F. Fava, M. Ponti, M. Abbiati

Centro Interdipartimentale di Ricerca per le Scienze Ambientali (CIRSA), Università di Bologna,
Via S. Alberto, 163 - 48123 Ravenna, Italia.
federica.fava8@unibo.it

COLONISATION PATTERNS ON THE CORALLIGENOUS OUTCROPS OF THE NORTHERN ADRIATIC SEA

DINAMICA DEI PROCESSI DI COLONIZZAZIONE SUGLI AFFIORAMENTI ROCCIOSI DELL'ADRIATICO SETTENTRIONALE

Abstract - *A long-term colonisation field experiment was carried out to investigate the ecological processes that could lead to the differentiation of the epibenthic assemblages on northern Adriatic subtidal biogenic outcrops. Early recruitment appears to be related to local larval supply, while post-settlement processes and lateral invasion from the surrounding assemblages play a major role in structuring the mature assemblages. The results of this study stress the complexity of the colonisation dynamics leading to the heterogeneity of the assemblages dwelling in the northern Adriatic biogenic outcrops.*

Key-words: *recruitment, benthos, species diversity.*

Introduction - Coralligenous subtidal outcrops occur in soft silty-sandy bottoms of the northern Adriatic continental shelf offshore Chioggia and Venice between 19 and 27 metres in depth. Their epibenthic assemblages, mainly characterised by calcareous algae, algal turf, sponges and colonial ascidians, can be distinguished in three main typologies. Previous studies showed that spatial heterogeneity of assemblages, at local and regional scales, prevailed over temporal variation. Spatial variability was related to the geo-morphological features of the outcrops and to environmental variables (Ponti *et al.*, 2011). However, complex recruitment processes and species interactions play a key role in structuring the assemblages and in maintaining their diversity (Connell, 1985; Osman and Whitlatch, 2004). In order to investigate the role of the recruitment processes in determining such variability, patterns of colonization have been studied in a 3-years field experiment.

Materials and methods - One outcrop belonging to each of the three main assemblage typologies found in the northern Adriatic Sea was randomly chosen (Fig. 1, Tab. 1). In August 2005, forty-eight travertine tiles (15.0×11.5×1.0 cm) were deployed at each study site in three random plots on the natural rocky bottoms. Tiles were photographically sampled using an Olympus Cammedia C-7070 WZ underwater digital camera (7 Mpixel) equipped with a TTL strobe and two 50 Watt halogen lights. Samples were collected in August 2006, August 2007 and August 2008. Four random samples for each plot and sampling date were analysed. Percent cover of sessile organisms was quantified by superimposing a grid of 100 equal sized squares and identifying all taxa visible within each quarter of these squares, corresponding to 0.25% of the total sampled area (Bianchi *et al.*, 2004). Percent cover was related to the total readable area of each image, obtained subtracting dark and blurred zone or portion covered by motile organisms. Organisms were identified to the lowest possible taxonomic level and assigned to morphological and ecological groups. The endolithic bioeroder bivalve *Gastrochaena dubia* (Pennant, 1777) was quantified by counting the siphon holes.

Differences in the colonisation pattern were analysed among dates (3 levels, random: 2006, 2007, 2008), sites (3 levels, fixed: P204, MR08, P213) and plots (3 levels, random, nested in sites). Distance-based three-way permutational analysis of variance (PERMANOVA; Anderson and ter Braak, 2003) was applied to the experimental
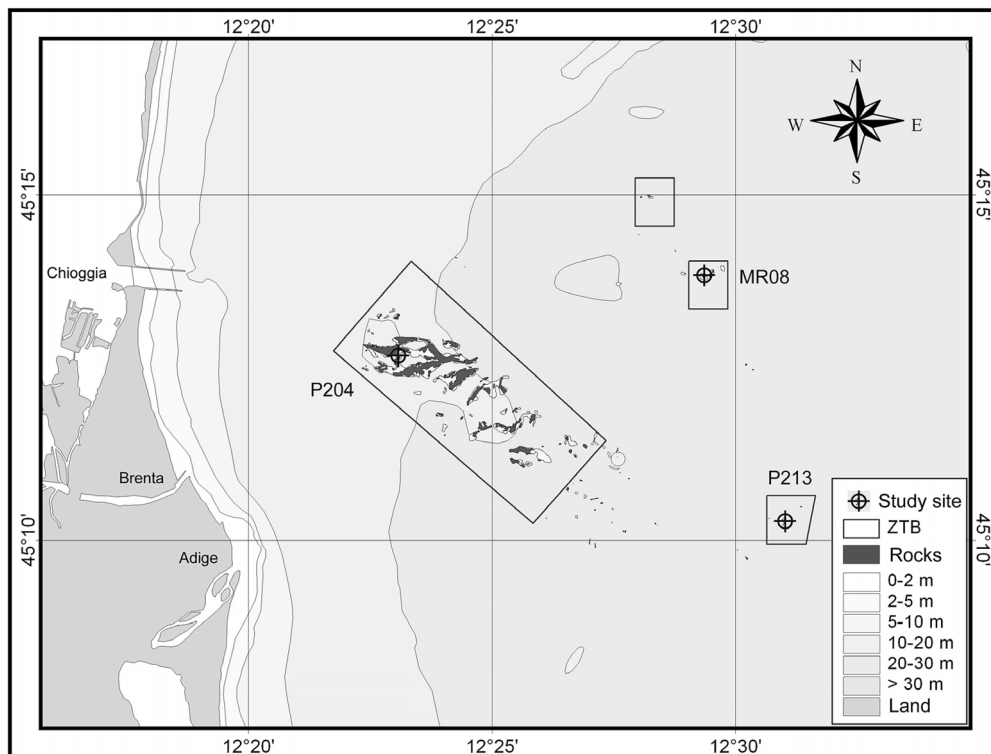
Fig. 1 - Map of the study area, showing the three investigated sites.
   Mappa dell'area di studio con indicati i siti investigati.

design to test for differences related to the investigated factors. Univariate analyses were based on the Euclidean distances on untransformed data, while multivariate tests were based on Bray-Curtis similarities on squared root transformed data. Similarities among assemblages were represented by principal coordinate analysis plot (PCO, Gower, 1966). The DISTLM forward procedure provided a selection of the species that better explain the observed similarity patterns (McArdle and Anderson, 2001).

Tab. 1 - Location (geographic coordinates, datum wgs84) and geo-morphological features (depth, distance from the coast, extent and height of relief) of the study sites.
   Posizione (coordinate geografiche, datum wgs84) e caratteristiche geo-morfologiche (profondità, distanza da costa, estensione ed altezza dell'affioramento).

Site	Lat N	Lon E	Depth (m)	Coast Dist. (km)	Extent (m²)	Height (m)
MR08	45° 13.831'	12° 29.354'	22.2	14.6	2096	1.5
P204	45° 12.674'	12° 23.076'	20.2	6.6	276297	2.2
P213	45° 10.270'	12° 31.013'	25.4	15.0	1288	1.2

Results - The analysis of the assemblages showed differences through years at both spatial scales: sites and plots (Tab. 2). The pair-wise test for the interactions

Date X Site highlighted a progressive site-specific temporal differentiation of the assemblages. Each site showed a divergent annual trend of the assemblages except for the P213 site whose assemblages in August 2008 seemed to be similar to those recorded in 2006. The taxa that mostly contributed to the differences among assemblages were the coralline algae *Lithothamnion minervae* Basso, 1995 and *Lithophyllum stictaeforme* (Areschoug in J. Agardh) Hauck, 1978 and the serpulid polychaetes at MR08, algal turf at P204 and the sponge *Tedania anhelans* Lieberkühn, 1859, the serpulid polychaetes and *Gastrochaena dubia* (Pennant, 1777) at P213 (Fig. 2). The
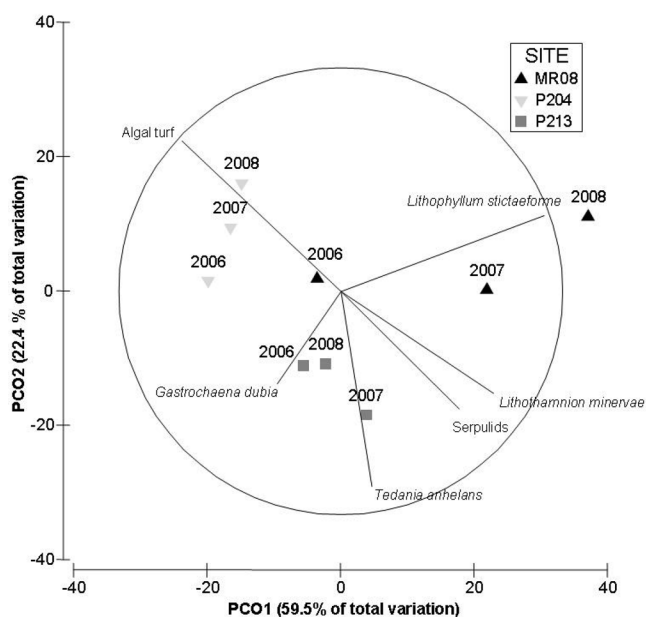

Fig. 2 - PCO ordination based on Bray-Curtis dissimilarities of square root-transformed tile assemblages percent cover data. Each point represented the centroid of the observed similarity among the interaction Date x Site, while the superimposed vectors represented the correlation of single taxa with PCO Axes.

Ordinamento PCO basato sulla similarità di Bray-Curtis calcolata sui ricoprimenti percentuali epibentonici trasformati con radice quadrata. Ciascun punto rappresenta il centroide delle similarità osservate nell'interazione Data x Sito, mentre i vettori sovrapposti rappresentano la correlazione dei singoli taxa con gli assi PCO.

Tab. 2 - PERMANOVA results based on Bray-Curtis similarities of square root-transformed epibenthic percent cover data.

Risultati dell'analisi PERMANOVA basata sulla similarità di Bray-Curtis calcolata sui ricoprimenti percentuali epibentonici trasformati con radice quadrata.

Source	df	SS	MS	Pseudo-F	*P*(perm)	Unique perms
Date (Da)	2	10029	5015	4.531	0.003	9949
Site (Si)	2	31057	15529	2.962	0.012	9933
Plot(Si)	6	21921	3654	3.301	0.001	9910
Da x Si	4	9881	2470	2.232	0.016	9932
Da x Plot (Si)	10	11068	1107	2.049	0.000	9839
Res	75	40510	540			
Total	99	127190				

percent cover of algal turf varied through years among sites (PERMANOVA: Da x Si *P*<0.01 and Pl(Si) *P*<0.01) in particular in the first year it showed similar low density at all sites, while in 2007 and 2008 it increased at P204 site and strongly decreased at MR08 and P213. The calcareous algae *L. minervae* (PERMANOVA: Da x Pl(Si) *P*<0.01) and *L. stictaeforme* (PERMANOVA: Da x Si *P*<0.01) showed low densities at the beginning, increasing with time, especially in the site MR08. Early colonisers, like serpulid polychaetes (PERMANOVA: Da x Pl(Si) *P*<0.01), were particularly abundant in the first year, then they decreased with time showing high variability at small spatial scale.

Conclusions - Recruitment dynamics of sessile assemblages on artificial substrates varied both at local and regional spatial scales. During the 3 years of study, an increasing differentiation among the assemblages colonising the artificial substrata was observed. While early recruitment are generally influenced by local larval supply (Underwood and Fairweather 1989), post-settlement processes and lateral invasion from the surrounding assemblages played a major role in structuring the mature assemblages of the investigated northern Adriatic coralligenous outcrops. Long-term colonisation processes could be affected by several environmental condition that vary among sites at regional scale. The water turbidity at P204, due to the closeness of the rivers and of Venice Lagoon, could promote the development of algal turf. Instead, the major density of calcareous algae in the MR08 assemblages, located far from the coast, was probably favoured by lower sedimentation rates and higher level of irradiance (Ponti *et al.*, 2011). The complex colonisation dynamics contribute to maintain the overall heterogeneity of the assemblages inhabiting the northern Adriatic biogenic outcrops.

References

ANDERSON M.J., TER BRAAK C.J.F. (2003) - Permutation tests for multi-factorial analysis of variance. *J. Stat. Comput. Sim.,* **73**: 85-113.
BIANCHI C.N., PRONZATO R., CATTANEO-VIETTI R., BENEDETTI-CECCHI L., MORRI C., PANSINI M., CHEMELLO R., MILAZZO M., FRASCHETTI S., TERLIZZI A., PEIRANO A., SALVATI E., BENZONI F., CALCINAI B., CERRANO C., BAVESTRELLO G. (2004) - Hard bottoms. In: Gambi M.C., Dappiano M. (eds), Mediterranean marine benthos: a manual of methods for its sampling and study. *Biol. Mar. Mediterr.*, **11** (Suppl.): 185-216.
CONNELL J.H. (1985) - The consequences of variation in initial settlement vs. post-settlement mortality in rocky intertidal communities. *J. Exp. Mar. Biol. Ecol.,* **93**: 11-45.
GOWER J.C. (1966) - Some distance properties of latent root and vector methods used in multivariate analysis. *Biometrika,* **53**: 325-338.
McARDLE B.H., ANDERSON M.J. (2001) - Fitting multivariate models to community data: a comment on distance-based redundancy analysis. *Ecology,* **82**: 290-297.
OSMAN R.W., WHITLATCH R.B. (2004) - The control of the development of a marine benthic community by predation on recruits. *J. Exp. Mar. Biol. Ecol.,* **311**: 117-145.
PONTI M., FAVA F., ABBIATI M. (2011) - Spatial-temporal variability of epibenthic assemblages on subtidal biogenic reefs in the northern Adriatic Sea. *Mar. Biol.,* **158** (7): 1447-1459.
UNDERWOOD A.J., FAIRWEATHER P.G. (1989) - Supply-side ecology and benthic marine assemblages. *Trend. Ecol. Evol.,* **4**: 16-20.