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Oxygen isotope composition of Sparidae (sea bream) tooth enamel from well-dated archaeological sites as an environmental proxy in the East Mediterranean: A case study from Tel Dor, Israel

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ABSTRACT

This paper examines the potential of oxygen stable isotope composition of Sparidae (sea-bream) tooth enamel phosphate ($\delta^{18}O_P$) as an indicator of the habitat in which the fish were captured. The isotopic compositions of Sparidae molariform teeth recovered from the coastal site of Tel Dor (northern coast of Israel), from a sequence dated to the 12th–7th centuries BCE and from modern samples were studied. The $\delta^{18}O_P$ values of the archaeological specimens exhibited a wide range of values, varying between 21.3 and 25.2 ± 0.2‰.

While $\delta^{18}O_P$ values from the teeth dated to the 12th–9th centuries BCE resembled typical East Mediterranean coastal water, some of the later teeth, dated to the 9th–7th centuries BCE, exhibited higher values. The later values indicate tooth enamel deposition in a hyper-saline environment similar to $\delta^{18}O_P$ values of Sparidae observed at Bardawil Lagoon (Southeastern Mediterranean coast, east of the Suez Canal, Egypt). Prior to this study all Sparidae fish recovered at Tel Dor were regarded as evidence of local fishing activity. The current results exhibit, for the first time, that some of the Sparids may have been exported from the Bardawil Lagoon. We discuss, however, an alternative scenario, namely, the possible existence of saline lagoons near Tel Dor in antiquity.

1. Introduction

Fish remains are considered good indicators of the habitat in which they were captured, since their distribution is restricted by water salinity level and temperature, and they respond directly to changes in these parameters (Casteel, 1976; Schmölcke and Ritchie, 2010). Being ectothermal (body temperature = ambient water temperature), fish teeth and bone oxygen isotope composition ($\delta^{18}O_P$) record the ambient water $\delta^{18}O$ and the temperature of the water at the time of formation (*e.g.*, Longinelli and Nuti, 1973; Kolodny et al., 1983; Pucéat et al., 2010; Lécuyer et al., 2013). Indeed, $\delta^{18}O$ records of fish tooth enamel were used by several scholars to extract the upper ocean temperatures (Kolodny and Raab, 1988; Lécuyer et al., 2003; Pucéat et al., 2003), water mass exchange (Dera et al., 2009), and marine to brackish paleo-environmental conditions (Pelc et al., 2011; Barham et al., 2012; Fischer et al., 2012) throughout the Cretaceous period, as well as the ice volume effect over the Permian sea water (Chen et al., 2013). Recently, $\delta^{18}O_P$ of freshwater fish remains obtained from archaeological horizons were tested as an indicator of the geographical origin of the fish (Dufour et al., 2007; Otero et al., 2011). Surprisingly, although Mediterranean marine fish remains are highly abundant in well-dated archaeological sites along the East Mediterranean coast (Van Neer et al., 2005; Bar-Yosef Mayer and Zohar, 2010), they have not yet been used as proxies for the environmental conditions of the coastal habitats exploited by ancient civilizations.

The current study examines, for the first time, the potential of oxygen isotope values of Sparidae (gilt-head sea bream) tooth

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enamel recovered from archaeological horizons, as a proxy to determine their origin of habitats along the Eastern Mediterranean coast. Sparidae, especially *Sparus aurata* 1st molariform tooth are excellent as an archaeological proxy because they are easy to identify to species level, frequent in coastal and inland sites, and have been widely traded in the past (Van Neer et al., 2005; Bar-Yosef Mayer and Zohar, 2010). Crucially, *S. aurata* ecology, migration patterns and breeding behaviors are well understood as they are of commercial importance in present day aquaculture (Arabaci et al., 2010; Pita et al., 2002; Tancioni et al., 2003).

In this study we analyzed $\delta^{18}O_P$ values of archaeological Sparidae recovered at Tel Dor, from different chrono-stratigraphical horizons. These were compared to $\delta^{18}O_P$ values of modern Sparid teeth both from the East Mediterranean littoral and from a hypersaline lagoon (previously published; data of Kolodny et al., 1983); and also to a theoretical range of $\delta^{18}O_{PO4}$ calculated for the East Mediterranean littoral. Based on this comparison we discuss the relevance of our data in terms of the identification of the geographic/environmental origin of the Tel Dor Sparidae.

2. Background

2.1. Tel Dor

The archaeological site of Tel Dor is a large mound located on Israel's Carmel coast, about 30 km south of Haifa (Fig. 1). The site is flanked by a large open lagoon to the south and a bay to the north, which provided excellent locations for maritime activities. Dor is identified with D-jr of Egyptian sources, Biblical Dor, and with Dor/Dora of Greek and Roman sources. The documented history of the site begins in the Middle Bronze Age, ca. 2000 BCE, and ends in the Crusader period. From the Bronze Age to Roman times the site primarily functioned as a commercial *entrepôt* for commodities marketed up and down the East Mediterranean coast and a gateway between East and West (Gilboa and Sharon, 2008). From the perspective of this paper, Dor's importance lies in the evidence uncovered at the site for inter-regional exchanges during the early Iron Age (ca., mid-12th–mid-9th centuries BCE) - currently significantly more so than in any site along the East Mediterranean seaboard (Gilboa et al., 2015). Dor was a Phoenician town then, *inter alia* engaged extensively in trade with Egypt, again more so than in any site outside Egypt in this period, evidenced mainly by Egyptian containers at Dor (see below). Therefore, Dor holds a key for understanding emerging Phoenician commercial networks in the Eastern Mediterranean after the collapse of the Bronze Age world in the late 13th/early 12th centuries BCE. Ceramics, indeed, are the best surviving archaeological index for exchanges with Egypt (and other regions), but they (and their contents) comprised a fraction of the merchandize exchanged. This paper, therefore, is also part of a concerted attempt to identify the other commodities shipped from Egypt and its environs Dor (and vice versa), in order to shed light on the nature of these early Iron Age exchanges.

Studies on fish remains recovered from different excavation areas at Tel Dor exhibited that throughout the town's existence, fish played an important role in its economy (Raban-Gerstel et al., 2008; Bartosiewicz et al., in press). The identified fishes indicate intensive fishing along the littoral zone. In addition to the diverse composition of "local" fish, a group of "exotic"/non-local fish was identified. This category comprises Nile perch, *Latesniloticus*, and catfish of the genus *Bagrus* (Raban-Gerstel et al., 2008; Zidane, A., unpublished data). Their appearance at the site indicates that fish were part of the goods traded from Egypt. The fish were either consumed by Tel Dor inhabitants and/or possibly further distributed to other coastal or inland populations (Arndt et al., 2003; Van Neer et al., 2005). While exotic fish are relatively easily-identifiable when distributed through terrestrial trade routes, in coastal sites, the origin of species with a wide distribution along the eastern and western Mediterranean basin is impossible to pinpoint based on classical taxonomic identification.

2.2. Iron Age stratigraphy, dates and contexts

For the Iron Age (Ir), the period investigated here, excavations at Dor produced a very detailed chrono-stratigraphical sequence

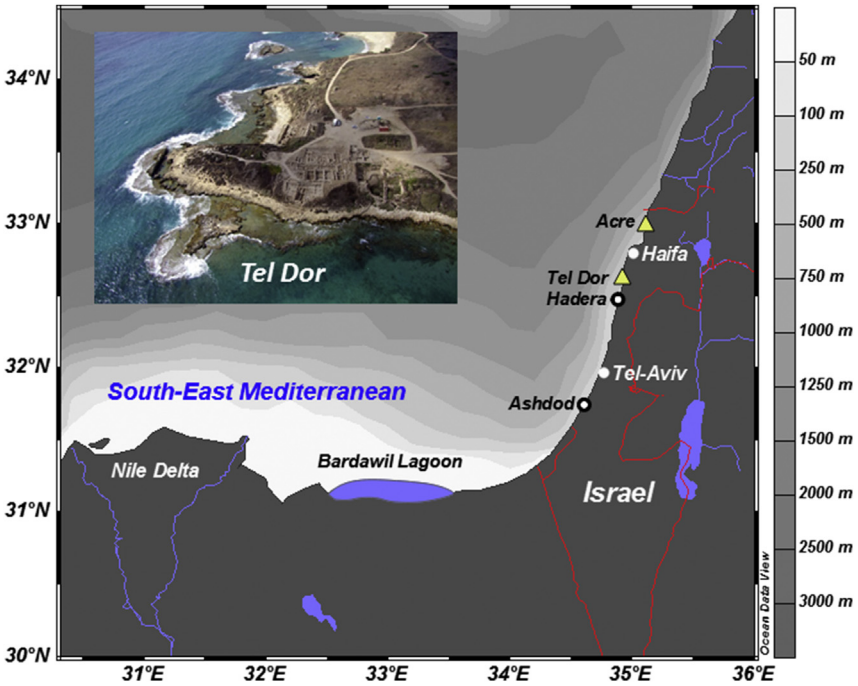

Fig. 1. Location of the archaeological site of Tel Dor and aerial photograph, including other sites mentioned in the text.