The Bountiful Sea: Fish Processing and Consumption in Mediterranean Antiquity

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This special issue has its origins in an international conference entitled *The Bountiful Sea: Fish Processing and Consumption in Mediterranean Antiquity*, made possible by the generous support of Christian Levett, and The Craven Committee, Red Boat, Green Pastures, The Oxford Roman Economy Project, and the British School at Rome. The conference, held at the University of Oxford on 6–8 September 2017,¹ grew from an ambitious idea proposed by Andrew ‘Bone’ Jones, over dinner at the 2015 ICAZ Fish Remains Working Group meeting in Lisbon: to bring together archaeologists, archaeological scientists, ecologists, classicists, and culinary experts—groups who work in very different spheres, but who possess a shared interest in fishing and fish—to illuminate the evolution and significance of the exploitation of marine resources in the ancient Mediterranean and to identify areas where the past could inform the present. This event was to be a feast for body as well as mind, and an innovative culinary program led by Sally Grainger offered a tasting dinner of recreated recipes, with further opportunities to sample an array of contemporary processed fish products and artisanal fish sauces (see Mylona and Grainger 2018). These opportunities to engage with fish and fish sauces on an experiential level offered far more than simply a conversation starter; they also raised questions about ancient versus modern taste preferences, the nutritional value of fish products, and traditional methods of production—questions which in many instances the modern producers present, Red Boat and Green Pastures, were able to address. Red Boat produces a fish sauce using only fish and salt following ancestral recipes; their insights into food safety, fish to salt ratios, pressing methods, and marine species present in catches for sauce production have direct relevance for study of ancient sauce production and residue analyses. Green Pasture’s innovative use of fermented fish oils as dietary supplements, offers an instructive case of resilience of

¹ For details on the conference academic program and activities see <http://oxrep.classics.ox.ac.uk/pages/thebountifulsea/>.

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traditional technology and adaptation to the changing needs of the consumers, a phenomenon very much relevant to the study of the ancient world.

This special issue aims to be as bountiful as the conference in the evidence and approaches it encompasses, to offer a cornucopia of research on fish and fish processing in Mediterranean antiquity that extends geographically from east to west and thematically from sea to table. The contributions in this volume were originally presented as papers at this conference, although, unfortunately, inclusion of all the papers and posters was beyond the scope of a single issue and some presenters chose not to submit. As at the conference, the contributions published herein focus on classical antiquity in the Mediterranean as a defined region but occasionally venture outside it chronologically and geographically. The papers provide an update on the state of research into fish processing in Mediterranean antiquity from different vantage points: archaeological, historical, archaeometric, and gastronomic. Together, they unite different approaches, consider the value of sensory experience, and promote dialogue between scholars of the ancient and modern worlds. The scope of the papers invites discussion between specialists working in the eastern and western Mediterranean and fosters a new dialogue with researchers interested in contemporary Mediterranean fish policy and issues of sustainability (see Koutrakis 2018). Finally, this issue captures a small part of one of the conference's most innovative aspects: the opportunity for a sensorial approach to processed fish, offered by a series of culinary events, including the conference dinner of re-created dishes from antiquity, the “bring and share” processed fish buffet, and the live demonstrations by modern producers of contemporary processed fish products (see Mylona and Grainger 2018).

Overview

Fish processing—and that of other elements of the marine world—is one of the most intensively researched aspects of the marine economy of the ancient Mediterranean, due both to the abundance of identifiable remains of the industry, and to its far reaching implications for local and regional economies. Research on the nature and exploitation of marine resources in Mediterranean antiquity has blossomed over the last 30 years, reflecting not only the re-orientation of archaeological and historical research towards fields pertaining to the ancient economy and environment, but also the increasing tendency towards interdisciplinarity. The literature on the topic is vast. Ichthyo-archaeological studies from all over the Mediterranean have increased significantly in recent years, including research into classical and related periods (e.g. Morales-Muñiz and Roselló-Izquierdo 2012; Çakırlar et al. 2016). Research on fishing technology, an important but consistently understudied area, is currently gaining momentum (Powell 1996; Ayodeji 2004; Bekker-Nielsen and Bernal-Casasola 2010; Galili et al. 2013). Regional comprehensive studies, with varying chronological focus, have demonstrated the potential of the extant archaeological and historical records and have indicated future research directions (Bekker-Nielsen 2005; Mylona 2008; Costa and Fernández 2012; Marzano 2013; Moya-Cobos 2016). Attention on processing installations continues, from individual reports on excavated *cetariae* (fish processing plants) (Bernal-Casasola et al. 2016), to compilations of data (Trakadas 2015), and the creation of

databases (RAMPPA²). As knowledge of ancient fishing has expanded, so has the dialogue between archaeologists and natural scientists, as better understanding of ecological history can lead to better informed decisions on contemporary management of resources (Boero 2016; Mazzoldi et al. 2018).

The last decade has also seen greater consensus that fishing and fish processing was an economically important and profitable enterprise in Classical antiquity, especially in the Roman western Mediterranean—a topic which has generated great interest amongst Classical scholars (Kron 2008; Marzano 2007, 2015; Marzano and Brizzi 2009). The material wealth the industry could bring to an individual is beautifully illustrated in the mosaic floor that proudly adorns the house of Pompeian fish-sauce producer and merchant Aulus Umbricius Scaurus: at each corner of the shallow *impluvium* in the centre of the floor, a vessel for fish sauce is depicted, complete with descriptive label (Curtis 1984). However, leaving aside some early works (e.g. Rostovtseff 1926, 1941), the attention given to fish production as an economically significant activity has only gained traction in recent decades. Previous studies (e.g. Gallant 1985) were much influenced by the work of authors like Moses Finley (1973), who held the view that the ancient economy was under developed, with fish playing a minor role in trade and manufacture.³ Fishing was perceived only in the sphere of subsistence. The current re-framing of our understanding of the significance of ancient marine exploitation goes hand-in-hand with current appreciation of the impact of contemporary low-level ‘artisanal’ fishing: there is now increasing realization of major consequences of recreational and semi-subsistence fisheries on fish stocks (Pinnegar and Engelhard 2008; Hyder et al. 2017).

This growing appreciation of the social and economic significance of ancient fish exploitation in Mediterranean antiquity has led to a proliferation of scholarly activity on the topic in the last decade, well represented by international meetings dedicated to fish and fish processing in a Mediterranean context: *Sal, Pesca y Salazones Fenicios en Occidente*, Ibiza 2011 (Costa and Fernández 2012); *Fish and Ships*, Rome 2012 (Botte and Leitch 2014); the *International Workshop on the Ancient and Mediaeval Marine Eco-history and Environmental History of Greece and the Eastern Mediterranean*, Haifa 2014 (contributing to Bekker-Nielsen and Gertwagen 2016); and mostly recently a panel on ‘Salt, fish processing and amphorae production across the Mediterranean in the 1st millennium BC’ at AIAC 2018 organized by García-Vargas, García-Fernandez and Sáez-Romero. Other recent meetings have addressed marine taxa in a cultural sphere, such as the 2014 *Harvesting the Sea: Aegean societies and marine animals in context* (Theodoropoulou and Gallant, forthcoming). The ICAZ Fish Remains Working Group and European research and network initiatives such as COST-Oceans Past Platform provide additional fora for relevant debate (e.g. Mazzoldi et al. 2018).

While the study of ancient fishing and fish processing now benefits from an abundance of literature on the topic, this wealth of research and publication brings with it particular challenges (Bernal-Casasola 2016). Ancient fishing can be approached from a range of specialist perspectives, from tax ledgers to preserved fish bones. Such studies may be published in equally specialist venues, and in diverse languages. To address this variety

² RAMPPA Atlantic-Mediterranean Excellence Network on Ancient Fishing Heritage. <http://ramppa.ddns.net/cetariae>.

³ For a recent historiography of scholarship on ancient economy see Flohr and Wilson (2016). For a review of the scholarship on the economic significance of fishing in antiquity see Mylona (2008: 5–15), and Marzano (2013) for discussion of marine exploitation in the context of studies on the ancient economy.

of perspectives, recent anthologies typically focus on a particular area within the wider region (west, east, Aegean, Adriatic, etc.); few works aim for a unified pan-Mediterranean perspective. Furthermore, a dichotomy remains between scholarship on fish production, focusing on archaeological installations and trade, and that concerned with the social and cultural context of fish consumption. Recent contributions have begun to break down these divisions through more interdisciplinary and integrated approaches (e.g. Marzano 2013; for the North Sea region see Barrett and Orton 2016), but few volumes follow a sea-to-table approach, beginning with fish ecology and fishing technology and extending to the taste preferences of the men, women, and children eating fish at home (such as Mylona 2008). This separation hampers knowledge exchange between researchers. It also hinders engagement with practitioners and experts outside the small sphere of ancient fish-centred scholarship, from whom much knowledge and insights can be gained—food historians, policy makers, biologists, and even modern producers.

Perhaps because of the focused nature of the discipline and the degree of expertise needed to interpret many of the data (as well as the ever-decreasing amount of time researchers have at their disposal), it is difficult to take a step back and address the broad view that is generally agreed to be so important. A sound understanding of fish biology and past ecological conditions is widely recognised as central to the study of marine exploitation in antiquity, and some recent works have begun to aim for a broad and interdisciplinary view in relation to fish production and environmental change (e.g. Bekker-Nielsen and Gertwagen 2016; Mazzoldi et al. 2018); however, to what extent is cultural or experiential knowledge relevant? Should scholars of ancient fish sauces have tasted *garum* (or at least something close to it)? Should we know the texture of the flesh of different fish or their cooking or preservation properties? These are questions that merit further consideration.

The Bountiful Sea conference and the papers that are published in this volume reflect in many ways the state of the art in research on fish processing in the ancient Mediterranean. At the same time they point, explicitly or more subtly, to future areas of enquiry and research. The papers are broadly ordered by three themes: fish and fish products in their cultural context; archaeological evidence in the western and eastern Mediterranean; and the logistical and social organization of production of processed fish and associated materials (salt). The volume also includes an editorial on the role of food at the conference, and a postscript from the perspective of a modern biologist on the current state and future directions of Mediterranean fish exploitation, with thoughts on the relevance of archaeological and historical research on the issue.

Eating Fish: Fish Products in Their Cultural Context

Deliberation on the importance of consumers' demand for fish products and of culinary tastes and preferences, as well as on the multitude of ways in which fish products acquired certain meanings in different cultural contexts formed an important part of the conference, and this is reflected by several papers in this volume. Fish were not only a mode of generating profit—a vehicle for economic gain—but also medicine and food for gods and men. Consideration of fish consumption, particularly from historical evidence, allows us to access personal attitudes towards fish, which are so elusive in the archaeological record. Wilkins's paper, which is based on the author's keynote speech to the conference, takes a rather unusual stand and “considers the topic from an ancient perspective”. Based on literary evidence he explores how fish, fresh and processed, were embedded in the life of

Greeks and Romans through their role as food. Issues of cooking, taste, pleasure and health are explored, offering a variety of possible incentives for the production and trade in processed fish. This paper alerts readers to the significance of intangible cultural aspects that could have been forceful incentives for economic development. In the same field, Weingarten's paper discusses dietary rules and taboos around the cooking and consumption of processed fish in the ancient Levant, as revealed by Talmudic texts in conjunction with archaeology. In contrast to Graeco-Roman sources, evidence for marine exploitation and consumption in the Talmudic literature has not been extensively explored. This under-utilized source provides rich evidence for non-elite and quotidian concerns, as well as the long-distance trade of fish products from as far away as Spain. Marzano also considers some of the more intangible aspects of fish consumption, through her analysis of the different social values ascribed to fresh and processed fish in the Roman world—social values which in turn impacted a product's market value.

Grainger brings new insight to how Romans considered and referred to their fish sauces. She integrates her experience of experimental fish sauce production with a meticulous lexicographic exploration of iconic terms for fish sauces to trace the development of these products over time and in different cultural environments. She highlights the role of the consumer and culinary tastes in shaping the terminology of fish sauces. This analysis challenges researchers of ancient fish sauce to be specific in their terminology, by highlighting the significant differences in production behind *garum* and *liquamen*, and it emphasizes the need for contextual awareness when discussing fish processing.

Nicholson and colleagues offer an alternative, archaeological view of the same issues. The exceptional deposit of organic material from the Cardo V sewer in Herculaneum has been discussed elsewhere (Rowan 2014, 2017), but Nicholson, who identified the fish remains, and J. Robinson, who analyzed the molluscs, provide a more in-depth consideration of the faunal material. These remains represent repeated, everyday food consumption of the non-elite population of the town, and they illustrate a number of choices and preferences on the part of those people, as well as the actual fishing processes used in the area. Furthermore, this study provides some background to other discussions of fish processing within this volume, by highlighting the type of fresh fish consumption that was probably quite typical in coastal locations of the Mediterranean (Rose 1994; Mylona 2008). It also highlights the difficulties encountered in trying to distinguish processed from unprocessed fish in a mixed collection of small bones. Assemblages like that of the Cardo V sewer present inspiring opportunities for the application of ZooMS, a method of collagen protein fingerprinting (Buckley 2018) that can identify even tiny fragmented fish bones to species (Richter et al. 2011).

Analyses of stable carbon and nitrogen isotopes from bone collagen, which offer a means of comparing the contribution of marine foods to ancient diets, are logically at the center of current discussion of fish consumption. As a result, research projects on dietary habits, using these isotopes, are becoming increasingly common throughout the Mediterranean. Italy is one of the most investigated regions with data representing populations in Rome (Prowse et al. 2004, 2005; Rutgers et al. 2009; Killgrove and Tykot 2013), Gabbii (Killgrove and Tykot 2018), and Herculaneum (Martyn et al. 2018). A growing number of analyses relate to other areas: Spain (Rissech et al. 2016; Salazar-García et al. 2016), Greece (Petroutsas and Manolis 2010; Vika 2011; Nafplioti 2016; McConnan Borstad et al. 2018) and the Black Sea (Keenleyside et al. 2006). Especially interesting are intra-population differences, related to gender and occupation (Crowe et al. 2010; Martyn et al. 2018). These methods have huge potential to inform on ancient fish consumption, but we must remain aware of their complications and limitations. Overlap between isotopic values from

marine and terrestrial resources may obscure certain forms of fish consumption (Vika and Theodoropoulou 2012), and caution must be exercised when selecting modern reference materials (Roffet-Salque et al. 2017).

West and East

Archaeological and historical work concerning fish processing has been undertaken all around the Mediterranean; however, the material evidence is not equally distributed. The substantial archaeological evidence for impressive processing installations, well known along the Iberian (e.g. Baelo Claudia, Troia) and northern African coasts (Sabratha, Cotta) are not similarly documented across the Adriatic and eastern Mediterranean. Research in the western Mediterranean (including the northwest coast of Africa) already has several decades of scholarship behind it, permitting comprehensive syntheses and nuanced interpretations which are solidly based on archaeological evidence, as illustrated in this volume. Following recent excavations of new fish-salting factories at the well-known halieutic site of Baelo Claudia, Bernal-Casasola, Expósito and Díaz present the first synthesis of archaeological research relevant to the initial stages of the production cycle. Their contribution offers a comprehensive and current picture of the fish processing industry at the site, through discussion of marine resources, fishing equipment, processing facilities and food products. Similarly, Trakadas presents the many sources of data for marine resource exploitation along the coasts of north western Africa, from archaeological finds to ethnographic evidence, in order to present a nuanced look at fish processing in Lixus, a coastal site in Morocco. Her robust methodological approach highlights the importance of understanding the environmental context in which fishing occurred, as well as the need to consider multiple lines of evidence, including what is offered by suboptimal data, when reconstructing production activities. Garnier and colleagues engage chemistry to contribute to discussion of past fish processing. Their paper explains their methodology and highlights certain important findings. They were able to detect the presence of fish sauces in the walls of fish-salting vats located along the Atlantic coast (Marsa, Baelo Claudia, Troia, Kerlaz, and Etel) using a combination of experimental archaeology and organic residue analysis. Analysis of samples from the vats, when compared with actual *garum* sauces made from mackerel, sardines, and/or oysters, revealed the presence of common markers of fermented fish-based products and, significantly, demonstrated the addition of molluscs and fruits to the sauce.

Fish processing in the central Mediterranean is also documented by archaeological and historical sources, but research in this region has been comparatively less intense. The quantity of reported finds and number of research projects demonstrate this lower level of attention, which has persisted despite recognition of the area's role in dispersal of the fish-processing industry during its formative centuries, and evidence for intense consumption of processed fish in the region during the Roman period (Botte 2009; Marzano 2013). The situation in the later first millennium BC is less clear. The short contribution by Botte focuses on fish processing in Sicily and Italy from the pre-Roman period to post-second century AD. This contribution departs from his previous research (Botte 2009) by instead focusing on certain puzzling aspects of fish processing. The morphological and technical differentiation between the earlier salting vats in areas of Greek and Phoenician cultural influence in Sicily and the intriguing apparent absence of specialised containers for fish sauces and salted fish in the Greek area of Sicily and Magna Grecia are considered. Although focused on southern Italy, this discussion of economic activity versus taphonomic factors is equally

relevant to other parts of the central Mediterranean where archaeological evidence for processing installations is absent (e.g. Busana-Maria 2018).

Problems with the archaeological visibility of fish processing plants are not confined to the central and western Mediterranean. The dearth of concrete archaeological evidence for large-scale fish processing in the eastern Mediterranean has previously been noted (e.g. Wilson 2006; Botte 2009), despite written evidence for production in the region (Curtis 2016). Several of the papers in this volume attempt to tackle this issue from different vantage points, offering a range of perspectives. Theodoropoulou provides a diachronic overview of (mostly) archaeo-ichthyological evidence on fish processing in the Aegean over the *longue durée*, discussing the nature of the archaeological evidence and its consequences in research. She incorporates faunal remains with the wider discourse on fish processing to address how the scale of production can impact evidence from the Aegean, and highlights the connection between long-distance trade and local production. Lytle focuses on the Classical and Hellenistic periods in the same geographical area and explores economic aspects of fish processing. His analysis of literary and epigraphic sources from the Aegean concludes that the absence of evidence for fish processing in the region is indeed evidence for its absence. He argues that local conditions—both institutional and environmental—constrained production beyond a household scale. The third paper in this group, by Mylona, examines the paradox of the scarcity of archaeological evidence in contrast to the literary references to fish products in the eastern Mediterranean, adopting a broader geographical perspective. It revisits some of the basic themes in relevant research (e.g. development of fish processing technology, resource availability, geographical location, market demand) and highlights the effects of different archaeological agendas on the visibility of fish processing along the coasts of Mediterranean. It is argued that focused research is necessary before we can firmly establish the importance of fish processing in the area, an observation shared by other contributions in the volume.

Logistical and Social Organization of Fish Production

The social organization of salted fish and fish sauce production, as well as technical and logistical aspects underlying these processes, are topics that are subject to a growing body of research (e.g. Bekker-Nielsen and Bernal-Casasola 2010; Marzano 2013; Botte and Leitch 2014). Salt has been the subject of considerable attention (Carusi 2008; Harding 2013; Marzano 2013), due to its central importance to fish preservation, alongside its role in general food preservation, human/animal health, and industrial processes. Carusi, in her concise review, expands on the topic through discussion of the conditions that supported long distance trade in salt as opposed to local production and consumption. Fish processing on an industrial scale provided the impetus for such a trade. Within this context, Lowe's consideration of the logistics of fish salting—through the lens of *Astronomica*, a poem by Roman writer Marcus Manilius—combines literary and archaeological evidence to offer insight into the salting process and its close relationship with salt production. These papers highlight the need for, and rewards of, an inclusive approach to the study of ancient fish processing that incorporates complementary activities. Sánchez López's (2018) recent analysis of water-related structures in Roman halieutic plants (presented as a poster at the conference and published as a separate paper) is another welcome contribution to this trend.

Marzano also considers fish-salting, but through a more human lens. Her contribution offers a rich exploration of the social context of fish consumption and considers the relationship between fish-salting establishments and the fishermen who provided the fish. Ragia investigates the social organization of fish production/consumption in the eastern Mediterranean by confronting the traditional dichotomy between producers and consumer–buyers in Byzantium. Many more groups than typically considered were involved in the supply and distribution of fish products: when products distributed by military, administrative, and religious institutions are included, the pool of fish consumers is also much larger than previously recognized, with significant economic implications. These contributions on the social framework of fish processing remind us of the many agents involved in fish production and acquisition, and they help flesh out a lucrative industry which impacted a large range of individuals far beyond fisherman and market shoppers.

Ancient Fish and Future Directions

Study of marine exploitation in antiquity is gaining an increasingly important role in modern marine sciences and fisheries policy at a European and at a global level (Schwerdtner-Máñez et al. 2014). As issues of sustainability become more urgent, there is increasing realization that lessons can be drawn from the past to inform present strategies (MacKenzie and Mariani 2012). However, despite institutional support from organizations that promote interdisciplinary dialogue (e.g. Mazzoldi et al. 2018), opportunities for discussion between those who study ancient fish/fishing and contemporary biologists and policy makers are still very few. The gulf between scholars of antiquity, physical scientists and officials is perhaps sustained by a lack of mutual understanding of the research undertaken by these groups; while there is general positive feeling towards interdisciplinary dialogue, finding the time and avenues to initiate it is more challenging, as is developing useful, measureable outcomes (which require a sustained discussion). In this context, Koutrakis's contribution to this volume, in the form of a postscript, represents an important step towards the cross-fertilization of ancient and modern studies. Better understanding of past scenarios can lead to better-informed decisions on future management of Mediterranean resources (Boero 2016), and, as Koutrakis points out, such intervention is badly needed if over-fishing and habitat depletion are to be sustainably addressed. It is clear that there is much scope for more focused discussion between the practitioners of both historical and natural sciences, and it is hoped that the papers in this volume can provide a starting point for future dialogue.

References

- Ayodeji KA (2004) Fishing equipment and methods in the Roman world. PhD thesis, Royal Holloway, University of London
- Barrett J, Orton D (eds) (2016) Cod and herring: the archaeology and history of medieval sea fishing. Oxbow Books, Oxford
- Bekker-Nielsen T (ed) (2005) Ancient fishing and fish processing in the Black Sea region, vol 2. Black Sea Studies. Aarhus University Press, Aarhus
- Bekker-Nielsen T, Bernal-Casasola D (2010) Ancient nets and fishing gear. In: Proceedings of the international workshop on nets and fishing gear in classical antiquity: a first approach, Cádiz, November 15–17, 2007. Universidad de Cádiz, Servicio de Publicaciones, Cádiz

- Bekker-Nielsen T, Gertwagen R (2016) The inland seas: towards an ecohistory of the Mediterranean and the Black Sea, vol 35. *Geographica historica*. Franz Steiner, Stuttgart
- Bernal-Casasola D (2016) Garum in context: new times, same topics in the post-Ponsichian era. In: Bekker-Nielsen T, Gertwagen R (eds) *The inland seas: towards an ecohistory of the Mediterranean and the Black Sea*. *Geographica Historica* 35. Franz Steiner, Stuttgart, pp 187–214
- Bernal-Casasola D, Arévalo-González A, Díaz-Rodríguez JJ, Expósito-Álvarez JA (2016) Baelo Claudia y sus actividades haliéuticas. In: *Una nueva cetaria y una posible domus en el barrio meridional*. Proceedings of the II Jornadas Internacionales de Baelo Claudia, Junta de Andalucía, Sevilla, pp 147–176
- Boero F (2016) Mediterranean scenarios. In: Bekker-Nielsen T, Gertwagen R (eds) *The inland seas: towards an ecohistory of the Mediterranean and the Black Sea*, vol 35. *Geographica historica*. Franz Steiner, Stuttgart, pp 387–399
- Botte E (2009) Salaisons et sauces de poissons en Italie du sud et en Sicile durant l'Antiquité. Collection du Centre Jean Bérard 31; *Archéologie de l'artisanat antique* 1. Centre Jean Bérard, Naples
- Botte E, Leitch V (eds) (2014) Fish and ships: production and commerce of salsamenta during antiquity. Actes de l'atelier doctoral, Rome, 18–22 juin 2012. Bibliothèque d'archéologie méditerranéenne et africaine 17. Errance, Arles
- Buckley M (2018) Zooarchaeology by Mass Spectrometry (ZooMS) collagen fingerprinting for the species identification of archaeological bone fragments. In: Giovias CM, LeFebvre MJ (eds) *Zooarchaeology in practice: case studies in methodology and interpretation in archaeofaunal analysis*. Springer International Publishing, Cham, pp 227–247
- Busana-Maria S (2018) Fishing, fish farming and fish processing during the Roman age in the northern Adriatic: literary sources and archaeological data. *Reg Stud Mar Sci* 21:7–16
- Çakırlar C, Ikram S, Gates M-H (2016) New evidence for fish processing in the ancient Eastern Mediterranean: formalised *Epinephelus* butchery in fifth century BC Kinet Höyük, Turkey. *Int J Osteoarchaeol* 26:3–16
- Carusi C (2008) Il sale nel mondo greco (VI a.C.–III d.C.). Luoghi di produzione, circolazione commerciale, regimi di sfruttamento nel contesto del Mediterraneo antico. *Pragmateiai* 15. Edipuglia, Bari
- Costa B, Fernández JH (eds) (2012) Sal, pesca y salazones fenicios en occidente: XXVI jornadas de arqueología fenicio-púnica (Eivissa, 2011). *Treballs del Museu Arqueològic d'Eivissa i Formentera* 67. Museu arqueològic d'Eivissa i Formentera, Eivissa
- Crowe F et al (2010) Water-related occupations and diet in two Roman coastal communities (Italy, first to third century AD): correlation between stable carbon and nitrogen isotope values and auricular exostosis prevalence. *Am J Phys Anthropol* 142:355–366
- Curtis RI (1984) A personalized floor mosaic from Pompeii. *Am J Archaeol* 88:557–566
- Curtis R (2016) Ancient processed fish products. In: Bekker-Nielsen T, Gertwagen R (eds) *The inland seas: towards an ecohistory of the Mediterranean and the Black Sea*, vol 35. *Geographica historica*. Franz Steiner, Stuttgart, pp 159–186
- Finley MI (1973) *The ancient economy*, 2nd edn. University of California Press, Berkeley
- Flohr M, Wilson A (2016) Roman craftsmen and traders: towards an intellectual history. In: Wilson A, Flohr M (eds) *Urban craftsmen and traders in the Roman world*. Oxford studies on the Roman economy. Oxford University Press, Oxford, pp 23–54
- Galili E, Zemer A, Rosen B (2013) Ancient fishing gear and associated artifacts from underwater explorations in Israel—a comparative study. *Archaeofauna* 22:145–166
- Gallant TW (1985) A fisherman's tale: an analysis of the potential productivity of fishing in the ancient world. *Belgian Archaeological Mission in Greece*, Gent
- Harding A (2013) *Salt in prehistoric Europe*. Sidestone Press, Leiden
- Hyder K et al (2017) Research for PECH Committee—Marine recreational and semi-subsistence fishing—its value and its impact on fish stocks. European Parliament, Policy Department for Structural and Cohesion Policies, Brussels
- Keenleyside A, Schwarcz H, Panayotova K (2006) Stable isotopic evidence of diet in a Greek colonial population from the Black Sea. *J Archaeol Sci* 33:1205–1215
- Killgrove K, Tykot RH (2013) Food for Rome: a stable isotope investigation of diet in the Imperial period (1st–3rd centuries AD). *J Anthropol Archaeol* 32:28–38
- Killgrove K, Tykot RH (2018) Diet and collapse: a stable isotope study of Imperial-era Gabii (1st–3rd centuries AD). *J Archaeol Sci Rep* 19:1041–1049
- Koutrakis, ET (2018) Through the eyes of a biologist or how the past can guide us to the future: thoughts on the management of fisheries in the mediterranean. *J Mari Arch*. <https://doi.org/10.1007/s11457-018-9206-2> (this volume)

- Kron G (2008) Animal husbandry, hunting, fishing, and fish production. In: Oleson JP (ed) *The oxford handbook of engineering and technology in the classical world*. Oxford University Press, Oxford, pp 175–222
- MacKenzie BR, Mariani P (2012) Spawning of bluefin tuna in the Black Sea: historical evidence, environmental constraints and population plasticity. *PLoS ONE* 7:e39998. <https://doi.org/10.1371/journal.pone.0039998>
- Martyn REV, Garnsey P, Fattore L, Petrone P, Sperduti A, Bondioli L, Craig OE (2018) Capturing Roman dietary variability in the catastrophic death assemblage at Herculaneum. *J Archaeol Sci Rep* 19:1023–1029
- Marzano A (2007) Fish salting versus fish breeding: the case of Roman Italy. In: Lagostena L, Bernal D, Arevalo A (eds) *Cetariae* 2005. Salsas y salazones de pescado en Occidente durante la Antigüedad. Actas del congreso internacional (Cádiz, 7–9 de noviembre de 2005). *British archaeological reports international series* 1686. British Archaeological Reports, Oxford, pp 301–313
- Marzano A (2013) Harvesting the sea: the exploitation of marine resources in the Roman Mediterranean. *Oxford studies on the Roman economy*. Oxford University Press, Oxford
- Marzano A (2015) The variety of villa production: from agriculture to aquaculture. *Oxford studies on the Roman economy*. Oxford University Press, Oxford
- Marzano A, Brizzi G (2009) Costly display or economic investment? A quantitative approach to the study of marine aquaculture. *J Roman Archaeol* 22:215–230
- Mazzoldi C, Barausse A, Canadelli E, Fortibuoni T, Raicevich S (2018) Historical ecology of semi-enclosed basins and coastal areas: past, present and future of seas at risk. *Reg Stud Mar Sci* 21:1–6
- McConnan Borstad C, Garvie-Lok S, Katsonopoulou D (2018) Diet at ancient Helike, Achaia, Greece based on stable isotope analysis: from the Hellenistic to the Roman and Byzantine periods. *J Archaeol Sci Rep* 18:1–10
- Morales-Muñiz A, Roselló-Izquierdo E (2012) Especies pescadas, especies ingeridas: el consumo de pescado y moluscos en las sociedades fenicio-púnicas. In: Costa-Ribas B, Fernández-Gómez JH (eds) *Sal, pesca y salazones fenicios en Occidente*. Museu Arqueologic d'Eivissa i Formentera, Eivissa, pp 123–156
- Moya-Cobos L (2016) *Los fenicios occidentales y la explotación de los recursos marinos*. Universidad de Sevilla, Sevilla
- Mylona D (2008) Fish-eating in Greece from the fifth century BC to the seventh century AD. *British archaeological reports international series* 1754. Archaeo Press, Oxford
- Mylona D, Grainger S (2018) Fish products in the ancient mediterranean: smell, taste and texture of flesh in a conference hall. *J Mari Arch*. <https://doi.org/10.1007/s11457-018-9212-4> (this volume)
- Nafplioti A (2016) Eating in prosperity: first stable isotope evidence of diet from Palatial Knossos. *J Archaeol Sci Rep* 6:42–52
- Petroutsia EI, Manolis SK (2010) Reconstructing Late Bronze Age diet in mainland Greece using stable isotope analysis. *J Archaeol Sci* 37:614–620
- Pinnegar JK, Engelhard GH (2008) The 'shifting baseline' phenomenon: a global perspective. *Rev Fish Biol Fish* 18:1–16
- Powell J (1996) Fishing in the prehistoric Aegean, vol 137. *Studies in Mediterranean archaeology and literature*. Paul Åströms Förlag, Jonsered
- Prowse T, Schwarcz HP, Saunders S, Macchiarelli R, Bondioli L (2004) Isotopic paleodiet studies of skeletons from the Imperial Roman-age cemetery of Isola Sacra, Rome, Italy. *J Archaeol Sci* 31:259–272
- Prowse TL, Schwarcz HP, Saunders SR, Macchiarelli R, Bondioli L (2005) Isotopic evidence for age-related variation in diet from Isola Sacra, Italy. *Am J Phys Anthropol* 128:2–13
- Richter KK, Wilson J, Jones AKG, Buckley M, van Doorn N, Collins MJ (2011) Fish'n chips: ZooMS peptide mass fingerprinting in a 96 well plate format to identify fish bone fragments. *J Archaeol Sci* 38:1502–1510
- Rissech C, Pujol A, Christie N, Lloveras L, Richards MP, Fuller BT (2016) Isotopic reconstruction of human diet at the Roman site (1st–4th c. AD) of Carrer Ample 1, Barcelona, Spain. *J Archaeol Sci Rep* 9:366–374
- Roffet-Salque M, Lee MRF, Timpson A, Evershed RP (2017) Impact of modern cattle feeding practices on milk fatty acid stable carbon isotope compositions emphasise the need for caution in selecting reference animal tissues and products for archaeological investigations. *Archaeol Anthropol Sci* 9:1343–1348
- Rose M (1994) *With line and glittering bronze hook: fishing in the Aegean Bronze Age*. PhD thesis, Indiana University, Bloomington
- Rostovtseff MI (1926) *The social and economic history of the Roman empire*. Clarendon, Oxford

- Rostovtzeff MI (1941) The social and economic history of the Hellenistic world. Oxford University Press, Oxford
- Rowan E (2014) The fish remains from the Cardo V sewer: new insights into taphonomy, consumption and the fishing economy of Herculaneum. In: Botte E, Leitch V (eds) Fish and ships: production et commerce des salsamenta durant l'antiquité. Errance, Arles, pp 61–74
- Rowan E (2017) Bioarchaeological preservation and non-elite diet in the Bay of Naples: an analysis of the food remains from the Cardo V sewer at the Roman site of Herculaneum. *Environ Archaeol* 22:318–336
- Rutgers LV, van Strydonck M, Boudin M, van der Linde C (2009) Stable isotope data from the early Christian catacombs of ancient Rome: new insights into the dietary habits of Rome's early Christians. *J Archaeol Sci* 36:1127–1134
- Salazar-García DC, Romero-Rameta A, García-Borja P, Eulàlia Subirà M, Richards MP (2016) A combined dietary approach using isotope and dental buccal-microwear analysis of human remains from the Neolithic, Roman and Medieval periods from the archaeological site of Tossal de les Basses (Alicante, Spain). *J Archaeol Sci Rep* 6:610–619
- Sánchez López EH (2018) The role of fresh water in fish processing in antiquity. *J Marit Archaeol* 13:83–96
- Schwerdtner-Máñez K et al (2014) The Future of the Oceans Past: towards a global marine historical research initiative. *PLoS ONE* 9:e101466. <https://doi.org/10.1371/journal.pone.0101466>
- Theodoropoulou T, Gallant T (eds) (forthcoming) Harvesting the gifts of the sea: Aegean societies and marine life. Springer, New York
- Trakadas A (2015) Fish-salting in the northwest Maghreb in antiquity: a gazetteer of sites and resources. Archaeo Press, Oxford
- Vika E (2011) Diachronic dietary reconstructions in ancient Thebes, Greece: results from stable isotope analyses. *J Archaeol Sci* 38:1157–1163
- Vika E, Theodoropoulou T (2012) Re-investigating fish consumption in Greek antiquity: results from $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis from fish bone collagen. *J Archaeol Sci* 39:1618–1627
- Wilson A (2006) Fishy business: Roman exploitation of marine resources. *J Roman Archaeol* 19:525–537