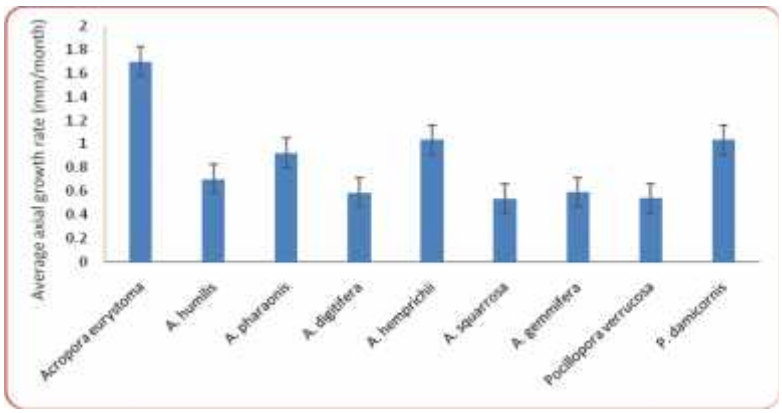


Fig. 5: Monthly mean axial growth rate of transplanted fragments

Table 2: Estimated mean colony radial extension rates in mm/month

| Species | Mean (mm/month) | Number of estimates obtained | Minimum | Maximum |
|---|---|---|---|---|
| *Acropora eurystoma* | 1.699 ± 0.1213 | 118 | 0.00 | 5.5 |
| *A. humilis* | 0.700 ± 0.0750 | 70 | 0.00 | 2.5 |
| *A. pharaonis** | 0.923 ± 0.2585 | 13 | 0.00 | 3.0 |
| *A. digitifera* | 0.585 ± 0.0765 | 82 | 0.00 | 2.5 |
| *A. hemprichii** | 1.033 ± 0.1980 | 15 | 0.00 | 2.5 |
| *A. squarrosa* | 0.533 ± 0.0756 | 61 | 0.00 | 3.0 |
| *A. gemmifera* | 0.588 ± 0.0687 | 57 | 0.00 | 2.0 |
| *Pocillopora verrucosa* | 0.538 ± 0.0536 | 120 | 0.00 | 3.0 |
| *P. damicornis** | 1.033 ± 0.1380 | 45 | 0.00 | 3.5 |

(*mean for 7 months)

Among the acroporids, *A. eurystoma* was the fastest annual axial grower with an average increase of 22.87 ± 4.089 mm than most of other acroporids within 14 months, followed by *A. humilis* (8.87 ± 2.01 mm) and *A. gemmifera* (7.75 ± 1.36 mm) (Fig. 6). Among the pocilloporids *P. verrucosa* showed 8.17 ± 1.74 mm average axial growth rate (Plates 1 & 2).

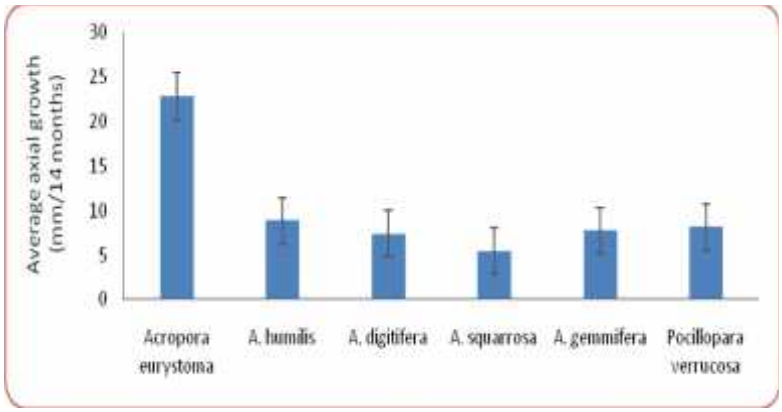


Fig. 6: Annual mean axial growth rate (14 months after transplantation).

### *3.4 Effect of temperature on mortality rate of transplanted colonies:*

The regression lines displayed for transplanted species showed a highly significant increase in mortality rate with decrease temperature ($P < 0.01$). The highest mortality rate was recorded in January 2012 with more than 11% and 25% of total fragments of acroporidae and pocilloporidae respectively, was died and there was no mortality in the last 3 months of transplantation period for acroporidae species and last 2 months for pocilloporidae species (Fig. 7).

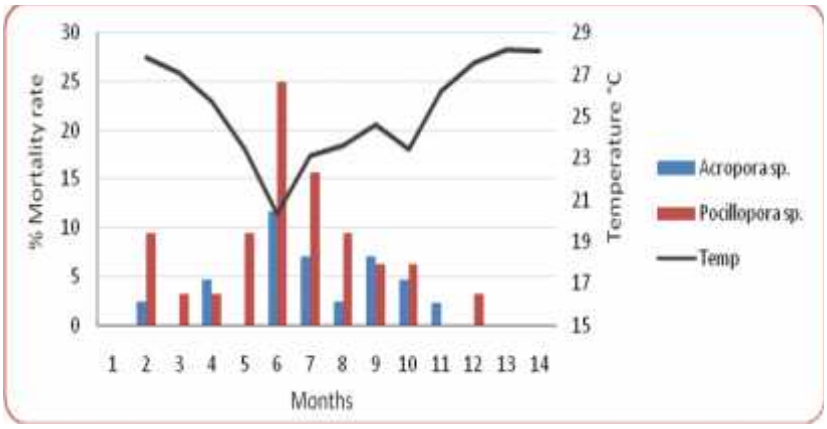


Fig. 7: Mortality rate of coral fragments every months along with sea surface temperature.

### *3.5 Holdfast development:*

All acroporidae showed a very high regeneration potential manifested by the development of a firm proliferating foothold onto the PVC pipe (Fig. 8). In opposition to it, some *Pocillopora* sp. did not develop such a holdfast at their bases; they have been only fixed in the PVC pipe by the plastic strap.

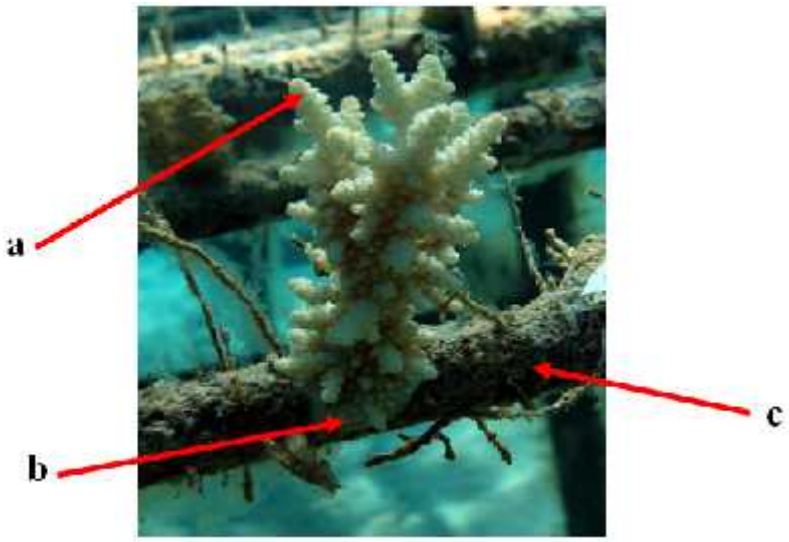


Fig. 8: *Acropora eurystoma* in the construction after transplantation. (a) New buds at the top of the branches clearly grew. (b) A strong holdfast development. (c) Algae settling on the substrate.

### *3.6 Natural recruitment of corals to experimental design:*

Coral recruits on experimental design first observed 6 months after the experimental design had been emplaced. Soft coral species *Nephthealaevis* and *Litophyton arboretum* were dominant on experimental design (42% of recruits) followed by *Pocillopora* species (26% of recruits) and *Millepora* species (25% of recruits). Detailed data on the growth rate of these recruits were collected and measurements for about 22

months. However, preliminary observations indicated that survival rate was high and growth rates were fast, with some *Pocillopora verrucosa* and *P. damicornis* colonies that attained a colony diameter approaching to 60 mm within 12 months of first being recorded (Fig. 9).

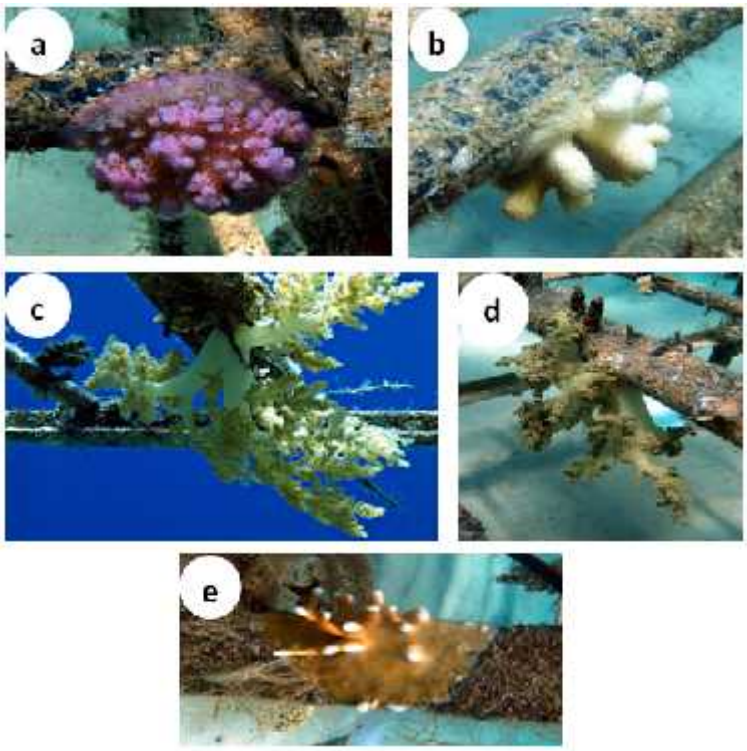


Fig. 9: Examples of coral recruits on the experimental design.
(a) *Pocillopora verrucosa*. (b) *Stylophora pastillata*. (c) *Litophyton arboretum*.
(d) *Nephthea laevis*. (e) *Millepora dichotoma*.

### *3.7 Environmental conditions and disturbance:*

Figure (10) shows an *Acropora eurystoma* and *Pocillopora verrucosa* infested with the snail *Drupella cornus*. Another disturbance to the transplanted coral fragment was the herbivores like parrotfish that feed in algae from the surface of the coral leading to scratch and broken in some fragments.

Fig. 10: *Acropora eurystoma* and *Pocillopora verrucosa* on a husbandry tray infested with *Drupella cornus*.

### *3.8 Sedimentation:*

The average sedimentation rate was calculated for the sediment traps, (about 50 $cm^2$), was 42.8 g/14months. Therefore, the sedimentation rate equal to 0.856 $g/cm^2$/14 months. Daily, the sedimentation rate in the study site was 2 $mg/cm^2$/d.

## 4. DISCUSSION

Growth of coral fragments is an important natural process, at least, in corals with branchy forms of colonies. Colony fragments rest anchor somehow occasionally on the PVC pipe, then adhere to the substrate through regeneration and outgrowth of soft tissues and skeleton. Our results do not contradict the conclusion of Okubo, *et al.* (2005) who concluded that attachment to the substrate is a precondition of a successful long-term process of transplantation. In the other hand, these results are similar to that of James *et al.* (2009) who found that *Acropora muricata* had the fastest self-attachment than the encrusting-foliaceous species *Echinopora lamellose* and at the end of the study (about 8 months) 74% had achieved self-attachment.

Overall survivorship of transplanted coral colonies of 37.4 % at 14 months compares favorably with Auberson (1982) and Alcala *et al.* (1982). The high survivorship of some species of *Acroporidae* on the study site, where sedimentation rates were approximately 2 mg $cm^{-2}$ $d^{-1}$, emphasizes that such rates were tolerable for the recruits. This conclusion is further supported by Rogers (1990) who found that only sedimentation rates above 10 mg $cm^{-2}$ $d^{-1}$ are destructive for most coral species.

The lowest percent of survival rate of *Acropor apharaonis*, *Pocillopora damicornis* and *P. verrucosa* in nursery construction, after 6 months, indicates that, these species are highly sensitive to mechanical stress during transplantation. Contrary to that result, fragments of two other species of the same genus (*A. squarrosa* and *A. humilis*) were not significantly affected by handling during transplantation.

In this study most mortality of transplanted colonies occurred during the middle five months following transplantation (winter and spring) when about 45% of colonies were died or torn loose by wave action. Brikeland, *et al.* (1979) had greater loss problems in their studies in Guam where 505 out of 643 transplanted colonies (79%) belonging to nine genera were lost from an open coast site at Tanguisson. Natural accretion of almost *Acropora* colonies (i.e. *A. humilis*, *A. eurystoma*, *A. digitifera* and *A. gemmifera*) within two months of transplantation, and by four months all *Acropora* colonies had naturally accreted at their bases and firmly attached themselves to the PVC trays. These results are in contrast to those of Birkeland, *et al.* (1979) who found no natural accretion of transplanted corals onto the substrate.

We found that *Acropora eurystoma*, *A. humilis* and *A. gemmifera* are the fastest growing species, among those transplanted. However, *A. hemprichii* and *A. pharaonis* showed significantly greater mortality than *A. gemmifera* and *A. eurystoma*. Suggesting that among the *Acroporid* species examined, *A. gemmifera* and *A. eurystoma* offers the best combination of life-history characteristics. Among the *pocilloporid*, *Pocillopora damicornis* and *P. verrucosa* have intermediate growth rate and suffered significantly very higher mortality rate, so they are not suitable for transplantation in our study site. These results are in contrast to results of Nsajigwa, *et al.* (2010) who monitored high survivor rates of *Pocillopora verrucosa* and *Acropora hemprichi* in Tanzania.

Growth rates of corals of the present study are considered high compared with the previous records in other areas of the same species after unifying the units of growth rates. Glynn (1977) studied the growth rate of *P. damicornis* within 7m depth in the Gulf of Panama and the Gulf of Chiriqui (Pacific coast of Panama). He found that the mean growth of 0.256 and 0.321 mm/month respectively and related that higher growth to

the higher temperature in the Gulf of Chiriqui. His growth data were much lower than the present work values for the same species (1.033 ± 0.1380 mm/month).

But in the same area, we found similarity in growth rate for some species. The annual mean growth rates of *A. humilis* was 8.87 ± 2.01mm/year. It is similar to that of Aamer (2004) who concluded that sites or location influenced significantly the linear growth rates of *A. humilis* at Sharm El-Shiekh which ranged between 6.17mm/year and 9.80mm/year.

Shaish, *et al.* (2008) studied the size augmentation of length and width for *Pocillopora damicornis* after 9 months and found it was 2.83 ± 0.73 and 3.73±0.32times from initial size, respectively. It was higher than our result for the same species after 7 months with 1.19 ± 0.06 and 1.18 ± 0.06times from initial size, respectively.

During the monitoring process, the coral-eating snail *Drupella cornus* was found on the experimental area preying on *Acropora eurystoma* and *Pocillopora verrucosa*.

In conclusion *Acropora eurystoma*, *A. humilis* and *A. gemmifera* were the fastest growing transplanted species, and they offer the best combination of life-history characteristics, especially in moderate temperature. However, *A. hemprichii* and *A. pharaonis* showed significantly greater mortality than other species, so they are not suitable for transplantation in Ras Muhammad site.

## 5. REFERENCES


Aamer, M. A. A. (2004). The role of zooplankton and water quality on some biological and ecological aspects of corals along the Egyptian Red Sea coast. A Ph.D. Thesis, Suez Canal University, Ismailia, Egypt, 325 pp.

Alcala, A. C.; Gomes, E. D. and Alcala, L. C. (1982). Survival and growth of coral transplants in central Philippines. Kalikasan, the Philippine J. Biology, 11:136-147.

Auberson, B.(1982). Coral transplantation: an approach to the reestablishment of damaged reefs. Kalikasan, Philippines J. Biology, 11: 158-172.

Birkeland, C.; Randall, R. H. and Grimm, G. (1979). Three methods of coral transplantation for the purpose of reestablishing coral community in the thermal effluent area of the Tanguisson Power Plant. University of Guam, Marine Laboratory Technical Report, 60. 24 pp.

Burke, L.; Selig, E. and Spalding, M. (2002). Reefs at Risk in Southeast Asia. World Resources Institute (WRI), Washington, D.C., USA, 76 pp.

Burke, L. and Maidens, J.(2004). Reef at Risk in the Caribbean. World Resource Institute. Washington. 81 pp.

Cesar, H. S. J. (2002). Coral Reefs: Their Functions, Threats and Economic Value." In Collected Essays on the Economics of Coral Reefs, Sweden: Kalmar University, 14:39pp.

Clark, S. and Edwards, A. J. (1995). Coral transplantation as an aid to reef rehabilitation: evaluation of a case study in the Maldive Islands. Coral Reefs, 14: 201–213.

Connell, J. H. (1978). Diversity in tropical rain forests and coral reefs. Science, 199: 1302-1310.

Costanza, R.; d'Arge, R.; De Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; Raskin, R.G.; Sutton, P. and van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. Nature, 387: 253-260.

Done, T. J. (1995). Ecological criteria for evaluating coral reefs and their implications for managers and researchers. Coral Reefs, 14(4): 183-192.

Edwards, A.D. and Glynn, P. W. (1977). Coral growth in upwelling and non-upwelling areas off the Pacific coast of Panama.
J. Mar. Res., 35 (3): 567-585.

Goreau, T. J.; Hayes, R. L. and Mc Mlanahan, T. (2000). Conservation of Coral Reefs after the 1998 Global Bleaching Event. Conservation Biology, 14: 5-15.

Grigg, R. W. and Dollar, S. J. (1990). Natural and anthropogenic disturbance on coral reef ecology. In: Dubinsky Z. (Eds.), Ecosystems of the world 25, Coral reefs. Elsevier, Amsterdam, pp. 439-452.

Hughes, T. P. (1994). Catastrophes, Phase Shifts, and Large-Scale degradation of a Caribbean coral reef. Science, 265 (5178): 1547-1551.

James, R. Guest; Rommi, M.Dizon; Alasdair, J. Edwards; Chiara, Franco and Edgardo, D. Gomez (2009). How Quickly do Fragments of Coral "Self-Attach" after Transplantation? The journal of the Society for Ecological Restoration International. 18 (4):399–407.

Nsajigwa, E. J.; Spanier, E. and Rinkevich, B. (2010). Testing the first phase of the 'gardening concept' as an applicable tool in restoring denuded reefs in Tanzania. Ecological Engineering, 36: 713–721.

Okubo, N.; Hiroki, T. and Tatsuo, M.(2005). Successful methods for transplanting fragments of *Acropora formosa* and *Acropora hyacinthus* Coral Reefs, 24: 333–342.

Rajasuriya, A.; Silva, R. N. D. and hman M.C.(1995). Coral Reefs of Sri Lanka: Human Disturbance and Management Issues Research and Capacity Building for Sustainable Coastal Management. Ambio, 24: 428-437.

Riegl, B. and Velimirov, B. (1991). How many damaged corals in the Red Sea reef systems? A quantitative survey. Hydrobiologia, 216/217: 249-256.

Rogers, C. S. (1990). Responses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress, 62: 185-202

Sebens, K. P. (1994). Biodiversity of Coral Reefs: What are we losing and Why? American Zoologist, 34: 115-133.

Shaish, L.; Levy, G.; Gomez, E. and Rinkevich, B. (2008). Fixed and suspended coral nurseries in the Philippines: Establishing the first step in the "gardening concept" of reef restoration. J. Exp. Mar. Biol. Ecol., 73: 86-97.

Shutler, S. K.; Gittings, S.; Penn, T. and Schittone, J. (2006). Compensatory restoration: how much is enough? Legal, economic, and ecological considerations. In: Precht

W. F. (2006). Coral Reef Restoration Handbook. CRC Press/Taylor and Francis, Boca Raton, Florida, USA: pp.77-93.

Westmacott, S.; Cesar, H. and Pet-Soede, L.(2000). Socieconomic Assessment of the Impacts of the 1998 Coral Reef Bleaching in the Indian Ocean. Resource Analysis and Institute for Environmental Science (IVM) Repot to the World Bank. African Environmental Division for the CORDIO program.

Yap, H.T. and Gomez, E. D. (1981). Growth of *Acroporapulchra* (Brook) in Bolinao, Pangasinan, Philippines. Proceedings of the 4th International Coral Reef Symposium, 2: 207-213.

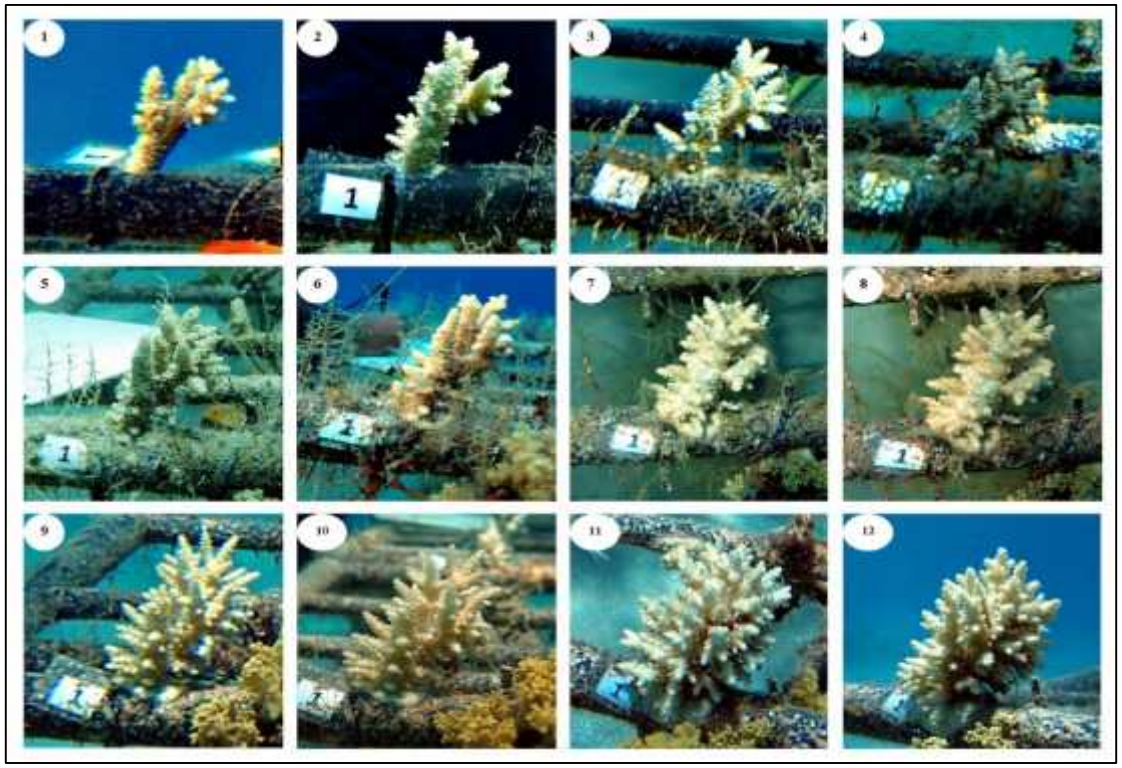

Plate 1: Growth of *Acropora eurystoma* during one year of transplantation.

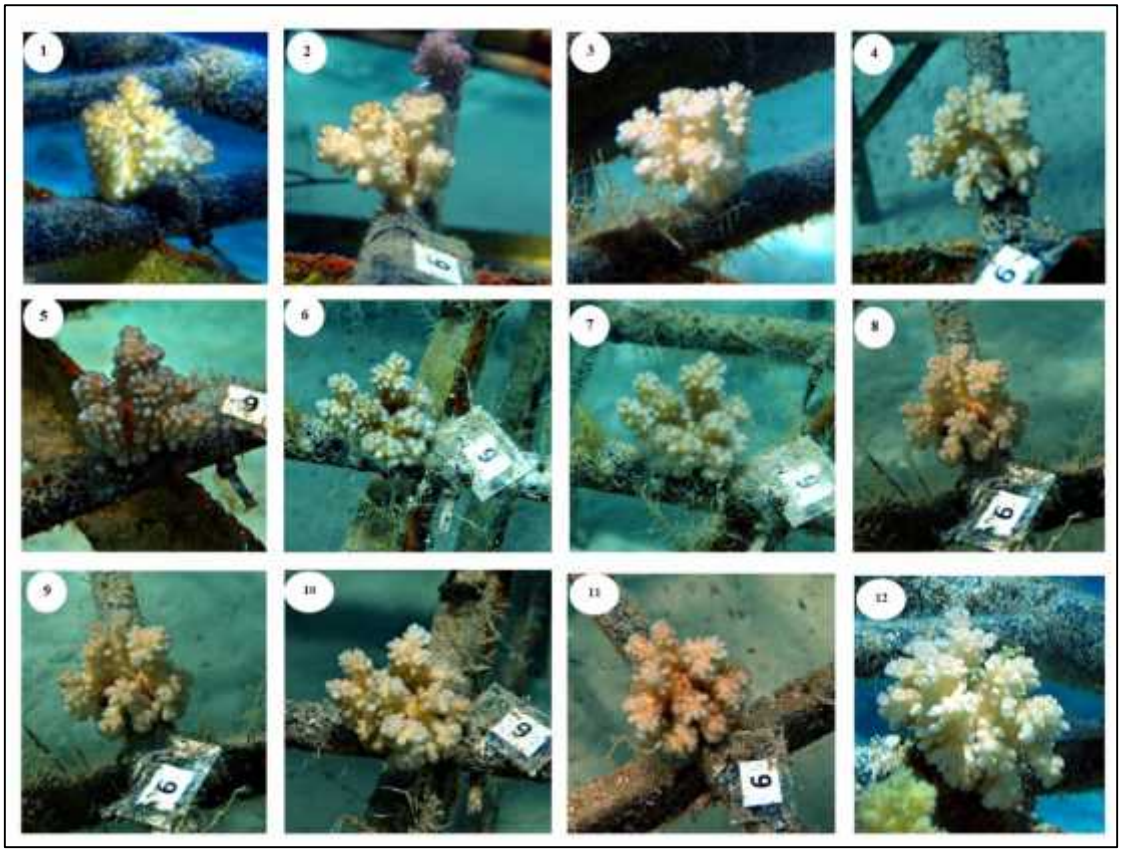

Plate 2: Growth of *Pocillopora verrucosa* during one year of transplantation.