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Marine fungi from different habitats recorded from 2001 to date in México

Abstract

Marine fungi are essential as recyclers of organic matter in the ocean, as well their secondary metabolites are now studied as potential drugs for different diseases. Despite Mexico having an extensive coastline, few resources have been allocated to the research of this group. Through a thorough review of scientific literature between 2001 and February 2021, a systematic listing of marine fungi on Mexico's marine waters was constructed. In this work, two orders, forty-nine genera, and thirteen species are recorded, of which 50 are new records. The most frequent phylum was Ascomycota (92%; 50 genera), followed Chytridiomycota (4%; 2 genera) and Basidiomycota (4%; 2 genera). Most of them have been reported in the Gulf of Mexico, followed by the Pacific Ocean, Gulf of California and, the Caribbean. A new halophile species isolated from deep sediment in the Gulf of California (Aspergillus loretoensis) is also reported.

Keywords: Ascomycota, Basidiomycota, Gulf of México, Pacific Ocean, Gulf of California

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Introduction

Marine fungi in México have been studied since 1968.[1] The studied fungi were isolated from coastal water and foam, sand beach, detritus, mangrove wood, and rhizosphere.[2-13] Gonzalez et al.,[3] reported the last checklist of marine fungi in México, where it contained sixty-one ascomycetes and one basidiomycete, all of them isolated by culture. Since then, only ten papers on marine fungi in México have been published. However, knowledge of marine fungi's biodiversity is biased because it is difficult to cultivate and subsequently identify them. It is estimated that only 5% have been isolated with traditional methods, as they cannot sporulate and grow.[14] However, new studies using sequences derived from the metagenomic analysis have increased the richness of fungi in the marine environment.[15]

México's coastline of 11,122 km, of which 7,828 km belong to the Pacific Ocean and 3,294 km to the Gulf of Mexico and the Caribbean.[16] It also has the Gulf of California long by 48-241 Km wide; despite the marine waters of México is home to a great diversity of species of which some are native,[17] very few species and resources have been used to research marine fungi species.[11] Fungi are essential in marine ecosystems because they participate in recycling organic matter.[14] Furthermore, industrial and pharmaceutical compounds have been discovered from marine fungi.[18] Their ecological and biotechnological benefits make studying this kingdom important. Considering the importance of the marine fungi, We summarized here forty-nine genera and thirteen species reported for the first time in México and a new halophile species.[13] Most of them were isolated from different marine habitats, and some genus identified by DNA sequences using molecular markers (18S rRNA gene).[7]

Materials and methods

An extensive bibliographic search was carried out in the main databases such as PUBMED (NCBI), ScienceDirect, DOAJ, Google scholar, and SCIELO (Table 1).

Table 1 Studies from marine fungi in México

Coast	México State
Pacific Ocean & Gulf of Mexico	NAY, CHP, TAM[7]
Gulf of México	TAM, VER, CAM, YUC[4]
Gulf of México	TAB[5]
Caribbean	QROO (Cozumel island)[6]
Gulf of California	BCS[8]
Gulf of México	VER[9]
Gulf of California	BCS[10]
Gulf of México[11]	
Gulf of California	BCS[13]
Gulf of México	BC[12]

Results and discussion

From 2001 to date were recorded fifty marine fungi. Being Ascomycota the most representative (92%), with thirteen species and a new halophile species (*Aspergillus loretoensis*) isolated from 275 m deep marine sediment at Loreto Bay of Baja California Sur (Table 2; Figure 1, no.2).

New records in México were *Chytriomyces* sp. and *Rhyzophydium* sp. of the phylum Chytridiomycota. Those were registered in the Pacific ocean.[7] Members of this phylum are zoosporic fungi that use a monocentric thallus as anucleate filamentous rhizoids to anchor the substrate absorb their nutrients. They are saprophytes, pathogens and can degrade chitin, cellulose, and keratin.[20]

Table 2 Marine fungi from México recorded from 2001-2021

Ascomycota	Substrate found	Ocean	Locality	Culture
Orden Microascales	sand from the deep ocean	GC	BCS	Culturable[8]
Orden Pleosporales	sand beach, sand from the deep ocean	P, GC	BC, BCS	Culturable[12]
Acremonium sp.	rhizosphere sediment	GM	VER	Culturable[9]
Alternaria sp.	rhizosphere sediment	GM	VER	Culturable[9]
Arthrographis kalrae	sand beach	P	BC	Culturable[12]
Ascosacculutus heteroguttulatus	sand beach	GM	TAB	Culturable[5]
Aspergillus spp.	rhizosphere sediment, ocean water, sand beach, sand from the deep ocean	GM, P, GC	VER, TAM, CHP, GRO, BCS	culturable & non[7,9,10]
Aspergillus loretonensis (new sp)	sand from the deep ocean	GC	BCS	Culturable[8]
Aspergillus terreus	sand beach	P	BC	Culturable[12]
Aureobasidium sp.	sand from the deep ocean	GM	TAM,VER, CAM,YUC	Culturable[4,11]
Blastomyces sp.	rhizosphere sediment	GM	VER	Culturable[9]
Candida sp.	ocean water	P	NAY	Non culturable[7]
Ceriosporopsis capillacea	sand beach	GM	TAB	Culturable[5]
Chaetomium sp.	sand from the deep ocean	GC	BCS	Culturable[8]
Chysoporthe sp.	ocean water	P	CHP	Non culturable[7]
Cladosporium sp.	sand from deep ocean	GM, GC	VER, TAB, TAM, CAM, YUC, BCS	Culturable[8,11]
Corollospora spp.	sand beach	P, GM, C	TAB, ROO, BC	Culturable[5,6,12]
Epicoccum sp.	sand from the deep ocean	GC	BCS	Culturable[8]
Exophiala sp.	sand beach	P	BC	Culturable[12]
Fusarium sp.	rhizosphere sediment	GM	VER	Culturable[9]
Geotrichum	rhizosphere sediment	GM	VER	Culturable[9]
Gymnoascus hyalinosporus	sand beach	P	GRO	Culturable[10]
halenospora varia	sand beach	GM	TAB	Culturable[5]
Haiyanga salina	sand beach	GM	TAM,VER, CAM,YUC	Culturable[4]
Humicola sp.	rhizosphere sediment	GM	VER	Culturable[9]
Lasiosphaeriaceae sp	sand beach	P	BC	Culturable[12]
Leptosphaerella sp.	sand beach	GM	TAM,VER, CAM,YUC	Culturable[4]
Meyerozyma guilliermondii	sand beach	P	BC	Culturable[12]
Microascaceae sp.	sand beach	P	BC	Culturable[12]
Monacrosporium sp.	rhizosphere sediment	GM	VER	Culturable[9]
Mucor sp.	rhizosphere sediment	GM	VER	Culturable[9]
Mycosphaerella sp	sand beach	GM	TAM,VER, CAM,YUC	Culturable[4]
Nais inornata	sand beach	GM	TAM,VER, CAM,YUC	Culturable[4]
Nectria sp.	rhizosphere sediment	GM	VER	Culturable[9]
Neocosmopora solani	sand beach	P	BC	Culturable[12]
Paecilomyces sp.	ocean water	P, GM	TAM, NAY, CHP	non culturable[7]
Parengyodontium album	sand beach	P	BC	Culturable[12]
Penicillium sp.	sand beach, sand from deep ocean, mangrove rhizophere	P, GM	BC, TAM, VER, CAM, YUC	Culturable[9,12]

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Table continued...

Ascomycota	Substrate found	Ocean	Locality	Culture
Penicillium brevicompactum	sand from deep ocean	GM	TAM,VER, CAM,YUC	Culturable[11]
Phialocephala sp.	sand from deep ocean	GM	TAM,VER, CAM,YUC	Culturable[11]
Phoma sp.	ocean water, sand from deep ocean	GM, GC	TAM, BCS	non culturable[7,8]
Phomopsis sp.	rhizosphere sediment	GM	VER	Culturable[9]
Phytophthora sp.	rhizosphere sediment	GM	VER	Culturable[9]
Remispora sp	sand beach	GM	TAB	Culturable[5]
Scopulariopsis sp.	sand beach, sand from deep ocean	P, GC	BC, BCS	Culturable[8,12]
Sepedonium sp.	rhizosphere sediment	GM	VER	Culturable[9]
Talaromyces sp.	rhizosphere sediment, sand from deep ocean	GM, GC	VER, BCS	Culturable[9]
Trichoderma sp.	rhizosphere sediment	GM	VER	Culturable[9]
CHYTRIDIOMYCOTA				
Chytriomyces sp	ocean water	P	NAY	non culturable[7]
Rhyzophydium sp	ocean water	GM	TAM	non culturable[7]
BASIDIOMYCOTA				
Nia sp.	sand beach	P	BC	Culturable[12]
Peniophora sp.	sand from deep ocean	GC	BCS	Culturable[8]

Abbreviations: Ocean: GM, Gulf of México; P, Pacific Ocean; GC, Gulf of California; C, Caribbean. México States: BC, Baja California; BCS, Baja California Sur; CHP, NAY, Nayarit; GRO, Guerrero; CHP, Chiapas; TAM, Tamaulipas; VER, Veracruz; CAM, Campeche; TAB, Tabasco; YUC, Yucatán; ROO, Quintana Roo

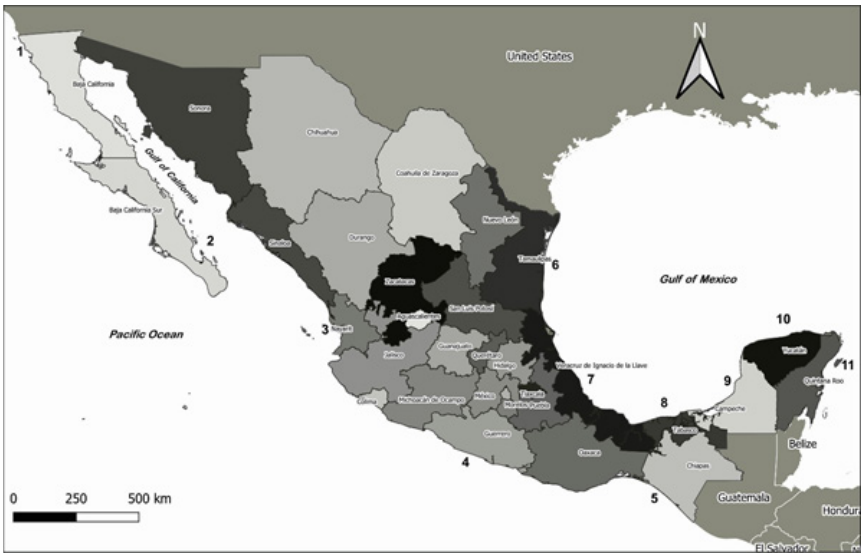

Figure 1 Map of México showing the studied cost. Pacific Ocean: 1, Baja California. Gulf of California: 2, Baja California Sur. Pacific Ocean: 3, Nayarit; 4, Guerrero; 5, Chiapas. Gulf of México: 6, Tamaulipas; 7, Veracruz; 8, Campeche; 9, Tabasco; 10, Yucatán. Caribbean: 11, Quintana Roo.

By another hand, the genus *Nia* sp (Basidiomycota) was reported previously in foam from the Caribbean.[21] However, the new register was found in the sand beach of the Pacific ocean[12] (Figure 1, no.1). It is important to say that this species is a wood-rotting fungus and cosmopolite in its distribution. The other Basidyomycota is *Peniophora* sp. some species have been reported as mangrove endophytic and are being studied as laccase enzyme producers.[22]

The Ascomycota members were found in different substrates or water. From sand beach were isolated twenty-two genus and seven species (*Ascosacculutus heteroguttulatus, Ceriosporopsis capillacea*, *Gymnoascus hyalinosporus*, *Halenospora varia, Meyerozyma guilliermondii, Neocosmopora solani, Parengyodontium album*), mangle rhizosphere sixteen genera. Nine genus and two species (Penicillium brevicompactum and A. loretoensis) were found from sediment of the deep ocean. Seven genera were registered from the ocean water (Table 2).

The principal studies of marine fungi have been done in the Gulf of México. Scarce studies are in the Caribbean (one study in the sand beach at Cozumel island[6]), the Pacific Ocean (one study in sand beach[12]), and the Gulf of California (one sand survey from deep ocean[8]). More efforts must be made in those areas since they have a particular environment where it can be found, corals reefs, hydrothermal chimneys (at the Gulf of California), kelp forests, mangroves, among others.[17,23]

It is essential to say that the Pacific ocean has template waters, and the Gulf of California has extreme conditions since it is a semi-close area (large evaporation basin) and is next to desert territories.[17] These changes could explain why other genera are not found in the Gulf of México as *Exophiala* sp., *Lasiosphaeriaceae* sp., *Meyerozyma guilliermondii*, *Microascaceae* sp., *Neocosmopora solani*, *Parengyodontium album*, *Arthrographis kalrae*, *Aspergillus terreus, Scopulariopsis* sp., *Aspergillus loretoensis* and the order Pleosporales.

Although some genera are here reported as marine, there are also found in terrestrial substrates. Among them are *Geotrichum* sp., *Blastomyces* sp. (dermatitis), *Sepedonium* sp. (plant pathogen), *Phialocephala* sp. (forest ecosystem), *Arthrographis kalrae* (nail mycosis), *Parengyodontium album* (colonize mineral building materials), and *Chysophorte* sp. (*Eucalyptus* sp. canker).[24-29]

Conclusion

This study of marine fungi shows limited research in México. Biotechnological companies and the government must make more efforts to study this group from particular habitats in the Caribbean, the Pacific Ocean, and the Gulf of California (corals reefs, hydrothermal chimneys, kelp forest, mangroves, marshes, coastal lagoons, among others). Microorganisms from extreme environments offer new metabolites and enzymes to be used in the pharmaceutical industries; from an economic viewpoint, this is why marine fungi are essential to study.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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