Distribution of marine fungi, and fungal-like organisms, in the South China Sea, and their potential commercial use in industry and pharmaceutical application

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Marine fungi have been known for over 100 years, and found in all the oceans of the world, occurring as endophytes, saprobes and pathogens of both marine animals and plants. They occur as free floating organisms in the water column, in the intertidal zone on a variety of substrata, and in sediments in the deep sea. However, their role in the wider ecology of the oceans has only recently being noted. Most marine fungi are secondary inhabitants of the sea, the precise time they invaded maritime habitats' has yet to be determined. Sequence data indicates that they are continually evolving and have given rise to a number of

new lineages of the fungi. Many texts on marine fungi do not include all groups, such as, chytrids, yeasts and Mucoraceous fungi. Fungal-like organisms include many taxa previously studied by marine mycologists, as Oomycota, Hyphochytriomycota, Labyrinthulomycota, and Phytomyxea. Fungal-like organisms are a diverse group of eukaryotic microorganism, with a heterotrophic nutrition, and often possess motile zoospores. Again, there is no cohesive treatment of fungal-like organisms. An edited volume by Jones and Pang (2012) gives the most up-to-date account of the phylogeny, ecology and potential commercial application of marine fungi and fungal-like organisms.

Currently, some 530 species (Jones et al. 2009) have been described and documented, but Jones (2011) estimates there may be some 10,000 marine fungi and suggested areas for finding the "missing fungi". Until recently, most marine fungi were characterized by their morphology, but the use of molecular techniques has highlighted the existence of a wider range of taxa, and radically transformed the phylogenetic classification of these organisms. Extraction of DNA from various substrata/sediments has yielded a number of new lineages of fungi and resulted in a reappraisal of the taxonomy of various taxa. The development of tag-encoded 454 pyrosequencing of the nuclear ribosomal internal transcribed spacer-1 is a rapidly evolving technique that will provide an even wider range of taxa, and dramatically improve our knowledge of their ecology and role in the food web of the oceans.

Marine fungi from the South China Sea have been well documented over the past 25 years with active research groups in Hong Kong, Philippines, Taiwan, Thailand and Malaysia (Jones and Vrijmoed 2003). Most of the taxa reported are from mangrove substrata, which reflect the readily available biomass emanating from coastal mangrove forests. This has led to extensive studies on their ability to produce secondary metabolites with cultures derived from Hong Kong (Zhu and Lin 2006), China (Liu et al. 2006, 2008) and Thailand (Isaka et al. 2009; Trisuwan et al. 2008, 2011). Currently, some 300 marine fungi are known from the South China Sea, most isolated by conventional mycological techniques. The isolation of DNA from seawater, marine substrata and sediments, using advanced pyrosequencing techniques, will dramatically extend our knowledge of marine fungi and fungal-like organisms as these are not extensively employed.

The uniqueness of marine fungi has drawn attention to their potential as sources of new pharmaceutical products and new chemical structures, while the thraustochytrids are of biotechnological interest for their ability to produce significant yields of omega-3-fatty acids (PUFA), especially docosahexaenoic acid (DHA). The latter has application not only for human health, but also for marine aquaculture operations. The first antibiotic was detailed for siccayne produced by the marine basidiomycete *Hyalocyphina villosa*, and currently some 1100 new natural products have been reported from marine and marine-derived fungi. However, few have reached commercial production. Structurally they belong terpenoids, alkaloids, peptides, polyketides and prenylated polyketides, with a few lipids and shikimates. With the realization of increased resistance to many antibiotics for control of common bacterial diseases, there will a continued and pressing demand for new bioactive compounds. The main focus has been to search for new chemical structures with bioactive compounds, while less attention been paid to the enzymes they produce. Marine fungi possess novel physiological characteristics, such as, high salt tolerance, hyper thermostability, cold adaptivity and barophilicity. Thus the developing interest in the enzymes the produce.

Many may regard the study of marine fungi as an esoteric activity, forgetting they play a major role in the decomposition of complex recalcitrant organic matter in coastal waters, releasing nutrients that support other microorganism, which in turn are part of the food web of the oceans. They also play a role in the sequestration of pollutants, a topic worthy of greater study. The activity of fungi and carbon dioxide sequestration in mangroves and salt

marshes (blue carbon ecosystems) is a topic that will attract particular attention and importance with man's concern with global warming.

For those interested in learning more about marine fungi and their role in marine ecosystems, we commend the following book: Marine Fungi and Fungal-like Organisms, edited by E.B.G. Jones and K.-L. Pang (2012), De Gruyter, Germany, 532 pp.