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Environmental Design of Low Crested Coastal Defence Structures

Deliverable 38

WP 3.2

Identification of design features to minimise bioerosion of breakwaters

Contract n°EVK3-CT-2000-00041

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5. Bioerosion in natural marine systems

Bioerosion is a well known phenomena observed on carbonate-based substrata such as limestone and coral reefs. A large variety of species can bioerode the substratum, including microroganisms, algae, marine invertebrates and fish. These species can abrade, scrape and bore the rock using mechanical action (e.g. with teeth) and chemical (e.g.secretion of acid substances). The intensity of bioerosion varies with latitude; in tropical waters bioerosion causes serious problems for the conservation of coral reefs (see for a comprehensive review, Hutchings, 1986).

Bioerosion caused by microroganisms can be relatively important on rocky shores. Some microorganisms including various kinds of bacteria, fungi, algae and protozoa can promote rock erosion by boring the surface and speeding rock weathering by mobilising mineral constituents with inorganic or organic acids or ligands that they excrete (Ehrlich, 1998). Endolithic micro-organisms are an often neglected component of microbial communities in marine environments. A wide variety of micro-organisms are able to bore into rock. These include microalgae (Peyrot-Clausade *et al.*, 1995) and fungi (Schneider, 1976).

Microboring organisms consist primarily of cyanobacteria, although green and red algae and fungi can also actively penetrate carbonate substrates (Perkins and Tsentas, 1976; Schneider, 1976; see for reviews Golubic *et al.*, 1975; Hirsch *et al.*, 1995) and the pore spaces of granite and sandstone (Hirsch *et al.*, 1995). It is widely recognised that cyanobacteria play an important role in bioerosion, by dissolving the carbonate and indirectly by increasing the porosity of a substrate which subsequently becomes more vulnerable to attack by macroborers and abrasion by grazers (Le Campion-Alsumard, 1989). It is widely accepted that blue green algae are the most important cause of erosion of limestone coasts (e.g. Purdy and Kornicker, 1968; Schneider, 1976). Potts and Whitton (1980) observed that endolithic blue-green algae grow very rapidly in limestone.

The boring mechanisms and the consequent dissolution of carbonate material is not well known, although it seems endoliths secrete acid substances (Le Campion-Alsumard, 1975). Alexandersson (1975) demonstrated that cyanobacteria can dissolve carbonate by means of specialised organelles. In intertidal systems, cyanobacteria may penetrate rock surfaces up to a depth of 1-2 mm (Schneider, 1976), although maximum density is generally around 0.4 mm depth. On limestone shores blue-green algae are found at all tidal heights, where they can remove up to 50% of the upper 400 μm of rock surface (Donn and Boardman, 1988). Colonisation of new substrata by endolithic microalgae is quite rapid; cyanophytes appear after 8-9 days, and after 1 month the endolithic diversity increased significantly and some species penetrated the rock up to 30-50 microns (Le Campion-Alsumard, 1975). Endolithic microalgae also represent an important source of food for many grazers including molluscs, echinoderms and fish, which rasp, bite and scrape away a thin layer of rock using specialised feeding structures (Warme, 1977; Ogden, 1977; Trudgill, 1987; Hawkins *et al.*, 1989), thus increasing rock erosion.

Macroborers are very common in tropical waters and include sponges, poychaete, sipunculids, and bivalves (Macintyre, 1984, Hutchings, 1986). The abundance and distribution of these species is regulated by physical factors such as wave exposure, tidal level, geographical location and sedimentation (Peyrot-Clausade and Brunel, 1990; Hutchings and Peyrot-Clausade, 2002). Macroboring organism have an important impact not only on degradation and destruction of carbonate rocks but also increase the fine sediment production (Acker and Risk, 1985).Biological factors such as grazing can, however influence the composition of boring communities and also the erosion rates (Perry, 1998). Macroerosion has been observed also along the Mediterranean coasts (Sartoretto, 1998).

2. Bioerosion in artificial reefs (including coastal defences)

Bioerosion on artificial reefs has been little investigated. Most of studies focussed on erosion of marine wooden structures (Santhakumaran, 1969; Gara and Greulich, 1995, Sipe *et al.*, 2000). The main group of wood borers is represented by shipworms. These are bivalves belonging to the family Terenidae. Their capacity to bore into wood results in dramatic economic losses due to damages to wooden structures in both marine and estuarine systems worldwide (Nair, 1959; Sipe *et al.*, 2000). Several species of Crustaceans are also responsible for damages to pilings and jetties, as shown by Santhakumaran (1969) in the Lagoon of Venice.

No literature is available on bioerosion effects on rocky artificial structures. The potential effects of bioerosion were therefore investigated during the broad scale survey on LCS and coastal defence structures during year 1 and 2 in the UK and in Italy at a local scale (Gulf of La Spezia).

3. Results from the broad scale survey

In the UK during the broad scale survey carried out in year 2001 and 2002 more than 80 coastal defence structures were sampled. Twenty-six structures were made of granite, five consisted of a mixture of concrete units and limestone blocks and the rest were made of limestone blocks only (see D35 and D46 for details). Each structure was screened for any sign of bioerosion, represented by bore holes, rasp and graze marks. No sign of bioerosion was detected in any structure surveyed. Some small bore holes were observed only on two series of rock groynes in Cristchurch, and Poole Bay, South of England. On these groynes the limestone blocks showed very small holes (<0.5 cm diameter, <0.3 cm depth) on the seaward face at mid intertidal level. These holes, although relatively dense (approximately 0.5/cm^2), are completely irrelevant in terms of stability of the groynes. Considerable erosion due to weathering was observed on the limestone blocks, especially those on the exposed side of the groynes. This can be due to the type soft limestone used for the construction. No relevant weathering was observed on the other coastal defences made of limestone. Similarly granite and concrete structure did not show any sign of physical or biological erosion.

A similar result was obtained during the broad scale survey carried out by FF along the Adriatic coast in Italy (see D35 and D46). Bioerosion was not detected in any structure surveyed.

4. Results from a qualitative study on the off-shore breakwater in the Gulf of La Spezia, Thyrrhenic Sea, Italy.

In summer 2003, a qualitative study was carried out by the MBA on the off-shore breakwater in the Gulf of La Spezia, Italy. This breakwater was chosen because seriously affected by bioerosion. The breakwater was initially built in 900’ and is approximately 2km long. It consists of large limestone blocks, approximately between 2 and 3m in diameter. In the subtidal, rocks are colonised by various macroborers including bivalves, polychaetes and crustaceans. These organisms secrete acidic substances to create holes of different diameters and depths. The holes are used to host the organisms, mainly as a protection and for feeding. Macroborers start excavating holes in the rock at the early stages of the life cycle. As a consequence, hole created by the same species can vary greatly in size.

A quantitative sampling of the rocks eroded by macroborers in the subtidal was not allowed for safety and technical reasons, as professional divers are required. However, a semi-quantitative assessment of the extent of bioerosion was carried out on the blocks lying on the top of the breakwater. These were old blocks that were removed from the submersed part of structures and re-allocated on the top. Bioerosion was therefore indirectly estimated by counting and measuring the holes left by the dead boring organisms. Ten blocks were inspected and for each rock 5 quadrat 25x25cm were placed randomly on the surface. The percentage cover of the holes of bivalve (Large holes), polychaetes (medium holes) and crustaceans (small holes) was recorded. Also the amount of rock destroyed by macroborers was estimated on selected holes. For each type of holes ten areas were sampled and in each area the volume of 5 holes wasestimated. Two methods were used. The first method used the measures of diameter and depth of holes to calculate the volume. Alternatively the volume was estimated by filling the holes with water and then calculating the relative volume of water. In some case however, this second method was not reliables as the holes were communicating.

Bore holes made by bivalves were the most abundant on the rock surface, as shown in Figure 1. The percetage cover of small and medium holes was much lower. However large variability in the distribution and abundance of bore holes was observed between and within blocks (Figure 2). As shown in Figure 3 the amount of rock destroyed in large holes is quite important, whilst the in the medium and small size holes is irrelevant. In rocks densely colonised by these macroborers the erosion effect could be important leading to potential problems for the stability of the structures. In the case of the breakwater in La Spezia, however, this risk is quite low due to the very large size of the building blocks.

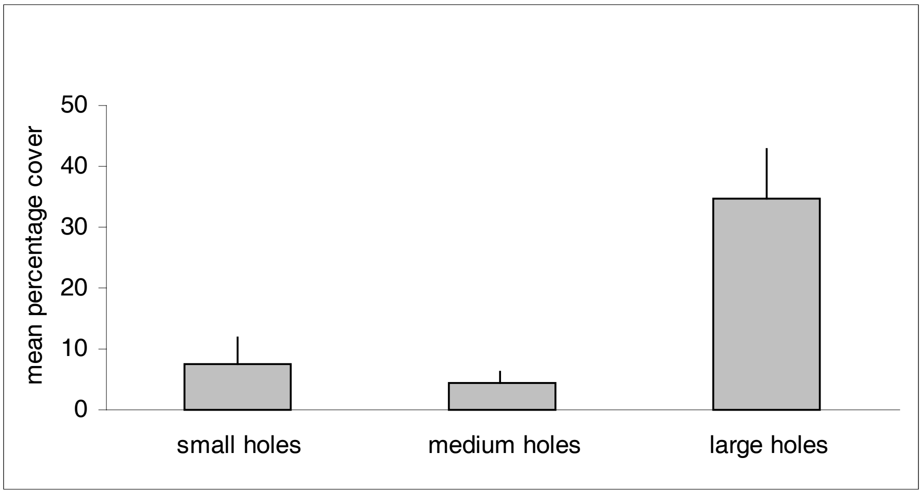

Figure 1 – Mean percentage cover of holes observed on the rock surface of limestone blocks on the offshore breakwater of La Spezia Gulf. Small holes were created by probably amphipods, medium holes by polychaetes and large holes by the bivalves.

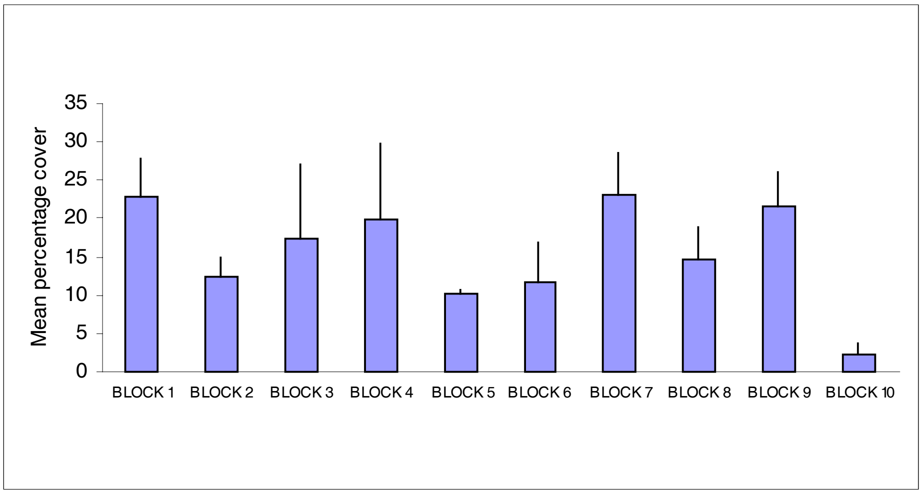

Figure 2 – Mean percentage cover of holes observed on the rock surface of each limestone blocks on the offshore breakwater of La Spezia Gulf.

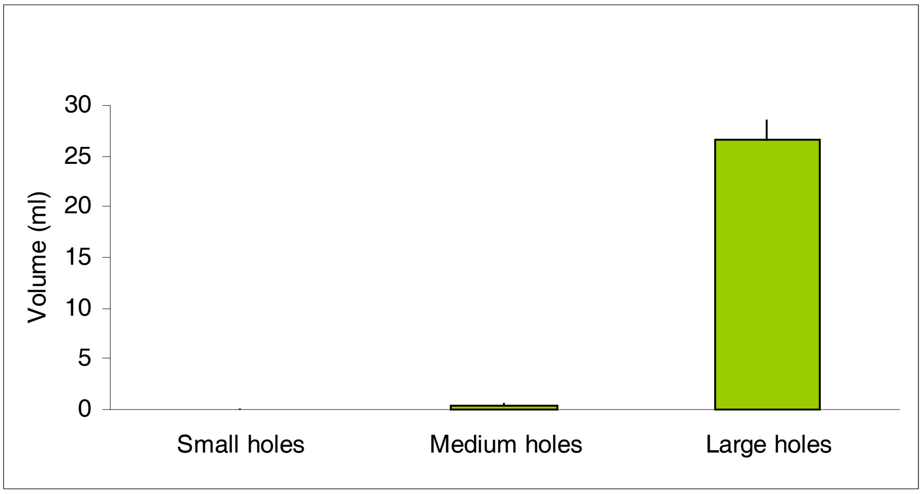

Figure 3 – Mean volume (ml) per holes of rock destroyed by the different types of macroborers on the offshore breakwater of La Spezia Gulf. Large holes are those created by bivalves. Medium by poluchaetes and small by amphipods.

Conclusions

- Bioerosion can have detrimental consequences for carbonate substrates, as widely assessed on coral reefs. This however seems not to be the case on coastal defences. This is because most of the structures are built in granite, concrete and very hard limestone, thus this rock substratum is not suitable for boring organisms.

- Secondly, in temperate waters bioerosion seems limited only to certain geographical locatios. No bioerosion was observed in several coastal defence structures in UK and Italy (Adriatic coast).

- When bioerosion occurs on artificial structures, the effects on stability are still relatively small and limited to the surface layer, not deeper than10 cm. However, using a different material or larger blocks can counter balance the loss of rock eroded.

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