

Oxygen and strontium isotopes as provenance indicators of fish at archaeological sites: the case study of Sagalassos, SW Turkey

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Abstract

In this paper, we investigate the potential use of oxygen and strontium isotope ratios ($\delta^{18}\text{O}_p$ and $^{87}\text{Sr}/^{86}\text{Sr}$) measured in archaeological fish enamel as provenance indicators. $\delta^{18}\text{O}_p$ and $^{87}\text{Sr}/^{86}\text{Sr}$ were measured in a suite of archaeological carp remains recovered from the Anatolian townsite of Sagalassos dated to the Early Byzantine period (AD 450–650) and compared to that of modern fish, river and lake waters from the Anatolian region. We used sequential leaches in weak acetic acid to remove diagenetic Sr from fossil tooth enamel, monitoring the effectiveness of this approach by measuring the Sr/Ca ratios of the leachates via an isotope dilution thermal ionization mass spectrometry method (ID-TIMS). $\delta^{18}\text{O}_p$ values mostly excluded a riverine origin. $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of one fish overlapped with the $^{87}\text{Sr}/^{86}\text{Sr}$ signatures of two lakes in the Anatolian region, and at least one lake (Gölcük) could be removed as a candidate owing to a very distinctive $^{87}\text{Sr}/^{86}\text{Sr}$ signature not found in any of the fish remains. Most of the tooth samples analyzed could not be assigned a precise geographical origin since the $^{87}\text{Sr}/^{86}\text{Sr}$ ratios measured in enamel did not match that of any of the local lakes selected as potential origin. This result suggests that carp may have originated from lakes that have not yet been sampled, although this conclusion is not supported by other archaeological evidence. Alternatively, the lack of correspondence between lakes and fish Sr isotope ratios highlights several possible sources of uncertainties including spatial heterogeneity in $^{87}\text{Sr}/^{86}\text{Sr}$ ratio within a lake, the contribution of dietary strontium to the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of fish tooth enamel, and post-mortem alteration of the tooth Sr isotope signal during fossilization. In spite of the high precision of the strontium isotope analyses and the wide range of variation in the surface waters of the Anatolian lakes and rivers, this method may remain limited to distinguishing between lakes situated in regions of bedrock of very distinct age and geology until these sources of uncertainty are more fully investigated.

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1. Introduction

Documenting the origin of imported food items such as fish is essential to identify former trade connections (Van Neer et al., 2004). The classical town of Sagalassos is located in western Anatolia (Turkey) approximately 110 km north of the coastal town of Antalya (Fig. 1). Archaeological excavations of Roman and Early Byzantine contexts, dating between the 1st and 7th century AD, yielded abundant fish remains

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Fig. 1. Map of Anatolia showing the locations of the sampling sites.

belonging to at least 17 species (Van Neer et al., 1997, 2004). None of the fish species found at Sagalassos are native to the local river Ağlasun (Van Neer et al., 2000a) and therefore must have been imported. Fish can be grouped into three broad categories based on their origin: Anatolian freshwater, exotic freshwater, and Mediterranean (Van Neer et al., 1997, 2000b, 2004). In some cases the geographic distribution of species permits determination of provenance, sometimes with high precision, as in the case of the cicek (*Pseudophoxinus handlirschi*) a small cyprinid that is endemic to Eğirdir Lake (Geldiay and Balık, 1996), located ~35 km from Sagalassos. Conversely, the wild carp (*Cyprinus carpio*), an Anatolian species that dominates the fish remains recovered at Sagalassos (Van Neer et al., 1997) has a very wide distribution. Literature data (e.g., Geldiay and Balık, 1996) and results from surveys carried out between 1996 and 1999 in Anatolian waters (Van Neer et al., 2000a; in press) permit reconstruction of the ancient carp distribution. Today, domesticated carps have been introduced into numerous reservoirs impounded by modern dams where the species was not previously present. In other locations the pre-existing wild form was gradually replaced by continuous stocking. Taking the natural distribution of species into account, the wild carp found at Sagalassos may

have been imported from several large lakes (Eğirdir Lake, Beyşehir Lake, Akşehir or Eber Lake) or rivers (Büyük Menderes, Gediz, Sakarya, Küçük Menderes, Porsuk) situated to the north, west, or east of Sagalassos. Because of the widespread occurrence of carp in Anatolian lakes and rivers it is possible that the fishes consumed by the people of Sagalassos came from many different local sources. Alternatively, it is possible that most of the fish were captured from a single lake, or from a specific location within a lake. This information could lead to inferences regarding the scale of fishing activity and, therefore, the importance of a fisheries industry to the local Anatolian economy.

One approach to connecting fish remains with their origin is through the analysis of mitochondrial DNA, by comparing fossils and modern populations of fish from various areas. This technique was successfully applied to *Clarias gariepinus*, an exotic freshwater species found at Sagalassos (Arndt et al., 2003). Comparison of ancient and modern haplotypes indicates a lower Nile origin of *C. gariepinus* consumed at Sagalassos. Because modern carp stocking in Turkey has diluted natural genetic structuring, DNA analysis cannot be used to determine origin. Instead, this study aims to establish the geographic origin of carp consumed in Sagalassos using

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