ECOLOGICAL MAPPING FOR THE PREVENTIVE CONSERVATION OF PREHISTORIC MURAL PAINTINGS IN ROCK HABITATS: THE SITE OF FILIANO (BASILICATA, ITALY)

Giulia Caneva*, Marco Tescari, Flavia Bartoli
Dip. Scienze, Università degli Studi Roma Tre, Viale Marconi 446, Roma, Italia

Maria Pia Nugari, Anna Maria Pietrini
Istituto Superiore Conservazione e Restauro, Via di San Michele 22, Roma, Italia

Ornella Salvadori
Lab. Scientifico Polo Museale Veneziano, Cannaregio 3553, Venezia, Italia

Keywords: mural paintings, biodeterioration ecology, rock settlements, water mapping

1. Introduction

The conservation of mural paintings in rocky habitats may be affected by several environmental factors, such as infiltrations of rainwater, condensation, presence of salts [1]. These phenomena are also linked to the use of caves as human and animal shelters and to their close contact with soil, often enriched with organic nutrients, etc. [2]. It is in these conditions that biodeterioration phenomena frequently occur. Photosynthesising organisms prevail when lighting conditions are sufficient, but colonization due to heterotrophic organisms becomes more evident when enrichment of organic material occurs [3].

The literature gives more or less detailed information on the prevalent taxonomic composition of such communities. However, little information exists on the ecology of the different biodeterioration patterns, but is nevertheless important for preventive and long-lasting conservation. In fact, such knowledge can help in assessing the best environmental conditions to be maintained and those to be avoided [4].

Rinaldi's shelter in Filiano, which is of high value due to the significant traces of Palaeolithic age paintings, is an emblematic case of the delicate balance, achieved throughout the centuries, between the environment and artwork.

The aim of this study is to analyse the ecological aspect of such biodeterioration phenomena, in order to contribute to the correct planning of conservation activities.

2. Study area

Rinaldi's shelter is located in Filiano, in the anthropological reserve in the Southern Apennine hilly belt (Basilicata, Italy). The reserve is characterized by a dense forest canopy with a predominance of turkey oak (*Quercus cerris*), together with other deciduous species, such as *Carpinus betulus*, *Fraxinus ornus*, *Q. pubescens, Q. frainetto, Acer pseudoplatanus* probably already present at the time of the settlement.

* Corresponding author: giulia.caneva@uniroma3.it

The prehistoric paintings, made with pigments identified as red ochre based on haematite, were executed following the oldest kind of parietal art technique, which consisted in laying the colours directly on the rock walls without any previous plastering.

The anthropic use of the shelter is evident from the diffuse blackening of carbonaceous matter mixed with sulphur, probably due to fire traces. Moreover a widespread presence of phosphate and calcium oxalate can be related to the accumulation of bird's guano and of grazing animals' excrements. The occurrence of widespread concretionary layers appears as the result of dissolution and re-crystallization cycles of the carbonaceous sandstone cement triggered by water permeating into the sediment [5].

During the multi-millennial history of the site, a part of the ceiling made of calcareous sandstone collapsed, reducing the functions of the shelter and exposing the pictures to more aggressive environmental conditions.

Macroclimatic conditions changed during this period, with cycles of warm and cold periods.

Today, the average annual temperature is around 12.5°C; February is the coldest month, with 3.1°C and August is the warmest with 21.0°C. Often during the winter season below-zero values are registered, which can lead to the formation of ice that favours the rise of fractures in the lithic substrate. The average annual rainfall is around 684.3 mm, with a high concentration in autumn and winter and the lowest values in summer, the typical trend of a Mediterranean bioclimate. The prevailing winds come from the Western quadrants and those associated with rain come from the Eastern and Western quadrants.

Figure 1. Rinaldi's shelter and the dense forest cover surrounding it.

3. Methodology

In order to investigate the nature of the biodeterioration phenomena, various samples of the main alterations observed *in situ* were collected. In the case of phototrophic microflora, taxonomic characterization was carried out by observation, under optical microscope, of the morpho-anatomic features of microorganisms and cultural analyses, as described in a previous study [2]. For lichens and vascular plants, identification was carried out following the usual analytical characters by microscopy observation.

In the case of endolithic growth forms, polished cross sections were prepared in order to observe and measure the possible deep penetration of the organisms.

After identification of the communities, their distribution was also determined through surveys in the field and photographs. Ecological evaluation of the different biodeterioration patterns was then carried out by accessing different data bases [6-8]. The data of the biodeterioration pattern distribution were used to highlight the gradient of the most relevant limiting factor. The distribution of the community was also used to calculate the risk of stone damage relating to each community by taking into consideration structural and physiological characteristics, as referred from the literature.

4. Results

The distribution of the different weathering patterns observed in such rich environments seems mostly linked to the gradients of water and its variations (Figure 2b). Light, that is highly relevant for photosynthesising organisms, seems here to have a secondary role. The forest favours the sciaphylous species, but light is not a limiting factor. The most hygrophylous species are clearly mosses and ferns, concentrated along the percolation lines. The lichen cover, such as the green algae, is also favoured by high humidity. Cyanobacteria prevail in the xeric conditions. The most xerophylous species are however the microcolonial fungi (MCF) penetrating into the substrate, whose growth is also favoured by the enrichment of nutrients typical of the forest habitat. They probably also cause the high spread of calcium oxalate patinas in different areas of the rocks.

The major part of the deterioration phenomena detected in the area close to the shelter are, however, not linked to the development of photosynthetic microflora. The few species found belong to a community of cyanobacteria (*Chroococcus lithophilous*, *Gloeocapsa sanguinea*, *Calothrix parietina* e *Lyngbya* sp.) and of eukaryotic microalgae *(Pleurococcus vulgaris e Muriella terrestris*), ubiquitarian components of the microbial communities which develop over ground or rock surfaces.

The development of black meristematic fungi, as a most xerotolerant microflora, is detectable as little superficial black spots, in some areas near the paintings. Such fungal species are frequently found on lithic materials exposed to the open air in hostile environmental conditions [9].

5. Conservative interventions

The presence of black meristematic fungi close to the painted area is the most critical phenomenon for conservation of the paintings. Special attention, however, should be given to the presence of vascular plants which can be found in the narrower areas (Figure 2a). In fact, the roots of the plants tend to penetrate through the part with less resistance, giving way to the breaking of rocks. Some species, such as *Quercus cerris* and *Fraxinus ornus* show, in general, a high level of potential aggressiveness, but for the moment this risk is not highly relevant. On the contrary, the neighbouring forest covering seems to exert a protective effect from the erosion caused by the prevailing winds and the effects of sun radiation.

It can be hypothesized that in the prehistoric age some kind of biological colonization may already have taken place, but the high level of dryness in the vertical and sheltered areas prevented its biological development.

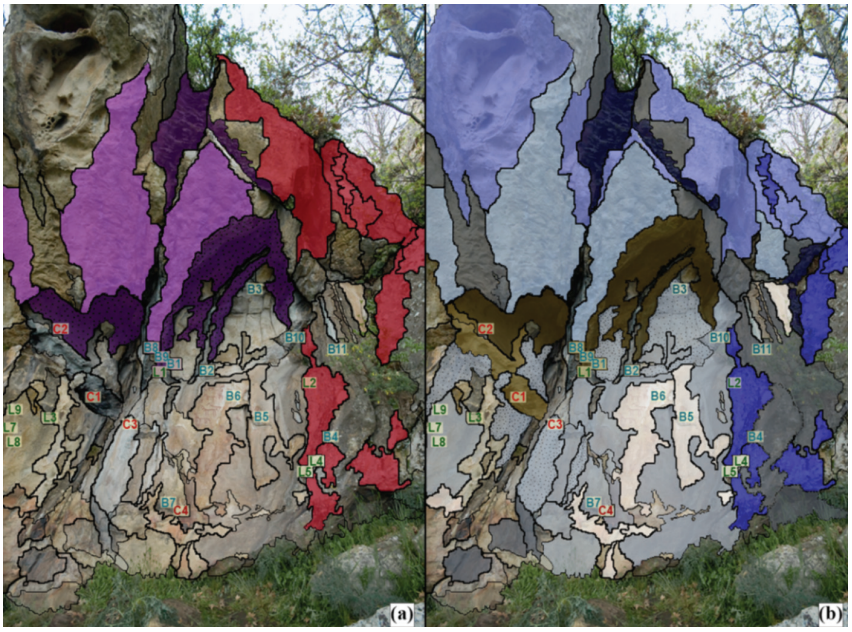

Figure 2. (a) Several biodeterioration patterns and other weathering forms: the red areas correspond to the most dangerous colonization, due to lichens and higher plants; the violet areas correspond to the highest algal growth, and the dark violet areas show an accumulation of carbonaceous particles. (b) Water mapping according to a blue-gray gradient: mosses and ferns in areas with the highest water input, followed by lichens, green algae, cyanobacteria and microcolonial fungi.

Today, due to the fragile balance of the shelter, and in spite of some limited protection, it has nevertheless partially collapsed. It would be advisable to intervene with extreme caution in changing such ecological conditions, acting especially on improving seepage of watercourses near the painted area by diverting them away from the mass of stone. This intervention will have to be carried out above the shelter, by altering the flow of water.

Building a cover which could further remove the risk of water seepage during rain phenomena has to be studied carefully and should avoid excessively modifying existing microclimatic conditions, which could cause the formation of micro air currents and possibly give rise to evaporation phenomena.

On the other hand, a protective covering from the rain could be an effective barrier from chemical and biological weathering processes which could interfere with the endolithic growth already established on the site.

6. Conclusions

Taking into account biological components in rocky habitats, an ecological approach, which considers the micro-climatic conditions and the diversity of biodeterioration patterns, plays a central role in preventive conservation.

A forward-looking risk assessment is necessary in the case of a complex and important site such as Filiano. The ecological mapping, which considers the biodeterioration pattern distribution according to the gradient of the limiting factors, is a powerful tool for the analysis of site conditions. When biological colonization is relevant, a map based on the ecological characteristics of species must form the core of any conservation plan.

Aknowledgments

This work was supported by grants from the Zetema foundation (Matera).

References

[1] Caneva G., Nugari M.P., Salvadori O., (2008) *Plant Biology for cultural heritage*. Los Angeles: Getty Conservation Institute.

[2] Caneva G., Nugari M.P., Pietrini A.M., Salvadori O., Tufano M., Lombardozzi V., (2010) Biodeterioration problems of mural paintings in rock habitat: the prehistoric site of Filiano (Basilicata, Italy). In: Ferrari et al. (eds.), *Science and Technology for the Safeguard of Cultural Heritage in the Mediterranean Basin,* 4th Int. Congress, Cairo, 2009, vol. II, pp. 95-98.

[3] Nugari, M.P., Ricci, S., Roccardi, A., Monte, M., (1998) Chiese ed Ipogei, in Mandrioli P., Caneva G. (eds.), *Aerobiologia e beni culturali*, Nardini, Fiesole, pp. 229-246.

[4] Caneva, G., Bartoli, F., Ceschin, S., Salvadori, O., Futagami, Y., Salvati, L., (2015) Exploring ecological relationships in the biodeterioration patterns of Angkor temples (Cambodia) along a forest canopy gradient, *Journal of Cultural Heritage*, **16(5)**, pp. 728-735.

[5] Giovagnoli, A., Paradisi, A., Polidoro, A., Ricci, M.A., Santonico, G., Sodo, A., (2010) Alteration and decay study of a rock painting in outdoor exposure. The "Riparo di Tuppo dei Sassi" at Filiano *(PZ)*, in Ferrari et al. (eds*.), Science and Technology for the Safeguard of Cultural Heritage in the Mediterranean Basin*, 4th Int. Congress, Cairo, (2009) vol. II, pp. 99-102.

[6] Nimis, P.L., (1987) *I macrolicheni d'Italia: chiavi analitiche per la determinazione*, Museo friulano di storia naturale.

[7] Guiry,M.D. & Guiry, G.M., (2015) AlgaeBase, World-wide electronic publication, National University of Ireland, Galway, http://www.algaebase.org.

[8] Ellenberg, H., (1988) *Vegetation Ecology of Central Europe*, 4th Ed. Cambridge: Cambridge University Press.

[9] Onofri, S., Zucconi, L., Isola, D., Selbmann, L., (2014) *Rock-inhabiting fungi and their role in deterioration of stone monuments in the Mediterranean area*, Plant Biosystem, **148**, pp. 384-391.

Biographical notes

Giulia Caneva, full professor of Botany and Vegetation ecology c/o Science Department of Roma Tre University, Director of the University Centre for Studies of Rome (CROMA). Coordinator of the Applied Botany group of *Società Botanica Italiana* (SBI)

and *Ordine Nazionale Biologi* (ONB) member of the Cultural Heritage Committee. Author of several publications and monographs on the conservation of works of art.

Maria Pia Nugari, biologist and former Director of the Scientific Laboratory of the Istituto Superiore per la Conservazione ed il Restauro (MiBact). Author of monographs and numerous scientific publications on the biodeterioration of art works.

Anna Maria Pietrini, biologist and Director of the Phycology Area, Biology Laboratory of the Istituto Superiore per la Conservazione ed il Restauro (MiBact). Author of numerous scientific publications on the biodeterioration of stone.

Marco Tescari, degree in "Genetics and Molecular Biology" at the University "La Sapienza" of Rome; PhD student at the Univ. "Roma Tre", dealing with the characterization of biodeteriogens microorganisms of stone monuments.

Flavia Bartoli, degree in "Ecosystems Management and Biodiversity" at the University "Roma Tre", PhD on the conservation of cultural heritage by biological colonization.

Ornella Salvadori, biologist, Director of Lab. Scientifico Polo Museale Veneziano. Author of monographs and numerous scientific publications on the biodeterioration of art works.

Summary

Biodeterioration phenomena are of great relevance in rock settlements, due to favourable environmental conditions, such as the infiltration of rainwaters, condensation phenomena and abundance of salts and organic nutrients. Rinaldi's rock shelter in Filiano, which is located in a natural forest of mixed oaks is of great value due to the important traces of prehistoric paintings. It is an emblematic case of the delicate balance, achieved throughout the centuries, between the environment and artwork. During the plurimillenarian history of the site, a portion of the ceiling that covered the shelter collapsed, leaving signs that are still visible today, together with traces of blackening left by the fires of ancient settlements. Several of the biodeteriogens typical of rocky habitats have already been detected and include algae, cyanobacteria, mosses, lichens, vascular plants and fungi, which form macroscopic communities.

Each community has an ecological preference and the mapping of their distribution is a suitable tool for understanding variations in the environmental factors that most affect them. Relating ecological data to the taxonomical characterization of the species and to the spatial distribution of each community, a site map of the humidity and of the nutrients was obtained. Among the various communities, microcolonial fungi (MCF), which appear as little black spots, here, represent the most critical risk factor, due to their low water needs. An evaluation of the biological risk for the possible future attack of such a biological community was made, suggesting indirect mitigation measures, through modification of the microclimatic and local ventilation conditions.

Riassunto

I fenomeni di biodeterioramento causati da condizioni ambientali favorevoli, come infiltrazioni di acqua piovana, fenomeni di condensazione e abbondanza di sali e nutrienti organici, sono di grande importanza negli insediamenti rupestri. Il rifugio Rinaldi, all'interno di un habitat forestale naturale a querceto misto presente nella località di Filiano, rappresenta un sito di particolare importanza per la presenza di pitture preistoriche. Il sito costituisce un caso emblematico del delicato equilibrio raggiunto attraverso i secoli, tra ambiente e opera d'arte. Sono oggi visibili le tracce del collasso di parte della volta che copriva il rifugio e i segni di annerimento causati dai fuochi degli antichi insediamenti. Sono stati già individuati molti dei biodeteriogeni tipici dell'habitat roccioso, come alghe, cianobatteri, funghi, licheni, muschi e piante vascolari, che formano comunità individuabili macroscopicamente. Ogni comunità ha una propria preferenza ecologica e la mappatura della loro distribuzione è uno strumento utile per capire le variazioni dei fattori ambientali maggiormente incidenti. Applicando le informazioni ecologiche alla caratterizzazione tassonomica delle specie e alla distribuzione spaziale di ogni comunità, è stata costruita una mappatura dell'umidità e della presenza di nutrienti nel sito. Fra le varie comunità, i funghimicrocoloniali (MCF), che appaiono come piccoli spot neri, rappresentano il maggior fattore di rischio del sito a causa del loro scarso bisogno d'acqua. È stata effettuata anche una valutazione del rischio biologico legato alla loro presenza, suggerendo delle misure di mitigazione indiretta tramite la modificazione del microclima e delle condizioni di ventilazione locali.