

Monitoring and mapping fungal diversity for nature conservation

Jorinde Nuytinck^{1,2}, Jean-Michel Bellanger³, Sergio de-Miguel^{4,5}, Bálint Dima⁶, Margarita Dueñas⁷, Ursula Eberhardt⁸, Vasco Fachada^{9,10}, Danny Haelewaters¹¹, Reda Iršénaitė¹², Håvard Kauserud¹³, Franz-Sebastian Krah¹⁴, María P. Martín⁷, Tuula Niskanen¹⁵, Viktor Papp¹⁶, Julia Pawlowska¹⁷, Lukas Picek¹⁸, Kadri Põldmaa¹⁹, Andrea Rinaldi²⁰, Anton Savchenko¹, Holger Thüs⁸, Annemieke Verbeke², Carlos Vila-Viçosa²¹, Alfredo Vizzini²², Alessandra Zambonelli²³, Georgios Zervakis²⁴, Jacob Heilmann-Clausen²⁵

Fungi are increasingly appreciated as networkers, recyclers and symbionts in natural ecosystems, and as crucial active agents for sustainable society transformation and innovation. New technologies including machine-learning tools and molecular methods allow steps towards automated identification of fungi, exploration of environmental fungal DNA from various substrates, and deeper insights into fungal biodiversity patterns and ecosystem functioning. Citizen science has emerged as a highly engaging approach to data collection involving a rich community of mycologists from a wide range of professional backgrounds with and without institutional backup. Fungi have also entered the global conservation agenda, with 625 species assessed for the IUCN Red List. Despite obvious synergetic potentials, these methodological approaches have largely been developed in parallel tracks. They often rely on different species concepts, mostly either morphology or DNA-based. In many cases, neither of these are unambiguously linked to biologically well-defined species with a scientific binomial, hindering comparisons of species lists across datasets. The goal of the pan-European project 'FunDive' is to bridge this gap and provide a knowledge platform allowing the inclusion of fungi in biodiversity conservation and monitoring in an integrative manner. The project aims to: (1) align scientific binomials of fungi with molecular species hypotheses by sequencing of type specimens preserved in European fungaria, (2) apply and improve AI tools for fungal monitoring, (3) involve citizen scientists in biodiversity discovery and monitoring, (4) sample fungal communities by eDNA, and (5) analyze fungal biodiversity patterns in time and space.



AI tools for fungal monitoring

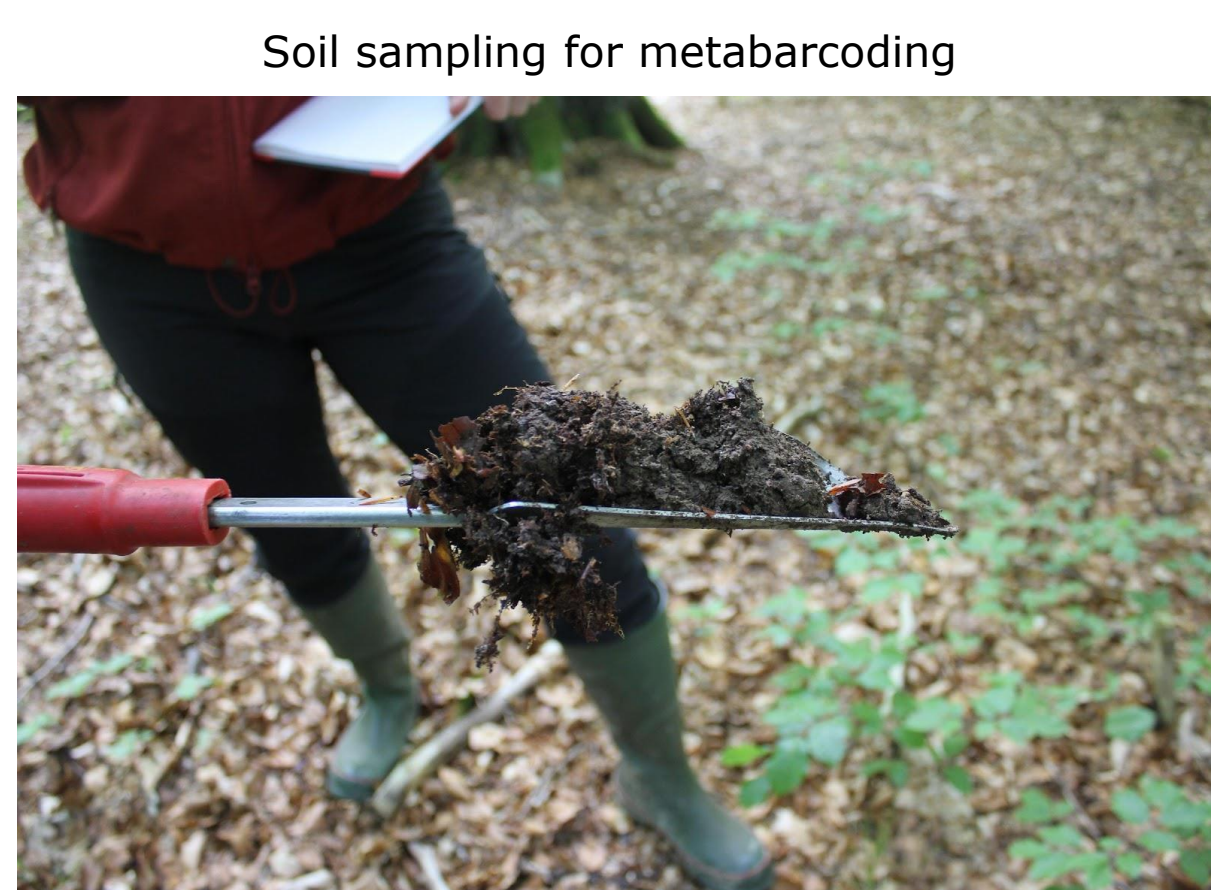
- Develop AI-based identification tools
- Re-train AI-models
- Add metadata on fungal records
- Species recognition in open-species-set scenario

Empower and involve citizen scientists

- Citizen science sampling campaigns
- Epitypification mission
- Molecular field laboratories
- Explore motivation factors of citizen scientists
- See also poster #990 (Haelewaters et al.) for more information

Fine-tune environmental DNA-based sampling

- Capture fungal diversity in pine forests
- Sample different substrate types
- Compare short- and long-read sequencing pipelines
- Fungal alpha diversity, unicity, and phylogenetic diversity across European pine forests



Lactarius scrobiculatus | SH1840900.10FU in UNITE

Accession number	UNITE taxon name	INSID taxon name	Interacting taxa	Sampling area
AF140282	<i>Lactarius scrobiculatus</i>	<i>Lactarius scrobiculatus</i> (Lactarius...		Germany
HQ271366	<i>Lactarius</i>	Russulaceae (uncultured Lactarius)	Pinus	Mexico
JF908281	<i>Lactarius scrobiculatus</i>	<i>Lactarius scrobiculatus</i> (Lactarius...		Italy
UD8011465	<i>Lactarius leonis</i>			Estonia
UD8011531	<i>Lactarius scrobiculatus</i>			Estonia
UD8015751	<i>Lactarius leonis</i>			Estonia
UD8015842	<i>Lactarius leonis</i>			Estonia
UD8016013	<i>Lactarius tuomikoski</i>			Finland
UD8016033	<i>Lactarius tuomikoski</i>			Finland
KF432968	<i>Lactarius scrobiculatus</i>	<i>Lactarius scrobiculatus</i> (Lactarius...		Slovakia
UD8019701	<i>Lactarius leonis</i>			Estonia
UD8019740	<i>Lactarius tuomikoski</i>			Norway
KF617507	<i>Lactarius</i>	Fungi (uncultured fungus)		United States
UD8022822	<i>Lactarius scrobiculatus</i>			Latvia
UD8024862	<i>Lactarius scrobiculatus</i>			Canada
KX394276	<i>Lactarius alnicola</i>	<i>Lactarius alnicola</i> (Lactarius alnic...		Australia
UD8034296	<i>Lactarius</i>		<i>Picea abies</i>	United States
MF955022	<i>Lactarius scrobiculatus</i>	<i>Lactarius scrobiculatus</i> (Lactarius...		Canada
UD8035784	<i>Lactarius scrobiculatus</i>			Norway
UD8036808	<i>Lactarius tuomikoski</i>			Norway
UD8036928	<i>Lactarius leonis</i>			Norway
UD8038472(2)	<i>Lactarius leonis</i>			Norway
UD8038556	<i>Lactarius tuomikoski</i>			Norway
UD8038763	<i>Lactarius tuomikoski</i>			Italy

H7027492 holotype of *Lactarius leonis* Kytöv.



DNA barcoding and annotation

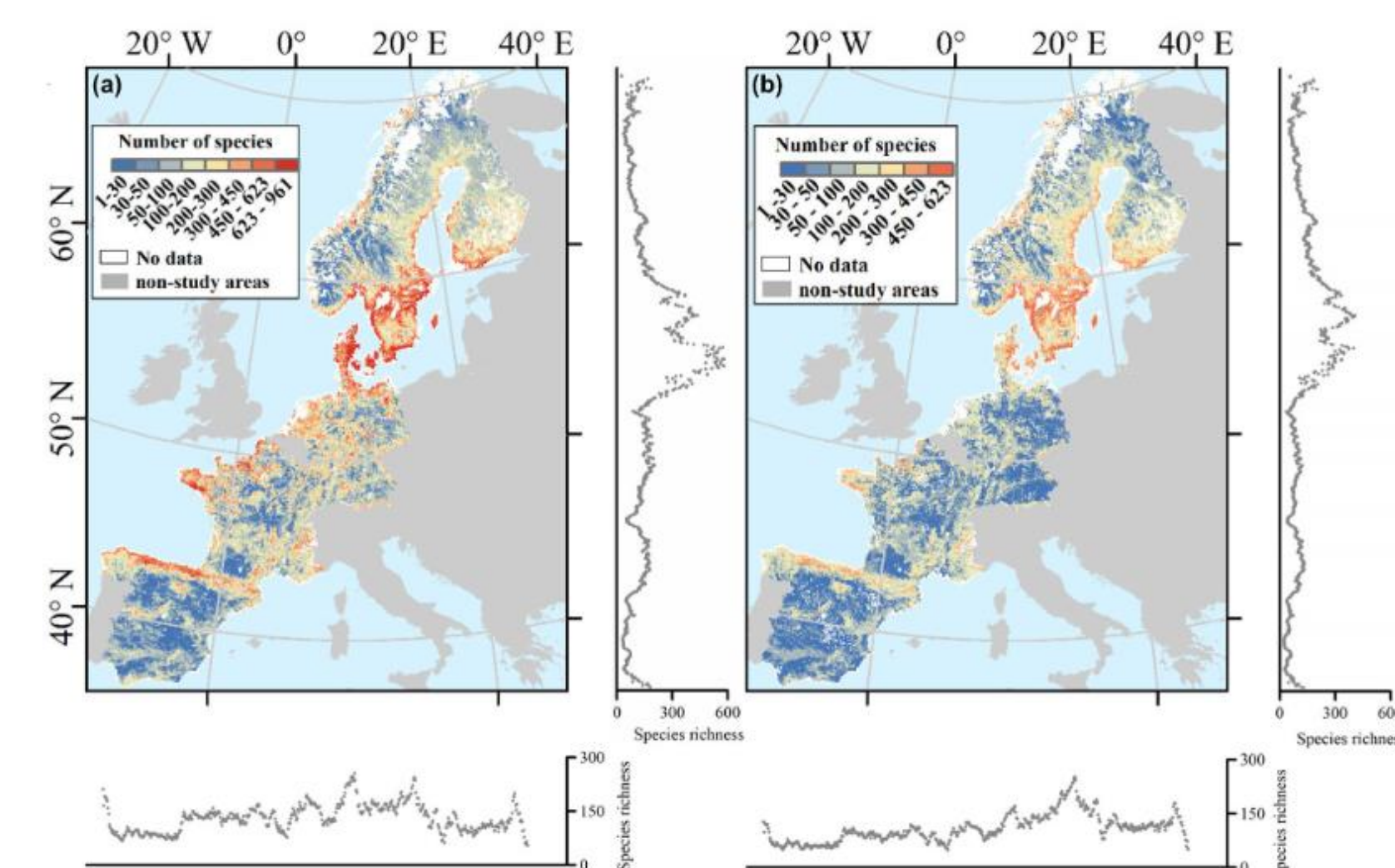
- Sequence type specimens
- Develop molecular protocols
- Select species for epitypification
- Improve linking scientific names to UNITE Species Hypotheses based on DNA barcodes

The fungarium in Leiden, the Netherlands

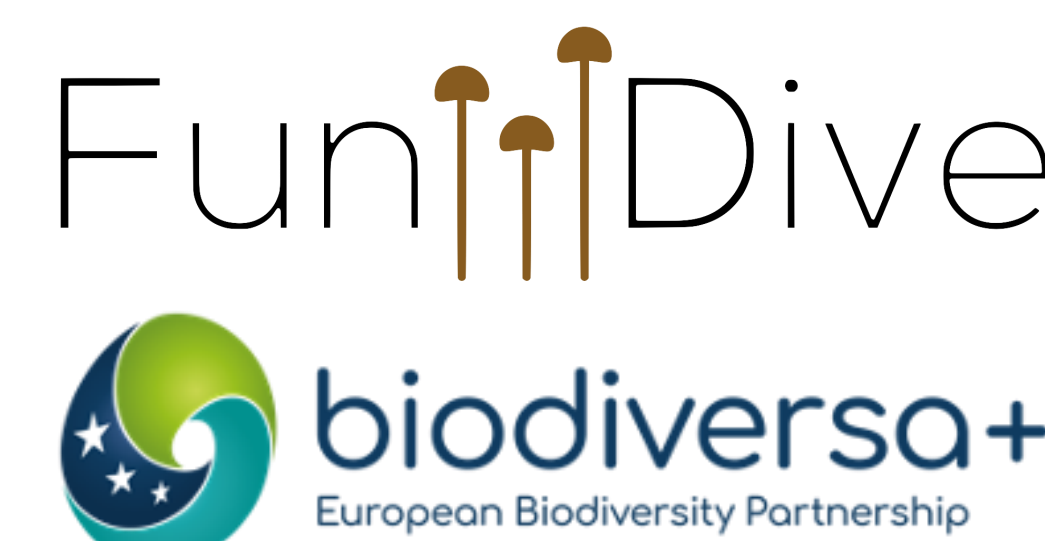


Investigate biodiversity patterns

- Handle sampling bias in citizen science
- Compare eDNA and citizen science sporocarp data
- Evaluate existing conservation measures for threatened macrofungi
- Analyze environmental factors to explain temporal and spatial biodiversity patterns



The distribution of the predicted number of species of two different functional groups of macrofungi, (a) saprotrophic fungi and (b) ectomycorrhizal fungi. From Yu H, Wang T, Skidmore A, Heurich M, Bässler C (2021) The critical role of tree species and human disturbance in determining the macrofungal diversity in Europe. *Global Ecol. Biogeogr.* 30: 2084–2100.



Contact: jorinde.nuytinck@naturalis.nl

Affiliations: ¹Naturalis Biodiversity Center, The Netherlands, ²Ghent University, Belgium, ³Université de Montpellier, France, ⁴University of Lleida, Spain, ⁵Forest Science and Technology Centre of Catalonia, Spain, ⁶Eötvös Loránd University, Hungary, ⁷Real Jardín Botánico-CSIC, Spain, ⁸State Museum of Natural History Stuttgart, Germany, ⁹University of Helsinki, Finland, ¹⁰University of Porto, Portugal, ¹¹University of South Bohemia, Czechia, ¹²Nature Research Centre, Lithuania, ¹³University of Oslo, Norway, ¹⁴University of Bayreuth, Germany, ¹⁵Finnish Museum of Natural History, Finland, ¹⁶Hungarian University of Agriculture and Life Sciences, Hungary, ¹⁷University of Warsaw, Poland, ¹⁸University of West Bohemia, Czechia, ¹⁹University of Tartu, Estonia, ²⁰University of Cagliari, Italy, ²¹Universidade do Porto, Portugal, ²²University of Torino, Italy, ²³University of Bologna, Italy, ²⁴Agricultural University of Athens, Greece, ²⁵University of Copenhagen, Denmark