Elsevier Editorial System(tm) for Quaternary International

Manuscript Draft

Manuscript Number: QUATINT-D-15-00557R1

Title: Collection and consumption of echinoderms and crustaceans at the Mesolithic shell midden site of El Mazo (northern Iberia): opportunistic behaviour or social strategy?

Article Type: Intertidal Resources UISPP

Keywords: shellfish; shell midden; echinoderms; crustaceans; Mesolithic

Corresponding Author: Dr. Igor Gutiérrez-Zugasti, Ph.D.

Corresponding Author's Institution: University of Cantabria

First Author: Igor Gutiérrez-Zugasti, Ph.D.

Order of Authors: Igor Gutiérrez-Zugasti, Ph.D.; Emma Tong; Asier García-Escárzaga; David Cuenca-Solana; Geoffrey N Bailey; Manuel R González-Morales

Abstract: Recent studies in Atlantic Europe on crab remains, goose barnacles and sea urchins have revealed that these species can be of great help in determining patterns of shellfish collection and providing new information on subsistence strategies of hunter-fisher-gatherers. Current excavations at the Mesolithic shell midden site of El Mazo cave (Asturias, northern Iberia) have produced a sizeable amount of crustacean and echinoderm remains from a long stratigraphic sequence that covers an important part of the Mesolithic chronological range, providing the opportunity to investigate long-term exploitation patterns. Results show that echinoderms (sea urchins) and crustaceans (goose barnacles and crabs) were present throughout all of the stratigraphic units (from 8.9 to 7.6 cal kyr), suggesting that they were a persistently exploited food source. However, these resources were not intensively exploited, save perhaps sea urchins at the base of the sequence. From a quantitative perspective, these resources have been traditionally interpreted as minor resources exploited opportunistically to help group survival. However, given the pattern of continuous exploitation exhibited by these resources in northern Iberia and other areas of Atlantic Europe, we suggest that they can be interpreted from a qualitative perspective as stable resources with a significant social value.

Quaternary International

We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We understand that the Corresponding Author is the sole contact for the Editorial process. He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

Signed by all authors as follows:

Igor Gutiérrez Zugasti (Corresponding Author)

Emma Tong

Asier García-Escárzaga

David Cuenca-Solana

Geoffrey N. Bailey

Manuel R. González-Morales

*Cover Letter

Dear Editor

It is a pleasure for us to submit the paper "*Collection and consumption of echinoderms and crustaceans at the Mesolithic shell midden site of El Mazo (northern Iberia): opportunistic behaviour or social strategy?*" to the special issue "Intertidal Resources UISPP" to be published in the journal Quaternary International. The role of coastal resources in the subsistence strategies of past human populations has become an important topic in the last years.

Among these resources, crustaceans and echinoderms can provide information not only about subsistence practices but also on social behaviour. Current excavations at the Mesolithic shell midden site of El Mazo cave (Asturias, northern Iberia) have produced a sizeable amount of crustacean and echinoderm remains from a long stratigraphic sequence that covers an important part of the Mesolithic chronological range, providing the opportunity to investigate long-term exploitation patterns. Results show that sea urchins and crustaceans (goose barnacles and crabs) were present throughout all of the stratigraphic units, suggesting that they were a persistently exploited food source. From a quantitative perspective, these resources have been traditionally interpreted as minor resources exploited opportunistically to help group survival. However, given the pattern of continuous exploitation exhibited by these resources in northern Iberia and other areas of Atlantic Europe, we suggest that they can be interpreted from a qualitative perspective as stable resources with a significant social value. Results from this study will help to better understand hunter-fisher-gatherer societies from Atlantic Europe.

Due to the international relevance of these studies, we think that this paper would be very suitable for publishing in the special issue devoted to the intertidal resources.

Thank you for your time and consideration

The corresponding author, Dr. Igor Gutiérrez-Zugasti

Instituto Internacional de Investigaciones Prehistóricas de Cantabria
Edif. Interfacultativo Universidad de Cantabria
Avda. Los Castros s/n.
39005 Santander, Spain.
Phone: 0034 942 202035
Email: igorgutierrez.zug@gmail.com

Santander (Spain), 5th May, 2015

*Manuscript
Click here to view linked References

Collection and consumption of echinoderms and crustaceans at the Mesolithic shell midden site of El Mazo (northern Iberia): opportunistic behaviour or social strategy?

Igor Gutiérrez-Zugasti[1], Emma Tong[2], Asier García-Escárzaga[1], David Cuenca-Solana[3], Geoffrey N. Bailey[2], Manuel R. González-Morales[1]

[1] Instituto Internacional de Investigaciones Prehistóricas de Cantabria, Universidad de Cantabria, Ed. Interfacultativo, Avda. de los Castros s/n, 39005 Santander, Cantabria, Spain

[2] Department of Archaeology, University of York, King's Manor YO1 7EP, York, UK

[3] Centre de Recherche en Archéologie Archéosciences Histoire, UMR 6566 CNRS CReAAH. Université Rennes 1. Campus Beaulieu - Bât 24 – 25. 263 avenue du Général Leclerc - CS 74 205. 35042 RENNES Cedex. (Francia)

Abstract

Recent studies in Atlantic Europe on crab remains, goose barnacles and sea urchins have revealed that these species can be of great help in determining patterns of shellfish collection and providing new information on subsistence strategies of hunter-fisher-gatherers. Current excavations at the Mesolithic shell midden site of El Mazo cave (Asturias, northern Iberia) have produced a sizeable amount of crustacean and echinoderm remains from a long stratigraphic sequence that covers an important part of the Mesolithic chronological range, providing the opportunity to investigate long-term exploitation patterns. Results show that echinoderms (sea urchins) and crustaceans (goose barnacles and crabs) were present throughout all of the stratigraphic units (from 8.9 to 7.6 cal kyr), suggesting that they were a persistently exploited food source. However, these resources were not intensively exploited, save perhaps sea urchins at the base of the sequence. From a quantitative perspective, these resources have been traditionally interpreted as minor resources exploited opportunistically to help group survival. However, given the pattern of continuous exploitation exhibited by these resources in northern Iberia and other areas of Atlantic Europe, we suggest that they can be interpreted from a qualitative perspective as stable resources with a significant social value.

Keywords: shellfish, shell midden, echinoderms, crustaceans, Mesolithic

1. Introduction

Shellfish exploitation was a common activity among coastal hunter-fisher-gatherers worldwide. As a reflection of that, the formation of large shell mounds, composed mainly of molluscs but also of echinoderms, crustaceans, fish, etc., is evidence of the intense exploitation of coastal areas and marine resources during prehistory. Thus, literature concerning the study of some marine species such as molluscs is abundant (e.g. Claassen, 1998; Bar-Yosef Mayer, 2005; Bailey et al., 2013; Szabo et al., 2014 and references therein), but this is not the case for other shellfish organisms. Until recently, very little attention has been paid to the study and analysis of the less visible marine species found within prehistoric midden deposits, such as crustaceans, barnacles and echinoderms (see Moss and Erlandson, 2010, and Jerardino, 2014 for examples from the Northwest Coast of North America and South Africa respectively). Recent studies in Atlantic Europe of crab remains (Gruet, 2002; Gruet and Laporte, 1996; Dupont and Gruet, 2005; Milner, 2009a; Pickard and Bonsall, 2009; Dupont et al., 2010; Gutiérrez-Zugasti, 2011a), goose barnacles (Dupont et al., 2008; Dean, 2010; Álvarez-Fernández et al., 2010, 2013; Gutiérrez-Zugasti, 2011a) and sea urchins (Dupont et al., 2003; Campbell, 2008; Gutiérrez-Zugasti, 2011a, 2014; Bejega et al., 2014) have revealed that these species can be highly informative about general patterns of shellfish collection and subsistence strategies.

Crustacean and echinoderm remains are commonly found in Mesolithic shell middens from the Atlantic Façade but usually in limited numbers (e.g. Schulting et al., 2004; Dupont et al., 2009; Gutiérrez-Zugasti, 2011a; Gutiérrez-Zugasti et al., 2011). The importance given to the quantitative perspective when analysing food procurement and consumption patterns, together with the limited amount of available data, can easily give rise to the idea of occasional consumption of these organisms in time and space, associated with an opportunistic and casual pattern of exploitation (see for example Álvarez-Fernández et al., 2010; Gutiérrez-Zugasti, 2011a). However, some ethnographic (Moss and Erlandson, 2010; Moss, 2013) and archaeological studies (Milner, 2009b) have emphasised that a qualitative perspective should be taken into account when assessing the role of these resources. Sea urchins, crabs and barnacles can be used for different purposes, not only for food, but also, for example, as fishing bait (Claassen, 2013). They can also be valued in different ways in different societies or by different members of the same society, being highly valued as food in some cases or surrounded by taboos in others (Moss, 1993, 2013) They can also play an

important role in social organisation acting as a delicacy or special food consumed during social encounters.

Recent excavations at the Mesolithic shell midden site of El Mazo cave in northern Spain (Gutiérrez-Zugasti et al., 2013, 2014; Gutiérrez-Zugasti and González-Morales, 2014) have produced a sizeable amount of crustacean and echinoderm remains from a stratified sequence that covers an important part of the Mesolithic period. The assemblages recovered from each stratigraphic unit represent an opportunity to study the evolution in the exploitation of these species through time, with the potential to provide interesting new data, to reassess previous hypotheses, and in particular to shed light on the qualitative and social role of these resources.

In this paper we analyse the crustacean and echinoderm remains recovered from El Mazo cave. We use a number of methods, including quantitative and biometric analyses, to provide new information regarding shellfish collection and subsistence strategies. Discussion of the results focuses on the exploitation of these resources through time, shellfish collection patterns and the role of echinoderms and crustaceans both as food and as a social resource. The approach undertaken is intended to reveal more about the social organisation of hunter-fisher-gatherers and the way that these human groups interacted with the surrounding environment during the Mesolithic.

2. El Mazo cave: location, description and archaeological features

El Mazo cave is located in the village of Andrín, very close to the town of Llanes (Asturias, northern Spain) (Fig. 1). The eastern region of Asturias contains a characteristic topography represented by a coastal platform bounded towards the south by mountainous terrain. These mountains can be crossed relatively easily along rivers that flow in a north–south direction. The mountainous and coastal landscapes are dominated by karstic forms that include numerous caves and rockshelters. The current distance from the El Mazo to the coastline is around 1km. During the Mesolithic, this distance would have varied due to the rise in sea level. However, in the last 9000 years, this distance was no greater than 2.5km.

The site is situated in a hillside depression near a large doline. The archaeological deposit is located in the rockshelter, which is approximately 18m long and 7m deep (Fig. 2A). Two square metres were excavated (squares V15 and V16) in the area close to the walls of the rockshelter (inner test pit) during the 2009 and 2010 campaigns (Gutiérrez-Zugasti et

al., 2013, 2014) (Fig. 2B). Eight major stratigraphic units (SUs) were identified corresponding to shell midden deposits: SUs 100/101, 102, 103, 103.1, 104, 105, 106 and 107. Some of these units included other units or depositional events that were identified on the profiles at the end of the 2010 campaign (Fig. 2C). Unit 100/101 is a thick shell matrix formed by two different units of very similar characteristics. Units 102 and 106 are composed of shells mixed with carbonate (forming a crust), while unit 104 is a fire structure (hearth) mixed with shells. Unit 103 includes also unit 112 and 101.1, and they are defined as shell matrix alternating with charcoal layers; unit 103.1 is a shell matrix remnant only present in the eastern part of square V15; and unit 105 (characterized by a higher amount of sediment relative to shell) includes two additional units: 113 and 120 (both shell matrix). Finally, unit 107 (a thick shell matrix) is composed of additional units: 110, 111, 114 and 115. Below, unit 108 represents the base of the shell midden. In the outer area, in front of the rockshelter two square metres were excavated (outer test pit, squares S9 and S10) (Fig. 2B and D). A subsurface stratigraphic unit (SU 1) characterised by compact orange clay was identified in both squares. In square S10, below SU 1, there is a shell midden stratigraphic unit containing lithics, mammal bones and teeth, and charcoal (SU 3). The bottom of the test pit (SU 5) contains archaeologically sterile compact orange clay (see Gutiérrez-Zugasti and González-Morales, 2014; Gutiérrez-Zugasti et al., 2013, 2014 for a detailed explanation of the stratigraphy). All the shell midden units were dated to the Mesolithic (Table 1).

3. Material and Methods

The material used in this study comes from the inner test pit carried out in squares V15 and V16 and from the outer test pit dug in square S10. Remains of echinoderms and crustaceans from SUs 100/101 to 107 (in the latter only materials from square V16 were used) and from SU 3 were analysed. The whole sequence covers a duration of ~1300 cal years of the Mesolithic in northern Iberia.

For the analysis of the archaeological remains we used the methodology proposed by Gutiérrez-Zugasti (2009, 2011a) for echinoderms and crustaceans. The anatomical and taxonomic identification was carried out from specialized guides (Ingle, 1997) and comparative collections (personal and also the collection at the Museo Nacional de Ciencias Naturales, Madrid). For terminology, the nomenclature proposed by WoRMS (World Register of Marine Species, http://www.marinespecies.org/index.php) was used. Regarding

abundance estimators, NISP (number of identified specimens) and MNI (Minimum Number of Individuals) were calculated, together with their relative frequencies and their corresponding weights. Also we calculated the density of material (MNI) per dm^3 (10 cm x 10 cm x 10 cm) of sediment excavated.

For quantification we used a method based on the creation of categories of fragmentation based on disarticulation patterns of echinoderms and crustaceans. The remains of echinoderms were divided into the following categories of fragments: semi-pyramids (complete, COMSP; apical, AFSP; and basal, BFSP – separated into right and left); *rotulae* (COMR); tooth (complete, COMT; apical, AFT; and basal, BFT); epiphysis (COME, separated into right and left); compasses (COMC); buccal and shell fragments (BSF); and spines (SPF). For crustaceans, barnacle remains were separated into the following categories of fragmentation: Carina (complete, CC; apical, AFC; basal, BFC), Tergum (complete, CT; apical, AFT; basal, BFT; separated into right and left); and Scutum (complete, CS; apical, AFS; basal, BFS; separated into right and left). Finally, the fragment categories of crustaceans of the order Brachyura were derived from the dactylopods and propods (right, RD, RP; and left, LD, LP).

To calculate the MNI, first we calculated the minimum number of individuals for each category of fragment. In the case of categories with left and right remains, lateralization was taken into account when making the calculation with the exception of the epiphysis of echinoderms. Regarding categories with apical and basal remains, in each case we added complete remains plus the apical or basal, whichever was more abundant. The number of individuals obtained for each category was divided by five in the case of echinoderms, as that is the number of items from each category present in a sea urchin. For both echinoderms and crustaceans the category with the greatest number of remains was taken as the MNI. Fragmentation indices were calculated for each unit using the formula MNI/NISP. In the case of sea urchins, the spines were not taken into account for the calculation of these indices. For a detailed description of the fragment categories, the formulae for calculating the MNI and the fragmentation index, and for taphonomy methods followed here see Gutiérrez-Zugasti (2009 and 2011a).

It is important to note that the material was sieved using a 4 mm sieve; therefore some of the smallest diagnostic fragments of sea urchins may have been lost. However, since the same sieve size was used to analyse the material coming from the different stratigraphic units

throughout the deposit, the conclusions about the relative importance of these resources over time are consistent.

Biometric studies were also carried out on the remains in order to determine species size in an attempt to answer questions regarding selective harvesting and human pressure on exploitation. Urchin remains from the archaeological deposits are fragmented and it is not possible to measure the test diameter. However, the length of the semi-pyramid is correlated with the test diameter (Dupont et al., 2003; Ebert, 2001). An approach to the reconstruction of the overall size of the test was attempted using data from a modern reference collection from Brittany (France) (Dupont et al., 2003). Therefore for the purpose of this study the lengths of all semi-pyramids were measured. The barnacle plates (*tergum*, *scutum* and *carina*) were measured in an attempt to separate the adult individuals from the juveniles. It is known that adult individuals have plates measuring 10 mm or more (Álvarez-Fernández et al., 2010); this can be used to give an indication of whether the inhabitants of El Mazo cave were purposefully selecting the adult barnacles for consumption. Crab pincers (dactylopods and propods) were measured following the indications given by Gruet and Laporte (1996), where L is the total length of the claw and L1 is the length from the larger tubercle to the apex of the pincers. These measurements were transformed into overall carapace crab sizes using the regression equations obtained by the same authors using a modern reference collection from the island of Oléron (Atlantic coast of France). The overall size of each crab was calculated by obtaining the mean size between L and L1. For statistical analysis of measurements, we use the PAST (Paleontological Statistics) software package for education and data analysis (Hammer et al., 2001).

4. Results

4.1 The Sea Urchin *Paracentrotus lividus* (Lamarck, 1816)

The data clearly indicate that sea urchins were persistently exploited throughout the period of midden accumulation. The highest values for NISP, MNI and weight are found in unit 107, followed by units 100/101 and 105, and to a lesser extent in the rest of the units. When density values are taken into account, unit 107 still shows the higher numbers but there appear not to be significant differences between the remaining units (Table 2; Fig. 3). Therefore, a sharp decrease in the amount of sea urchins is apparent between the oldest unit

107 and the overlying units. Fragmentation is high and quite stable across the sequence while the percentage of burning is low (between 2.2 and 7.9%). Carbonate coating is considerable only in units 100/101 and 105.

The mean size of the semi-pyramids is quite homogeneous through the sequence, except in unit 107 where a smaller size was recorded (Table 3; Fig. 4). According to a Kruskall-Wallis test there are significant differences in mean sizes ($p < 0.01$) between unit 107 and most of the other units (which do not present differences between them, in all paired comparisons $p \geq 0.05$). A Shapiro-Wilk normality test was employed against all stratigraphic units in order to determine whether the size distribution from each stratigraphic unit resembles a normal distribution. The test reveals that small samples with low MNI are normal ($p > 0.05$) and this indicates collection of sea urchins of all sizes. However the larger samples with a high MNI in stratigraphic units 100/101, 105 and 107 are neither normal nor log-normal ($p < 0.001$) which in principle further suggests that there was some sort of selection process taking place during collection. Also, the shape of the distributions, with positive skewness in all cases (from 0.1 to 0.4 even in the case of normal distributions) except in unit 104 (-0.4), seems to imply a certain preference for the selection of larger sea urchins. A comparison with a modern reference collection (Dupont et al., 2003) allowed a preliminary reconstruction of the length of the semi-pyramids into the overall length of the tests. Results showed that the size of the sea urchin tests recovered at El Mazo ranged from ~27 to ~55 mm in all units, and only a few individuals from unit 100/101 reached larger sizes close to 60 mm.

4.2 The Goose Barnacle *Pollicipes pollicipes* (Gmelin, 1790)

The goose barnacles were also exploited throughout the period of midden accumulation. Only unit 100/101, located at the top of the sequence, shows a significant amount of barnacles, highly fragmented (0.204) and with burning traces (23%). The rest of the units present just a few individuals. This pattern is corroborated by density values (Table 4; Fig. 5). Given the limited number of remains present in most of the units, information on taphonomy should be taken cautiously.

Biometrical data from unit 100/101, the only one with enough numbers to conduct a statistical study, show that the mean size of the different plates was: 12.2 mm (*Scutum*), 13.3 mm (*Carina*), 15.6 mm (*Tergum*) (Table 5). A normality test (Shapiro-Wilk) was employed

against all different kinds of plate. The results indicated that all size distributions are normal ($p > 0.05$), which implies that there was nothing unusual in the collection and preservation of barnacles. The size distributions imply that both juveniles and adult barnacles were present within the deposit (Fig. 6). It is probable that the juvenile barnacles were not being targeted but rather that people were collecting bunches of barnacles, which would be expected to contain individuals of different sizes.

4.3 The Crabs Brachyura sp.

The highest values for NISP, MNI and weight are found in unit 100/101, followed by units 105 and 107. The rest of the units present smaller amounts of crab remains. However, density values show a different pattern with similar densities in all stratigraphic units, except in unit 107 where crabs are less represented than in other units (Table 6; Fig. 7). A homogeneous pattern of fragmentation (with indices around 0.5) and significant burning traces (between 25 and 77%) are present throughout most of the sequence, although an unusually high degree of fragmentation was recorded in unit 107.

Several species of crabs were exploited during the occupation of the shell midden. The most abundant was the Warty Xanthid crab *Eriphia verrucosa* (Forskål, 1775), followed by the Velvet Swimming crab *Necora puber* (Linnaeus, 1767), and the Marbled crab *Pachygrapsus mamoratus* (Fabricius, 1787). The Common shore crab *Carcinus maenas* (Linnaeus, 1758), the Brown crab *Cancer pagurus* Linnaeus, 1758, and the Furrowed Xanthid crab *Xantho* (Leach, 1814) were collected to a lesser extent (Table 7).

A biometrical analysis was conducted on the claws (dactylopods and propods) of the crabs. Due to the limited sample size available in most of the units only data from dactylopods (the most abundant anatomical part) recovered in units 100/101, 105 and 107 were used. For the same reason, we used the length L1 in our calculations as it presented a larger sample size. Results showed that the mean size and range of the dactylopods is very similar across the sequence (Table 8; Fig. 8A). In fact, results from a Kruskall-Wallis test showed no significant differences ($p > 0.5$) between units. A Shapiro-Wilk test used against the units showed that only crabs from unit 100/101 present a non-normal distribution ($p < 0.001$). However, marked positive skewness in all cases (between 0.9 and 1.6 even in the case of normal distributions), seems to imply a certain preference for the selection of larger crabs. In order to test if this pattern could be biased by the inclusion of different species of crabs in

the analysis, size distributions of dactylopods and propods from *Eriphia verrucosa* (the most abundant species) were transformed into overall size of the crabs using the regression equations proposed by Gruet and Laporte (1996). As in the previous case, only data from units with a significant sample size (100/101, 105 and 107) were used. Results showed a similar mean size (Table 9; Fig. 8B), although a Kruskall-Wallis test revealed slight differences between the distributions of units 100/101 and 105 (p = 0.02). A normality test showed that only unit 107 presents a normal distribution, although unit 105 shows a log-normal distribution, which means that data deviate only slightly from normality. Skewness was similar to that of the analysis of the claws of all species together in the three units (between 0.9 and 1.4), suggesting again the existence of a trend towards selection of larger sizes. Therefore, results obtained from *Eriphia verrucosa* confirm the pattern found when analyzing all crab species together.

5. Discussion

5.1 Time trends

The results show that sea urchins, goose barnacles and crabs were collected during the whole time period represented in the stratigraphy of El Mazo. These resources have been found in many other Mesolithic coastal sites along the Cantabrian coastline (Álvarez-Fernández, 2011; Gutiérrez-Zugasti, 2011a; Álvarez-Fernández et al., 2013), although in limited amounts in most of the sites. The importance of each resource in the sequence of El Mazo depends on the abundance estimator used, although sea urchins from unit 107 present the highest intensity of exploitation regardless of the estimator. The marked differences in the exploitation of sea urchins and crabs obtained in units 100/101 and 105 with respect to the other units (except unit 107), when the MNI is used, are diluted when taking into account the densities (MNI/dm^3). Only the differences in the representation of the goose barnacles in different units remain similar regardless of the estimator used. Given the characteristics of the stratigraphic units 100/101, 105 and 107, in which a much larger volume of sediment was excavated, the densities seem to give a more realistic reflection of the evolution of exploitation patterns over time. Nevertheless, the interpretation of density values should be taken as preliminary, since sedimentation rates for the site remain still unknown. Sea urchins are clearly predominant in unit 107 but they follow a very similar pattern through the rest of

the sequence, although there seems to be a slight decrease in their exploitation through time. Crab figures behave in a similar way, with similar quantities throughout the sequence, except in unit 103.1 where they are the most abundant. It is further interesting to note that in stratigraphic unit 100/101 there is a substantial increase in the quantity of goose barnacles in relation to older units. The increase of goose barnacles at the end of the Mesolithic and in later periods has been identified in other sites of northern Spain such as Mazaculos II (Gutiérrez-Zugasti and González-Morales, 2010) and J3 (Álvarez-Fernández et al., 2013). Environmental factors may have played a role, as its current geographic distribution between northern France and Senegal suggests that the goose barnacle *P. pollicipes* prefers temperate climates. This means that this species would not be present in the region during glacial periods. However, recent studies show that the Cantabrian coast could have acted as a glacial refugium for this species (Campo et al., 2010), although the archaeological record does not show any evidence for the human exploitation of goose barnacles at that time (Álvarez-Fernández, 2011; Gutiérrez-Zugasti, 2009). This scenario suggests two possible explanations: 1) hunter-fisher-gatherers did not exploit goose barnacles during the Upper Palaeolithic, or 2) populations of goose barnacles living in glacial refugia were small and confined to certain locations within the region. According to ecological data goose barnacles inhabit low and exposed shores and these areas appear to have been exploited in a limited way during the Upper Palaeolithic and with much more intensity during the Mesolithic, based on decreasing shellfish size and increasing collection of molluscs (mainly limpets) from lower and exposed shores (Gutiérrez-Zugasti, 2011b). However, despite the fact that the Mesolithic started in the region at ~10.5 cal kys, current evidence shows that people did not begin to exploit goose barnacles in a systematic manner until ~8 cal kys. Thus, it is likely that after that date, and due to the amelioration of the climate, there was an influx of these species in northern Spain from refugia. Given that the sea urchin *P. lividus* and some of the crabs (e.g. *Eriphia verrucosa*, *Pachygrapsus marmoratus*) found at El Mazo also prefer warmer climates, the introduction of these organisms in the human diet could have followed a similar pattern but with differences in timing depending on specific habitat tolerances. The first evidence of systematic exploitation of sea urchins appears during the late Magdalenian (~16–13 cal kys) and Azilian (~13–10 cal kys) at Santa Catalina cave (Gutiérrez-Zugasti, 2014), while the collection of crabs was not substantial until the Mesolithic (from ~9 cal kys) as evidenced not only at El Mazo but also at the site of Arenillas (Gutiérrez-Zugasti, 2011a).

5.2 Shellfish collection patterns

The characteristics of the shell midden at El Mazo, which includes not only the marine faunas presented here but also large amounts of molluscs, mainly limpets and topshells (García-Escárzaga et al., 2015), as well as other human-made artefacts and features (Gutiérrez-Zugasti et al., 2014), suggest a clear human origin of the taphocenoses. In addition, the distance from the site to the shore during the occupation (~2.5km during the earliest Mesolithic settlement and ~1km at the top of the shell midden) was large enough to rule out the possibility that other animals, such as otters or birds, were responsible for the accumulation of marine resources in the midden. Therefore, the diversity, abundance and ecology of species identified in the assemblage of crustaceans and echinoderms from El Mazo are able to provide insights into the way that human groups used these resources and the social behaviour involved in their harvesting.

Collection of shellfish is usually carried out in the intertidal (i.e. the area under the influence of the tides). Echinoderms and crustaceans usually inhabit the intertidal but also the subtidal (i.e. the area never exposed by the tides, extending from shallow waters down to ~100m) so they could also have been picked from deeper waters using spears, creels, fish traps or dip nets. As an example, there are accounts of the Tlingit collecting sea urchins using some of these aforementioned techniques (Moss 1993; and see also Waselkov, 1987 for similar practices described in other ethnographic accounts). However, the shellfish exploitation pattern, similar to that of other Mesolithic sites in Atlantic Europe (Gruet, 2002; Dupont, 2006; Dupont and Gruet, 2005), appears to indicate that the inhabitants of El Mazo cave focused on the rocky intertidal zone when exploiting sea urchins and crustaceans.

Sea urchins are particularly common in the subtidal, down to depths of 10–20 m but also in intertidal pools, mainly on solid rocks, boulders and in seagrass meadows. Densities usually range from a few to a dozen individuals per square metre, but very high densities (over 50 to 100 ind. m^{-2}) may occur (Boudouresque et al., 2013). Current research in the study area demonstrates the existence of populations in intertidal locations, and also shows that the size of these intertidal sea urchins (ranging from 30 to 43 mm) is typically smaller than for those that live in the subtidal zone (from 55 to 70 mm) (González-Irusta et al., 2010). The size of the sea urchins recovered from El Mazo cave usually ranges from 30 to 55 mm in all units suggesting that they were most probably gathered from intertidal locations at low tides. Campbell (2008) found similar size distributions in the Roman site of Le Yaudet

(France), but he also found that two different populations, with smaller and larges sizes respectively, were exploited. The smaller population would have been collected in low intertidal shores or rock pools. However, a comparison with the size of modern subtidal populations from a coastline located close to the site revealed that the larger population from Le Yaudet was collected at or just below the low tide line rather than at fully subtidal locations.

Goose barnacles in the region form dense aggregates over the wave-exposed rocky shore of the lower intertidal zone (Bald et al., 2006). Lower and exposed shores were heavily exploited for molluscs during the Mesolithic (Gutiérrez-Zugasti, 2011b), so goose barnacles were probably picked during excursions to the lower wave-beaten rocks.

All crabs identified at El Mazo are able to inhabit the intertidal and subtidal zones, except *P. marmoratus*, which is an exclusively intertidal species. Nevertheless, migration from subtidal to intertidal areas during the high tide is common for crabs. For example, two different populations have been observed amongst species of *C. pagurus*, *C. maenas* and *N. puber*. Some individuals of these species usually migrate in and out of the intertidal zone with the tidal cycle whilst others inhabit the intertidal permanently (da Silva, 2014). Subtidal individuals are usually bigger than those inhabiting the intertidal (da Silva, 2010, 2014). The size of the crabs *Eriphia verrucosa* from a modern reference collection obtained in an intertidal location in Atlantic France ranged from 35 to 65 mm (Gruet and Laporte, 1996), a very similar range to that presented by the assemblages found at El Mazo (from 27 to 65 mm, except one individual from unit 107 that reached 75 mm, see Fig. 8B). In addition, crabs colonising the intertidal during the high tide can get trapped in intertidal rock pools and then be collected by hand or by using some kind of trap or implement during the low tide. The absence of exclusively subtidal species, such as for example *Maja squinado* (Herbst, 1788), may also reflect the fact that people did not forage into the sublittoral zone. Therefore, crabs collected by Mesolithic people were most likely collected in the intertidal. It is noteworthy that most of the species found at El Mazo have a nocturnal activity, suggesting that collection could have been performed at night during spring low tides.

The ecological data gathered on the echinoderms and crustaceans present within the midden deposits at El Mazo demonstrate that the majority of these species would have had year-round shoreline availability. Sea urchins and goose barnacles could have been collected year round from the intertidal zone (González-Irusta et al., 2010; Sestelo and Roca-Pardiñas, 2011). However, the meat yield of the sea urchins is conditioned by the reproductive cycle

which is at the same time determined by seasonal factors, such as temperature, photoperiod and nutritional stage (González-Irusta et al., 2010). Before gametogenesis, the sea urchin gonads (i.e. the edible part) increase in size by storing nutrients, such as proteins, carbohydrates and lipids. As gametogenesis proceeds, the stored nutrients get depleted and the gonads decrease in size (Unuma, 2002). Gonadal development of *P. lividus* in northern Iberia starts in autumn and continues until early spring (González-Irusta et al., 2010). Therefore, autumn and winter would be the best seasons for sea urchin collection and consumption, whilst meat yield during the rest of the year would be negligible. All the identified crabs inhabit the intertidal and subtidal zones but the adult females of several of the species have been reported to migrate to the subtidal for several months after mating in shallow waters (Howard, 1982). Biological studies present different opinions about the availability of crabs during winter. Some studies state that both adult shore crabs (*C. maenas*) and adult edible crabs (*C. pagurus*) are rarely found on the shore during winter as they migrate to deeper waters, although juvenile edible crabs occupy intertidal waters year round (Brown and Bennet, 1980; Pickard and Bonsall 2009; Crothers 1968). Other studies point out that shore crabs *C. maenas* and *C. pagurus* are present throughout the year with similar densities in all seasons (da Silva, 2014). During the spring months the Warty Xanthid crab (*Eriphia verrucosa*) migrates to shallow waters at depths of <1m, and thus it would be more difficult to catch. Therefore it was probably collected in some of the other seasons. According to this picture, establishing the season of capture of these organisms is a complicated task using only ecological data, and other methods should be implemented in the future to obtain additional information on this topic (see for example Coutts and Jones, 1974 for a method to derive seasonality information from sea urchins).

As with molluscs, the collection of sea urchins, goose barnacles and crabs could have been a communal activity shared by both adults and children alike. Many ethnographic accounts refer to collection of shellfish as an activity carried out by women and children, although men can also participate sometimes (Bird and Bliege Bird, 2000; Matthews, 1991; Meehan, 1982; Moss, 1993, 2013; Waselkov, 1987). Thus, adults and children could easily have picked sea urchins from rock pools at low tides either by hand or using dip nets. Modern day goose barnacle collection is male dominated possibly due to the strength required to operate on the rocks in the hostile waters in which they are collected. However, the difficulty in collecting barnacles today is related to intensive exploitation for commercial purposes (Bald et al., 2006; Molares and Freire, 2003), which means that it is only possible to find this

species in areas that are extremely difficult of access. It is likely that during the Mesolithic it was possible to collect barnacles in more accessible areas of the lower intertidal (Dean, 2010) and this activity could have been carried out by women and children as well. Despite being fast-moving (and sometimes dangerous) organisms, crabs could have been collected by hand or by using some tool in rock pools during the low tide by women and children. An ethnographic account written by Gregor (1891) speaks of how children collected crabs from the species *Carcinus maenas* and *Cancer pagurus* whilst playing, attesting that children could have been part of the harvesting process.

5.3 The role of crustaceans and echinoderms as a food resource

The increased exploitation of goose barnacles, sea urchins and crabs in northern Spain has been argued to be related to the overall intensification of marine resources that started at the end of the Upper Palaeolithic and reached a maximum during the Mesolithic period (Gutiérrez-Zugasti 2011b). This intensification implies the exploitation of a wider range of available marine resources, and environmental changes caused by Holocene warming most likely also contributed to this widening availability. In this framework, echinoderms and crustaceans obviously provided nutritional value for the inhabitants of El Mazo and would have supported dietary requirements. But it is necessary to assess the role of these resources more closely as a food source and to determine their social value.

First, these were not the only food types available to the inhabitants of El Mazo; other remains discovered point to the consumption of large amounts of molluscs such as limpets *Patella vulgata* Linnaeus 1758, *Patella depressa* Pennant 1777 and *Patella ulyssiponesis* Gmelin, 1791, topshells *Phorcus lineatus* (Da Costa 1778), mussels *Mytilus galloprovincialis* Lamark 1819, and other marine and terrestrial resources (Gutiérrez-Zugasti et al. 2013). Second, the MNI and densities (MNI/dm^3) of sea urchins, goose barnacles and crabs are quite low, especially when compared to the amount of molluscs recovered (García-Escárzaga et al., 2015). Although taphonomic and methodological issues could be responsible for the low numbers, that does not seem to be the case at El Mazo. Sea urchins and goose barnacles have probably not suffered important problems of differential preservation at El Mazo since they have strong carapaces/plates and they are only slightly affected by taphonomic processes. Besides, shell middens are known to have neutral or slightly alkaline pH due to the high content of calcium carbonate of the shells, which results in much better preservation of

mineral components (Bernstein, 1993). However, some differential preservation could have affected crabs, although it was probably limited to the carapace (not used in MNI calculations) and not to the claws, which are thicker and stronger (and they are the most abundant anatomical element from crabs preserved in shell middens). The use of more precise recovery techniques (smaller mesh screens) have been proved to increase the significance of sea urchins in shell middens but even so they still reach no more than 10% of the MNI (García-Escárzaga et al., 2015; García-Escárzaga et al., in press).

In addition, biometrical evidence indicates that the inhabitants of El Mazo cave were selecting the larger sized sea urchins and also that they were not intensively collecting them as there is no evidence of a decrease in the size through time. In fact, the smallest mean size was detected in the older unit 107, so that if small size is an indicator of intensive exploitation, this occurred only at the beginning of the sequence rather than as the cumulative outcome of a progressive time trend. Size distribution of goose barnacles indicates a lack of size selection, probably due to the collection strategy followed, since catching this species involves the collection of grab samples, which would be expected to contain individuals of different sizes. Comparison with data from other sites and modern samples (Álvarez-Fernández et al. 2013) also shows that goose barnacles were not intensively collected. Regarding the crabs, similar mean sizes have been recorded throughout the sequence and size distributions suggest the existence of selection of larger specimens. This pattern also indicates that the collection of crabs was not intensive.

According to this data, gathering echinoderms and crustaceans was not an activity carried out with such intensity as for example the collection of molluscs, which suggests, from a quantitative perspective, that these resources were not so important in Mesolithic hunter-fisher-gatherer diet. Previous research has followed this interpretation based on the limited MNIs recorded in shellfish assemblages (Gutiérrez-Zugasti, 2011a), arguing that these were probably gathered as part of an opportunistic collection strategy while gathering molluscs (which would reinforce the hypothesis of these resources as being of incidental value) as some scholars have stated (Álvarez-Fernández et al., 2010; Gutiérrez-Zugasti, 2011a; Losey et al., 2004). Nevertheless, they were systematically targeted over time which implies some significance for human populations. And the same interpretation is supported by information from other sites in Atlantic Europe (Dupont et al., 2009; Gruet and Laporte, 1996; Milner, 2009a; Pickard and Bonsall, 2009; Dean, 2010; Gutiérrez-Zugasti, 2014; Gutiérrez-Zugasti et al., 2011), which show the occurrence of a persistent exploitation pattern

from the Late Palaeolithic to the Neolithic. Therefore, if opportunism is understood as taking advantage of favourable conditions when they arise, meaning that echinoderms and crustaceans were not intentionally sought after but simply collected casually and intermittently during the course of molluscs gathering or other activities, we consider that the pattern derived from El Mazo and other sites in Atlantic Europe does not describe an opportunistic behaviour but rather a more stable and continuous one. This implies that these shellfish species were targeted and gathered intentionally. But even if the collection and consumption of these resources was part of a planned strategy, their relatively small quantities prompt us to pose the additional question as to whether they were gathered exclusively as a food resource to be consumed during daily subsistence, or had some additional value.

It is important to remember that food means more than just eating as part of a diet to satisfy nutritional needs; food consumption can also provide satisfaction through taste (e.g. goose barnacles and some crab species, such as *Eriphia verrucosa* and *Cancer pagurus* are very esteemed nowadays for their flavour) and even more, it can play an important role in the social life of human groups. Quantification of food remains and the application of 'scientific' methodologies have often been viewed with suspicion as necessarily leading to a narrowly economic interpretation of the data. However, as the original ethnoarchaeological work in Australia demonstrated in relation to marine molluscs (Bailey, 1975; Meehan, 1977, 1982), systematic quantification can actually open up greater diversity of interpretations by demonstrating that a food resource that makes a relatively minor dietary contribution must necessarily have some additional significance if quantification also demonstrates persistent and continuous exploitation of such a resource over long periods of time. That same conclusion emerges from our quantitative and statistical analysis of the El Mazo remains.

Resources are transformed into food and eaten, not only for their calories but also for pleasure and the maintenance of social relations (Milner, 2005). For example, the studies by Moss (2013) on the Tlingit (Alaska) and the Kwakwaka'wakw (British Columbia) showed that the social and symbolic meanings of shellfish for these people reflect practices and ideas structured by gender, social status and life stage differences. Sea urchins, goose barnacles and crabs may not be a substantial part of the hunter-fisher-gatherer diet but they do however make a nutritionally valuable supplement (Edwards and Early, 1967; Yenko, 2011) and were perhaps valued as a delicacy due to their flavour (Charles et al., 2004; Dean, 2010).

Ethnographic information from the Northwest Coast of North America reveals that barnacles played a variety of dietary roles, ranging from emergency food to feast food (see examples in Moss and Erlandson, 2010). If these resources were emergency foods they would be expected to appear in the shell assemblages occasionally and not systematically as is the case at El Mazo and other sites in Atlantic Europe. An alternative explanation from a qualitative perspective suggests that they could have been a delicacy collected to share with the group (or with other groups) during daily meals or during the celebration of feasts, which would give an important social value to these resources. But tracing the evidence of feasts in shell middens (and in hunter-gatherer societies in general, see Hayden, 2001) can be a difficult challenge. A good range of activities has been identified at El Mazo, supporting the hypothesis of the site being used as habitation camp for daily subsistence activities. However, we cannot rule out the possibility that the occupation of El Mazo (and many other Asturian Mesolithic sites) could have mixed residential settlement with occasional feasts or special meals. The occurrence of feasts is attested in ethnographic accounts for many modern hunter-gatherer groups (Dietler and Hayden, 2001), and they should certainly have played a role in prehistoric societies. Evidence of using shells in feastings or in social/ritual activities (beyond the commonly recorded use of shells as personal ornaments) has also been identified in archaeological contexts (Hildebrandt et al., 2009; Claassen, 2010; Thompson and Andrus, 2011; Klokler, 2014). The existence of aggregation sites, where social and ritual activities were carried out, has been proposed for the Upper Palaeolithic in the region (Conkey, 1980), and despite the reorganization of subsistence, social and ritual activities that took place with the arrival of the Mesolithic, it is supposed that the last hunter-fisher-gatherers were in need of social strategies to handle relationships with neighbouring groups. The abundance of Mesolithic shell midden sites in northern Iberia (mainly in the Asturian area, see Clark, 1983; González-Morales, 1982) suggests the existence of considerable population numbers in the region, and therefore the need for structured social relationships between groups. An example of symbolic behaviour can be found in the presence of shell beads at El Mazo and the nearby shell midden of El Toral III, attesting to the existence of circulation networks for ornamental objects and inter-group social relationships associated with exchange (Rigaud and Gutiérrez-Zugasti, in press). The territoriality argued for the Asturian area during the Mesolithic (Arias, 2005), with different human groups occupying coastal and inland environments, would have triggered the need for more intense and frequent social arrangements of this sort. In a context like this, shellfish (and especially crustaceans and echinoderms, resources not so easily

obtainable and perhaps therefore with a heightened rarity value) could have played an important role. Unusually high densities of sea urchins such as those of unit 107 at El Mazo or in the Late Magdalenian and Azilian levels from Santa Catalina cave (Gutiérrez-Zugasti, in press) could have been related to the use of these resources in social encounters.

In summary, whether these resources were collected to be used during social practices or during common everyday meals is a question that we cannot answer definitely with the data presented here. However, we think that there is evidence enough to show that these non-molluscan shellfish resources were intentionally sought after, and hence to reject opportunistic behaviour as a sufficient explanation for their presence in Mesolithic shell middens from Atlantic Europe. Opposing the common interpretation of echinoderms and crustaceans as opportunistic and relatively insignificant food resources, we propose that the social, symbolic and cultural aspects of shellfish collection and consumption need to be considered (see Milner, 2009). This perspective highlights the possible social importance of some shellfish for Mesolithic hunter-fisher-gatherers in northern Iberia, a topic usually neglected. Obviously this point of view needs to be considered also for (and in conjunction with) molluscs, the most abundantly preserved shellfish resource in Mesolithic shell middens, to have a better understanding of the whole picture. Current excavations at El Mazo are generating new data that will contribute to a better understanding of the role of these resources in Mesolithic societies.

Conclusions

Echinoderms (sea urchins) and crustaceans (goose barnacles and crabs) were present throughout all of the stratigraphic units at El Mazo (from 8.9 to 7.6 cal kys). The procurement pattern is quite stable through time although sea urchins are especially abundant at the bottom of the sequence and goose barnacles only appear in considerable numbers at the top. This continuity in the exploitation pattern suggests that they were a regular, stable food source. The onset of the exploitation of these resources in northern Iberia was different for each type of resource, and this is probably related to the differential onset of favourable climate conditions for their development. The limited numbers of echinoderms and crustaceans compared to molluscs, the lack of size decrease (except in sea urchins from unit 107) and their collection in the intertidal suggest that collection of these resources was carried out in general with low intensity. The inhabitants of El Mazo cave focused on the rocky intertidal

zone (including rock pools and wave beaten areas), and according to ethnographic information it is likely that women and children were primarily responsible for the collection of these resources, although participation of men cannot be ruled out. Although due to their general year-round availability, echinoderms and crustaceans could have been collected throughout the year, data on sea urchin meat yield and availability of some crab species suggest a seasonal collection of these resources.

The exploitation pattern described above has usually been interpreted from a quantitative perspective, implying that they were opportunistic resources contributing to the survival of the group. However, given the pattern of continuous exploitation exhibited by these resources in northern Iberia and other areas of Atlantic Europe, they could be interpreted from a qualitative perspective, and so they should be considered as stable resources with a significant social value. Therefore, we propose that they could have been sought after as delicacies involved in the celebration of social activities (at group and/or inter-group level), which would increase their social significance and general importance. However, for the moment this is a hypothesis to be tested in the future, in conjunction with the study of molluscs and other activities carried out at the site.

Acknowledgements

This research was part of the projects HAR2013-46802-P and HAR2014-55722-P, both funded by the Ministry of Economy and Competitiveness of the Spanish Government. IGZ is a Juan de la Cierva researcher (Research Programme of the Spanish Government), AGE is supported by a grant from the Government of Cantabria. The authors would like to thank Peter Hogarth and Hannah Russell for their help with the identification of crabs, the Museo Nacional de Ciencias Naturales (Madrid) for facilitating access to their crab collections, the Department of Archaeology, University of York, for making available laboratory facilities for some of the analyses, and Lucía Agudo, Alejandro García-Moreno and Luis Teira and for their help with figures.

References

Álvarez Fernández, E., 2007. La explotación de los moluscos marinos en la Cornisa Cantábrica durante el Gravetiense: primeros datos de los niveles E y F de La Garma A (Omoño, Cantabria). Zephyrus LX, 43–58.

Álvarez-Fernández, E., 2011. Humans and marine resource interaction reappraised: Archaeofauna remains during the late Pleistocene and Holocene in Cantabrian Spain. Journal of Anthropological Archaeology 30, 327–343.

Álvarez-Fernández, E., Ontañón-Peredo, R., Molares-Vila, J., 2010. Archaeological data on the exploitation of the goose barnacle *Pollicipes pollicipes* (Gmelin, 1790) in Europe. Journal of Archaeological Science 37, 402–408.

Álvarez-Fernández, E., Barrera, I., Borja, A., Fernández, M.J., Iriarte, M.J., Arrizabalaga, A., 2013. Biometric analysis of the stalked barnacle *Pollicipes pollicipes*, at a Holocene archaeological site in Jaizkibel (Basque Country, northern Spain). The Holocene 23, 1373–1380.

Arias, P., 2006. Determinaciones de isótopos estables en restos humanos de la región Cantábrica: aportación al estudio de la dieta de las poblaciones del Mesolítico y el Neolítico. Munibe 57 (3), 359–374.

Bald, J., Borja, Á., Muxika, I., 2006. A system dynamics model for the management of the gooseneck barnacle (*Pollicipes pollicipes*) in the marine reserve of Gaztelugatxe (Northern Spain). Ecological Modelling 194, 306–315.

Bailey, G.N., 1975. The role of molluscs in coastal economies: the results of midden analysis in Australia. Journal of Archaeological Science 2, 45–62.

Bailey, G.N., Hardy, K., Camara, A., 2013. Shell Energy: Mollusc Shells as Coastal Resources. Oxbow Books, Oxford.

Bar-Yosef, D., 2005. Archaeomalacology: molluscs in former environments of human behaviour. Proceedings of the 9th ICAZ Conference, Durham, 2002, Oxbow Books, Oxford.

Bernstein, D.J., 1993. Prehistoric subsistence on the southern New England coast. The record from Narragansett Bay. Academic Press Inc., San Diego.

Bird, D.W., Bliege Bird, R., 2000. The ethnoarchaeology of juvenile foragers: shellfishing strategies among Meriam children. Journal of Anthropological Archaeology 19, 461–476.

Boudouresque, C.F., Verlaque, M., John, M.L., 2013. Chapter 21 – *Paracentrotus lividus*. In: Sea Urchins: Biology and Ecology, Developments in Aquaculture and Fisheries Science, Elsevier, pp. 297– 327.

Brown, C.G., Bennett, D.B., 1980. Population and catch structure of the edible crab (Cancer pagurus) in the English Channel. Journal du Conseil 39, 88–100.

Campbell, G., 2008. Wrong phylum: A neophyte archaeomalacologist´s experiences in analyzing a European Atlantic sea urchin assemblage. Archaeofauna 17, 77–90.

Campo, D., Molares, J., Garcia, L., Fernandez-Rueda, P., Garcia-Gonzalez, C., Garcia-Vazquez, E., 2010. Phylogeography of the European stalked barnacle (*Pollicipes pollicipes*): identification of glacial refugia. Marine Biology 157, 147–156.

Charles, B., Cooke, V., Grinnell, E., Morganroth Iii, C., Morganroth, L.M., Peterson, M., Riebe, V., Smith, A., Wray, J., 2004. "When the Tide is Out". An Etnographic Study of Nearshore Use on the Northern Olympic Peninsula. In: Shaffer, A., Wray, J. (Eds.), Native American Traditional and Contemporary Knowledge of the Northern Olympic Peninsula Nearshore. Olympic Peninsula Intertribal Cultural Advisory Committee, Coastal Watershed Institute, pp. 8–41.

Claassen, C., 1998. Shells, Cambridge University Press, Cambridge.

Claassen, C., 2010. Feasting with Shellfish in the Southern Ohio Valley. Archaic Sacred Sites and Rituals. The University of Tennessee Press, Knoxville.

Claassen, C., 2013. Invertebrates on San Salvador Island, Bahamas: The Use of Shellfish as Bait. In: Bailey, G.N., Hardy, K., Camara, A. (Eds.), Shell Energy: Mollusc Shells as Coastal Resources, Oxbow Books, Oxford, pp. 59–67.

Clark, G.A., 1983. The Asturian of Cantabria. Early Holocene Hunter-Gatherers in Northern Spain, University of Arizona Press, Tucson.

Conkey, M.W., 1980. The identification of prehistoric hunter-gatherer aggregation sites: the case of Altamira. Current Anthropology 21 (5), 609–630.

Coutts, P.J.F., Jones, K.L., 1974. A proponed method for deriving seasonal data from the echinoid Evechinus chloroticus (Val.), in archaeological deposits. American Antiquity 39 (1), 98-102.

Crothers, J.H., 1968. The biology of the shore crab *Carcinus maenas*: the background, anatomy, growth and life history. Field Studies 2, 407–434.

Dean, R., 2010. Delicacy or Desperation? Eating Peduncular Barnacles in Neolithic Portugal. Journal of Ethnobiology 30, 80–91.

Dietler, M., Hayden, B., 2001. Feasts. Archaeological and Ethnographic Perspectives on Food, Politics and Power. The University of Alabama Press, Tuscaloosa.

Dupont, C., 2006. La malacofaune des sites mésolithiques et néolithiques de la façade atlantique de la France. Contribution à l´economie et à l´identité culturelle des groupes concernés., BAR International Series 1571, Archaeopress, Oxford.

Dupont, C., Gruet, Y., 2005. Malacofaune et crustacés marins des amas coquilliers mésolithiques de Beg-an-Dorchenn (Plomeur, Finistère) et de Beg-er-Vil (Quiberon, Morbihan). In: Marchand, G., Tresset, A. (Eds.), Unité et diversité des processus de néolithisation sur la façade atlantique de l'Europe (6e-4e millénaires avant J.-C.). Table ronde de Nantes 26-27 avril 2002, *Mémoire de la Société Préhistorique Française*, pp. 139–161.

Dupont, C., Álvarez Fernández, E., Gruet, Y., 2008. Un nouveau crustacé identifié sur le site gaulois de Port Blanc (île d'Hoedic, Morbihan): le pouce-pied *Pollicipes pollicipes* (Gmelin, 1790). Bulletin de l'A.M.A.R.A.I. 21, 17– 23.

Dupont, C., Gruet, Y., Leroy, A., Marchand, G., Pailler, Y., Sparfel, Y., 2003. Le site préhistorique de Beniget-3 (Le Conquet, Finistère). Bulletin de l'A.M.A.R.A.I. 16, 5-24.

Dupont, C., Tresset, A., Desse-Berset, N., Gruet, Y., Marchand, G.G., Schulting, R., 2009. Harvesting the seashores in the Late Mesolithic of Northwestern Europe: a view from Brittany. Journal of World Prehistory 22, 93–111.

Dupont, C., Marchand, G., Carrión Marco, Y., Desse-Berset, N., Gaudin, L., Gruet, Y., Marguerie, D., Oberlin, C., 2010. Beg-an-Dorchen (Plomeur, Finistère): une fenêtre ouverte sur l'exploitation du littoral par les peuples mésolithiques du VI millénaire dans l'Ouest de la France. Bulletin de la Société Préhistorique Française 107, 227–290.

Ebert, T.A., 2001. Growth and survival of post-settlement sea urchins. In: Lawrence, J.M. (Ed.), Edible Sea Urchins: Biology & Ecology. Developments in Aquaculture and Fisheries Science 32, Elsevier, Amsterdam, pp. 79–102.

Edwards, E., Early, J.C., 1967. Catching, Handling and Processing Crabs. Torry Research Station, Ministry of Technology, http://www.fao.org/wairdocs/tan/x5905e/x5905e01.htm#Introduction.

García-Escárzaga, A., Gutiérrez-Zugasti, I., González-Morales, M.R., 2015. Análisis arqueomalacológico de la unidad estratigráfica 108 del conchero mesolítico de El Mazo (Llanes, Asturias): conclusiones socio-económicas y metodológicas. In: Gutiérrez-Zugasti, I., Cuenca-Solana, D., González-Morales, M.R. (Eds.), La Investigación Arqueomalacológica en la Península Ibérica: Nuevas Aportaciones, Ed. Nadir, Santander, pp. 77-89.

García-Escárzaga, A., Gutiérrez-Zugasti, I., González-Morales, M.R., Cobo-García, A., In press. Shells and Humans: Molluscs and Other Coastal Resources from the Earliest Human

Occupations at the Mesolithic Shell Midden of El Mazo (Asturias, Northern Spain). Papers from the Institute of Archaeology.

González-Irusta, J.M., Goñi De Cerio, F., Canteras, J.C., 2010. Reproductive cycle of the sea urchin *Paracentrotus lividus* in the Cantabrian Sea (northern Spain): environmental effects. Journal of the Marine Biological Association of the United Kingdom 90, 699–709.

González Morales, M.R., 1982. El Asturiense y otras culturas locales. La explotación de las áreas litorales de la región cantábrica en los tiempos epipaleolíticos, Monografía Nº 7, Centro de Investigación y Museo de Altamira, Santander.

Gregor, W., 1891. The Scotch fisher child. Folklore 2, 73–86.

Gruet, Y., 2002. Reconnaissance des quelques espèces communes de Crustacés (balanes et crabes): application au site Mésolithique de Beg-er-Vil (Morbihan, France). Revue d'Archéometrie 26, 125–139.

Gruet, Y., Laporte, L., 1996. Crabes pêchés au Néolithique Final à Ponthezières: identification des modes de pêche et application de la métrique. Actes du colloque de Périgueux, 1995, Supplément de la Revue d'Archéometrie, pp. 197-201.

Gutiérrez Zugasti, F.I., 2009. La explotación de moluscos y otros recursos litorales en la región cantábrica durante el Pleistoceno final y el Holoceno inicial, PUbliCan, Ediciones de la Universidad de Cantabria, Santander.

Gutiérrez-Zugasti, F.I., 2011a. The use of echinoids and crustaceans as food during the Pleistocene-Holocene transition in Northern Spain: methodological contribution and dietary assessment. Journal of Island and Coastal Archaeology 6, 115–133.

Gutiérrez-Zugasti, I., 2011b. Coastal resource intensification across the Pleistocene-Holocene transition in Northern Spain: evidence from shell size and age distributions of marine gastropods. Quaternary International 244, 54–66.

Gutiérrez Zugasti, I., 2014. El aprovechamiento de recursos costeros durante el Tardiglaciar: los equinodermos y crustáceos de la cueva de Santa Catalina (Lekeitio, Bizkaia). In: Berganza, E., Arribas, J.L. (Eds.), La Cueva de Santa Catalina (Lekeitio): La intervención arqueológica. Restos vegetales, animales y humanos. Kobie, Excavaciones Arqueológicas en Bizkaia 4, Diputación Foral de Bizkaia, Bilbao, pp. 151-160.

Gutiérrez-Zugasti, F.I., González-Morales, M.R., 2010. New data on Asturian shell midden sites: the cave of Mazaculos II (Asturias, Northern Spain). In: Álvarez-Fernández, E., Carvajal-Contreras, D.R. (Eds.), Not only Food: Marine, Terrestrial and Freshwater Molluscs in Archaeological Sites: Proceedings of the 2nd Meeting of the ICAZ Archaeomalacology Working Group (Santander, February 19th-22th 2008) Aranzadi Zientzia Elkartea, Donostia, pp. 110–118.

Gutiérrez Zugasti, I., González Morales, M.R., 2014. Intervención arqueológica en la cueva de El Mazo (Llanes, Asturias): campañas de 2009, 2010 y 2012. Excavaciones Arqueológicas en Asturias 2007-2012, Consejería de Cultura y Deporte del Gobierno del Principado de Asturias, Oviedo, pp. 159–167.

Gutiérrez Zugasti, I., Andersen, S., Araújo, A.C., Dupont, C., Milner, N., Soares, A.M.M., 2011. Shell midden research in Atlantic Europe: state of the art, research problems and perspectives for the future. Quaternary International 239, 70-85.

Gutiérrez-Zugasti, I., González-Morales, M.R., Cuenca-Solana, D., Fuertes, N., García-Moreno, A., Ortiz-Menéndez, J.E., Rissetto, J., Torres, T.D., 2013. Back to the Asturian: first results from the Mesolithic shell midden site of El Mazo (Asturias, Northern Spain). In: Daire, M.Y., Dupont, C., Baudry, A., Billard, C., Large, J.M., Lespez, L., Normand, E., Scarre, C. (Eds.), Anciens peuplements littoraux et relations Homme/Milieu sur les côtes de l'Europe Atlantique / Ancient Maritime Communities and the Relationship between People and Environment along the European Atlantic Coasts, BAR International Series 2570, Archaeopress, Oxford, pp. 483–490.

Gutiérrez-Zugasti, I., González-Morales, M.R., Cuenca-Solana, D., Fuertes, N., García-Moreno, A., Ortiz-Menéndez, J.E., Rissetto, J., Torres, T.D., 2014. La ocupación de la costa

durante el Mesolítico en el Oriente de Asturias: primeros resultados de las excavaciones en la cueva de El Mazo (Andrín, Llanes). Archaeofauna 23, 25–38.

Hammer, O., Harper, D.A.T., Ryan, P.D., 2001. Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4, 9pp. http://palaeo-electronica.org/2001_2001/past/issue2001_2001.htm.

Hayden, B., 2001. Fabulous feasts: a prolegomenon to the importance of feasting. In: Dietler, M., Hayden, B. (Eds.), Feasts. Archaeological and Ethnographic Perspectives on Food, Politics and Power. The University of Alabama Press, Tuscaloosa, pp. 23–64.

Hildebrandt, W., Rosenthal, J., Gmoser, G., 2009. Shellfish transport, caloric return rates, and prehistoric feasting on the Laguna De Santa Rosa, Alta California. California Archaeology 1, 55–78.

Howard, A.E., 1982. The distribution and behaviour of ovigerous edible crabs (*Cancer pagurus*), and consequent sampling bias. Journal du Conseil 40, 259–261.

Ingle, R.W., 1997. Crayfishes, Lobsters and Crabs of Europe. An illustrated guide to common and trade species, Chapman & Hall, Cambridge.

Jerardino, A., 2014. Variability in late Holocene shellfish assemblages: the significance of large shore barnacles (*Austromegabalanus cylindricus*) in South African West Coast sites. Journal of Archaeological Science 52, 56–63.

Klokler, D., 2014. A ritually constructed shell mound: feasting at the Jabuticabeira II site. In: Roksandic, M., Souza, S.M.D., Eggers, S., Burchell, M., Klokler, D. (Eds.), The Cultural Dynamics of Shell Midden sites, The University of New Mexico Press, Albuquerque, pp. 151– 162.

Losey, R.J., Yamada, S.B., Largaespada, L., 2004. Late-Holocene Dungeness crab (*Cancer magister*) harvest at an Oregon coast estuary. Journal of Archaeological Science 31, 1603–1612.

Matthews, E., 1993. Women and fishing in traditional Pacific Islands cultures. In: Workshop on people, society and Pacific Islands fisheries development and management: selected papers. Inshore Fisheries Research Project, Technical Document No. 5, South Pacific Commission, Noumea, New Caledonia, pp. 29–34.

Meehan, B. 1977b. Man does not live by calories alone. In: Allen, J., Golson, J., Jones, R. (Eds.) Sunda and Sahul. London: Academic Press, pp. 493–531.

Meehan, B., 1982. Shell Bed to Shell Midden. Australian Institute for Aboriginal Studies, Canberra.

Milner, N., 2005. Seasonal consumption practices in the Mesolithic: economic, environmental, social or ritual? In: Milner, N., Woodman, P. (Eds.), Mesolithic Studies at the Beginning of the 21st Century, Oxbow Books, Oxford, pp. 56–67.

Milner, N., 2009a. Consumption of crabs in the Mesolithic, side stepping the evidence? In: Hardy, K., Whickam-Jones, C. (Eds.), Mesolithic and Later Sites around the Inner Sound, Scotland: the Work of the Scotland´s First Settlers Project 1998-2004. The Society of Antiquaries of Scotland, Council for British Archaeology and Historic Scotland., URL: http://www.sair.org.uk/sair31/.

Milner, N., 2009b. Mesolithic consumption practices. Food for thought. Journal of Nordic Archaeological Science 16, 49–63.

Molares, J., Freire, J., 2003. Development and perspectives for community-based management of the goose barnacle (*Pollicipes pollicipes*) fisheries in Galicia (NW Spain). Fisheries Research 65, 485–492.

Moss, M.L., 1993. Shellfish, gender and status on the northwest coast: reconciling archaeological, ethnographic, and ethnohistorical records of the Tlingit. American Anthropologist 95 (3), 631–652.

Moss, M.L., 2013. beyond subsistence: the social and symbolic meanings of shellfish in Northwest Coast shocieties. In: Bailey, G.N., Hardy, K., Camara, A. (Eds.), Shell Energy: Mollusc Shells as Coastal Resources, Oxbow Books, Oxford, pp. 7–20.

Moss, M.L., Erlandson, J.M., 2010. Diversity in North Pacific shellfish assemblages: the barnacles of Kit'n'Kaboodle Cave, Alaska. Journal of Archaeological Science 37, 3359–3369.

Pickard, C., Bonsall, C., 2009. Some observations on the Mesolithic crustacean assemblages from Ulva Cave, Inner Hebrides, Scotland. In: Burdukiewicz, J.M., Cyrek, K., Dyczek, P., Szymaczak, K. (Eds.), Undertanding the Past. Papers offered to Stefan K. Kozlowski, Centre for Research on the Antiquity of Southeastern Europe, University of Warsaw, Warsaw, pp. 305–313.

Rigaud, S., Gutiérrez-Zugasti, I., in press. Symbolism among the last hunter-fisher-gatherers in northern Iberia: personal ornaments from El Mazo and El Toral III Mesolithic shell midden sites. Quaternary International (2015), doi:10.1016/j.quaint.2015.10.029.

Schulting, R., Tresset, A., Dupont, C., 2004. From harvesting the sea to stock rearing along the Atlantic Façade of North-Western Europe. Environmental Archaeology 9, 143–154.

Sestelo, M., Roca-Pardiñas, J., 2011. A new approach to estimation of the length/weight relationship of *Pollicipes pollicipes* (Gmelin, 1789) on the Atlantic Coast of Galicia (Northwest Spain): Some Aspects of Its Biology and Management. Journal of Shellfish Research 30, 939–948.

Silva, A.C.F., Hawkins, S.J., Boaventura, D.M., Brewster, E., Thompson, R.C., 2010. Use of the intertidal zone by mobile predators: influence of wave exposure, tidal phase and elevation on abundance and diet. Marine Ecology Progress Series 406, 197–210.

Silva, A.C.F., Boaventura, D.M., Thompson, R.C., Hawkins, S.J., 2014. Spatial and temporal patterns of subtidal and intertidal crabs excursions. Journal of Sea Research 85, 343–348.

Szabó, K., Dupont, C., Dimitrijevic, V., Gastélum, L.G., Serrand, N., 2014. Archaeomalacology: Shells in the Archaeological Record. British Archaeological Reports International Series 2666, Archaeopress, Oxford.

Thompson, V., Andrus, C., 2011. evaluating mobility, monumentality, and feasting at the Sapelo Island shell ring complex. American Antiquity 76, 315–344.

Unuma, T., 2002. Gonadal growth and its relationship to aquaculture in sea urchins. In: Yokota, Y., Matranga, V., Smolenicka, Z. (Eds.), The Sea Urchin: From Basic Biology to Aquaculture, A.A. Balkema Publishers, Lisse, pp. 115-127.

Waselkov, G.A., 1987. Shellfish gathering and shell midden archaeology. Advances in Archaeological Method and Theory 10, 93–210.

Captions list

Table 1: Radiocarbon dates from Mesolithic units at El Mazo. Calibration was performed using Oxcal 4.2 (Calibration Curve: Intcal13).

Table 2: Number of identified specimens (NISP), minimum number of individuals (MNI), density (MNI/dm^3), weight and taphonomic descriptors (fragmentation index MNI/NISP and percentage of burnt remains) of sea urchins (*Paracentrotus lividus*) per stratigraphic unit.

Table 3: Mean size of the sea urchin *Paracentrotus lividus* by stratigraphic unit. SD: Standard Deviation.

Table 4: Number of identified specimens (NISP), minimum number of individuals (MNI), density (MNI/dm^3), weight and taphonomic descriptors (fragmentation index MNI/NISP and percentage of burnt remains) of goose barnacles (*Pollicipes pollicipes*) per stratigraphic unit.

Table 5: Mean size of plates (*Scutum*, *Carina*, *Tergum*) from the goose barnacle *Pollicipes pollicipes* in unit 100/101. SD: Standard Deviation.

Table 6: Number of identified specimens (NISP), minimum number of individuals (MNI), density (MNI/dm^3), weight and taphonomic descriptors (fragmentation index MNI/NISP and percentage of burnt remains) of crabs (Brachyura sp.) per stratigraphic unit.

Table 7: Species representation (MNI: Minimum Number of Individuals) of crabs by stratigraphic unit.

Table 8: Mean length (L and L1, in mm) of dactylopods and propods from crabs recovered in different stratigraphic units at El Mazo.

Table 9: Mean overall size of the Warty Xanthid crab *Eriphia verrucosa* by stratigraphic unit. SD: Standard Deviation.

Fig. 1: Location of El Mazo rockshelter in the study area.

Fig. 2: A: general view of the rockshelter, B) topographic plan of the site (shaded squares represent excavation areas from which materials were used for this study), C) north stratigraphic profile of the inner test pit (squares V15-V16) with indication of units, D) west stratigraphic profile of the outer test pit (square S10) with indication of units.

Fig. 3: Sea urchin (*Paracentrotus lividus*) fragmentation categories found at El Mazo rockshelter: a) right semi-pyramid, b) left semi-pyramid, c) epiphysis, d) teeth, e) *rotuale*, f) spines, g) carapace fragments.

Fig. 4: Box plot with size distributions (length) of semi-pyramids from the sea urchin *Paracentrotus lividus* by stratigraphic unit. Note the significantly smaller size in unit 107.

Fig. 5: Goose barnacle (*Pollicipes pollicipes*) fragmentation categories found at El Mazo rockshelter: a) left scutum, b) right scutum, c) carina, d) left tergum, e) right tergum, f) plate fragments.

Fig. 6: Box plot showing size distributions of goose barnacles *Pollicipes pollicipes* from stratigraphic unit 100/101 by plates (*Scutum*, *Carina*, *Tergum*).

Fig. 7: Crab fragmentation categories for the different taxa identified at El Mazo rockshelter. Rows (taxa): 1) *Xantho* sp., 2) *Pachygrapsus marmoratus*, 3) *Necora puber*, 4) *Eriphia verrucosa*, 5) *Carcinus maenas*, 6) *Cancer pagurus*. Columns (fragmentation categories): A) right dactylopod, B) left dactylopod, C) right propod, D) left propod.

Fig. 8: Box plots with size distributions of crabs by stratigraphic unit: A) length of right dactylopods from all crab species; B) overall length of the Warty Xanthid crab *Eriphia verrucosa*.

Figure 1

Click here to download high resolution image

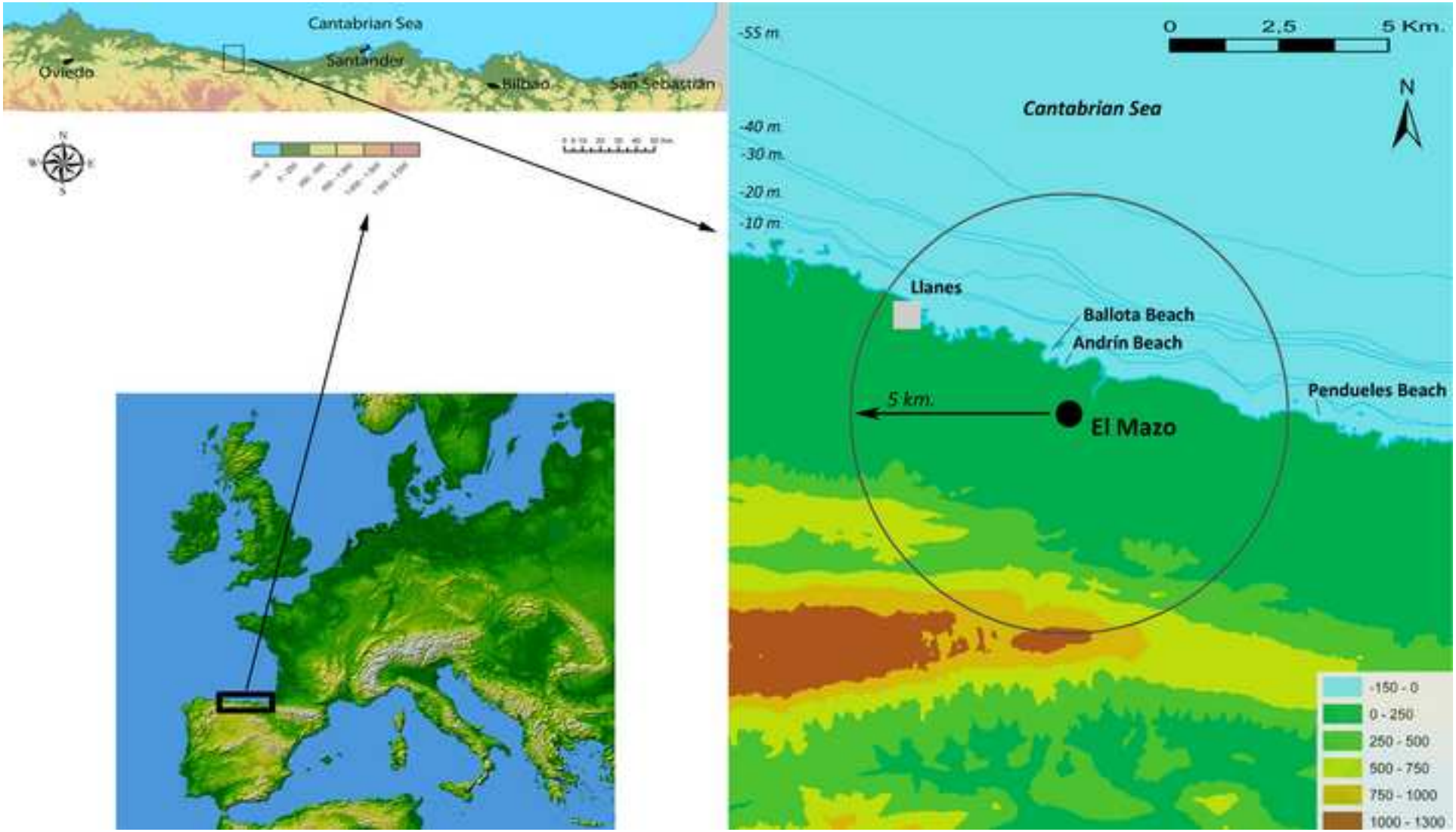

Figure 2
Click here to download high resolution image

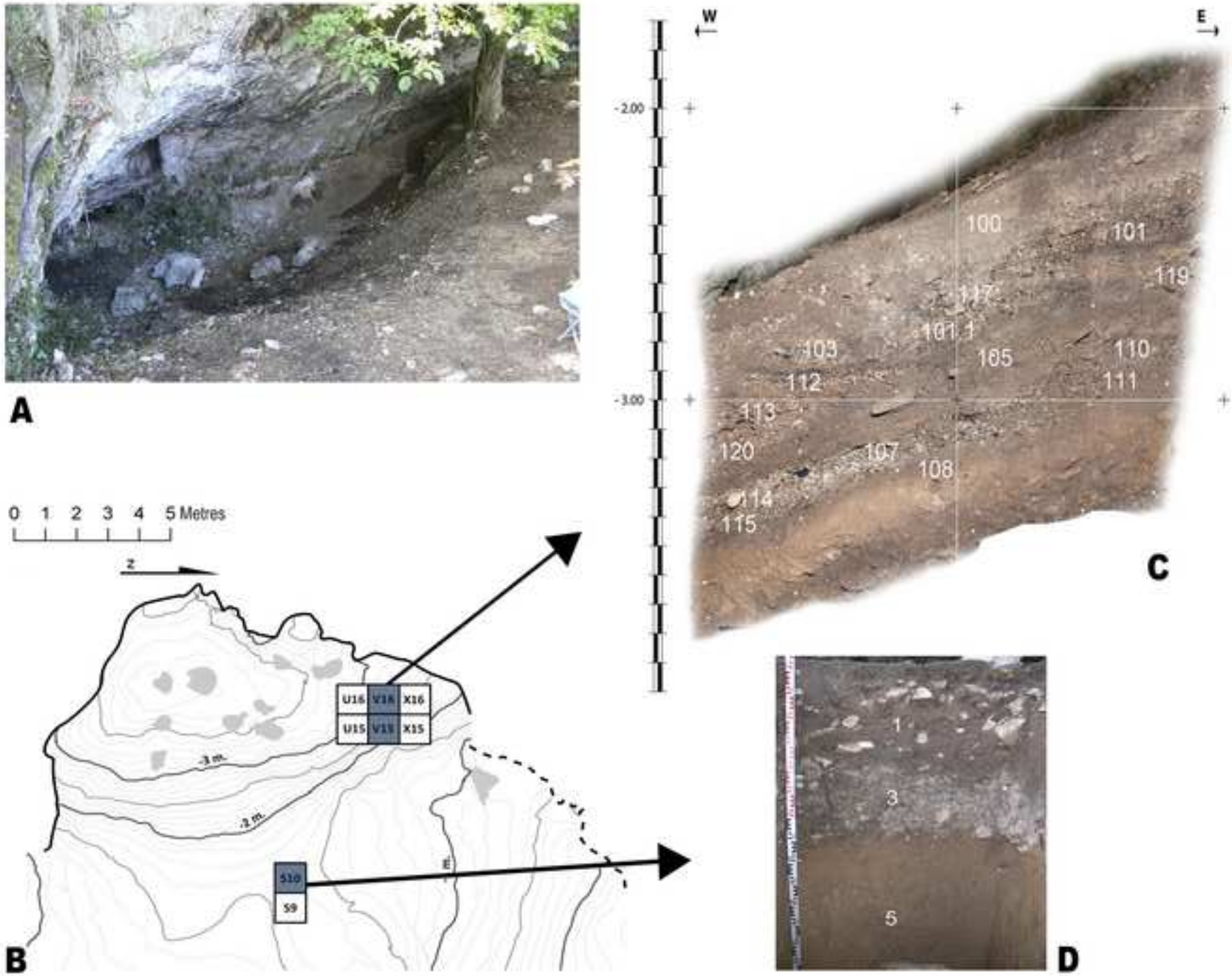

Figure 3
Click here to download high resolution image

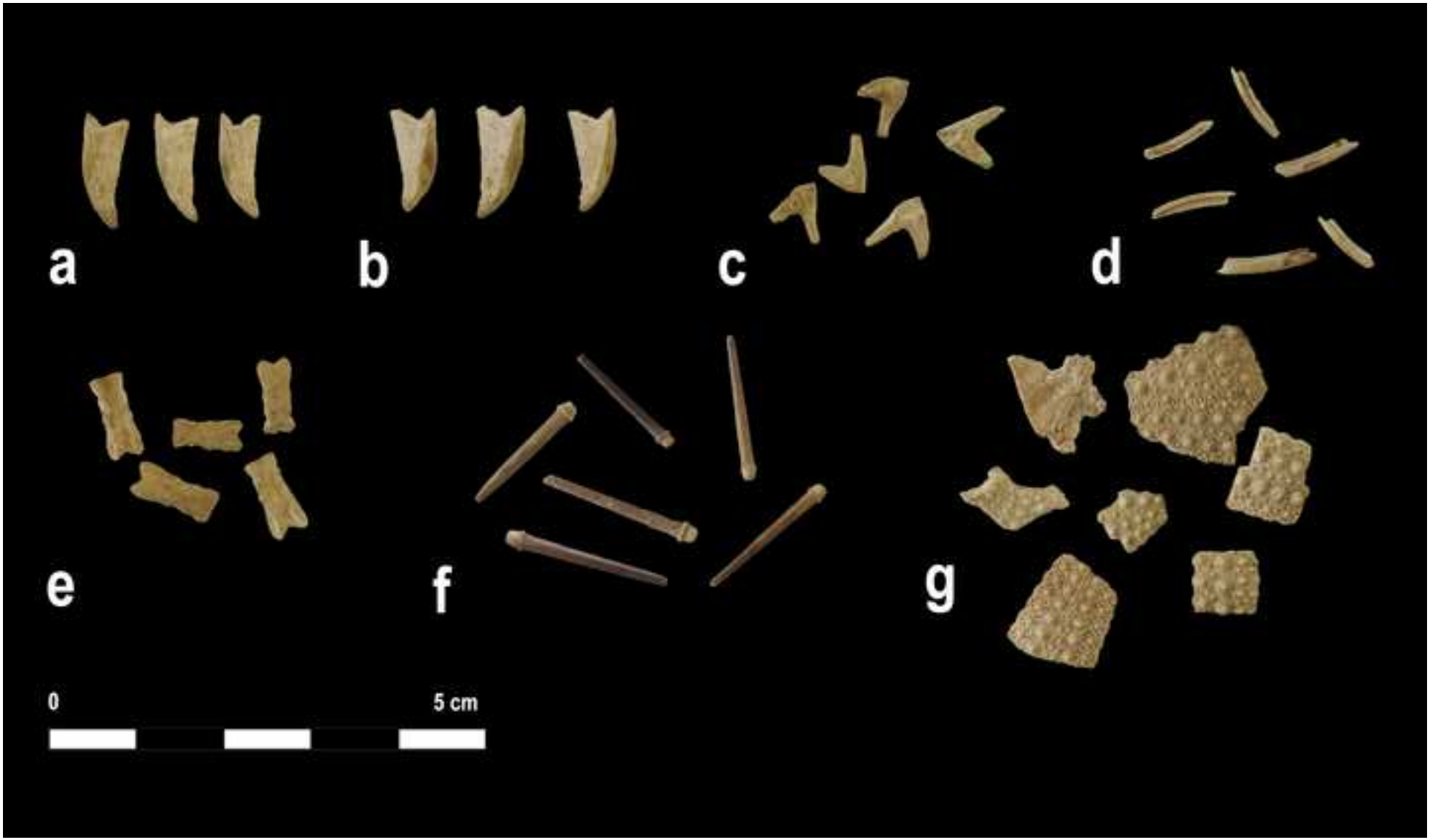

Figure 4
Click here to download high resolution image

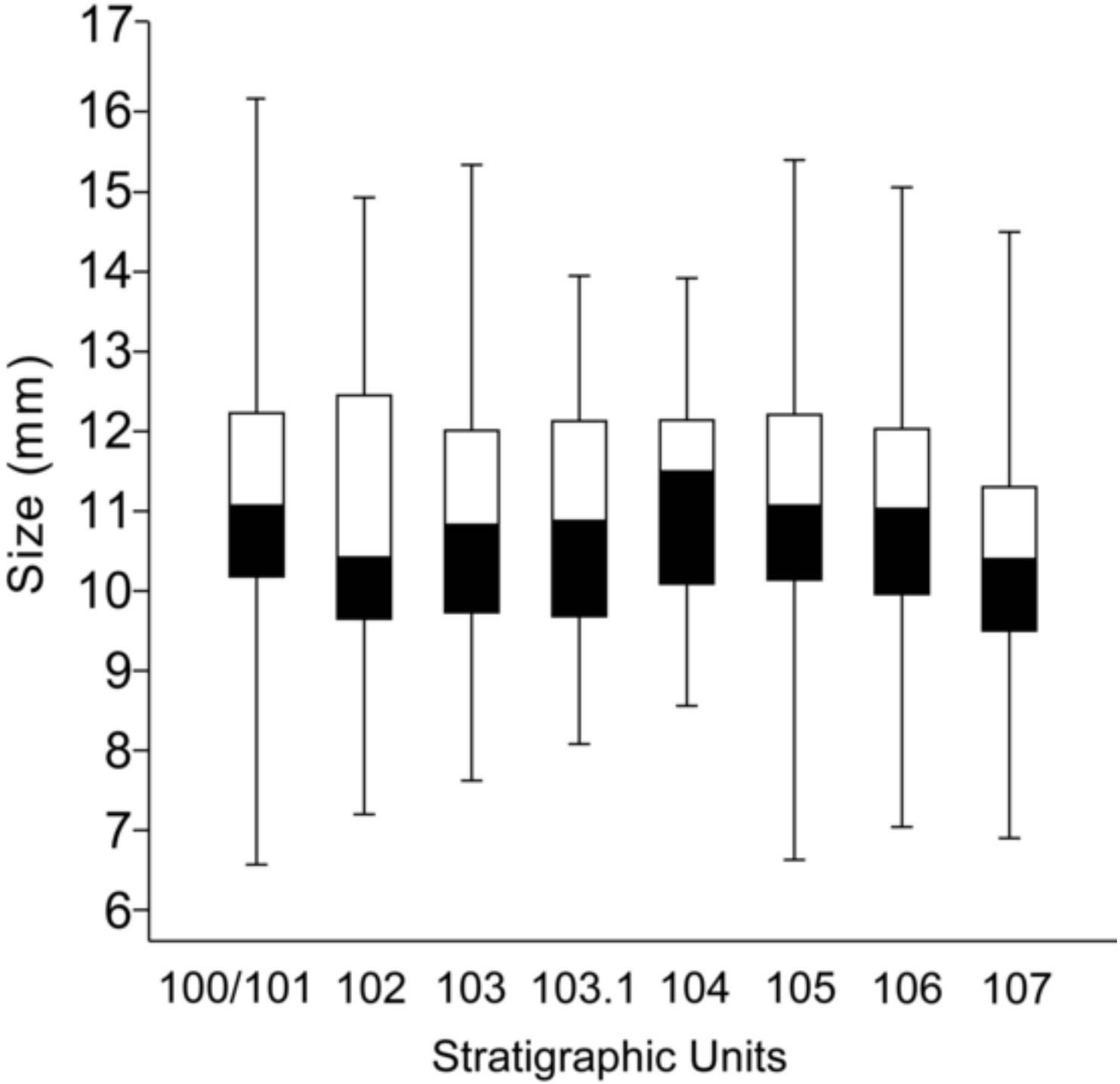

Figure 5
Click here to download high resolution image

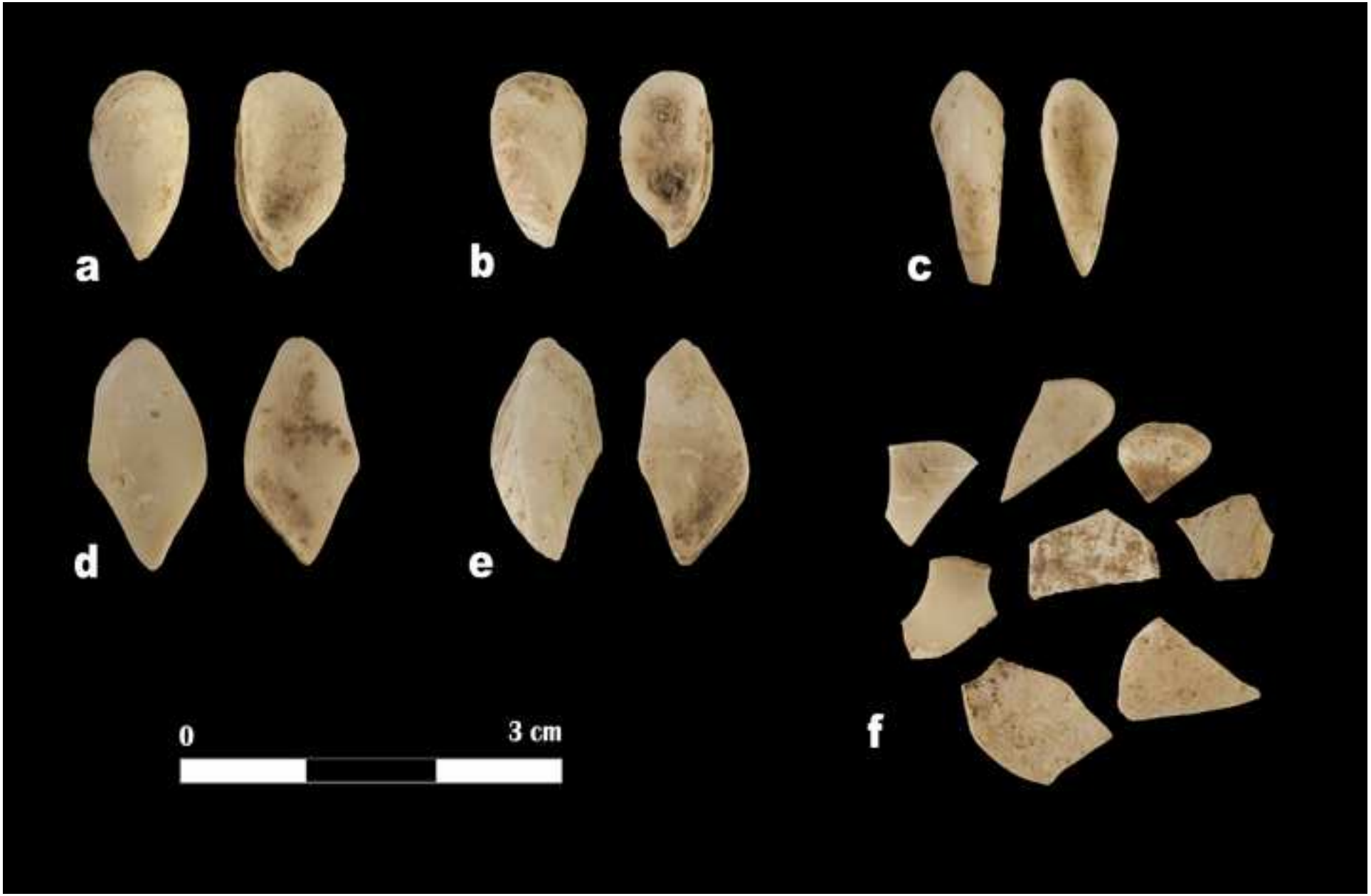

Figure 6
Click here to download high resolution image

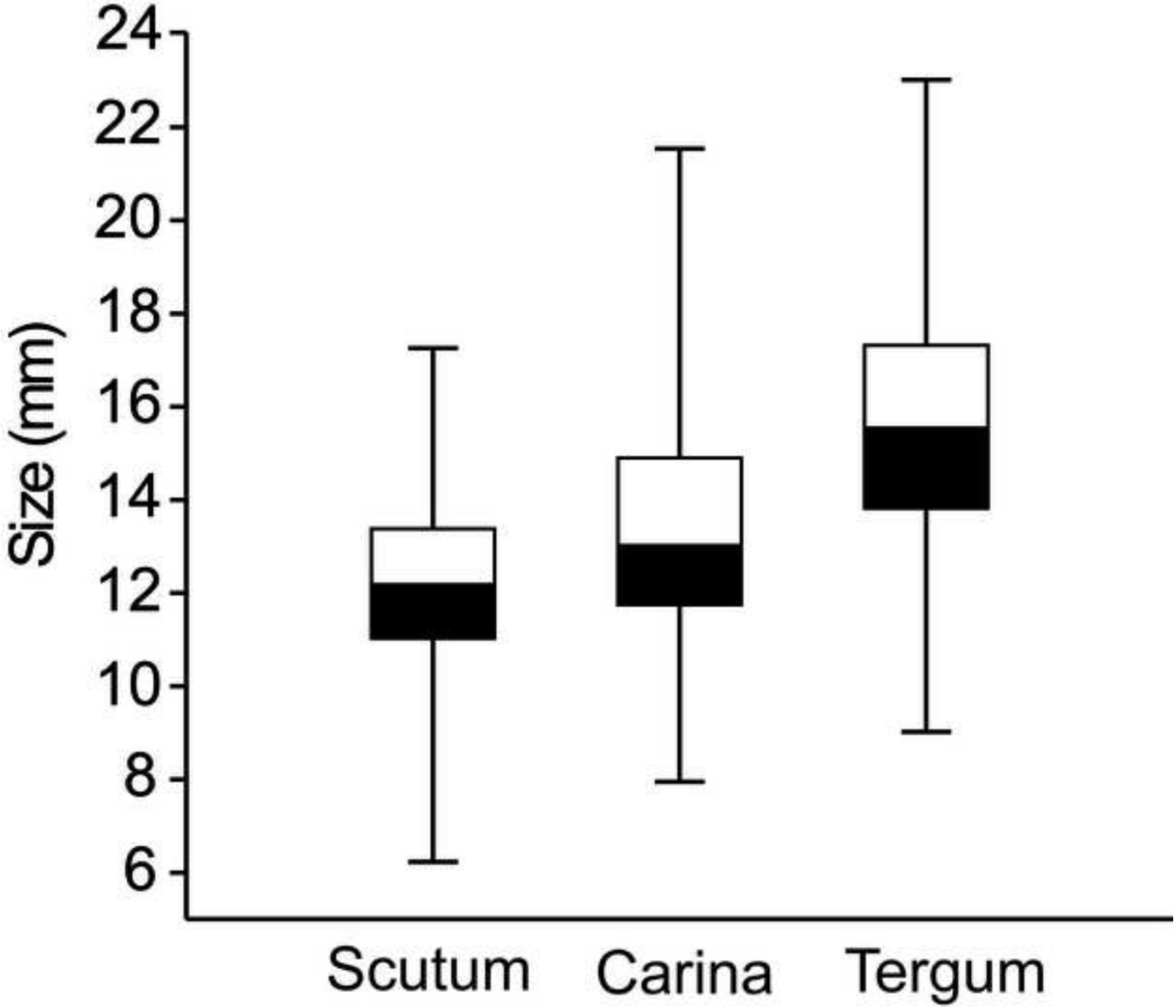

Figure 7
Click here to download high resolution image

Figure 8
Click here to download high resolution image

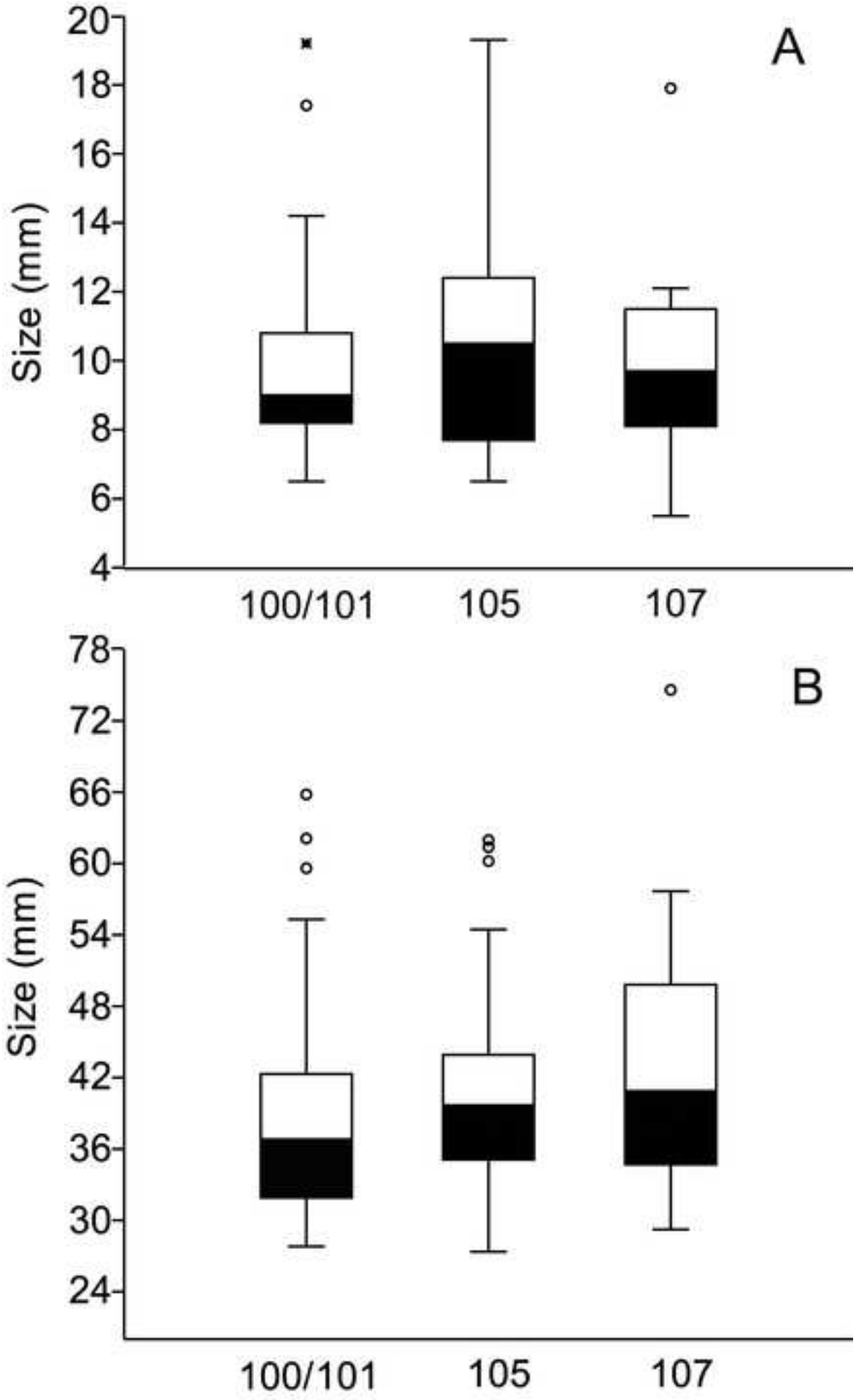

Table 1

Unit	Lab Ref	Date BP	Interval cal BP		Median cal BP	Material	Method
3	UGAMS-5407	6790±30	7676	7587	7634	Bone	C14 AMS
100	OxA-28397	6772±37	7674	7576	7624	Bone	C14 AMS
101	OxA-28389	7230±36	8160	7971	8039	Bone	C14 AMS
112	OxA-28401	7294±37	8176	8021	8102	Bone	C14 AMS
105	UGAMS-5408	7640±30	8517	8384	8423	Charcoal	C14 AMS
114	OxA-27969	7990±38	9006	8662	8869	Bone	C14 AMS

Table 2

Unit	NISP	MNI	MNI/dm^3	Weight (g)	MNI/NISP	% Burning
3	106	1	0.01	7	0.009	16
100/101	27365	111	0.20	1398	0.004	3.6
102	655	11	0.15	48	0.017	5.3
103.1	289	3	0.18	13	0.010	3.5
103	2695	15	0.27	135	0.006	7.7
104	691	4	0.27	35	0.006	3.7
105	20880	166	0.38	1105	0.008	2.2
106	4180	34	0.31	220	0.008	7.9
107	136004	614	1.46	2950	0.005	2.5

Table 3

Unit	N	Mean (mm)	SD
100/101	845	11.2	1.6
102	57	10.8	1.6
103	85	10.9	1.6
103.1	19	10.9	1.6
104	19	11.2	1.4
105	1314	11.2	1.5
106	249	11	1.5
107	3227	10.4	1.3

Table 4

Unit	NISP	MNI	MNI/dm^3	Weight (gr)	MNI/NISP	%Burning
3	7	2	0.01	2	0.286	25
100/101	1553	317	0.56	183	0.204	23.3
102	11	3	0.04	1.5	0.273	25
103	30	8	0.14	4	0.267	16.1
103.1	1	1	0.06	1	1.000	100
104	1	1	0.07	1	1.000	0.0
105	29	8	0.02	6	0.276	26.9
106	3	2	0.02	1	0.667	0.0
107	15	6	0.01	4	0.400	6.7

Table 5

Plates	N	Mean (mm)	SD
Scutum	535	12.2	1.8
Carina	166	13.3	2.3
Tergum	378	15.6	2.6

Table 6

Unit	NISP	MNI	MNI/dm^3	Weight (g)	MNI/NISP	%Burning
3	18	3	0.02	2	0.167	50
100/101	222	97	0.18	192	0.437	42
102	28	18	0.25	22	0.643	77
103	23	15	0.27	18	0.652	32
103.1	11	8	0.47	8	0.727	58
104	4	4	0.27	4	1.000	25
105	163	70	0.16	185	0.429	47
106	53	27	0.25	44	0.509	52
107	486	48	0.11	76	0.099	36

Table 7

Taxa	100/101	102	103	103	104	105	106	107
Cancer pagurus	3	3	1			7	3	4
Xantho sp.	8	2	3		2	4	6	1
Carcinus maenas	8	3	2			7	2	5
Necora puber	14	3	1	4	1	12	2	4
Pachygrapsus mamoratus	15	2	1	2		5	2	12
Eriphia verrucosa	49	5	7	2	1	29	8	20
Brachyura sp.						6	4	2
Total	97	18	15	8	4	70	27	48

Table 8

Unit	Right Dactylopods				Left Dactylopods				Right Propods				Left Propods		
	n	L	n	L1	n	L	n	L1	n	L	n	L1	n	L	n
100/101	35	13.4	39	10.0	16	12.7	18	10.2	16	9.7	30	7.8	9	9.5	16
102	3	12.5	3	9.2	1	19.5	1	13.5	3	8.8	6	7.6	0		2
103	1	18.3	1	13.0	1	8.8	1	6.7	1	8.9	5	8.6	0		2
104	2	13.5	2	9.5	0		0		0		0		0		
105	25	14.4	28	10.7	7	13.7	10	10.5	16	10.6	23	7.6	4	9.1	12
106	5	12.4	8	9.8	1	8.8	3	9.5	4	10.3	6	7.4	2	8.6	5
107	12	14.3	14	10.1	8	14.0	8	11.0	11	9.7	16	7.7	7	7.0	13

Table 9

Unit	N	Mean (mm)	SD
100/101	62	38.3	8.3
102	8	43.2	11.1
103	6	39.6	4.1
105	51	40.9	7.8
106	13	38.9	5.7
107	18	42.8	11.3

Manuscript Number: **QUATINT-D-15-00557**
Title: **Collection and consumption of echinoderms and crustaceans at the Mesolithic shell midden site of El Mazo (northern Iberia): opportunistic behaviour or social strategy?**
Authors: **Gutiérrez-Zugasti, I. et al**

Comments

This is a truly interesting, and long overdue, paper on a group of archaeological faunas that have received little attention in Paleolithic sites, both at the local (Cantabrian), the "regional" (i.e. European) and worldwide level for a variety of reasons.

From the formal standpoint, the paper is clear, well-written and, although a bit more speculative in the last section of the Discussion than I judge necessary, well structured and justified. For such reasons, I consider it worth publication provided the issues that are raised below are addressed in the final version.

In terms of facilitating the understanding of the rationale behind the trends/patterns these assemblages evidence, and given that the sequence covers more than a millennium and seems to be neatly stratified, I think it would do no harm if the authors could at times slightly reframe their wording when speaking about the sequence and use also descriptive terms in addition to mere units (i.e., *base* of the sequence, *latest* level, oldest stage, etc).

Ok, we have added descriptive terms when possible. In any case, the position of the units in the stratigraphy can be seen in Fig. 2C and radiocarbon dates in Table 1.

On the contrary, I consider that using terms such as "big", "medium" and "small", when referring to organisms that grow for life and (in the case of crabs, at least) incorporate species of very different sizes, is a bit ambiguous (i.e. a medium-size *Cancer pagurus* would qualify as a very large *Carcinus maenas*, etc.). I would thus urge, if at all possible, that the authors "quantify" these terms or perhaps simply provide a Table where these size categories would be translated into numerical data (for all crab species pooled together or, better still, for each of the crab species reported). In this way, I feel the readers would be able to more clearly grasp statements such as the phrase that appears between lines 243 and 244.

Ok, we have conducted a proper biometrical analysis on the crabs found at the site and results have been discussed.

There exist four issues that I am not fully convinced the authors have entertained fully in their reasoning:

1. Seasonality. Although it is repeatedly stated that sea urchins would be available year round and were "permanently" exploited, in view that, except during reproduction, sea urchins do not have anything to offer in terms of foodstuff, I bear some doubts that this could have been the case. Re-framing the discussion on availability from the standpoint of seasonality might also throw light on issues such as (a) the reported selective harvesting of the larger sea urchins (vs. the normal distributions that all the crustaceans exhibited), and (b) the (contagious?) distribution that sea urchin remains featured in the various units of the sequence (to a certain extent, as briefly mentioned by the

authors, such seasonal availability issue would also apply in the case of some crabs).

Ok, we have included some comments about the seasonality of sea urchin collection in section 5.2. Regarding the crabs, contradictory information obtained from different studies along Atlantic Europe about the seasonal availability of *Carcinus maenas* and *Cancer pagurus* made us to be cautious interpreting the seasonality of collection. Until more precise data is obtained we prefer not to make assumptions on this topic. Nonetheless, we completed the sentence referred to *Eriphia verrucosa* saying that they could have been collected at any season except spring.

2. Origin of the taphocenoses. I would like to see some words on why the authors judge people as the sole collectors of these invertebrates. One peculiar "feature" I have noticed in the paper is that crabs that people in the area despise today, such as *Pachygrapsus marmoratus* or *Xanto* sp., not only happen to be the smallest species in the samples but also appear regularly in the diet of things such as otters and many marine bird species from the cantabrian region. Again, some words along these lines might prove helpful for other aspects of the Discussion.

Ok, we have included some words about the origin of the taphocenoses in the section 5.2.

3. Preservation. Contrary to mollusks, the skeletons of the marine groups considered in this paper are comparatively feeble, due to a very weak –or else a most peculiar- mineralization. Indeed, at times, the exoskeletons of crustaceans have more organic matter than mineral matter (e.g., people love recently-molted portunid crabs apt to generate no preservable remains). For such reason, I think that the absence of sea urchins and "crabs" *sensu lato*, in addition to sampling biases, may often reflect a differential preservation that I would like the authors to briefly comment or, at least, incorporate when discussing the presence and abundance of these invertebrates in the archaeological record in terms of intensification (i.e. lines 523-524) and other man-related phenomena.

We do not think that sea urchins and goose barnacles have suffered problems of differential preservation at El Mazo since they have much stronger carapaces/plates than crabs (and are slightly affected by taphonomic processes as stated in our study). In addition, shell middens are known to decrease the ph of the soils due to the high content of calcium carbonate of the shells, which results in much better preservation of organic matter. However, we agree that some differential preservation could have affected crabs, although it was probably limited to the carapace (not used in MNI calculations) and not to the claws, which are thicker and stronger (and they are the most abundant anatomical element from crabs preserved in shell middens). In any case, we have included some comments about this question in section 5.3.

4. Harvesting. Two thoughts for fodder…..

(a) absence of certain highly appreciated items at EL MAZO, such as the Spider crab (*Maja squinado*) may reflect that, indeed, people did not forage into the sublittoral zone

Ok, we have included a sentence about that in section 5.2.

(b) *Eriphia verrucosa*, the most common crab at El Mazo happens to be also the most esteemed crab in French (Mediterranean) cuisine to this day….I believe the authors

have here a hint that crab capture might not be so opportunistic after all and more focused instead on highly palatable items. How that translates into the social context I would not dare to comment.

Ok, we have included a sentence about this question in section 5.3.

Other bits

a. Figure 4: How does semi-pyramid lengths translate into overall (test) size/weight of the urchins?

We have explained this in the text (sections 3, 4.1 and 5.2).

The caption for this figure should specify what is being measured here

Ok, specified.

b. Figure 6: How does Scutum, Carina and Tergum lengths translate into overall size/weight of the goose barnacle?

There are no reference studies to transform the length of the plates into overall size of the goose barnacle.

The caption for this figure should specify that these measurements all derive from unit 100/101

Ok, done

c. Table 6: is correct the MNI for Unit 107? (figure seems too low for that NISP)

Yes, it is correct, the high NISP is due to counting all the spines recovered.

d. Line 233: what is meant by "*medium*" fragmentation? This just a point/range within a scale of values?

Yes, we have reworded the sentence.

e. Line 26: "*highest* levels of exploitation"….. meaning?

We have changed "levels" by "intensity" in order to clarify the sentence.

f. Line 295: "…*most* of the crabs found at El Mazo..prefer warmer waters" Which species are these?

We have clarified this sentence including the name of the species preferring warmer waters.

Line 324-325: "Due to the *size distributions* of the urchins……it can be suggested that they were probably gathered from rock pools…" what is the range of sizes of the subtidal and intertidal populations at present? Do these change with latitude/temperature of the water? What is the estimated range of sizes of the sea urchins from El Mazo?

We have expanded this part of the discussion to address these questions.