

Patterns of spatial variability in distribution of benthic invertebrates and algae at Sharm el Sheikh (South Sinai, Egypt)

J. Giraldi, S. Acunto, L. Piazzini, F. Cinelli

University of Pisa. Dept. of Biology - Marine Biology and Ecology Unit - Via Derna, 1 -56126, Pisa, Italy,
Jessika.giraldi@gmail.com

Abstract. A survey of benthic community was conducted as part of a project to construct an Underwater Observatory on the coast of Sharm el Sheikh (Egypt). To provide the first step of the EIA based on a “Beyond BACI” design, the spatial distribution of benthic invertebrates and algae was studied at a hierarchy of spatial scales: 5 sites, 3 areas within each site and 20 1m² frames within each area were randomly selected. Plots were sampled using the photo-quadrats method. A combination of univariate and multivariate analysis of the percentage cover was used to describe differences in the abundance of organisms identified at the genus level and, when necessary, grouped into broader categories. Results showed significant differences in the distribution and abundances of organisms among sites as well as among areas, indicating that abundances varied at the scales of hundreds and tens of meters along the coast investigated. These results are likely to be due to spatial differences of the hydrodynamic conditions of the studied sites, other than to stochastic events. One of the sites with the lowest percentage cover of living organisms was suggested as the most suitable to place the Underwater Observatory in order to minimize the impact of the structure.

Key words: Spatial variability, Coral reef, Red Sea, Photo-quadrats, EIA

Introduction

This study is a part of the “Pilot project for the sustainable development of environmental sound management in South Sinai, Sharm el Sheikh, Ras Mohammed National Park” funded by the Italian Ministry of the Environment. Within this project, the construction of an Underwater Observatory close to the Visitor Center of the park was proposed. In response, the coast of Sharm el Sheikh was surveyed to provide information about spatial variability in distribution of benthic invertebrates and macroalgae.

Variability in the distribution of natural species can occur at different spatial scales (Kennelly and Underwood 1992; Underwood and Petrait 1993; Underwood and Chapman 1996; Connell et al. 1997; Benedetti-Cecchi et al., 1998; Menconi et al. 1999; Ferdeghini et al. 2000; Balata et al. 2006). Documenting the spatial scales at which variability in the abundance of organisms occurs can help to focus attention on the relative importance of different ecological processes that can determine the patterns observed (Underwood and Chapman 1996).

In this study, the sampling procedure was designed in order to be the first step of an Environmental Impact Assessment based on a “Beyond BACI” (Before-After, Control-Impact; Underwood 1991) design.

The logic of this design is to separate the spatio-temporal natural fluctuations of the structure of benthic assemblages from those due to anthropogenic activities. Thus, an appropriate analysis would consist of properly replicated sampling several times before the development and several times after in potentially impacted and in reference locations. From these data, it is possible to ascertain interactions in impacted and control sites through time (Underwood 1991, 1992, 1993, 1994).

Moreover, documenting the spatial distribution of living organisms was essential to suggest the most suitable stretch of coast to place the Underwater Observatory.

Materials and Methods

The study was carried out at Ras Mohammed National Park along the coast of Marsa Ghoslani bay (Fig. 1). Blocks of organic framework of dead and living corals characterized the substrate of the study area.

A nested sampling design was used at a hierarchy of spatial scales: 5 sites (100s of m apart), 3 areas within each site (10s of m apart) and 20 replicates of 1m² frames within each area were randomly selected in the Northern part of Marsa Ghoslani bay (Fig. 2).

Plots were sampled using the photo-quadrats method (English et al. 1997; Acunto et al. 2001; Hill

and Wilkinson, 2004). All samples were collected at a depth of 10 m on a gently sloping rocky bottom (with an angle ranging from 10 degrees to a maximum of about 15 degrees).



Figure 1: Study location along the coast of Sharm el Sheikh, Egypt.

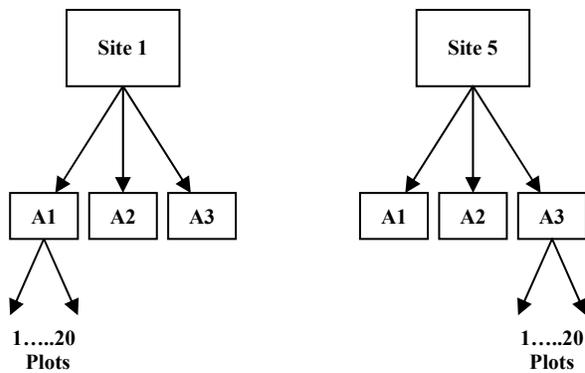


Figure 2: Sampling design.

A permutational multivariate analysis of variance was used to study the spatial variability among sites and areas by PERMANOVA (Anderson 2001; McArdle and Anderson 2001). This computer program uses permutation procedures to obtain the null hypothesis distribution (indicated as “pseudo” F) and P -values for the tests (including interactions), for any balanced multi-factorial ANOVA design. It is a non-parametric test.

The analysis consisted in a 2-way model with SITE (5 levels) as a random factor, AREA (3 levels) as a random factor nested in SITE. This analysis was performed using cover of sessile invertebrates identified at the genus level (De Vantier et al. 2006; Balata et al. 2005; Wielgus et al. 2004) while algae grouped into morpho-functional groups (Littler 1980; Littler and Littler 1980; Steneck and Dethier 1994; Ateweberhan et al. 2006). A two-dimensional nMDS

(non-metric multidimensional scaling), based on the centroids of replicate areas, was used for a graphical representation of the assemblages. Distances among centroids were obtained using principal coordinate axes from the original Bray–Curtis similarity index matrix.

The same model was used to perform the analysis of variance (ANOVAs) on total number of taxa, total percentage cover of organisms, percentage cover of the morphological forms of hermatypic corals (Veron 2000), soft corals, sponges and filamentous algae.

Results

The nMDS showed Site 3 separated from all the other sites. The dispersion of the centroids representing areas within each site were homogeneous with the exception of Site 4 where one area scattered far from the others (Fig. 3).

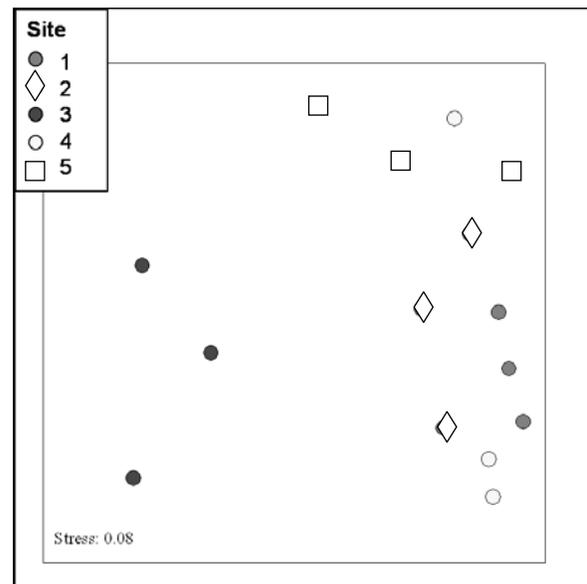


Figure 3: nMDS calculated on the cover values of benthic organisms for each Area

PERMANOVA showed significant differences in the structure of assemblages at both spatial scales investigated (Table 1).

ANOVA showed an analogous pattern, but branching corals showed significant differences only among sites while filamentous algae, sponges and the total number of taxa showed significant differences among areas (Table 2).

The mean percentage cover of all organisms was higher at Site 3 (30.15 ± 2.4 considering the mean among areas) than in the other sites with values between 11% and 16%. Filamentous algae were the most abundant organisms at all the sites with the exception of Site 3 where the percentage cover of massive corals was highest (Fig. 4).

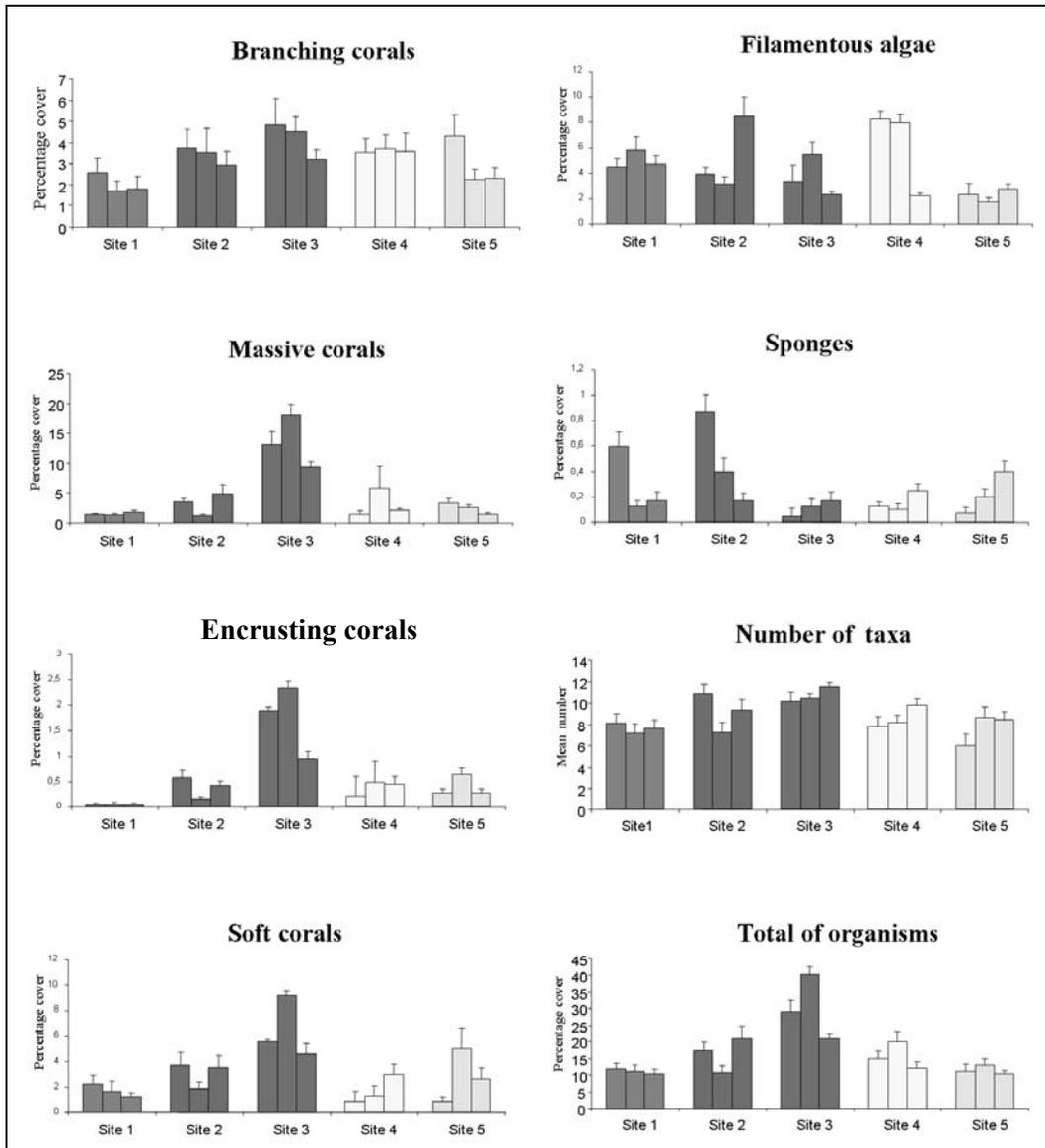


Figure 4: Distribution and abundances of the response variables used for ANOVA. Error bars indicate + SE, n = 20.

Table 1: PERMANOVA results. Significant values bold. (df: degrees of freedom; MS: mean squares; P(perm): P-values obtained using permutations; Pseudo-*F*: explanation in Materials and Methods; perm: n° of permutable units)

Source of variability	df	MS	Pseudo- <i>F</i>	P(perm)	perm
Site	4	33120.00	4.92	0.0001	15
Area(Site)	10	6727.20	3.35	0.0001	300
Residual	285	2007.00			
Total	299				

Table 2: ANOVA results. Significant values are in bold (* P < 0.05; ** P < 0.01; *** P < 0.001).

Source of variability	df	Branching corals		Massive corals		Encrusting corals		Soft corals		Filamentous algae		Sponges		Number of taxa		Total of organisms	
		MS	F	MS	F	MS	F	MS	F	MS	F	MS	F	MS	F	MS	F
Site	4	2.70	11.60***	1476.54	12.69***	25.80	10.35**	224.62	4.36*	4.70	2.01	0.55	1.33	95.23	3.33	3614.40	6.62**
Area (Site)	10	0.23	0.41	116.33	3.14***	2.49	3.98***	51.49	4.03***	2.34	4.92***	0.41	7.82***	28.60	2.18*	545.61	4.96***
Residual	285	0.57		37.08		0.63		12.78		0.48		0.05		13.11		109.98	
Total	299																
Cochran C test		C = 0.1205 (us) ln(s+1)		C = 0.1681 (P: 0.01) none		C = 0.4010 (P: 0.01) none		C = 0.2773 (P: 0.01) none		C = 0.1207 (us) ln(s+1)		C = 0.1364 (us) ln(s+1)		C = 0.1089 (us) none		C = 0.1681 (P: 0.01) none	

Discussion

Our findings indicate that the structure of the assemblages and the abundances of dominant taxa varied at the scales of tens and hundreds meters along the investigated coast.

Understanding the scales of natural variability of the response variables analysed is a fundamental requisite for the design and optimisation of any environmental sampling programme (Underwood 1991). As a first step of the environmental impact assessment based on a “Beyond BACI” design, the variability observed during this study will be taken into account and compared with the results of future sampling.

One of the studied sites (Site 1) showed a low cover of living organisms; therefore this site can be considered, from an ecological point of view, the most suitable for the construction of the Underwater Observatory. Patterns of distribution showed that Site 3 hosted the largest abundances of corals. This was likely due to spatial differences in the hydrodynamic conditions of the studied coast. Even if further investigations should be necessary to confirm this hypothesis, it is possible that recruitment and development of corals at Site 3 is enhanced by exposure to waves and currents greater than at the other sites.

History of previous disturbances that have occurred along this coast (storms, bleaching events and *Acanthaster planci* outbreaks) could explain low percentage cover of scleractinian corals and the relative high abundance of filamentous algae. However, the observation of numerous small colonies suggests beginning recovery of corals (authors personal observations).

Acknowledgement

We would like to thank Dr. David Balata for his contribution to this work and the scientists of EEAA (Egyptian Environmental Affair Agency), in particular Dr. Essam Saadalla, for their collaboration during sampling activities and assistance in the field. A special thanks to our friend Anna Proietti-Zolla for her collaboration to this work and for her invaluable human support.

References

- Acunto S, Balata D and Cinelli F (2001) Variabilità spaziale nel coralligeno e considerazioni sul metodo di campionamento. *Biol. Mar. Medit.* 8 (1): 191-200
- Anderson MJ (2001) A new method for a non-parametric multivariate analysis of variance. *Austral Ecology* 26:32-46
- Ateweberhan M, Bruggemann JH and Breeman AM (2006) Effects of extreme seasonality on community structure and functional group dynamics of coral reef algae in the southern Red Sea (Eritrea). *Coral Reef* 25: 391-406
- Balata D, Acunto S and Cinelli F (2006) Spatio-temporal variability and vertical distribution of a low rocky subtidal assemblage in the north-west Mediterranean. *Estuarine, Coastal and Shelf Science* 67: 553-561
- Balata D, Piazzoli L, Cecchi E and Cinelli F (2005) Variability of Mediterranean coralligenous assemblages subject to local variation in sediment deposition. *Marine Environmental Research* 60: 403-421
- Benedetti-Cecchi L, Airoldi L, Abbiati M and Cinelli F (1998) Spatial variability in the distribution of sponges and cnidarians in a sublittoral marine cave with sulphur-water springs. *J. mar. boil. Ass. U.K.* 78: 43-58
- Connell JH, Hughes T and Wallace CC (1997) A 30-year study of coral abundance, recruitment, and disturbance at several scales in space and time. *Ecological Monographs* 67 (4): 461-488
- DeVantier LM, De'ath G, Turak E, Done TJ and Fabricius KE (2006) Species richness and community structure of reef-building corals on the nearshore Great Barrier Reef. *Coral Reefs* 25: 329-340
- English S, Wilkinson C and Baker V (1997) Survey Manual for Tropical Marine Resources, 2nd Edition. (Townsville: Australian Institute of Marine Science). 390pp
- Ferdegini F, Acunto S, Cocito S and Cinelli F (2000) Variability at different spatial scales of a coralligenous assemblage at Giannutri Island (Tuscan Arcipelago, northwest Mediterranean). *Hydrobiologia* 440: 27-36
- Hill J, Wilkinson C (2004) Methods for ecological monitoring of coral reef (Version 1). AIMS ed. 123pp
- Kennelly SJ and Underwood AJ (1992) Fluctuations in the distributions and abundances of species in sublittoral kelp forests in New South Wales. *Aust. J. Ecol.* 17: 367-382
- Littler MM (1980) Morphological form and photosynthetic performances of marine macroalgae: tests of a functional/form hypothesis. *Bot. Mar. Vol. XXII*:161-165
- Littler MM and Littler DS (1980) The evolution of thallus form and survival strategies in benthic marine macroalgae: field and laboratory tests of a functional form model. *Am. Nat.* 116: 25-44
- McArdle, B.H. & Anderson, M.J. (2001) Fitting multivariate models to community data: a comment on distance-based redundancy analysis. *Ecology* 82: 290-297
- Menconi M, Benedetti-Cecchi L and Cinelli F (1999) Spatial and temporal variability in the distribution of algae and invertebrates on rocky shores in the Northwest Mediterranean. *J. exp. mar. Biol. Ecol.* 233: 1-25
- Steneck RS and Dethier MN (1994) A functional group approach to the structure of dominated communities. *Oikos* 69:476-498
- Underwood AJ (1991) Beyond BACI: experimental designs for detecting human impacts on temporal variations in natural

- populations. *Australian Journal of Marine and Freshwater Research* 42: 569–587
- Underwood AJ (1992) Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. *Journal of Experimental Marine Biology and Ecology* 161:145–178
- Underwood AJ (1993) The mechanisms of spatially replicated sampling programmes to detect environmental impacts in a variable world. *Austral Journal of Ecology* 18: 99-116
- Underwood AJ (1994) On Beyond BACI: sampling designs that might reliably detect environmental disturbances. *Ecological Applications* 4: 3–15
- Underwood AJ and Chapman MG (1996) Spatial patterns of distribution of intertidal invertebrates. *Oecologia* 107: 212-224
- Underwood AJ and Petraitis PS (1993) Structure of intertidal assemblages in different locations: how can local processes be compared? In Ricklefs RE, Schluter D (eds) *Species diversity in ecological communities: historical and geographical perspectives*. University of Chicago Press, Chicago: 39-51
- Veron JEN (2000) *Corals of the World*. Australian Institute of Marine Science, Townsville.
- Wielgus J, Chadwick-Furman NE and Dubinsky Z (2004) Coral cover and partial mortality on anthropogenically impacted coral reefs at Eilat, northern Red Sea. *Marine Pollution Bulletin* 48: 248-253