

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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Amelia Portillo-López, Sophia González-Martínez

Facultad de Ciencias, Universidad Autónoma de Baja California, México

Correspondence: Amelia Portillo López, Facultad de Ciencias, Universidad Autónoma de Baja California, Km 103 carretera Tijuana-Ensenada, Ensenada, B.C. México, CP 22860, Tel +52 646 1744560, Email portillo@uabc.edu.mx

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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, CHR, 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 *Chytriumyces* sp. and *Rhizophydium* 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
<i>Orden Microascales</i>	sand from the deep ocean	GC	BCS	Culturable ⁸
<i>Orden Pleosporales</i>	sand beach, sand from the deep ocean	P, GC	BC, BCS	Culturable ¹²
<i>Acremonium sp.</i>	rhizosphere sediment	GM	VER	Culturable ⁹
<i>Alternaria sp.</i>	rhizosphere sediment	GM	VER	Culturable ⁹
<i>Arthrographis kalrae</i>	sand beach	P	BC	Culturable ¹²
<i>Ascocaculatus heteroguttulatus</i>	sand beach	GM	TAB	Culturable ⁵
<i>Aspergillus spp.</i>	rhizosphere sediment, ocean water, sand beach, sand from the deep ocean	GM, P, GC	VER, TAM, CHP, GRO, BCS	culturable & non ^{7,9,10}
<i>Aspergillus loretonensis (new sp)</i>	sand from the deep ocean	GC	BCS	Culturable ⁸
<i>Aspergillus terreus</i>	sand beach	P	BC	Culturable ¹²
<i>Aureobasidium sp.</i>	sand from the deep ocean	GM	TAM, VER, CAM, YUC	Culturable ^{4,11}
<i>Blastomyces sp.</i>	rhizosphere sediment	GM	VER	Culturable ⁹
<i>Candida sp.</i>	ocean water	P	NAY	Non culturable ⁷
<i>Ceriosporopsis capillacea</i>	sand beach	GM	TAB	Culturable ⁵
<i>Chaetomium sp.</i>	sand from the deep ocean	GC	BCS	Culturable ⁸
<i>Chysoporthe sp.</i>	ocean water	P	CHP	Non culturable ⁷
<i>Cladosporium sp.</i>	sand from deep ocean	GM, GC	VER, TAB, TAM, CAM, YUC, BCS	Culturable ^{8,11}
<i>Corollospora spp.</i>	sand beach	P, GM, C	TAB, ROO, BC	Culturable ^{5,6,12}
<i>Epicoecum sp.</i>	sand from the deep ocean	GC	BCS	Culturable ⁸
<i>Exophiala sp.</i>	sand beach	P	BC	Culturable ¹²
<i>Fusarium sp.</i>	rhizosphere sediment	GM	VER	Culturable ⁹
<i>Geotrichum</i>	rhizosphere sediment	GM	VER	Culturable ⁹
<i>Gymnoascus hyalinusporus</i>	sand beach	P	GRO	Culturable ¹⁰
<i>halenospora varia</i>	sand beach	GM	TAB	Culturable ⁵
<i>Haiyanga salina</i>	sand beach	GM	TAM, VER, CAM, YUC	Culturable ⁴
<i>Humicola sp.</i>	rhizosphere sediment	GM	VER	Culturable ⁹
<i>Lasiosphaeriaceae sp</i>	sand beach	P	BC	Culturable ¹²
<i>Leptosphaerella sp.</i>	sand beach	GM	TAM, VER, CAM, YUC	Culturable ⁴
<i>Meyerozyma guilliermondii</i>	sand beach	P	BC	Culturable ¹²
<i>Microascaceae sp.</i>	sand beach	P	BC	Culturable ¹²
<i>Monacrosporium sp.</i>	rhizosphere sediment	GM	VER	Culturable ⁹
<i>Mucor sp.</i>	rhizosphere sediment	GM	VER	Culturable ⁹
<i>Mycosphaerella sp</i>	sand beach	GM	TAM, VER, CAM, YUC	Culturable ⁴
<i>Nais inornata</i>	sand beach	GM	TAM, VER, CAM, YUC	Culturable ⁴
<i>Nectria sp.</i>	rhizosphere sediment	GM	VER	Culturable ⁹
<i>Neocosmopora solani</i>	sand beach	P	BC	Culturable ¹²
<i>Paecilomyces sp.</i>	ocean water	P, GM	TAM, NAY, CHP	non culturable ⁷
<i>Parengyodontium album</i>	sand beach	P	BC	Culturable ¹²
<i>Penicillium sp.</i>	sand beach, sand from deep ocean, mangrove rhizosphere	P, GM	BC, TAM, VER, CAM, YUC	Culturable ^{9,12}

Table continued...

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

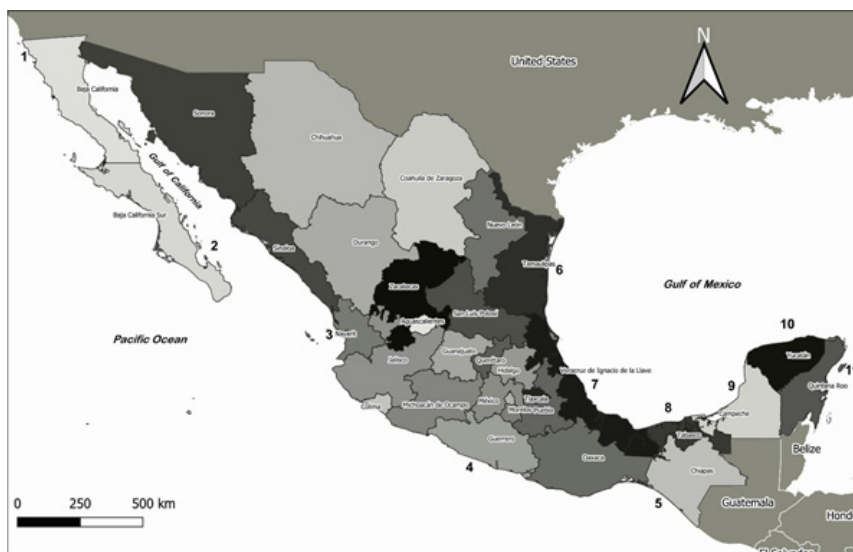


Figure 1 Map of México showing the studied cost. Pacific Ocean: 1, Baja California. Gulf of California: 2, Baja California Sur. Pacific Ocean: 3, Nayarit; 4, Guerrero; 5, Chiapas. Gulf of México: 6, Tamaulipas; 7, Veracruz; 8, Campeche; 9, Tabasco; 10, Yucatán. Caribbean: 11, Quintana Roo.

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 ocean¹² (Figure 1, no.1). It is important to say that this species is a wood-rotting fungus and cosmopolite in its distribution. The other Basidiomycota 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 (*Ascospiculus heteroguttulatus*, *Ceriosporopsis capillacea*, *Gymnoascus hyalinusporus*, *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 island⁶), the Pacific Ocean (one study in sand beach¹²), and the Gulf of California (one sand survey from deep ocean⁸). 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 temperate 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 *Chysothorpe* 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.

References

- Kohlmeyer J. Marine fungi from the tropics. *Mycologia*. 1968;60(2):252–270.
- Kohlmeyer J. Marine fungal pathogens among Ascomycetes and Deuteromycetes. *Generalia*. 1979;35(4):437–439.
- González MC, Hanlin RT, Ulloa M. A Check List of Higher Marine Fungi of Mexico. *Mycotaxon*. 2001;80:241–253.
- Velez P, Gonzalez MC, Rosique-Gil E, et al. Community structure and diversity of marine ascomycetes from coastal beaches of the southern gulf of Mexico. *Fungal Ecol*. 2013;6(6):513–521.
- Velez P, Gonzalez MC, Capello-García S, et al. Diversity of marine ascomycetes from the disturbed Sandy beaches of Tabasco, Mexico. *J Marine Biol Assoc United kingdom*. 2015;95(5):897–903.
- Velez P, Gonzalez MC, Cifuentes J, et al. Diversity of sand inhabiting marine ascomycetes in some tourist beaches on Cozumel island, Mexico. *Mycoscience*. 2015;56:136–140.
- Valderrama B, Paredes-Valdez G, Rodríguez R, et al. Assessment of non-cultured aquatic fungal diversity from different habitats in Mexico. *Revista Mexicana de Biodiversidad*. 2016;87(1):18–28.
- Gonzalez-Martinez S, Soria I, Ayala N, et al. Culturable halotolerant fungal isolates from Southern California Gulf sediments. *Open Agric*. 2017;2(1):292–299.
- Lumbreras-Martínez H, Espinoza C, Fernández JJ, et al. Bioprospecting of fungi with antiproliferative activity from the mangrove sediment of the Tampamachoco coastal lagoon, Veracruz, México. *Scientia Fungorum*. 2018;48:53–60.
- Aparicio-Cuevas MA, Gonzalez MC, Raja HA, et al. Metabolites from the marine-facultative *Aspergillus* sp. MEXU 27854 and *Gymnoascus hyalosporus* MEXU 29901 from Caleta Bay, Mexico. *Tetrahedron Letters*. 2019;60:1649–1652.
- Velez P, Gasca-Pineda J, Riquelme M. Cultivable fungi from Deep-sea oil reserves in the Gulf of Mexico: Genetic signatures in response to hydrocarbons. *Marine Environ Res*. 2019;153:104816.
- Velez P, Walker AK, Gasca-Pineda J, et al. Fine-scale temporal variation of intertidal marine fungal community structure: insight from an impacted Baja California sandy beach. *Marine Biodiversity*. 2021;51:6.
- González-Martínez S, Galindo-Sánchez C, Portillo-López A. *Aspergillus loretoensis*, a single isolate from marine sediment of Loreto Bay, Baja California Sur, México resulting as a new obligate halophile species. *Extremophiles*. 2019;23(5):557–568.
- Jones EBG. Are there more marine fungi to be described? *Botanica Marina*. 2011;54(4):343–354.
- Vargas-Gastélum L, Riquelme M. The mycobiota of the deep sea: What omics can offer? *Life*. 2020;10(292):2–18.
- Instituto Nacional de Estadística y Geografía (INEGI), Mapas; 2021.
- Brusca RC, Findley LT, Hastings PA, et al. Macrofaunal diversity in the Gulf of California. En: *Biodiversity, ecosystems, and conservation in northern Mexico*. JLE Cartron, G Ceballos, RS Felger (eds.). Oxford University Press; 2005. 179–203 p.
- Overy DP, Rama T, Oosterhuis et al. The neglected marine fungi, *sensu stricto*, and their isolation for natural product's discovery. *Mar Drugs*. 2019;17(1):42.
- Wang JF, Lin XP, Qin C, et al. Antimicrobial and antiviral sesquiterpenoids from sponge-associated fungus, *Aspergillus sydowii* ZSDS1-F6. *J Antibiot*. 2014;67(8):581–583.
- Dee JM, Landry BR, Berbee ML. Actin guides filamentous rhizoid growth and morphogenesis in the zoospore fungus *Chytrium hyalinus*. *Mycologia*. 2019;111(6):904–918.
- González MC, Hanlin RT, Ulloa M. A Check List of Higher Marine Fungi of Mexico. *Mycotaxon*. 2001;80:241–253.
- Glazunova OA, Moiseenko KV, Savinova OS, et al. Purification and characterization of two novel laccases from *Peniophora lycii*. *J Fungi*. 2020;6(4):340.
- Goffredi SK, Johnson S, Tunnicliffe V et al. Hydrothermal vent fields discovered in the southern Gulf of California clarify role of habitat in augmenting regional diversity. *Proc Biol Sci*. 2017;284(1859):20170817.
- Pottier I, Gente S, Vernoux JP, et al. Safety assessment of dairy microorganisms: *Geotrichum candidum*. *Int J Food Microbiol*. 2008;126(3):327–332.
- Da Silva Guimarães LM, Vilela de Resende MD, Lau D, et al. Genetic control of *Eucalyptus* urophylla and *E. grandis* resistance to canker caused by *Chysothorpe cubensis*. *Gen Mol Biol*. 2010;33(3):525–531.
- Sugiura Y, Hironaga M. *Arthrographis kalrae*, a rare causal agent of onychomycosis, and its occurrence in natural and commercially available soils. *Med Mycol*. 2010;48(2):384–389.
- Grüning CR, Queloz V, Sieber TN, et al. Dark septate endophytes (DSE) of the *Phialocephala fortinii* s.l.-*Acephala applanata* species complex in tree roots: classification, population biology, and ecology. *Botany*. 2008;86(12):1355–1369.
- Ponizovskaya VB, Rebrikova NL, Kachalkin AV, et al. Micromycetes as colonizers of mineral building materials in historical monuments and museums. *Fungal Biol*. 2019;123(4):290–306.
- Frost HM, Novicki TJ. *Blastomyces* antigen detection for diagnosis and management of blastomycosis. *J Clin Microbiol*. 2015;53(11):3660–3662.