Development of a coral nursery as a sustainable resource for reef restoration in Abu Al Abyad Island, Abu Dhabi, United Arab Emirates, Arabian Gulf

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Abstract Populations of once dominant reef building coral Acropora clathrata in Arabian Gulf is declining, mainly due to thermal bleaching and anthropogenic factors such as rapid urbanization, toxic wastes, destructive fishing practices, land reclamation and sedimentation. To actively restore coral populations, continuous supply of corals is required without causing damage to the existing reefs. In this study, as part of the coral gardening approach, mid water coral nurseries were constructed in Abu Al Abyad Island, United Arab Emirates following the coral tree nursery model. Six hundred fragments, with an average length of 6.32 cm (SD ± 1.23 cm) of Acropora clathrata were mounted in the nursery and reared for 21 months while monitoring the health of the fragments continuously and estimating the growth rate and survivorship of the corals every three months. Only 9.8% of mortality was recorded in the entire study period, while a linear growth rate of 6.44 cm·year⁻¹ (SD ± 0.72) was achieved in the first 12 months and 9.25 cm·year⁻¹ (SD ± 0.63) in the remaining 9 months. Almost negligible mortality and satisfactory growth of corals during the entire nursery period suggest that the coral tree nursery model is suitable for propagating A. clathrata in Arabian Gulf.

Keywords coral tree nursery, coral gardening, Arabian Gulf, Acropora clathrata

Introduction

Despite being in one of the harshest environments known for coral survival, reef corals of the Arabian Gulf have persisted for centuries (Sheppard et al. 2010). Corals in the Arabian Gulf survive daily-mean surface water temperatures exceeding 32°C in summer (June–September) and as low as 12°C in winter (January–March), an annual range of 20°C, (Purkis et al. 2011; Riegl and Purkis 2012), much higher than other coral reefs of the world. In spite of being remarkably thermotolerant (Hume et al. 2013; 2015), coral reefs of Arabian Gulf are still declining (Riegl 1999, 2002) which can be attributed to frequent natural disturbances, mainly associated with anomalous sea surface temperature and other anthropogenic factors such as rapid urbanization of coastal areas, toxic wastes, destructive fishing practices, oil pollution, land reclamation, sedimentation, etc. The marine environment of Abu Al Abyad Island is a microcosm of the larger Arabian Gulf marine environment. The coral communities off the island
mostly consist of small coral colonies in the north and northwest sides of the island and are dominated by *Acropora* spp. and *Porites* spp. (Al Abdessalaam 2002).

Once dominant reef building coral, *Acropora* spp. in the region has become sparse (Riegl 2002). In the absence of matured corals, degraded reef often fall short to recover through sexual spawning. To mitigate further loss or damage of coral reefs, active reef restoration methods have been adopted (Clark and Edwards 1999). Although the long term effect of active reef restoration is still in its infancy, many studies have also revealed promising result by showing that active restoration may enhance reef recovery (Rinkevich 2014). The recent trend of ‘coral gardening’ is one such accepted method where corals are propagated in-situ conditions and transplanted to the degraded reef site as a part of restoration (Rinkevich 1995). Johnson et al. (2011) believe that restoring coral populations through vegetative ways also has an added advantage of increasing the number of gametes in an area during spawning and thus great chance of producing higher number of sexually reproducing embryo (Horoszowski-Fridman et al. 2011).

Here we document the efficacy of culturing a locally common species, *Acropora clathrata*, in a mid water nursery for about 21 months. In an attempt to follow a cost effective and less labour oriented practice, we have adopted the coral tree nursery model as described by Nedimyer et al. (2011). This is the first time such an effort has been undertaken in the Arabian Gulf. This study mostly focuses on the growth and survival rate of *A. clathrata* in coral tree nursery as sustainable coral source for reef restoration.

**Material and Methods**

**Study area**

The study site is located in Abu Al Abyad Island, situated west of Abu Dhabi, United Arab Emirates in the southern Arabian Gulf (24°20′32″N, 53°49′52.3″E). The region is typically characterized by high summer seawater temperatures (>32°C) in contrast to low winter temperatures of 19°C. Coral reef is found at a depth of 6 m, but was severely degraded due to the 1996, 1998 catastrophic bleaching events (Riegl 2002). However, the natural recovery of the reef is under process and presence of healthy *A. clathrata* colonies are cited, but their numbers are scarce.

**Nursery design and collection of coral fragments**

The coral tree nursery (Fig. 1, Nedimyer et al. 2011) was constructed in October 2012 at a depth of 6 m. In brief, the nurseries were made of PVC pipes – a central column (1.5 m length and 2.54 cm diameter) and six horizontal arms (1 m length and 1.27 cm diameter). Subsurface buoy, polypropylene rope and anchors (stone blocks) were used to attain the vertical position of the coral tree nursery. Total 60 coral fragments in each nursery unit were tethered using short and long PVC coated tie wires to avoid adjacent corals from touching each other.

In October 2012, coral fragments of *A. clathrata* were
collected 12 km away from the nursery site, at a depth of 3 m. Ten large donor colonies were fragmented (<10% of the size of the colony) to collect 600 fragments, of an average linear length of 6.32 cm (SD±1.23 cm), to use in 10 coral tree nurseries, leaving donor colonies for self-recovery. Fragments were transported in wet condition to the nursery site and tethered using PVC coated tie wire and hung to the nursery. Each coral tree nursery is represented by individual donor colonies.

**Maintenance and Monitoring**

Every week the nursery site was visited to check any damage or death of fragments. Accumulated sediments and other growths were removed periodically. As corals gained weight, additional subsurface buoys were added to the nursery. Growth and survivorship of the fragments were measured every 3 months. Because of the complex morphology of the branching corals, the growth of a subset of branches was used as the growth of the entire colony. From each tree nursery, 3 fragments (total 30 fragments) were tagged using cable ties and during each sampling time linear extension was measured till the tip of all branches and summed the measurement (Gladfelter et al. 1978; Herlan and Lirman 2008). As for the total growth, maximum length was measured using flexible tape. Total survivorship was calculated based on the number of available live fragments (100% live tissue), partially dead (60% tissue is dead), dead fragments (complete dead) and detached (or loss) from the nursery structure (Shaish et al. 2010).

**Seawater Temperature**

Seawater temperature was monitored using HOBO pendant water temperature logger (Onset Computer Corporation, USA). Two loggers, one at nursery site and another 20 km apart on a natural reef at 6 m depth were placed and programed to record temperature at 30 minutes’ interval between October 2012 and August 2014.

**Results and Discussion**

Maximum coral growth rate was 2.56±0.22 cm (±SD) per 3 months between October and December 2013, followed by 2.27±0.35 cm per 3 months between April and June 2013 (Fig. 2a). Slower growth rates of 0.67±0.14 cm and 1.48±0.25 cm were noticed at the initial 6 months of nursery culture October–December 2012 and January–March 2013 respectively. The initial fragments size (maximum length) was 6.32±1.23 cm (±SD) (Fig. 3a). After six months in nursery, it increased by 34% (8.47 cm±1.43 cm). Towards the end of the study period, the fragments increased by 175% (17.41±2.11 cm) (Fig. 3b–d). Six months after nursery culture was commenced, many reef dwelling fishes were observed at the site including juvenile corallivore butterflyfish *Chaetodon nigropunctatus*.

At the end of 21 months *A. clathrata* showed a high survival rate of 90.2%, mainly due to the larger fragments (6.32±1.23 cm) used in nursery (Fig. 2b) (Omori and Iwao 2014). Total or partial mortality (such as bleached fragment) of coral fragments during the study period was negligible. However, fragments detached from the nursery during the stormy weather. Maximum loss of the fragments was 3.5% per 3 months between January and March 2013,
followed by 1.8% during January–March 2014. No significant mortality was noticed during the rest of the period.

Since the temperature differences between two sites were negligible, mean daily seawater temperature was averaged from both the sites (Fig. 4). Maximum and minimum daily mean temperature was recorded 35.3°C and 18.7°C in August 2013 and January 2013 respectively. Despite a high fluctuation of 16°C between the summer and winter temperatures, coral fragments in the nursery have high survival rate. Such instance is rare around the world, where most of the nurseries are constructed in tropical conditions where seasonal temperature difference is not high.

Despite the shallow depth of the nursery site, the coral tree nursery (Nedimyer et al. 2011) has been successfully adopted for the first time in Arabian Gulf with low mortality and satisfactory growth rate of A. clathrata. Loss of the coral fragments can only be attributed to the seasonal weather patterns, when strong north-westerly winds, locally known as ‘Shamal’, hit the southern basin of Arabian Gulf at a speed of 40–50 km/h with gusts up to 100 km/h during winter (Riegl and Purkis 2012).

The slow coral growth of first six months (October 2012 to March 2013) might be due to the shock of the fragmentation and small fragments also took time to
acclimatize to the new environment (Soong and Chen 2003). However, the rate of growth has increased after one year of nursery culture once the fragments adapted well to the new environment. Maximum coral growth was noticed particularly during October to December 2013, closely followed by April to June 2013, when seawater temperature ranged in between 25 and 32°C. Increasing of growth rate during this period only signifies that physiological functioning of A. clathrata is at its optimal level and it is similar to that of acroporid corals in Caribbean (Gladfelter et al. 1978). Corals have survived during very warm period for a week in August 2014, when water temperature was above 35°C. No bleaching was noticed in the nursery corals.

As suggested by many investigators, coral nurseries can be very productive and contribute to preserving local coral populations (Shaish et al. 2008; Schopmeyer et al. 2012; Rinkevich 2014). After 21 months, the nursery grown coral colonies were transplanted to the nearby degraded reef where environmental setting is almost similar to the nursery site. At least 50 cm distance was maintained between the transplants to avoid the competition among species (Al-Horani 2013; Omori and Iwao 2014). Immediately after transplanting, transplants show sign of stress and pale colouration was observed, however, after six months of transplantation, all transplants recovered the initial stress and appeared healthy while new tissue development was observed onto the epoxy used for fixing the corals. With high survivorship and growth rate, in situ culture of locally available coral species in coral tree nursery has the potential to produce mass production of acroporid corals in the Arabian Gulf.

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