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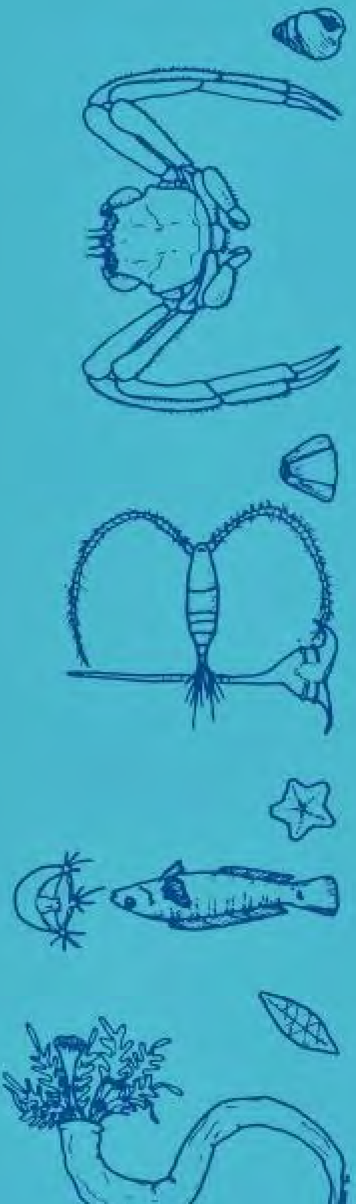

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51° S.I.B.M.

CONGRESSO ON LINE

14-17 GIUGNO 2022

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BENTHIC ASSEMBLAGES OF BIOGENIC REEFS IN THE NORTHERN ADRIATIC SEA: SYNTHESIS AND NEW INSIGHTS

POPOLAMENTI BENTONICI SUGLI AFFIORAMENTI ROCCIOSI DELL'ALTO ADRIATICO: SINTESI E NUOVE CONOSCENZE

Abstract *- Biogenic reefs in the northern Adriatic Sea have a high ecological and economic value, but they are subject to different impacts and require more protection. Here we reviewed recent literature on biogenic reefs and presented new data on their diversity, connectivity and the potential factors affecting species distribution. Results showed that biogenic reefs have a high spatial heterogeneity primarily driven by hydrodynamic factors and nutrient loads. Connectivity simulation helped to explain this diversity and stressed that current protection measures should be extended to other important sites for species dispersal.*

Key-words: *macrobenthic communities, connectivity, temperate reefs, coralligenous, Mediterranean.*

Introduction - Biogenic reefs in the northern Adriatic Sea are considered a hotspot of biodiversity (Ballesteros, 2006) with a great economic value for the ecosystem services they provide (Tonin, 2018). At present, different studies have assessed their genesis and the environmental factors affecting their assemblages (*e.g.* Ponti *et al.*, 2011; Falace *et al.*, 2015). However, since the reefs in this region are numerous and heterogeneous, many remain unexplored and much information is still needed to enhance their protection. In this note, we summarized past studies that assessed benthic assemblages of northern Adriatic biogenic reefs, integrating them with new data on community structure and composition, connectivity and bio-geophysical factors accounting for their spatial variability.

Materials and methods - The text was organized into three sections describing: 1) diversity and habitat typology; 2) environmental factors influencing species distribution; 3) hydrodynamic connectivity. In the first two sessions, we reviewed primary literature (Ponti *et al*., 2011; Falace *et al*., 2015 and references therein) and presented new data on composition and cover of species collected between 2014 and 2017 by photographic sampling (ten random photo-quadrates, 17×26 cm) at each of 21 reefs (Fig. 1). To identify groups of sites with similar taxa, we applied a fuzzy k-means (FKM) clustering method. A redundancy analysis (RDA), applied to the results of the FKM and performed as in Falace *et al*. (2015), was used to model the relationship with hydrodynamic, abiotic and morphological variables. Data on hydrodynamic variables (yearly mean and maximum velocity and mean kinetic energy of currents) and physicochemical variables [yearly median, fifth (P5) and ninety-fifth (P95) percentile of chlorophyll, temperature, salinity, NH_4, NO_3, PO_4, dissolved oxygen] at the surface and bottom were obtained as described in Falace *et al*. (2015). We used P5 and P95 instead of the absolute minimum and maximum values to avoid possible biases. Morphological data of the reefs (depth, height, extent and distance from the coast) were obtained as in Ponti *et al*. (2011). Connectivity among these biogenic reefs has never been assessed and we presented results of recent simulations (Bandelj *et al.*, 2020) between 10 coastal segments and 33 reefs (filled circles in Fig. 1), using the LTRANS Zlev model (Laurent *et al*., 2020). Different pelagic propagule durations (PPDs) (3 hours, 1 day, 3 days, 1 week, 2 weeks, 1 month) were considered to account for different reproductive and spreading habits of species. Passive particles were released from each reef and coastal segment (nodes) for all PPDs over the whole three-month seasons. Connectivity graphs were constructed with the graph analysis method (Carrington *et al.*, 2005) and we calculated three structural measures: connectedness (*Conn*), graph hierarchy (*Hier*) and redundancy (*Red*) (Everett and Krackhardt, 2012). To select the nodes that guarantee the highest network connectivity, we first calculated the individual importance of each node using the M-reach closeness centrality and then we applied the keyplayer algorithm (An and Liu, 2016). The final subset of nodes was chosen considering how many times each node is selected in each season and PPD. Analyses were performed in R.

Results - *Diversity and habitat typology*. A total of 573 taxa are reported in literature: 191 seaweeds and 382 invertebrates. In our sampling, a high number of taxa (92) was also recorded, with species richness varying between 3.5±0.4 to 15.1±1.2 (mean±SE) taxa among sites. 'Sponges' was the category more representative with 31 taxa, followed by 'Ascidians' (16 taxa), 'Reef builders' (14 taxa) and 'Turf' (9 taxa). Four taxa were classified as 'Bioeroders' and 'Non-calcareous (NC) encrusting algae'. Past studies and the results of the FKM clustering agreed on classifying biogenic reefs in three habitat typologies according to the dominant taxa. A first cluster comprises sites closer to the coast, in front of Chioggia (Fig. 1), characterized by opportunistic and stress-tolerant species: algal turf (*e.g. Antithamnion* spp.), encrusting sponges and bioeroders of the genus *Cliona*. On the contrary, reef builders are abundant at sites far from the coast and deeper, mainly represented by coralline algae (*e.g. Lithophyllum* spp.), serpulids and some Anthozoa. The third group includes sites with intermediate characteristics, mainly located offshore Grado, dominated by sponges, NC encrusting algae (*Peyssonnelia* spp.) and ascidians.

Environmental factors. An onshore-offshore gradient, caused by the river inflows and nutrient loads, is the main responsible factor for the differences of the reefs (Ponti *et al*., 2011; Falace *et al.*, 2015). The RDA model (R^2 adj=0.82) confirmed this gradient: sites near Chioggia are clearly influenced by the mean kinetic energy of currents and the P5 of chlorophyll at the surface, the P95 of PO_4 at the bottom, sedimentation and mud sediments. Contrarily, the other groups of sites, dominated by sensitive species, are located relatively offshore, where the effect of these factors is reduced. The median salinity, the P95 of temperature and the P5 of NH_4 at the surface, positively influence sites offshore Grado. Presence of sites of the third group was not clearly explained by the model, being negatively affected by these factors and positively influenced by the P5 of chlorophyll at the surface.

Connectivity. At short PPDs the system is made by several disconnected subgraphs and isolated nodes. Coastal segments are connected for short PPDs, but disconnected from the reefs until PPD of 3 days. At higher PPDs, the connectivity graphs are more complex, and it is more difficult to analyse them visually (Fig. 2). *Conn* increases with PPDs and the graphs resultes fully connected at PPD 1 day in autumn and 3 days in the other seasons. *Hier* is high for PPDs up to 3 days, meaning that particles mainly moved in one direction between nodes (asymmetry). Contrarily, symmetric relationships between the nodes predominated at higher PPDs. The lowest *Red* values were at PPDs up to 3 days, while the highest at PPDs 1 month, when all nodes were connected. The keyplayer procedure selected 16 reefs as the most important for species dispersal, each 8 or more times for all seasons and PPDs. Only 5 of them are currently protected (Fig. 1).

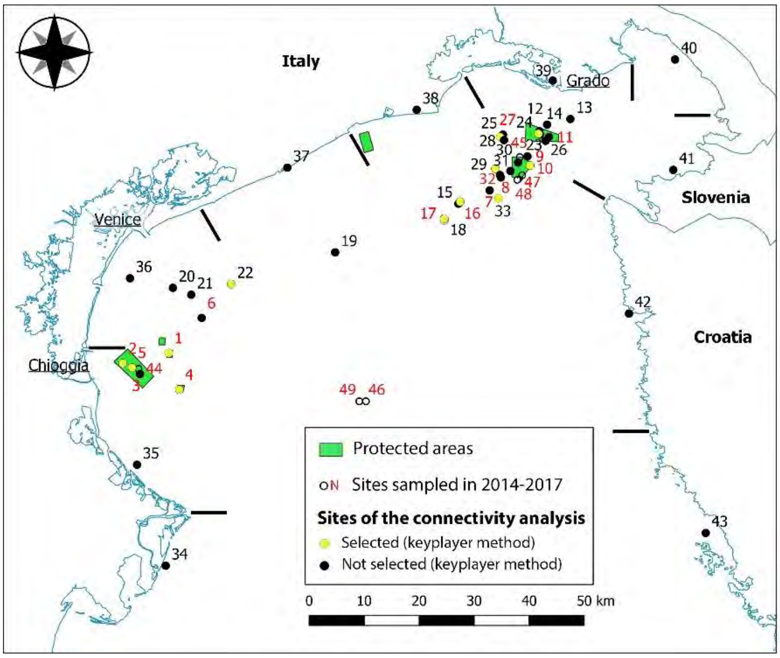

Fig. 1 - Study reefs.
Affioramenti studiati.

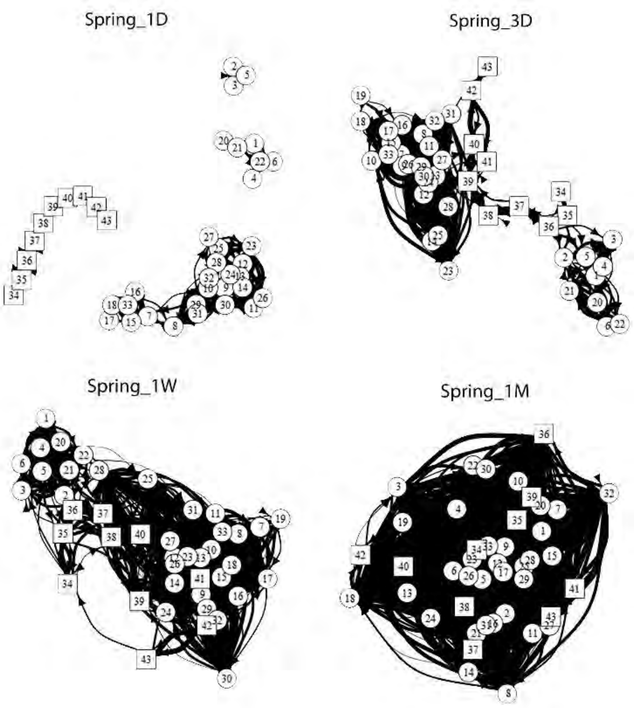

Fig. 2 - Connectivity graphs for different PPDs in spring (numbers as in Fig. 1). Circles=biogenic reefs, squares=coastal segments.
Grafici di connettività per diverse PPD in primavera (numeri come in Fig. 1). Cerchi=affioramenti, quadrati=tratti costieri.

Conclusions - Results obtained in our sampling agreed with previous studies showing an ecological gradient as the distance from the coast increases. However, part of the variability among the outcrops rests unexplained. Likely, the interaction among the environmental factors and other impacts plays a crucial role that deserves further investigations. Hydrodynamic connectivity may also explain the observed differences, since up to 3 days biogenic reefs and the mainland are split in subgroups, thus different meta-community dynamics can be expected. Our analysis also showed that the current protection is not representative since it does not include the 'key-outcrops' that better guarantee cross-scale connectivity. The establishment of a protected area network, including highly connected reefs, should be the primary goal for the conservation of these habitats.

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