J. Mar. Biol. Ass. U.K. (2006), **86**, 5103/1–2
Printed in the United Kingdom

A method to measure three-dimensional substratum rugosity for ecological studies: an example from the date-mussel fishery desertification in the north-western Mediterranean

Valeriano Parravicini*, Alessio Rovere, Marco Donato, Carla Morri and Carlo Nike Bianchi

DipTeRis, Dipartimento per lo studio del Territorio e delle sue Risorse, Università di Genova, Corso Europa 26, 16132 Genoa, Italy.
*Corresponding author, e-mail: vparravicini@libero.it

The impact of the date-mussel fishery on substratum rugosity was evaluated at Capo Noli and Isola di Bergeggi (Savona, north-western Italian coast) in summer 2004. A new measure of substratum rugosity was used as a surface-dependent index of complexity. The results were compared between impact and control sites using 2-way analysis of variance and suggested that the mussel fishery reduces substratum complexity.

One of the human activities that endanger the biodiversity of Mediterranean rocky reefs is the collection of European date-mussel, *Lithophaga lithophaga* (Linnaeus), a bivalve living within carbonatic rocks (Bianchi & Morri, 2000). The mussel fishery causes the removal of the epibenthic assemblages covering the rock, with the obvious consequence of the desertification of vast areas of shallow subtidal rocks. The recovery of the epibenthic assemblages is rather slow because of sea urchins grazing off newly settled propagules (Fraschetti et al., 2001). The removal of the sessile biota together with the portion of rock to which they adhere was also shown to reduce the complexity of the substratum (Devescovi et al., 2005).

Many studies confirmed the negative effects of substratum smoothing on the biological diversity of the benthic community (e.g. Jacobi & Langevin, 1996 and references therein). Bulleri (2005) suggested that the settlement of invertebrate and algal propagules can be affected by the topography of the substratum at a number of spatial scales. High rugosity of the substratum facilitates the settlement of propagules that get trapped in a particular microhabitat simply due to passive transport. The reduced complexity of the substratum caused by the date-mussel fishery is therefore likely to hamper propagule settlement, thus reducing rocky reef biodiversity for a long time after the desertification. Low substratum complexity will also reduce the occurrence of refuges for settled propagules, thus increasing the incidence of predation (Bulleri, 2005).

In this paper, we propose a new index for measuring substratum rugosity and test the hypothesis that *Lithophaga lithophaga* fishery affects habitat complexity. We carried out a survey in the area of Capo Noli–Isola di Bergeggi during the summer of 2004. The surveyed area was divided into 'impact' and 'control' situations according to the practice of date-mussel fishery. For each situation, 4 sampling sites were selected randomly. In each site, three sampling quadrats were randomly placed at about 5 m depth.

To measure substratum rugosity in both impacted and control sites, we developed a three-dimensional method that adopts the same quadrats currently used to estimate the cover of the sessile epibiota (Bianchi et al., 2004). We placed 50×50 cm wire-frame quadrats on subvertical surfaces; these quadrats were in turn divided into 25 equal squares by a nylon line. With a millimetre ruler positioned at the 36 vertices of the 25 squares perpendicularly to the quadrat plane, we measured the distance of the quadrat plane from the actual substratum. The resulting data set was interpolated using the Delaunay triangulation algorithm (Lee & Schachter, 1980) to obtain the surface area of the substratum underlying each quadrat (Figure 1). Then we calculated the surface rugosity index S_r according to the following formula:

$$S_r = (S_c/S_p) - 1 \quad (1)$$

where, S_c is the calculated surface area of the substratum underlying the quadrat frame and S_p is the projected surface area (i.e.

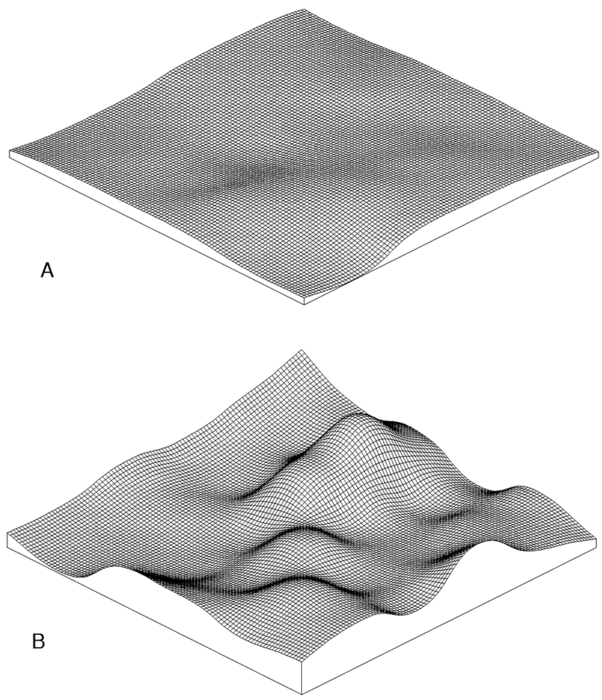

Figure 1. Substratum surfaces obtained using the Delaunay triangulation algorithm for (A) an impacted-site quadrat; and (B) for a control-site quadrat.

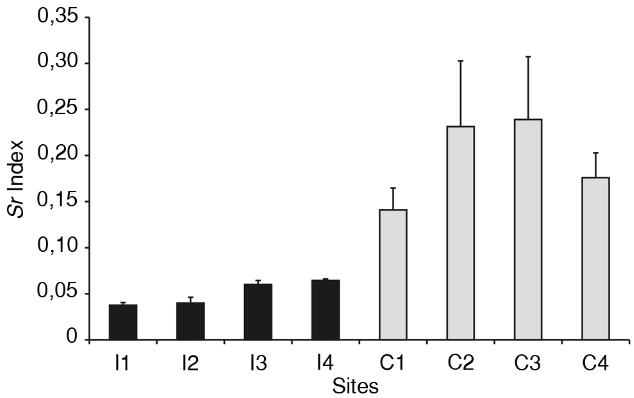

Figure 2. Mean values (+SE) of the S_r index for each site.

Table 1. *Results of 2-way analysis of variance on the three-dimensional substratum rugosity index* S_r *(Cochran's test, C = 0.461, not significant).*

Source	SS	DF	MS	F	*P*	F versus
Situation	0.128	1	0.128	36.12	0.001	Site (situation)
Site (situation)	0.021	6	0.004	0.28	0.937	Residuals
Residual	0.201	16	0.013			
Total	0.350	23				

the area of the quadrat itself), in this case 2500 cm^2. The subtraction of 1 makes this index range from 0 (completely smooth surface) to, theoretically, +8. In this study, the maximum value of S_r was 0.48, in a control site, and the minimum was 0.02 in an impacted site. In general, all control sites turned out to exhibit higher S_r values (Figure 2) than impacted sites. Despite high variability of substratum rugosity in control sites, only differences between situations were significant (Table 1). Although preliminary, these results clearly evidenced that the date-mussel fishery causes significant reduction in substratum complexity, with all the likely consequences on rocky reef biodiversity.

Most published measurements of substratum rugosity are simply linear, in that they use chain transects or related techniques (Bianchi et al., 2004). The method here developed not only was of rapid application in the field and contextual to the survey of epibenthic cover, thus allowing the collection of both substratum and biotic data in a single instance, but also proved efficient in providing a three-dimensional estimation of substratum rugosity, rather than the linear measure of the traditional methods.

REFERENCES

Bianchi, C.N. & Morri, C., 2000. Marine biodiversity of the Mediterranean Sea: situation, problems and prospects for future research. *Marine Pollution Bulletin*, **40**, 367–376.

Bianchi, C.N. et al., 2004. Mediterranean marine benthos: a manual of methods for its sampling and study. 6: Hard bottoms. *Biologia Marina Mediterranea*, **11** (suppl. 1), 185–215.

Bulleri, F., 2005. Experimental evaluation of early patterns of colonisation of space on rocky shores and seawalls. *Marine Environmental Research*, **60**, 355–374.

Devescovi, M., Ozretić, B. & Iveša, L., 2005. Impact of date mussel harvesting on the rocky bottom structural complexity along the Istrian coast (Northern Adriatic, Croatia). *Journal of Experimental Marine Biology and Ecology*, **325**, 134–145.

Fraschetti, S., Bianchi, C.N., Terlizzi, A., Fanelli, G., Morri, C. & Boero, F., 2001. Spatial variability and human disturbance in shallow subtidal hard substrate assemblages: a regional approach. *Marine Ecology Progress Series*, **212**, 1–12.

Jacobi, C.M. & Langevin, R., 1996. Habitat geometry of benthic substrata: effects on arrival and settlement of mobile epifauna. *Journal of Experimental Marine Biology and Ecology*, **206**, 39–54.

Lee, D.T. & Schachter, B.J., 1980. Two algorithms for constructing a Delaunay triangulation. *International Journal of Computer and Information Sciences*, **9**, 219–242.

Received ●●●. *Accepted* ●●●.