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Community structure and diversity of marine ascomycetes from coastal beaches of the southern Gulf of Mexico

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ABSTRACT

Diversity of marine fungi in the Gulf of Mexico remains unknown for the most part, therefore the geographical distribution patterns of these microorganisms are mostly unknown too. Twelve sandy beaches located in this sea were sampled to evaluate the diversity of marine fungi, revealed by fruiting on natural substrata incubated in the laboratory for up to 12 months. Species richness and diversity differed between beaches, and corresponded with the presence of main and highly polluted river mouths, nearshore marine environments, and core industrial and port developments. Contaminants and local anthropogenic activities may be reducing the diversity of marine ascomycetes. Connections between beaches and different nearshore habitats explain the high diversity observed, since they represent a varied source of substrata for decomposition and heterogeneous environmental conditions. We recognized four main local species distribution patterns. Moreover, the constrained correspondence analysis showed that temperature is a major environmental variable affecting the distribution of these fungi. By a linear regression we showed a significant relationship between temperature and diversity.

Introduction

Marine ascomycetes are an important component of biodiversity in sandy beaches. This group of fungi represents an ecological assemblage of mostly saprotrophic microorganisms that play an active role in the ecological function of sandy beach marine ecosystems (Kohlmeyer and Kohlmeyer, 1979; Hyde et al., 2000; Sakayaroj et al., 2004). These saprobes occur on different substrata rich in lignin, cellulose, or chitin (e.g., calcareous molluscan and crustacean exoskeletons, plant material associated with sand grains on beaches, drift wood, algae and seaweeds, sea grasses, and roots, stems, leaves, fruits, seeds of

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mangrove and other vascular plants) (González, 2009). Other trophic levels depend on these saprotrophic fungi to cleave lignocellulose so it can enter the food web through mycophagic invertebrates and bacteria (Newell and Porter, 2000).

Worldwide only about 530 species of marine fungi are known, out of which 424 species are ascomycetes (Jones et al., 2009). Currently for Mexico, barely 62 species of marine fungi are recorded, of which 47 are ascomycetes. In the Gulf of Mexico, a total of 60 species of marine fungi have been described, out of which 48 are ascomycetes (González, 2009; Walker and Campbell, 2010). Therefore, the marine fungal diversity of Mexico, and of the Gulf of Mexico, remains unknown for the most part. Moreover, the geographical distribution patterns of this ecological group of fungi are undefined especially at a local scale (Kohlmeyer, 1968, 1983, 1984; González and Herrera, 1993; Volkmann-Kohlmeyer and Kohlmeyer, 1993; González et al., 1998, 2001).

The distribution of marine fungi is principally determined by the temperature and salinity of the water. Five temperature-determined regions are recognized: arctic, temperate, subtropical, tropical and Antarctic (Hughes, 1974). However, local geographical patterns have also been reported (Nakagiri et al., 1999). Moreover, species diversity may be also controlled by a combination of other factors such as, effects of habitats, availability of substrata for colonization, inhibition, competition, dissolved organic nutrients, hydrogen ion concentration, osmotic effects, oxygen availability, pollutants, abundance of propagules in the water, ability to attach to a suitable substrata, hydrostatic pressure, substrate specificity, etc. (Booth and Kenkel, 1986; Jones, 2000).

The Gulf of Mexico is a diverse ecosystem that provides a wide array of valuable resources to the nations on its shores, in terms of fisheries, tourism, agriculture, trade, shipping, infrastructure and oil (Cato and Adams, 1999). As a result of pollutant discharges, oil and gas development, and nutrient loading, the ecosystems of the Gulf of Mexico show signs of stress in coastal regions. The Mississippi–Atchafalaya River Basin and Gulf of Mexico hypoxic zone is the largest zone of anthropogenic coastal hypoxia in the western hemisphere (Birkett and Rapport, 1999; Rabalais et al., 1999).

Assessing marine fungal diversity of threatened ecosystems is an imperative task considering that species diversity may be declining. Furthermore, the conservation and utilization of this diversity requires full knowledge about the species diversity and their distribution, thus the study of unexplored beaches is also an important task (Das et al., 2006). Hence, the aim of this investigation was to analyze the diversity and distribution patterns of marine ascomycetes inhabiting 12 sandy beaches spread along the coastline of the southern Gulf of Mexico, and to evaluate the effect of three environmental variables (mean annual temperature, average of annual rainfall and annual salinity) on their geographical distribution.

Materials and methods

Study area

The Gulf of Mexico is bordered by the United States of America to the north (states of Florida, Alabama, Mississippi, Louisiana, and Texas), Mexico to the south (states of Tamaulipas, Veracruz, Tabasco, Campeche, and Yucatan), and the island of Cuba to the southeast. It measures approximately 1 600 km from east to west, 900 km from north to south, and has a surface area of 1 500 000 km^2 (Uchupi, 1975; Salvador, 1991; Gore, 1992).

The Gulf of Mexico may be divided into seven provinces according to its physiogeographical characteristics: Gulf of Mexico Basin, Northeast Gulf of Mexico, South Florida Continental Shelf and Slope, Northern Gulf of Mexico, Campeche Bank, Bay of Campeche, Eastern Mexico Continental Shelf and Slope (Antoine, 1972). The last three provinces comprise the Mexican Gulf of Mexico. The Campeche Bank is an extensive carbonate bank located to the north of the Yucatan Peninsula (Ordonez, 1936). The Bay of Campeche is an isthmian embayment extending from the western edge of Campeche Bank to the offshore regions on the east of Veracruz, and it is characterized by salt domes, a predominance of thick terrigenous sediments, and production of large quantities of oil. The Eastern Mexico Continental Shelf and Slope is located between Veracruz to the south and the Rio Grande to the north. This province spans the entire eastern shore of Mexico, and is characterized by sediment-covered folds that parallel the shore created by sediment-covered evaporites (Bryant et al., 1968).

Water enters the Gulf of Mexico through the Yucatan Strait, circulates as the Loop Current, and exits through the Florida Strait eventually forming the Gulf Stream. However, portions of the Loop Current often break away forming eddies affecting regional current patterns (Nowlin, 1971).

Sampling and procedures

The samplings were conducted from Mar. 22nd to Apr. 6th 2011 during low tide. We studied 12 sandy beaches spread along the coast of the Mexican Gulf of Mexico (Fig 1, Table 1), out of which 11 represent unexplored sites for marine fungal diversity assessments (González et al., 2001). The beach environment was characterized according to the scheme proposed by Carranza-Edwards and Caso-Chávez (1994), and a sample was taken in the mesobeach of each site, a region that is covered with water and is exposed to the air in a rhythmic and alternate way and which extends from the maximum withdrawal of the outflow at low tide up to the maximum inflow at high tide. Samples were collected randomly, and consisted of 50 sample units (*su*) of washed-up detritus (wood pieces, algae and other debris) covered with moist sand from the collecting site and placed in plastic bags (Ziploc®). In the laboratory, the *su* were incubated for up to 12 months and examined periodically for the presence of reproductive structures (Kohlmeyer and Kohlmeyer, 1979; González et al., 1998). When necessary the *su* were moistened with artificial seawater (Instant Ocean® Sea Salt, USA).

For identifying the fungi, *su* were examined with a stereomicroscope (Nikon SMZ1000, Japan), and a microscope with Nomarski differential interference contrast optics (Nikon Eclipse 80i, Japan). We removed ascomata from the sand grains with a sterilized needle. Next, ascomata were placed in a drop of distilled water on a slide, covered with a cover slip, and squashed. The identification of the fungi was done based