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Re-investigating fish consumption in Greek antiquity: results from $\delta^{13}C$ and $\delta^{15}N$ analysis from fish bone collagen

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ABSTRACT

One of the frequently encountered issues in ancient Greek dietary reconstructions through isotope analyses has been the apparent unimportance of fish protein in human diets. The significance of this observation is amplified by the abundant ichthyofaunal remains, iconographic evidence and literary information on fish and fishing, pertaining to almost all sites and time periods of Greek antiquity. In this project, we measured for the first time isotopes from a large number of fish bones from Greek sites dating from the Mesolithic to the Classical times, aiming to investigate whether this absence is an artefact of the methodology or whether it reflects a reality of restricted fish consumption. Results show that regional trends are stronger that temporal ones in fish isotope values. The range of values overlaps with terrestrial resources, making it difficult or impossible to reject fish consumption based on isotope data alone. This variability proposes a reconsideration of the amount of fish in ancient Greek diets specifically for each site and amplifies the importance of interdisciplinary studies, especially for regions with variable ecological resources.

1. Introduction

1.1. Isotopic evidence of fish consumption in ancient Greek diets

The geographic area of Greece has become quite thoroughly studied isotopically over the last years (Papathanasiou, 2003; Bourbou and Richards, 2007; Richards and Vika, 2008; Triantaphyllou et al., 2008; Vika et al., 2009; Petroutsa and Manolis, 2010; Vika, 2011). An emphasis is placed on prehistoric sites, where other lines of evidence are missing. The results of these studies present a rather uniform pattern of diet, with protein from plants of the C3 photosynthetic pathway being dominant. Protein from animals living on land also contributed to the diet, although methodologically it is not possible to identify how much of this came from the meat and how much from the milk of these animals. This information corresponds to archaeozoological and botanical finds, when these are available.

For the Neolithic (Papathanasiou, 2003), low nitrogen values seen in all sites studied suggest a diet with small contributions of animal protein (Franchthi 9.23 ± 1.83, Kephala 9.17 ± 0.98, Tharrounia 8.04 ± 0.67, Theopetra 7.40 ± 1.05, and Kouveleiki 8.09 ± 0.33). An interesting observation for this period is the slight enrichment of human carbon values in the sites of Franchthi (−18.66 ± 0.78) and Kephala (−19.09 ± 1.24), which was attributed by the authors to the inclusion of a C4 type plant in the diets (Papathanasiou, 2003: 321). The Bronze Age is studied more broadly geographically. Sites from the Peloponnese (Richards and Vika, 2008; Ingvarsson-Sundström et al., 2009; Petroutsa and Manolis, 2010; Vika, 2011) indicate that animal products are starting to assume a larger part in human diets compared to previous periods. Intra-population variability is attested, as different social structures are observed throughout Greece. To date, there is only one published study on Classical Greece (Vika et al., 2009), which suggests that the sudden increase of nitrogen values in this time period (c.5‰) should also be addressed with freshwater fish consumption in mind. The Hellenistic period is scarcely studied (Vika, 2011), but a pattern of low nitrogen and carbon values seems to continue.

With one exception, none of the aforementioned studies consider either marine or freshwater fish as a dietary option for the populations studied. However, none of the above studies have actually measured fish isotope values from the concerned sites, due to lack of suitable fish bone material. Most studies relied on comparisons with North European material previously analysed, and researchers remained confident in their assumption that fish consumption was such an infrequent event, that it was unable to leave an isotopic signal in the diets.

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1.2. Non isotopic evidence of fish consumption in ancient Greek diets

In contrast to the apparent absence of fish consumption through isotopic analyses, there is abundant archaeological evidence, which points to the omnipresence of the sea in the life of circum-Aegean populations. This observation further highlights the hiatus observed between everyday dealings with fish and the sea and the apparent lack of fish consumption seen in isotopic reconstructions.

The archaeological record (material culture, iconography, faunal remains) offers a plethora of information pertaining to the close relation of Aegean populations with the sea. Fishhooks and net weights are not uncommon finds in excavations (for example, Powell, 1996; Stratouli, 1996). When methodology allows, fish bones and fishing gear are recovered *in situ*. Pottery and frescoes depict the marine world and seafaring adventures (for example, Gill, 1985; Powell, 1992, 1996; Bradfer, 2000). But the most descriptive allusions are provided by the ancient written sources. The ancient physicians, like Hippocrates and Galen, have made significant observations on the benefits of a fish diet (Hipp. *Diet,* 35.9, 75.2, 79.2, 80.1, 81.2, 82.2). Ancient cooks, like Archestratos, devote much of their work to fish recipes (*Hedypatheia*). Comedians, like Aristophanes, use similes inspired from the sea world to enhance their satire (*Acharnians*, l.940-50; *Peace,* l.1000).

It so appears that fish and seafood were well known food sources, and this not only to populations that lived by the sea. Fish preparations and by-products (roe, poutargue, garum, salsamenta) were also consumed, alternatively to fresh fish. Although these preparations are not easily identified on faunal remains (Theodoropoulou, 2007b), textual and iconographic evidence suggest that their presence dates back to the later prehistory and becomes increasingly widespread through antiquity (Curtis, 1991; Rose, 1994; Dalby, 1996).

Therefore, for the researcher of ancient Greek diets remained the question as to the reason behind the lack of fish protein signatures in isotopic reconstructions of diet, when all other evidence pointed to the contrary.

1.3. Aims and objectives

The main aim of this project was to introduce into dietary studies direct evidence of fish consumption, gained through stable isotope analysis of fish bone collagen. The objective was to collect fish bone samples from sites in Greece and to measure the carbon and nitrogen stable isotope values. This would provide for the first time data comparable to human and faunal values and help understand the importance of fish protein in diets. The task was challenging. Ichthyofaunal material is not ubiquitously collected, as it requires specific knowledge and research goals that regrettably elude several excavations. The cumbersome task of its collection and laboratory identification implies that most fish assemblages usually require a significant time of study, a fact prohibitive to any further analyses.

2. Carbon and nitrogen isotopes in marine and freshwater ecosystems

The bibliography offers a review of the complexity of isotopes in water ecosystems (see for example Keeley and Sandquist, 1992; Chisholm et al., 1982, 1983; Schoeninger and DeNiro, 1984). It is briefly outlined that seawater bicarbonate has $\delta^{13}C$ values approximately 7‰ more enriched than atmospheric CO_2. Since HCO_3 is more abundant in seawater than dissolved CO_2, marine algae utilise it in preference to CO_2, a fact that explains why marine plants are enriched in ^{13}C relative to land plants. This difference is maintained through trophic levels; therefore marine and terrestrial ecosystems have distinct values (Dufour et al., 1999).

Freshwater sources exhibit an inherent complexity and variability in compositions (Raymond and Bauer, 2001; Ambrose et al., 1997; Katzenberg and Weber, 1999). Dissolved inorganic carbon in freshwater exhibits a variable isotopic composition, as it represents mixing with different sources of CO_2: atmosphere or CO_2 from bacterial oxidation of organic matter in the water or in soils. The relative contribution of each source depends on lake size (Keeley and Sandquist, 1992). Primary producers in the deeper levels of a lake are typically depleted by 2‰–10‰ in ^{13}C relatively to primary producers in the littoral zone (Schweizer et al., 2006). Furthermore, it has been observed that isotope values change significantly with season in eutrophic lakes-like lake Orestis involved in the present study (Yoshioka et al., 1994; Vreča and Muri, 2006; Lehmann et al., 2004). Fish isotopes should reflect the average values between seasons (Zeng et al., 2008). Additionally, palaeodietary reconstructions involving freshwater resources can be even more complex if one considers consumption of migrant fish, such as the eel, grey mullet or flounder, which could present isotopic values intermediate between purely freshwater and marine resources. Fish isotope analysis is further complicated by the fact that isotope analysis and collagen quality criteria studies to date are mainly concerned with human and mammalian collagen. Only recently the study by Nehlich and Richards (Nehlich and Richards, 2009) dealt specifically with fish collagen quality for sulphur analysis, and even more so the study by Szpak (2011), which examined in detail fish collagen structure and paleodietary reconstructions.

3. Paleogeographical and zooarchaeological background

The Aegean Sea is one of the more complex Mediterranean regions due to a great climatic and hydrological variability within the basin (Fig. 1). The mountainous geological character of Greece is reflected on the coastal and sub-water relief of the Aegean Sea, mainly consisting of rocky shores (70% vs. 30% sandy bottoms) and a relatively extended but shallow continental shelf (Barić and Gašparović, 1992; Bintliff, 1977). Specific hydrological and geological conditions are found in the Northern Aegean (situated above the 38th parallel, between the north Euboean sea and Psara island: Papaconstantinou, 1988), mainly due to the freshwater discharge from several large rivers, and the outflow of the Black Sea. Salinity levels in the Northern Aegean are lower compared to the southern part, especially during spring outflow (35‰ in summer, 36‰–38‰ in winter, Maheras, 1983; Papageorgiou, 1997; Emeis et al., 2000). The Aegean Sea may therefore be described as a transitional zone between the brackish Black Sea (16‰–18‰ salinity for surface waters) and the hypersaline Western Mediterranean (37‰–39‰), while median values for the N. Atlantic Ocean are reported around 35.5‰ (Stanley and Blanpied, 1980; Papaconstantinou, 1988).

Due to these specific hydrological conditions, the Aegean is an oligotrophic sea, twelve times less rich in nutrients than the Atlantic Ocean, with relatively low production levels of phytoplankton, zooplankton, and benthic invertebrates (Coull, 1972; Nicolson, 1979; Wheeler and Jones, 1989; Caddy, 1993). Higher nutrient values may be found in deltaic areas, such as those in the North Aegean, especially in warmer temperatures (Legakis and Sfendourakis, 1999). Regional and seasonal water variability thus needs to be taken into account.

The described conditions offer the habitat for various marine and freshwater organisms (Table 1), many of which are reported in zooarchaeological assemblages (Rose, 1994; Powell, 1996; Theodoropoulou, 2007a; Mylona, 2008):