

The use of a database for conservation – case studies with macrofungi

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Abstract. Fungal conservation needs a good knowledge of the ecology and distribution of target species. A computerized database is essential to store large amounts of records which can be enhanced and corrected. Three examples are given to illustrate the potential of a database for conservation management and developing conservation strategies. Distribution maps and especially estimated areas of occurrence, obtained by modelling, help build reliability. Associated organism of wood-inhabiting fungi identifies pioneer trees as exceptionally rich woody substrata which have implications in forestry management. The correlation between area size and number of inhabitants reveals the importance of urban areas for conservation.

Key words: conservation, database, ecology, modelling

Introduction

Biological conservation needs sound scientific bases to be effective. Knowledge about distribution, occurrence and ecology is a prerequisite for facilitating measurements and management of species. As fungi are a very diverse and extremely species rich group of organisms, an appropriate relational database management system is advantageous. However, many larger databases, maintained and enlarged over many years, suffer from structural shortcomings. Very often the original purpose of such a database differs from later uses. The start may be a specific task such as the storage of mycological observations of a three-year period survey of a nature reserve. Later further data with a different quality and eventually additional data types from other projects are added summing slowly up into a database with a rather interlaced structure based on uneven sampling. Baseline samplings help to verify the representativity of the information. With incoming data from different sources the demand for a variety of answers also rises and the database develops towards an being all-purpose in character. Biodiversity databases are particularly subject to such multi-purpose goals.

In Switzerland the Federal Office for the Environment initiated a decentralised national data centre for biodiversity (www.bafu.admin.ch/biodiversitaet/index.html?lang=en) as a nationally significant biological resource. Data on fungi are stored in the databank Swissfungi. Since 1992 georeferenced fungal records are stored with a focus on macrofungi to deepen ecological knowledge about the national species diversity. Georeferences are a prerequisite for all records, as a main objective of SwissFungi is presentation of updated distribution maps for each fungus species in Switzerland. These distribution maps serve as a base for developing the Red List of threatened species using IUCN criteria. They also inform authorities about the presence of species needing protection in each region. Georeferenced data should allow modelling various ecological demands of a given species via overlays in a geographical information system (GIS) such as ArcGIS.

Biodiversity databases, however, store more information than simple georeferences. Many records include ecological information. Records of lignicolous fungi in particular are often accompanied by indications about the substratum and the vegetation type.

Conservation bodies need spatially explicit information for actions. Time and funds are often lacking for detailed new field observations. Biodiversity data centres should therefore deliver essential information about the verified or estimated presence of threatened species.

Three examples will illustrate applications of the database SwissFungi for conservation. The first example demonstrates how models of distribution and occurrence may help build reliability. The second example, with analysis of woody substratum data from fungi, leads to explicit recommendations in forestry. The third example provides indications for conservation strategies and points towards urban areas as important areas for biodiversity.

Case 1. From distribution maps to estimated areas of occurrence – building reliability

Conservation management requires information on a diverse range of environmental attributes, including species distributions, natural ecosystem potential, human uses, threats and risks. Often this takes the form of spatial predictions such as maps that present the best estimates of these attributes across the landscape. Ideally, these spatial predictions are produced using rigorous methods for integrating and generalizing underlying information.

The base of such predictions is the analysis of species-environment relationships, a central issue in ecology. The quantification of such species-environment relationships represents the core of predictive geographical modelling in ecology. These models are generally based on various hypotheses as to how environmental factors control the distribution of species and communities.

Climate is particularly important to explain animal and plant distribution, and has a long tradition. Climate in combination with other environmental factors has been

much used to explain the main vegetation patterns around the world (e.g. Walter 1985). Up to now, surprisingly few studies have been published explaining biogeographic patterns of fungi through statistical models. At a landscape scale, climatic factors such as mean minimum temperature of the coldest month and annual mean moisture index were found to be important explanatory variables in a study about hypogeous fungi in Australia (Claridge *et al.* 2000). Vacher *et al.* (2008) also found climate, particularly temperature seasonality and host abundance, to play a great role in explaining distribution of parasitic fungal species. Wollan *et al.* (2008) showed that temperature is a key factor governing the distribution of macrofungi in Norway.

Species distribution models may serve as a basis to calculate areas of extent and occupancy, important criteria for preparing Red-lists according to IUCN (2005).

For the Swiss Red list of threatened species (Senn-Irlet *et al.* 2007) we used the concept of a generalized regression analysis and spatial prediction, the so-called GRASP (see Lehmann *et al.* 2003). Fungal species being assessed were attributed to one of three ecological life types: ectomycorrhizal, wood saprotrophs, and terrestrial saprobes on humus and litter. Each group was modelled separately using selected predictors. The hitherto georeferenced records of a given ectomycorrhizal fungal species were correlated with data on the associated tree species together with environmental data. Data of the National forest inventory (Brassel & Brändli 1999), based on a 1 km² grid, were used as the symbiotic predictors. Environmental data (climate, soil, exposition) taken from the national area statistics (Swiss Federal Statistical Office 2001), served as additional spatial predictors (extent 41 000 km², grain 1 ha). Wood saprotrophs were treated in the same way including tree species and environmental data. Terrestrial saprobic species were related exclusively to environmental information resulting in a less precise spatial model.

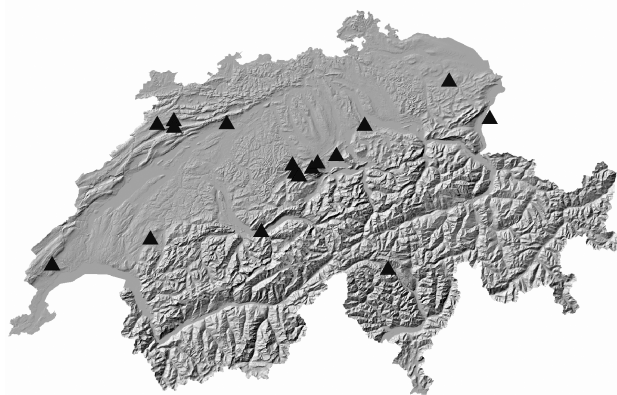


Fig. 1. Observed presence of *Cortinarius pholideus* with 20 records mainly in the Jura mountains and the Northern Prealps

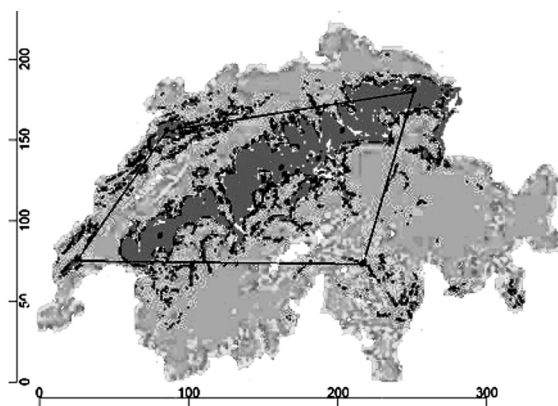


Fig. 2. Distribution model for *Cortinarius pholideus* based on the mycorrhizal symbiosis with birch trees and climatic site parameters: dark spots = area of occupancy, light grey = area of extent. The black line encompasses the area of extent following the strict IUCN criteria (calculated by A. Lehmann, CSCF 2005).

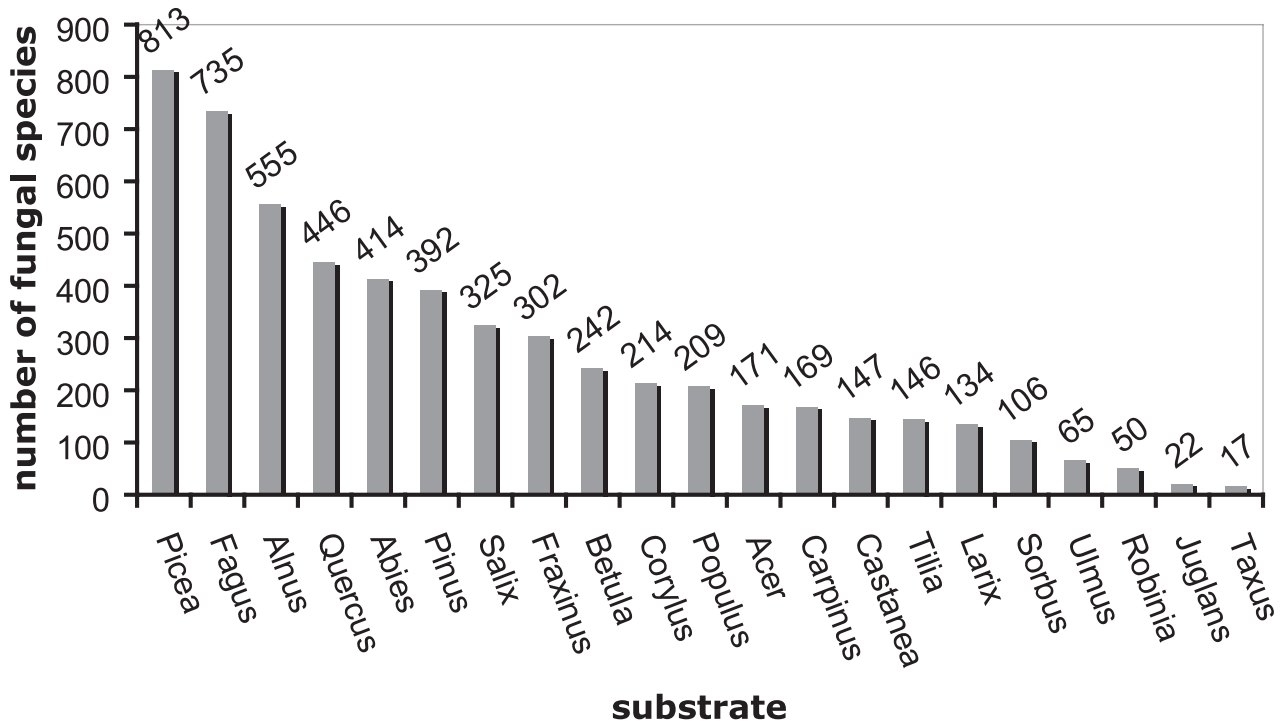


Fig. 3. Species richness of fungi on various woody plant species of Switzerland based on data of the database Swissfungi

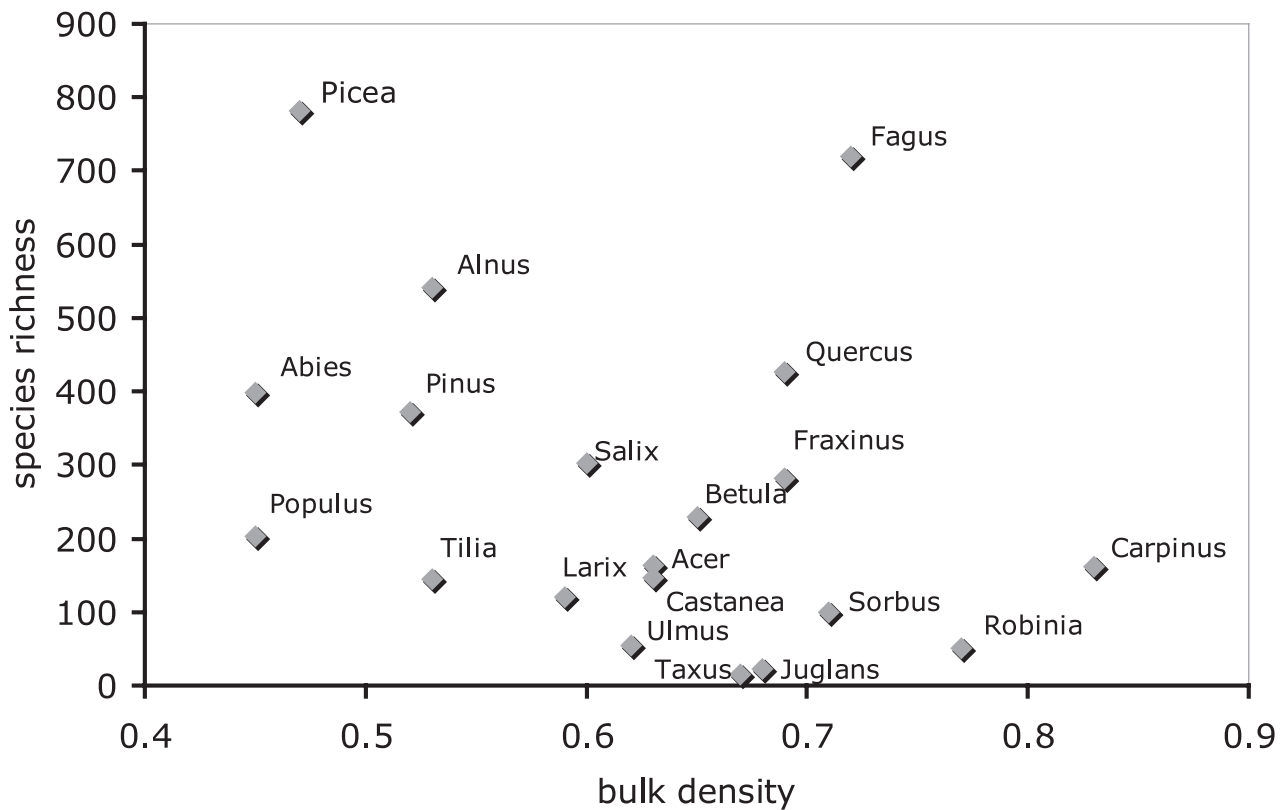


Fig. 4. Correlation between bulk density and fungal species richness. Bulk densities according to Wagenführ (2007)

Example

Cortinarius pholideus, a rather rare mycorrhizal species of birch (*Betula*), illustrates the spatial evidence (Fig. 1) and the spatial prediction (Fig. 2) using this method. The model predicts a wider presence of the species in the Jura mountains and in the northern pre-alps, especially in the area of mires and bogs. Presence is also, however, predicted in parts of Southern Switzerland (Puschlav / GR, Valle Mesolcina / GR).

Conclusions

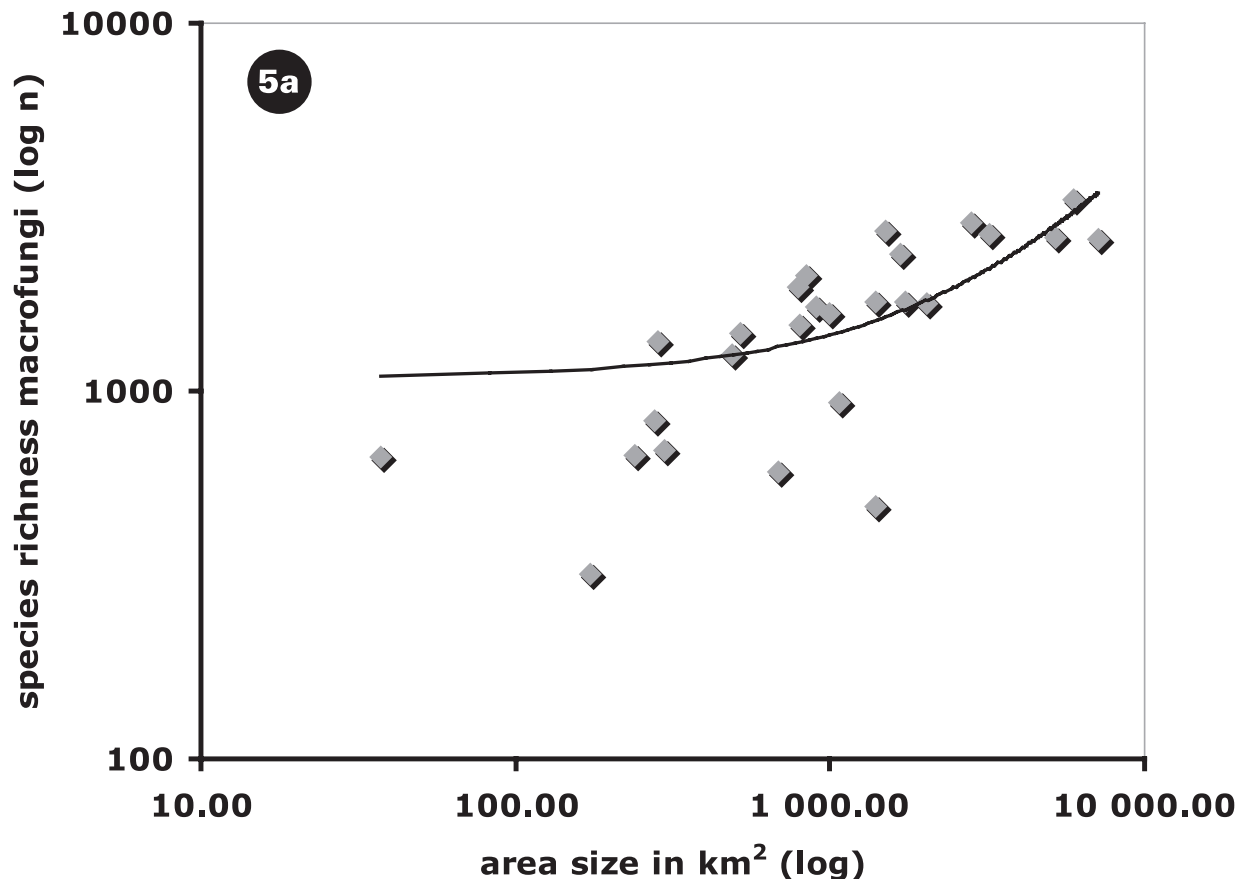
A georeferenced database is essential in defining conservation strategies for macrofungi based on objective methods. The problems of missing explicit information at a local scale, i.e. not enough records for evaluating threats and conservation measurements, can be alleviated by estimated distribution, i.e. with models. Such models visualize that spatial context in which fungal ecology can be studied. In addition such models provide a base for further mycoecological and biogeographical research.

Case 2. Associated organism information identifies pioneer trees as exceptional rich woody substrata

The database of SwissFungi stores 41 035 records (to June 2007) of wood-inhabiting species with some sort of additional information about the substratum, particularly the main associated plant. Beside the associated plant species, ecological details cover the point of fruit-body attachment, and the degree of wood decay. Substratum is classified into twigs (i.e. very fine dead wood), lying branches (i.e. fine dead wood), lying trunks (i.e. coarse dead wood), standing trunks, snags, roots, and stumps. There are four categories of decay, from living to very rotten wood. The recorded species are mainly members of *Aphyllphorales* and *Agaricales*, wood-inhabiting ascomycetes such as *Pyrenomycetes* s.l. and anamorphic fungi are under-represented. A total of 1700 fungal species are associated with some kind of substratum information.

Fungal richness per woody plant species

Most records are from dead wood, especially stumps, fallen trunks or parts of fallen trunks and fallen branches. Norway spruce (*Picea abies*) has the highest number of species, with



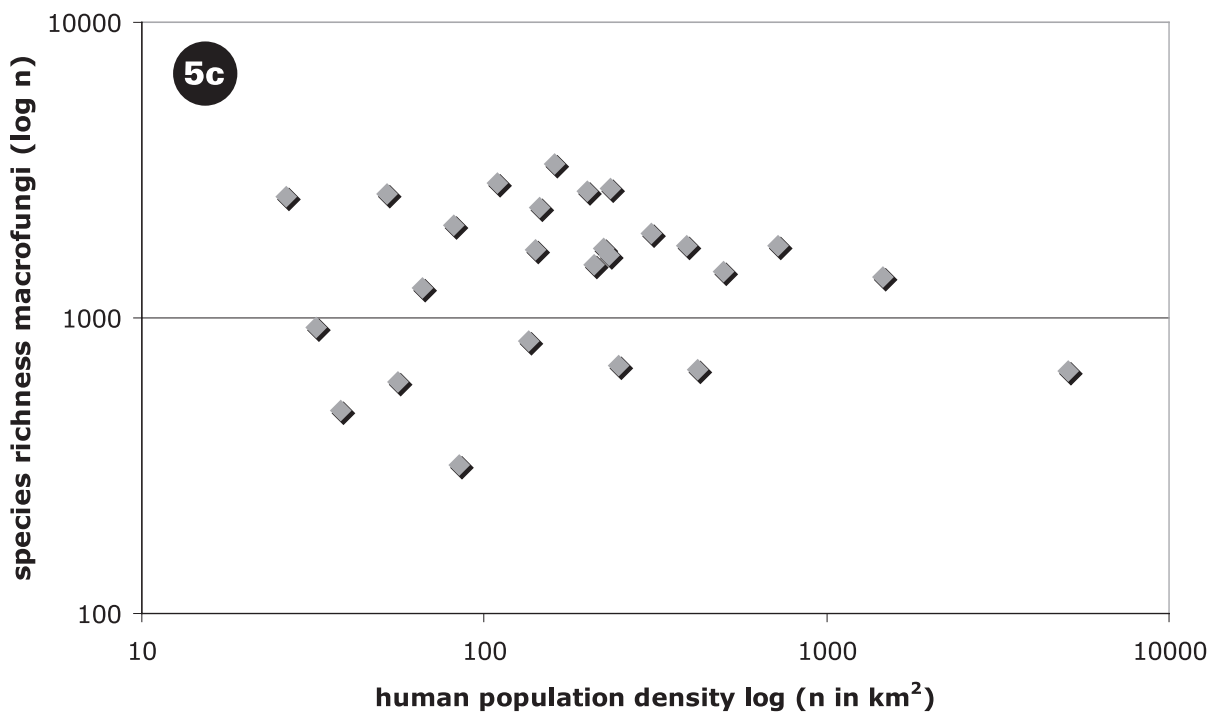
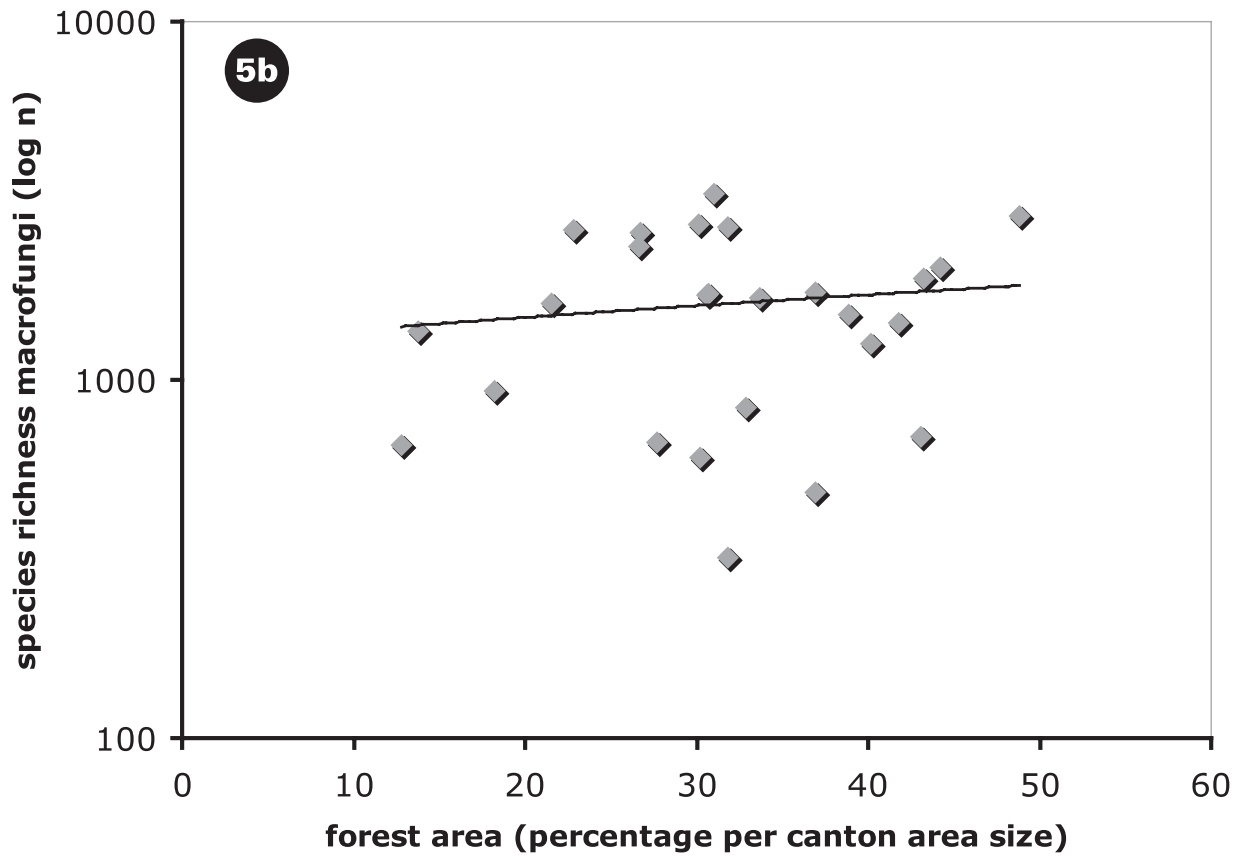


Fig. 5. Fungal species richness in 26 Swiss cantons in correlation with area size (maximum in GR), forest area (maximum in TI), human population density (maximum in BS) and human population size (maximum in ZH) (data from the national statistical survey 2000)

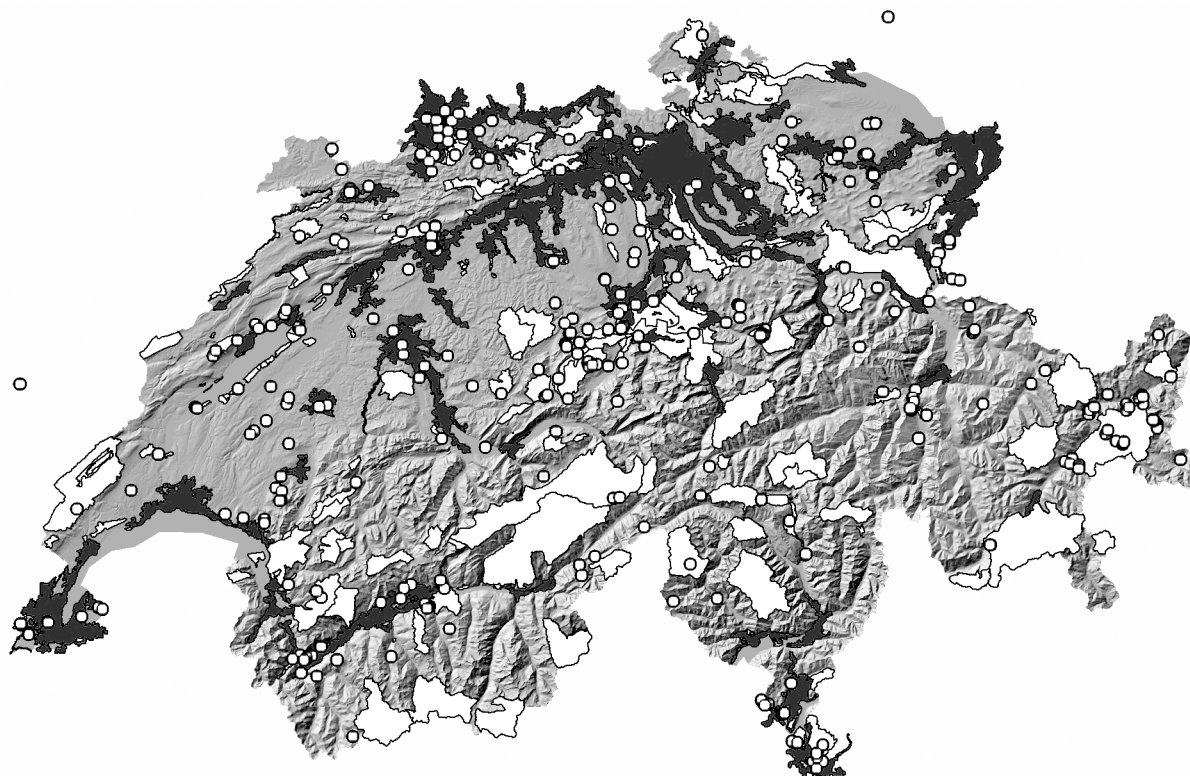


Fig. 6. Records of the 81 critically endangered fungi in Switzerland (white circles with a black stroke), areas of national interest for natural heritage (in white), and areas with high human population densities (in dark gray)

a total of 813, followed by 735 species from beech (*Fagus sylvatica*). After a gap, alder, oak, fir and pine follow as the next most rich woody substrata (Fig. 2). Woody substrata of yew, walnut, locust, and elm are particularly poor in species. These species-poor trees are characterized by hard wood, and have a low presence in Swiss forests.

These records are based on serendipity rather than directed searching, and as a result suffer from a bias towards more investigated substrata. There is a clear correlation between the number of records per host plant and species richness on this woody host. In the present dataset the correlation is significant ($r^2 = 0.86$, data not shown) and means that more observations surely lead to more species recorded. Three associated plants, however, show distinctly more species than expected from a mean value: beech, Norway spruce and alder.

Correlation with substratum availability

Swiss forests are composed mainly of Norway spruce (39.2%), beech (18.3%) and fir (10.9%) (Brassel & Brändli 1999), whereas alder (all three indigenous species together, i.e. *Alnus glutinosa*, *A. incana*, *A. viridis*) comprise only a very small fraction, 2.2%. The fungal records therefore, in reality, point towards alder as a particularly interesting host plant for fungal species richness.

The National forest inventory, moreover, estimates the number of trees present and the timber volume for the main forest tree species. Analysis of these data of substratum availability reveals that willow (*Salix*), rowan (*Sorbus*) and alder are extremely rich in fungal species whereas Norway spruce, larch and fir are characterized by low species richness. The individual experiences of many field mycologists confirm this analysis: in general, on a given piece of hardwood, a higher species richness is observed than on coniferous wood.

Correlation with wood traits

Species richness of wood-inhabiting fungi correlates well with an obvious character of the wood: bulk density. A weak negative correlation exists between the air-dried bulk-density of wood and species richness of fungi. If the two woody plant species with the highest species richness in fungi, beech and Norway spruce, are left out, it may also be said that on harder and heavier wood fewer fungi can be expected.

Conclusions

Species richness of wood-inhabiting fungi is high. Trees like Norway spruce and beech are richest overall, with more than

700 species. Even wood known to be extremely resistant towards decay such as yew (*Taxus*) harbours at least 17 species according to current knowledge. Fungi able to decompose the wood of the two most abundant tree species in Switzerland, Norway spruce and beech, profit from the presence of all kinds of different niches of moisture and temperature.

In respect of availability of various woody plant species, high fungal species richness is observed on deciduous trees with soft wood such as willow, rowan and alder. These trees, typical of early successional stages of forest development harbour many fungi.

Records from the database Swissfungi help to assert the ecological claim for more pioneer shrubs and small trees in managed forests as is required for the FSC-certificate. Fungal richness profits from forests with soft wood.

Case 3. The correlation between area size and number of inhabitants reveals the importance of urban areas for conservation

Species richness and diversity is driven by many factors. Species richness increases with area, a simple finding of many studies across various groups of organisms. For macrofungi Tofts & Orton (1998) demonstrated it for agarics and boletes, and Cafaro (2002) for gut-inhabiting trichomycetes.

Temperature and substratum variability (Küffer *et al.* 2008; Wollan *et al.* 2008) are additional important factors for high species richness and a high diversity in fungi. Environmental heterogeneity, in particular habitat heterogeneity was found by Schouten *et al.* (2009) to be a major determinant of variation in species richness in five different species groups in The Netherlands.

Urban areas offer both, a microclimate with higher temperatures than the surrounding areas and, with all the introduced and planted trees and woody ornamentals, a high potential for fungi.

Pautasso & Zotti (2009) analysed whether there is a spatial correlation between macrofungi and human population in Italy's regions. Although fungal richness increases with increasing number of inhabitants (censused in 1986 and 2006 and predicted for 2026) and with their density, these relationships are found not to be significant when controlling for variations in area amongst regions. Large-scale spatial correlation of people and fungi is also related to factors such as area, habitat heterogeneity and energy availability. The observation that highly populated areas also harbour a high fungal species richness is, however, still worth being highlighted and discussed in terms of conservation strategies.

Data from the databank Swissfungi were checked for spatial correlations between area size, human population size and human population density, forest areas, and fungal species richness (see Fig. 5) in the 26 cantons. Graubünden is the largest canton, Basel-Stadt a small-sized city canton; while Zürich has the highest population and Appenzell-Innerhoden the lowest, population density is highest in Basel-Stadt and

lowest in Graubünden. Large forests cover Ticino with 49 % percentage of forested area, whereas coverage is only 12 % in Basel-Stadt.

The correlation between area size and species richness is clear and significant ($r^2 = 0.86$, $p = 0.001$, Fig. 5a), indicating that the database is sound enough to allow some generalizations. A correlation between human populations size and species richness seems obvious (Fig. 5c), however, the correlation is not significant. Population density seems not to be correlated with species richness. Moreover, fungal richness does not even really increase with percentage of forest cover per canton (Fig. 5b), the correlation remains very weak ($r^2 = 0.016$) and not significant.

Highly forested areas harbour no more fungal species than less forested areas, regions with a high population density are not poorer in species richness than less populated areas. Highest species richness is found in larger cantons with a high geographical heterogeneity such as Graubünden, Bern and Valais covering several climatic zones with a varied land use, which may also include cities.

Occurrence of critically endangered species

Fungal richness increases only slightly with percentage of protected area, as illustrated by a simple overlay of areas of national interest for natural heritage (BLN 1998), which cover 19 % of Switzerland and may correspond partly to Natura2000 sites, and the areas with a high human population density. i.e. the urban areas (Fig. 6). Most records of critically endangered species originate from places outside the network of areas of national interest for natural heritage, suggesting that conservation of fungi also needs to be addressed outside the current network of national and regional nature reserves. The urban areas on the other hand may harbour several threatened species. Most records are situated in neither urban areas nor in areas of national interest for natural heritage.

Conclusion

A database with as much information as possible on species occurrence and ecology, including serendipitous records and therefore, at least in Switzerland, with a bias towards more populated areas with volunteering collaborators, allows for several recommendation in conservation management and conservation strategy planning.

It highlights the species richness of peri-urban areas. Densely populated areas harbour many fungi. Populations of threatened species cannot be maintained solely within existing nature reserves. Conservation management outside nature reserves is also necessary, and urban areas should be included in management strategies. Veteran trees, and unfertilized grassland in parks are key habitats of threatened species.

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