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Fungal Conservation

First steps in myxomycete conservation activities

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Myxomycetes an ideal model for building conservation strategy
Slime moulds are eukaryotic, phagotrophic, fungus-like organisms, which living nearly in all terrestrial ecosystems. In previous systems slime molds include several groups: *Myxomycetes* -"true slime moulds", *Protosteliomycetes* – microscopic relatives of *Myxomycetes*, *Dictyosteliomycetes* –soil inhabitants, *Copromyxida* – animal dung inhabitants, *Acrasida* – with individual independent cells that can act as one organism, *Plasmodiophoromycota* – cell parasitic species. All this groups have a plasmodial stage in their life cycle. Modern systems recognize only *Dictyosteliomycetes*, *Protosteliomycetes* and *Myxomycetes* (Adl et al., 2012). *Copromyxida* belong to the same phylogenic branch as *Amoebozoa*. No close relatives are known for *Acrasida* and *Plasmodiophoromycota*. The conservation strategy model begins with *Myxomycetes*, characterized by a remarkable transformation from an animal-like to a fungus-like form. These organisms develop very rapidly, have a high reproductive potential, and seem to possess effective dispersal mechanisms. Myxomycetes tend to be rather inconspicuous. Most parts of the myxomycete life cycle exist as vegetative stages, mobile free-living plasmodia that typically thrive in cool and shady moist places. They feed on bacteria, protozoa, yeast cells, fungi, organic remains etc. After a period of feeding and growth, fruiting bodies develop in drier and more exposed locations. Most are relatively ephemeral. They contain numerous spores which can be dispersed by wind and will eventually germinate and develop into a plasmodium under suitable conditions. Myxomycetes spend a portion of their life cycle in a state where their very presence in a given habitat can be exceedingly difficult if not impossible to determine. Their inconspicuous nature and complex life history strategy provide an immense challenge in biodiversity assessments, so have often been neglected. This has far-reaching consequences for estimates of the number of species and their conservation. There is convincing evidence that we know only about 20% of the actual diversity in many protist groups. Considering the dramatic losses of habitats, a large portion of the Earth's biodiversity will disappear before it has been discovered (Foissner & Hawksworth, 2008).

Problems of evaluation of myxomycete distribution
Myxomycetes are found in nearly all terrestrial ecosystems worldwide from Antarctica to desert. Approximately 30% of the species are cosmopolitan. The highest diversity is in the temperate climatic zone of the northern hemisphere, where moisture and decaying organic matter are available. Myxomycetes are associated with a number of different microhabitats. These include remains of woody origin, fallen logs, the bark surface of living trees, forest floor litter, the dung of herbivorous animals, and herbaceous plants. Myxomycetes are fundamentally terrestrial organisms and they have a significant impact on the species diversity of soil microorganisms. Study of rDNA from soil shows that myxomycetes (including protostelids and dictyostelids) are a dominant group of protists in this habitat (Stephenson et al., 2000). Temperature and humidity are the main factors limiting myxomycete distribution and abundance in nature. Climate, altitude and plant type also represent an important factors influencing the occurrence of myxomycetes. Species richness tends to increase with more diversity and biomass of the vascular plants providing various types of detritus that support the bacteria and other microorganisms needed to feed myxomycetes. The pH of the substrates may also represent an important factor influencing the distribution of these organisms, although many myxomycetes appear to have a relatively wide pH tolerance (Wrigley de Basanta, 2000). Myxomycetes have a cosmopolitan distribution due to a presumed easy dispersal by wind and water. Feeding by invertebrates may also help to spread spores. These properties allow them to exploit successfully habitat islands occurring both temporally and spatially in nature.

A distribution map presents only the fruiting body stage of myxomycetes. It is certainly possible that there are habitats where myxomycetes live as amoebal and plasmodial populations only and do not fruit. Approximately 50% of all described species of myxomycetes are known only from the type locality or fewer than five localities worldwide. It seems likely that many of these "species" are no more than morphologically distinct biotypes present in particular habitats or confined to a certain regions of the world (Stephenson et al., 2000). A number of the more common and widespread morphospecies actually consist of complexes of geographically restricted apomictic clonal lines (Clark, 2004). These genetically isolated lines are capable of independent evolution, which can lead to the accumulation of minor morphological differences that reflect specific adaptations to the particular set of environmental conditions in which they occur. Direct environmental sampling with the use of molecular techniques such as DNA probes would represent a way of detecting hidden amoebal and\or plasmodial populations of myxomycetes, which would be regarded as "sink" populations in terms of dispersal capacities (Foissner & Hawksworth, 2008).

Threatens for myxomycetes

Myxomycetes have not yet been sufficiently evaluated for conservation status, but at least some are undoubtedly threatened by climate change, disturbance, habitat destruction and pollution. A particular habitat within which a species of myxomycetes has been established may persist for only a short period of time. The species always survives by reestablishing itself in some new habitat, which may be the same location if conditions once again become favorable. In unfavourable conditions spores may be covered by proteoglycans and create cysts. Plasmodia also can transfer to the survival stage scletotium. Urban pressure can change native biota of myxomycetes, because in town introduced species often appear. Parks and gardens can harbour more biodiversity of myxomycetes than in native ecosystems of the same regions. Acid rain reduces species diversity from the order *Physarales* as result of leaching lime from the soil, which need for normal morphogenesis. In general, members of the *Stemonitales* develop under more acidic conditions than do members of the *Physarales* and the *Trichiales* (Stephenson et al., 2000). Climate change has an especially important effect on nivicolous myxomycetes, occurring at the edge of melting snow at high altitude.

Conservation activities

The IUCN Specialist Group promoting Conservation of Myxomycetes is beginning to prepare a foundation on which future conservation policy for Myxomycetes can be developed.

UK

First steps for conservation of myxomycetes was the creation of a myxomycete reserve by Bruce Ing in Wales near the town of Mold, in a small town park in agreement with the Forestry Commission. In this place native ash and hazel grow on calcareous soils with introduced poplars and maples. Protection actions are the termination of clearing of dead wood and leaves, which are favorable substratum for myxomycetes.

Russia

1) In 2005 Yuri Novozhilov proposed to include 21 endangered species of myxomycetes in the Red Book of Nature of Leningradskaya oblast in Russia: *Colloderma oculatum, Comatricha longa, Cribraria purpurea, Diachea splendens, Diderma floriforme, D. niveum, D. trevelyani, Didymium serpula, Lepidoderma carestianum, L. tigrinum, Enteridium splendens, Lindbladia tubulina, Physarum alpinum, Ph. auriscalpium, Ph. flavidum, Ph. globuliferum, Ph. listeria, Stemonitis splendens, Hemitrichia serpula, Metatrichia floriformis, Trichia alpina*.

2) In 2007 Alexander Lebedev recommended including in the Red Book of Tver' oblast 10 species of rare myxomycetes: *Arcyria glauca, A. minuta, Brefeldia maxima, Colloderma oculatum, Diderma fallax, Didymium iridis, Hemitrichia intorta*, *Lycogala conicum*, *Physarum famintzinii, Ph. oblatum.*

Ukraine

1) Preliminary analyses of threat were made for 278 species of myxomycetes in Ukraine. Species considered as endangered included 12 myxomycetes species, with 22 mainly nivicolous species being assessed as vulnerable (Kryvomaz, personal data).

Cribraria purpurea – endangered species in Ukraine and in Leningradskaya oblast of Russia. Image © Alain Michaud

Potentially endangered myxomycetes in Ukraine are: *Barbeyella minutissima, Colloderma oculatum, Cribraria ferruginea, C. mirabilis, C. purpurea, Diderma chondrioderma, Elaeomyxa cerifera, Lamproderma columbinum, Lepidoderma tigrinum, Licea pusilla, Physarum tenerum* and *Trichia subfusca.*

Potentially vulnerable myxomycetes in Ukraine are: *Diderma alpinum, D. meyerae, D. niveum, Didymium dubium, Lamproderma aeneum, L. carestiae, L. cristatum, L. cucumer, L. echinosporum, L. ovoideoechinulatum, L. ovoideum, L. pulveratum, L. retirugisporum, L. splendens, L. zonatum, Lepidoderma alpestroides, L. carestianum, L. chailletii, Physarum albescens, Ph. alpestre, Ph. vernum* and *Trichia alpina.*

Lamproderma ovoideum – a very common nivicolous species in European Alps, but presumably vulnerable in Ukrainian Carpathians; can be affected by climate change on a global level. Image © Alain Michaud

Also in Ukraine 34 species of myxomycetes were identified, which are rare not only in Ukraine, but in the world as well. This is likely to be the result of general data deficiency. They include *Arcyria globosa, Badhamia melanospora, Clastoderma debarianum, Comatricha ellae, C. longipila, Cribraria macrocarpa, C. splendens, Diderma chondrioderma, D. cingulatum, D. montanum, Didymium sturgisii, Echinostelium apitectum, Fuligo muscorum, Hemitrichia intorta, Lepidoderma tigrinum, Licea inconspiqua, L. tenera, Oligonema flavidum, Perichaena pedata, Physarum citrinum, Ph. confertum, Ph.* conglomeratum, Ph. decipiens, Ph. *digitatum, Ph. gyrosum, Ph.*

licheniforme, Ph. murinum, Ph. notabile, Ph. oblatum, Stemonaria longa, Stemonitopsis amoena, S. gracilis, Trichia alpina and *T. lutescens.*

2) Detail evaluations were made for the biggest genus of myxomycetes, *Physarum.* A total of 40 *Physarum* species have been recorded in Ukraine. Only three species – *Ph. album*, *Ph. cinereum* and *Ph. cinereum* are certainly not threatened, widely distributed and found in the whole of Ukraine. Six species: *Ph. bivalve*, *Ph. leucopus*, *Ph. compressum*, *Ph. contextum*, *Ph. globuliferum* and *Ph. psittacinum* are not threatened also, and are at least fairly common in Ukraine. Seven species – *Ph. flavicomum*, *Ph. leucophaeum*, *Ph. citrinum*, *Ph. decipiens*, *Ph. gyrosum*, *Ph. mutabile* and *Ph. pulcherripes* are probably not threatened, as they are recorded from several Ukrainian regions. But 60% (24 species) of the genus was found once or only several times from a limited number of Ukrainian regions. From this big group *Ph. albescens*, *Ph. alpestre* and *Ph. vernum* need to be emphasized, which are nivicolous species and are proposed to be plaved in the endangered category, due to the threat from climate change. *Ph. lakhanpalii* is usually found in tropics but in Ukraine was discovered in the mediterranean climate of Crimea. Some species from this big group – *Ph. bitectum*, *Ph. didermoides*, *Ph. pusillum* and *Ph. virescens* are rare not only for Ukraine. *Ph. licheniforme* and *Ph. digitatum* that were collected in strongly threatened habitat types in the vicinity of megapolises near Lviv and Kyiv (Dudka et al., 2011).

Physarum psittacinum – a fairly common and beautiful species. Image © Alain Michaud

3) Irina Dudka is preparing a proposal for the next edition of Red Book of Ukraine (Dudka, personal data) to include *Oligonema aurantium*. This species is very rare in Ukraine and was found only once in Desnans'ko-Staroguts'kiy National Nature Park (Dudka & Krivomaz, 2005). From Europe it is known from only two records: the first one in Netherlands (*locus classicus*) and the second one in Great Britain. Criteria for inclusion in the next edition of the Red Book of Ukraine include:

- species that only occur in threatened habitats
- species that are described as new for science from Ukraine and are unknown in other countries or species with very limited world area
- species are characterized with macroscopic features allowing field recognition

Germany

Martin Schnittler (Schnittler, personal data) placed 413 myxomycetes species from Germany into nine conservation categories:

1. very common: on most local species lists, regularly to be found when checking the microhabitat;
2. common: usually to be found during systematic surveys of the respective microhabitat;
3. fairly common: occasionally found, but well over 100 records from Germany known;
4. rare: but more than 20 records;
5. very rare: less than 20 records known;
6. extremely rare: less than 5 records known from Germany;
7. extinct or presumably extinct: not recorded since more than 40 years;
8. data deficient: no assessment possible;
9. not estimated:

Species only recorded in cultures or those found occasionally in microhabitats which have not yet been systematically investigated, will be assessed as data deficient. Notoriously confused species will be assessed in this category as well.

Global-level assessment

1) For nivicolous myxomycetes emphasize threats by climate change. Tentative evaluations of conservation status for ten nivicolous species were made: *Diacheopsis metallica, Diderma alpinum, Didymium dubium, Lamproderma echinosporum, L. ovoideum, Lepidoderma carestianum, L. chailletii, Physarum albescens, Ph. vernum, Trichia alpina* (Kryvomaz et al., 2010). The strong association between nivicolous myxomycetes and melting snow patches suggests that their distribution is likely to be strongly and negatively affected by global warming as winter snow cover diminishes.
2) The first myxomycete *Diacheopsis metallica* was published in Red List Species on the Edge of Survival (Species on the Edge of Survival, 2011).
3) Evaluation of conservation status for 10 species of order Trichiales: *Arcyria denudata, A. minuta, A. stipata, Calomyxa metalica, Hemitrichia clavata, Metatrichia vesparium, Perichaena chrysosperma, Trichia decipiens, T. scabra, T. varia* (Kryvomaz et al., 2012). Information base include specimens, databases, bibliographic sources and field observations. Using the program "Geocat" (geocat.kew.org) estimates were made of extent of occurrence and occupancy. For each species population trend and threats were analyzed, and evaluation using IUCN criteria took place.

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