Marine Fungi: Opportunities and Challenges

Subjects: Microbiology

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Marine fungi play a crucial role in energy flow and nutrient recycling, mediating the cycling of dissolved organic matter in marine environments. However, despite being a prolific group of organisms, marine fungi have been largely neglected for a long time. Besides their importance in the marine food web, marine fungi represent an active source of natural products. Over the last years, researchers have focused on studying marine organisms to discover new metabolites with antibacterial, antiviral, and anticancer activities. Moreover, with the advances in high-throughput sequencing technologies and mass spectrometry techniques, genomic and metabolomic approaches have revealed to be of paramount importance in natural products discovery. The marine mycobiome includes many organisms still to be identified, and the ones already known are still underutilized in biotechnological applications. For this reason, it is undeniable that exploring the marine mycobiome including new habitats and substrates, even those of remote access, is fundamental for describing the true magnitude of the Earth's mycobiome.

Keywords: marine fungi ; diversity ; taxonomy ; biological activities ; metabolomics ; genomics

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Fungi are ubiquitous organisms widely distributed in ecosystems, including marine environments [1][2][3]. Marine environments represent the last frontier of biodiversity. Even though marine habitats account for 70% of the surface of the planet, they still remain biologically unexplored. Fungi are key players in terrestrial and marine environments representing a substantial proportion of the microbial diversity on Earth [1].

Over time, different definitions of marine fungi have been used. Marine fungi were originally defined based on their physiological characteristics, such as the requirement of more than 30% salinity to grow [4]. The first attempt to define 'marine fungi' and still the most quoted definition was given by Kohlmeyer and Kohlmeyer [5]. These authors restricted 'marine fungi' to two ecological groups: obligate and facultative marine fungi. Obligate marine fungi are those that grow and sporulate exclusively in a marine or estuarine habitat; facultative marine fungi are those from freshwater or terrestrial milieus, able to grow and sporulate in marine environments. However, this distinction is not always easy nor clear to establish, and it is somehow controversial. Later, Jones et al. [6] labelled 'obligate' marine fungi as those isolated from submerged substrates or sediments from marine environments. The term "marine-derived fungi" has been extensively used in the field of natural product chemistry [7]. Recently, Pang et al. [8] reviewed the use of the terms "marine fungi" and "marine-derived fungi" and proposed a wide-ranging definition. These authors replaced Kohlmeyers' definition by a broader concept. From this point forward, marine fungi are defined as any fungus able to: (i) grow and/or sporulate (on substrata) in marine environments; (ii) form symbiotic relationships with other marine organisms; or (iii) adapt and evolve or be metabolically active in marine environments.

In the past, marine fungi were viewed as an exotic group, relatively species-poor, with low abundance. Over the last two decades the use of culture-independent approaches and, more recently, of next-generation sequencing methods have started to disclose a considerable hidden fungal diversity from a wide range of environments [9]. In this respect, only recently, marine fungi have attracted attention and are yet to find a prominent place in biotechnology [3].

Marine fungi are a biochemically diverse group of organisms representing a promising source of novel bioactive natural compounds. The secondary metabolites produced by marine fungi include terpenes, steroids, polyketides, peptides, alkaloids, and polysaccharides. These metabolites are mainly associated with antimicrobial, anticancer, antiviral, antioxidant, and anti-inflammatory activities [3][10]. Considering this wide range of activities, these metabolites hold great promise since they can be used for drug discovery and medical, pharmaceutical, agriculture and cosmetic applications [3]. Besides being a source of bioactive compounds, marine fungi are also recognized for their metabolic capacities for bioremediation. This capacity aids, for instance, in the degradation of recalcitrant cell wall compounds (marine fungi express catalases, laccases, peroxidases) and environmental contaminants (e.g., toxic pollutants and microplastics) [11].

References

1. Grossart, H.P.; Van den Wyngaert, S.; Kagami, M.; Wurzbacher, C.; Cunliffe, M.; Rojas-Jimenez, K. Fungi in aquatic ecosystems. Nat. Rev. Microbiol. 2019, 17, 339–354.
2. Hyde, K.D.; Jeewon, R.; Chen, Y.J.; Bhunjun, C.S.; Calabon, M.S.; Jiang, H.B.; Lin, C.G.; Norphanphoun, C.; Sysouphanthong, P.; Pem, D.; et al. The numbers of fungi: Is the descriptive curve flattening? Fungal Divers. 2020, 103, 219–271.
3. Tarman, K. Marine fungi as a source of natural products. Encycl. Mar. Biotechnol. 2020, 4, 2147–2160.
4. Johnson, T.W.; Sparrow, F.K. Fungi in Oceans and Estuaries; J. Cramer: Weinheim, Germany, 1961; p. 685.
5. Kohlmeyer, J.; Kohlmeyer, E. Marine Mycology: The Higher Fungi; Academic Press: London, UK, 1979; p. 704.
6. Jones, E.B.G.; Sakayaroj, J.; Suetrong, S.; Somrithipol, S.; Pang, K.L. Classification of marine Ascomycota, anamorphic taxa and Basidiomycota. Fungal Divers. 2009, 35, 187.
7. Jensen, P.R.; Fenical, W. Secondary metabolites from marine fungi. In Fungi in Marine Environments; Hyde, K.D., Ed.; Fungal Diversity Research Series; Fungal Diversity Press: Hong Kong, China, 2002; Volume 7, pp. 293–315.
8. Pang, K.-L.; Overy, D.P.; Jones, E.B.G.; Calado, M.; Burgaud, G.; Walker, A.K.; Johnson, J.A.; Kerr, R.G.; Cha, H.-J.; Bills, G.F. ‘Marine fungi’ and ‘marine-derived fungi’ in natural product chemistry research: Toward a new consensual definition. Fungal Biol. Rev. 2016, 30, 163–175.
9. Richards, T.A.; Jones, M.D.; Leonard, G.; Bass, D. Marine fungi: Their ecology and molecular diversity. Ann. Rev. Mar. Sci. 2012, 4, 495–522.
10. Queirós, B.; Barreira, J.C.; Sarmento, A.C.; Ferreira, I.C. In search of synergistic effects in antioxidant capacity of combined edible mushrooms. Int. J. Food Sci. Nutr. 2009, 60, 160–172.
11. Zeghal, E.; Vaksmaa, A.; Vielfaure, H.; Boekhout, T.; Niemann, H. The potential role of marine fungi in plastic degradation—A review. Front. Mar. Sci. 2021, 8, 738877.
