The biodiversity of fungi

Fungi are heterotrophic eukaryotic microorganisms that play unique roles as decomposers, mutualistic symbionts, and pathogens of plants and animals in terrestrial and aquatic ecosystems. The magnitude of fungal biodiversity on the globe has been estimated at 500 K to 9.9 M species. However, only approx. 100,000 species have been catalogued, according to the most recent Dictionary of Fungi published in 2008. These numbers indicate that the majority of fungi on the earth are yet to be discovered and described, most of which are considered to be distributed in such ‘hotspots’ as aquatic environments, inside and outside of arthropods, and forest canopies, especially those in tropical regions. It is easy to imagine that the global inventory has a very long way to go, as a recent estimate indicates that at the current rate of species description (approx. 1,200 new species per year over the last decade) it will take more than 1,000 years to complete the global fungal inventory.

To approach a complete catalogue of fungal biodiversity within a reasonable time frame, it will be necessary to accelerate the speed of species description dramatically. Traditional morphology-based taxonomy will be critical to this effort, but a further increase in the number of active taxonomists would be needed to carry it out. Fortunately, new methodologies of sequence-based taxon discovery from environmental samples have emerged in recent years, such as high-throughput sequencing technologies and pyrosequencing methods. These methods also have numerous potentials for achieving further understanding of fungal biodiversity, ecology, and geographical distributions. The potential impact of pyrosequencing methods is reviewed and discussed in a paper of Hibbett et al. (2011) in Fungal Biology Reviews in detail.

Fungal biodiversity research projects in Yanbaru

We are currently conducting research projects aimed at revealing fungal biodiversity and functioning in Asian regions, and a core study site was established in the mountainous area in the northern part of Okinawa Island, southern Japan. The subtropical forest in that area is called Yanbaru in Ryukyuan languages and is known as one of the biodiversity hot-spots in Japan. Yanbaru is especially known for its richness in endemic birds, frogs, and land reptiles. Biodiversity assessments are urgently needed for other groups of organisms in this species-rich region, especially of fungi that are too minute to be visible to the naked eye but play crucial roles in ecosystem functioning and services. Thus, we established study plots in the Yona experimental field of the University of the Ryukyus (26°9’N, 128°5’E, http://www.agr.u-ryukyu.ac.jp/eng-field.html) that are covered with a broad-leaved evergreen forest dominated by Castanopsis sieboldii and Schima wallichii. The mean annual temperature of the site is 22°C and the annual precipitation is 2,456 mm.

Now we are surveying the biodiversity of fungi, such as litter- and wood-decomposing, mycorrhizal, foliar endophytic, and soil fungi. Over the last seven years, fieldwork has been carried out several times per year to collect fruiting bodies, plant tissues, and other substrata for fungal biodiversity assessments. The samples are taken back to the laboratory and used for the isolation of fungi and molecular phylogenetic analyses. Metagenomics of environmental samples such as live leaves, dead leaves, and soils, using clone libraries and next-generation sequencing techniques, have been performed for the last two years.

Subtropical forest of Yanbaru
We are now analyzing more than 1.1 M fungal DNA sequences that a Roche 454 pyrosequencing has yielded. A preliminary analysis indicated that more than 200,000 reads of fungal ITS regions obtained from healthy-looking live leaves of C. sieboldii and S. wallichii were grouped into approx. 3,600 operational taxonomic units (with a threshold of 95% similarity), suggesting a hyper-diverse nature of the subtropical endophytic fungal assemblage.

To relate the fungal biodiversity to functioning, we are studying interspecies interactions and ecosystem processes, such as recurrences between trees and fungi, the decomposition processes of leaf litter, the accumulation and turnover of coarse woody debris, and the production and turnover of mycorrhizal roots. Moreover, our research interest has now become extended to biodiversity conservation, with an emphasis on the effects of clear-cutting and the transformation of natural forests into secondary forests on the fungal biodiversity and functioning. Until now, more than 20 researchers and graduate students of mycology, ecology, and biogeochemistry have been involved in the projects that have been supported by 14 national and private funding organizations. You can access some publications of the project at the C.V. page of our website (http://www.ecology.kyoto-u.ac.jp/~tosono/). Future research interests include studies of other functional groups of fungi, such as plant pathogenic fungi, arthropod-associated fungi, and lichens, and construction of a database to manage massive DNA sequence data. Finally, we welcome international cooperative research and your future contributions to the projects.