HERITAGE 2018

Proceedings of the 6th International Conference on Heritage and Sustainable Development

10th Anniversary Edition

VOLUME 2

Edited by

Rogério Amoêda
Sérgio Lira
Cristina Pinheiro
Juan M. Santiago Zaragoza
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Fabián García Carrillo

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In Memoriam
Professor Gregory Ashworth

(1941-2016)

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Foreword

Heritage 2018 - 6th International Conference on Heritage and Sustainable Development celebrates the 10th anniversary of Heritage Conferences. As the previous editions *HERITAGE 2018* aimed at maintaining a state of the art event regarding the relationships between forms and kinds of heritage and the framework of sustainable development concepts, namely the framework of the 2030 Agenda for Sustainable Development.

However, the four dimensions of sustainable development (environment, economics, society and culture) are, as in the past, the pillars of this event defining an approach on how to deal with the specific subject of heritage sustainability. Furthermore, beyond the traditional aspects of heritage preservation and safeguarding the relevance and significance of the sustainable development concept was to be discussed and scrutinised by some of the most eminent worldwide experts.

For a long time now, heritage is no longer considered as a mere memory or a cultural reference, or even a place or an object. As the previous editions of "Heritage" (2008, 2010, 2012, 2014 and 2016) have proven, heritage is moving towards broader and wider scenarios, where it often becomes the driven forces for commerce, business, leisure and politics. The Proceedings of the previous editions of this conference are the "living" proof of this trend.

As stated by some the Sustainable Development Goals of the 2030 Agenda, the role of cultural and social issues keeps enlarging the statement where environment and economics had initial the main role. The environmentalist approach (conceiving the world as an ecological system) enhanced the idea of a globalised world, where different geographic dimensions of actions, both local and global, emerged as the main relationships between producers, consumers and cultural specificities of peoples, philosophies and religions. In such a global context heritage became one of the key aspects for the enlargement of sustainable development concepts. Heritage is often seen through its cultural definition and no further discussion seams to be appropriate. However, sustainable development brings heritage concepts to another dimension, as it establishes profound relationships with economics, environment, and social aspects.

Nowadays, heritage preservation and safeguarding is constantly facing new and complex problems. Degradation of Heritage sites is not any more just a result of materials ageing or environmental actions. Factors such as global and local pollution, climate change, poverty, religion, tourism, commodification, ideologies and war (among others) are now in the cutting edge for the emerging of new approaches, concerns and visions about heritage. Recent events in the Middle-East and other parts of the World are saddling proving the rightness of these assertions and deserve our attention.

Thus, *HERITAGE 2018 - 6th International Conference on Heritage and Sustainable Development* proposed a global view on how heritage is being contextualised in relation with the four dimensions of sustainable development. What is being done in terms of research, future directions, methodologies, working tools and other significant aspects of both theoretical and fieldwork approaches were the aims of this International Conference. Furthermore, heritage governance, and education were brought into discussion as key factors for enlightenment of future global strategies for heritage preservation and safeguarding.

A special chapter on Preservation of Muslim heritage was included in this edition because of its singular and utmost significance and because the Venue of this edition was the city of Granada, one of the most extraordinary places to understand and feel the merging of cultures, arts and traditions. When religious and cultural issues are raising significant misunderstandings Heritage 2018 aimed at contributing to a valid, peaceful and fruitful discussion under the broad umbrella of sustainable development goals.

Authors submitting papers to Heritage 2018 were encouraged to address one of the topics of the Conference by providing evidence on past experience and ongoing research work. As a result, Heritage 2018 welcomed a significant number of papers and presentations addressing field work and case studies but also theoretical approaches on a diversity of thematic. As in the previous editions Early Stage Researchers were welcome to share the results of their research projects, namely post-graduation projects and doctoral projects, among others.

The Organising Committee also expresses its gratitude to all Members of the Scientific Committee who reviewed the papers and made suggestions that improved the quality of individual work and the over-all quality of the event.

The editors would like to express their gratefulness to all the partners and sponsors of this edition of Heritage who joined the effort to make a significant Conference. Our special word or recognition to the University of Granada that joined efforts with Green Lines Institute to make this event. Also to the Municipality of Granada, to the Bureau of Tourism of Granada and to the Council of the Alhambra and Generalife our recognition for their participation.

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Changes in the Alhambra Palaces algal biodeterioration after 25 years

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ABSTRACT: The architectural complex of the Alhambra in Granada is an important part of our cultural heritage, both for its historical and artistic relevance. Selected as UNESCO World Heritage Site in 1984, it is currently one of the most visited monuments in Europe. In order to preserve it, constant conservation and restoration activities are needed. An important deterioration agent that affects cultural heritage is microalgae, which are capable of colonizing and modifying stone, especially those sites with high humidity or in which water is present, like the numerous fountains, ponds and channels in the Alhambra. Microalgae form biofilms and mats that cause aesthetic alterations on stone, as well as harmful chemical and physical changes like, for instance, mineral crust formation. In the present paper, we analyze the microalgal colonization and the state of conservation of the most relevant fountains in the Nasrid Palaces of the Alhambra, and we compare it with the state of conservation and colonization they presented 25 years ago. Samplings have been carried out to identify the different species present on the fountains and to assess any modification on algal communities after this period of time, during which fountains have been subjected to different treatments and restoration processes. Presence of microalgae on the fountains and the characteristics of their communities after 25 years can serve as an indicator of the utility of the treatments employed for conservation. Despite some fountains have experienced an improvement regarding colonization in relation to the past, there are no significant changes regarding the type of the most persistent and mineralizing microalgae. It should be noted that the problem of algal colonization has not disappeared, and it would be very interesting to address it with an eye to the future.

1 INTRODUCTION

The beginning of the construction of the Alhambra dates back to the IX century. However, it was Al-Ahmar, founder of the Nasrid Dynasty, who decided to establish in it the Court's Headquarters in 1238 and began the reconstruction of the Alhambra, starting the construction of the building we know today. Water has a fundamental role in Nasrid and Islamic art in general, and consequently this architectural complex contains a large and diverse number of fountains, canals, spouts, ditches and ponds that are affected by microalgal colonization.

Microalgae are one of the most important biodeterioration agents of ornamental fountains, mainly due to the presence of water. The alterations caused by these organisms are usually related to the formation of biofilms on the stone. These biofilms are composed by the own microalgae and a combination of substances excreted by them, and they promote several mechanisms that lead to deterioration of the underlying substratum. For instance, the stone surface loses cohesion because of the contraction and expansion of these biofilms, and this causes the detachment of stone fragments from the original material and its adhesion to said film. This is one of the mechanisms (apart from other exclusively biological mechanisms) by

which microalgae create mineral crusts composed primarily of calcium carbonate (Peraza et al., 2005). An additional problem with biofilms and mineral crusts is that, once they have formed, they protect microorganisms from adverse conditions, such as drying or the effects of biocides, if they are present. In addition to physical damage, microorganisms also contribute to chemical deterioration with the release of metabolic products such as organic and inorganic acids. In conclusion, microalgae deteriorate stone over time and they cause a number of chromatic, physical and chemical alterations that pose a problem in the maintenance of the fountains and other artistic and cultural goods.

In this work we have studied the state of conservation of the most representative fountains of the Alhambra and their colonization by microalgal communities, and we have compared it with the state they presented 25 years ago. Because of its greater historical and artistic value, we have focused on the most relevant fountains of the Nasrid Palaces. We have studied the fountain of the Court of the Golden Room (also called the fountain of the Mexuar), the northern and southern fountains of the Court of the Myrtles, the Fountain of the Lions and the fountain of the Court of Lindaraja.

The fountain of the Court of the Golden Room is inside the Mexuar (derived from the Arabic term Maswar, the place where the Counsel of Ministers met). It is located in the center of the courtyard, which is connected to the Golden Room on the north. It is a gallonade fountain of 2 meters in diameter located over a slightly sunken hexagonal base. This fountain was placed here in 1943 to replace another fountain that is still preserved today: the gallonade basin of the Fountain of Lindaraja. Apparently, when it was placed, the base on which it is settled was also rebuilt (Bolívar, 1994).

The fountains of the Court of the Myrtles, commonly known as "guitars" because of their shape, are located at the north and south ends of a large pool, in the center of the Palace of Comares. Both fountains are schematic basins with a gargoyle through which the water flows into the pool.

The Fountain of the Lions gives its name to the courtyard where it is located, which is in turn located inside of the Palace of the Lions. This is probably the most emblematic monumental fountain of the Alhambra. As it is today, this fountain consists of a twelve-sided sculpted and inscribed basin of 2'52 meters in diameter which appears to be supported by twelve lions that spurt water from their mouths, although actually it is supported by a simple central cylinder.

The fountain of the Court of Lindaraja was constructed in 1626, using the basin that was located in the Court of the Golden Room of the Mexuar. It is located in the Court of Lindaraja, at the exit of the Palace of the Lions. The gallonade basin, of 2 meters in diameter, is positioned on the top of a pilaster placed inside another basin whose shape is the intersection of a square and a circle.

Both the fountain of the Mexuar and the fountains of the Court of the Myrtles receive general mechanical cleaning periodically and algaecide treatment. On the fountain of Lindaraja, in addition to these treatments, chlorine tablets are used in the water. The Fountain of the Lions has its own purified and chlorinated water system, as well as being cleaned on a daily basis.

2 MATERIALS AND METHODS

2.1 *Studied material*

We have studied a total of five fountains, all made of white Macael marble. For each fountain, we focused on one specific area for the sampling and the study of the state of conservation. The considered areas were the following: 1) The marble jet of the Fountain of the Mexuar. 2) The surface of the curb of the North Guitar of the Court of the Myrtles.3) The gargoyle of the South Guitar of the Court of the Myrtles. 4) The inner surface of the basin of the Fountain of the Lions. 5) The outer surface of the elevated basin of the Fountain of the Court of Lindaraja. For the comparative study of the state of conservation, photographs of all these areas were taken and they were compared with photographs of the same areas from 25 years ago taken from the doctoral thesis of Bolívar Galiano (1994).

2.2 *Sampling*

With the permission of the competent authorities from the Council of the Alhambra and Generalife, representative samples of epilithic microalgae were collected from our five areas of study using scalpel and pliers in July of 2017. The samples were then fixed in a solution of glycerol and glutaraldehyde 25% for their conservation and further examination.

2.3 *Identification of algae*

For the identification of the different algae, all the samples were examined by stereoscopic microscope and optical microscope; the different species were identified using the following keys and taxonomic identification works: Bourrelly (1966), Bourrelly (1970), Komárek and Anagnostidis (1998), Bolívar Galiano and Sánchez Castillo (1999), Komárek and Anagnostidis (2005) and Komárek (2013). Each species forming the algal communities were quantified by the assignment of an index (+ - 5) depending on their proportion in the sample. The indexes represent the following percentages in relation to the total: + = 0-1%; 1 = 1-10%; 2 = 10-25%; 3 = 25-50%; 4 = 50-75%; 5 = 75-100%. The results were compared with those obtained from samplings carried out in the same time of the year 25 years ago by Bolívar Galiano (1994). These samplings took place between July and August of 1992 and 1993.

2.4 *Algal cultures*

Some of the samples were cultured in solid medium for the identification of certain groups of microalgae. The cultures were elaborated in agar plates with BBM medium for the culture of green algae, and BG11 medium for the culture of cyanobacteria. We used an agar concentration of 2%.

3 RESULTS

The algal populations that colonize the fountains generally give rise to epilithic formations (that is, which grow on the stone) visible to the naked eye. They form films, pustules or mats of different colour schemes depending on the species that form them.

In the fountain of the Court of the Golden Room we studied the marble jet of the fountain, which is composed of two differentiated bodies: the upper one above the water, and the lower one, which is bigger and whose cross section goes from star-shaped to square at the base. In 1992 the jet presented pitting (loss of matter in the form of small cavities) on its horizontal surfaces, inside of which there were, in addition, pustular communities of algae. It also had cracks in its base, and it was clogged due to the proliferation of organisms and sediments on the inside. It presented incrustations of pustular communities and stromatolitic algae, and crustal accretion on its submerged area (Fig. 1a). This fountain was restored in January 2017, so currently it presents hardly any alterations. The clog and the cracks have been repaired, and the marble jet is much cleaner, without biological crusts (Fig. 1b). However, the pitting is still present on the upper body, although there are no longer algal communities associated with it. In July 2017 samples were taken from the surface of the marble jet that was submerged in the water of the basin. The concavities of the lower body of the jet presented a green film constituted by an apparently unialgal population of the genus *Apatococcus* (coccoid green algae). About 25 years ago, in the same area, a complex community of microalgae was found, in addition to the genus *Apatococcus*. This community included pustules, mats and crusts, and the following species were predominant: the filamentous cyanobacteria *Phormidium favosum*, *Phormidium uncinatum*, *Lyngbya* sp and *Oscillatoria* sp; the coccoid cyanobacteria *Chamaesiphon* sp and *Pleurocapsa minor*; the filamentous green algae *Stigeoclonium* sp; and diatoms such as *Gomphonema* sp, *Nitzschia* sp and *Fragillaria* sp.

In the north fountain of the Court of the Myrtles we focused on the curb of the basin. In 1992 it presented concretions and pustules of algae on its outer surface caused by splashing of the jet, as well as loss of matter in the form of pitting and disintegration, and peeling. The curb was covered with a casmolithic greenish brownish film (that grew on cracks and fissures) (Fig. 2a)

formed by populations of *Chlorogloea microcystoides* (coccoid cyanobacteria) and *Schizothrix gomontii* (filamentous cyanobacteria). At the present moment, the concretions and the biological film have been eliminated, and no superficial growth of any type of algae is observed. However, the stone is still quite deteriorated, presenting pitting, disintegration and peeling (Fig. 2b).

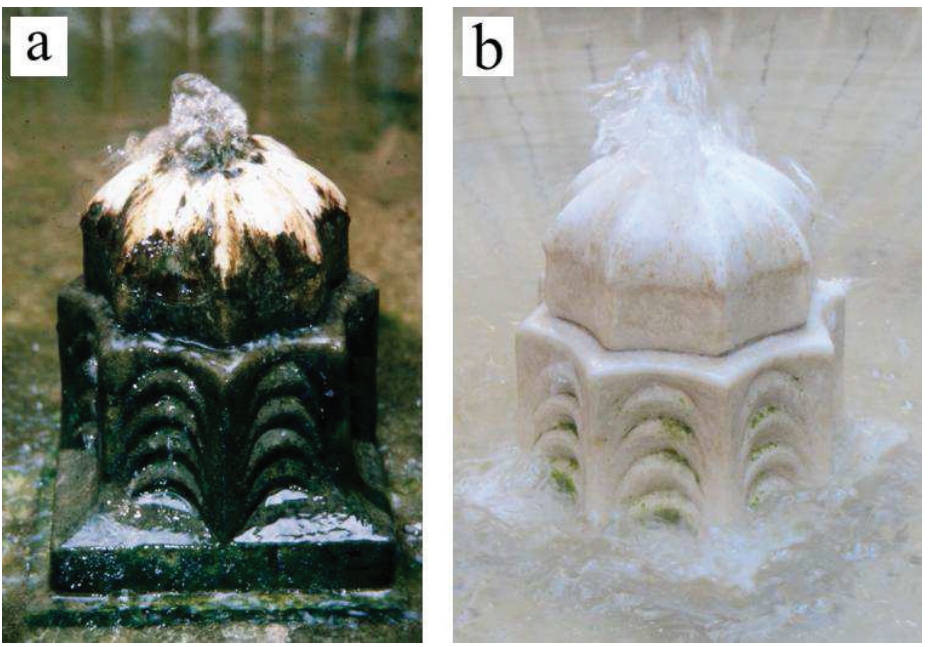

Figure 1. Comparison of the marble jet of the fountain of the Mexuar. a) year 1992; b) year 2017.

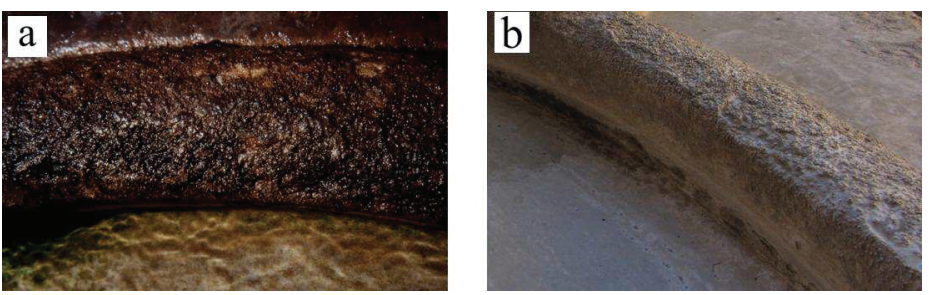

Figure 2. Comparison of the curb of the north fountain of the Court of the Myrtles. a) year 1992; b) year 2017.

In the South Fountain of the Court of the Myrtles, we studied the state of the gargoyle. 25 years ago there was crustal accretion, especially on the horizontal surface of the gargoyle, submerged in the water, as well as algal growth (Fig. 3a). At the present moment the state of the gargoyle has not changed significantly: it still presents green films, mineral crust and superficial deposits, especially at its end (Fig. 3b). We took samples of the mineral crusts from the inner surfaces of the gargoyle, both from the horizontal surface, which is submerged under the water that flows into the pool, and from the vertical surface, which is a more amphibious area. Said crusts were mainly constituted in the present by the following species: the filamentous cyanobacteria *Phormidium* sp, the coccoid cyanobacteria *Chlorogloea* sp, and diatoms of the genera *Cymbella* and *Navicula*. About 25 years ago, the predominant species found in the same

area were the following: *Phormidium subfuscum* and *Phormidium uncinatum* (filamentous cyanobacteria), *Pleurocapsa minor* (coccoid cyanobacteria), the filamentous green algae *Cladophora* sp and *Leptosira trombi* and diatoms such as *Achnanthidium* sp and *Navicula* sp. In this area, algae growth has persisted and, although there have been changes in the populations, some types of algae remain stable.

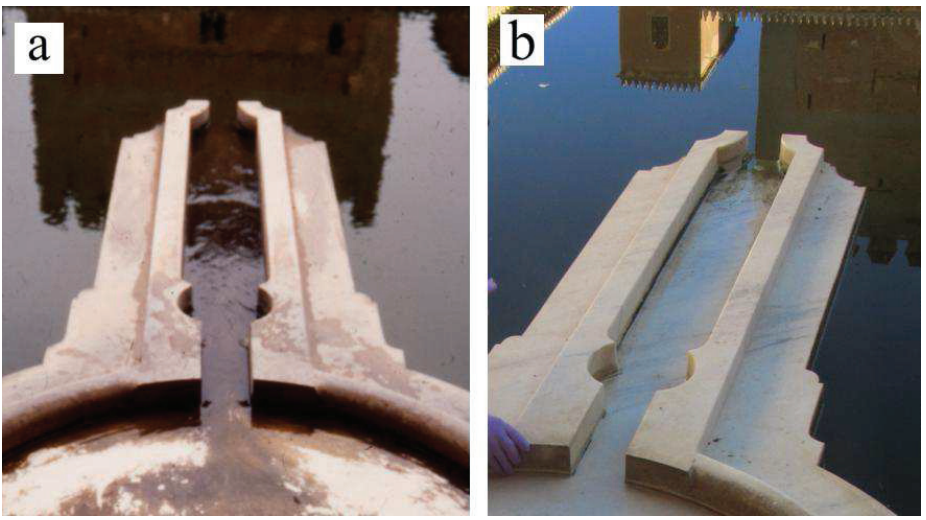

Figure 3. Comparison of the gargoyle of the south fountain of the Court of the Myrtles. a) year 1992 b) year 2017.

In the Fountain of the Lions we studied the inside of the basin in both periods of time. In 1992 the inner surface of the basin presented a stratified biological film of variable coloration (mainly olive green) (Fig. 4a). A multi-colored crust was also present on the horizontal surface of the step located just below the water level. The predominant species in this crust were: the filamentous cyanobacteria *Phormidium calidum* and *Calothrix elenkinii*, and the filamentous green algae *Oedogonium* sp and *Cladophora* sp. At the present moment, this is one of the fountains that present least algal growth. Due to its importance, it is more thoroughly maintained in comparison to other fountains, and the basin is very clean (Fig. 4b). In 2017 samples were taken from the amphibious area of the inner vertical surface of the basin and no species of algae were found in summer; however, a remarkable population of a diatom species (*Achnanthidium* sp) was found in a vertical submerged area in a later sampling, on February 2018.

Finally, in the fountain of the Court of Lindaraja, we focused on the outer surface of the marble gallonade basin that is elevated on a pilaster made of limestone from Sierra Elvira. In 1992, a predominantly green biological film and chromatic alterations such as limonitisation (colorations associated with the oxidation of iron minerals) were found in the basin (Fig. 5a). There were also crusts, efflorescence and loss of matter caused by the erosive action of water, especially in the south orientation, where the water overflowed. At present the state of this fountain has not improved significantly. The biological films still remain, and they coexist with accretions and other superficial deposits (Fig. 5b). Efflorescence has been eliminated, but no effort has been made in order to eliminate the microorganisms. In 2017 we took samples of a dark green nodular film that grew on the engraving of the basin, and that was mainly constituted by a population of coccoid cyanobacteria of the genus *Chamaesiphon*. Although in a much smaller proportion, coccoid green algae of the genus *Apatococcus* was also present. About 25 years ago, *Apatococcus lobatus* also grew in this area, forming part of a mat whose predominant population was the filamentous cyanobacteria *Symploca muralis*.

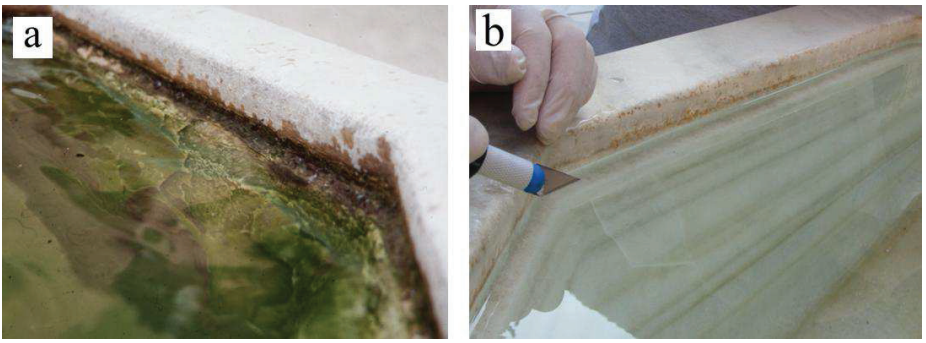

Figure 4. Comparison of the inner vertical surface of the basin of the Fountain of the Lions. a) year 1992: b) year 2017.

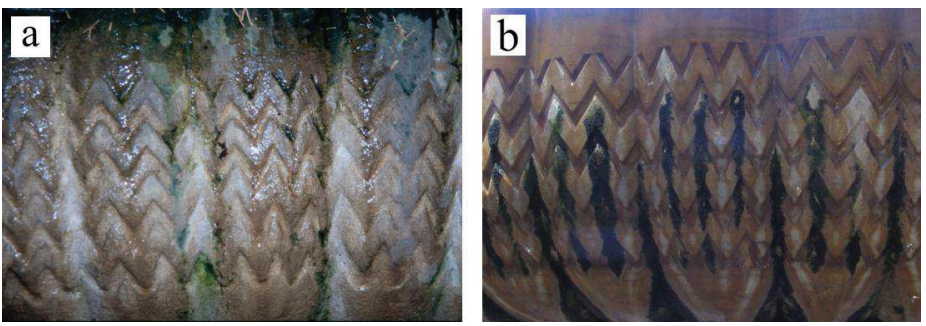

Figure 5. Comparison of the outer vertical surface of the elevated basin of the fountain of the Court of Lindaraja: a) year 1992; b) year 2017.

4 DISCUSSION

In general terms, it seems that the state of the fountains has improved in relation to the state they presented 25 years ago. Restorations and continued maintenance of the fountains have made this possible. However, we observe different scenarios in the different areas of study.

At some points there has been an obvious change in relation to colonization by microalgae. It is the case of the north Fountain of the Court of the Myrtles, the Fountain of the Lions and the fountain of the Court of the Golden Room. The biological film that covered the curb of the north fountain of the Courts of the Myrtles 25 years ago has been completely removed, thus eliminating the casmolithic populations that damaged the stone. Although the fountain has not been restored and continues to present alterations in the curb, the elimination of the algae prevents further deterioration, since the populations that grow on cracks and fissures cause an acceleration of the deterioration of the stone. The Fountain of the Lions is currently one of the fountains of the Alhambra that presents less algal colonization, since it is one of the most emblematic works of the monument and it undergoes a thorough maintenance. In fact, it is the only fountain that has a water purification system. Because of this, it is understandable that the algae that 25 years ago were part of a community inside the basin and had formed an important mineral crust are no longer present. Currently the basin is very clean, and in the sampling on July of 2017 no algal populations were found. In spite of this, it is interesting to mention that in a later sampling (in February 2018) a population of the diatom *Achnanthidium* sp was found in that same area. This shows that, despite the treatment used on the water, there are still populations of algae capable of growing on the stone and potentially damaging it. The case of the fountain of the Court of the Golden Room is similar to the previous two. Although in this case the fountain is not completely exempt from colonization by microalgae, there has been a

reduction of it, both in extension and in complexity. Where 25 years ago was a complex community constituted by different species that formed mats and mineral crusts, in the present there is only one unialgal population. This fountain has been restored very recently, at the beginning of 2017, so it is understandable that colonization by microalgae is currently low. Despite this, we observe how the *Apatococcus* genus, which was already present 25 years ago together with many other species, has been able to persist over time and to proliferate again. This could be indicating a greater resistance of this type of algae to the treatments that are used in the maintenance of the fountain.

In the areas studied in the south fountain of the Court of the Myrtles and in the fountain of the Court of Lindaraja, there is not much improvement in terms of conservation and colonization by microalgae. This is probably because their maintenance over time has been less stringent than that of other areas. Algal communities continue to appear in the studied areas in both fountains as they did 25 years ago. The gargoyle of the south fountain of the Court of the Myrtles continues to present mineral crusts formed by different types of algae, and the state of the fountain of the Court of Lindaraja has changed the least over time: the colonization by microalgae of the outer surface of the elevated galloned basin is still remarkable. The species of algae that colonize these two fountains have varied slightly over the years. However, it should be noted that some types of algae remain stable, like the genus *Phormidium* in the South Fountain of the Court of the Myrtles, which continues to be one of the predominant species after 25 years, and the genus *Apatococcus* in the fountain of Lindaraja, although the latter seems to appear in a smaller proportion at present.

5 CONCLUSIONS

In general, we observe that the populations of algae that colonize the fountains we have studied have not changed much over time. In most of the fountains where microalgae still grow, there are species that remain constant, showing that they have resisted the different treatments and / or restorations that have taken place. In the case of the fountain of Lindaraja, we observe a great diversity of algae proliferating despite the fact that its water is treated, in addition to algaecide, with chlorine tablets. This indicates that this treatment with chlorine, which is sometimes quite aggressive for the stone of the fountain, is not enough to avoid colonization by microalgae on its own. In the fountains subjected to more rigorous maintenance, like the Fountain of the Lions, microalgae growth is lower, but it has not been completely eliminated.

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