

# IET Project No. 18

## Coral Recruitment

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### **1. Objectives**

The major goal of the project was to monitor the recruitment rates of corals along the Eilat coasts with emphasize on comparing the rates in sites suspected as anthropogenically disturbed versus reference sites. The project was motivated by the notion that anthropogenic activities may damage the coral reefs of Eilat via their effect on the recruitment process of reef-building corals. As a first step, there was a need to examine the recruitment rates in sites neighboring disturbance hotspots and relatively far sites, as reference sites. One year study on coral recruitment is extremely limited and cannot provide sufficient information for scientific-based decisions. The present report, therefore, includes data of a limited, one year study as well as data of previous projects that have been conducted in Eilat.

In this report, therefore, we aim at summarizing the data which have been obtained by the present 'IET recommendation project' as well as various other studies that are related to coral recruitment in Eilat during the last seven years.

### **2. Methods**

Monitoring of coral recruitment was conducted in five different approaches. First, by using ceramic tiles, which served as settlement substrates, on vertical racks (5 stations), a method which has been previously used in the Indo-Pacific (Sammarco and Andrews, 1988, 1989). Second, belt-transect censuses of recruits on shallow rocks in seven sites (16 stations) ranging from the Jordanian border to near the Egyptian border, to cover the whole coastal range of Eilat. This approach was applied by two methods: 1) normal visual censuses during day-time surveys, which are limited to coral size of >1 cm., and 2) night-time surveys with U.V. illumination system (NightSea Co.), which enables detection of newly settled corals of a few polyps only. The third approach was of documenting all the surveyed branching corals on the shallow rocks (using them as "functional group bioindicators"), and analyzing their size frequency distribution (16 stations). Fourth, belt-transect censuses of recruits on natural reef substrates. Finally, artificial-reef modules (21 modules in 7 stations from Ardag to Taba (Princes hotel)), which served as settlement substrates for diverse reef and biofouling species.

### **3. Results**

As noted, the present report summarizes diverse data, which have been obtained by different approaches of studying coral recruitment, including: settlement plates on vertical racks (Figs. 1,2; Table 1), day-time censuses of young coral colonies on natural substrates (Figs. 3,4; Table 2), night-time censuses of newly-settled corals on natural substrates (Table 2), coral recruitment onto artificial-reef modules (Fig. 5), size

distribution of coral colonies (to spot historical anomalies of recruitment events; Fig. 6), coral recruitment onto natural substrates in three locations along the Gulf of Aqaba coasts (from Eilat to Nueiba; Fig. 7), genotype composition of young and adult corals of the species *Stylophora pistillata* (Fig. 8), and a comparison of the settlement-plates data with data from other geographical regions (Table 3).

Overall, from the diverse results it may be inferred that stony coral recruitment onto settlement (artificial) and natural substrates in the Eilat reefs vary both spatially (between sites and depths) and temporally (between years; Figs. 1-7, Tables 1,2). However, the results show two major sites, which based on the recruitment rates, can be considered as disturbed environments, namely: the North Beach (i.e. Ardag and Peace Lagoon) and the Port region (i.e. Dekel Beach, Naval Base, Port and Dolphin Reef; Figs. 1-3,5,6; Tables 1,2). Of these two, the more stressed site is the North Beach, notably the eastern part (Figs. 1-3, 5, 6; Tables 1,2). The recruitment rates of stony corals to the North Beach are much lower than the recruitment to the southern sites. It can be seen that in the Peace Lagoon (North Beach) the number of newly-settled recruits ("recr. night") is higher than in the Princes Hotel (southernmost beach); whereas, the number of one-year old recruits in the Peace Lagoon decreases and is lower than in the Princes Hotel (Table 2). This changing trend (which can also be indicated in the size frequency distribution of branching corals; Fig. 6) indicates higher mortality of recruits in the North Beach.

The molecular study revealed that the genotypic diversity of adult populations from the north beach (Fish Cages, FCA; Peace Lagoon, PLA; Galey Eilat, GEA) was significantly lower than that of adult populations from the southern sites (Tur-Yam, TYA; Marine Lab, MBLA; Taba TA;  $P < 0.01$ ; Fig. 8; Zvoluni et al., submitted). Moreover, the genotypic variability of adults at both the northern and southern sites were significantly lower than that of the young recruits ( $P < 0.01$ ), where the reduction in the northern sites was significantly higher than in the southern sites (Fig. 8).

#### **4. Discussion**

As noted earlier, this report is aimed at summarizing the data which have been obtained by the present 'IET recommendation project' as well as our various studies on coral recruitment in Eilat during the last five years. Our results show two major sites, which can be considered as disturbed environments, namely: the North Beach and the Port region. It should be emphasized that our study on stress symptoms of corals at the cellular level, pointed out these sites as disturbed environments. Of these two, there is no doubt that the more stressed site is the North Beach, notably the eastern part (i.e. Peace Lagoon and Ardag). The recruitment rates of stony corals to the North Beach are much lower than the recruitment to the southern sites. It seems, however, that when new substrates are immersed, the recruitment in the North Beach is fairly intensive (e.g. Fig. 1, the recruitment during 1998, and Fig. 6, the relatively high recruitment of the smallest size classes in Ardag). However, in all cases it can be seen that with the age of either the substrate (Figs. 1,2), or the recruits (Fig. 6; Table 2), the survival declines and leads to significantly lower recruitment rates in the North Beach sites. Moreover, this 'low-survival argument' can be shown clearly in a comparison between the rates of newly settled recruits and up to one year old recruits (Table 2). It can be seen that in the Peace Lagoon (North Beach) the number of newly-settled recruits ("recr. night") is higher than in the Princes Hotel (southernmost beach); whereas, the number of one-year old recruits in the Peace Lagoon decreases and is lower than in the Princes Hotel (Table 2). This

changing trend (which can also be indicated in the size frequency distribution of branching corals; Fig. 6) indicates higher mortality of recruits in the North Beach, and point out the survival as the key factor in determining the recruitment state.

Beyond its dramatic effect on recruitment which may lead to smaller population sizes, the low survival of recruits, if differential, can change the genotype structure of populations and the species composition of communities. The first effect can be easily seen by the sparsely occupied substrates; the latter phenomenon, however, requires more sophisticated, molecular tools. The aim of the molecular study of *S. pistillata* was to examine the potential effect on genotype structure of populations. As noted, this study revealed that the genotypic diversity of adults at both the northern and southern sites were significantly lower than that of the young recruits, where the reduction in the northern sites was significantly higher than in the southern sites. Tajima's D-test has shown that the reduction is most likely due to selection. Where in the southern sites the significantly negative values are very likely to be due to positive selection (selective sweep; Zvoluni et al. submitted); whereas in the northern sites the results (i.e. positive values close to zero;  $D = 0.0248$ ;  $P > 0.1$ ), may indicate either neutrality, or background selection (purifying selection). With the above described dramatic decline in genotypic diversity, very low survival rates of recruits, and strong stress responses, purifying selection is a much more likely explanation of the data.

A comparison with a short list of studies that have used ceramic tiles as settlement plates (Table 3) suggests that the overall recruitment of corals to the coral reefs of Eilat is very low relative to other geographical regions, including high-latitude regions. Our findings are not in accord with the results of Glassom et al. (2004), who concluded that the overall recruitment in Eilat is similar to other high-latitude coral reefs. Their conclusion was based on a comparison with diverse studies that had applied highly different experimental protocols and designs. Several factors can impart significant variation among studies, and consequently may lead to erroneous conclusions. These include duration of plate deployment, substrate type, rack orientation, depth and height above the seabed.

The problem of a comparison between studies that lack standardized methodologies can be demonstrated by a comparison between the results of Glassom et al. (2004) and our study of recruitment on settlement plates. Both studies were conducted in the same locale and during the same period, but nonetheless revealed substantial differences in their recruitment patterns. In addition to the above noted factors that might have contributed to the dissimilar results, there are two other causes that are assumed to be dominant in determining the differences between the two studies. First, the tiles in Glassom et al., (2004) were significantly smaller (10X10cm) than the tiles used in our study (15X15 cm). The edge effect of smaller tiles is much greater and may enhance settlement densities. The edge effect can enhance settlement through the creation of a separation bubble and resultant substrate-ward flow (Mullineaux and Butman, 1991; Abelson and Denny, 1997). Second, Glassom et al. (2004) did not examine recruitment in the North Beach, which is the most human affected region in Eilat, and whose final recruitment and survival rates were found to be the lowest in Eilat. The first issue may have resulted in methodologically-driven variation; whereas, the latter omission may misrepresent the broader geographic pattern of recruitment potential in the Eilat region.

Based on the above-noted patterns, it appears that the exceedingly low recruitment rates may contribute to the deteriorating state of the Eilat reefs. The low recruitment rates,

regardless of their governing factors (natural or anthropogenic), seem to be too low to compensate for the elevation in mortality rates in recent years (Ben-Tzvi et al., 2004). The general pattern of North-South gradient in both the natural substrates and the settlement plates, the stress symptoms at the cellular level, and the observed low survival and high biofouling cover in the North Beach, suggest a human-mediated geographical impact superimposed on the region-wide natural low recruitment rates.

The results of the present study add to those of other studies that indicate anomalies in vital symptoms and ecological processes in the North Beach site (e.g. Bresler et al., 1999, 2003; Ben-Tzvi et al., 2004; Loya et al., 2004; Loya, 2004). In the only other study that investigated coral recruitment in Eilat (Glassom et al., 2004), such findings, as mentioned above, do not appear, since none of the 20 designated sites were in the North Beach. However, the closest site to the NB (site no. 20 in their paper) indicates very low rates of Pocilloporids and zero recruitment of all the massive and encrusting species.

## **5. Conclusions**

- I.** A comparison with other studies that have used ceramic tiles as settlement plates suggests that the overall recruitment of corals to the coral reefs of Eilat is very low relative to other geographical regions, including high-latitude regions.
- II.** Based on this project finding, as well as the results of our previous recruitment projects, we claim that there are very low recruitment rates to the North Beach sites and the Port area, where the observations on both artificial and natural substrates provide the same pattern. It should be stressed that the present project data show that in the North Beach the low recruitment is due to very low survival of newly settled recruits, rather than low settlement rate. Likewise, the results of the coral size-frequency distribution suggest that the problem of recruitment to the North Beach ('Peace Lagoon') has started around four-five years ago.
- III.** Another point of concern that is raised by the study is a decline in recruitment to the southern part of the Nature Reserve, which implies a "hot spot" of environmental stress in sites other than the North Beach and the Port area. However, the data of these more southern sites is either limited due to lack of study during previous years, or inconsistency with other data.
- IV.** Summarizing the whole set of data of our settlement studies (which is presented here) and taking into account the findings of our project on stress symptoms (IET recommendation of metabolic studies in the coral reef: Cellular-level biomarkers), it is well reasonable to claim that human-related, environmental stressors are responsible for the anomalies of low recruitment in the North Beach and Port area.
- V.** It should be noted that in our conclusion we refer to the anomalies of low recruitment in certain sites, which we consider as environmentally disturbed sites. However, we do not examine the question of the 'recruitment state' of the whole Eilat area relative to other geographical sites. This important question, which may help us in resolving the issue of the impact of the disturbance sources on other, remote sites, deserve much more effort in the future since there are diverse variables affecting the results of the various cited studies. Two studies have compared data from different regions with their results of the Eilat recruitment (Olinky 2000 and Abelson et al. submit. versus Glassom et al. 2004). The two studies raise contradicting conclusions. Both studies were conducted in the same locale and during the same period, but nonetheless revealed substantial differences

in their recruitment patterns. In this report, an attempt is made to explain the differences between the two studies.

Finally, our previous research showed that the recruitment rates to natural southern reefs in Sinai were dramatically lower than in other sites along the Gulf of Aqaba (i.e. Coral Island and Nuweiba; Olinky 2000, Abelson et al. submit.).

## 6. Open questions

- I. Although the general pattern is fairly clear, there are some unclear anomalies that should be mentioned. First, in the easternmost North Beach, the Marina site, the recruitment is relatively very high (Fig. 3), although it is very low in the nearby Red-Rock Hotel (Fig. 5). Another anomaly is the relatively low recruitment to the southern sites during two of the shallow rock surveys and fairly high during the third (Fig. 3). Finally, there is a peculiar decline in the recruitment to the southern reefs of the nature reserve ("Japanese Gardens; Fig. 4). These phenomena cannot be explained by the present data and further study is required to uncover them.
- II. The results, although indicate potential sites of environmental disturbances, do not show causality in terms of pinpointing the exact agent(s) responsible for the observed low recruitment rates.

## 7. References







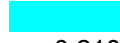
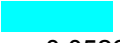
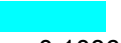



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**Table 1:** Recruitment of stony-corals to settlement plates (ceramic tiles 15X15cm) at five sites along the coasts of Eilat. Number of recruits is per a set of a couple of plates (15X15 cm). The sites are: North Beach (NB), Dolphin reef (DR), Nature Reserve north (RN) and south (RS) and the Inter-University Institute (IUI).

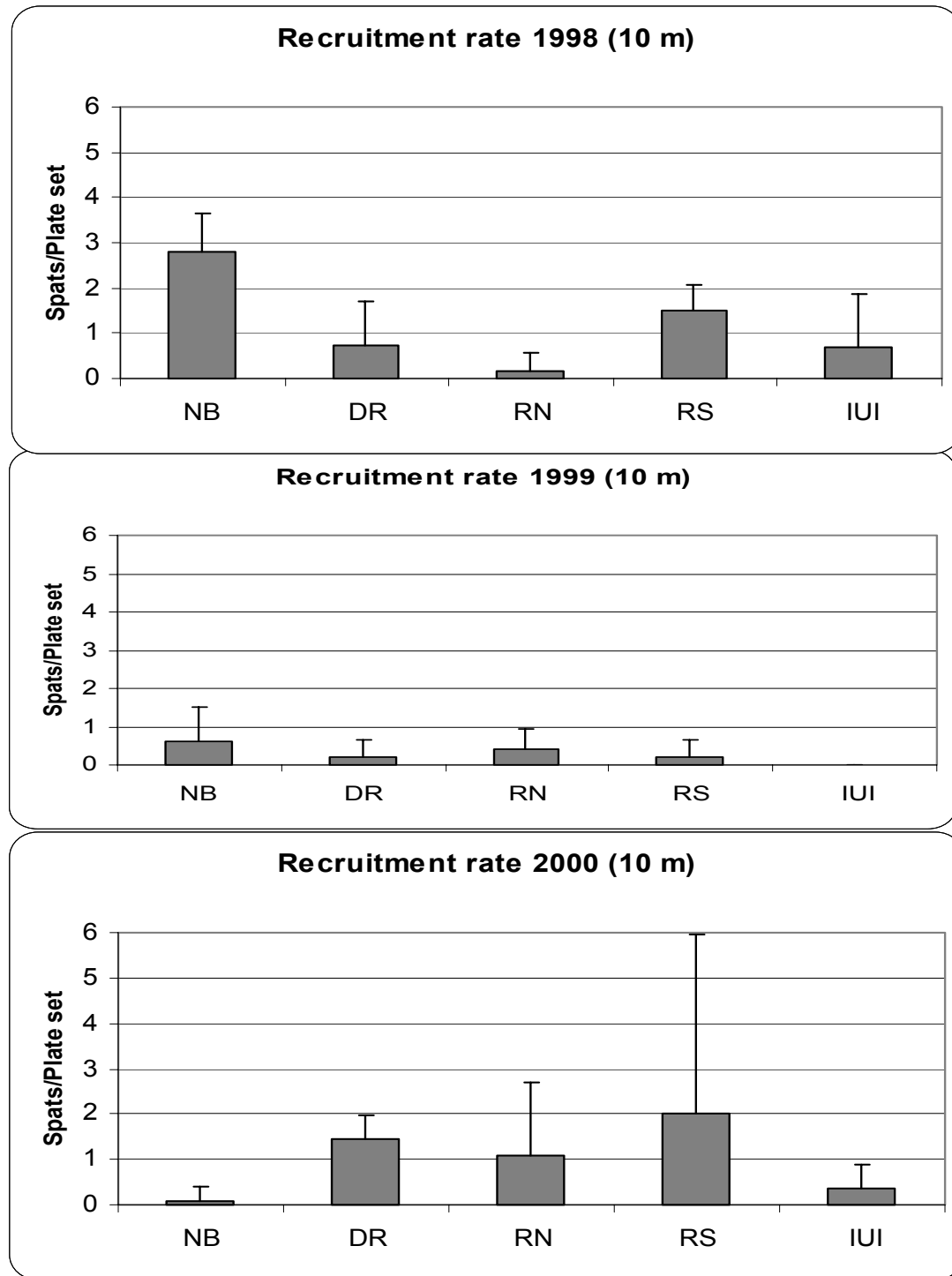
	Number of recruits					
	10 m depth	#	Std	30 m depth	#	Std
North Beach		0.	0.		0.	1.
Dolphin Reef		1.	1.		0.	0.
North Reserve		1.	1.		1.	1.
South Reserve		2.	2.		1.	
MBL (IUI)			1.		1.	1.

**Table 2:** Recruitment of stony-corals to the Princes Hotel and Peace Lagoon boulders. The number of recruits was determined by two methods: 1) day-time surveys (recr. Day) - normal visual censuses which are limited to coral size of >1 cm., and 2) night-time surveys (recr. Night) with U.V. illumination system (NightSea Co.) which enables detection of newly settled corals of a few polyps only.

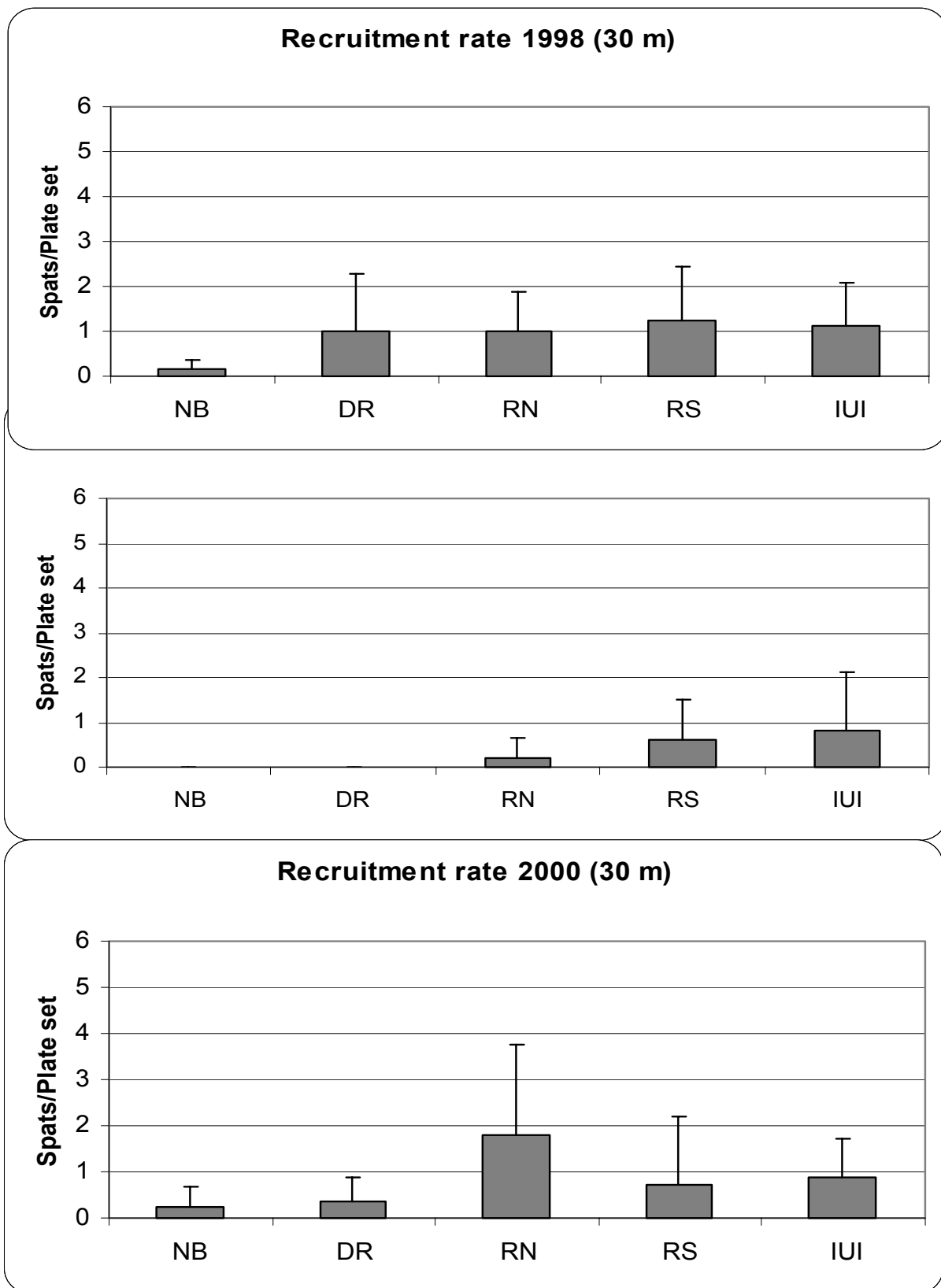
Transect number	Princes Hotel			Peace Lagoon		
	1	2	3	1	2	3
recr. day						
recr. night						
recr. day/night	0.2105	0.0526	0.1086	0.0169	0.0555	

**Table 3:** Stony coral recruitment rates onto ceramic tiles in different geographic regions. Abundances of recruits (number of recruits per pair of plates per year) were averaged across sites and time in each location. FP – French Polynesia, SE AU– South-East Australia, GBR – Great Barrier Reef, Australia.

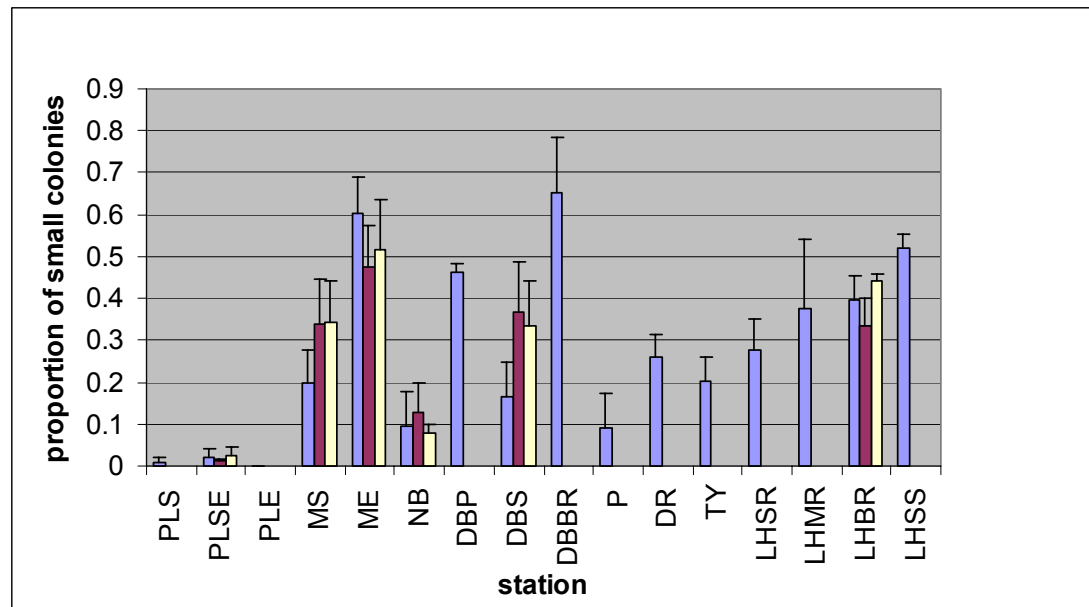
<b>Region</b>	<b>Plate area (cm<sup>2</sup>)</b>	<b>Period (months)</b>	<b>Mean # Recruits</b>	<b>Source</b>
Eilat	225	5-12	0.8	Our data
SE Australia	225	2	2.8	Banks & Harriott 1996
SE Australia	225	6	4	Harriott 1999
Barbados	225	12	15	Tomascik 1991
FP	225	4	6.4	Gleason 1996
S GBR	400	5	18	Dunstan & Johnson 1998
Mid GBR	225	6	95	Fisk & Harriott 1990
Mid GBR	122	2	193	Hughes et al. 1999



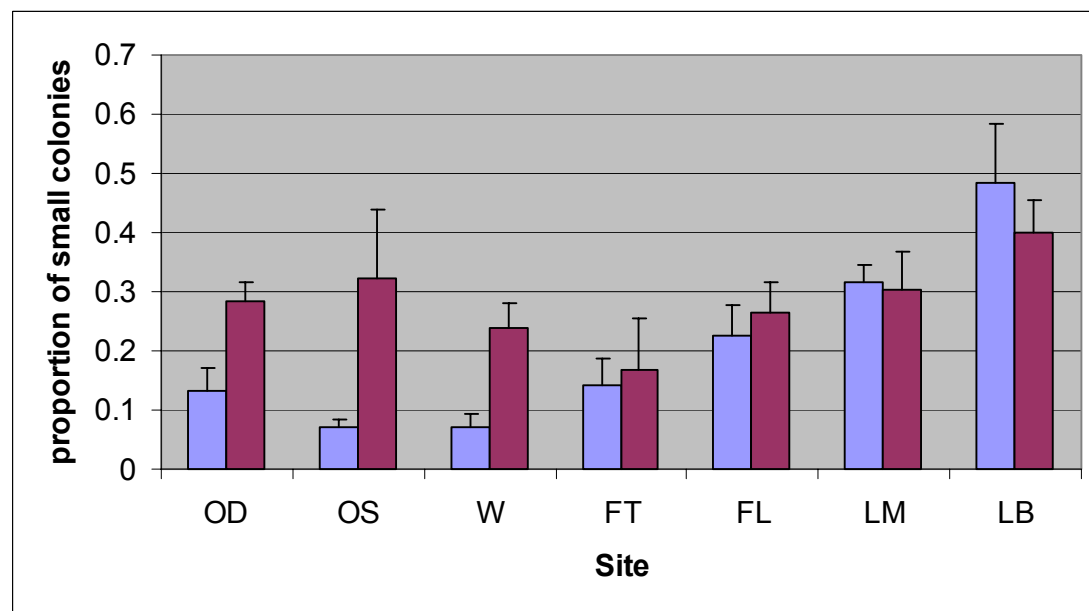
**Figure 1.** Recruitment to settlement plates (10 m depth) in five sites along the coasts of Eilat. The number of recruits is per a set of two plates (15X15 cm). The sites are: North Beach (NB), Dolphin reef (DR), Nature Reserve north (RN) and south (RS) and the Inter-University Institute (IUI).



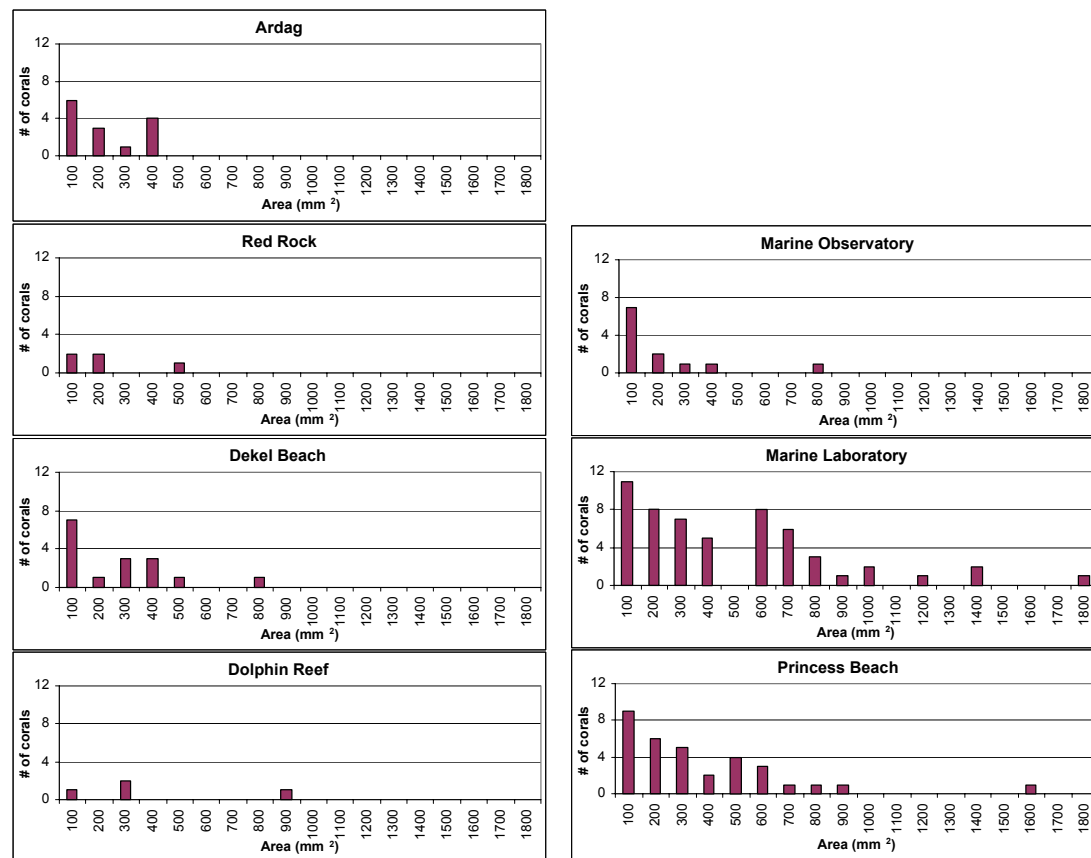
**Figure 2.** Recruitment to settlement plates (30 m depth) in five sites along the coasts of Eilat. The number of recruits is per a set of two plates (15X15 cm). The sites are: North Beach (NB), Dolphin reef (DR), Nature Reserve north (RN) and south (RS) and the Inter-University Institute (IUI).



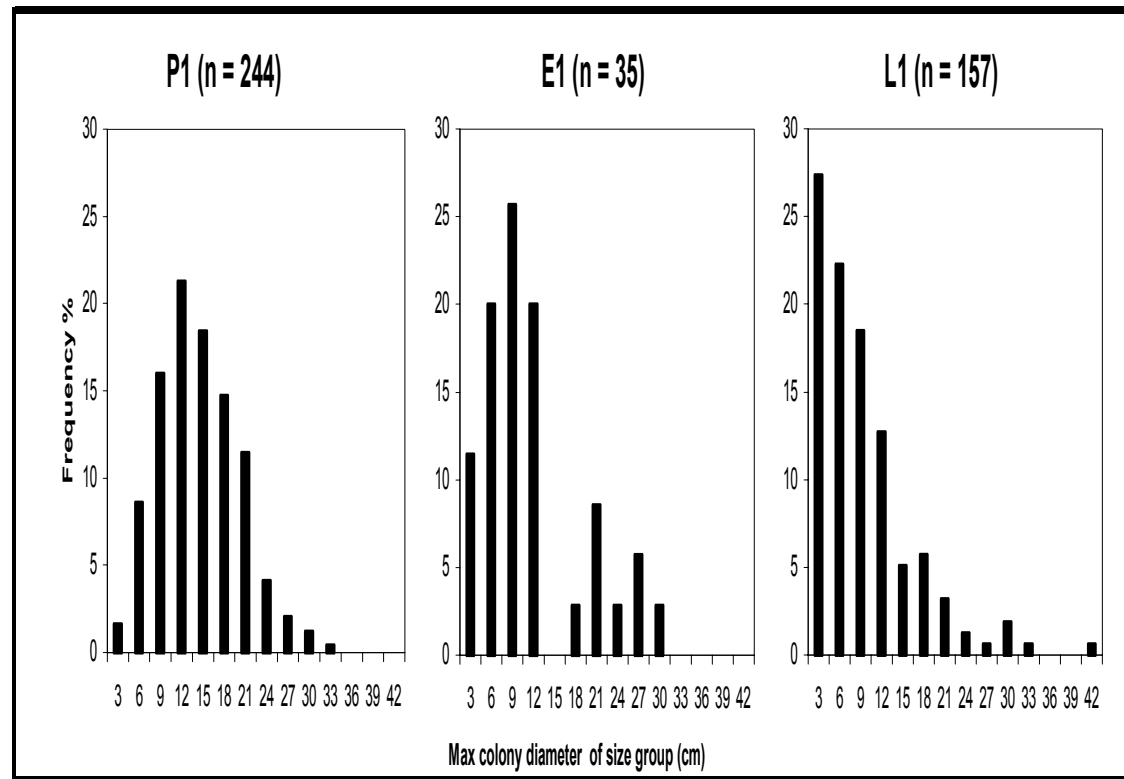
**Figure 3.** Recruitment of stony corals to shallow rocks (0.5-3 m depth) along the Eilat coasts (16 stations). The number of recruit (colony size <3 cm) is given in proportion to the number of adult corals (colony size >3 cm). The stations: Peace lagoon (PLS, PLSE, PLE), Marina (MS, ME), Naval base (NB), Dekel Beach (DBP, DBS, DBBR), Port (P), Dolphin reef (DR), Tur-Yam (TY) and Lighthouse (LHSR, LHMR, LHBR, LHSS).



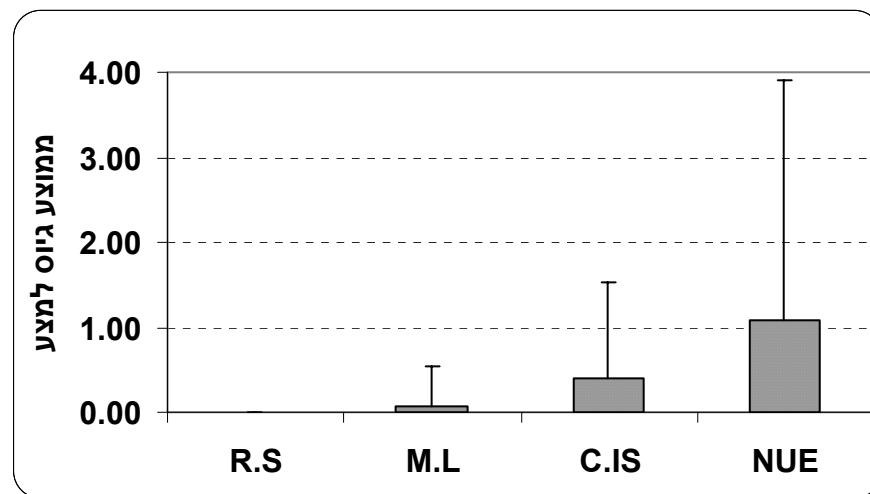
**Figure 4.** Recruitment of stony corals along two transects (from the lagoon to 5 m depth) in two sites of the coral reefs of the Nature Reserve (purple - North Reserve, blue - South Reserve; Japanese Gardens). The number of recruit is given in proportion to the number of adult corals. The sampling sites along each transect, are: OD – Open water deep, OS – Open water shallow, W – reef table edge, FT – Reef table, FL – Front lagoon, ML – mid-lagoon, BL – Back lagoon.



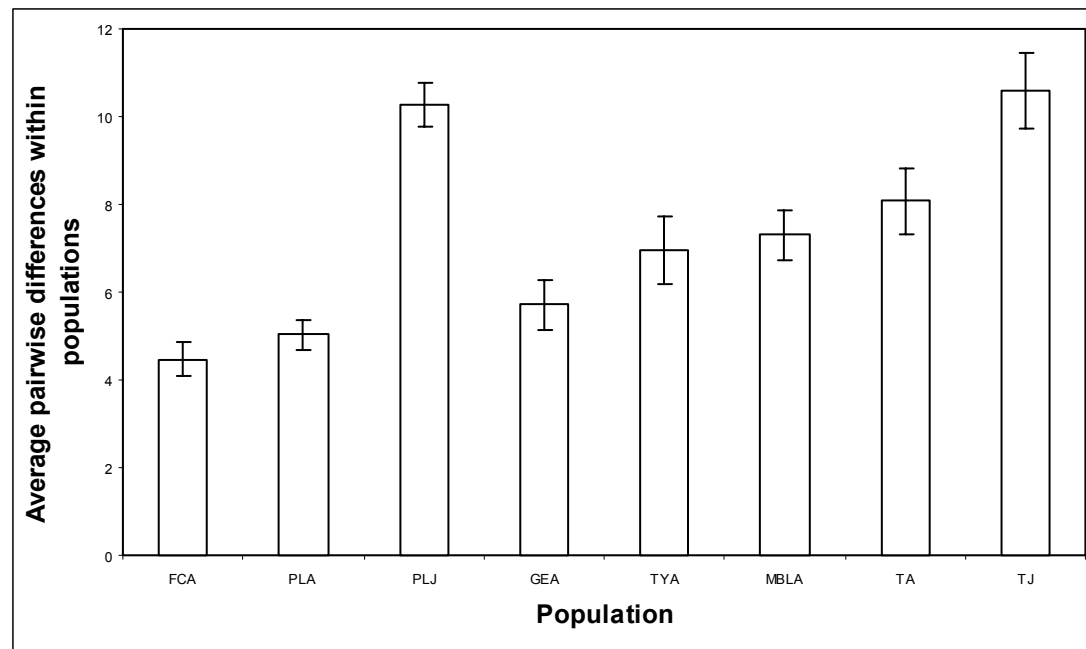
**Figure 5.** Coral recruitment cohorts to the artificial-reef modules. The number of recruits is given per module. The coral size is given as base area of the colony.



**Fig. 6:** Size distribution of branching corals in three given sites: the Peace Lagoon (P1), the Port (E1), and the Light House (L1).



**Figure 7:** Coral recruitment onto natural substrates in three locations along the Gulf of Aqaba coasts: Eilat (two sites: Nature Reserve South, RS; Marine Lab, ML), Coral Island (C.IS) and Nueiba (NUE).



**Figure 8.** Average pairwise differences within populations ( $\pm$ SE) of *Stylophora pistillata* in Eilat. Samples of adult corals: FCA – Fish cage farms, PLA – Peace Lagoon, GEA – Galei Eilat, TYA – Tur Yam, MBLA – Marine Lab (IUI), TA – Taba. Samples of juvenile corals: PLJ – Peace Lagoon, TJ – Taba.