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Ecological volume of transplanted coral speciesof family Acroporidae in the northern Red Sea, Egypt.

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Abstract: *Family Acroporidae (seven coral species) were studied in the northern Red Sea (Ras Muhammad National Park, South Sinai) to know their suitability for transplantation and to determine the fragments growth rate and to know the space that colonies occupied in the structure. Coral fragments were collected and transplanted onto a Fixed modular tray nursery made from PVC connected to rectangular frame-tables. Survival and growth rates were assessed; more than 58% of the fragments survived after 14 months. The overall growth rate was 0.940 ± 0.049 mm/month. The Acroporidae showed a significant positive relationship between growth rate and colony size. Some species showed more than duplicate in ecological volume after 14 months of transplantation.*

Keywords*:Coral species, Transplantation, Ecological volume, Ras Mohammed, Red Sea, Egypt.*

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I. Introduction

Coral reefs are biogenic, three-dimensional marine habitats composed of carbonate structures that are deposited by hermatypic Scleractinian corals and are generally found in areas where water temperature does not fall below 18°C for extended periods of time (Ladd 1977, Achituv and Dubinsky 1990).

The Arab Republic of Egypt is home to over 1800 km of diverse coral reef habitats along the western Red Sea coast and in the Gulfs of Suez and Aqaba. Ras Muhammad National Park Established in 1983, the Park occupies part of the southern portion of the Sinai Peninsula (27°44'N - 34°15'E) extending to and including Tiran and Senafir islands, and covers an area of roughly 750 km^2. The Park houses a particularly high diversity of flora and fauna, including coral reefs, seaweed and seagrass beds, mudflats, mangroves. Until recently the reefs were considered healthy and free of major anthropogenic stresses but recently sedimentation from land reclamation works, oil spills and physical damage from the 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(coral cover at many places has dropped by up to 30%).

II. Material and Methods

Study sites:

This study was conducted at two locations inside Ras Muhammad National Park in the southernmost tip of the Sinai Peninsula, Egypt. The sites were selected, one as a donor (North area of Breika Bay) and the other as experimental (Fig. 1). The site selected for rehabilitation experiments was Cony Bay at the middle of the large Breika Bay (N 27° 47.567′, E 34° 13.909′). The inner end of the Cony Bay is exposed to permanent importation of sand and dust, resulting in a comparably low cover of living corals (10-30%) and it far from the donor area (about 3 Km) to prevent stress-free transport of coral fragments. Coral fragments of family Acroporidae used for transplantation were collected from donor area and transported to experimental site where the seabed is gently sloping down to about 13 m depth.

Nurseries design:

The Fixed modular tray nurseries technique used for transplantation because that’s the best technique for branching coral fragments, (Shaish et al., 2008) (Fig. 2).

The Trays were designed with 3.6 cm diameter PVCs (1 m × 1.2m), which connected by a plastic strap to rectangular frame-tables (2.5 m × 1 m). There are a few centimetres gap between the trays for ease of operation . Wide-angle tables were made of iron with thickness 3cm were installed in the sea bed .The tray’s pipes have been perforated to reduce the buoyancy rate. coral fragments installed on trays that are placed on the experimental site in 4.8 m depth and up to about 1 m from the bottom.

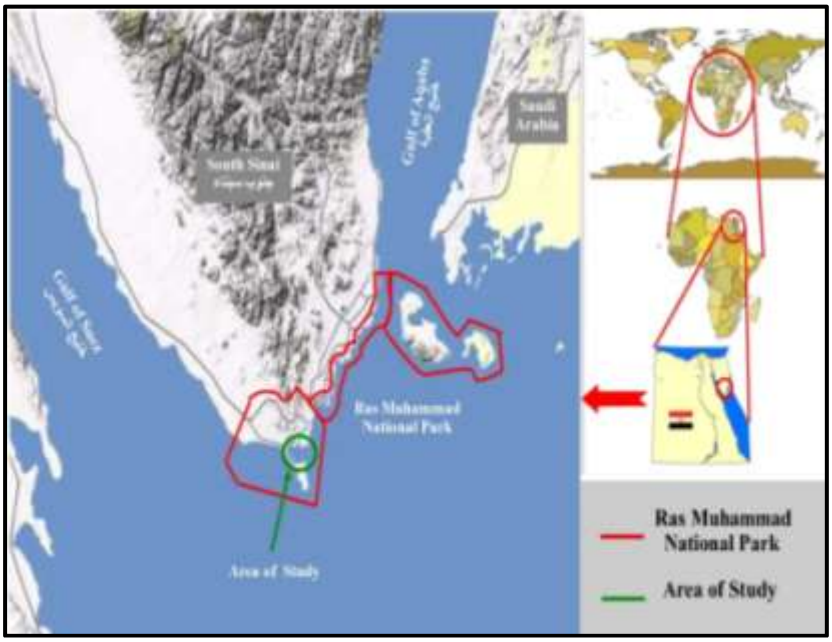

Fig. 1: Ras Muhammad National Park and area of study.

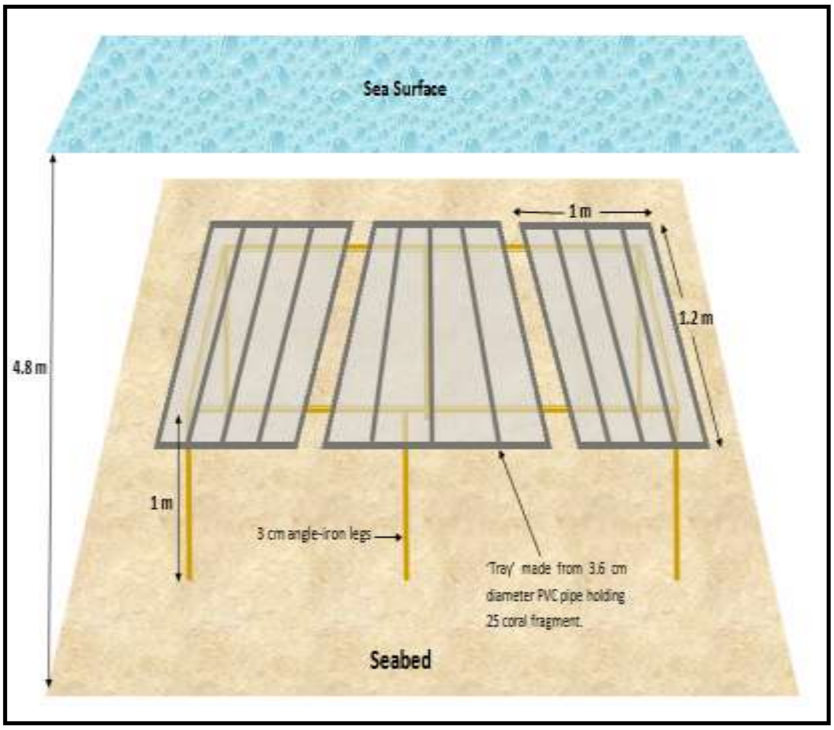

Fig. 2: Design for a fixed modular tray nursery (based on Shaish *et al.*, 2008).

Fragmentation of donor colonies:

The remaining living fragments (sizes ranging from finger size to large heads (Edwards, 2010), 2–9 cm long) of Acropora species (Table 1) from tourism activity were collected from South Breika dive site using SCUBA diving.Fragments were collected in plastic bags and transferred to study site. Each genotype was placed in a separate plastic bag to avoid harmful interactions, fragments broken *in situ* into smaller fragments and inserted into the hole of a PVC pipes by cutting open the grid to reduces detachment and using strap to fix them (Fig. 3).Growth rate (Axial, width, and base diameter) were taken by a Vernier calliper.

Table 1: Coral species List that used for transplantation

Species	% of all colonies
Acropora eurystoma	28.4
Acropora humilis	16.8
Acropora pharaonis	3.1
Acropora digitifera	19.7
Acropora hemprichii	3.6
Acropora squarrosa	14.7
Acropora gemmifera	13.7

Fig. 3: Arrangement and spacing of corals in the nursery

Estimation of colony diameter and ecological volume:

The average colony diameter (d) of each fragment was calculated as:

$$d = (1 + w)/2$$

(w) Width of fragments.

An ecological volume index was established for each fragment by approximating the initial and developing structures to the shape of a cylinder (Rinkevich and Loya, 1983a,b).

$$V = \pi r^2 h$$
$$(r = (l + w)/4)$$

(V) Ecological Volume.
(h) Height of colony.
(l) Length of fragment.
(w) Width of fragments.

Ecological Volume was found to be the best to express the general architecture of developing colonies.

III. Results

Survival rates of transplanted colonies:

After improving the nursery design, the coral fragments present high survival rates. Within Acroporidae 93% of the transplanted fragments survived the first five months, a high portion of them with a remarkable axial growth. After the six-month survival rate decreased to 81% until reach 58% in eleven months(Fig.4). *Acropora pharaonis*, *A. hemprichii* had similar survival rates (equal 0% after 14 months).

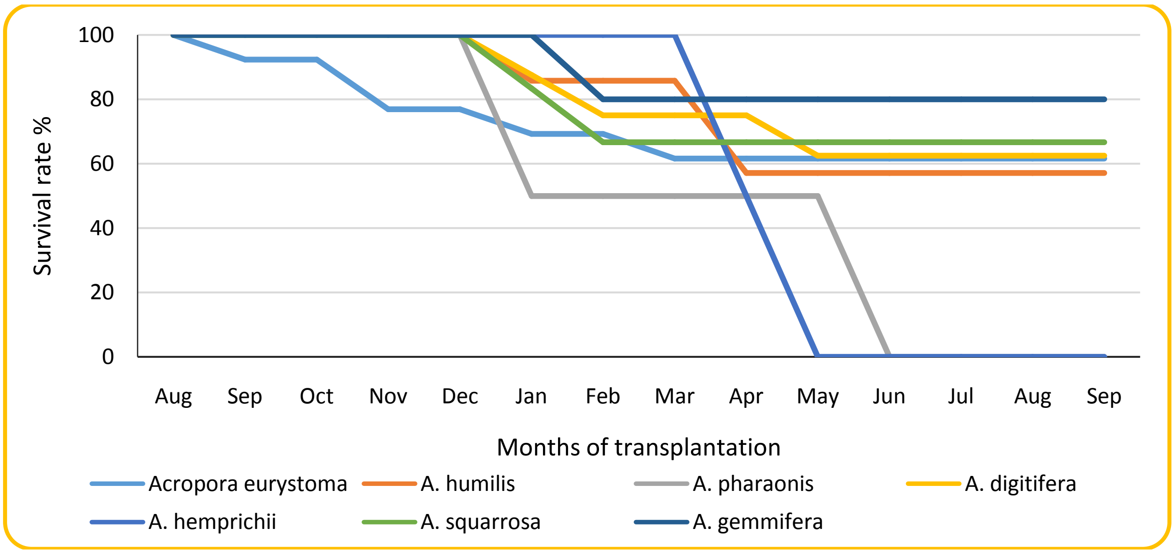

Fig. 4: Survivalrate of transplanted fragments of different coral species.

Monthly axial growth rates of transplanted colonies:

Axial growth rates (mm/month) was calculated for transplanted coral during the study period. Colonies that showed negative growth rates because of partial mortality, breakage or predation were excluded from mean growth rate calculations. Overall growth rate was 0.940 ± 0.049 mm/month. Growth rates varied widely between colonies within one species and between congeneric species (P-value <0.05). The highest average monthly growthratewas showing in *Acropora eurystoma* (1.76 mm/month), whilethe lowest one was found in *A. squarrosa* (0.42 mm/month).

Average axial growth rates might have been affected by colony size. Growth rates for each species in study period were compared using analysis of variance. The Acroporidae showed significant positive relation between growth rate and colony size (P< 0.05) (Fig. 5).

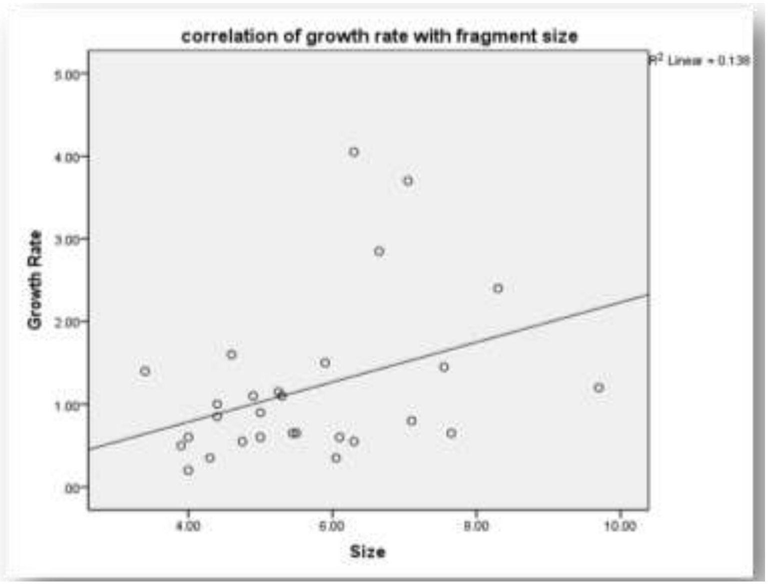

Fig. 5: Regression lines relationship between fragments size and growth rate.

Fragment width growth rates of transplanted colonies:

Transplanted coral fragments width growth rates showed that the fastest growing species were *Acropora eurystoma*(1.017 ± 0.0926 mm/month). The slowest growth rates were found in *A. squarrosa* (0.279 ± 0.0445 mm/month) and *A. hemprichii* (0.233 ± 0.0826 mm/month) (Fig. 6).

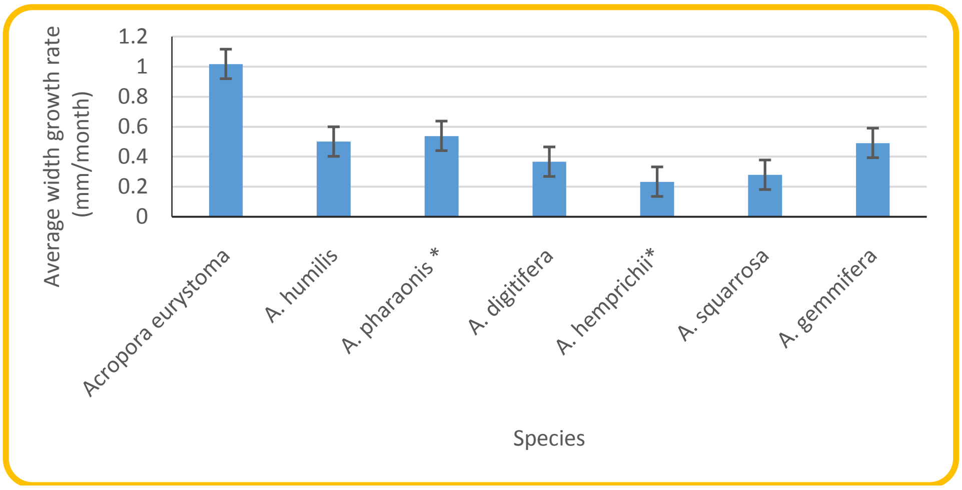

Fig. 6: Average width growth rate of fragments from selected species 14 months after transplantation (*mean for 7 months only).

Fragment base diameter growth rates of transplanted colonies:

Transplanted coral fragments base diameter growth rates showed that the fastest base diameter growing species was *Acropora eurystoma* (0.716 ± 0.0669 mm/month), followed by *A. gemmifera* (0.588 ± 0.0698 mm/month). The slowest growth rates were found in *A. squarrosa* (0.303 ± 0.0564 mm/month) and *A. hemprichii*(0.300 ± 0.0816 mm/month) (Fig. 7).

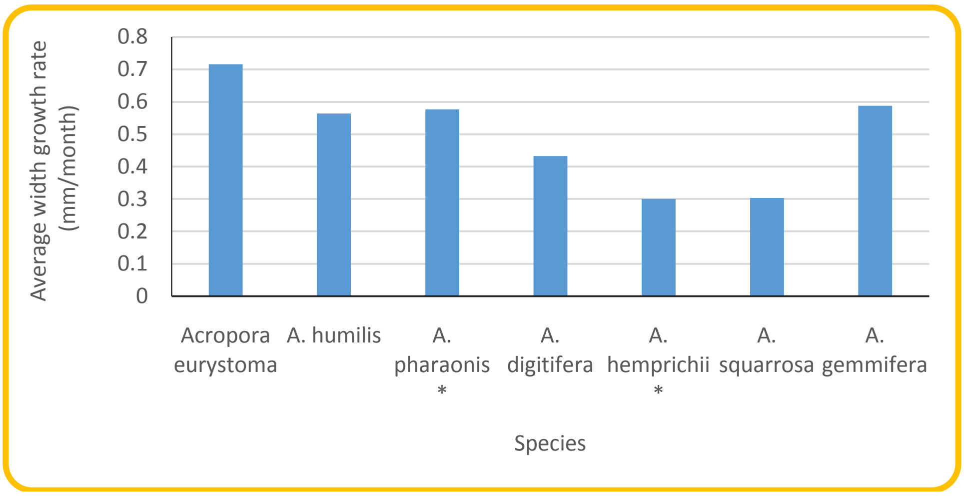

Fig. 7: Average base diameter growth rate of fragments from selected species (14 months after transplantation) (*mean for 7 months only)

Ecological Volume (EV):

Ecological volume is the best expressed the general architecture of developing colonies to know the space that colonies occupied in the structure and the size augmentation from the initial size. *Acropora eurystoma* showed more than duplicate in ecological volume after 14 months of transplantation while *A. squarrosa* showed the less increase of volume than the initial volume (1.38 ± 0.05 times) (Table 2).

Table 2: Size augmentation of ecological volume of transplanted corals after 14 months. (* for 7 months only)

Species	Months	Ecological volume ($mm^3 \times 10^4$)	Size augmentation
Acropora eurystoma	**Initial**	18.758 ± 5.342	-
	7 Month	28.126 ± 6.765	1.57 ± 0.11
	14 Month	43.297 ± 9.065	2.63 ± 0.34

A. humilis	Initial	17.151 ± 4.082	-
	7 Month	21.245 ± 5.057	1.24 ± 0.09
	14 Month	25.669 ± 6.450	1.51 ± 0.19
*A. pharaonis**	Initial	13.190 ± 1.961	-
	7 Month	18.342	1.63
A. digitifera	Initial	5.536 ± 1.273	-
	7 Month	7.022 ± 1.834	1.25 ± 0.07
	14 Month	8.575 ± 1.961	1.61 ± 0.24
*A. hemprichii**	Initial	9.634 ± 0.635	-
	7 Month	13.266 ± 0.956	1.38 ± 0.01
A. squarrosa	Initial	6.562 ± 1.005	-
	7 Month	7.709 ± 1.154	1.18 ± 0.03
	14 Month	8.934 ± 1.221	1.38 ± 0.05
A. gemmifera	Initial	7.892 ± 1.406	-
	7 Month	10.006 ± 1.688	1.27 ± 0.05
	14 Month	12.195 ± 1.876	1.57 ± 0.14

IV. Discussion

The present study aimed to evaluating the potential of restoration using small branch fragments (mostly 2-9 cm length) from the common Red Sea branching coral families Acroporidae and to show the efficiency of transplantation of fragments onto an artificial construction installed in the natural environment. All nurseries were successful operations. After 14 months of monthly monitoring, over 58% survivorship was recorded in nurseries that developed colonies suitable for transplantation which are considered low compared with the previous records of the same some species in same area by Schuhmacher et al. (2000).

All fragments of seven Acropora species used in our experiment, tissue began to spread over the plastic strap that fixed them onto the experimental installationa few days after transplantation.*Acropora eurystoma* had the fastest self-attachment times for all species fragments. About 27% of fragments had self-attached by month 3 and by the end of the study (14 months) 87% of survived fragments had achieved self-attachment. These results are similar to James et al. (2009) who found that *Acropora muricata* had the fastest self-attachment than the encrusting-foliaceous species *Echinopora lamellose* and in the end of the study (about 8 months) 74% had achieved self-attachment.

Overall survivorship of transplanted coral colonies of 58% at the end of study compares with other studies. For example, in the Philippines, Alcala et al. (1982) recorded 40% survival of transplants in 1-1.2 m depth over one year in a study at Sumilon Island, whilst Auberson (1982) recorded 70% survival in average over one year in the same locality for transplants placed at depth of 1.5 - 10.5 m.

The high survival rate that reached 65% in some coral species, after one year, beside the considerably formed substrate and the incredible low cost, recommend the present technique as a good and cheap one for building artificial reefs in comparison with the high costive techniques done by Van Treek and Schuhmacher (1999) and Schillak et al. (2001) using electrolysis of sea water to build the substrate.

In this study, we found that *A. eurystoma* skeletons grew more rapidly in terms of linear extension than the other Acroporidae species during harsh winter conditions and during the most favourable conditions of summer (i.e. highest illumination levels and temperatures). Therefore, it can be deduced that *A. eurystoma* could survive more successfully in extreme conditions than *A. squarrosa* and *A. gemmifera*.

The present results show that ecological volume (EV) of corals are considered very low compared with the previous records in other areas of the same species. Nsajigwa et al. (2010) studied the ecological volume growth rate of *Acropora hemprichii* after 9 months in the Chumbe, Zanzibar and Chole Bay, Mafia (Tanzania). He found mean ecological volume of 187300 mm^3 and 109900 mm^3, respectively, with size augmentation of 108.4 and 49 times of initial size, respectively. His growth data of ecological volume are much higher than the present work values for the same species. Our result show ecological volume growth rate of *A. hemprichii* after 7 months was 36315.4 mm^3 with size augmentation of 1.38 ± 0.01 times of initial size.

From the observations made in this study, it appeared that it was not the stress of transplantation and low temperature in winter *per se* that caused mortality of the corals, but rather the invasion of the weakened tissue by either algae or Drupella snails. These last two factors exerted different effects. Algae act as competitors of corals for space and light, and can over-grow the animal tissue and eventually smother it physically (McCook et al., 2001 and Diaz-Pulido & McCook, 2002). The snails are predators that actually consume the tissue. In our monitoring, the coral-eating snail *Drupellacornus* was found in experimental design preying on *Acropora eurystoma*. This was similar to Annick and Tim (2003) observations of *D. cornus* preying on *Porites palmate* who recorded three to four snails on each branching coral and they killed 60% of each colony/transplant. Also, genus Acropora and the family Pocilloporidae eating by *D. cornus* on damaged reefs in Kenya and western Australia (McClanahan, 1994).

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