Universitat de Barcelona

Study of Biological Communities at Tarxien Temples (HM.04.11, Lot 1)

Final Report

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INDEX

1. INTRODUCTION & OBJECTIVES

Tarxien Temples are a Neolithic archeological site, located within the city of Tarxien. The remains were firstly excavated at the beginning of the 20th century, and some restoration processes were held. The digging of the remains exposed the stones to weathering by atmospheric agents, namely temperature, wind and rain. In addition, those stones represented a new substrate for being colonized by organisms, among them vascular plants and cryptogamic crusts. The communities developing on those substrates are dependent on environmental conditions, as the joint effect of climatic parameters and anthropogenic factors; such are changes on land use and pollution. This later component has been more significant with the development of the surrounding urban area. The current communities at Tarxien Temples are the result of the co-evolution between the established organisms and all the aforementioned environment factors.

A major problem at Tarxien Temples, like other outdoor archeological sites in Malta, is the weathering and deterioration of rock surfaces. The main causes are thermoclastism, wind abrasion, and precipitation. Therefore, to prevent stone deterioration by atmospheric agents, a shelter will be built. This would alter the current environmental conditions, at least in terms of climatic factors; reducing daily thermal amplitude, precipitation, and solar radiation and changing atmospheric humidity. Those changes will affect directly to the current phototrophic communities growing on the different surfaces present in the site. In order to evaluate which communities are developing on each available substrate, and establish how the changes in environmental conditions would alter them and which consequences could have on the site, a throughout study on the biological phototrophic communities is mandatory.

A point to have in mind is the role of organisms as deteriorating or protective agents. The preponderance of one or other activity on the same substrate depends on the composition of the community, at which stage of succession or colonization we are facing, as well as climatic factors. Changes on environmental conditions would also determine a shift between a protective role to a deteriorating one or vice versa. The importance of surveying and monitoring the state and dynamics of current communities is crucial to assess future changes and establish the more accurate management to minimize the consequences on the archeological site.

The main objectives of the study are:

- To characterize all the biological communities in the entire site.
- To identify and interpret essential life support mechanisms.
- To assess potential damage and/or beneficial effects of these organisms.
- To map the distribution of biological communities at Tarxien Temples.

- To issue predictive analyses of possible changes undergone by biological communities once the shelter would be built.
- To suggest for possible methods of control and/or elimination of damaging organisms and plans to prevent further proliferation.

2. METHODOLOGY

The study of the biological communities developing on the Neolithic Temples of Tarxien should be considered on the terms of the different environments that can be distinguished during the subsequent seasonal visits to the site. Two main environments have been identified: soils and rock surfaces.

The identification of most of organisms is carried on the site. However, there are several organisms, belonging to different biological groups, which require lab techniques for a precise identification. Consequently, to collect a representative sample turns to be necessary. Due to the characteristics of the site, biological samples will be collected avoiding damage and respecting the integrity of the monument.

The sampling of each biological group target of this survey requires particular methodology:

Vascular plants and bryophytes

The sampling of vascular plants and bryophytes just requires a fragment, which does not affect the integrity of the stone. The fragments of vascular plants and bryophytes should include key characters of the morphology of vegetative and reproductive parts for the identification of the organisms. In the case of vascular plants they must encompass leaves and flowers and/or fruits. Therefore, we can sample the whole plant when size is small or just a representative part, about 5-10 cm long. For bryophytes we should collect few millimetres due to their small size. The sampling methodology for vascular plants requires cutting the needed fragment, while bryophytes are just lifted up carefully with a knife or a scalpel.

Lichens and fungi

Lichens and fungi are organized in thallus, a laminal structure attached to the surface of the stone. The sampling of those organisms requires separating them from the substrate. We will use a scalpel to detach the thallus from the stone surface, and an adhesive tape, around 1 squared cm, to fix and subject the sample.

The study of the substrate and which part of the monument is examined is done by applying different techniques:

Soils

Soils are colonized by several biological groups: vascular plants, bryophytes, lichens, fungi, microalgae, and cyanobacteria. The sampling of those organisms does not mean a risk for the integrity of the monument. The study of soil communities will require collecting a tiny portion of soil, less than 1 cm^2.

Rock surfaces

The communities of cryptogamic crusts growing on rock surfaces are examined following this protocol:

- Each monitoring sample is pointed out by indicating the stone in the corresponding temple map and giving the references of its location. There are also indicated coordinates *x* and *y* from the border of the stone to the centre of the frame, the height from the ground; and the orientation of the right border of the square.
- For each community three squares of 15 × 10 cm has been chosen, which have been photographed using a plastic frame fastened to the stone with hands.
- Afterwards a transparency film is placed over the plastic frame and all the thalli are traced using a permanent felt-tip pen with a thin point. The delimitation and identification of thalli is carried out using a hand-lens with 10× or 20× magnification.
- Once in the lab, the draws are digitalized as JPG-files using a scanner in order to touch up pictures, when necessary, with the software Adobe Photoshop.
- The digitalized pictures are analyzed with ImageJ v. 1.37 to calculate the cover surface of each species.

Data regarding the biological communities developing on each space of Tarxien Temples, and gathered during the surveys (spring'11, summer'11, autumn'11 and winter'12) is compiled in Annex 1.

3. SOILS

Soils are a main component of the Tarxien Temples. They can be distinguished in two main groups (Figure 1). A first group encompasses the soils of rooms composed of flagstones, which left small areas where particles can accumulate and generate a proper soil. and the ground surrounding the temples. The second group consists of rooms with turf, meaning the presence of a layer of soil bound by plant roots and biological crusts. This group comprises the remnant rooms as well as the surrounding ground of temples and the soils on top of walls.

Figure 1. Distribution of the different sort of soils in Tarxien Temples. Blue indicates soils with flagstones; orange depicts turf soils; and green signals soils on top of walls.

The importance of studying the soil communities of Tarxien temples lies in its role as binding agents, reducing the release of dust and maintaining the structure of walls. In addition, these communities enhance evapotranspiration. Two main components are distinguished, vascular plants and biological crusts.

3.1 Vascular plants

The aggregating role of vascular plants is driven by their roots. However, the importance is linked to the life form; we have classified vascular plants according to Raunkiær (1934)[1] into therophytes, geophytes, hemicryptophytes, chamephytes, nanophanerophytes and macrophanerophytes. While therophytes and hemicryptophytes span for a short time, related with optimal climatic conditions, chamephytes and phanerophytes are perennial plants and have roots that grow deeper and with a secondary growth. Consequently, later groups will have a more important role to bind the soil than formers. The seasonal survey has yield a catalogue of 92 vascular plants. The main component of this catalogue corresponds to therophytes, which represent the 67.4% of all the taxa identified on soils of rooms at Tarxien Temples. Only hemicryptophytes represent more than the 10% of vascular plants. Perennial vascular plants (chamephytes, nano- and macrophanerophytes) gather almost the 16% of identified vascular plants (Figure 2).

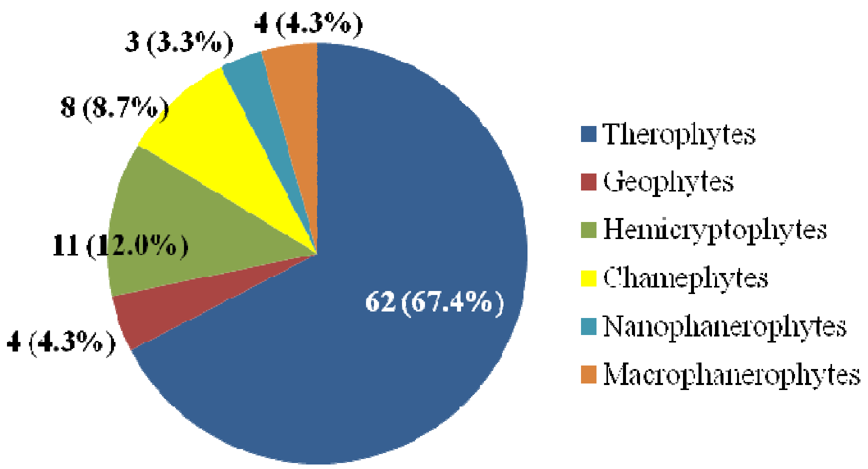

Figure 2. Distribution of species richness of life forms of vascular plants in the soils of Tarxien Temples. Values refer to absolute number of species for each group and percentages are in brackets.

The distribution of species richness and the life forms changes depending on the season (Figure 3). The most dramatic effect is seen in therophytes, and secondarily on hemicryptophytes. The reduction of precipitation during summer, and consequently the availability of water, determines the reduction on the number of this group, while the number of perennial plants does not change so markedly between both seasons.

[1] Raunkiær, C. 1934. *The Life Forms of Plants and Statistical Plant Geography, being the collected papers of C. Raunkiær*. Oxford University Press, Oxford. Reprinted 1978.

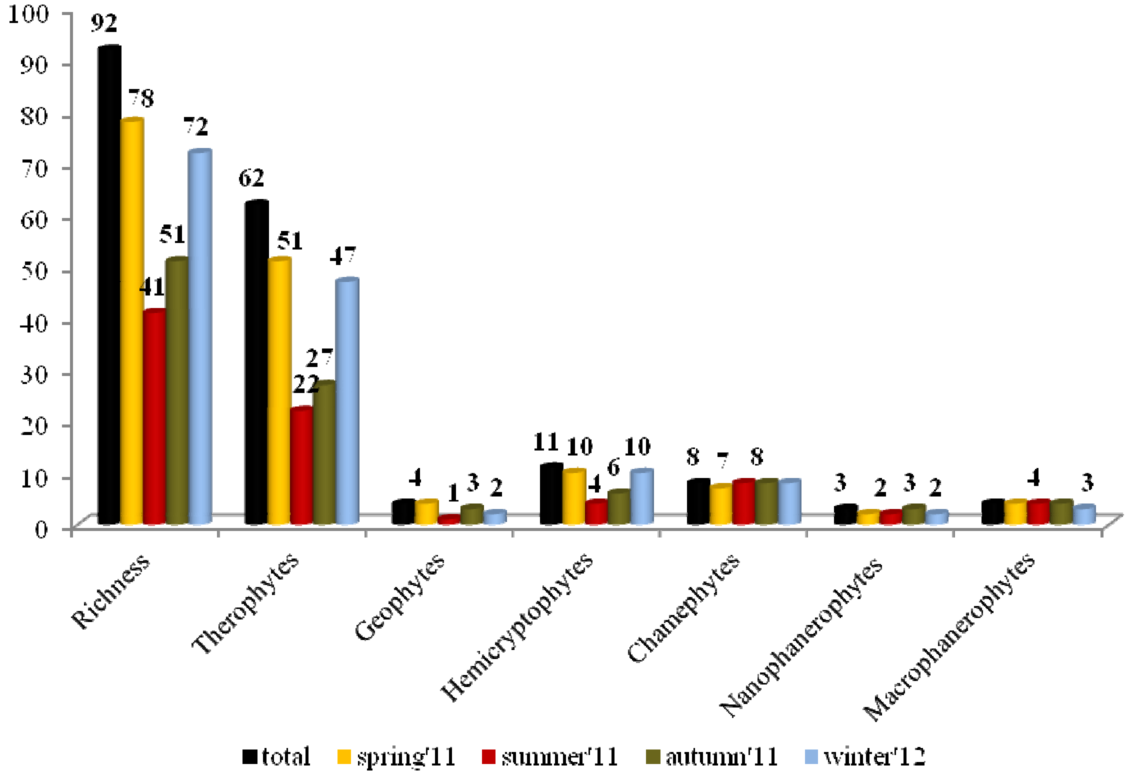

Figure 3. Seasonal distribution of species richness and life forms of vascular plants in the soils of Tarxien Temples. Values refer to absolute number of species for each group.

No significant differences arise on this pattern between the different sort of soils, flagstones or turf. However, soils between flags use to hold less species richness as well as lower abundance of different life forms.

In addition to the composition of vascular plants, there is also a change on the cover of those plants, being wildly reduced in summer season, compared with the survey carried on during other seasons. This pattern shows some exception. A first set includes those rooms with flagstones (1, 2, 4, 6, 8, 9, 10, and 10a), where no changes in terms of cover are noticed between both seasons. A second set contains few turf soils from rooms located on the eastern and further eastern temples (17, 19, 22 and 29). Moreover, room 29 is located in a hollow, which retains humidity.

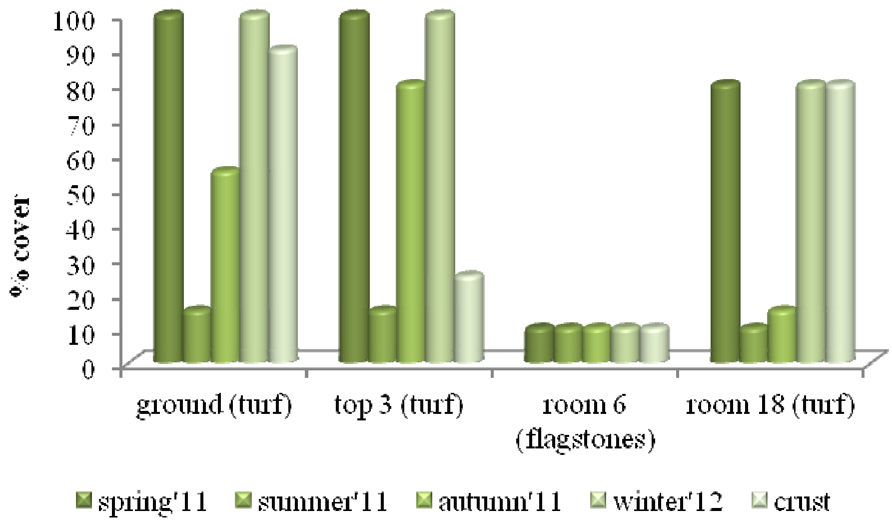

Figure 4. Seasonal distribution of the percent of cover of vascular plants and the cover by biological crusts from some representative soils of Tarxien Temples.

3.2 Biological soil crusts

The biological soil crusts (BSC), which also drive part of the aggregation role, can be defined as rugose crusts with no frost heaving; their surface roughness has a thickness of 1-3 cm. They are mainly composed by bryophytes, and also encompass cyanobacteria, green algae, fungi and lichens. Those organisms are poikilohydric, meaning that their water content tends to fluctuate with the environmental humidity; therefore, the communities involved in soil crusts are more dependent on rain than vascular plants. The BSC present at Tarxien Temples contribute to surface roughness; consequently, they provide surface detention, increase net infiltration and reduce net runoff[2]. The drastic reduction in water availability during summer season induces a process of cryptobiosis. However, remnants of the biological crusts can be distinguished (Figure 5). Moreover, the percentage of cover does not change significantly between all the surveys that have been carried on.

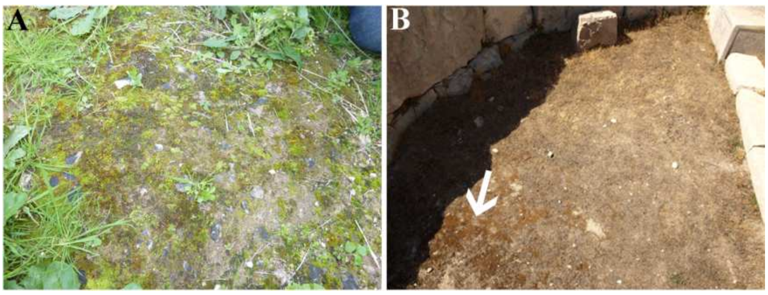

Figure 5. Biological soil crusts. A. Detail of a biological soil crust in room 25. B. View of the soil in room 3 in summer, with remnants of biological crust soil (arrow).

[2] Belnap, J. & Lange, O. L. 2001. *Biological Soil Crusts: Structure, Function, and Management*. Springer-Verlag. Berlin Heidelberg.

Bryophytes, the dominant component of BSC, can be differentiated in four main life strategies: perennial, colonists, annual shuttles and fugitives[3] (Figure 6). Perennial, fugitives and short-lived shuttles bryophytes are scanty on BSC at Tarxien Temples; two taxa of perennials and one taxon of short-lived shuttles and fugitives have been identified. Annual shuttles and colonists are the most abundant life strategies among bryophytes. Each life strategy represents the 45.2%. Annual shuttles correspond to liverworts and mosses with a very short lifespan, less than one year. They appear predictably after seasonal rains and cover grounds and small cracks between stone slabs. Colonists are mainly mosses with a short lifespan, being annuals or pauciannuals, and most of them desiccation tolerant. They remain all over the year but they thrive more vigorously when water is abundantly available, then they sprout new shoots or develop reproductive structures. Bryophytes on BSC contribute actively to retain water after heavy rain.

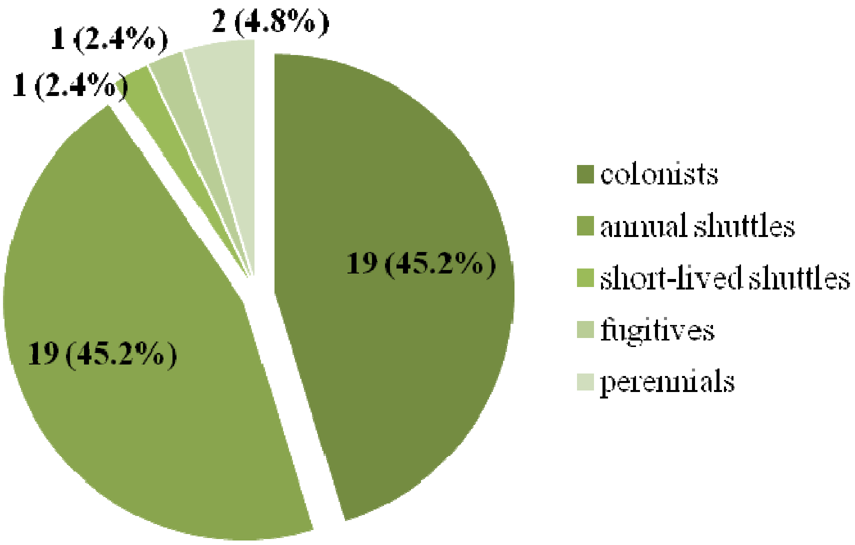

Figure 6. Distribution of bryophyte life strategies from BSC at Tarxien Temples. Values refer to absolute number and percentage (in brackets) of species for each group.

[3] During, H.J. 1979. Life strategies of Bryophytes: a preliminary review. *Lindbergia,* 5: 2-18; During, H.J. 1992. Ecological classifications of bryophytes and lichens. *In*: Bates, J. W. and Farmer, A. M. (eds.): *Bryophytes and Lichens in a Changing Environment*, Clarendon Press, Oxford, pp. 1-31.

4. ROCK SURFACES

The colonization of rock surfaces in Tarxien Temples depends on their situation. Two main groups are differentiated: walls and horizontal surfaces. The later will include also the scattered blocks on the surrounding grounds of the temples, except those specified as blocks in Figure 7.

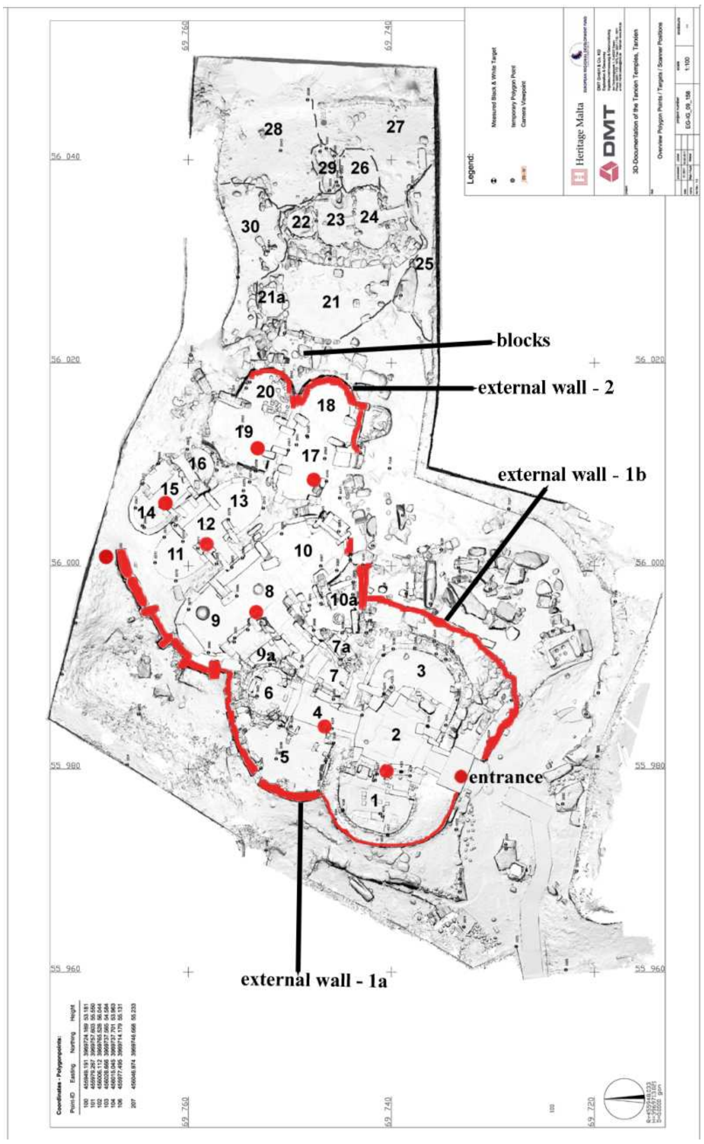

Figure 7. Distribution of rock surfaces at Tarxien Temples. In addition to room's codification, there are specified the outer walls and the standing blocks between the eastern and the farthest eastern temples.

4.1 Walls

The walls of temples are constituted by two sorts of slabs. There are walls made up of small to medium ashlars, with several interstitial spaces that provide place for the deposition of soil and the establishment of plants. A second sort of walls are made of vertical huge slabs, with not or few cavities to allow the growth of vascular plants. Those walls are colonized by epilithic and endolithic organisms, mainly lichens and, occasionally, of bryophytes, fungi and cyanobacteria. The later walls have been more affected by restoration in earlier 20th century, usually by application of plaster coating almost all the stone.

The colonization of walls by vascular plants is not as important as soils; however, plants are more common on walls made up of ashlars than in those composed by huge slabs. The survey carried on walls from spring 2011 until winter 2012 has yield a list of 47 taxa (Figure 8). They have been classified into life forms following Raunkiær[4]. The richness of vascular plants and the proportion of life forms change seasonally (Figure 9). Vascular plants are influenced by seasonal changes, and their development is more dependent on short term variations of climatic parameters. Therophytes are the most affected group, being dramatically reduced in summer, while species with secondary growth and lignifications or hypogeal structures remain almost unchanged between favourable and unfavourable seasons. The consequences on walls is almost different, the secondary growth of those life forms, affecting roots and steams, are active weathering agents and can imply the breaking of stones. Oppositely, therophytes have low effect on stones, except the enhancement on soil accumulation in crevices.

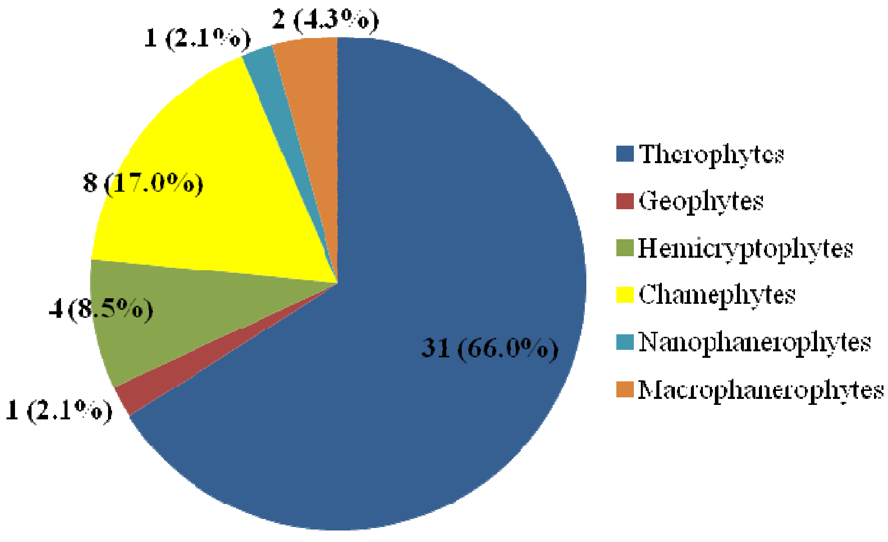

Figure 8. Distribution of species richness of life forms of vascular plants on the walls of Tarxien Temples. Values refer to absolute number of species for each group and percentages are in brackets.

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[4] See reference in page 8.

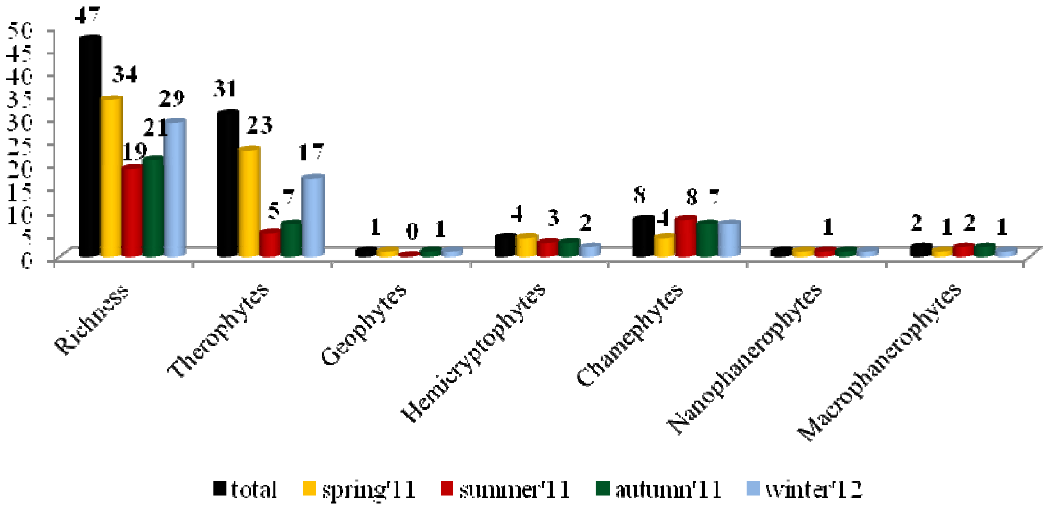

Figure 9. Seasonal distribution of species richness and life forms of vascular plants on walls of Tarxien Temples. Values refer to absolute number of species for each group.

The cryptogamic crusts encompass mainly lichens, but also green algae, cyanobacteria, and black fungi. These communities have a more protective role than a deteriorating one. The colonization of slabs is very heterogeneous, with slabs almost devoid of any colonization to stones with a cover ranging quite the 75% of its surface. However, most of the communities are diffuse, which make difficult to monitorize. A representative set of stones, including original slabs and plastered stones, has been selected for monitoring potential changes and alterations once the shelter should have been built. Cryptogamic crusts have a slower growth rate and changes in environmental parameters would lead to variations only noticeable after medium to long term periods.

Among the cryptogamic communities on vertical surfaces, one well defined community has been identified and selected for monitoring. It is referred as community of *Lecania spadicea* (Figure 10), and its location is referred in Figure 11, with the location of controls for communities growing on horizontal surfaces. The location of the control sample is on the east face of a stone on the outer ground of the middle temple. The coordinates are E 456005.7 N 3969739.1. For this community, only one sample would be monitorized; there have not been found more localities at Tarxien Temples, except for isolated individuals.

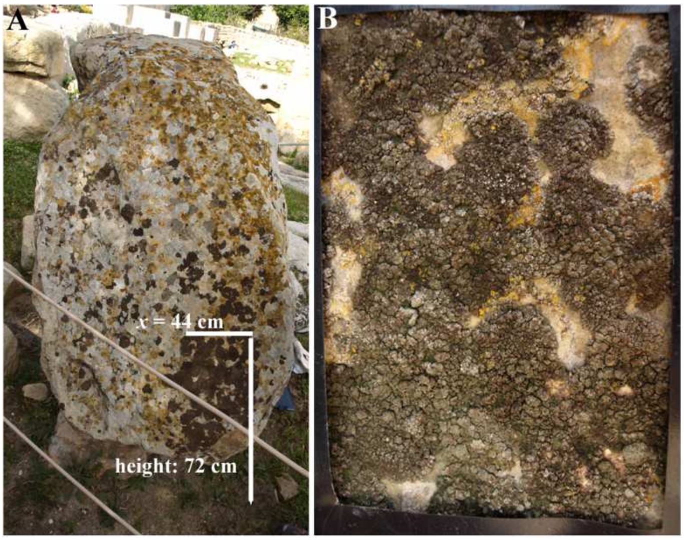

Figure 10. A: Location of the control for the community of *Lecania spadicea* (L1). B: Detail of the control, an area of 10 x 15 cm.

Several points have been selected in order to assess future changes on stones of Tarxien Temples. The available communities and their cover have been evaluated and illustrated; therefore, any alteration should be noticed when comparing the control image with the correspondent stone once the shelter would be built. The control stones are compiled in the Appendix 2.

4.2 Horizontal surfaces

The cryptogamic communities growing on horizontal surfaces are well defined, compared with most of the cryptogamic communities identified on vertical walls. In addition, no vascular plants develop on those surfaces. Only, some bryophytes grow on small cavities or depressions, but without representing a well constituted community. Therefore, we focus on lichen communities to monitorize horizontal stone surfaces. In addition, lichens have a slower growth rate and variations in environmental parameters would lead to alterations only noticeable after several years. Our suggestion is to repeat the survey on those communities about three or four years after the shelter is built.

Two lichen communities have been selected as controls to analyze changes due to the building of the shelter. The proposed communities to be monitored are a community mainly composed of *Caloplaca* sp. pl. (Ca) and a community where the main component is *Verrucaria nigrescens* (V). Locations for the different communities to be monitored are up lighted in Figure 11.

Figure 11. Location of control communities. Ca1, Ca2, Ca3: community of *Caloplaca* sp.; V1, V2, V3: community of *Verrucaria nigrescens*; and L1: community of *Lecania spadicea*.

The three representatives of the community of *Caloplaca* sp. pl. are selected in both original and plastered stones (Figure 12). Sample Ca1 is located at the eastern part on top of a stone at 134 cm from the ground, on the outer ground of the middle temple. The georeferences are E 456004.8 N 3969739.1, and its coordinates are *x*: 27 cm and *y*: 6 cm. Sample Ca2 is located on the right hand stone at the entrance of Room 11 at 261 cm from the ground. The georeferences are E 4560003.9 N 3969760.4, and its coordinates are *x*: 73.5 cm and *y*: 8.5 cm. Sample Ca3 is located at the top of the replicate of the "Mother Goddess" in Room 3 at 126 cm from the ground. Its georeferences are E 455986.7 N 3969736.7, and the coordinates are *x*: 113.5 cm and *y*: 7 cm.

Figure 12. Location of samples to monitorize the community of *Caloplaca* sp. pl. A: Ca1; B: Ca2; C: Ca3. Arrows indicate the position of samples. Detail of control samples, the size of each frame is 15 x10 cm. D: sample Ca1; E: sample Ca2; F: sample Ca3.

The selected control samples of the community of *Verrucaria nigrescens* are growing on original and replicate stones (Figure 13). The sample V1 is located on replicate of carved goats in Room 1 at 32 cm of the ground. The georeferences of the sample are E 455977.8 N 3969738.7, the coordinates are *x*: 74.5 cm and *y*: 17.5 cm. The sample V2 is located in one slab at ground level in front of the entrance of Room 5. Its georeferences are E 455982.6 N 3969747.6, and its coordinates are *x*: 177 cm and *y*: 17 cm; height. The third sample, V3, is located on the slab at the entrance of Room 15 10 cm from the ground. The georeferences are E 456007.5 N 3969759.3. The coordinates of the sample are *x*: 30.5 cm and *y*: 7 cm.

Figure 13. Location of samples to monitorize the community of *Verrucaria nigrescens* (V). A: V1; B: V2; C: V3. Arrows indicate the position of samples. Detail of control samples, the size of each frame is 15 x10 cm. D: sample V1; E: sample V2; F: sample V3.

5. CONCLUSIONS AND RECOMENDATIONS

5.1. Soils

Usually, on soils, there is a normal process of evapotranspiration of water accumulated by condensation and precipitation. There is an inverse correlation between rain and evapotranspiration which determines water availability for communities dwelling on soils of Tarxien. The most affected groups will be therophytes and biological soil crusts. The richness on therophytes depends on the difference between rain and evapotranspiration (Figure 14), being maximum in spring, when the accumulation of water in soils is higher. The remaining life forms do not change so dramatically (Figure 3), and they do not correlate with water accumulation in soil. Thus, the changes on therophytes will have more effect on the stability of soil particles than other life forms of vascular plants.

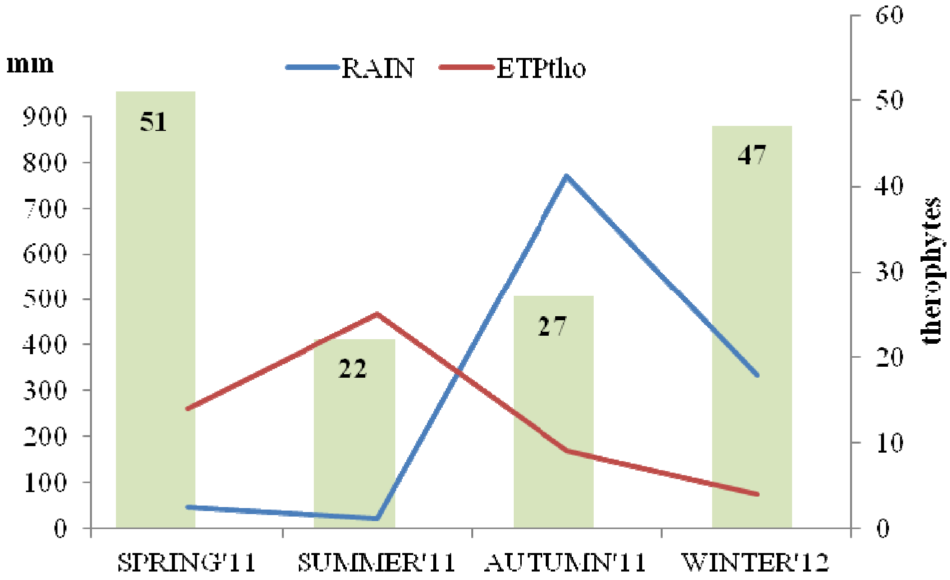

Figure 14. Seasonal variation of the richness of therophytes, rain and evapotranspiration (ETPtho).

Bryophytes, the main component on biological soil crusts, show a similar pattern as therophytes. The most frequent life strategy corresponds to colonists, followed by annual shuttles (Figure 15). They are also the most abundant taxa. They depend on rain and flooding of soils to develop. No significant differences arise when comparing temples or sort of soils (flagstones vs. turf)

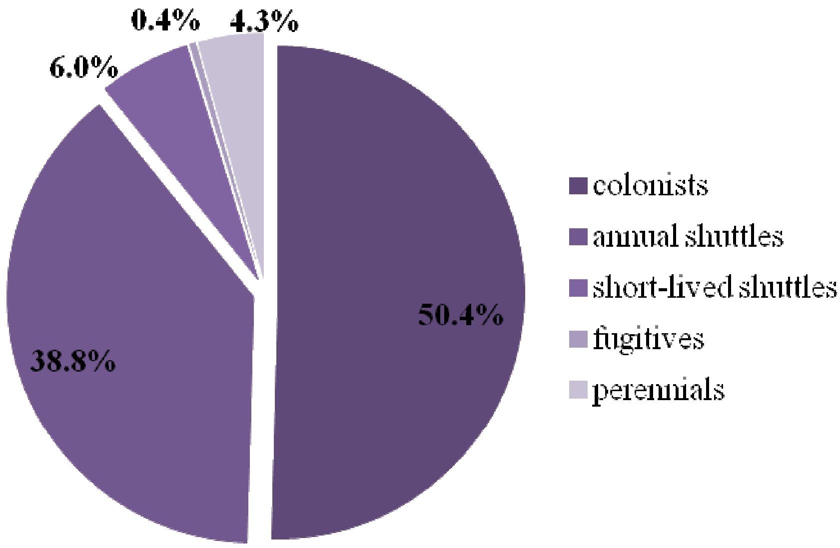

Figure 15. Distribution of the frequency of life strategies of bryophytes at Tarxien Temples.

The shelter will protect soils from rain, but not from water condensation. Will this amount of water be enough for autotrophic organism growth? If these organisms disappear, water from soil and condensation will evaporate, and consequently, phenomena of inverse lixiviation can appear. In addition, the disappearance of vascular plants entails the lost of the root layer. Root layer and biological crust act as binding agents in the soil. Their lost will lead to the erosion of soil and release of mineral particles, which will incorporate in the atmosphere.

The observed soil crusts represent an inconspicuous community but very important to aggregate and structure the mineral particles. The life cycle of these communities require being completely flooded temporarily year after year. The disappearance of these crusts will lead to an unbinding of soil, which consequently will be eroded and the mineral particles will move and lose.

The release of mineral particles into an altered atmosphere, with a slowing of internal currents, could induce an increase in the deposition of dust on the walls of the temples.

<u>Our suggestions are:</u>

1. Seasonal monitoring of room soils during a year after the installation of the shelter and assessment of changes.

2. To do not remove vegetation of soil, in case the amount of water was enough to keep it naturally. When we need keeping room soils clean, grass mowing with a string trimmer has been shown a good method. On the other side, this procedure should avoid pulling out roots and removing plant debris. To maintain roots and plant debris will protect soils from erosion.

3. To keep soil well aired, avoiding covering the bare soil with material that impedes good ventilation.

__4. To observe the lower areas of walls in order to notice accumulation of humidity from the soil, this will favour the growth of cyanobacteria or even bryophytes on stones.__
__To consider the installation of a raised artificial soil that will allow a good airing of the natural soil.__

The soils on top of walls will also lose the vegetation cover, likewise room soils, and consequently will be disaggregated. In addition, there will be a gravimetric process where the soil particles will fall through the gaps of the wall stones.

Our suggestions are:

__5. Seasonal monitoring of soils on top of walls during a year after the installation of the shelter and assessment of changes.__
__6. To consider using some artificial consolidative material to bind the mineral part of soil on top of walls.__

5.2. Stones

The role of vascular plants and non-vascular plants on stone surfaces has an opposite way. Vascular plants act as deteriorating agents due to their ability to thrive in small crevices and pierce the stone with their roots. The consequences of secondary growth of roots bring the break of stones or enhance weathering by climatic agents. Otherwise, cryptogamic crusts, mainly composed by lichens, have first a deteriorating role, but once the community stabilizes, the protective role overpasses the initial deterioration.

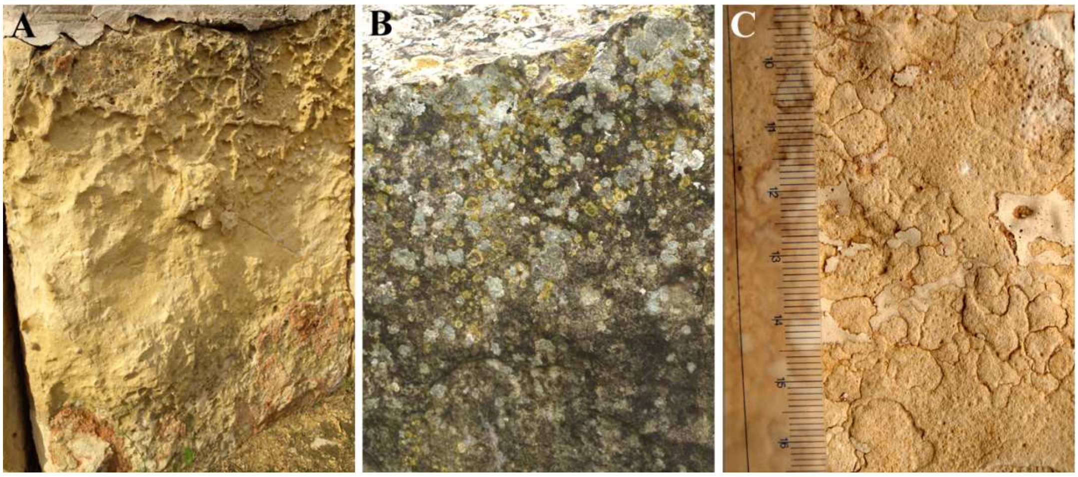

Figure 16. The effect of weathering on nude rock (A) and the protective role of lichen communities (B) or the remaining dead crusts (C).

The protective role is significant to reduce the weathering of rock surfaces by thermoclastism and also wind (Figure 16A). The lichen communities can resist much better the reduction in water availability than vascular plants; thus, the protective role will last longer (Figure 16B). Even the remains of former lichen crusts act as a protective layer against atmospheric weathering agents (Figure 16C).

Due to the unbinding of soils and depending on internal air currents, particles deposition can happen mainly on horizontal surfaces of stones, modifying the original colour of stone. A similar effect happened in the temples of Mnajdra, where the lack of protection of grounds released larger amount of dust that felt on stones covering them with a layer of 1 mm

Figure 17. View of the accumulation of dust on stones from Mnajdra Temples after the shelter.

in thickness (Figure 17).

The support of the shelter can provide more perching areas for birds with the aesthetical effect on stones, but also as an income of nutrients for some organisms due to the accumulation of excrements.

As a consequence of the presence of the shelter, deterioration of stone due to physical and chemical agents will diminish. Under these circumstances, the protective role played by biological crusts is going not to be as relevant. Consequently, biodeterioration should be more important than bioprotection.

The shelter will generate different micro environmental conditions, resulting in less variation in temperature, humidity and light. This homogenization of the microclimate will render a reduction of the community diversity, but it will not imply, necessarily, a diminution of cover. The current situation with a high coverage by several communities will undergo to a high cover also, but by few communities.

Under shelter conditions, water availability will be strongly different that in open exposition. While the shelter will intercept rainfall, there are other sources of water from the atmosphere, such as condensation of air humidity, dew, or fog. These sources can make possible the growth of organisms on the stone. These changes on water availability will promote changes of saxicolous inhabitants (including photoautotrophic organisms like lichens, cyanobacteria, algae, bryophytes…, and heterotrophic ones, such as fungi or bacteria) Communities dominated by algae or a different lichen community can displace the current lichen communities. This displacement will imply the death of the present species. The availability of organic matter will enhance the proliferation of fungi, which can black the stones temporarily. Then, new communities will occupy the free space.

Depending on the amount of humidity and, specially, the persistence of the humidity throughout the day and the year, algae can substitute the lichen community.

Light amount, reduced because of the shelter, would not act as a restricting factor for those organisms. Changes in the intensity and quality of the light go to promote changes in the specific composition of communities. These modifications will result in changes in the coloration of the stone surface.

Any scenario will entail changes in the lichen communities that will modify the colouring of stone surfaces, mainly those with a high lichen cover. These changes will take place in a longer term than those due to the disappearance of vascular plants.

Our suggestion is:

7. Yearly monitoring of walls after the installation of the shelter, repeating the data on colonization and control samples.

6. GLOBAL BIOLOGICAL DIVERSITY ON SOILS AND WALLS

Due to the amount of collected specimens and new species will predictably be found in the forthcoming surveys, we present a provisional list. A definitive list should be provided at the final report.

ASCOMYCOTA

Lamprospora miniata

ASCOMYCOTA (LICHENS)

Aspicilia contorta ssp. *contorta*
Bagliettoa calciseda
Botryolepraria lesdainii
Caloplaca aurantia
Caloplaca citrina
Caloplaca flavescens
Caloplaca gr. *citrina*
Caloplaca marmorata
Caloplaca navasiana
Caloplaca subochracea
Caloplaca teicholyta
Caloplaca variabilis
Clauzadea metzlerii
Clauzadea monticola
Collema crispum var. *metzleri*
Collema tenax
Diplotomma hedinii
Endocarpon pusillum
Lecania spadicea
Lecania turicensis
Lecanora dispersa
Lecanora pruinosa
Opegrapha rupestris
Placidium rufescens
Placidium squamulosum
Polyblastia sp.
Porina linearis
Toninia aromatica
Verrucaria muralis
Verrucaria nigrescens
Verrucaria sp.

BASIDIOMYCOTA

Arrhenia sp.

CHLOROPHYTA

Trentepohlia sp.

ANTHOCEROPHYTA

Anthoceros punctatus
Phaeoceros laevis

MARCHANTIOPHYTA

Fossombronia caespitiformis
Fossombronia incurva
Fossombronia sp.
Lunularia cruciata
Riccia ciliata
Riccia glauca
Riccia lamelosa
Riccia sorocarpa
Riccia sp.
Sphaerocarpus michelii

BRYOPHYTA

Aloina ambigua
Aloina rigida
Aloina sp.
Bryum caespiticium
Bryum dichotomum
Bryum kunzei
Bryum sp.
Dicranella sp.
Didymodon acutus
Didymodon luridus
Didymodon sp.

Didymodon vinealis
Entosthodon convexus
Entosthodon durieui
Entosthodon fascicularis
Entosthodon sp.
Fissidens crispus
Fissidens sp.
Fissidens viridulus
Funaria hygrometrica
Gymnostomum viridulum
Microbryum davalliamum
Phascum cuspidatum
Pseudephemerum nitidum
Pseudocrossidium revolutum
Timmiella barbuloides
Tortella nitida
Tortula marginata
Tortula muralis
Weissia controversa

PTERIDOPHYTA

Adiantum capillus-veneris
Anogramma leptophylla

MAGNOLIOPHYTA

Ajuga iva
Amaranthus viridis
Anagallis arvensis
Antirrhinum siculum
Arisarum vulgare
Armeria sp
Asparagus aphyllus
Aster squamatus
Astragalus boeticus
Avena barbata
Beta maritima
Blackstonia perfoliata
Borago officinallis
Brachypodium distachyon
Bromus diandrus
Bromus madritensis
Campanula erinus
Capsella bursa-pastoris
Centaurium tenuiflorum
Cerastium glomeratum
Convolvulus althaeoides
Convolvulus arvensis
Conyza bonariensis
Cynodon dactylon
Daucus carota
Desmazeria rigida
Diplotaxis erucoides
Diplotaxis tenuifolia
Dittrichia viscosa
Ecballium elaterium
Erodium malacoides
Euphorbia helioscopia
Euphorbia peplus
Euphorbia prostrata
Euphorbia segetalis
Ficus carica
Foeniculum vulgare
Fumaria capreolata
Fumaria officinalis
Galactites tomentosa
Galium verrucosum
Heliotropium europaeum
Hippocrepis multisiliquosa
Hordeum murinum
Hypericum pubescens
Hypochoeris achyrophorus
Juncus bufonius
Lactuca serriola
Lagurus ovatus
Lamium amplexicaule
Lavatera cretica
Lophochloa cristata
Lotus edulis
Lotus ornithopodoides
Malva sylvestris
Medicago polymorpha

Melilotus indica
Mercurialis annua
Micromeria microphylla
Misopates orontium
Nicotiana glauca
Orobanche densiflora
Oryzopsis miliacea
Oxalis pes-caprae
Papaver dubium
Papaver hybridum
Papaver rhoeas
Papaver setigerum
Parietaria judaica
Pittosporum tobira
Poa annua
Polycarpon tetraphyllum
Polypogon maritimus
Reichardia intermedia
Reseda alba
Rumex bucephalophorus
Sagina maritima
Schinus terebinthifolius
Senecio vulgaris
Smyrnium olusatrum
Solanum luteum
Sonchus oleraceus
Sonchus tenerrimus
Spergularia rubra
Trapeolum majus
Trifolium campestre
Trifolium nigrescens
Urospermum picroides
Urtica dubia
Valantia hispida
Veronica polita
Vitis vinifera

7. GLOSSARY

Annual shuttles	Bryohytes with a very short life span of <1 year, high sexual reproductive effort, and spores larges > 20 µm. The shuttle bryophytes are adapted to microhabitats that disappear predictably at varying rates but reappear. Annual shuttles occur in seasonally suitable habitats.
Anthocerophyta	Scientific name for the hornworts.
Ascomycota	Scientific name for the largest group of Fungi. They are saprobes, parasites (especially of plants), or lichenized as lichens.
Basidiomycota	Scientific name for the second largest group of Fungi. Including, among others, mushrooms, puffballs, jelly fungi and boletuses.
Biofilm	A biological colonization on stone surfaces, a complex microbiome composed by several different organisms (bacteria, cyanobacteria, algae, fungi, lichens, bryophytes and vascular plants).
Biological crust	Community of organisms living within, or immediately on top of, the uppermost millimetres of soil. Major components are cyanobacteria, algae, fungi, lichens and bryophytes.
Black fungi	Practical term to group heterogeneous lineages of fungi with melanised cell walls.
Bryophyta	Scientific name for the mosses.
Bryophytes	Traditional name used to refer, as a collective term, for mosses, hornworts, and liverworts.
Chamephytes	Vascular plants that carry their dormant buds openly on branches above the ground, up to 40 cm.
Chlorophyta	(= green algae) Scientific name for a group containing the green-pigmented algae, commonly found in oceans, freshwater or moist terrestrial habitats or as symbionts in lichens. They contain chlorophylls a and b, carotenes, and xanthophylls, store food reserves as starch, and always have cellulose cell walls.
Colonists	Bryophytes with a short life span of 1-fews years, high reproductive (asexual and sexual) effort, spores small < 20 µm. They occur in habitats that appear unpredictable (usually after disturbance) and last for several years. The pioneering colonists make habitat suitable for others

	species.
Cryptobiosis	Is a temporary state in an organism in which metabolic activity is absent or undetectable.
Cyanobacteria	(= blue-green algae) or Cyanophyta is the scientific name for a group of prokaryotes that obtain their energy through photosynthesis. These organisms can be found in almost every terrestrial and aquatic habitat: in oceans, fresh water, even bare rock and soil, and as symbionts in lichens.
Endolithic	Living within the stone, under the surfaces.
Epilithic	Living on the surface of stones.
Fugitives	Bryophytes with a very short life span, 1-fews years, high sexual reproductive effort, small spores < 20 µm. They occur in unpredictable environments.
Geophytes	Vascular plants with reproductive buds buried underground during the unfavourable period (in bulbs, tubers, on rhizomes, etc.)
Hemicryptophytes	Vascular plants with perennial buds situated at or just below the soil surface
Lichens	A stable self-supporting association of a fungus (mycobiont) and an alga or cyanobacterium (photobiont). Lichens are a biological and not a systematic group.
Macrophanerophytes	Vascular plants that carries its dormant buds openly on branches above the ground, more than 2 meters in height.
Magnoliophyta	Scientific name for the flowering plants.
Marchantiophyta	Scientific name for the liverworts.
Patina	Chromatic modification of the stone surface, generally resulting from the ageing of different minerals.
Nanophanerophytes	Vascular plants that carries its dormant buds openly on branches above the ground, between 40 cm and 2 meters in height.
Perennials	Bryophytes with a long life span, low reproductive effort, small spores <20 µm. They occur in stable habitats.
Pteridophyta	(= ferns) Scientific name for vascular plants that have stems, leaves, and roots, but reproduce via spores and have neither seeds nor flowers.
Short –lived shuttles	Bryophytes with a short life span of 1-fews years, high sexual reproductive effort, spores larges > 20 µm. They are adapted to habitats that last suitable for 1-3 years.
Thallus	(pl. thalli) The vegetative body of a thallophyte, for

	example “lichen thallus”.
Therophytes	Annual vascular plants which survive the unfavourable season in the form of seeds and complete their life-cycle during favourable seasons.
Vascular plants	Plants with lignified tissues for conducting water, minerals, and photosynthetic products through the plant. The term include, among others, the ferns, the conifers and the flowering plants.