Fungal conservation in Africa

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Abstract. Nature conservation and conservation training in Africa are actively pursued and receive much international interest, but there is little awareness of fungi, of their importance, their uses, their unexplored diversity and the need to protect them. This review summarises the current state of fungal conservation in Africa, describes the recent establishment of the African Workgroup on Fungal Conservation, and discusses possible ways forward for fungal conservation on the continent.

Key words: Africa, fungal conservation, status, threats, tools

Introduction

The ancient Roman, Pliny the Elder wrote, "ex Africa semper aliquid novi" ("always something new from Africa"). His words are undoubtably true for this continent's incredibly rich biodiversity. Conservation International recognizes eight biodiversity hotspots in Africa (www.biodiversityhotspots.org), and the continent harbours countless UNESCO World Heritage Sites (http://whc.unesco.org/). Reasons for this diversity include the presence of a multitude of diverse vegetation types and climatic zones within the 53 constituent countries. Most of these vegetation types are under severe anthropogenic threat. Although charismatic mammals, such as the lion, elephant, antelopes and great apes are popularly showcased by the media, and various high-profile studies conducted on them, conservation and sustainable ecology often compete with human needs of this largely developing, densely populated and poor continent.

Conservation efforts have gathered momentum in some African countries, but remain largely underdeveloped in most. Even in countries with strong conservation initiatives such as South Africa, conservationists are faced with many challenges where human needs conflict with the rights of natural biological life, or where people remain ignorant of the importance of preserving natural surroundings and ecological processes.

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Basic biodiversity research such as inventorying, ecosystem characterization, and discovery and describe novel species, are crucial for sound conservation planning and implementation. In many African countries, biodiversity surveys of variable quality are being conducted, often assisted by non-African collaborators. Yet, even in countries such as South Africa where there exists good infrastructure for this work, several gaps and difficulties still exist. Surveys usually focus on vertebrates and plants. Insects may receive some attention, but other groups are usually overlooked to the point of exclusion. This is disconcerting, as vertebrates and plants represent a small fraction of the total diversity.

Fungi and their chromistan and protist analogues form an extensive but understudied part of any ecosystem. Many form symbiotic associations with animals both invertebrate and vertebrate, and plants. Some are agents of serious crop or veterinary diseases, while others can be used to develop food, medicine or industrially beneficial products. Many species of fungi form fruiting structures (e.g. mushrooms and brackets) which have culinary or medicinal value, thus forming an integral part of many African cultures (see Gryzenhout 2007a). Yet even these more conspicuous species are often ignored in biodiversity studies.

The reasons why biodiversity beyond animals and plants is so understudied can be attributed to the incredibly high numbers of taxa, the large proportion of unknown species,

the logistical difficulties of studying them, the lack of basic checklists and a huge lack of experts capable of identifying them. These difficulties are, however, not restricted to Africa, and are even evident in the higher income countries of Europe and North America. The problem with biodiversity research on these organisms in developing African countries is, however, compounded by the usual difficulties in conducting research in the developing world and an even more acute pressure for scientists to concentrate on applied research which focuses on agriculture or other economic enterprises.

This report presents a short review on the status of fungal conservation in Africa compiled for the special meeting *Fungal Conservation: science, infrastructure and politics* held in Whitby, United Kingdom, in October 2009 (www.cybertruffle.org.uk/whitbymycosynod). It is not complete and no attempt has been made exhaustively to cite all relevant research, databases and literature on biodiversity and conservation of fungi in Africa. It also largely reflects opinions of members of the newly formed *African Mycological Association* [**AMA**] Workgroup on Fungal Conservation. It does, however, constitute a document which summarizes current status and needs, and can be used to create awareness of fungal biodiversity and the need for its conservation in Africa.

Mycology in Africa, with emphasis on conservation of fungi

Fungi have been studied in Africa for a long time, initially and even recently mainly by Europeans, who usually took collected specimens back to their respective countries (for example Pegler 1977; Högberg 1982; Ivory & Munga 1992; Rameloo & Walleyn 1993). However, today many African countries have at least one or two trained mycologists, and collectively they cover almost all aspects of the discipline, although still often assisted through collaboration with non-African mycologists. They are served by the **AMA** (www.africanmycology.org) which maintains an active list of e-mail contacts and produces the quarterly newsletter, *MycoAfrica*. In addition, the interests of mycologists in Arabic-speaking countries of Africa are served by the Egyptian-based *Society of Basic and Applied Mycology* [**SBAM**], which held its first conference from 9–11 March 2010 in Assiut, Egypt.

The challenge of creating awareness of fungi to protect them and stimulate much needed and fundamental research on their biodiversity remains. During the 6th **AMA** Regional Mycology Meeting in January 2009, held jointly with the 46th Congress of the *Southern African Society for Plant Pathology* [**SASPP**], a workshop, "Evaluating the conservation status of fungi using **IUCN** criteria" was presented as part of a UK Darwin Initiative (http://darwin.defra.gov.uk/) project to raise awareness of the need to conserve fungi, particularly microfungi. During this workshop, conservation issues relating to fungi were discussed, and as a result, the **AMA** soon after established a *Fungal Conservation Workgroup* to stimulate and co-ordinate activities related to and useful for fungal conservation.

The **AMA** *Fungal Conservation Workgroup* aims eventually to submit conservation evaluations of fungal taxa to the *International Union for Conservation of Nature* [**IUCN**]. The workgroup also provides a suitable platform to promote fungal conservation in governmental biodiversity and conservation bodies, to make important literature available and to consolidate checklists. Currently the workgroup consists of about 40 members representing 13 countries and is led by a steering committee consisting of Dr Marieka Gryzenhout (FABI, University of Pretoria), Dr Francois Roets (Dept. of Conservation Ecology and Entomology, University of Stellenbosch, South Africa) and Dr Rian de Villiers (Faculty of Education, University of Pretoria, South Africa). These mycologists have diverse interests and taxonomic expertise.

The African *Fungal Conservation Workgroup* is still in its infancy and will have to develop significantly in terms of acquiring basic resources. From support already received, it has been possible to establish and maintain a new **AMA** website and domain, and to fund the 2009 **AMA** workshop already mentioned. A fungal conservation training workshop, again in South Africa, is scheduled for 2010; thereafter further funding needs to be found.

The workgroup and its steering committee need engagement with colleagues and with collaborators beyond Africa for guidance and support on fungal conservation and biodiversity issues, implementation of **IUCN** criteria and guidelines, interpretation of governmental biodiversity and conservation laws, the raising of public awareness, and most importantly assistance in fungal taxonomy and databasing. To address these various needs it will also be necessary to co-ordinate and build African capacity, creating opportunities to practise fungal conservation and to developing biodiversity tools such as literature and database resources. Through these opportunities, much needed training of African mycologists can be given by local and international experts, while targeted and scientific sampling can be simultaneously done to start filling the gaps in African fungal collections.

The status of fungal conservation in Africa

There are many conservation organizations and activities in Africa, but none include micro-fungi and most do not even include macrofungi. For instance, no fungi are documented on the red data list of any African country, nor are fungi necessarily recognized as important by relevant governmental and funding bodies unless they are of direct economic value. This void is undoubtedly the result of general ignorance of their importance, coupled with difficulties in dealing with them in bioinventories. Necessary resources such as complete checklists and distribution data are unavailable for fungi and the numbers of undiscovered species remain vast.

Before the *Fungal Conservation Workgroup* was established, no-one had focused on fungi in Africa. Some African mycologists are, however, involved with fungal conservation groups in Europe, or have received graduate and post-graduate

training at Asian, European or North American institutions. Although individual mycologists in some African countries have contact with conservation groups in their respective countries, the *Fungal Conservation Workgroup* has not yet established formal collaborations with any conservation body or received any governmental funding. The workgroup is, however, starting to engage with conservation groups and governmental bodies, especially those involved with red data listing. In this regard, formal establishment of the workgroup has been helpful in providing an official means of communication.

Fungi are not explicitly included in biodiversity legislation, biodiversity action plans and conservation policies of most African countries. At best they are doubtfully covered under the incorrect title of microbe or plant. In the case of microbes, policy makers and governments usually do not know how to handle such a poorly defined, incredibly diverse and vastly understudied group. Fungi are thus usually implicitly rather than explicitly protected under the general heading of 'biodiversity'. There are, however, a very few examples of explicit protection for fungi in some African countries. In Zambia, for example, mushrooms are included and in Uganda 184 genera and 420 species of fungi are mentioned.

Fungal pathogens are usually regarded as a threat to agricultural and forestry crops of a country, and to its natural vegetation, or as agents of veterinary or human diseases. For this reason, quarantine measures in the form of lists of pathogens already present or to be kept out, are routinely available and regularly updated. Regulatory bodies and governmental departments involved with these organisms, however, are usually different from those dealing with natural biodiversity protection and conservation, and there is no recognition that such organisms are also part of biodiversity and may themselves be threatened.

Threats to fungi in Africa necessitating awareness and conservation

Threats to fungi in Africa are similar to those elsewhere. Some are, however, more pronounced in an African context as the continent faces numerous developing world problems and a severe lack of mycological expertise. Shifts in ecological balance attributable to extensive degradation of ecosystems may trigger sudden emergence of fungal epidemics or insect pests with disastrous results. At the same time, conservation strategies for ecosystems and habitats in Africa disregard fungi, yet the survival of extensive biomes such as the Miombo, depend on their fungi (see Gryzenhout 2009) and, tellingly, Miombo ecosystems directly support almost 40 million people in Central Africa where some of the world's poorest countries are found (Desanker *et al.* 1997).

Ecologically, fungi are just as threatened as animals and plants. The most important threats include poor land management and habitat alteration, degradation and transformation. In Africa, these are especially evident where people are poor and have to rely on immediate natural resources for a living. The result is huge areas cleared for agriculture by slash and burn (Achard *et al.* 2002). Indiscriminate spraying of non-selective fungicides by farmers, especially by subsistence farmers, is especially threatening to native fungi. Loss of habitat by overgrazing is a great problem, as is over use of native trees for firewood, charcoal, and tourist ornaments. Loss of vegetation and constant removal of dead wood from forests result in loss of associated fungi (Berg *et al.* 2002). Damage to those trees and stresses associated with land alteration and degradation also predispose them to pathogens and pests.

Cultural practices such as ethnobotany and ethnomycology impact significantly on fungi. Harvesting of medicinal plants is often destructive and predisposes those plants to pathogens and pests attracted to wounds. This can lead to death of the plants with subsequent loss of substratum for their associated fungi. Africa has a rich tradition of ethnomycology (Gryzenhout 2007a; Wallyen & Rameloo 1994; Lowore & Boa 2001; Jefwa *et al.* 2007; Boesch & Mbago 2008), including the consumption of native edible mushrooms. Yet these mushrooms can be over-harvested, and their occurrence can be threatened by human developments.

Invasion biology and climate change are highly relevant and potentially damaging factors for biodiversity and conservation. Invasive animals and plants impact on the biodiversity of other native organisms (Anagnostakis 1987; Elton 2000; 2001; Pimental *et al.* 2001). The same can happen for fungi. Besides invasive fungal pathogens, the impact of other types of invasive fungi on native ecosystems has not been evaluated. These fungi may be just as threatening to native fungi as invasive animals and plants are to native animals and plants. The effects of climate change on African fungi remain unforeseen but ominous, but one possible impact may be to cause weak fungal pathogens to become more aggressive (Kamata *et al*. 2002; Kühnholz *et al.* 2003; Desprez-Loustau *et al.* 2007; Six & Bentz 2007; Six 2009).

Threats at the political and practical level are as important as ecological threats. Priority should be given to create awareness among the general public, and in governmental and conservation circles about the importance of fungi for the environment and consequently for humans. It will often be necessary to change incorrect perceptions that fungi are insignificant or only damaging. Where decisions relating to biodiversity are being made, every effort should be made to promote the fungi and, ideally, scientific data should always be ready for presentation in the political arena.

Comprehensive data are very important in any conservation effort. Inclusive data sets are used to prioritise and assess problem areas, to recognize rare and endangered species, to place them on Red Data Lists of the **IUCN** and individual countries, to add a voice for fungi to other conservation efforts and to protect particular sites important for fungi. Africa is still at the level of compiling first generation fungal checklists and has great numbers of undescribed species. A huge lack of capacity hinders existing mycologists

from characterizing fungal biodiversity beyond that directly related to economically important crops. A lot of funding is needed to enable these activities to proceed.

Mycologists themselves are threatened in Africa because of very low numbers. They must work more closely, combine strengths and, to avoid duplication of effort, improve personal awareness of the work of other mycologists. A lot of networking is thus needed. In this regard, the **AMA** and **SBAM** play an important role. The so-called brain drain of capable professional mycologists, particularly students, out of Africa is especially worrying. This is stimulated by difficult working conditions and lack of funds. Young and trained mycologists often change careers in frustration at lack of employment opportunities in national institutions, which at best retain single mycologists and usually none at all. The problem is exacerbated because mycology in most institutions is still organized as an afterthought under the umbrella of botany or microbiology departments and, until that changes, will always occupy a peripheral position.

Governmental and funding bodies need continuous reminding of the importance of living fungal collections and dried fungal reference collections, and of the need to prioritize those with national and international significance. The role of private culture collections in conserving the natural biodiversity of a country should be given more prominence and support. To address these various issues, it is necessary to identify mycological centres of excellence of different types in Africa in addition to known living and dried collections.

The availability of tools for fungal conservation in Africa

Many African mycologists and collaborators from beyond Africa are carrying out research relevant to fungal conservation, but currently conservation itself is not being actively pursued. In this regard conservation should be seen as different from biodiversity, although sound knowledge of fungal biodiversity is necessary for conservation. The establishment of the *Fungal Conservation Workgroup* has enabled its members to co-ordinate conservation activities, and the membership list of the **AMA** further enables networking and collaboration. Yet to pursue conservation, tools will be necessary to provide data for assessments, development of strategies and identification of gaps in knowledge and expertise.

The most important for fungal conservation in Africa is establishment, updating, auditing, and possible merging of fungal checklists for different areas. Ideally, these should be established not just for countries, but also for cross-country "biomes", thus making available pooled data not restricted by country borders, but rather representative of zones defined by ecology, geology or vegetation. Lists of literature about African fungi are also extremely important, and these need to be freely and openly available. Various resources are becoming available on-line but those designed by botanists or zoologists and adapted for use by mycologists rarely handle associated organism information well. Specialist literature lists are provided through the **AMA** newsletter, for example of African Zygomycetes or slime moulds, including literature unavailable from searchable on-line databases. On-line databases containing African literature, specimens or cultures have also been listed previously in *MycoAfrica* **1** (2) and *MycoAfrica* **1** (3) (Gryzenhout 2007b, c). The African content of more general mycological literature resources, such as those of *Cyberliber* (www.cybertruffle.org.uk/cyberliber) need strengthening.

Checklists, descriptions and first reports of fungi are meaningless if specimens and isolates cannot be deposited in dried reference collections and living culture collections. Ideally these isolates and specimens should be curated in Africa, but in reality they are still often deposited by collaborators in collections elsewhere. Numerous collections do, however, exist in Africa (Jones 1995) although, barring a few countries such as South Africa, their status has not been audited for 15 years. High overhead costs and the need for trained technicians, especially for culture collections, make these resources very dependent on funding, and their importance is often neither understood nor acknowledged by governmental bodies. This is especially true for culture collections of living fungi, which have needs very different from those of herbaria, museums and zoos. Private culture collections also represent an important repository of biodiversity but are even more threatened, as they often depend on research funding and continuation of a specific research programme. Once the research stops, or when the researcher moves or retires, they are in great danger of being lost.

The way forward

How can one deal with the great lack of capacity and absence of data necessary for fungal conservation in Africa? This is especially important for its hyper-diverse fungal communities, particularly in the tropics and sub-tropics. The fynbos ecosystem of South Africa alone has an estimated 200 000 fungal species of which only 4 % have names (Crous *et al.* 2006). How can one possibly deal with so many fungi having so few mycologists? How can the message be conveyed to governments and conservation bodies that fungi need active and explicit inclusion in national surveys and inventories, not just passive and implicit protection?

A clear strategy with stepped priorities is needed to document the biodiversity of African fungi and ensure they are included in the continent's conservation framework. This planning should be carried out at a continental level, not just in individual countries. Localities where where expertise and data exist form obvious starting points, and fungi as yet undiscovered in those areas should not be neglected. It will also be useful to identify key geographical areas as focal points for extensive fungal surveys to produce fuller checklists. Possible candidates for surveys with conservation orientated outputs should be old or undisturbed vegetation, biodiversity

hotspots, endangered vegetation types and certain rare, endemic and/or endangered plants. Help of experts from beyond Africa should be sought for taxonomic groups where indigenous expertise does not exist. Such efforts should also be combined with training of local mycologists and conservationists.

Molecular approaches can be immensely useful to address the large numbers of fungi awaiting characterization in Africa, of which most will be novel. Conventional yet thorough culture methods and sampling of conspicuous or visible fungi cannot be the only means of surveying, as there are simply too many fungi to cover and these methods are time and capacity consuming. Barcoding of fungi cultured during surveys would be invaluable to create a DNA database accessible internationally, and that would enable the linkage of known and novel fungi to unexpected lineages or environmental groups.

Several molecular based methods directly amplify fungal DNA from environmental samples. Some of these methods, e.g. ARISA (Fisher & Triplett 1999), exist to compare and quantify the diversity of communities, while not necessarily confirming the identities of individuals. Others such as pyrosequencing provide DNA sequence data from environmental samples. These sequences can be linked to DNA barcodes and global DNA databases. The methods are less time consuming than whole-organism isolation techniques, although usually more expensive and not linked to cultures or dried reference collection specimens for species descriptions. However, such methods can give an idea of the diversity and composition of fungal communities over different habitat types, climatic zones and/or specific niches. As such, they could provide meaningful basic data on community structure and would enable better planning of the sampling and culturing which would need to follow.

Important by-products will surely stem from Africa's fungal biodiversity: medicines, industrially important enzymes or other compounds, and fungi useful for the food industry. These will underline the importance of knowing our fungal biodiversity and the value of associated collections. They could also potentially stimulate research and facilitate acquisition of funding. Plants have already been used extensively in bioprospecting, and ethnobotany as a study is growing. The same type of bioprospecting is possible for fungi and indeed has already been done by some researchers in Africa (see Gryzenhout 2008).

Mycologists, especially those interested in fungal biodiversity and conservation, should engage, publish and be present in other disciplines, such as botany, entomology, biodiversity science, ecology, conservation and education. Multi-disciplinary research with other biologists is necessary. Mycologists can, for example, remind ecologists and conservationists that fungi must be taken into account if assessments and sustainable land management strategies are to be valid.

Public awareness is an important component of any conservation effort, even more so for organisms such as fungi which may be unknown to the public or even feared. Awareness raising should also extend to government bodies and especially other biologists. Amateurs can help scientists and may achieve a lot on their own for conservation. For mycology in particular, amateurs are indispensable to alleviate the lack of capacity and to help the few professional mycologists produce more complete biodiversity lists and promote conservation. This has been done elsewhere, e.g. through the North American Mycological Association (NAMA; www.namyco.org) and, in Australia, the Fungimap project (www.rbg.vic.gov.au/fungimap_/welcome). In South Africa, a new initiative provides an e-mail list server for amateurs called Mycorrhiza, with a linked website, www.SaFungi.org, to aid enthusiasts to learn more about fungi, to answer the queries of amateur mycologists, to help identify fungi encountered, and to facilitate work on future checklists, distribution maps and host lists. This initiative at present focuses mainly on those macrofungi which most people encounter and are likely to know.

Flagship fungi can be used in the same way as charismatic flagship animals or plants to create awareness and interest for conservation purposes. People are naturally interested in large, conspicuous or edible fungi, in fungi with interesting relationships with other organisms, and species useful to humans. *Termitomyces* spp. make good candidates in this regard. Fungal pathogens often receive attention as they impact directly on the public and industry - that is why plant pathology and development of fungicides or resistant plant cultivars are strong research fields. With care, they can also be used to create awareness of fungi occurring in the natural environment. The proposal of a National Fungus for each country could also raise awareness.

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