Coral Translocation: Mitigating Adverse Impact ofDevelopment along the Aqaba Coastline/Jordan

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ABSTRACT

The present study describes corals translocationinitiated in response to theEnvironmental Impact Assessment study (EIA)conducted for the new South Port project in Aqaba. A galvanized steel structure painted with anti-fouling and anti-rust paints for the establishment of nursery structures was used. Concrete pipes and fossil reef rocks were utilized for the creation of a new cave-shape dive site. Marine cement was used to fix the colonies at the designated sites.About7000 coral colonies were translocated from the new port site to selectedlocations within the Aqaba Marine Parkshowed a survival rate of 89.8%during the first year.Thestudy indicated that coral translocation is a good tool for conservationif well designed and controlled.It would help in mitigating any potential adverse impacts resulted from development activities in coastal areas.

Key words: Artificial reefs, Restoration,Coral translocation, Coral transplantation, Coral nursery, Red Sea, Jordan.

INTRODUCTION

The most significant feature of Jordan's marine environment is the coral reef ecosystems.The Jordanian reefs lie within the Red Sea and designated as a World Wide Fund for Nature global 200 eco-region on account of its unique marine biodiversity.The Gulf of Aqaba is a separate biogeographic zone within the Red Sea, and is of global significance in having the northern-most latitude reefs in the Western Indo-Pacific (Sheppard and Sheppard, 1991).

Reefs in Jordan are among the most threatened in the Red Sea.They are shallow, easily accessible, and adjacent to a major population and industrial centre, suffering from a combination of factors common to reefs worldwide, including sedimentation caused by construction, algal overgrowth, and physical damage from divers, boats, recreational activities, and pollution.

The local authorities in Aqaba are planningthrough the Ports Development Project to close port operations at the Main Port of Aqaba, and to relocate the services to modernized South Port, on Aqaba's southern coastline.The proposed new site at Dirreh Bay for relocating the portsis considered as one of the most important diving sites along the Gulf of Aqaba.Because of its uniqueness in terms of coral cover, biodiversity and the presence of the famous coral wall that attracts many recreational divers to the site and is visited by many local tourists, especially during summer (MSS, 2007).

Relocation of the main cargo port to an undeveloped site, near the international border with Saudi Arabia, will result in the destruction of approximately 40,000 m^2 of high quality coral reefs. In recognition of the importance of coral habitat,)ASEZA, 2001) has a policy of requiring projects proponents to provide specific mitigation measures and alternatives as well as to compensate for any planned or accidental destruction of coral reefs. An opportunity has thus been provided to preserve some portions of coral reef that are currently slated for complete destruction.Recommendations to mitigate such impact were to create an equivalent habitat consistent of artificial reefs with corals translocated from Dirreh Bay before construction begins, artificial substrate, nursery grown coral nubbins; and monitor the coral transplanting process.

Transplantation and relocation have been used as a tool to mitigate potential impacts on coral colonies as well as enhance and establish new areas for tourism activities in a number of sites worldwide. Several success models that have used different methods and techniques have been recorded. One of the earlier attempts for transplantation has taken place in the Gulf of Aqaba in 1981 where large coral heads have bee transplanted to enhance a tourism area, Bouchon et al. (1981).Harriott and Fisk (1988b) researched whether transplantation could accelerate recovery of coral areas damaged by the crown-of-thorns starfis (Acanthaster plancii) in the Great Barrier ReefMarine Park.Transplantation was also used to reintroduce and study survival of two species of corals in an area polluted by sewage in Kanehoe Bay, Hawaii (Maragos 1974; Maragos et al. 1985).The potential for transplantation to aid reef recovery following dynamite fishing has been extensively studied in the Philippines, (Auberson 1982; Yap and Gomez 1984; Yap et al. 1990, 1992).The present studydescribes the process of the translocation and transplantation of coral reef colonies from the new port site into selected receptor sites within the boundaries of the Aqaba Marine Park (AMP), which was launched as part of the implementation of the above mitigation measures. In addition, the data of one year monitoring was used to evaluate the success of the work.

MATERIAL AND METHODS

Study Area

The present study was conducted along the southern Jordanian sector of the Gulf of Aqaba (29° 212 N, 34° 572 E). The gulf is the northernmost sea-flooded part of the Syrian-African rift system. The gulf is a semi-closed basin, separated from the Red Sea by the Straits of Tiran, a narrow passage about 250m deep, (Fig.1).

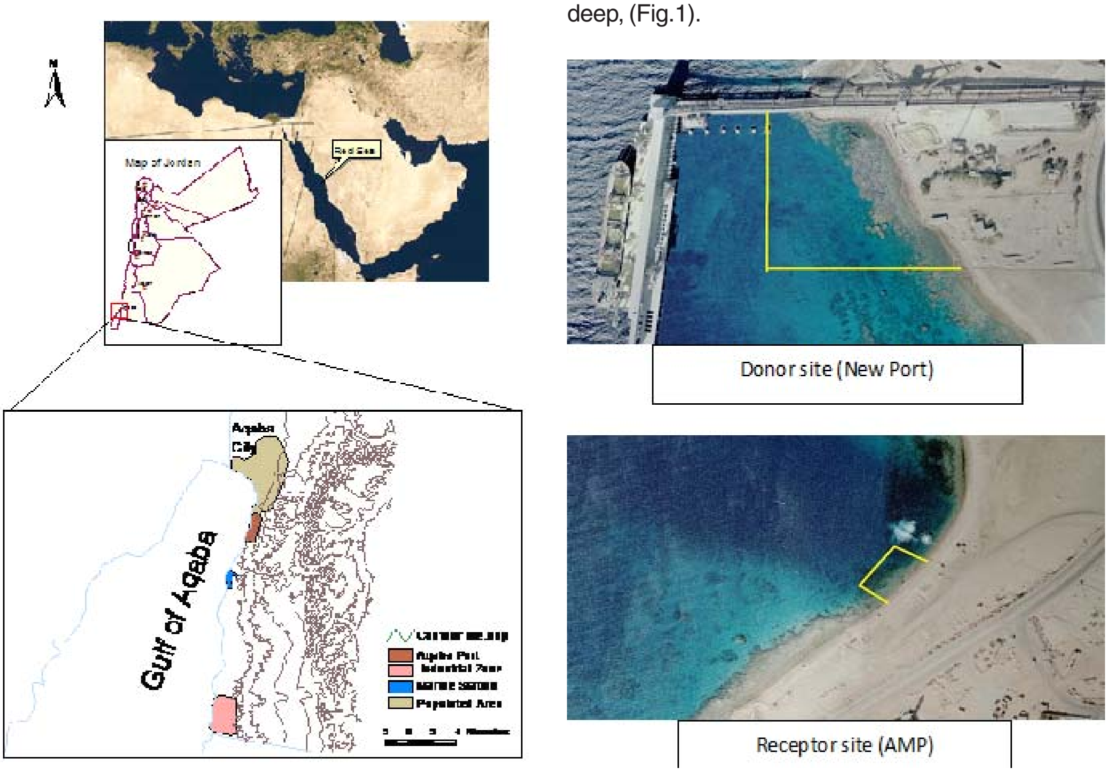

Fig. 1: Study site along the south coast of Aqaba (donor and receptor sites)

The 27 kilometer-long Jordanian shoreline of the Gulf of Aqaba provides the only access to the sea for Jordan for ship transport, fishing, and industrial development that requires large amount of cooling water.The coast has been divided generally into zones for development purposes, the city of Aqaba, and the port area, the south tourist area including the marine park and the public beach and the industrial zone area.The fringing reefs along the Jordanian coast are of extreme environmental importance. It is part of the northern most reef in the Northern Hemisphere. This reef system is considered the most diverse within the Northern Hemisphere with many endemic species (IUCN, 1993).The north beach of Aqaba consists primarily of sand and gravel beaches. Further south along the coast, more coral reef areas are evident. These reefs are found scattered nearshore where that of offshore is extending in a more continuous way, although such continuity is interrupted by several bays.

Detaching, translocating and fixing coral colonies

The transplantation of corals includes detaching of the coral colonies from the donor site, translocating and re-attaching of these colonies at the receptor sites.

Pliers, chisels, and hammers were used to detach coral colonies. Colonies were transported using cages/baskets (2m x 1m x 0.5m in size) made from galvanized metal and manufactured by the work team specifically for this purpose, (Fig.2).

Fig. 2: Galvanized metal cages used for translocation coral colonies

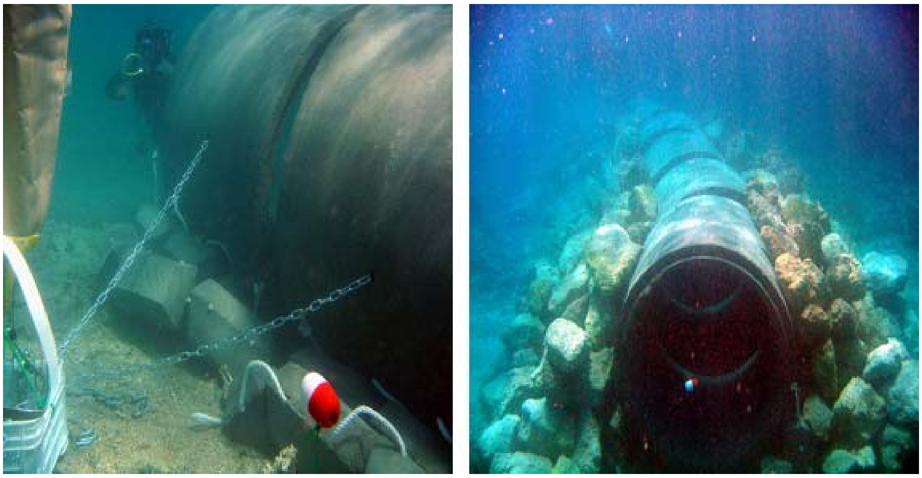

Fig. 3: Establishment of the new cave dive site.Concrete pipes are secured by stone mats and manta moorings (left) and stabilized by using fossil reef rocks on both sides (right)

Cages/baskets were kept submerged and buoyant close to the water surface at 1.5m depth, using lifting bags to avoid any further stress to these colonies, which may consequently affect their survival rate (Edwards and Gomez, 2007). The cages were dragged by a towing boat at a low speed to avoid the displacement of the coral colonies inside the cages against each other. The coral colonies were transported 7 km to their final destination at AMP(i.e. distance from the donor to receptor sites).The translocated colonies were deployed at receptor site at 2 to 8m depths similar to that of their original site.

Due to the variance in shape and size of coral colonies targeted for transplantation, different methodologies for fixation and attachment were applied. Marine cement was used to fix the colony directly to the substratum at the degraded reef sites (Kotb, 2003; Edwards and Gomez, 2007; Edwards, 2010).

Survey of donor and receptor sites

A detailed survey was conducted forthe donor sites (to define the coral priority species and communities to be relocated) and the receptor sites (to verify the exact location to meet the criteria specific to the success of the translocation exercise).

The degraded reefs within AMPwere selected as receptor sites for a number of reasons including: the area is protected and patrolled by the park rangers.The relevant existing environmental

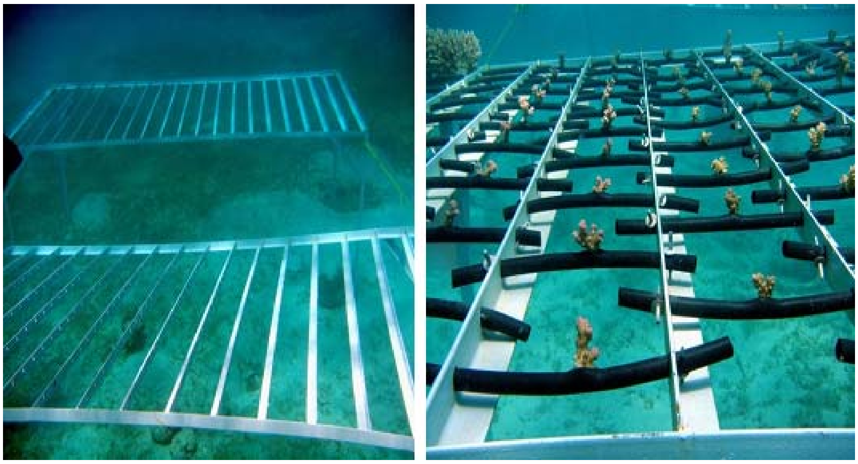

Fig. 4: Nursery tables after deployment and fixation underwater before (left), and after (right) the fixation of coral nubbins

Fig. 5: Tent-like structures made of galvanised metal net used to fix the hard branched corals

conditions at the marine park are similar to the original translocated corals habitat and; the marine park is covered by an on-going monitoring program for seawater, sediment quality, fish and coral cover.

The surveyconducted for the different receptor sites aimed at evaluating: the suitable locations/spots, which have similar environmental conditions to the donor site(s); the suitability of the targeted locations/spots areas to receive the translocated coral colonies/heads in terms of size and volume; assess the existing coral, fish, and invertebrate communities. Moreover,identify the capacity of each degraded (receptor) site to accommodate the translocated corals, i.e. estimates of the approximate species, number, and volumes of coral colonies to be transplanted into the site and; selectingsuitable locations for the artificial reef structures and nursery ground.Three sites within AMPwere selected to accommodate the translocated corals and three ecological examples were applied into these sites: reef restoration using coral transplantation at site-1 (Mamlah area); creation of new reef habitat (i.e. cave habitat) at site-2 (shore entrance of the new canyon dive site); and reef rehabilitation at site-3 (in front of the AMP visitor centre).

Table 1: Numbers and mean growth rates of the transplanted coral colonies at the transplantation sites

Genera	Mamlah	Cave	Visitor Centre	Mean growth rate in 1 year (in mm)
Platygyra	33	189	80	5.6
Favia	1	41	15	11.2
Favites	20	42	25	16.6
Hydnophora	4	10	2	14.7
Porites	7	30	45	31
Acropora	27	242	114	4.2
Pocillopora	7	6	10	5.2
Stylophora	1	20	30	5.7
Montipora	1	-	-	6
Turbinaria	-	8	4	-
Tubastrea	-	-	7	-
Lobophylia	-	-	2	-
Nephthya	7	-	-	-
Millepora	-	3	-	-
Astreopora	-	1	-	-
Galaxea	-	3	-	-
Total	108	595	334	-

Table 2: Fish species and abundance recorded at all sites before transplantation and one year after

Site	before		after	
	species	abundance	species	abundance
Mamlah	3	70	11	333
Cave	0	0	22	1880
visitor centre	3	40	8	378

Creation of the cave reef habitat

Seven concrete pipes (1.5m length, 2m diameter and 3 tons weight each) made from non-toxic cement were used to create the cave-shape dive site (Fig. 3). Manta moorings and fossil coral boulders and rocks were used to cover the pipes and give further stabilization and secure them from rolling-over or buried risk during strong wave actions. The boulders and rocks brought from nearby sites were washed thoroughly from the debris and sand by water-jet before deployment. Transported colonies were fixed onto the rocks and boulders outside the cave.

Coral nursery and coral tents

Metal rods multi coated by antirust paint were used to establish two table-like structures with a dimension of 2m x 4m x 2m (Fig. 4). Different sizes of rodswere used and proved their efficiency (Edwards, 2010). The nursery structures were placed at 2m depth at the lowest low tide and fixed on a sandy bottom area by ropes to ensure its stability against current effects.Short plastic tubes (30cm long) were usedfor these structures to facilitate both; planting and removal of the coral nubbins at a later stage of growth (Fig. 4).Plastic tubes would make it possible to reuse them several times for several coral nubbins.Five artificial tent-like structures (2m base diameter and 125cm height) of galvanised metal net were usedto fix the hard branched corals and as refuge hide for fishes (Fig. 5).

Monitoring Programme

Several regular monitoring plan and missions were put in place.Ideally, the monitoring plan suggested that monitoring activities to continue over the long term (more than 5 years) taken into account the low growth rate of corals. The plan intended to be comprehensive, providing biological, ecological, and physical assessments such as survival rates of the translocated colonies. The success of reattached organisms, reproductive capacities, fish census; abundance estimation of other organisms, recruitment, changes in community structure, and the stability and

Table 3: Species richness and abundance of invertebrates at all sites before and one year after transplantation

Site	before		after	
	species	abundance	species	abundance
Mamlah	0	0	2	3
Cave	0	0	8	83
visitor centre	0	0	5	20

Table 4: Fish and invertebrate habitat species within the cave area

	Common name	Species
Fish	Aqaba cardinalfish	*Cheilodipteruslachneri*
	Yellowtail sweeper	*Pempherisschwenkii*
	Cardinalfish	*Cardinalfish sp.*
	Blotcheyesoldierfish	*Myripristismurdjan*
	Yellow boxfish	*Ostracioncubicus*
Invertebrate	Herdman's ascidian	*Herdmaniamomus*
	Apricot synascidia	*Eusynstyelamisakiensis*
	Moseley's ascidian	*Didemnummoseleyi*
	Hydroids	*Sertularia sp.*
	Guilded pipefish	*Corythoichthys cf. schultzi*
	Leach's sea star	*Leiasterleachi*

inhabitation of the artificial reefs as well as cleaning-up the receptor sites from solid wastes might be resulting from the AMP visitors.As well as to remove the corallivore Diadema sea urchin and Drupella shells from the vicinity of the transplantation locations (recorded along the marine park in high numbers due to the degradation of the AMP'sreefs). In addition to collect all relevant baseline data and monitoring data, maintenance measures were proposed and included removing any rubbles, *Drupella* shells, *Diadema* sea-urchin, and solid wastes (e.g. fishing nets, fishing lines, plastic bags, bottles, etc.).

Donor site

Part of Al-Dirreh donor site was dominated by sandy bottom areas with seagrass meadows down to 4m depth, while the rest of the area was dominated by developed reefs with hard corals coverageof 30-70% of different species. The recorded corals were: *Porites* spp., *Platygyra* sp., *Favia* spp., and *Favites* spp., withdiameters ranged between 30 cm at the reef edge zone and reached 2m at the bottom area. Branched corals were recorded but with less abundance. The two dominating generawere *Acropora* spp. and *Stylophora* sp., with an average diameter of 20cm.

Receptor sites

The area is experiencing serious damage and characterized by the existence of reef flat that extends for 30m seawards with coral cover of 10-20%. The coral community is dominated by the fire-corals *Milleporadichotoma* at the reef edge and upper reef slope, while dominated by the brain-corals *Platygyra spp.* and *Acropora spp*. at the lower reef slope. A total of 108 colonies (Table 1) were transplanted into Receptor Site 1.

The artificial cave reef site was established at an area characterised by shallow water (5-6m depth); a gentle slope (steeply at 20m depth) and sandy bottom with no reef cover(Fig. 3). The outer surface area offered by this structure was around 100m^2 and hosted a total of 595 colonies (Table1), resultingin a coral cover of about 60-70%.

Site 2 at the front of the visitor centre hosted a total of 334 colonies of the translocated corals (Table 1), resulting in an increase of coral cover to about 60-70%. These colonies were used for the restoration of a totally damaged reef area estimated at 20 m^2.

Around 350 nubbins (3cm to 5cm-long broken coral branches resulted from the detaching and transporting operations) of *Acropora spp*., *Pocilloporadamicornis*, and *Stylophorapistillata* were transplanted and attached to the plastic pipes on the two nursery structures/tables which were established at this site as potential source of coral colonies hosted (Fig. 4).

Around 50 branched colonies were fixed into another artificial metal/tent-like structures (Fig. 5) in order to provide new and different geometry for the coral cover at that area.

Monitoring results

The findings of the first year monitoring were very encouraging as the recorded survival rates were relatively high at all transplantation sites (Table 1).

A survival rate of transplanted coral colonies was recorded with an average of89.9% at all transplantation sites after one year of monitoring, 82.4% atMamlah area (Site 1); 91.4% at the Cave area (Site 2); and 95.8% at the visitor centre area (Site 3).

The transplanted coral colonies continued their growth after one year of transplantation with similar rates recordedin other areas alongthe Red Sea for the same coral genera (Table 1).

Diversity and number of fish (abundance)of fishes and invertebrate organisms at the receptor sites, after one year of transplantation,werehigher than donor sites(Table 2 and 3). Furthermore, several coral reef fishes recorded within the Cave area and few of them were cave habitat inhabitants. Other cave inhabitant invertebrates were recorded as well on the inside walls of the cave, (Table 4).The ongoing monitoring activities for the three sites confirmed the existence of other small organisms such as damselfishes, invertebrates, algae and sponges at the transplanted colonies.

DISCUSSION

Coral translocation has been applied in the present case not only as one of the mitigation measures recommended in the EIA study of the new port project. However, to save as much as possible coral colonies and to use artificial reefs as anefficient tool in enhancement of fishery and mitigation of marine ecosystems deterioration (Seaman and Sprague, 1991; Collins and Jensen, 1999; Jensen, *et al.,* 2000). Moreover, it was intended to maximize environmental benefits expected from artificial reefs (Collins and Jensen, 1999, Kotb, 2003), including; the conservation of natural reefs by diverting human activities from them (e.g. diving pressure), offering refuge for rare and endangered species of invertebrates and fish and provide nursery grounds for young stages of reef species (Salm, *et al*, 2000).

The coral reef of Al –Dirreh site offered for a long time an attractive and unique dive site due to its high biodiversity. The establishment of the new port at that site has significantly affected the diving options in Aqaba. As anticipated and recommended in the mitigation measures of the EIA study,and in order to compensate for the coral damage, an equivalent habitat consists of artificial reefs with corals transplanted from Dirreh Bay wasproposed and consequently, creation of a new dive site with a new concept i.e. "cave dive site" has been adopted and agreed upon among the diving community in Aqaba who has been extensively consulted. The support of this option was attributed mainly to the fact that there is no cave dive sites exist along the Aqaba coastline.

Using coral transplantation over artificial reef structures for management purposes is becoming of interest to many researchers during the last decades (Clark and Edwards, 1995; Edwards and Clark, 1998; Yap, 2000, 2003; Epstein, *et al*., 2001, 2003; Sabater and Yap, 2002).

There are currently more than 25 dive sites along the 27km coastline of Aqaba, however, most of them are shallow reefs and experiencing degradation due to a number of factors including destruction fishing practices, solid wastes, anchoring, etc., and therefore,diving attraction in Aqaba are diminishing. The construction of the new port has contributed to this diminishing by the damage it will bring to the "Saudi border" dive site and its marine biodiversity. This dive site has been known for more than 30 years, as one of the most favourite's site for divers and snorkelers due to its uniqueness in terms particularly of coral cover and fish community. Consequently, having an alternative and an acceptable option for the diving community in Aqaba was highly needed, and since there is no way to compensate and create a similar dive site to that of Al Dirreh bay, the only chance was to invest in a new concept such as creating new dive site with a cave-shape. This type of dive sites does not exist in Aqaba, so it is expected that it would create an interest by divers. The introduction of this new concept to Aqaba will consequently result in having this "Diving speciality" that is recognized by all diving schools worldwide (e.g. PADI, BSAC and CMS). It is also expected that opening this site in 2-3 years after ensuring that the survivorship of corals is acceptable may minimize pressure and the impact on other dive sites.

The translocation process has contributed to saving a significant amount of coral cover, whichcould have been damaged by the construction activities of the new port. Moreover, the translocation has resulted in the restoration of a number of sites that have been degraded by anthropogenic activities during the past years.The use of different translocation and techniques provideda new approach for educationand raising awareness on the value of coral reefs and the importance of conservation.

Coral nurseries are usually established to maintain a source of coral colonies to restore the damaged reefs as well as to make a benefit and use of the fragmented coral colonies resulted either by natural effects such as strong wave action or by anthropogenic effects such as visitors trampling on corals (Edwards and Gomez, 2007). Several simple, cost effective techniques have been used worldwide as nurseries to propagate the corals rescued from coastal development areas such as the coral trays (Le Berre and Guignard, 2008).

The nursery structures applied in the present study would maximize benefits from a given amount of source material.And thus minimize damage to donor areas given that corals can be successfully cultured from asexually produced fragments as it was indicated in a number of successful models applied in many other reef restoration projects worldwide (Edwards and Gomez, 2007) and in the Red Sea area (Kotb, 2003 and 2006).

The annual growth rates of the branched species (i.e. *Acropora* spp., *Pocillopora damicornis,* and *Stylophora pistillata)* collected from the donor sitesare7-9cm as recorded along a number of sites along the Egyptian Red Sea (Kotb, 2001; Mohamed, *et al.,* 2007). Therefore, it is expected that nubbins succeed to grow up at the transplantation sites would form colonies at fist-size or bigger after about 6-9 months. Such colony size is suitable for transplantation purposes and can withstand the transplantation effects (Edwards and Gomez, 2007; Edwards, 2010).

The present study showed that transplanted coral colonies continued their growth after one year of transplantation with rates similar to the recorded rates in other Red Sea areas for the same coral genera (Kotb, 2001; Mohamed, *et al.,* 2007).

The survival ratesrecorded through the monitoring program at all transplantation sites are relatively high when compared with similar projects (e.g. Edwards and Gomez, 2007; Edwards, 2010).

Such survival rates are worldwide acceptable rates to prove the success of the transplantation (Clark and Edwards, 1995; Van-TreeckandSchumacher., 1999; Kotb, et al., 2000 and 2003).

Recording higher density of fishes and the observation of different fish feeding habits in the transplantation areas (e.g. herbivores and corallivores) might be considered as an indicator ofprogressive inhabitation and normal habitats conditions emerge after the increase in coral richness in transplantation areas, which inturns offer different feeding grounds and sources for different fishes.

The existence of other small organisms such as damselfishes, invertebrates, algae, spongesat the transplantedcolonies, which means that new substrate and change in underwater topography have been created by these colonies.

The data collected from the new cave dive site on theexistence of different species related to the cave and crevices habitats with considerable abundance and diversity are of considerable importance.As this proves the success of cave structure in creating suitable habitats for such organisms and the progressive development of the area to create normal cave ecological and biological habitat conditions.

The successful transplantation has resulted in shift in the perception of all concerned institutions in Aqaba towards the " coral translocation/ transplantation" as a possible and feasible mitigation measure in case no other options and alternatives for some development projects and in events where the appropriate methodology and techniques as well as subsequent monitoring are applied.

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