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## Preservation and sampling of fish, shell and other invertebrate remains

Tatiana Theodoropoulou

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# FIELD SAMPLING for Laboratory Analysis in Archaeology

Evi Margaritis, Artemios Oikonomou,  
Efthymia Nikita and Thilo Rehren (Eds)



This project has received funding  
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No 811068

PROMISED 

H2020 Twinning PROMISED project: "Promoting  
Archaeological Science in the eastern Mediterranean"



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## FOREWORD

The application of methods from the natural and environmental sciences to archaeology has become common practice in many excavations and research projects, world-wide. Numerous research groups, both *ad hoc* in universities or museums and those situated in more long-term centres dedicated to one or more branches of archaeological science, devote their skill, experience and infrastructures using scientific methods to address archaeological research questions. At the same time, the number of archaeological fieldwork projects is ever-increasing, both for research and driven by ongoing development. The pressures of daily work, and the physical separation of field-based and laboratory-based archaeologists often prevent the level of communication and practical interaction that one would like to see, in order to ensure a seamless transmission of experience and skill between the field and the lab. This Handbook aims to help bridge this gap in the daily practice of archaeological fieldwork and lab-based research. There are, of course, numerous handbooks of archaeological science, of chemistry for archaeology, and even whole textbooks of specific branches within the archaeological sciences; these offer detailed explanations of how the science works, and how to do the labwork. However, we felt that few of these were addressing the daily needs of the field-based archaeologist who may be confronted with an unexpected find, and needs to brush up quickly on the practicalities of how to document and sample finds for future analysis in a lab.

And there is something else, too, to consider. So far, science-based archaeological research and postgraduate training have been heavily concentrated at museum laboratories and university departments in central and northern Europe, the US, Canada and Australia, while relatively few such research hubs exist in the EMME region, a region of vast archaeological richness and fast-growing populations. As a result, much of the professional practice has been developed within the financial, structural, ecological and archaeological reality of these 'global northern' countries – relatively few archaeological sites, stable institutions, strong economic frameworks, and a deep pool of human talent with access to well-established research centres and universities. The reality in the wider EMME region is the polar opposite: the region is drowning in archaeology, has few and often fragile and permanently understaffed institutions, and generally rather stretched economies. Thus, the benchmarks of the global north are not really applicable for the daily reality here.

The research potential of the region in archaeology and cultural heritage is enormous, ranging through the full spectrum of human occupation from the Palaeolithic to the recent past, while the scientific potential of such material can only be reached through the use of techniques and methodologies that require dedicated expertise. This Handbook hopes to offer an accessible and practical guide for colleagues working in the field, focussing on the practical steps that often mark the beginning of a larger journey. Steps that can be done without all the heavy kit and high-end expertise that characterises so much of modern science – initial steps which are absolutely essential as sampling protocols and form the basis for any subsequent work!

Archaeological Science research at The Cyprus Institute is focussing on primary production activities in the widest sense, from important foodstuffs such as olive oil and wine to basic metals such as copper and iron, and ceramics, and how the production and long-distance exchange of these goods is reflected in the osteobiographies of the humans engaged in these activities. Within this broad field, we aspire to contribute to the shaping of disciplinary practice in the EMME and beyond. To do this, we joined forces with the KU Leuven and the University of Cambridge, two leaders in archaeological science, and received generous funding from the European Commission under the H2020 framework. Our project *Promised* – Promoting Archaeological Sciences in the Eastern Mediterranean, Grant Agreement 811068, ran from 2018 to 2022, and facilitated a large number of key activities, including supporting three international summer schools in Cyprus for emerging and mid-career researchers from the EMME region, two conferences (ICAS-EMME 2 and 3), and numerous training, mentoring and outreach activities. As part of our ambition to support the wider archaeological community in the EMME region to benefit from archaeological science, we humbly present this handbook as one of the outputs of *Promised*.

*Evi Margaritis, Efthymia Nikita, Artemios Oikonomou and Thilo Rehren, with special thanks to Patrick Degryse and Cyprian Broodbank*

This book is dedicated to Myrto Georgakopoulou, who dedicated her life to promoting archaeological science in Greece and EMME

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## CHAPTER 7

### Preservation and sampling of fish, shell and other invertebrate remains

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#### Introduction

Marine and freshwater resources have constituted an important part of the human diet in many periods and many regions over the world. They have also served as bait, ornaments, tools, containers, fill, temper, building material, or have been treated to extract colour, skin, sea-silk, or produce glue, medicinal substances or fertilizers. In order to understand the role and importance of marine resources in human societies in the past, it is paramount to properly retrieve their remains from archaeological sites. Retrieval and sampling are among the most important steps in the study of faunal remains and determine the quality of the results (Chaix and Méniel 2001, 14). Although aquatic faunal remains are generally considered part of the faunal material found in an archaeological site and globally share some of the general rules applied to any other faunal remains, their specific nature calls for specific sampling strategies that will be presented in this chapter.

#### Research scope

As any other type of organic remains, fish bones and invertebrate remains may inform us on both palaeoenvironmental conditions and on human exploitation (for a general introduction to Archaeozoology, see [Chapter 5](#), this volume). Wheeler and Jones (1989, 44-45) offer a set of general questions with respect to fish remains that may be valid for all aquatic assemblages: What species are present? Are they freshwater or marine? What information do they provide on past environments and environmental conditions? Are the different species spread evenly across the site or are they concentrated in particular areas or periods of occupation? What does the distribution of remains across the excavated area tell us about human activities within a site? Is there evidence of fish/mollusc processing? Were the individuals from a site different in size from those at another site? What does the faunal assemblage tell us about the methods of exploitation or processing? Beyond this general research framework, specific questions may be raised depending on the nature of each deposit, and it is important that there is close collaboration between the excavator and the faunal specialist, in order to decide on the best strategy to choose for the retrieval of the remains, as it will be further detailed in the section 'Implementation'.

#### What to look for

Before presenting the sampling methods adequate for the retrieval of aquatic remains, it is necessary to present the different types of remains of aquatic animals likely to be retrieved in the field ([Figure.1](#)).<sup>1</sup>

**Fish:** 95% of animals included in this huge group are vertebrate fish. Bony fish (Osteichthyes) will leave a larger number of remains than cartilaginous fish (Chonrdichthyes). Head bones (jaws and other tooth-bearing bones, toothed bones of the pharyngeal region, gill bones, isolated teeth), otoliths ("ear-stones" formed from calcium carbonate), bones at the junction of the head and the body (pectoral and pelvic), vertebrae, fins, dermal denticles and scales can be recovered from an archaeological site. For cartilaginous fish (most usually sharks and rays), only calcified cartilaginous

<sup>1</sup> Marine mammal remains are not included in this chapter, as general sampling of faunal remains may be applied to this type of material (see [Chapter 5, Zooarchaeology](#), this volume).

vertebrae, teeth and dermal denticles can be preserved. Otoliths are not well developed in these fish.

2 This chapter presents the remains of aquatic animals (marine, freshwater) that may be found in the archaeological record. Among invertebrate animals, namely molluscs, some classes may also be found on earth (land snails). The explanations given with respect to the retrieval and sampling of molluscs can be considered valid also for land snails found within cultural archaeological deposits (see, for instance, Evans 1972, Barber 1988), as opposed to terrestrial molluscs retrieved from geological coring (e.g., Pagli et al. 2020).

**Invertebrates<sup>2</sup>:** this is a vast group of animals that do not possess a vertebral column but may present a shell or an exoskeleton. Among marine organisms that belong to this group, several may leave preservable remains.

**Molluscs:** the external hard shell of molluscs that protects their mantle is the commonest invertebrate remain found in archaeological sites. It may have various forms (spiral or conical for gastropods, composed of two valves for bivalves, in a tubular form for scaphopods, multiple plates for chitons, etc.). Also, many marine gastropods and freshwater/terrestrial snails have a corneous or calcareous structure that closes their aperture, called operculum.

**Crustaceans:** this vast group of shelled animals includes decapods, shrimp, branchiopods, barnacles, etc. Their body is composed of segments (the head or cephalon, the thorax or pereon, and the abdomen or pleon), protected by a hard preservable exoskeleton, the carapace. They also possess pairs of hard-tissue appendages (antennae, mandibles and maxillae, and legs or claws).

**Corals:** within the subphylum of Anthozoa, the stony corals, composed of a polyp, can be preserved in the archaeological sediment. Other Anthozoa (soft corals, sea anemones) are not expected to leave any remains, nor do other members of the phylum Cnidaria (e.g., jellyfish).

**Echinoderms:** animals of this phylum, of which the sea-urchins are best preserved in the archaeological record, are protected by a test, composed of fused calcite-based plates named ossicles. The ossicles may bear hard spines, granules or warts. Another element that may be preserved is the chewing organ of sea urchins, called "Aristotle's lantern".

**Cephalopods:** among this class, shelled molluscs such as *Nautilus* and the argonaut possess a coiled external shell. Octopi, cuttlefish and squids have an internal cuttlebone, gladius or shell that is often preserved in soil.

**Sponges:** many sponges have internal skeletons of spicules made of calcium carbonate or silicon dioxide, which could be preserved under extraordinary circumstances.

Figure 1. Different types of aquatic faunal remains: (A) cuttlefish bone (sepion), (B) mollusc shells, (C) urchin plates and spines, (D) fish bones (cranial bones, vertebrae of teleost and cartilaginous fish).



3 Pre-depositional, natural or anthropogenic factors that may affect the accumulation or presence/absence of specific body parts or taxa are not discussed in this chapter.

## Taphonomy and survival of fish bones and shell remains

In order to evaluate the survival probability and integrity of aquatic faunal remains in an archaeological site and assess the fidelity of the retrieved assemblage compared to the buried one, it is important to understand the taphonomic processes that affect bone and shell preservation. There are two factors that influence whether a fish bone, cartilage, scale, otolith, or shell will survive in archaeological contexts once deposited: the nature and properties of the hard tissues of organisms, and the burial environment.<sup>3</sup>

The composition and mechanical properties of the hard tissue are determining in the survival of the remains. Some hard tissues found in fish are more resistant than others. Bony fishes generally have more robust bones as compared to cartilaginous ones, but their robustness can vary significantly depending on the families or taxa, the size of the individuals within a single species, and even the various skeletal elements within the same individual (several examples in Wheeler and Jones 1989, 62-63). The vertebrae forming the vertebral column in bony fishes tend to be tougher than cranial bones, with the exception of teeth. Otoliths, scales, dermal structures (denticles, spines) can also survive. Cartilaginous fishes, on the other hand, are subjected to the burial conditions. Most cartilage, especially from cranial elements, does not persist, as it breaks into small prismatic particles that are not easily recognisable in the soil. However, ossified cartilaginous vertebrae of sharks and rays, as well as teeth and dermal structures (denticles, spines), do survive.

Shells are more or less robust, depending on their shape (gastropods, bivalves, scaphopods, sea-urchins, crustaceans, corals, etc.) and structure (Currey 1980, 80). In general, they tend to break at their structurally weak points (aperture and spire for gastropods, pallial line and growth lines for bivalves, a sea-urchin test into its multiple plates, etc.). Nacreous shells are more resistant to tension, compression, bending; prismatic shells are more adaptive; homogeneous structures are very weak in tension; foliated shells are the weakest in compression; crossed-lamellar are the stiffest of all.

The physical and chemical conditions of the sediment also influence the survival of fish bones and shells (for general principles, see Collective 2016 (2023), 17-27). Although fish bones are generally considered more fragile than bones of other animals, especially with respect to attrition (Wheeler and Jones 1989, 62-63), it has been shown that they should survive at any site where juvenile mammal and small bird remains are preserved (Desse 1980). Neutral and alkaline soils are generally conducive to fish bone and shell survival, although otoliths would only survive in base-rich environments. On the contrary, acidic soils are not favourable for fish bone or shell preservation. Within calcareous soils, bones and shells will tend to be more severely fragmented but suffer less from dissolution. Specific conditions, such as waterlogged sites, may offer a protective environment for the preservation of fish remains. Organic-rich soils are also better candidates for the mechanical survival of fish bones and shell compared to soils containing mineral particles. However, the presence of bioturbators (plants and animals) in these soils may cause severe damages on the surface of bones and shells.

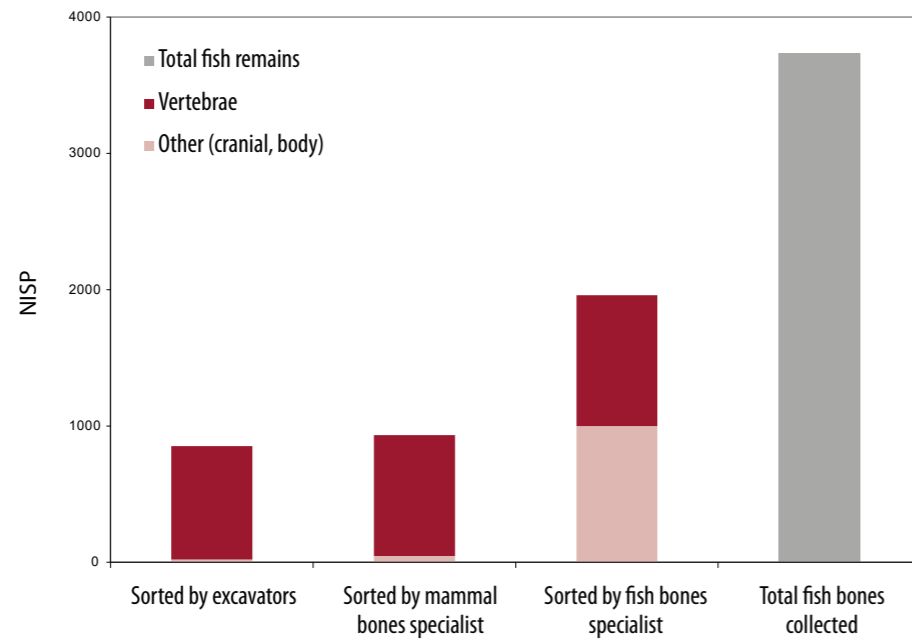
## Sampling procedure

### Implementation

As any faunal material, fish bones and shells can reach the specialist by two means: either by direct retrieval by the latter in the field, or as retrieved/sorted materials after the excavation. The need for collaboration between the excavators and the faunal specialist has often been emphasised (Chaix and Méniel, 2001, 14; Desse et al., 2002; Mueller 1975; Payne 1975; Reitz and Wing 1999, 30; Uerpman 1973; Wheeler 1978; Wheeler and Jones 1989, 40-43, see also Chapter 5, Zooarchaeology, this volume). Ideally, the zooarchaeologist is invited to participate in the excavation from the first stages of the fieldwork in order to specify and indicate the sampling methods adapted to the



Figure 2. Different types of fish remains retrieved according to the degree of familiarisation with this type of remains (excavator, mammal bones specialist, fish bones specialist, fish bones specialist) from the Neolithic site of Dimitra, Greece.



excavated deposit. The call for a specialist on-site becomes even more necessary in the case of aquatic remains, in particular fish bones and shells, which are often small and fragile, not always easy to identify in the excavation, and can therefore only be recovered by specific sampling (Figure 2).

Before all, the excavator should provide the general information as well as research questions/objectives that will allow the specialist to determine the adequate sample for archaeo-ichthyological or malacological analysis. In particular, the zooarchaeologist will evaluate the nature of the site (geographical setting, period of occupation), the type of the site (open-air settlement, cave, shell-midden (With respect to shell middens, an extended list of references and relevant sampling methods may be found in Claassen 1998, 99-100), specific structure such as temple, fortress, latrine, etc.), the type of archaeological structures (domestic area, hearth, pit, refuse zone, artisanal area), the type of intervention (surface survey, rescue excavation, systematic excavation of the entire site or of selected areas or structures), the richness of the archaeological structures, the state of preservation of the environmental material, and the costs and personnel involved in the sampling and subsequent sorting procedure (Chaix and Méniel 2001, 14; Claassen 1998, 100; O'Neil 1993; Reitz and Wing 1999). At this time, the zooarchaeologist must be able to specify the potential of the ichthyological or malacological material and the constraints related to the contextual or taphonomic conditions.

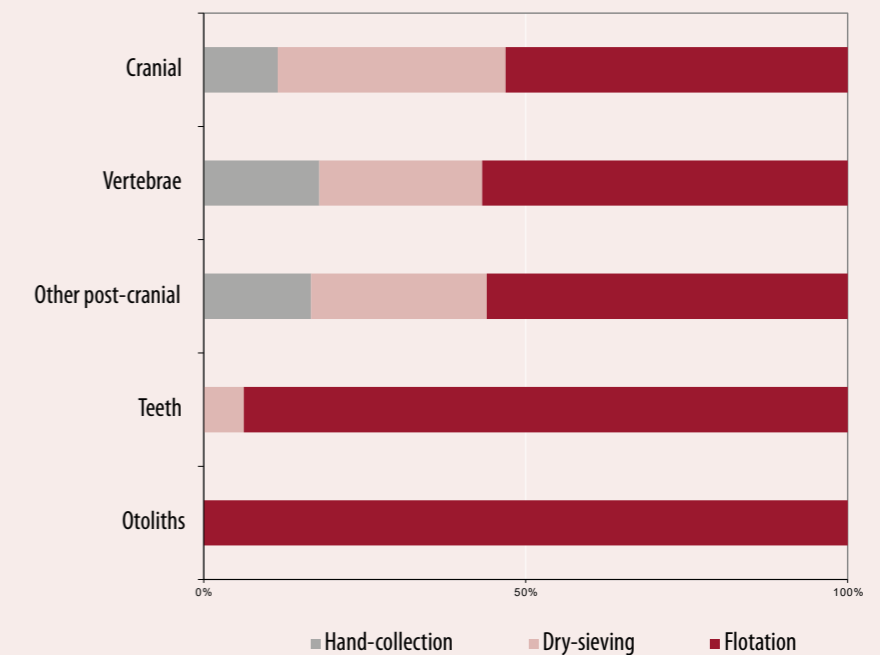
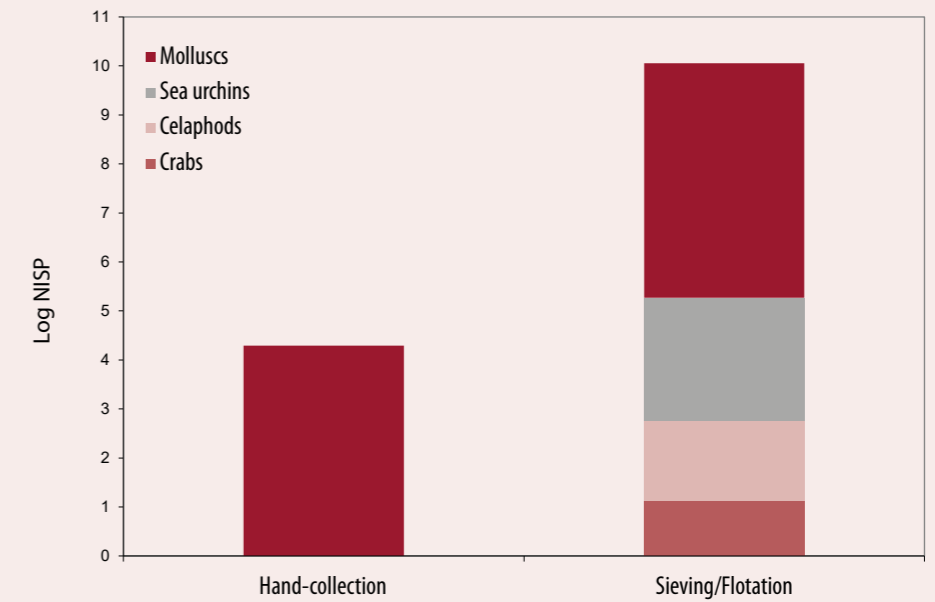
### Sampling methods

As is the case with any environmental sampling, different methods of retrieval include hand-collecting, dry-sieving, wet-sieving. In general, fish bones and shells are more variable in size, shape and physical characteristics than other types of faunal remains. Thus, different retrieval methods will result in different sample composition (Figures 3a-b). The following add some specifications to the general principles of collection and documentation of animal remains (Chapter 5), with respect to fish and invertebrate remains.

#### Hand-collecting

Hand-collecting allows to retrieve the material from all the archaeological structures from a site relatively fast and without the need for specific equipment. Some shell and fish remains can be recovered without sieving. This is often the case with larger molluscan species with robust shell, which makes them easily distinguishable during excavation. Other invertebrate remains, such as crab claws or coral fragments have a striking appearance that allows recognizing them in the archaeological soil. Some fish

Figure 3a. LogNISP of various invertebrate remains and b. NISP of various anatomical parts of fish retrieved through hand collecting and dry-sieving and water-flotation at the Bronze Age site of Mikro Vouni, Greece.



remains, especially those from larger species or bigger individuals, can also be visible in the sediment. If specific concentrations are observed, e.g., an articulated fish skeleton or a shell necklace, they should be given a specific find number (or 'spot find') and be stored separately from the rest of fish bones/shells retrieved from the same layer (Wheeler and Jones 1989, 48). Photos /sketches of the connected remains should be taken before removing them. In any case, with hand-collecting it is recommended that all visible remains are retrieved and not just samples (Collective 2016 (2023), 32), although this might not be the case of shell-midden sites, where sub-sampling could be chosen upon estimation of the representative samples and confidence level (Claassen 1998, 99-100, potentially between 38-50% of the site area, or a standard shell weight sub-sampled from each sample). In the latter case, hand-collecting might also be performed in column-sampling.

**Biases/limitations:** Experiments have shown that hand-collecting is biased in favour of larger bones of larger species and tends to overlook small-sized remains, thus leading to an underestimation of the importance of smaller species or to fragments of bones from larger individuals (Casteel 1976a-b, 1977a-b; Clason and Prummel 1977 (Figure 3b).



Furthermore, there is a relationship between the representativeness of different taxa (diversity, richness, anatomical representation, [Figure 3a](#)) and the sampling method (hand-collecting, dry sieving, water sieving, size of mesh). The representativeness is also dependent on the size of the sample (Clason and Prummel 1977; Grayson 1984; Morales and Roselló 1998; Payne 1975; Struever 1968; Zohar and Belmaker 2005).

**Necessary infrastructure:** although no particular infrastructure is necessary for hand-collecting of fish bones or shells, it is recommended that they are not washed before being stored. In case the remains are retrieved from damp soils, it is necessary to let the samples air dry onto trays. If shells contain much soil, either samples are stored with their matrix, or they are screened through multiple mesh sizes (25, 12.5, 6, 3, 1.5 mm) to remove the soil (Claassen 1998, 104). It may be advised to store the contents of each screen in separate bags to facilitate fragmentation estimates. If an experienced archaeo-ichthyologists/archaeomalacologist is present on site, fish bones and shells may be stored separately from other animal remains. The general conditioning rules known for other types of organic remains (humidity, type of bags/boxes, etc.) should apply to fish bones and shells (see Chapter 5, section on post-excavation care and treatment of animal remains) and extra care should be taken when dealing with fragile pieces (e.g. wrap with cotton/cloth before putting into bags, or use sturdy boxes). In any other case, fish bones should better be left in the bone bags, as sorting by non-specialists may often lead to displacing important remains. It is generally easier to distinguish shell remains than fish bones. Fish skeletons in anatomical connection or joined valves of bivalves should be retrieved as a whole, preferably together with the sediment, stored in sturdy containers, and remain articulated until study.

### Sieving

Given the variable size of molluscan and fish species and extremely varied nature of their remains, the importance of sieving is paramount to the unbiased recovery of the full range of aquatic remains present in an archaeological site (Claassen 1991, 209). Wet-sieving is preferred over dry-sieving for aquatic remains, even in the case of larger fish bones or more robust shells, as it causes less damage to the remains. However, in shell-bearing sites dry-sieving in order to separate larger and smaller shell (all shells larger than 1.5 mm sorted, and >1.5 mm classified as matrix) or to sub-sample extremely big samples, may be necessary (Claassen 1998, 103). Dry-sieving of fish bones may also be a good solution in totally dry deposits (e.g., sand-dune), where the use of a mesh down to 1 mm is possible (Wheeler and Jones 1989, 50), but is not preferred for damp sediments.

The following mostly concern wet-sieving:

Sieving is generally more punctual and requires a well-designed sampling strategy, according to previously defined research questions. The sieving for marine faunal remains can be included in the general sampling strategy chosen for an archaeological site, or it can be dictated by the particularities of each context. It is also important to further determine the best strategy to obtain a representative quantity of remains. Several sampling strategies have been proposed for fish bone remains in particular (Casteel 1972, 1976b, Desse 1980; Wheeler and Jones 1989, 40–43; Colley 1990; Desse-Berset and Radu 1996; Plogmann 1996; Barrett et al. 1999). Systematic sampling across a site, random sampling, and focused sampling, or a combination of the previous may be chosen.

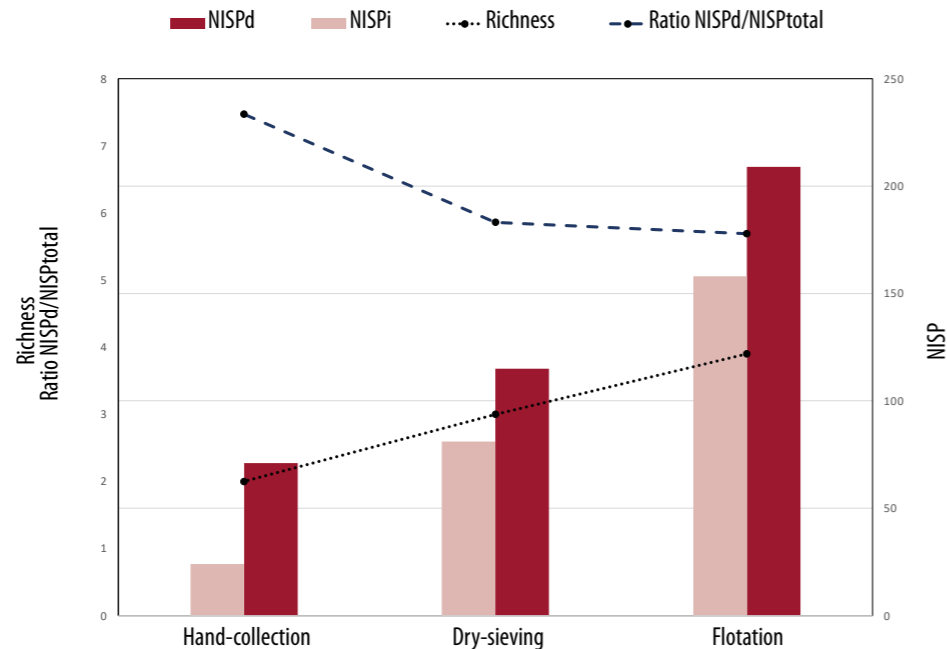
1. A generalized sampling may be applied in some cases, such as middens or food waste deposits, but it will inevitably count against the refinement level. For example, all excavated soil of a site can be sieved through a 10 mm mesh, and a 5l sample from each layer will be sieved through a 2.5 mm mesh. The quantity of soil removed can also prove useful in the case of an analysis of the density of the remains by volume of sediment (Barrett et al. 1999; Claassen 1998, 100). However, in order to avoid multiplying samples poor in fish bones or shell, a preliminary test could be applied throughout the site, to determine which features have greater chances in producing these types of remains.

2. Random sampling can also be selected for fish and molluscan remains. Some experiments in fish-rich deposits indicate that random sampling of 10–20l of soil across the site (with intervals to be determined by the excavators, e.g., in each square unit, at regular intervals or at intervals that match the spatial scale of the zones of a site) may provide a satisfactory representation of major taxa (Wheeler and Jones 1989, 45; Buxo i Capdevila 1991; up to 35l in some cases, if possible, Collective 2016 (2023), 48). An increase in the number of samples will certainly offer a better visibility of secondary/rare taxa. A preliminary study of a series of control samples may help determine the optimum volume of sediment needed to attain a recurrent number of taxa or minimum number of individuals (MNI) (Wheeler and Jones 1989, 45; an example in Desse-Berset et Radu 1996; Claassen 1998, 102). However, as it is highly unlikely that aquatic remains are evenly distributed across an archaeological site, several problems may arise. If only some excavation units are sieved, any differences between contexts will not be easily attributed to real discrepancies or to differential recovery (Colley 1990, 209). Random sampling in deposits that do not contain many aquatic remains may increase the samples that are not statistically reliable, and inversely, under-sample the deposits crucial to the interpretation of the use of fish/shell at a site. Random sampling of zones/layers poor in organic remains (e.g., construction fill) may also be valuable in order to assess the environmental, zoo-ecological conditions, e.g. in the case of land snails, and provide comparisons with the results from within the limits of the site. For the latter, column (core) sampling may be a more adequate method. It may also be used in naturally accumulated deposits over longer periods (e.g., fish or shell remains in peats or lacustrine deposits) (Claassen 1998, 101; Wheeler and Jones 1989, 48). It should be noted that this type of sampling is not useful for recovering rare species or isolated deposits (Claassen 1998, 101).
3. In some cases, sampling efforts can focus on providing more complete, i.e., voluminous sampling (up to 150–300l) of “reference” layers within a larger phase (Buxo i Capdevila 1991; an example in Radu 2003, 51). The choice of these layers should be based both on archaeological criteria and on a preliminary estimation of the species richness for selected layers. Some deposits accumulated over a short period (e.g., house floors) may provide small amounts of material but are highly instructive with respect to the use of fish/molluscs (Wheeler and Jones 1989, 47). Also, special features, such as rubbish pits, bone dumps, latrines, or relevant structures, can be fully sieved (especially if small) or according to their richness in remains (if possible 35l in rich deposits, up to 50l in poor deposits). The stratification should be respected, if observed, or at least take samples from the bottom, walls and base of the structure; otherwise, all the remains can be put in the same sample. Test sampling around the structure is also recommended (Collective 2016 (2023), 49).

**Biases/limitations:** With respect to extremely fragile fish remains, e.g., from waterlogged deposits or articulated elements, it may be advised not to proceed to sieving. Ideally, hand collection and sieving should be carried out in a complementary manner (Wheeler and Jones, 39). As a general rule, it is preferable that sieving is not preceded by hand-collecting, but bulk samples are taken from areas with higher concentrations for flotation, so that the sample obtained is statistically complete (Barrett et al. 1999; Claassen 1991). Samples for microscopic remains (pollen, phytoliths, microfossils, etc.) should be taken before the ones for macroscopic remains, such as fish bones and shells (Collective 2023, 28). Finally, although the need to employ sieving has been presented above, the difficulty and impracticality, in terms of time and cost, of applying sieving to the entire sediment is also a fact. Thus, generalized sampling is often not a realistic strategy.

**Necessary infrastructure:** Although for wet-sieving, the general techniques and wet-sieving machine used for other types of remains at a site (see Chapter 1 on the recovery of plant remains, figures 1–4, and Chapter 6 on the sampling procedure, figures 1–2) will also serve for the retrieval of fish bones and shells, some recommendations specific to these types of remains may be suggested. For smaller fish and shell remains to be retrieved, a minimum mesh size of 0.5–2 mm is generally advised (Casteel 1976b, 1977a–b; Clason and Prummel 1977; Jones 1984; Payne 1975; Wheeler and Jones 1989, 51), depending on

Figure 4. NISP of fish remains (NISP<sub>i</sub>=unidentifiable taxonomically, NISP<sub>d</sub>=identifiable taxonomically), species richness and ratio NISP<sub>d</sub>/total NISP according to the method of retrieval at the Bronze Age site of Mikro Vouni, Greece.



anatomical, cultural (type of processing) or regional (taphonomic) conditions (on the use of a finer sieve vs. the 3 and 6 mm sieve results proposed by Vale and Gargett 2002, see Zohar and Belmaker 2005). However, a smaller sieve mesh does not always equal more identified taxa. Fine sieving often results in the recovery of too many small unidentifiable fish bones and shell fragments, especially in the >1 mm mesh, and will not contribute to the increase of the species richness or anatomical representation. In this case, the ratio between the sampling effort/added information, especially with respect to the expected number of species against sample size, needs to be evaluated (Desse 1980). For instance, it has been demonstrated that the 0.5 mm fraction adds only smaller anatomical elements of less frequent species or unidentifiable splinters of larger-sized individuals and thus does not add significant information to the inventory of collected fauna (e.g., Buxo i Capdevila 1991), especially if the sorting procedure following the retrieval of sieved samples is selective, i.e., collecting only fish bones which are considered identifiable (Wheeler and Jones 1989, 50) (Figure 4). A special note should be made regarding the water flow as well as the manual disaggregation of lumps of soil, which should be moderate and gentle so that more fragile fish bones and shells are preserved. Drying should preferably be done indoors, especially in the case of small fish bones.

## Conclusions

Fish bones and shells offer valuable information regarding both past marine and freshwater environments and exploitation of these resources by humans. The specific nature of these remains demands for the presence of specialists during the excavation and the implementation of a carefully chosen sampling strategy. Although the latter will aim at answering a set of general questions, ultimately it is the particularities specific to each excavation that determine the sampling techniques and sampling strategies to be selected (Clason and Prummel 1977; Desse et al. 2002; Desse-Berset and Radu 1996; Plogmann 1996; Vale and Gargett 2002; Wheeler and Jones 1989). It lies at the archaeo-ichthyologist/archaeo-malacologist to evaluate what the additional result obtained by visual collection and systematic sieving will be. In the second case, the minimum mesh size and liters of soil sufficient to obtain a representative image of the presence of aquatic animals at a site will need to be specified (Watson 1972; Botkin 1980; Desse-Berset and Radu 1996; Plogmann 1996). In both methods, the human factor, in particular the expertise but also the attention or fatigue of the workforce involved in these procedures should not be neglected (Plogmann 1996).

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## CHAPTER 8

### Sampling archaeological remains for isotopic analyses

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#### Introduction

Isotopic ratios of archaeological materials can provide valuable information about past dietary habits, land use, domestic plant/animal management, residential mobility, and climate seasonality. Depending on the sampled tissues, the data can elucidate short- and long-term life histories of humans and animals that interacted at archaeological sites. This insight can shed light on dietary, mobility and management choices made by ancient populations at varying temporal and spatial contexts.

Over the past forty years, archaeological stable isotope analysis has experienced a rapid growth in the application of both 'standard' methods (e.g. bulk analysis of bone collagen, tooth enamel, whole grains/seeds), as well as more targeted analysis of specific compounds (e.g. single amino acids, plant cellulose, food residue fatty acids), providing a powerful toolkit for answering targeted questions about past human lives, landscapes, and climates (Lee-Thorp, 2008). This chapter is intended to help guide initial sampling of archaeological materials – specifically human/animal bones and teeth, plant grains and seeds – for isotopic analysis: stable isotope values of carbon ( $^{13}\text{C}/^{12}\text{C}$ ,  $\delta^{13}\text{C}$ ), nitrogen ( $^{15}\text{N}/^{14}\text{N}$ ,  $\delta^{15}\text{N}$ ), oxygen ( $^{18}\text{O}/^{16}\text{O}$ ,  $\delta^{18}\text{O}$ ), sulfur ( $^{34}\text{S}/^{32}\text{S}$ ,  $\delta^{34}\text{S}$ ), and radiogenic isotopic ratios of strontium ( $^{87}\text{Sr}/^{86}\text{Sr}$ ). The examples provided illustrate the most common 'standard' applications. This chapter aims to provide archaeologists with a basic familiarity of the materials, methods, and research questions crucial for a successful collaboration with isotopic specialists.

#### Research scope

##### Past human diets

Stable isotope analysis of organic remains (**bone collagen, hair keratin, tooth dentine**) allows investigation of the relative contributions of certain food categories in long-term human diets, including:

- Marine resources, from marine producers and low-trophic level fish to high-trophic level marine mammals (*carbon, nitrogen, sulfur*)
- Plant species that follow the  $\text{C}_4$  photosynthetic pathway, such as maize, millet, sorghum, and sugar cane (*carbon*)
- Crops cultivated in fertilized fields (*nitrogen, sulfur*)
- Plants that use different nitrogen-fixing mechanisms: cereals vs. pulses (*nitrogen*)
- Animal products (meat, milk) from species/individuals whose diets differed due to behavioral adaptations or human management choices, such as grazing in forested areas, grazing on intensively managed fallow fields, on  $\text{C}_4$  grasses, on seaweed, and grazing in locations where the isotopic values of plant communities differed due to variations in temperature, humidity, altitude and sunlight exposure (*carbon, nitrogen, sulfur*)
- Food products (plant, animal) sourced from coastal areas (*nitrogen, sulfur*)
- Breastmilk (*carbon, nitrogen*)
- Freshwater fish, including species whose isotope values are more similar to those of marine resources and those that are more similar to terrestrial resources (*carbon, nitrogen, sulfur*)