Palaeogeography, Palaeoclimatology, Palaeoecology 350–352 (2012) 49–61

Contents lists available at SciVerse ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Lipid biomarker signatures in a hypersaline lake on Isabel Island (Eastern Pacific) as a proxy for past rainfall anomaly (1942–2006 AD)

Lidia Romero-Viana [a,*], Ulrike Kienel [a,b], Dirk Sachse [a]

[a] DFG-Leibniz Center for Surface Process and Climate Studies, Institut für Erd- und Umweltwissenschaften, Universität Potsdam, Karl-Liebknecht-Strasse 24, Haus 27, 14476 Potsdam, Germany
[b] GFZ German Research Centre for Geosciences-Helmholtz-Centre Potsdam, Section 5.2, Telegrafenberg, 14473 Potsdam, Germany

ARTICLE INFO

Article history:
Received 12 August 2011
Received in revised form 23 May 2012
Accepted 12 June 2012
Available online 22 June 2012

Keywords:
Lipid biomarkers
Diol
Tetrahymanol
ENSO
Salinity
Paleoclimate
Mexico

ABSTRACT

Isabel Lake is a hypersaline crater-lake on Isabel Island, Mexico, situated in the eastern tropical Pacific, an area highly sensitive to hydrological changes. Today, annual rainfall mostly occurs during the wet season, from June to October, when the northern edge of the Intertropical Convergence Zone (ITCZ) extends over the island. In order to evaluate the potential of sedimentary lipid biomarker signatures as a proxy of past hydroclimatic variability we have performed a calibration analysis comparing changes in biomarker distribution in the upper 16 cm of the sediment core with a regional instrumental data set. Annual laminations present in the sediment sequence allow for precise chronological control (1942–2006). More than 80 different lipid compounds were identified in the sediment and could be assigned to three major groups of source organisms: (1) algal populations; (2) a mixed community of ciliates, bacteria and cyanobacteria; and (3) photosynthetic sulfur bacteria. We found that the observed changes in the relative contribution of the different lipid biomarkers to the sediment record were determined by the regional rainfall variability over the last 65 years. The planktonic community of Isabel Lake was highly sensitive to salinity fluctuations related to rainfall variability; seasonal precipitation results in freshwater input into the lake, driving an annual algal bloom and a relative decrease in the abundance of the more halotolerant populations of (cyano) bacteria and ciliates. Consequently, the concentration ratio between the two most abundant biomarkers in the Isabel Lake sediments, *n*-alkyl diols and tetrahymanol (which we define as the DiTe index), representing algal and ciliate planktonic populations, respectively, was significantly correlated with the seasonal rainfall anomaly ($r = 0.68$, $p < 0.01$). We propose that the DiTe index is a proxy of changes in the aquatic ecosystem of Isabel Lake and, by extension, regional hydrological changes in a sensitive climatic area of the eastern tropical Pacific.

1. Introduction

High-resolution climate records are essential for understanding the driving forces of past changes in climate (Jones et al., 2009). Lake sediment records with annual laminations are, in addition to ice core records, one of the prime targets for obtaining such records (Brauer et al., 2008). However, quantitative approaches for high-resolution reconstruction, especially of hydroclimatic variability (e.g., Romero-Viana et al., 2008, 2011), are still scarce. One approach to develop such a proxy is to explore the potential relationships between biotic and abiotic proxies and modern climate variability as recorded by instrumental data (Birks et al., 1998). In the search for quantitative climate reconstructions, an increasing variety of transfer functions for biological proxies such as pollen, diatoms, chironomids and ostracods as well as lipid biomarkers and their isotope composition has been performed in space or in time (Gasse et al., 1995; Sachse et al., 2004; Verschuren et ;al., 2004; Mischke et al., 2007). Unlike calibration in space (based in a set of lake surface sediments across an environmental gradient), calibration in time is achieved for a specific location by comparing a specific proxy with a record of environmental variables. This approach relies on accurate dating of a sedimentary record, hence such proxy calibrations in time have been largely limited to varved sediments.

Lipid biomarkers are excellent proxies tracing past environmental variability (e.g., Meyers, 1997; Volkman et al., 1998). Their taxonomic specificity enables qualitative differentiation of the sources of autochthonous (bacterial, algal and macrophytes) from allochthonous organic matter in sediments (Meyers, 1997 and references therein). Furthermore, different indices based on lipid compounds in marine sediments can be used as quantitative proxies for instance of sea surface temperature such as the $U^{k'}_{37}$ index (Brassell et al., 1986; Prahl and Wakeham, 1987) and for algal productivity, such as the ratio between different *n*-alkyl diols (Rampen et al., 2008). Lipid biomarkers have also been used to overcome the limitations of pollen records to

* Corresponding author. Tel.: +49 331 977 5836; fax: +49 331 977 5700.
E-mail address: Lidia.romero@geo.uni-potsdam.de (L. Romero-Viana).

0031-0182/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.palaeo.2012.06.011

infer past fluctuations of tree lines (Jansen et al., 2010). Nevertheless, quantitative reconstructions based on lipid biomarker proxies are still rare, particularly from lake sediments. However, these natural archives potentially record environmental variability at higher temporal resolution than marine sediments and show a higher sensitivity to regional climate changes; therefore, these archives are essential to a better understanding of the mechanisms of climate variability.

This study was undertaken to evaluate the potential of the sedimentary biomarker record of Isabel Lake as an archive of past hydrological conditions. Isabel Lake is a crater lake on the small volcanic island of Isabel 30 km off the Pacific coast of Central Mexico. The study site is ideal for developing a lipid-biomarker-based hydrological proxy for three main reasons. First, the highly seasonal precipitation regime is dominated by summer rainfall following the annual northward migration of the Intertropical Convergence Zone (ITCZ) (Cavazos and Hastenrath, 1990; Garcia-Oliva et al., 1991). The sensitive location of the island in the Eastern Subtropical Pacific under the influence of the El Niño/Southern Oscillation (ENSO) makes it a potential archive of past hydrological changes in the Tropical Pacific (Cobb et al., 2003; Sachs et al., 2009). Second, today, Isabel is a hypersaline and alkaline lake (>48 psu and pH 9–10 in the 0–2 m water column depth). Since the upper limit of planktonic photosynthetic activity is found in alkaline lakes (Talling et al., 1973; Imhoff et al., 1979), the degree of lipid biomarker production and preservation is expected to be high. Third, the annual laminations preserved in the sedimentary sequence of Isabel Lake allow for an accurate chronological control enabling a comparison of the sedimentary record with the instrumental climate data.

Therefore, we analyzed lipid biomarker abundance in the uppermost 16 cm of a short sediment core from Isabel Lake and compared the results with the hydroclimatic variability in the region over the last 65 years. We show that a comprehensive characterization of sedimentary biomarkers and their abundance can be used to establish a site-specific proxy to reconstruct past ecosystem changes.

2. Material and methods

2.1. Study site

Isla Isabel is a small island (2 km^2) approximately 30 km off the Pacific coast of Nayarit state, central Mexico (21°52′N and 105°54′W) (Fig. 1). The island is a complex of coalescent volcanoes aligned with the Tepic–Zacoalco Rift on the mainland (Housh et al., 2010). Isabel Lake is a flooded crater located in the southern part of the island. The circular lake has a diameter of 270 m. The crater walls stand up 19–25 m above the water surface, which is approximately 7 m above sea level (asl). A tide response in the lake level as suggested by Housh et al. (2010) was not observed during 45 days of field work in Isabel Lake (author's observations). Thus, seawater intrusion could be ruled out as a factor in water level fluctuations. The dominant vegetation type on the island is a deciduous forest composed mainly of bushes such as *Crataeva tapia* Linnaeus and *Euphorbia schlechtendalii* Boissier.

The most important climatic feature of the area on intra-annual timescales is the rainfall seasonality. Temperature shows only small variations throughout the year, while precipitation is almost exclusively delivered to Isabel Island during the wet season from June to October (Fig. 1). The maximum monthly rainfall amounts are recorded from July to September (300–400 mm $month^{-1}$). For the rest of the year, precipitation is almost negligible. Evaporation ranges between 120 mm in winter and 250 mm at the end of the dry season in May. Tropical cyclones occur sometimes in June and July but mostly in August, September and October. The historical archives (*National Oceanic and Atmospheric Administration (NOAA), National Hurricane Center*; http://csc.noaa.gov/hurricanes) show that in the 50 km around Isla Isabel several hurricanes with wind speeds higher than 50 knots (90 km h^{-1}) have passed or landed since 1950.

During four sampling campaigns (December 2006, May 2008, December 2008 and February 2009; Kienel, unpublished data) at Isabel

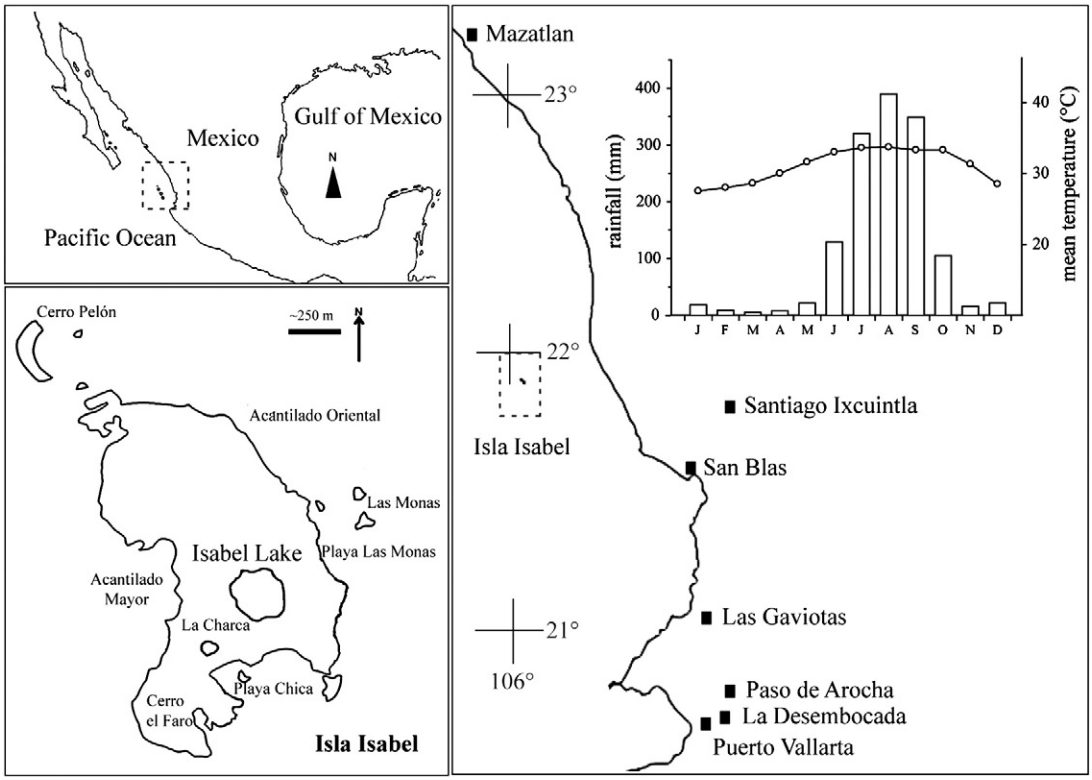

Fig. 1. Left: Isla Isabel location and a map of the island modified from Housh et al. (2010). Right: A detailed map of the region showing the localities whose instrumental datasets were used in this study. Inset: Monthly mean temperature (empty dots) and total rainfall amount (bars) based on the instrumental record of San Blas (1942–2000).