Fungi in Freshwaters

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Deprivation of protection for aquatic hyphomycetes is disturbing because they are key players in freshwater ecosystems across the globe. The knowledge of biodiversity of aquatic hyphomycetes and freshwater ecosystems were enriched.

Keywords: microfungi ; freshwater ; biodiversity

1. Introduction

Aquatic hyphomycetes were accidentally discovered in 1942 by Ingold while looking for chytrids [1]. They were greatly ignored until the limnologists realised the significant contribution of allochthonous organic materials to stream food webs [2]. Aquatic hyphomycetes play a paramount role in the decomposition of detritus through their enzymatic activities, consequently enhancing the palatability and nutritional quality of the litter for the invertebrates [3]. This activity facilitates the transfer of energy and nutrients to higher trophic levels [3][4]. With the advancement in taxonomic research, 335 morphospecies of aquatic hyphomycetes have been identified (for review, see Duarte et al. [5]), belonging mainly to Ascomycota with a small percentage attributed to Basidiomycota [6]. By the 2000s, growing evidence suggested that the aquatic hyphomycetes species richness or identity might influence the freshwater ecosystem processes [7][8]. This fundamental aspect restored the interest in the potential connection between aquatic hyphomycetes' biodiversity and freshwater ecosystem processes, health and integrity [8][9][10][11][12]. The ongoing global changes and anthropogenic impacts on the freshwaters have encouraged more insights into their biodiversity changes and occurrence in the little-explored regions across the globe [5].

Even though aquatic hyphomycetes are the cornerstone of the freshwater ecosystems' functional integrity and health [13], their conservation status is obscure. It is of utmost importance to systematically analyse their current status and future if conservation measures are to be administered. This approach will help to understand the knowledge gap and implement research into adequate management practices. Moreover, applying cutting-edge molecular techniques to identify aquatic hyphomycetes species and the ability to evaluate the entire fungal communities will enable researchers to determine and establish the trends in biodiversity and genetic patterns. These modern techniques, which favour species detection in the absence of reproductive structures, may open new avenues to fungal conservation.

2. A Responsible Approach towards Understanding the Biodiversity of All Fungi, including Aquatic Hyphomycetes, Is Needed

To date, the conservation status of most of the fungal species is unknown. Conservation agendas targeting fungi are mainly represented by macrofungi. They are distinguishable from other fungi by their visible spore-bearing fleshy fruiting body. To date, 425 macrofungal species have been evaluated by the IUCN Red List of Threatened Species [14]. Clearly, there is a tendency to protect visually noticeable and familiar species, severely reducing individuals focus on the global fungal extinction rate.

Invisible to the naked eye, microfungi make up the great majority of undescribed fungal taxa [15]. They are greatly present in people's lives and economy. Although some microfungal species are pathogenic to plants and animals, compromising crops, livestock production and human beings, most microfungi are highly beneficial to the society. For example, the microfungi belonging to the genus Penicillium are the source of penicillin, a group of antibacterial drugs, which revolutionised the health care industry [15]. In addition, the food industry relies greatly on yeasts for the preparation of bread and beer [15][16]. Moreover, as eukaryotic organisms, yeasts are excellent model research organisms, ushering considerable advancements in modern genetics [15][16]. Most predominantly, microfungi are crucial to sustaining a wide range of ecosystem processes, maintaining life on the planet [15][17]. The most acknowledged is the mycorrhizal fungi, accomplishing a symbiotic partnership with approximately 90% of all plant roots [18]; these fungi facilitate the plants' growth by improving the acquisition of nutrients from the soil; simultaneously the plant roots provide a reliable substrate for mycorrhizal fungal growth and reproduction [19]. In general, microfungi have impacted the environment for billions of years in a multitude of ways and are continuously touching millions of human lives. However, they need special attention because they are largely disregarded in the environment. Poeple lapse in estimating the biodiversity of the microfungi, including aquatic hyphomycetes, impedes their inclusion in the conservation goals. Taking steps towards filling this knowledge gap is pivotal to assisting efficient conservation policies and robust environmental management strategies to sustain freshwater ecosystems.

3. Embracing Aquatic Fungi in the Freshwater Biodiversity Conservation Strategies

The continuous degradation of freshwater ecosystems and the services they provide have led to the implementation of various international organisations and agreements (see **Table 1**), aiming to bend the curve of freshwater biodiversity loss [20]. Several biodiversity conservation organisations (**Table 1**) are involved in the data gathering and biodiversity analysis. The indicators produced by these projects are generally used to monitor biodiversity trends [21], raise awareness among the public and policymakers [22] and influence governments and other stakeholders by providing an unrestricted flow of information and advice. However, in most cases, due to inefficient management, the data gathered remain underutilised, confounding the development of data-driven policy decisions or the establishment of biodiversity conservation targets [23]. Despite supporting an impressive number of species and providing several irreplaceable ecosystem services, freshwater biodiversity is disproportionately under prioritised. Future strategies and actions should divert a greater focus on the distinctive ecology of freshwater organisms and their threats.

Table 1. International milestones in conservation strategies.

Year	Milestone	Conservation Strategies
1948	**International Union for the Conservation of Nature (IUCN)**	• Union composed by approximately 1400 members (countries, governments and civil organisations). • It is mainly involved in data gathering, analysis and education. • To influence government, and stakeholders by providing information, advice and partnerships.
1961	**World Wildlife Fund for Nature (WWF)**	• Organisation working in wilderness preservation and reduction of human impact on the environment. • Responsible for publishing ‘The Living Planet Report’ every two years since 1998.
1964	**First edition of IUCN Red List**	• The world’s most comprehensive catalogue of the global conservation status of several biological species was published.
1971	**Green Peace**	• Independent global network aiming to safeguard environment and biodiversity. • Focus on issues such as: climate change, deforestation, overfishing, commercial whaling, genetic engineering and anti-nuclear materials.
1971 *	**The Ramsar Convention on wetlands**	• First international agreement for conservation and sustainable use of wetlands; it came into force in 1975. • Representatives of the contracting parties meet every three years to discuss achievements and further steps.

Year	Milestone	Conservation Strategies
1972	**United Nations Conference on the Human Environment (Stockholm Declaration)**	• Held in Stockholm, resulting in the beginning of an international environmental law, alongside with the first agreement (26 principles and 109 recommendations) regarding environment, development, human rights and protection of natural resources.
1972	**The United Nations Environment Programme (UNEP)**	• Organisation aiming to develop international environmental agreements on climate change, management of marine and terrestrial ecosystems (including inland waters) and green economic development.
1973	**Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)**	• One of the oldest conservation agreements still in action; it came into force in 1975. • Mainly to protect plants and animals at risk of extinction and ensure that international trade in wild specimens does not threaten their survival in the wild.
1982	**The World Resources Institute (WRI)**	• Comprised by local and national governments alongside with private and public corporations. • Offer information on global climate change issues, sustainable markets, ecosystem protection and environmental governance services.
1988	**Intergovernmental Panel on Climate Change (IPCC)**	• One of the United Nation’s intergovernmental bodies. • Responsible for compiling knowledge on human-induced climate change, providing scientific information of the impacts on the natural, political and economic sectors.
1991 *	**World Water Week**	• Non-profit annual event on global water issues, organised by Stockholm International Water Institute. • Responsible to find solutions to the water-related challenges through partnerships with organisations from various countries and sectors.
1992	**Earth Summit-Convention on Biological Diversity (CBD)**	• Event held in Rio de Janeiro; it came into force in 1993, establishing a multilateral treaty (CBD). • Target the conservation of biodiversity in all its aspects, sustainable use of nature components and fair sharing of benefits arising from genetic resources.
2000	**The Cartagena Protocol**	• A protocol that arises as a supplementary agreement to the CBD (1992). • Aim to guarantee biosafety in the movements of living modified organisms (LMOs) between countries; it entered into force in 2003.

Year	Milestone	Conservation Strategies
2000	**The Millennium Development Goals (MDGs)**	• Comprises eight international development goals. • Focus mainly on human population needs, only goal 7, targeted to ensure environmental sustainability by 2015.
2001–2005	**The Millennium Ecosystem Assessment (MEA)**	• Comprehensive assessment, targeting the consequences of ecosystems changes due to anthropogenic activities as well as establishing scientific basis for the development of conservation and sustainable development.
2002	**The World Summit on Sustainable Development**	• Held in Johannesburg (“Rio + 10”), it united heads of state, delegates, NGOs and businesses groups. • Address the improvement of people’s lives while conserving nature in a world with a growing population and ever-increasing resource demands.
2002	**Strategic Plan for the Convention on Biological Diversity**	• A new strategic plan to effectively halt the loss of biodiversity and secure the continuity of its beneficial uses through the conservation and sustainable use of its components. • Raise the concern of fair and equitable sharing of benefits arising from novel genetic resources.
2010	**The United Nations World Water Development Report (WWDR)**	• The UN-Water’s report tackling water demand and sanitation issues, published by UNESCO. • It provides insights and knowledge concerning the state, use and management of freshwaters, as well as formulation and implementation of sustainable water policies.
2010	**Strategic Plan for Biodiversity Revision 2011–2020**	• Held in Nagoya, Japan, the meeting updated the Strategic Plan for Biodiversity for the 2011–2020 period, providing a framework on biodiversity for the UN and partners engaged in biodiversity management. • Resulted in the signature of the Nagoya Protocol and the development of the Aichi Biodiversity Target.
2010	**The Nagoya Protocol**	• A supplementary agreement to the CBD (1992). • To target the implementation of one from the three objectives of the CBD: the fair and equitable sharing of benefits arising out of the utilisation of genetic resources, setting out obligations for its contracting parties.
2010	**The Aichi Biodiversity Targets**	• A 10-year plan, created by the CDB parties, sub-divided into 20 targets, aiming to protect and conserve natural systems.

Year	Milestone	Conservation Strategies
2010	**The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)**	• Intergovernmental organisation established to improve the interface between science and politics on issues of biodiversity and ecosystem services. • It entered into force in 2013.
2012	**The world's 100 most threatened species**	• IUCN report with the 100 most threatened species was published by the Zoological Society of London as a book, named *Priceless or Worthless*? • The list contain species threatened of extinction, stressing that 'all species have an inherent right to exist'.
2015	**Sustainable Development Goals (SDGs)**	• Developed by the UN to replace the MDGs. • The SDGs run from 2015 to 2030, setting a 15-year plan to achieve 17 goals, aiming to end poverty, protect the planet and improve the quality of life on earth.
2020	**Post-2020 Global Biodiversity Framework**	• Reinforces the 2001–2020 strategic plan; it stipulates ambitious goals to generate a renovation in society's relationship with biodiversity, ensuring people are 'living in harmony with nature' by 2050.
2020	**The UN Decade on Ecosystem Restoration**	• A call to protect ecosystems around the world, aiming to halt their degradation, and implement restoration practices. • The UN Decade runs from 2021 to 2030, which is also the deadline for the SDGs.
2021	**Water and Climate Pavilion at COP 26**	• Held in Glasgow, the COP 26 (Convention of the Parties) led efforts to mobilise the water and global climate action communities to launch the first Water and Climate Pavilion in the history of the convention.
2021 *	**Water at the IUCN Congress**	• For the first time, freshwater was featured as its own thematic focus at the IUCN Congress.

* Milestone focussing directly on freshwaters.

The IUCN, founded in 1948, was the first global authority dedicated to nature protection and conservation. Later, several other environmental organisations emerged, such as Worldwide Fund for Nature (WWF; 1961) and Green Peace (1971) (**Table 1**). One interesting milestone was the Ramsar Convention (1971), the first international agreement related to freshwaters aiming to protect wetlands (**Table 1**). Especially in the freshwater conservation strategies, there is a tendency to embrace only the social benefits to humans, such as ceasing poverty, hunger, or diseases and economically beneficial macrofauna. Given the current mindset, aquatic fungi, particularly aquatic hyphomycetes, are likely to be neglected, disregarding their key ecological role to sustain freshwater ecosystems.

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