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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

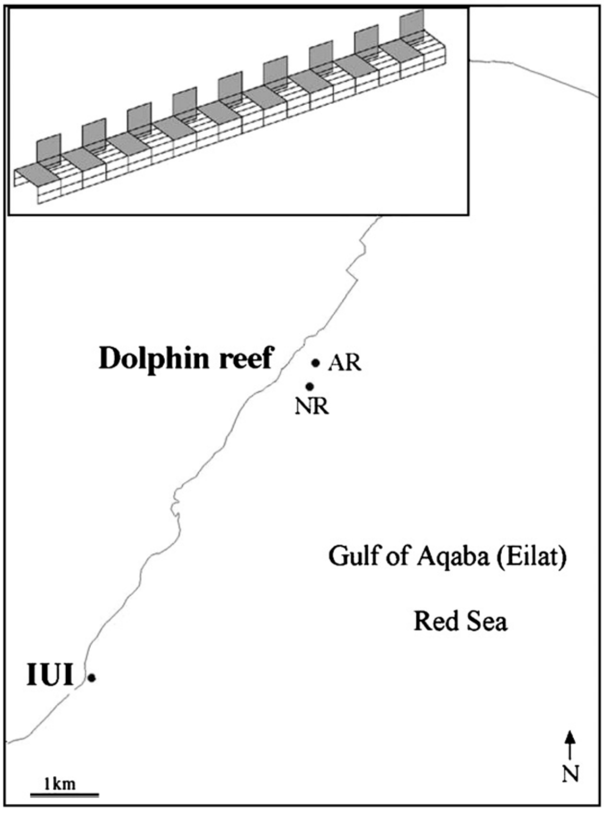

Fig. 1. Map of the study site. Inset: Schematic illustration of the experimental rack.

week until attachment. By using several donor colonies and randomly mixing the fragment used for the experiments, we avoided possible effects of reduced genetic heterogeneity among the fragments (see: Epstein et al., 2001). The second method followed Dahan and Benayahu (1997b) and Oren and Benayahu (1997), taking advantage of the natural fragmentation occurring in *D. hemprichi*. For this purpose larger PVC plates (20×11.5×0.5 cm) were placed at 12 m depth adjacent to numerous large colonies at the Dolphin-AR for a period of one month for natural colonization. Subsequently, the plates were retrieved and the number of *D. hemprichi* recruits per plate was counted at the IUI. Nubbins of *P. damicornis* comprising 10-15 polyps were obtained following the methodology described by Shafir et al. (2001). The nubbins, chosen randomly from a pool of fragments prepared from five donor colonies, were glued (using super glue-5 Loctite, France) in batches of four per PVC plate (10×5×0.3 cm), and placed for a one-week acclimatization period in the outdoor containers.

2.2. Experimental layout

PVC plates with the artificially-generated miniature colonies of *D. hemprichi* and plates with the nubbins of *P. damicornis* were fastened with plastic clips to 400×20×10 cm galvanized metal racks, and attached to both the AR and NR at a depth of 14 m, one rack per examined species at each reef type (Fig. 1, see also Perkol-Finkel and Benayahu, 2007). The plates were set on the racks at two orientations: vertical and horizontal; for each orientation plates were attached both to the outer (=exposed) and the inner (=oriented towards the reef substratum) faces of the rack. Four plates, each with 6-10 *D. hemprichi* miniature colonies, and five plates, each with 4 nubbins of *P. damicornis*, were placed at each position. The plates were deployed on February 2004, and were checked on days 1, 2, 4, 6, 13, 20 and 34 post-placement. This relatively short period of monitoring survival was determined, since preliminary observations had indicated a mortality of >50% of transplanted colonies as early as 2 weeks post-transplantation. On each monitoring date the colonies of both species were counted. A few days prior to the last monitoring date a severe southerly storm occurred and damaged the experimental setup by shifting plates from their initial position, causing extensive colony mortality on day 34 post-submersion. In addition to the small plates with the artificially-generated *D. hemprichi* miniature colonies, one larger PVC plate with naturally-recruited *D. hemprichi* corals was placed at each of the four examined positions (see above). The number of surviving corals on these plates was recorded on day 30 post placement.

2.3. Current and sedimentation measurements

In order to measure the current velocity at the AR and NR, "clod cards" (gypsum plaster cubes attached to PVC plates, see Doty, 1971; Perkol-Finkel et al., 2006b) were used. This method converts loss of plaster from molds after exposure to water motion to mass transfer rate of water with time. Cone-shaped clods were used, with a dry weight of 25±0.5 g (mean±range) after 48 h at 60 °C, glued with marine cement to 5×10×0.3 cm PVC plates. Each clod with its attached plate was weighed prior to placement in the sea. On 28 February 2004 five clod cards were attached to the experimental racks at the AR and NR using plastic clips, at both orientations and facings (see above). After 24 h of exposure the clods were retrieved, dried for 48 h at 60 °C and reweighed. Weight loss was calculated as percentage of plaster lost from the initial value. Using a calibration curve (Perkol-Finkel et al., 2006b) mass transfer rate values were transformed to current velocities at each reef type.

Sedimentation load was measured using sediment traps made of PVC pipes (30 cm long, diameter 3.6 cm) deployed at the AR and NR on the experimental racks (ca. 50 cm from the seabed at the former and 20 at the latter). Five traps were placed at each reef type for a month of exposure (26 February to 26 March 2004). Traps were then sealed underwater and transferred to the IUI, where their content was filtered onto a Whatman, 47 mm GF/C glass microfiber filter (pre-burnt for 6 h at 450 °C in a furnace to discard organic compounds) and weighed. Filtered material was washed twice with distilled water to remove salt from the samples, and the filters with the sediment were then burnt for 6 h at 450 °C. Subtraction of the initial weight of the filter from the final weighing provided the amount of sediment in the trap (see Shemla, 2001). Results are presented as amount of accumulated sediment in $g \times d^{-1}$ (±SD).

2.4. Data analysis

Differences between the AR and NR in coral survival on the plates were tested by repeated-measures ANOVA, with the factors being: reef type (AR, NR), orientation (horizontal, vertical), plate face (outer, inner) and time since deployment (day 1, 2, 4, 6, 13, 20 and 34). This test was applied in full for the *D. hemprichi* data, but only for the last four dates for the *P. damicornis* data, since up to then there had been no mortality in all treatments, and the test could not be performed with zero variance. Differences between the AR and NR in survival of the naturally-recruited *D. hemprichi* corals were tested by one-way ANOVA. In order to meet ANOVA assumptions, the percentage survival values were square root transformed, followed by an arcsine transformation. Values are presented with 95% confidence intervals (CI). Differences in weight loss of clod cards between the AR and NR were tested by Factorial ANOVA, with the same factors used for the survival, apart from the time factor. Percentage weight loss values were square root transformed. Differences in sediment load between the AR and NR were examined by *t*-Test.

3. Results

3.1. Formation of miniature colonies

The artificially-generated cuttings of *D. hemprichi* developed root-like processes (see Barneah et al., 2002) within 3-4 days after removal from the parent colonies, and by day 5 they were firmly attached to the PVC plates (Fig. 2). The attachment process followed a similar cascade of events previously described for naturally-occurring fragmentation (Dahan and Benayahu, 1997b). Ca. 70% of the fragments survived throughout the one week acclimatization period, yielding a density of 0.59±0.24 cuttings per cm^2 (mean±SD, n=40) with a maximum of 1 cutting per cm^2, i.e., the procedure yielded plates (10×5×0.3 cm) colonized at an average density of 9±3 (mean±SD, n=40) miniature colonies of *D. hemprichi* per plate. All colonies of *P. damicornis* survived the acclimatization period and thus all plates had four miniature colonies.

3.2. Survival of colonies

There were distinct differences between the AR and the NR in the survival of miniature colonies of *D. hemprichi*, already noted on day 4 of the experiment (Fig. 2a; Table 1). These differences increased over time according to Sheffe tests (data not shown). On day 20 of the experiment 73% of the colonies still survived at the AR while only 44.2% survived at the NR. Time affected survival at the two reef types differently (Table 1, repeated measures ANOVA, interaction term, $P<0.0001$). No significant differences in the survival of *D. hemprichi* were found between the vertical and horizontal plates or between the outer and inner faces of the plates (Table 1, repeated measures ANOVA). However, an interaction appeared between the orientation of the plate and its facing for the AR during the first six days of the experiment, as the

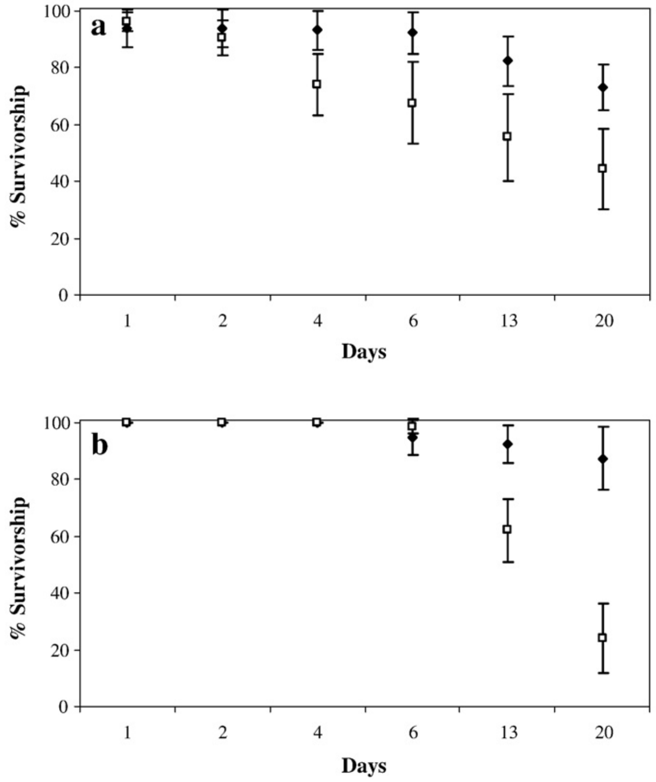

Fig. 2. Average percentage survival of miniature colonies (±CI 95%) over time at the artificial (black) and natural (white) reefs. a. *Dendronephthya hemprichi*, b. *Pocillopora damicornis*. n=16.

survival on horizontal plates was greater on the inner face of the plate, while on the vertical plates an opposite pattern was noted (Fig. 3; Table 1). From day 13 onwards, no difference in survival appeared at the AR between orientation (vertical *vs*. horizontal) and the face of the plates (Table 1, repeated measures ANOVA). At the NR, starting from day 13, survival was greater on the inner face of horizontal plates than on the outer one, while no such difference appeared for the vertical plates. Naturally-recruited *D. hemprichi* colonies showed a similar but more striking result compared to the artificially-generated ones, as 88% of them survived at the AR, but only 5% at the NR (1-way ANOVA, p<0.0001). However, in this case no significant difference was recorded in the survival of miniature colonies between orientation and plate facing on both reef types.

All colonies of *P. damicornis* survived the first week of the experiment, but on days 13 and 20 a significant decrease in their survival at the NR was recorded (Fig. 2b). A significant difference appeared in the survival of colonies at the two reef types by day 20 of the experiment, as >87% of the colonies at the AR still survived, compared with only 24% at the NR (Table 1, repeated measures ANOVA, interaction term, P<0.0001). *P. damicornis* survived equally on both the vertical and the horizontal plates, and similarly on both faces of the plates (Table 1). Only a weak interaction appeared between time and plate facing, with survival on the inner face being slightly higher than on the outer one after day 13 (Table 1, repeated measures ANOVA, interaction term, P<0.05).

Table 1
Repeated measures ANOVA for survival of miniature colonies of *Dendronephthya hemprichi* and *Pocillopora damicornis*

Factor	*D. hemprichi*			*P. damicornis*		
	df	F	P	*df*	F	P
Reef type (AR,NR)	1	15.154	***	1	27.3681	****
Orientation (H,V)	1	0.298	n.s.	1	0.0013	n.s.
Face (O,I)	1	1.598	n.s.	1	2.3675	n.s.
Type×Orientation	1	0.782	n.s.	1	3.5434	n.s.
Type×Face	1	3.956	n.s.	1	0.0105	n.s.
Orientation×Face	1	6.012	*	1	0.3358	n.s.
Type×Orientation×Face	1	0.014	n.s.	1	1.6051	n.s.
Time	6	130.783	****	3	324.6314	****
Time×Type	6	7.007	****	3	43.7591	****
Time×Orientation	6	0.280	n.s.	3	0.8018	n.s.
Time×Face	6	0.337	n.s.	3	3.4766	*
Time×Type×Orientation	6	1.226	n.s.	3	1.7169	n.s.
Time×Type×Face	6	0.745	n.s.	3	1.5329	n.s.
Time×Orient.×Face	6	0.347	n.s.	3	0.3835	n.s.
Time×Type×Orient.×Face	6	2.942	**	3	1.9115	n.s.

Artificial reef=AR, Natural reef=NR. Horizontal=H, Vertical=V, Outer face of the settlement plate=O, Inner face=I. Probability of significance: **** P<0.0001, *** P<0.001, ** P<0.01, * P<0.05, n.s. P>0.05.

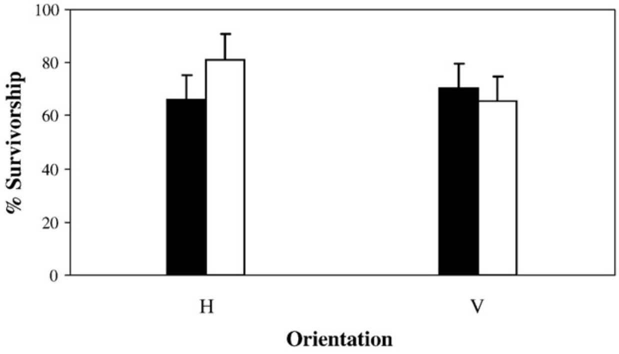

Fig. 3. Average percentage survival of miniature colonies of *Dendronephthya hemprichi* (+CI 95%) at horizontal (H) and vertical (V) orientations, for the outer (black) plate face and inner (white) face of the plates. n=8.

3.3. Current and sedimentation measurements

Average weight loss of clod cards and the corresponding current speed values as estimated using a calibration curve (Perkol-Finkel et al., 2006b) are presented in Table 2. Average current speed at the AR was significantly greater than on the NR (2.2 and 1.7 $\mathrm{cm}\times\mathrm{s}^{-1}$ respectively). Weight loss of clods positioned on the outer and inner faces of the plates did not differ; however, at the AR values on the outer face were slightly greater than on the inner ones, while an opposite pattern appeared at the NR (Factorial ANOVA, interaction term, P<0.01). Nonetheless, differences in weight loss due to the orientation of the plates were highly significant (Table 2). Average current speed on the vertical plates was much greater than on the horizontal ones (2.3 *vs*. 1.6 $\mathrm{cm\ s}^{-1}$). Sediment load at the AR was

Table 2
Average weight loss (%), current velocity ($\mathrm{cm\ sec}^{-1}$) and ANOVA results of weight loss of clod cards at the Dolphin Reef

Factor	Weight loss	Current velocity	*df*	F	P
Type AR	16.62	2.2	1	11.05	**
Type NR	14.83	1.7			
Face O	15.48	1.9	1	1.00	n.s.
Face I	15.97	2.1			
Orientation H	14.61	1.6	1	16.11	***
Orientation V	16.85	2.3			
Type×Face			1	8.54	**

Artificial reef=AR, Natural reef=NR. Vertical=V, Horizontal=H, Outer face of the settlement plate=O, Inner face=I. Probability of significance: **** P<0.0001, *** P<0.001, ** P<0.01, * P<0.05, n.s. P>0.05.

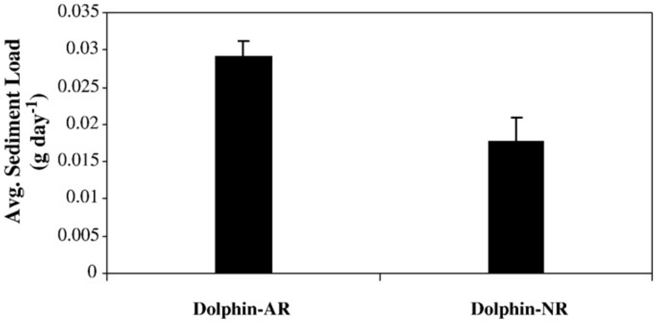

Fig. 4. Average sediment load (+SD) at the artificial reef (AR) and natural reef (NR). n = 5. Probability of significance: $P<0.001$.

significantly greater than at the NR (Fig. 4: 0.029 *vs*. 0.017 $g \times d^{-1}$ respectively, *t*-Test, $P<0.001$).

4. Discussion

The results of the current study support our working hypothesis and thus demonstrate a differential survival of miniature coral colonies between the studied reefs. The findings correspond to observed differences in the resident coral assemblages and demonstrate the role of post-recruitment survival in shaping the community structure on ARs and NRs.

Recent observations at the Dolphin reef AR and NR revealed an inconsistency between the resident coral assemblages at the site and the recruitment patterns recorded there. *D. hemprichi* accounted for almost 50% of the soft coral cover at the Dolphin-AR, yet this species was completely absent from the adjacent NR; and, similarly, *P. damicornis* accounted for 43% of the stony coral cover there but was far less common on the Dolphin-NR (Perkol-Finkel and Benayahu, 2004). Nonetheless, while the recruitment of *D. hemprichi* to the AR was indeed greater in comparison to the adjacent NR, *P. damicornis* predominantly recruited to the Dolphin-NR (Perkol-Finkel and Benayahu, 2007). The present results explain this inconsistency, as the survival of miniature colonies of both species was higher at the Dolphin-AR than at the NR (Fig. 2). Thus, despite the high recruitment rate of *P. damicornis* onto the Dolphin-NR, low post-recruitment survival reduces its abundance in the natural resident assemblage. The species' high abundance on ARs compared to nearby NRs has also been found at other northern Red Sea sites (Perkol-Finkel and Benayahu, 2005; Perkol-Finkel et al., 2006a). It is suggested that the opportunistic nature of *P. damicornis*, (Loya, 1976; Schuhmacher, 1977; Clark and Edwards, 1999; Loh et al., 2006) may have led to its high abundance on the AR. The low survival of *P. damicornis* at the Dolphin-NR is surprising since the species is considered to have strong competitive capabilities in Red Sea reefs (Abelson and Loya, 1999). A possible reason for the increased mortality of *P. damicornis* is that of the low water circulation at the Dolphin-NR (Table 2). Although Harii and Kayanne (2002) showed that larvae of *P. damicornis* are able to settle on a wide range of current velocities, it would seem that their *in situ* survival diminishes in low current habitats. These findings present a unique example of the critical role played by differential post-recruitment survival in shaping species composition when examining population dynamics of coral communities on artificial and natural habitats with different structural features.

Similarly to post-recruitment survival of juvenile corals, the survival of miniature coral colonies is strongly affected by environmental factors such as orientation of the substratum, current regime and sedimentation load (Harrison and Wallace, 1990; Babcock and Mundy, 1996; Mundy and Babcock, 2000). Such factors can greatly differ between ARs and NRs, depending on their structural features, regardless of the nature of the substratum (i.e., artificial or natural). The vertical Dolphin-AR offers a different suite of environmental conditions than the moderate slope of the surrounding NR. This may explain the high survival of miniature colonies of *D. hemprichi* at the Dolphin-AR (>70%), in comparison to the substantial mortality noted at the NR (>50%) as early as 20 days after transplantation (Fig. 2a). Other studies on Red Sea reefs have noted the dominance of this species on vertical NR formations, or inclined AR structures (e.g., Benayahu, 1985; Fabricius et al., 1995; Perkol-Finkel and Benayahu, 2005; Perkol-Finkel et al., 2006a). *D. hemprichi* is commonly found on inclined surfaces that are exposed to water flow that supplies its herbivorous needs and thus determines its distribution (Fabricius et al., 1995). Previous studies conducted in Eilat have demonstrated the elevated post-recruitment survival of miniature colonies of *D. hemprichi* on vertical settlement plates (Dahan and Benayahu, 1997a,b; Oren and Benayahu, 1997). Indeed, the current study showed that the survival of miniature colonies of the species was greatest in areas with high current velocities, such as those of the vertical Dolphin-AR (Table 2), indicating that flow is a critical factor affecting the survival of the species. Interestingly, in the current study the survival of both artificially-generated and naturally-recruited miniature colonies of *D. hemprichi* was not significantly affected by the orientation of the transplanted substratum (horizontal *vs*. vertical), but was influenced by the combined effect of orientation and plate facing (outer *vs*. inner). The greater survival on the inner face of horizontal plates and on the outer face of vertical plates can be attributed to a synergistic effect of high current velocity and low sedimentation load. Thus, it is suggested that the unique suites of environmental conditions of the two habitats may have determined the survival patterns obtained in the current study. These patterns do not seem to be related to the type of substratum (artificial *vs.* natural), as the miniature colonies whose survival was examined were attached to identical substratum (PVC settlement plates) placed on the AR and on the NR.

The present study demonstrates a link between current regime and sedimentation load and the differential survival of *D. hemprichi* and *P. damicornis* on an AR and a NR. Nonetheless, it is possible that other factors, such as predation pressure (Osman and Whitlatch, 2004) or shading (Glasby, 1999), act differentially too and thus may also affect survival of coral recruits on the two reef types. For example, Russ (1980) found that in southeastern Australia selective predation prevented dominant competitors from monopolizing space, thus promoting high diversity on settlement tiles exposed to predation *vs.* those protected from predation. It is possible that the studied NR experiences more predation than the AR, reducing the dominance of *P. damicornis* recruits there and elevating the species diversity, as supported by Perkol-Finkel and Benayahu (2004), who found greater diversity at the Dolphin Reef NR compared to the AR at the site. Nonetheless, the nature of the role played by predation has not been fully experimentally examined and thus remains to be determined. Survival of juvenile coral recruits can also be affected by spatial competition with various benthic organisms found on both reef types such as sponges or algae which may overgrow them (see Vermeij, 2006). However, *D. hemprichi* is considered as having a rapid growth rate (Fabricius et al., 1995) and *P. damicornis* to be aggressive towards other coral species (Abelson and Loya, 1999) and thus are not highly susceptible to overgrowth by other corals. Moreover, since the current study examined the survival of miniature colonies attached to bare PVC plates, the effect of spatial competition on both species was most probably minimal, especially as no overgrowth was observed.

The current study also demonstrates the effective application of novel methodologies in the field of coral cultivation for the investigation of the ecological and biological processes governing ARs and NRs. While there are several procedures by which stony corals can be cultivated, such as the use of extracts of massive colonies, nubbins comprising a small number of polyps or broken fragments of branching colonies (Davies, 1995; Carlson, 1999; Shafir et al., 2001; Lindahl, 2003), a similar use of soft corals has received only little attention (Oren and Benayahu, 1997; Barneah, 1999; Barneah et al., 2002). The method applied in this study for producing large numbers of miniature colonies of *D. hemprichi* proved successful, as the attachment of the fragments to the experimental settlement plates followed a similar cascade of events to the one described for naturally-occurring fragmentation (Dahan and Benayahu, 1997b), and since both artificially-generated and naturally recruited miniature colonies exhibited similar trends of survival. The new method developed in this paper for preparing artificially-generated miniature colonies of *D. hemprichi* is relatively simple, rapid, and even enables control over the size and number of colonies. In addition, this method enables a certain control over the genetic homogeneity of the formed colonies, by using a single donor colony if genetic homogeneity is required, e.g., for ecotoxicology studies, or a mixture of fragments from several donor colonies in cases where genetic heterogeneity is preferable, such as for restoration purposes (see also: Epstein et al., 2001). Furthermore, since the artificially-generated miniature colonies are attached to settlement plates they can be easily transplanted and without being subjected to overgrowth by other species (see above). The use of such artificially-generated miniature colonies has an added ecological value, in that it is expected that these colonies will rapidly grow and thus provide a source for the future formation of miniature colonies, reducing the need to harvest colonies from NRs. Moreover, the miniature colonies can be transplanted to NRs as part of a habitat restoration or enhancement project (e.g., Barneah, 1999; Montgomery, 2002; Lindahl, 2003).

The differential survival patterns of *D. hemprichi* and *P. damicornis* shed new light on the ability of ARs to mimic NR communities, suggesting that when the two reef types experience different environmental conditions, post-recruitment survival might significantly differ between them. Thus, according to our finding, in order to construct an AR that would mimic the typical species composition of northern Red Sea reefs, the AR must have a low relief design, generating a relatively slow currents and a moderate sediment deposition. Nonetheless, an AR constructed for enhancement purposes could be designed slightly differently to the common natural environment. This for example, will provide more inclined surfaces which are rather rare in the area, but can be commonly found in other parts of the Red Sea, and thus attract species that flourish in high current environments with minimal sediment load such as *D. hemprichi*, which is rare in the local NRs (Perkol-Finkel and Benayahu, 2004). Our results support the notion that studies of post-recruitment survival offer complementary information to those examining recruitment processes (Caley et al., 1996). Understanding the factors that contribute to the survival of juvenile colonies is necessary in order to predict the eventual species composition of ARs, and consequently to ensure correct AR design that will contribute to enhancing its biological performance. We suggest that in order to construct an AR for restoration purposes, it is essential that it will offer similar environmental conditions to those offered by the natural surrounding. Modification of its structural features may favor the survival of target species that might be rare in the surrounding NR, and thereby elevate the overall species diversity in the area and contribute to enhancing the local marine fauna.

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