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# The role of differential survival patterns in shaping coral communities on neighboring artificial and natural reefs

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ABSTRACT

Understanding the processes that shape artificial reef (AR) communities is critical if these are to be implemented for reef restoration or enhancement purposes. A study of the post-recruitment survival of coral colonies transplanted onto a 19-year-old AR and its adjacent natural reef (NR) was carried out at Eilat (Red Sea) in order to test the hypothesis that differences in benthic communities between the two reefs are derived from differential survival processes. Transplanted miniature coral colonies were monitored in situ on both reef types. It was found that the survival of those of the soft coral Dendronephthya hemprichi on the AR was nearly double that of those transplanted onto the NR. Similarly, survival of nubbins of the stony coral Pocillopora damicornis on the AR was over three-fold greater than on the NR. We suggest that the observed differential survival resulted from the unique suites of environmental conditions at the two habitats, mainly in terms of sedimentation load and current velocities, yet not from differences in substratum type (artificial vs. natural). The results demonstrate the role played by survival processes in shaping coral assemblages on ARs and NRs, and indicate that post-recruitment survival must be considered when designing ARs for restoration or enhancement purposes.



## 1. Introduction

In light of the ongoing deterioration of coral reefs worldwide (Wilkinson, 2000; Birkeland, 2004), several attempts have been made to examine the potential use of artificial reefs (ARs) for restoring and enhancing degraded marine environments (Aseltine-Neilson et al., 1999; Clark and Edwards, 1999; Lam, 2000; Miller, 2002; Lirman and Miller, 2003). However, whether ARs possess the ability to sustain benthic communities similar to those of natural reefs (NRs) is still a controversial issue (Aseltine-Neilson et al., 1999; Svane and Petersen, 2001; Perkol-Finkel et al., 2005; Seaman, 2007). In order to test the ability of ARs to mimic the surrounding natural communities, and thus to offer a potential tool for restoration purposes, a common approach has been to compare the community structure of the two reef types. Most such studies have compared relatively early stages of AR community development to those of adjacent NRs, and found significant differences in coral species composition, richness and cover between them (Chou and Lim, 1986; Wilhelmsson et al., 1998; Perkol-Finkel and Benayahu, 2005). However, recent studies comparing ARs >100-years-old to nearby NRs have revealed a high resemblance between the two reef types, depending on the similarity of their substratum orientation and complexity (Perkol-Finkel et al., 2005, 2006a). A more direct but far less common approach to measuring the ability of ARs to resemble NR communities, is to compare between recruitment patterns of corals and other benthic invertebrates on settlement plates attached onto the two reef types (Perkol-Finkel and Benayahu, 2007). Nonetheless, recruitment should not be considered as the only factor differentiating between coral communities on ARs and NRs, since post-recruitment survival may also contribute to shaping these communities.

A major weakness of most studies dealing with population dynamics of benthic communities is that of a lack of consideration of the survival of recruits (Caley et al., 1996). Post-recruitment survival of juvenile corals is affected by factors such as orientation and complexity of the substratum, current regime and sedimentation load, predation level, grazing pressure and competition with algae and fouling organisms (e.g., Harrison and Wallace, 1990; Babcock and Mundy, 1996; Mundy and Babcock, 2000). Coral species can exhibit varying degrees of tolerance to such factors, which might affect the community structure of the reef. For example, Fabricius et al. (2003) found increased mortality of coral recruits due to high sedimentation rate at the Great Barrier Reef (GBR), which consequently impeded reef recovery. Mundy and Babcock (2000) found that survival of stony corals at the GBR was dependent on the spatial orientation of the substratum (top *vs.* bottom facing of settlement plates). Similarly, Oren and Benayahu (1997) indicated a combined effect of depth and position of the substratum on the survival of some Red Sea stony and soft corals. Since survival of corals is highly dependent on the

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structural features of the substratum, it is likely that survival patterns may also vary between ARs and NRs.

One of the problems in studying post-recruitment survival is that patterns of coral mortality are much more difficult to measure than recruitment (Caley et al., 1996). Since examining the survival of small-sized coral recruits on natural substrata *in situ* is virtually impossible (but see: Baird et al., 2006), a common approach is to monitor their occurrence on settlement plates underwater, either by direct census or by means of photography (Knott et al., 2004; Bramanti et al., 2005; Field et al., 2007). These procedures are time consuming, and may be less accurate than examination of survival under a microscope (e.g., Bramanti et al., 2005). In order to conduct such a study the plates need to be repeatedly retrieved from the sea and then returned back at intervals (Perkol, 2001). This procedure is lengthy and can lead to inaccuracies due to physical damage or mortality of recruits (Turner and Todd, 1993; S P-F personal observations). An alternative approach is to examine the survival of small-sized corals derived from reared planulae larvae, nubbins or cuttings transplanted to the reef (e.g., Davies, 1995; Lindahl, 2003; Shafir et al., 2006). Cultivation of miniature colonies for such purposes has been successfully performed for various stony coral species, but less so for soft corals (Oren and Benayahu, 1997; Barneah, 1999; Barneah et al., 2002).

Several studies characterizing coral communities on various ARs and NRs in the Red Sea demonstrated distinct differences in species composition between the two reef types (Perkol-Finkel and Benayahu, 2004, 2005; Perkol-Finkel et al., 2005, 2006a). In order to better understand the ability of ARs to mimic NRs and thus serve as a tool for reef restoration and enhancement, we conducted the present study whose main goal was to investigate the role played by differential survival patterns in shaping coral communities on neighboring ARs and NRs. The two reefs were chosen for the study since they had different coral communities, despite of their close proximity. We tested the hypothesis that differences in coral communities between the two reefs are derived from differential survival processes related to the set of environmental features offered by the two reefs as a result of their structure. This hypothesis was tested against an alternative hypothesis recently examined by us, which suggested that differential recruitment patterns generate different benthic assemblages on adjacent ARs and NRs (Perkol-Finkel and Benayahu, 2007). The latter study revealed differential recruitment patterns on plates placed on the two reef types i.e., soft corals recruited mainly onto the studied ARs, while stony corals recruited mostly to the NRs. In order to investigate *in situ* survival processes on the two reefs, the survival of transplanted miniature colonies was examined on a neighboring AR and NR in Eilat (northern tip of the Gulf of Aqaba, Israel). For this purpose, cuttings of the soft coral *Dendronephthya hemprichi* and nubbins of the stony coral *Pocillopora damicornis* were used. These were selected since they were the most dominant residents at the site (Perkol-Finkel and Benayahu, 2004), and also exhibited differential recruitment between the two reef types; i.e., *D. hemprichi* recruited in greater numbers onto the studied AR in comparison to the NR, while recruitment of species of the family Pocilloporidae showed an opposite pattern (Perkol-Finkel and Benayahu, 2007). In order to reveal the factors responsible for the observed differences in the abundance of these species at the site, the survival of the miniature colonies was examined in relation to reef type (AR *vs.* NR), orientation (vertical *vs.* horizontal), and facing (outer *vs.* inner) as well as in relation to local current velocity and sedimentation load. Understanding the factors that determine the survival patterns at the two reef types is critical when considering the application of ARs for the restoration and enhancement of degraded marine environments in general, and of corals reefs in particular.

## 2. Materials and methods

### 2.1. Study site and formation of miniature colonies

The study was conducted at the Dolphin Reef, a recreational facility with dolphins kept in a net-fenced area, located at Eilat, northern Red Sea, Gulf of Aqaba, Israel (Fig. 1). The Dolphin-AR is a vertical net made of flexible PVC, hanging from the sea surface down to the seabed at a depth of 15 m. The net had been submerged for 19 years at the time of the study (February-March 2004). The Dolphin-NR is nearly horizontal, consisting of scattered knolls located 4–50 m around the net, at 14–18 m depth. The study was conducted on the outer perimeter area of the Dolphin Reef, so that the experimental array was unaffected by the recreational activities taking place at the site. The benthic communities of these two reefs had been extensively studied (Perkol-Finkel and Benayahu, 2004, 2007) and were chosen for the study since they have distinct coral communities despite of the fact that they are located one next to the other. Thus, it is anticipated that they are subjected to similar current regime and larvae supply.

In order to compare coral survival between the AR and its adjacent NR, we prepared mass numbers of miniature colonies (ca. 0.5 cm in diameter) of the soft coral *D. hemprichi* (family Nephtheidae) and of the stony coral *P. damicornis* (family Pocilloporidae). These species were chosen for the experiment following the results of a recruitment study that we had conducted recently at the site, indicating that they comprised the majority of the recruits onto settlement plates at the site (Perkol-Finkel and Benayahu, 2007). Using two methods, we placed both plates with artificially-generated miniature colonies and others with natural recruits of *D. hemprichi* in order to compare their applicability for ecological studies. In the first method, five large *D. hemprichi* colonies (>20 cm in length) located at ca. 12 m depth were removed from the oil jetties at Eilat (see Dahan and Benayahu, 1997a,b) and brought to the Interuniversity Institute for Marine Science (IUI) in Eilat, where they were kept for 24 h in running seawater for acclimatization. Fragments comprising 5-10 polyps were cut from the five colonies using fine stainless steel scissors and then scattered randomly on small PVC plates (10 × 5 × 0.3 cm) at the bottom of 500 l outdoor containers with running seawater, and kept for one

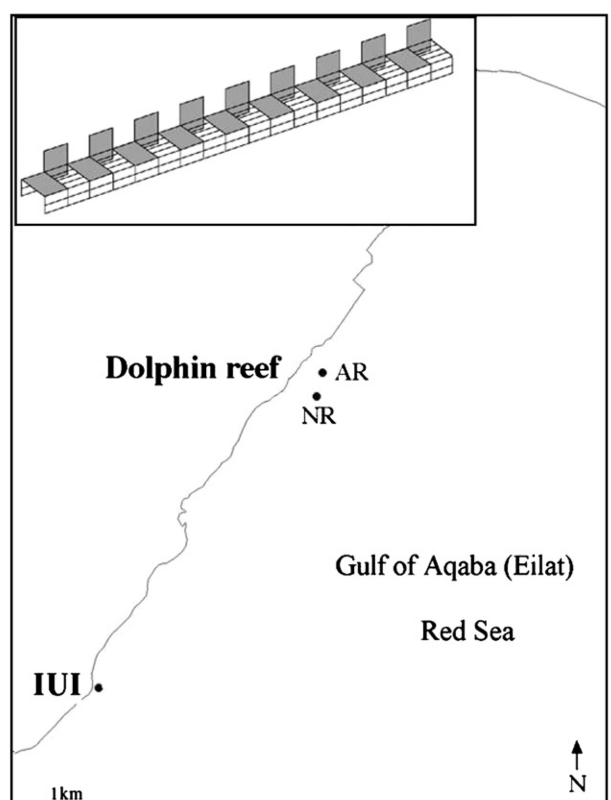


**Fig. 1.** Map of the study site. Inset: Schematic illustration of the experimental rack.