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Environmental forcing on the flux of organic-walled dinoflagellate cysts in recent sediments from a subtropical lagoon in the Gulf of California

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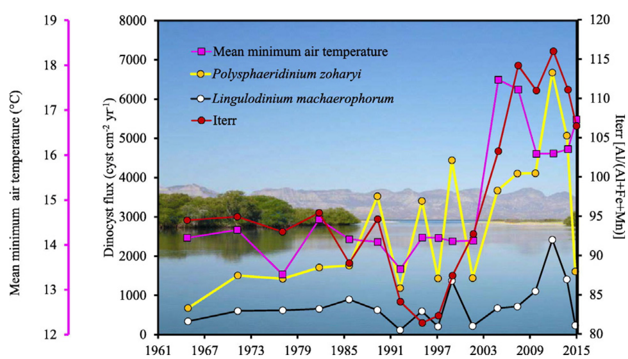
HIGHLIGHTS

- A ^{210}Pb-dated sediment core used to reconstruct dinocyst fluxes in San José Island
- Dinocyst fluxes were evaluated vs. rain, temperature, ENSO and terrigenous input.
- Cyst of *Pyrodinium bahamense* a toxic dinoflagellate increased over ca. 50 years ago
- Dinocyst fluxes responded to terrigenous input and minimum atmospheric temperature.

GRAPHICAL ABSTRACT



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ABSTRACT

To evaluate the relationship of changes in organic-walled dinoflagellate cyst (dinocyst) fluxes to sediments with environmental variables (air and sea surface temperatures, El Niño conditions, rainfall, and terrigenous index), cyst assemblages were analyzed in a ^{210}Pb-dated sediment core (~100 years) from the pristine San José Lagoon (San José Island, SW Gulf of California). The dinocyst abundance ranged from 3784 to 25,108 cysts g^{-1} and fluxes were of the order of 10^3–10^4 cysts cm^{-2} yr^{-1}. *Lingulodinium machaerophorum*, *Polysphaeridium zoharyi* and *Spiniferites* taxa accounted for 96% of the total dinocyst assemblages, and the abundances of these species increased towards the core surface. *P. zoharyi* fluxes increased from about 1965 onwards. Redundancy analyses, showed that mean minimum air temperature and terrigenous index were the key factors governing dinocyst fluxes. In this study, dinocyst fluxes of dominant taxa had responded to changes in climate-dependent environmental variables during the past ~20 years; this may also be the case in other subtropical coastal lagoons.

1. Introduction

Dinoflagellates are eukaryotic microorganisms with complex life cycles and diverse ecological roles. They are important contributors to

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marine primary production (Bravo and Figueroa, 2014), although most dinoflagellate species are mixotrophic, which is the combination of phototrophy and phagotrophy as a nutritional strategy (Jeong et al., 2010). Approximately, 100 dinoflagellate species are known to form harmful algal blooms (Moestrup et al., 2009), some of them producing toxins that affect to marine organisms and humans (Van Dolah, 2000).

About 200 dinoflagellate species produce resting cysts (hereafter dinocysts) during their life cycle (Head, 1996; Matsuoka and Head, 2013); these are deposited in the sediments and serve as a source of seeds to initiate blooms (Usup et al., 2012 and references therein); they can provide historical evidence of blooms (Matsuoka, 1999). The organic-walled dinoflagellates are preserved in the sediments owing to the presence of dinosporin in the cyst wall.

Dinocysts have been used as indicators of oceanographic variables [productivity, sea ice cover, salinity, temperature (e.g., de Vernal and Marret, 2007; Durantou et al., 2012; Cormier et al., 2016)], and of anthropogenic pollution and eutrophication (Dale, 2001; Pospelova et al., 2002), and to reconstruct past climatic conditions (e.g., Rochon et al., 1999; de Vernal et al., 2001; Candel et al., 2017).

In the Gulf of California, the main species of cyst-forming dinoflagellates that produce algal blooms are *Gymnodinium catenatum*, *Pyrodinium bahamense* and *Lingulodinium polyedra* (Páez-Osuna et al., 2016 and references therein). There is no information available about dinocyst records in sediment cores from the coastal lagoons, since the dinocyst studies have focused on surface sediment samples (Martínez-Hernández and Hernández-Campos, 1991; Morquecho and Lechuga-Devéze, 2003; Limoges et al., 2010) and Quaternary sediment cores from deep basins (Flores-Trujillo et al., 2009; Price et al., 2013; Price and Pospelova, 2014).

Variations in the cyst abundance of the above mentioned species in recent sediments, have been related to climatic variables such as rainfall, sea surface temperature, and El Niño-Southern Oscillation (Flores-Trujillo et al., 2009; Sanchez-Cabeza et al., 2012), as well as to anthropogenic influences (Peña-Manjarrez et al., 2001; Vásquez-Bedoya et al., 2008).

A dated sediment core spanning about 100 years, collected in a pristine coastal lagoon on an island in the southwestern Gulf of California, was used to reconstruct temporal changes in dinocyst assemblages, with the purpose to evaluate the influence of environmental variables on the variations in dinocyst assemblages and fluxes, with a special focus on potentially harmful species.

2. Regional setting

San José Lagoon (SJL) is a small and shallow coastal lagoon (2.7 km length, 5 to 10 m depth; Fig. 1) in the southern part of San José Island (24°52′-25°06′ N; 110°43′-110°35′ W). This is the third largest island in the Gulf of California (Lawlor et al., 2002), and is inhabited by a small local community (~70 residents; Espinosa-Gayosso and Alvarez-Castañeda, 2006) and its surrounding waters support a carbonate-rich biota with abundant coralline red algae, molluscs and hermatypic corals (Halfar et al., 2004; Hetzinger et al., 2006).

San José Island is the largest insular mangrove ecosystem in the Gulf of California (~1.09 km^2: Bourillón-Moreno et al., 1988; González-Zamorano et al., 2012). The connection of SJL to the sea (Fig. 1) mainly occurs through a 1.5 km-long channel in the north-northwest, and an intermittent outlet in the southwest (Morquecho et al., 2012). The climate is warm and dry, with mean annual temperature from 13.7 °C to 31.0 °C (Ruiz et al., 2006), and mean annual rainfall from 125 mm to 400 mm (UNAM, 1990). The lagoon has been a natural protected area since 1978 (SG, 1978), and it is considered to still remain as a pristine environment (Cuellar-Martinez et al., 2017).

3. Materials and methods

3.1. Sampling

One sediment core (SJ core, 42 cm long, 7 cm inner diameter) was collected by scuba diving with an acrylic tube in February 2015, in the

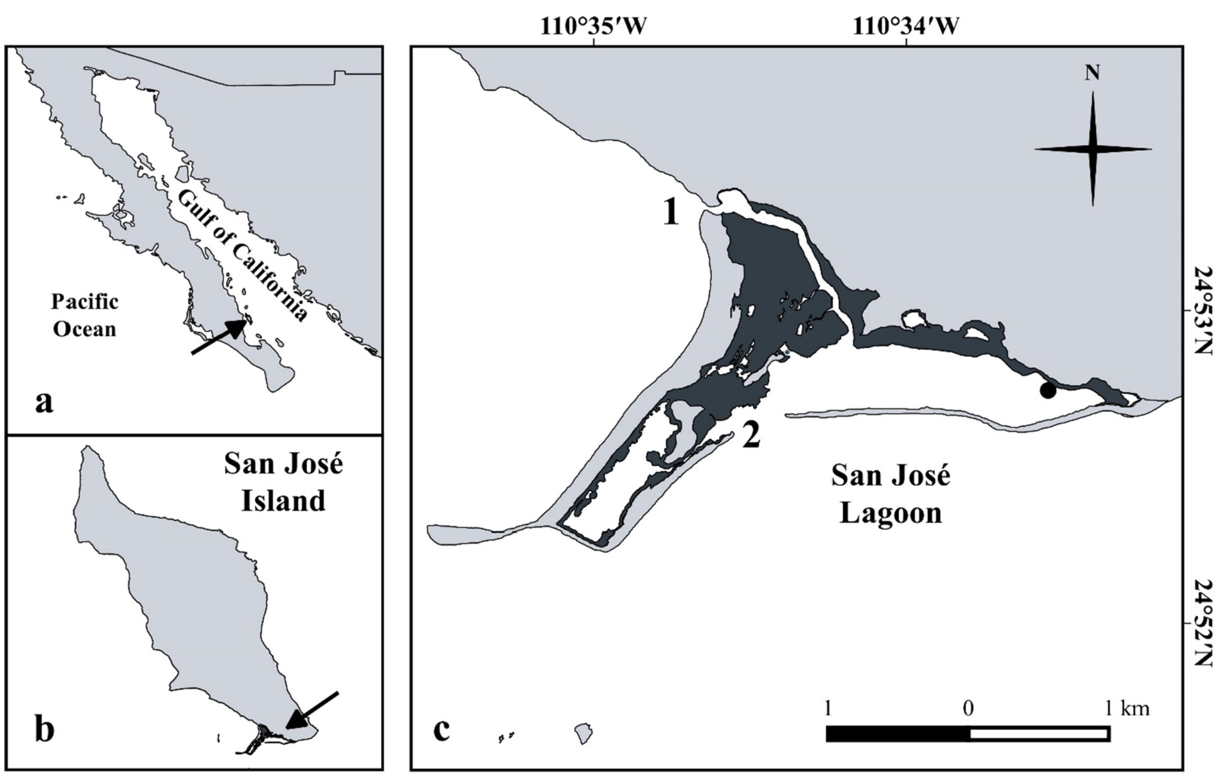

Fig. 1. Study area: a) location of San José Island in SW Gulf of California (arrow); b) location of the lagoon at the southern end of the island (arrow); c) collection site of sediment core (●); main (1) and intermittent (2) lagoon mouth; the dark gray shading indicates area covered by mangrove forests.