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Harmful algal blooms and eutrophication along the mexican coast of the Gulf of Mexico large marine ecosystem

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ABSTRACT

Harmful algal blooms (HABs) have been the subject of many reports released by Mexican Federal Authorities along the Mexican Coast of the Gulf of Mexico Large Marine Ecosystem (MC-GoM-LME), but extensive research that delves deeply into this issue is lacking. Although *Karenia brevis* blooms have appeared in all Mexican states (except Quintana Roo) and blooms of *Cladophora* spp., *Chattonella marina*, *Chattonella subsalsa*, *Glenodinium pseudostigmosum* and *Chaetoceros holsaticus* are fairly new to the MC-GoM-LME, their spatial and temporal variations are largely unknown. It appears that anthropogenic nutrient over-enrichment is the main driver of eutrophication along the MC-GoM-LME. Trophic conditions based on physico-chemical parameters, phytoplankton and submerged aquatic vegetation along the northern coast of Yucatan show the influence of Gulf of Mexico LME and Caribbean Sea LME waters, seasonal upwelling and polluted inputs from submarine groundwater discharges. Meso-eutrophic and oligo-mesotrophic conditions on the coast are associated with human activities such as domestic sewage discharges from septic tanks, harbor effluents and brackish waters from artificial inlets. Coastal lagoons in Veracruz have been impacted by urbanization expansion leading to waste-water discharges, fertilizer runoff and changes in land use. Overall, trophic conditions in Veracruz have improved relative to historic trophic index values. At least for the Yucatan State and the Quintana Roo State, there are sites that appear to link the occurrence of HABs and anthropogenic eutrophication. Additional research over inshore, estuarine, coastal and offshore environments requires future monitoring efforts and collaboration with the international community (especially the U.S.).

1. Introduction

The Gulf of Mexico Large Marine Ecosystem (GoM-LME) is a complex ecologically-defined area of high biodiversity and biocapacity providing ecosystem services (Sherman, 2014) (Fig. 1). Two major stressors to the ecosystem are nutrient loads from the Mississippi-Atchafalaya River system (Cardona et al., 2016; O'Connor et al., 2016) and the risk and consequences of accidents resulting from the extraction of petroleum (Joye et al., 2016; Sun et al., 2015; Yin et al., 2015), particularly in the deep waters of Perdido Fold Belt. Nutrient loadings in coastal waters can cause eutrophication, leading to changes in Chl-a, primary production,

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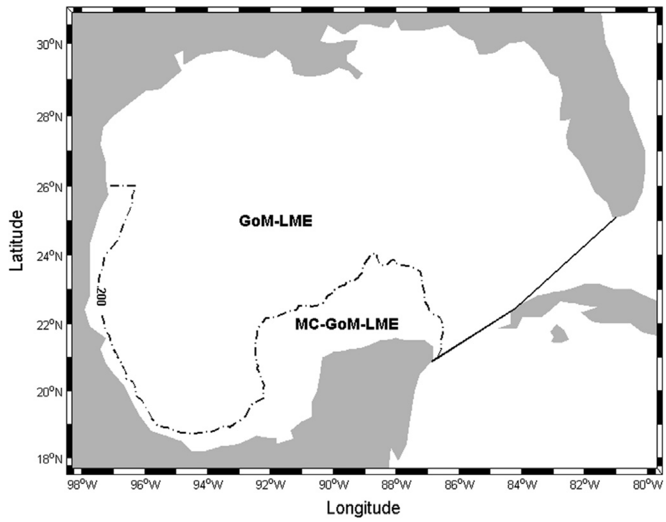

Fig. 1. Map of the GoM-LME and the MC-GoM-LME with a spatial domain limited by the 200 m isobath (dashed line).

macro- and microalgal biomass as well as benthos biomass, benthos community structure and benthic macrophytes, which in turn result in major changes in species composition, structure and function of marine communities over large areas (Cloern, 2001; Islam and Tanaka, 2004). Microalgal blooms are not only a consequence of aquatic pollution, but also natural phenomena linked with the seasonal cycle of photosynthetic organisms in aquatic ecosystems (Berdalet et al., 2016; Islam and Tanaka, 2004). The rise in toxic and harmful algae have adverse impacts on living marine resources and public health. For example, fish and bird mortality and contaminated shellfish (Deeds et al., 2010; Deventer et al., 2012; Driggers et al., 2016; Fauquier et al., 2013), in addition to respiratory and gastrointestinal illnesses caused by brevetoxin exposures and neurotoxic shellfish poisoning (Fleming et al., 2011; Hoagland et al., 2014; Kirkpatrick et al., 2011; Pierce and Henry, 2008; Reich et al., 2015; Steidinger, 2009; Watkins et al., 2008). Hence continuous monitoring and modeling the environmental conditions of the GoM-LME is a need to improve ecological understanding and management decisions based on a balance among coupled societal-ecological needs, sustainability and ecosystem health (Arkema et al., 2006; Long et al., 2015).

On a global scale, the inputs of land-derived nitrogen and phosphorous into the ocean have trebled between the 1970s and 1990s which has consequences for the biogeochemistry and ecology of coastal seas (Jennerjahn, 2012). Nutrient fluxes into estuaries and the marine environment may be due to sewage effluents (treated or untreated) and discharges from industrial plants, and also from non-point sources, mainly from agricultural runoff (Cardona et al., 2016; Islam and Tanaka, 2004; Rabalais, 2002a). Increased inputs of nutrients to coastal waters can lead to a rise in phytoplankton biomass and primary production (Anderson et al., 2012; Rabalais 2002a, 2002b). Worldwide eutrophication fueled by riverine runoff of fertilizers had exacerbated primary production in coastal zones leading to an increase in the formation of hypoxic zones ($<2 mgO_2 l^{-1}$) also known as dead zones (Díaz and Rosenberg, 2008; Rabalais et al., 1996, 2002a, 2002b; Scavia and Donnelly, 2007). Eutrophication can lead to hypoxia, however, estuarine and coastal systems can be eutrophic without develop hypoxic conditions depending on stratification, decomposition of organic matter, variations in the volume of river discharges, water residence times, suspended sediments, nutrient enrichment and the timing of the nutrient loads (Rabalais et al., 2002a, 2002b). Seasonal changes in the concentration of dissolved oxygen affect the habitats of many benthic organisms (Rabalais et al., 2010). Dead zones in the coastal oceans have spread exponentially since the 1960s and have serious consequences for ecosystem functions. The above-mentioned statements are all specifically well-established conditions associated with the northern Gulf of Mexico.

In comparison with the northern and offshore GoM-LME, the Mexican Coast of the Gulf of Mexico Large Marine Ecosystem (MC-GoM-LME) is a lesser-known coastal system (Fig. 1) which includes lower watersheds with highly urbanized areas and vulnerable habitats supporting a great variety of different living resources that are ecologically and economically important. Harmful algal blooms (HABs) and eutrophication are disturbances to coastal ecosystems causing cumulative socio-economic and human health costs. HABs are a matter of public interest and currently an issue of concern to local and federal authorities due to their recurrence along the MC-GoM-LME. This study aims to examine compiled reports of HABs from Mexican federal agencies and available publications to summarize our current state of knowledge in the MC-GoM-LME, providing a baseline information to propose regional studies for ecosystem-based management, monitoring and modeling.

2. Harmful algae

The list of HAB species for the GoM-LME includes those that are toxic or are potentially toxic. It was first generated as an activity to support a Harmful Algal Blooms Integrated Observing System (HABIOS) as a collaborative of the Gulf of Mexico Coastal Ocean Observing System and the Gulf of Mexico Alliance (see GCOOS/GOMA HABIOS Workshop #2: April 2009 at < http://gcoos.tamu.edu/?page_id=1452 >).