Marine Pollution Bulletin xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Recruitment failure of scleractinian corals in a subtropical marginal environment: Three-year monitoring in a Hong Kong marine park

Apple Pui Yi Chui, Put Ang Jr*

Marine Science Laboratory, School of Life Sciences, Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China

ARTICLE INFO

Keywords:
Tung Ping Chau Marine Park
Coral recruitment
Post-settlement mortality
Platygyra acuta
Fouling
Sedimentation

ABSTRACT

Coral recruitment was monitored for three years, using terracotta tiles, in two core coral areas in Tung Ping Chau Marine Park where coral coverage is one of the richest in Hong Kong. Results revealed an extremely low recruitment success of corals, with only 10 recruits recorded on 384 tile pairs, equivalent to 0.19 recruits $m^{-2}\,yr^{-1}$ throughout the study period. Recruits of *Platygyra acuta* pre-seeded on tiles that were subsequently grown in situ experienced very high mortality following settlement, with average mortality of 80% within half a month and < 0.1% survival through the first four months of deployment. Data suggested that low recruitment of corals may be due to the lack of arrival of competent coral larvae, low larval settlement; and/or low post-settlement survival of recruits due to high sedimentation or intense competition for space with fouling organisms, e.g. algae, oysters, barnacles and bryozoans, which may negatively affect coral recruitment.

1. Introduction

The importance of coral recruitment as a key process in maintaining coral communities and in facilitating reef recovery after disturbance has long been well recognized (e.g. Harrison and Wallace, 1990; Johnson and Preece, 1992; Connell, 1997; Hughes and Tanner, 2000). The number of settlement and post-settlement survival of coral recruits need to be monitored over time to provide the baseline information about coral recruitment patterns, coral abundance and diversity changes (Connell, 1997; Hughes and Tanner, 2000; Coles and Brown, 2007; Edmunds et al., 2015). Several processes are involved to ensure a successful coral recruitment event. First, there must be sufficient number of competent larvae available from the local coral community or from some external sources. These larvae, once arrived, must be able to find a suitable place to attach and metamorphose (settlement). Finally, these new settlers must be able to survive (i.e. post-settlement survivorship) to be detected during subsequent recruitment census (Keough and Downes, 1982; Connell, 1997; Ritson-Williams et al., 2009). All these different processes are particularly sensitive to local and global environmental pressures, including sedimentation (e.g. Hunte and Wittenberg, 1992; Gilmour, 1999; Humphrey et al., 2008), inorganic nutrients (e.g. Humphrey et al., 2008; Lam et al., 2015), rising sea surface temperature (e.g. Richmond, 1993; Byrne, 2011; Chui and Ang, 2015; Kwok et al., 2016; Chui et al., 2016; Chui and Ang, 2017), salinity stress (e.g. Vermeij et al., 2006; Humphrey et al., 2008; Chui and Ang, 2015; Chui et al., 2016; Chui and Ang, 2017) and ocean acidification (e.g. Albright, 2011; Byrne, 2011). Disruption of any of these processes could cause recruitment failure in a locality and lead to a breakdown in the reef sustainability.

To date, ex situ microscopic examination of removable settlement tiles has been used widely to study coral settlement and recruitment patterns (Harrison and Wallace, 1990; Glassom et al., 2004; Ho and Dai, 2014; Van Woesik et al., 2014; Edmunds et al., 2015). Newly settled corals are very small and their growth is slow (Babcock, 1985; Babcock et al., 2003). During this early stage of post-settlement, mortality is typically high (Babcock, 1985). Therefore, corals that settled on tiles may have already been exposed to certain degree of post-settlement mortality before being retrieved for microscopic examination. In the last decade, the development of fluorescence census technique helped in addressing the problem of early detection of coral recruits and allowed recruits to be more easily observed (Piniak et al., 2005). Using this census technique, up to 97.6% of all coral recruits bigger than 1 ml in diameter can be detected in situ (Schmidt-Roach et al., 2008). Therefore, the combination of in situ fluorescence census techniques and ex situ microscopic examination of retrieved tiles, can greatly help in estimating the abundance of new recruits for more accurate determination of the settlement and early post-settlement survival of corals (Schmidt-Roach et al., 2008).

Hong Kong is located in a subtropical region. Low seawater temperature in winter (14–16 °C) makes it a marginal place for coral growth (Ang et al., 2005; Chui et al., 2016). Yet, the coral diversity in Hong Kong is relatively high with at least 84 scleractinian coral species

* Corresponding author.
E-mail address: put-ang@cuhk.edu.hk (P. Ang).

http://dx.doi.org/10.1016/j.marpolbul.2017.06.005
Received 30 September 2016; Received in revised form 27 May 2017; Accepted 2 June 2017
0025-326X/

recorded (Ang et al., 2003). Previous researches have focused on the current state of Hong Kong coral communities (e.g. Ang et al., 2005; Tam and Ang, 2008; Yeung et al., 2014) showing that under the influence of the freshwater discharge from Pearl River to the west, large region of Hong Kong water, especially the western part, is relatively turbid and low in salinity, hence is not suitable for coral growth. Therefore, coral communities are mainly concentrated in the eastern and northeastern areas of Hong Kong where a true oceanic condition exists and the influence of the Pearl River runoff is least. It is here where high coral coverage of over 60% can be found, for example, in Tung Ping Chau Marine Park (TPCMP). However, having high coral abundance and cover in a community does not necessary imply the existence of an efficient recruitment pattern that maintains the community (Hughes et al., 1999). The early life stages of many animals are often more susceptible to stresses than their adult counterparts (Cossins and Bowler, 1987). These stages may be the bottleneck for the success of these species in the future. It is therefore important to examine the coral recruitment pattern in such a community in order to understand processes involved in its maintenance.

Until recently, coral recruitment dynamics in marginal coral communities worldwide have largely been understudied (Harriott and Banks, 2002; Hoey et al., 2011; Ho and Dai, 2014). Therefore, this study aimed at evaluating the detailed in situ coral recruitment pattern in Hong Kong, a subtropical marginal coral community, using both in situ fluorescence census technique and ex situ microscopic examination of settlement tiles. Recruitment patterns in two sites within TPCMP over a period of three years were examined. Two aspects of coral recruitment pattern were addressed: 1) Spatial and temporal patterns in settlement and post-settlement survival of natural coral recruits on settlement tiles; 2) Post-settlement survival of coral recruits using artificially seeded recruits of *Platygyra acuta*, the most dominant coral in TPCMP. Detailed documentation of the recruitment patterns in Hong Kong could be crucial in understanding processes critical to sustain the resilience of these marginal coral communities.

2. Materials and methods

2.1. Study sites

Tung Ping Chau (22°32′N, 114°25′E) is an island located in the north-eastern side of New Territories, Hong Kong Special Administrative Region, China. The two coral core areas within TPCMP, A Ye Wan (AYW) and A Ma Wan (AMW), are located along the east northeastern side of the island (Fig. 1). Corals are most abundant in depths that ranged from − 1 m CD (Chart Datum) to − 4 m CD (Tam and Ang, 2008). Zonation pattern of coral communities was observed in both sites, with shallow water zone, 0 to − 1 m CD, having significantly different coral communities than deeper water zone (> − 1 m CD). Substratum for both sites, from 0 to − 1 m CD, is mainly composed of rocks; whereas from − 1 m to − 3 m CD, it is mainly sandy to silty (Tam and Ang, 2008).

2.2. Coral recruitment on settlement tiles

To quantify the settlement and post-settlement survival rate of natural coral recruits, monitoring studies on coral recruitment patterns in TPCMP was carried out from May 2009 to July 2012. A total of 24 experimental set-ups for recruitment monitoring were established, with six set-ups each at two depth ranges (− 0.5 to − 1.5 m CD and − 2.5 to − 3.5 m CD) in both AYW and AMW. Terracotta tiles (15 × 15 cm) were used as settlement plate. Tiles were conditioned in the sites for six weeks prior to the commencement of the experiment to allow the development of biofilm and crustose coralline algae (CCA). Pre-conditioning for six weeks has been shown to be sufficient to attract coral settlement in the laboratory (Omori and Iwao, 2014). In each setup, three tile pairs were mounted at 45° angle (Glassom et al., 2004; Mangubhai et al., 2007), on stainless steel mesh bolted on concrete blocks. Each tile pair has one terracotta tile with the rough surface facing up (the face up tile) and one facing down (the face down tile). Of the three tile pairs in each set-up, one was for conditioning, one was for short-term (with seasonal replacement) and one for long-term (to be replaced once a year) monitoring of coral recruitment. Six of these set-ups were placed in each depth range in each site, each at 5 m interval from one another. Each set-up was haphazardly positioned in different orientations.

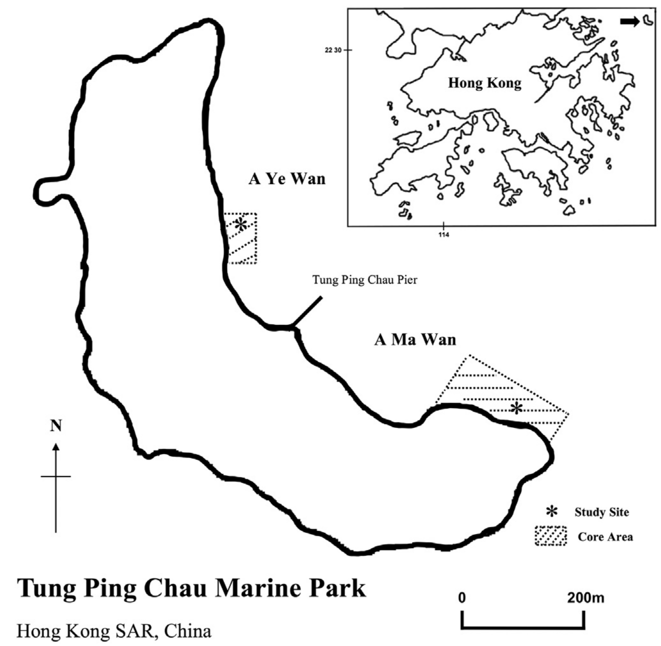

Fig. 1. Map of Tung Ping Chau Marine Park (TPCMP) showing the location of the study sites A Ye Wan (AYW) and A Ma Wan (AMW). The location of the marine park in Hong Kong is indicated by the arrow in the insert map.

Tiles removed were brought back to the laboratory and examined under the dissecting microscope for the presence of coral recruits, as well as for an estimate of the cover of other fouling organisms. Each coral recruit found was photographed with a Canon® G10 camera under the dissecting microscope for later identification. Since the morphology was not sufficiently developed to allow high taxonomic resolution during early stage of development, only two families (Acroporidae, Poritidae) can be distinguished with confidence (Babcock et al., 2003). All other coral recruits were categorized as others. Tiles with recruits in the first year of study were returned to the sites for weekly/bi-weekly post-settlement survival monitoring thereafter until they died or disappeared from the tile.

Other than examination of the settlement tiles in the laboratory, fluorescence census technique was used for weekly/bi-weekly monitoring of recruits on all the tiles in situ until they were retrieved from sites. Censuses were conducted during the day. The blinking mode of the flash light (FL-1 FLASH Light™, NightSea LLC, California, USA) with an internal blue exciter filter, together with a yellow barrier filter placed over the diver's mask, were used to facilitate the detection of new recruit on the tile. Each coral recruit was mapped and photographed with a Canon® G10 camera with underwater housing. Size (diameter and surface area), number of polyps present and condition (i.e. undamaged, damaged, overgrown by other organisms) of each recruit were recorded.

2.3. Post-settlement mortality of artificially seeded coral recruits of *Platygyra acuta*

The gamete collection and culturing procedures followed those