ABSTRACT

Successive reports of the Intergovernmental Panel on Climate Change (IPCC) projected increased risks of extreme climatic events by 2050 that will create sustenance crises by means of recurrent storms, coastal flooding, and agricultural- and/or ecological-droughts. This will cause a decrease in the availability of food and freshwater, degradation of settlements and human health, forcing large-scale human migration ('Climigration'). This led researchers including sociologists to predict the collapses of modern civilizations at least in parts and consequent global political disturbances. Clearly an understanding of the nature of the influence of climate on culture/human settlements in the past might be a useful approach to predict and mitigate such future climate-induced risks in modern human society. The archaeological records provide means to investigate the intricate interplay between environmental and human systems under various climatic regimes and at diverse geographical and temporal scales. For example, the near-contemporaneous disruptions of urbanism in the Old-world civilization (e.g. Egyptian, Mesopotamian, Indus Valley and Yangtze Valley) serve as potential case studies to understand the societal response to climate change. The current study focuses on Dholavira, a UNESCO World Heritage site and the largest excavated Indus Valley (Harappan) settlement in India. Presently located within the barren and desertic salt flat of Great Rann of Kutch (Gujarat, India), the settlement at Dholavira provides a unique opportunity to study why and how it originated in inhospitable terrain and eventually collapsed. Archaeologically Dholavira preserves seven stages each with unique cultural attributes. Radiocarbon dating of archaeological carbonates (e.g. bangles, molluscs and fish otoliths) from these stages suggests the beginning of occupation at ~5500 years B.P. (before present) that continued till ~3400 years B.P., with intermittent desertion in-between. High-resolution oxygen isotopic ($\delta^{18}O$) sclerochronology of molluscan shells and fish otoliths (ear bones) indicate a rapid settlement expansion under favorable monsoonal climate conditions during the Early and mid-Mature Harappan periods (~5500-4600 years B.P.), when significant glacier meltwater ($\delta^{18}O < -11$ ‰) from the upper Himalayas was also drained into the paleo-estuaries near Dholavira via rivers like Nara or other Indus distributaries (mythological ancient river Saraswati?), especially during the summer/monsoon months. Although the monsoonal regime continued, these river courses retreated post-4600 years B.P., and the expansion of the settlement slowed down before it nearly ceased. The humid fluvial landscape possibly changed due to a catastrophic drought driving temporary desertion of the settlement of Dholavira exactly at the onset of the Meghalayan Stage (~4300–4100 years BP, aka 4.2 ka event). A compilation of subcontinental-scale climate proxies and global climate drivers suggest that the 4.2 ka event was indeed a distinct abrupt event and could be due to either an altered Walker circulation during an El Nino-like condition, an overall cool North Atlantic climate, or a combination of both with Saharan desertification. The proxy climate data was also in accordance with the coupled General Circulation Climate (Earth system) model-generated precipitation over this region. Archaeological data suggest that the settlement had a modest rebound when the monsoon revived briefly during the late (post-urban) Harappan (4000-3600 years B.P.) period, after which the climate shifted to a modern-like arid/hyper-arid condition around 3400 years B.P. and the vestiges of Indus Valley Civilization finally disappeared forever. However, the climate recovery from the Meghalayan drought and evidence of sustained human population in this region, albeit sporadic and rural in nature, may indicate a cultural continuity to the Early Iron Age rather than the complete demographic collapse. Indeed, Dholavira presents a classic case for understanding how climate change can increase future drought risk and human migration as predicted by the IPCC working group.

Keywords: Dholavira; Harappan settlement; radiocarbon dating; High-resolution seasonality; paleoclimate; *Terebralia palustris*; *Arius spp.* otoliths; Meghalayan Stage; Rann of Kutch; river oxygen isotope