THE RED SEA SURVIVED THE LAST GLACIAL MAXIMUM

Morgan I. Chakraborty, Arash Sharifi, Francois Tissot, Ali Pourmand, Bolton J. Howes, Peter K. Swart, Chaojin Lu, and Sam J. Purkis

PROJECT OBJECTIVES

- To investigate the prevailing hypothesis of basin-wide extinction in the Red Sea during glacial sea-level lowstands

PROJECT RATIONALE

The Red Sea connects to the Indian Ocean via the Bab-el-Mandeb Strait, a narrow and shallow passage that controls water exchange between the two basins. Due to high evaporation rates and minimal freshwater input, the Red Sea is one of the warmest and saltiest marine basins on Earth. During glacial periods, lower sea levels further restricted this connection, leading to extreme salinity increases. Evidence from seabed cores shows that during the Last Glacial Maximum (LGM), when sea-level fell 110m below present, salinity rose to at least 50 PSU, possibly making conditions uninhabitable for marine organisms (Hemleben et al., 1996; Arz et al., 2003; Biton et al., 2008). The absence of microfossils, like planktonic foraminifera, suggests that parts of the Red Sea may have undergone total ecological collapse (Reiss et al., 1980; Fenton et al., 2000). Some researchers argue that during extreme lowstands, the Red Sea functioned more like a hypersaline lake, with recolonization only occurring after sea levels began to rise back to present-day levels around 15,000 years ago (Klausewitz et al., 1989).

However, the notion of complete ecological collapse is highly debated since some species, such as foraminifera, coccolithophores, and pteropods, may have survived in the northern Gulf of Aqaba and southern Red Sea (Locke et al., 1988). The high level of endemism among Red Sea fish and invertebrates also suggests that at least some marine life persisted through glacial sea-level lowstands (DiBattista et al., 2016). Two main hypotheses explain these refugia: one proposes that increased rainfall at the end of the glacial period reduced salinity, while another suggests that a narrow but continuous connection to the Indian Ocean remained open (de Lattin, 1967; Bailey et al., 2007; Lambeck et al., 2011). To test these theories, we analyzed deep-water coral skeletons from the northern Red Sea, using geochemical dating and isotopic analyses. These findings provide critical insights into how marine ecosystems respond to extreme environmental shifts and whether the modern biodiversity of the Red Sea developed only after the last deglaciation or persisted through past glacial period.

APPROACH

The study employed a multidisciplinary approach to investigate the survival of deep-water corals in the Red Sea during the last glacial lowstand. Fossil coral skeletons of *Rhizosmilia valida* and *Leptoseris cf. striatus* were collected from 26 sites in the northern Red Sea using submersibles from the R/V OceanXplorer (Fig. 1). To establish the chronology of coral growth, Uranium-Thorium (U-Th) dating was performed, providing precise ages. Geochemical analyses were conducted to assess environmental conditions, including clumped isotope (Δ_{47}) thermometry for past seawater temperatures, radiogenic strontium isotopes ($^{87}Sr/^{86}Sr$) for water-mass exchange between the Red Sea and the Indian Ocean, and stable oxygen isotopes ($\delta^{18}O$) to infer changes in salinity and evaporation rates (Fig. 2).

Additionally, a meta-analysis of 27 deep-sea sediment cores from previous studies was conducted to evaluate the presence or absence of microfossil groups, such as planktonic foraminifera, pteropods, and coccolithophores, through the last glacial period. This combined dataset tests the hypothesis of basin-wide extinction during the lowstand and explore the ecological dynamics of the Red Sea under extreme glacioeustatic sea-level changes.

SIGNIFICANCE

The prevailing hypothesis suggests that life was extinguished in the Red Sea when sea level fell at least 110-m below present at the end of the Last Glacial period. This sterilization is thought to have occurred because that drop restricted the basin from the Indian Ocean, inducing a hyper-salinity crisis. Dating and geochemical analyses of deep-water coral fossils which we collected during submersible dives, show that this delicate ecosystem thrived, even during the last sea-level minimum, with seawater temperature and chemistry comparable to modern values. Our findings challenge the paradigm of a complete ecological collapse in the Red Sea during the last sea-level lowstand. Our results imply that the basin’s fauna endured for a longer timescale than earlier estimates.

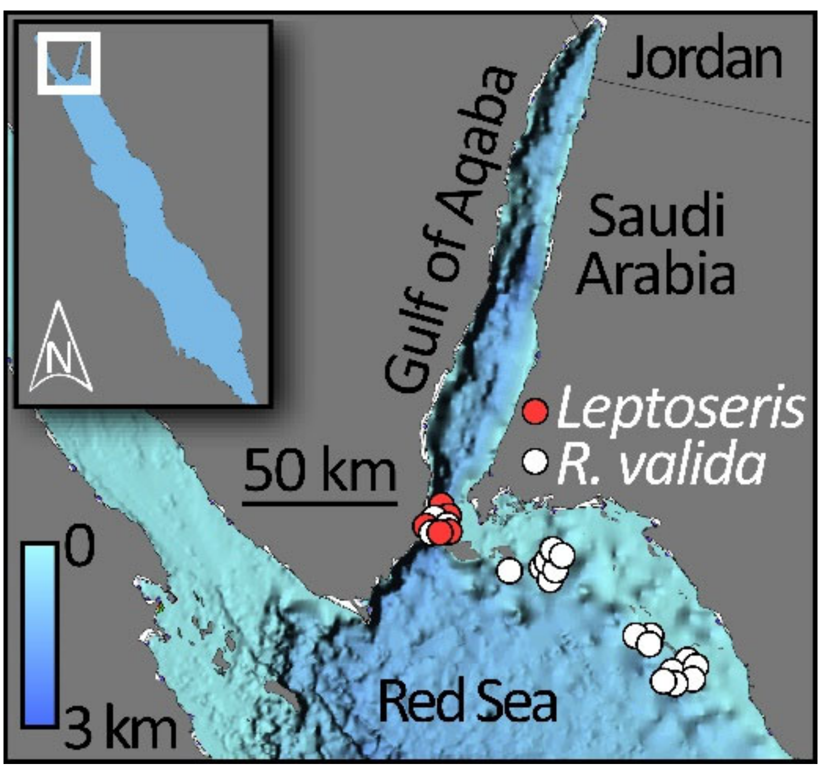

Figure 1. Locations of sampled corals and seawater in the northern Red Sea. Two coral species were sampled: Rhizosmilia valida from 20 sites at depths of 400-720 m, and Leptoseris cf. striatus from six sites at depths of 80-90 m.

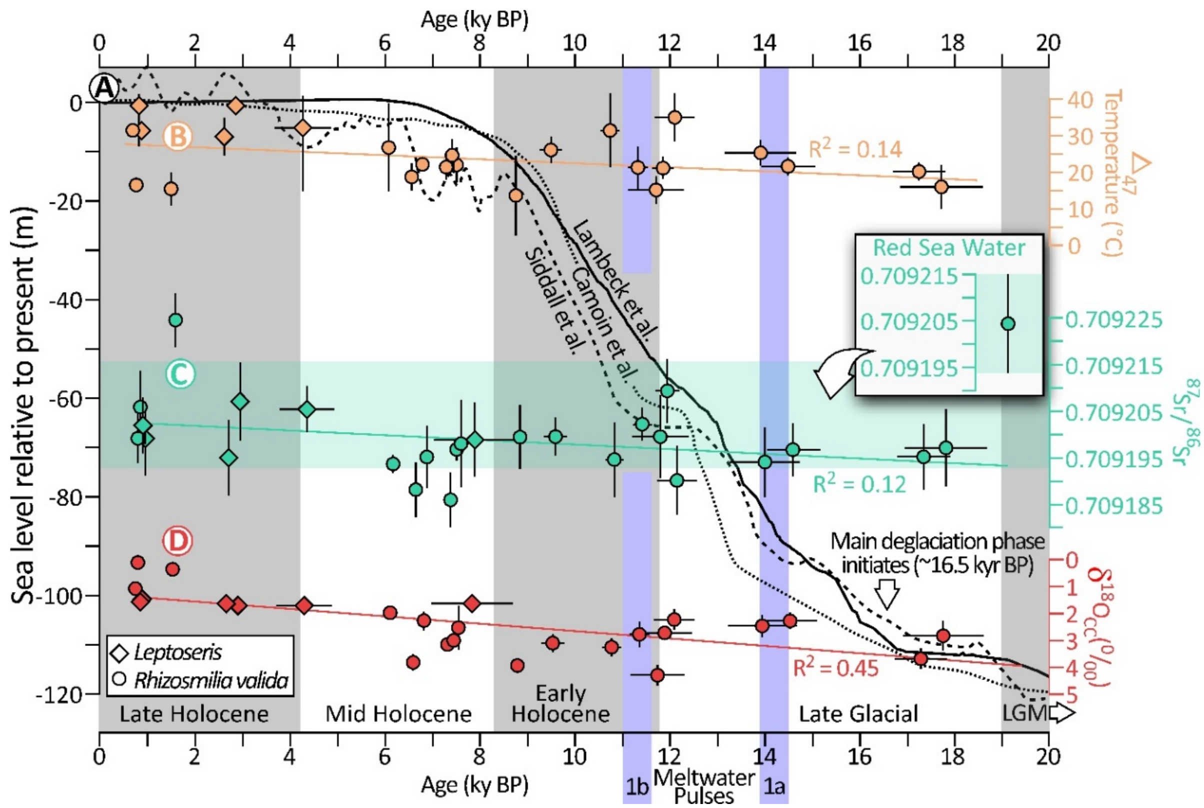

Figure 1: Geochemistry of coral samples through time. (A) Sea-level changes since 20 kyr BP, as reported by Lambeck et al. (2014), Camoin et al. (2004), and Siddall et al. (2003) plotted with 2.5-kyr running means. Lambeck et al. (2014) indicates that the major phase of deglaciation began at approximately 16.5 kyr BP. Timing of meltwater pulses 1a (~14.5 kyr BP) and 1b (~11.2 kyr BP) after Fairbanks et al. (1992). (B) Clumped isotope (Δ_{47}) thermometry of the coral carbonate. (C) $^{87}Sr/^{86}Sr$ ratios. (D) $\delta^{18}O_{CC}$ values. Horizontal error bars represent 95% confidence intervals (CIs) around mean Uranium-Thorium ages; vertical error bars, 95% CIs from triplicate geochemical measurements.

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