

## **Threats and state of conservation of aphylloroid fungi in the Mediterranean**

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Aphylloroid fungi is an artificial and diverse group of fungi, often little considered in mycological inventories, but very important in the forest dynamics. In this paper we summarize generally some of the most relevant and interesting habitats in the Mediterranean for this group of fungi, and briefly analyze the conservation problematics.

**Key words:** corticioids, diversity, Europe, polypores, virgin forest, wood inhabiting fungi

### INTRODUCTION

Fungal Red-List analysis rarely is considered in national conservation strategies and animals and plants are those who take leadership when delimiting areas and in conservation programs. Fungi are only recently starting to be contemplated under a perspective of ecological significance, and most European countries have recently started to produce fungal Red-Lists. Actually, around 5500 different macrofungi are tentatively red-listed in Europe (Senn-Irlet et al. 2007), but there are still large differences in the treatment between different parts of Europe. In this respect, there are considerable differences between northern and southern Europe and while in some countries fungi are actively considered in conservation programs, in other there are still no official lists and not even diversity and distribution is known for many groups of fungi.

The International Union for Conservation of Nature (IUCN) is also unequally considering the different groups of living organisms. Only three fungal species are listed in two categories (of a total of seven categories) of the 2012 IUCN Red List (<http://www.iucnredlist.org>): *Cladonia perforata* A. Evans (Endangered); *Erioderma pedicellatum* (Hue) P.M. Jørg. and *Pleurotus nebrodensis* (Inzenga) Qué. (Critically Endangered). To compare these two categories with other organisms, in the IUCN

Endangered category are listed 3262 species of animals and 2655 species of plants, and under Critically Endangered are considered 2261 and 1821, respectively.

Regarding aphyllorphoid fungi, an artificial category represented by a variable mushroom forming fungi, including corticioids, polypores, hydnums, jelly and coral-oid fungi, etc., while in some northern European countries (e.g., Norway, Sweden, and Finland) this group has extensively been studied and is actually considered of great importance in connection with the ecology and forest dynamics, in many of the countries from the Mediterranean area have even no an accessible checklist or a total or partial ignorance the of diversity. In many parts of southern Europe, studies and prospection is still inadequate, and most of the information is dispersed in scientific publications, many of which are difficult to obtain from non specialized people (Bernicchia 1999). These differences in the knowledge of the diversity and ecology of this group of fungi between northern and southern Europe, are conditioned by several factors such as scientific and mycological tradition, number of professional and amateur mycologists, fundings, and education and environmental awareness, among others.

The aim of this work is to reflect on the conservation status and threats of the aphyllorphoid fungi, but is valid by extension to other groups of fungi, and provide some ideas for their preservation, dedicating the present contribution to Maria Lawrynowicz, in recognition of her work in fungal conservation and in commemoration of the Jubilee of her scientific work.

## MEDITERRANEAN HABITATS OF INTEREST

The Mediterranean basin is one of the world biodiversity hotspots (Conservation International 2007) and the ecosystem diversity is considerable. Hardwood forests of deciduous, marcescent, and perennial species cover the majority of the area, intermixed with coniferous and abundant riparian formations. Is not our intention summarize here all the Mediterranean ecosystem diversity, but we want to highlight some very interesting forest formations from our mycological experience.

### Coniferous forests

The main and most abundant coniferous forests in the Mediterranean are those in which different species of *Pinus* L. are predominant. Many pine formations are reforestations and, although most of them are naturalized, the diversity and abundance of fungi is quite similar to other parts of Europe (some references to this substrate can be found in Manjón et al. 1983; Bernicchia 2005; Bernicchia et al. 2007; Bernicchia, Gorjón 2010). Because of this, we highlight here another most rare and reduced coniferous formations we estimate of great value for the aphyllorphoid diversity.

Juniper forests is under our personal appreciation but also because of the associated mycobiota, one of the most interesting mycological area in the Mediterranean. *Juniperus* L. is very often a selective substrate for wood-inhabiting rare species as for example *Antrodia juniperina* (Murrill) Niemelä & Ryvardeen, *Arrasia rostrata* Bernicchia, Gorjón & Nakasone, *Echinodontium ryvardeenii* Bernicchia & Piga, *Hypoderma etruviae* Bernicchia, *Lenzitopsis oxycedri* Malençon & Bertault, *Neolentiporus*

*squamosellus* (Bernicchia & Ryvardeen) Bernicchia & Ryvardeen, *Phellinus juniperinus* Bernicchia & Curreli, *Piloporia sajanensis* (Parmasto) Niemelä, *Trametes junipericola* Manjón, Moreno & Ryvardeen, *Vararia maremmana* Bernicchia, etc. Juniper trees become an irreplaceable substratum, and for this reason the survival of many wood-inhabiting aphylloroid species becomes uncertain. Many polypores and corticioids, restricted to very old specimens of *Juniperus*, follow the host genus wherever it occurs, with a scattered distributional pattern. Juniper forests are rare and restricted to special areas, presently in decline by natural competition with other species as well as human activity. Wood of several species of juniper has traditionally been used to build houses, fences, and huts. Although its use is currently limited and replaced by other materials, it is priority to promote its conservation. The reader is referred to the studies focused on the diversity of aphylloroid fungi on *Juniperus* (Manjón, Moreno 1981; Bernicchia 2000).

Another endangered coniferous formation is those of *Abies pinsapo* Boiss., actually restricted to Southern Spain and Northern Morocco. A very interesting catalogue of wood-inhabiting fungi was reported by Manjón and Moreno (1983b). The conservation of this relict area is evidently priority.

Some other conifers should be better considered by its rarity or as potentially interesting substrate. Few mycological studies have been made in *Abies alba* Mill. (Bernicchia et al. 2007b) and *Larix decidua* Mill. A remarkable conifer is *Cedrus atlantica* (Endl.) Manetti ex Carrière, where only few species have been reported and three corticioid fungi are only known from this substrate: *Aleurodiscus atlanticus* Maire, *Neoleurodiscus monilifer* (Malençon) Sheng H. Wu, and the recently described *Acanthophysellum verecundum* Duhem (Duhem 2001).

### Hardwood forests

In the Mediterranean area the main hardwood forests are formed by several oak species, forming monospecific or more commonly mixed forests with several shrubs. Each species tends to have its own associated fungi, and some aphylloroid species show an exclusively Mediterranean distribution. *Sarcodon quercinofibulatus* Pérez-De-Greg., Macau & J. Carbó has recently been described and reported growing associates mainly to Fagaceae in Spain and Italy (Vizzini et al. 2013). *Ramaria mediterranea* Schild & Franchi, has exclusively been found growing in the Mediterranean area in mixed forest related to various *Quercus* L. species and other mediterranean shrubs (Dániels, Gorjón 2009). Some species of corticioid fungi and polypores follow the *Quercus* distribution, even they also can be sporadically growth on other substrata, as for example, *Aleurocystidiellum disciforme* (DC.) Tellería, *Hexagonia nitida* Durieu & Mont., *Marchandiopsis quercina* (J. Erikss. & Ryvardeen) Ghobad-Nejhad, *Peniophora quercina* (Pers.) Cooke, and *Piptoporus quercinus* (Schrad.) P. Karst. For further information on aphylloroid fungi growing on *Quercus* see Bernicchia et al. (2008).

### Mediterranean shrublands

Some species are linked to Mediterranean shrubs. A conspicuous polypore, *Antrodia sandaliae* Bernicchia & Ryvardeen, has exclusively been found in Italy and Spain growing specifically on *Arbutus unedo* L. (Gorjón, Bernicchia 2009). That substratum proved particularly interesting for the numerous aphylloroid species growing on

it (Gorjón et al. 2006). Also, there are a large number of corticioid fungi inhabiting leaves, small twigs, and stems associated to Mediterranean shrubs. Recently, *Aphanobasidium gloeocystidiatum* Duhem and *Vuilleminia ericae* Duhem have been described growing on *Cistus monspeliensis* L. and *Erica arborea* L., respectively (Duhem 2010). Usually, conservation has focused their efforts in protect large forested areas but ecosystems as the Mediterranean marquis shrubland and garrigue, predominantly formed by varied small shrubs, are also interesting to be considered in an integral protection of the Mediterranean biodiversity.

### Riparian forest

Generally, species of *Alnus* Mill., *Betula* L., *Celtis* L., *Corylus* L., *Fraxinus* L., *Populus* L., *Salix* L., and *Ulmus* L., and are associated to permanent watercourses, forming the majority of the riparian forests in the Mediterranean. Seasonal or intermittent flow courses are also very common in the Mediterranean region having a vegetation of its own, dominated by *Nerium oleander* L., *Tamarix gallica* L., and *Securinega tinctoria* (L.) Rothm. Some species of aphylloroid fungi associated to riparian trees are in example, *Phanerochaete tamariciphila* Boidin, Lanq. & Gilles, *Trametes suaveolens* (L.) Fr., and *Vuilleminia coryli* Boidin, Lanq. & Gilles. Because of its rarity and restricted distribution, some of them are priority to be conserved, and many of these forests are critically endangered by certain human activities and most severely by the construction of hydroelectric stations and big dams. By the abundance of litter and dead wood in this ecosystems there are a number of wood-decaying species of polypores and corticioids.

### Extreme or particular habitats and hosts

In the Mediterranean area some particular habitats that have a restricted distribution, relicts of wider forests of the past, are very interesting and peculiar from a mycological point of view, with some threatened wood-inhabiting fungi associated. One of these is the *Ilex aquifolium* L. and *Taxus baccata* L. forest, a special and with a very restricted distributional area where the common holly grows in association with pluricentenary European yews. Those *Taxus baccata* trees are considered among the oldest giants in Europe. There are some good formations in the Northern of the Iberian Peninsula and in the northern part of Sardinia. In these last Italian forests, very peculiar indeed, has exclusively been collected *Aleurodiscus ilexicola* Bernicchia & Ryvardeen, while *Dendrothele tetracornis* Boidin & Duhem, and *D. wojewodae* Pouzar can be considered very rare species with a restricted distribution in Europe.

Another example is the dunal habitat. It is a particular, unstable, almost lost and very interesting ambient, that shows extreme growing conditions. It is present sporadically here and there where *Juniperus*, *Pistacia* L., *Erica* L., *Phillyrea* L., etc., colonize the sands of the dunes. It is one of the most interesting habitat for wood-inhabiting aphylloraceous species even if the growing period is very short, due to the windy conditions, the salinity, and its connection to the necessity of high humidity levels. The number of species is never numerous but very often they are unique like *Acanthophysellum dextrinoideocerussatum* (Manjón, M.N. Blanco & G. Moreno) Sheng H. Wu, Boidin & C.Y. Chien, *Phellinus pseudopunctatus* A. David, Dequatre & Fiasson, and *P. rosmarini* Bernicchia, and *Vararia maremmana*.

## EUROPEAN RED LIST OF FUNGI

There is no an official European red list of fungi, and progress to produce a checklist of endangered fungi is different among the European countries. The European Council for the Conservation of Fungi (ECCF) has compiled a preliminar European Red List of endangered macrofungi (<http://www.wsl.ch/eccf/candlist-subtotals.xls>) where list a total of 1643 candidates distributed in the next orders: Agaricales (794 especies), Atheliales (1), Boletales (45), Cantharellales (13), Ceratobasidiales (1), Corticiales (6), Dacrymycetales (2), Elaphomycetales (13), Geastrales (4), Gomphales (9), Helotiales (72), Hymenochaetales (32), Hypocreales (14), Pezizales (202), Phallales (65), Polyporales (214), Russulales (95), Trechisporales (3), Thelephorales (32), Tremellales (6), and Xylariales (20).

Aphyllorphoroid fungi are distributed among all the major orders of basidiomycetes, and almost 400 species are considered in the previous checklist. However, the list has some shortcomings and they are missing newly described species, but it serves as base list of species, and consequently habitats, to be preserved.

## PROBLEMATIC AND THREATS

There are several publications about fungal conservation and the reader can find more information and other reading suggestions in Moore et al. (2001). We will briefly and generally review below some of the problems and possible solutions to achieve an adequate conservation of habitats and species of fungi.

### **Unequal treatment of different groups of fungi**

Traditionally, some groups as agarics or bolets have received a considerably broad consideration by both, professional and amateur mycologists. Contrary, some groups and genera of basidiomycetes and ascomycetes are neglected in most inventory studies. Mycologists, above all, non professional mycologists, are less interested in some groups visual less attractive and where the need of a microscope is of critical importance and a limitation, resulting in the loss of interest for them. Also, some groups, with non pathogenic or agricultural importance, are usually discriminated by the administrations and to get funds for their study is much more difficult.

### **Inadequate knowledge of the diversity**

One problem to remark is the poor knowledge of some groups of fungi, and for the aphyllorphoroid fungi this is very patent in several families. For many species there are only few records (also is usual that only the type specimen is known and never recollected) and the taxonomical, ecological, and chorological information is very restricted. To add more confusion, species delimitation is still incomplete in many species complexes. Molecular information, when available, is often of exceptional value to resolve phylogenetical relationships, but also in some cases it contributes to add some confusion when molecular analysis is incomplete or deficient. Europe is probably the better explored and studied area in the world, but several new species

are still described every year. To illustrate this, two new corticioid genera were recently described (Bernicchia et al. 2011, Duhem & Schultheis 2011), but also more conspicuous species are described each year as in the case of two new species of *Hydnum* L. (Olariaga et al. 2012) and a *Sarcodon* Quél. ex P. Karst. (Pérez-De-Gregorio et al. 2011). Also, differences between countries or regions are patent and inside Europe, while in Portugal, Spain, France, and Italy, the knowledge is quite acceptable, in Eastern countries there are several deficiencies. The situation is even worst in North African countries, and the research advance is here fundamental to have a complete understanding of the Mediterranean area.

### **Habitat fragmentation and reduction**

This is probably the main problem regarding world conservation of the biodiversity. Considering the Mediterranean area a very populated place, it is a difficult challenge to make compatible the protection of the ecosystems and the demographic expansion, and the recently abusive and uncontrolled tourism style has not helped. Most of the forested areas have been reduced or eliminated and replaced by farming lands, roads, urbanized areas, and large tourist resorts for example, with an abusive use of resources and land colonization. In addition, in the last decades, large areas of native forests have been replaced by pine, poplar, and eucalyptus cultivations. Also, one of the biggest problems in the Mediterranean area for the conservation of forests is the risk of fire. We must not forget nevertheless that fire in the Mediterranean area is a natural method of regeneration conditioned by natural factors that would not cause major problems. Unfortunately, fires from natural causes are limited and more than 95% of fires in Mediterranean areas are intentional or caused by negligences, constituting a serious risk for the preservation of the biodiversity.

### **Desertification**

Some areas in the Mediterranean have experimented serious problems of desertification in the last decades. The problem is complex but it is imperative to do a responsible water and forest management promoting reforestation programs. In this sense the irresponsible housing bubble of the last years on the Mediterranean, has greatly contributed to the degradation of various forest environments and the situation is difficult to reverse in many of them.

### **Poor coordination between administration, research institutions and inadequate funds**

In the majority of cases, research is unfortunately not coordinate with the public administration. Often, results and advances of the research or individual projects are not further considered in public management and important information is restricted to academic or scientific circles and mycological journals. Scientific progress is not immediately applied in forest management or environmental legislation with the consequent loss of utility.

Basic research, biodiversity, and ecological studies with no important economic repercussion are usually considered less relevant and relegate to a second place. We must not forget the importance of basic science for the progress of other researches,

and in this time of reduction of the biodiversity is essential to concentrate efforts in the knowledge and the protection of the natural resources. In the present time, when in general, the national governments do severe cuts to research, is also necessary to get support and funding in the private sector, such as foundations or organizations interested in conservation and environmental education.

## STRATEGIES OF CONSERVATION

### **Highlight fungal importance**

Fungi play an important role in various ecosystems. Wood rotting fungi, mycorrhizogenous, and parasitic species are essentials in the forest dynamics. Nutrient cycle, soil structure, and forest productivity is largely regulated by fungi. Also, there is an underexplored field regarding chemical compounds and several species may be investigated as potentially important in medicine, natural therapy, nutrition, or organic dyes, as example.

### **Increase research in poor or unexplored areas**

As the knowledge of the aphylloroid biodiversity is still incomplete, it is mandatory to increase inventory work, in order to find out what and why we need to conserve and protect. It would be adequate that the research results were reflected not only in scientific journals, usually inaccessible to non specialized people, and try to disseminate as much as possible the acquired knowledge.

### **Protect key and vulnerable species**

We need to be more incisive and try to convince the administration for a rapid inclusion of the most vulnerable species in the national and European legislation. Sometimes it is difficult to approach the bureaucratic and legislative steps, but is much simpler try to sensitize forest managers and local people of the need to include fungi in the forest management planning. In this sense is essential to have good communication with directors, park rangers, and managers of the natural areas that are generally very receptive to the information exchange.

### **Promote conservation of priority habitats and creation of microreserves**

In coordination with botanists and zoologists, we need to emphasize the protection of the Habitats of the Directive 92/43/EEC. Under the guidance of the previous Directive, large natural areas in Europe have been mapped, but just under a strictly botanical perspective. Also several microreserves (singular, small areas of no more than 20 hectares) have recently been created for the protection of rare, endemic, or characteristic floristic elements. It would be interesting and necessary to combine the economic effort of the public administrations to get an integration of all biotic elements when proposing such reserves, and consideration of fungi is essential, as significant elements in the forest ecology.

### Good forest and agricultural practices

Forest management and the proper use of agricultural and pastoral areas are essential to the conservation of biodiversity. Traditionally, the administration of forested areas in much of the Mediterranean has been led out by forest engineers, and unfortunately in many cases from the point of view of timber production. Fortunately today, multidisciplinary teams handle their management and forests are beginning to be considered not only from a purely productive perspective but as a source of varied resources and many areas are being recolonized by original forests. The maintenance of different successional stages, adequate management favoring the abundance and decomposition of organic debris, and an equilibrate forestry are compatible to maintain a high fungal diversity. The change from extensive to intensive land use, has also enabled the regeneration of large areas. However, traditional farming is clearly possible and recommendable, following a few good practices compatibilizing land use and the presence of forests.

### Environmental education

This is probably the most important step in the immediate conservation of biodiversity. Educators have an essential role to play but it is also indispensable the efforts of individuals, mycological associations, foundations, research centers, universities, and administration. Provide and adequate knowledge and encourage an adequate protection of the ecological patrimony is fundamental to achieving diversity conservation.

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