Journal of Experimental Marine Biology and Ecology 340 (2007) 25–39

Journal of EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY

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Differential recruitment of benthic communities on neighboring artificial and natural reefs

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Received 10 June 2006; received in revised form 15 July 2006; accepted 8 August 2006

Abstract

Shedding light on the ability of benthic artificial reef (AR) communities to resemble those of a natural reef (NR) is of great importance if we are to harness ARs as tools for rehabilitation and restoration of degraded marine habitats. Studying recruitment processes to experimental settlement plates attached to ARs and NRs reveal the factors that shape community structure at the two reef types, and determine the ability of an AR to support communities similar to those found in adjacent natural habitats. In this study, conducted in Eilat (Red Sea), we used settlement plates to test the hypothesis that differences in benthic communities between ARs and NRs are derived from differential recruitment processes. A monitoring period of 18 months revealed great differences in the recruitment of corals and other benthic communities between the studied ARs and adjacent NRs. The ARs were either made of PVC or metal and 10–17 years old when the study commenced. The recruitment of soft corals reflected the species assemblage found in the area, consisting mainly of the family Nephtheidae and Xeniidae, species, while that of stony corals was mostly determined by the life history traits of the recruited taxa, e.g., the opportunistic nature of the family Pocilloporidae. Benthic organisms, mainly filter feeders like bryozoans, bivalves, sponges and tunicates, were more abundant at the ARs than at the NRs, mainly on the underside of the plates. We suggest that this differential recruitment resulted from a synergistic effect of abiotic and biotic factors, including current regime, sedimentation load and larval settlement preferences, which subsequently differentiated the composition of the benthic communities at the ARs and NRs. Thus, in order to construct an AR for restoration purposes, it must offer similar structural features to those found in the natural surrounding, leading to recruitment of local taxa. However, if the AR and NR will differ structurally, the composition of recruits will also differ and eventually the communities at the two reef types will become distinct, hereby increasing the species diversity in the area.

Keywords: Artificial reefs; Coral reefs; Current velocity; Recruitment; Red Sea

1. Introduction

Artificial reefs (ARs) have been suggested as a tool for rehabilitation and restoration of degraded natural reefs (NRs) (Bohnsack and Sutherland, 1985; Seaman and Jensen, 2000; Seaman, 2002). There are still doubts, however, regarding their performance and their possible effects on the natural surroundings (Svane and Petersen, 2001; Seaman, 2002). A key issue of the ongoing debate is the attraction vs. production hypothesis, i.e., whether ARs merely attract resources away from the natural surrounding, thus depleting them, or whether are they

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doi:10.1016/j.jembe.2006.08.008

capable of producing a biomass that would otherwise have been lost without the AR (Carr and Hixon, 1997; Grossman et al., 1997; Svane and Petersen, 2001). Most studies addressing this question have dealt with fish or motile invertebrates that are capable of migrating as post-larvae or adults from the NR to an adjacent AR, while this aspect has not been examined in relation to benthic communities in general and to coral reefs in particular (Svane and Petersen, 2001). Determining whether ARs merely divert propagules from NRs, or, rather, attract those that would otherwise be lost, is of great ecological importance. However, providing an appropriate answer is hindered by the difficulty of following larval movements in the ocean. Large-scale dispersal patterns of planktonic larvae can be evaluated using satellite-tracked drifters and simulated currents (Lugo-Fernández et al., 2001). Small-scale dispersal of marine organisms has been traditionally studied either by direct observation of their larvae, or by recording their settlement and recruitment (Mariani, 2003); but can be performed only on visible, relatively large larvae, for example certain tunicates (Bingham and Young, 1991). Coral planulae are by nature too small for such observations (e.g., Harrison and Wallace, 1990; Ben-David-Zaslow and Benayahu, 1998; Harii and Kayanne, 2002).

Settlement plates have been widely applied in ecological studies in order to characterize and quantify settlement and recruitment of benthic organisms including corals (e.g., Mundy and Babcock, 2000; Thomason et al., 2002; Glassom et al., 2004; Perkol-Finkel et al., 2006). It has been demonstrated that these processes are affected by abiotic factors related to the structural features of the substratum and the environment, and by biotic factors related to the inhabiting organisms (Table 1). Settlement plates have been extensively used for examining spatial and temporal variations in coral settlement and recruitment to NRs (e.g., Carleton and Sammarco, 1987; Fisk and Harriott, 1990; Mundy and Babcock, 2000; Glassom et al., 2004). However, only a few studies have implemented this approach for investigating these processes on ARs, particularly those that are beyond their initial successional stages (see Mariani, 2003).

The use of settlement plates for examining recruitment of benthic organisms on ARs in comparison to neighboring NRs may help to shed light on the factors that determine community structure at the two reef types. This in turn may enable us to resolve questions regarding the attraction vs. production debate (see above), and whether ARs can mimic NR communities and thus help restore them. Interestingly, most studies have revealed substantial differences in the species composition and abundance of benthic communities found on the two reef types (e.g., Wendt et al., 1989; Wilhelmsson et al., 1998; Perkol-Finkel and Benayahu, 2004). Clark and Edwards (1999) revealed in the Maldives different species assemblage on a 3.5-year-old AR compared to a control NR; i.e., recruitment on the AR consisted mainly of branching corals while slow-growing massive species were less abundant compared to the typical reef-flat communities in the area. Recently, Perkol-Finkel et al. (2005) demonstrated that community differences between ARs and NRs in the Red Sea might still prevail even after >100 years following the AR deployment, depending on the structural differences between the two reef types that can affect both species composition and percentage coral cover. Community differences between the two reef types might be a result of differential recruitment at early successional stages, or alternatively from differential survivorship of the recruits with time (Harrison and Wallace, 1990). Thus, it is suggested here that comparing settlement and recruitment occurring on ARs and NRs is essential in order to determine the grounds for an eventual degree of similarity between the communities of the two reef types.

Table 1
Abiotic and biotic factors affecting settlement and recruitment of benthic organisms

Abiotic
Orientation of the substratum (Harriott and Fisk, 1988; Oren and Benayahu, 1997).
Texture (Carleton and Sammarco, 1987; Thomason et al., 2002).
Current regime (Abelson and Denny, 1997; Eckman and Duggins, 1998).
Sediment load (Birrell et al., 2005).
Light attenuation and depth (Mundy and Babcock, 1998)
Water quality and nutrient levels (e.g., Tsemel et al., 2006 and references therein).
Biotic
Reproduction mode and life history traits (Benayahu and Loya, 1984; 1987).
Chemical attraction/inhibition (Harrison and Wallace, 1990; Morse and Morse, 1996).
Post-settlement predation by fish (Osman and Whitlatch, 2004).
Seasonal reproduction and larval availability (Richmond, 1997; Reyes and Yap, 2001).

Recent studies on benthic communities of ARs and their adjacent NRs at Eilat, Israel (Gulf of Eilat, northern Red Sea) revealed distinct differences between the two (Perkol-Finkel and Benayahu, 2004, 2005), e.g., stony corals were the major component in the NRs, while soft corals, mainly of the family Nephtheidae, dominated the ARs. These differences were evident in the species count, percentage living cover and cover diversity. These community differences were related to the vertical orientation of the ARs as opposed to the horizontal orientation of the NRs, which