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Introduction – Lichenised fungi (lichens) are often neglected in analyses of ecosystem services and in nature conservation management, mostly due to underestimation of their importance, to the lack of monitoring data for many regions, and to difficulties in species identification. A lichen thallus can be regarded either as an ‘individual’ or as a complex ‘microhabitat’ which includes a huge variety of coexisting fungal, algal and bacterial taxa. When considered as ‘individuals’, about 20% of all fungi (13.500 species) are lichen-forming. The estimated species number of lichens worldwide is of about 28.000 taxa, but the range of intraspecific genetic diversity and cryptic species makes this number notably increase. A review of EF and ES underpinned by lichen has been carried out, and the role of lichen traits involved in ecosystem functions and services has been analysed for the first time.

Ecosystem functions

Abiotic target:

rock, soil, water, air, climate

- ✓ Rock decomposition
- ✓ Primary colonization and soil formation
- ✓ Nitrogen fixation (cyanolichens)
- ✓ Photosynthesis and carbon fixation
- ✓ Denitrification
- ✓ Metal chelating
- ✓ Erosion prevention
- ✓ Water flow regulation
- ✓ Water and substrate quality regulation
- ✓ Air quality regulation
- ✓ Influence on substrate temperature
- ✓ Influence on ozone content

Biotic target:

bacteria, viruses, fungi, plants, animals

- ✓ Food provision
- ✓ Provision of lichen secondary metabolites
- ✓ Provision of habitat, shelter, camouflage and nesting material for diverse organisms
- ✓ Plant germination and growth support



Ecosystem services

Target: human beings

- ✓ **Supporting services.** Only indirect benefits: primary colonization of bare substrates, soil formation and rock decomposition, nutrient cycling, soil enrichment by organic matter, biomass production, clean drinking water and decomposition of wastes; influence on food and feed provision.
- ✓ **Provisioning services.** Direct benefits: use of lichens as food, bedding material, dyes, fuel and tinder, for medicinal and ornamental resources, in cosmetics and in the fragrance industry. Indirect benefits: from the support of the diversity of other organisms; influence on food and feed provision.
- ✓ **Regulating services.** Direct benefits: purification and detoxification of water, air and substrate; pest and disease control. Indirect benefits: Climate regulation, erosion prevention, regulation of water flow, water and substrate quality; support of the diversity of other organisms.
- ✓ **Cultural services.** Direct benefits: scientific importance; bioindication; inspiration for culture, art and design; esthetic, educational and recreational value. Indirect benefits: from the support of the diversity of other organisms.



Lichen traits involved in ecosystem functioning

- ✓ **Morphology:** thallus growth habit, growth rate, size, upper layers morphology, rhizoid structure formation, reproductive structures presence.
- ✓ **Photobiont:** photobiont type, cyanobiont presence.
- ✓ **Chemistry:** secondary metabolism, secondary metabolite type, release of volatile compounds, pigmentation of thallus and other structures, chelation capacity, crystal formation.
- ✓ **Ecology:** substrate preference, association in communities, extremophily, pollution tolerance, heavy metal tolerance, heavy metal accumulation, water-retaining capacity, adaptation by high thallus water content.



References

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- ✓ Rambold G, Stadler M, Begerow D (2013) Mycology should be recognized as a field in biology at eye level with other major disciplines – a memorandum. Mycological Progress. doi: 10.1007/s11557-013-0902-x
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Conclusions

- ✓ Lichenised fungi play a crucial role in ecosystem processes and support the diversity of many organisms. Even human beings profit directly or indirectly from lichen diversity (ecosystem services).
- ✓ Quantitative links between lichen diversity, traits and ecosystem services still need to be investigated.
- ✓ Long-term biodiversity monitoring, data gathering and archiving, mapping and modelling of ecosystem functions and services underpinned by lichens should be supported.
- ✓ The importance of lichens needs to be recognized in nature conservation management.