RESEARCH PAPER

Shells and Humans: Molluscs and Other Coastal Resources from the Earliest Human Occupations at the Mesolithic Shell Midden of El Mazo (Asturias, Northern Spain)

Asier García-Escárzaga*,†, Igor Gutiérrez-Zugasti*, Manuel R. González-Morales* and Adolfo Cobo-García†

Human populations exploited coastal areas with intensity during the Mesolithic in Atlantic Europe, resulting in the accumulation of large shell middens. Northern Spain is one of the most prolific regions, and especially the so-called Asturian area. Large accumulations of shellfish led some scholars to propose the existence of intensification in the exploitation of coastal resources in the region during the Mesolithic. In this paper, shell remains (molluscs, crustaceans and echinoderms) from stratigraphic units 114 and 115 (dated to the early Mesolithic *c.* 9 kys cal BP) at El Mazo cave (Asturias, northern Spain) were studied in order to establish resource exploitation patterns and environmental conditions. Species representation showed that limpets, top shells and sea urchins were preferentially exploited. One-millimetre mesh screens were crucial in establishing an accurate minimum number of individuals for sea urchins and to determine their importance in exploitation patterns. Environmental conditions deduced from shell assemblages indicated that temperate conditions prevailed at the time of the occupation and the morphology of the coastline was similar to today (rocky exposed shores). Information recovered relating to species representation, collection areas and shell biometry reflected some evidence of intensification (reduced shell size, collection in lower areas of exposed shores, no size selection in some units and species) in the exploitation of coastal resources through time. However, the results suggested the existence of changes in collection strategies and resource management, and periods of intense shell collection may have alternated with times of shell stock recovery throughout the Mesolithic.

Keywords: Mesolithic; Archaeomalacology; Shell midden; Biometry; Intensification

* Instituto Internacional de Investigaciones Prehistóricas de Cantabria, University of Cantabria, Edificio Interfacultativo, Avda. Los Castros s/n. 39005 Santander, España

† Photonic Engineering Group, Department of TEISA, University of Cantabria, Edificio I+D+i de Telecomunicaciones, Avda. Los Castros s/n. 39005 Santander, Spain

Corresponding author: Asier García-Escárzaga (a.garcia.escarzaga@gmail.com)

Introduction

The Mesolithic of Atlantic Europe is characterised by the formation of large shell middens in coastal locations, as a result of intensive exploitation of littoral areas by the last hunter-fisher-gatherers (Gutiérrez-Zugasti et al. 2011; Milner et al. 2007). One of the most prolific areas in Atlantic Europe is northern Spain, and especially the so-called Asturian area (located in the central part of the region, approximately between the cities of Oviedo and Santander, see **Fig. 1**), where more than 130 Mesolithic shell middens have been identified (Fano 1998; Arias et al. 2015). The Asturian Mesolithic has been defined by several key characteristics: chronology (10.7 – 6.8 kys cal BP), occupation of sites located in caves and rockshelters near the coastline (usually less than 5 km away, see Bailey and Craighead 2003), the presence of a distinct lithic artefact called the Asturian pick, and a subsistence based on a combination of marine and terrestrial resources (Clark 1983; González Morales 1982; Vega del Sella 1923).

Studies performed at the Asturian shell midden sites of La Riera (Ortea 1986), Mazaculos II (González Morales et al. 1980; Gutiérrez-Zugasti and González-Morales 2010), La Llana (Gutiérrez-Zugasti 2009), Poza l'Egua (Arias et al. 2007), El Toral III (Bello-Alonso et al. 2015) and El Mazo (García-Escárzaga et al. 2015) showed that limpets and topshells were intensively collected from intertidal areas of exposed shores, leading to the formation of huge shell middens. Apart from molluscs, other marine organisms such as fish, crustaceans (crabs and goose barnacles) and echinoderms (sea urchins) were also part of the human diet and were discarded in the middens (Álvarez-Fernández 2011; Fano et al. 2013; Gutiérrez-Zugasti 2011a). Marine resources were complemented by the exploitation of terrestrial mammal prey, including red deer, roe deer and wild boar (Andreu-Alarcón 2013; Marín-Arroyo 2013; Marín-Arroyo and González-Morales 2009).

According to the available evidence, the increased use of coastal resources started at the end of the Upper Palaeolithic in northern Iberia, culminated in the Mesolithic with the formation of huge shell middens (Álvarez-Fernández 2011; Gutiérrez-Zugasti et al. 2011). This process has been related to resource intensification as a result of population increase (Straus and Clark 1986). According to this interpretation, intensification was visible in a clear decrease in shell size through time. However, Bailey and Craighead (2003) rejected that explanation and proposed decreased shell size was induced by changes in climatic and environmental conditions. Recently, Gutiérrez-Zugasti (2011b) addressed this topic by studying size and age distributions of marine gastropods (limpets and top shells) from Upper Palaeolithic and Mesolithic sites in northern Iberia. Results revealed a decrease in the mean size and age of these species. Whilst the impact of certain factors, which might have played a significant role in shell size changes (e.g. sea level rise, changes in coastal morphology), are difficult to evaluate the available information about climate conditions, age-class frequencies, the reproduction of species and collection areas, demonstrated that molluscs were exploited with high intensity at least from the Azilian (c. 12.5 kys cal BP) suggesting the existence of resource intensification.

Understanding human-shell interactions in coastal locations is crucial in establishing subsistence patterns of Mesolithic groups along the Atlantic Façade. New evidence can provide information to better understand subsistence strategies, settlement patterns, social organisation and environmental conditions. 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 stratigraphic sequence that covers an important part of the Mesolithic period. The shell assemblages recovered from each stratigraphic unit present an opportunity to study the use of shellfish by hunter-fisher-gatherers in the region. In this paper we aim to determine

environmental conditions and coastal exploitation patterns in northern Iberia during the Mesolithic through the study of molluscs, echinoids and crustaceans from two stratigraphic units dated to ~9 ky cal BP at El Mazo cave. Results obtained on species representation, taphonomy, biometry and collection areas were compared to that from other sites in the region and discussed in the light of the intensification process proposed by previous research.

El Mazo shell midden site: background and environmental setting during the early Holocene
#### Background
El Mazo cave is located in the town of Andrín, in the municipality of Llanes, in Asturias, Northern Spain (**Fig. 1**). The rockshelter is approximately 18 m long and 7 m deep. Excavations were undertaken in the inner part of the rockshelter, close to the walls, in 2009, 2010 and 2012. A 2 x 1 m test pit was opened in 2009–2010 in squares V15 and V16 and the resulting north profile was sampled in 2012 in a limited extension (2 m in the east-west axis x 0.25 m in the north-south axis) of squares X15 and X16

(Gutiérrez-Zugasti and González-Morales 2014; Gutiérrez-Zugasti et al. 2014). The excavation produced several Stratigraphic Units (SUs) composed predominately of shell midden deposits (units 100 to 122). Most of these units were formed by a shell matrix characterized by the predominance of shells over any other remains, and the occurrence of limited amounts of sediment. In contrast, SUs 104, 117 and 122, corresponded to fire structures (hearths) with high densities of charcoal, ashes and burnt shells, which suggest these fire structures were related to shell processing (**Fig. 2**). Some units were cemented as a consequence of calcium carbonate precipitation in the midden, as was the case of SUs 102 and 106.

The units analysed in this study, were located at the base of the shell midden (**Fig. 2**). Unit 114 was a discrete shell lense (~2 cm thick) confined to the westernmost part of square X16 and characterised by loose, dark brown sediment, with some shells and considerable numbers of mammal bones, while unit 115 was a shell matrix (~5–15 cm thick) extended along the square X16 and composed by scarce fine grain and loose, brown sediment, and abundant shells
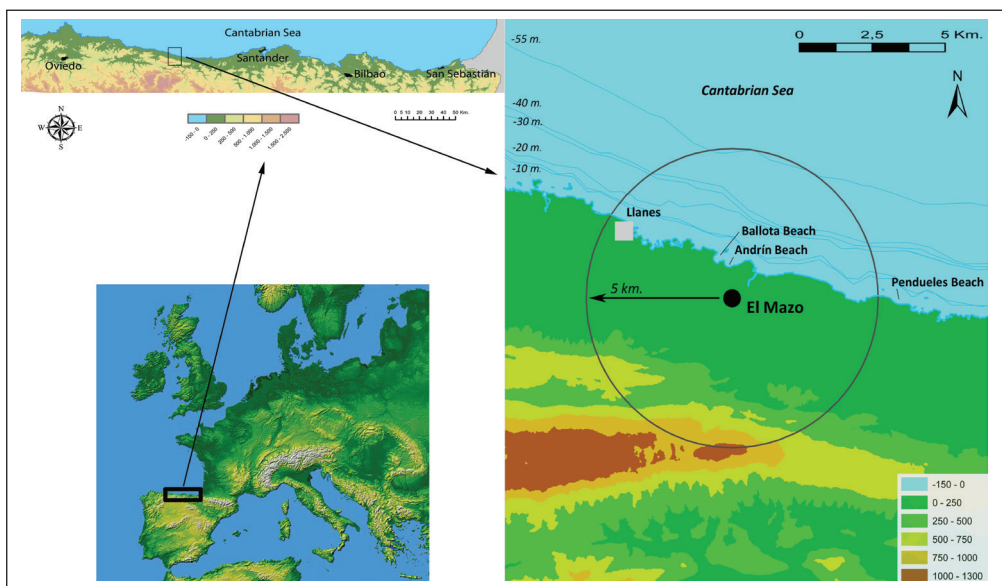
Figure 1: Localization of El Mazo shell midden site and the study area.
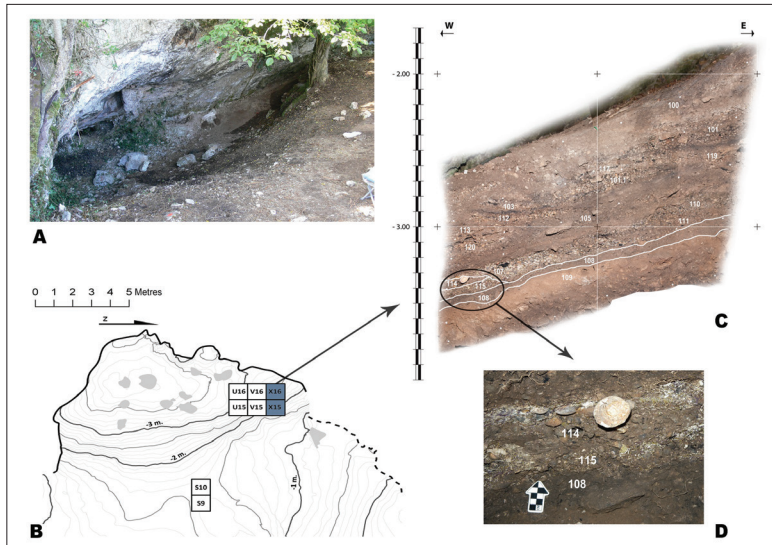
Figure 2: General view, topography and stratigraphy of the site: **A)** General view of the rock-shelter; **B)** Topographic map of the rockshelter showing excavation areas and provenance of the studied samples (shaded squares); **C)** Stratigraphy of the inner test pit (squares X15 and X16); **D)** Detailed view of stratigraphic units 108, 114 and 115.

(Gutiérrez-Zugasti and González-Morales 2014). Both units have been radiocarbon dated to the early Mesolithic (**Table 1**). The chronology of these units (including unit 108) suggests the recurrent use of the cave *c.* 9 kys cal BP and rapid formation of the shell midden units.

Environmental setting during the early Holocene

Environmental change between the Pleistocene and the Holocene has been recorded by global and regional proxies (North Greenland Ice Core Project Members 2004; Stoll et al. 2013). The onset of the Holocene (~11.6 – 8.7 kys cal BP) in northern Iberia has been characterised as a humid and warm period (Moreno et al. 2011; Rofes et al. 2015) with a considerable expansion of woodland (Muñoz Sobrino et al. 2005). Holocene warming conditions have also been identified in the region through the study of changes in shell assemblages. Gradual substitutions of colder species such as *Littorina littorea* (Linné 1758) with warmer species, such as *Phorcus lineatus* (da Costa 1778) and *Patella depressa* (Pennant 1777), have been recorded between the late Pleistocene and

Lab Reference	Unit	Material	Date BP	Interval cal BP	2σ Median cal BP	δ^{13}C	Method
OxA-27969	114	Bone	7990 ± 38	9006 – 8662	8869	−21.28	[14]C AMS
OxA-31054	115	Bone	8000 ± 40	9009 – 8717	8874	−22.57	[14]C AMS
OxA-31055	115	Bone	8004 ± 39	9009 – 8724	8877	−22.42	[14]C AMS
OxA-28411	108	Bone	8022 ± 39	9019 – 8729	8890	−20.85	[14]C AMS

Table 1: Radiocarbon dates from stratigraphic units 108, 114 and 115 at El Mazo (dates from unit 115 come from the same bone sample). Dates were calibrated using IntCal13 calibration curve (calibration program Oxcal 4.2, Reimer et al. 2013).

the early Holocene. The substitution process started at the end of the Magdalenian, during the Tardiglacial Interstadial, and ended ~10.8 kys cal BP, when warmer species were well established in the region (Gutiérrez-Zugasti and Cuenca-Solana 2014). In addition, isotopic analyses ($\delta^{18}O$ and $\delta^{13}C$) of land snails *Cepaea nemoralis* (Linné 1758) from Late Pleistocene and Holocene sites in northern Iberia (including samples from unit 105 at El Mazo) suggest the existence of more humid conditions in the early Holocene than in the Late Glacial (Yanes et al. 2012).

The current distance of El Mazo from the coastline is around 1km. During the Mesolithic, this distance would have varied due to the rise in sea level. According to recent studies (Leorri et al. 2012), sea level *c.* 9 kys cal BP would have been located ~25 m below the present sea level. Taking into account this information, the distance to the coastline at that time was calculated using bathymetric information from the BACO application, developed by the Environmental Hydraulics Institute of Cantabria and the Minister of Environment from the Spanish Government (Gutiérrez-Zugasti 2009). Combination between sea level studies and bathymetry showed that the distance from El Mazo to the coastline c. 9 kys cal BP was ~2.5 km.

Material and methods

The remains studied here were recovered from units 114 and 115, located at the base of the shell midden (**Fig. 2**) (Gutiérrez-Zugasti and González-Morales 2014). The total volume of sediment excavated between the two stratigraphic units was 12 dm³ (2 dm³ in 114 and 10 dm³ in 115). The remains analysed were recovered using 4, 2 and 1 mm mesh screen sizes.

Taxonomic identification was performed using different specialised guides (Fechter and Falkner 1993; Palacios and Vega de la Torre 1997). Nomenclature proposed by the World Register of Marine Species (http://www.marinespecies.org) and by Kerney and Cameron (1999) for land snails were used. The minimum number of individuals (MNI)

was calculated using the methodology proposed by Moreno (1994) and completed subsequently by Gutiérrez-Zugasti (2009; 2011a; 2011c), based on different fragmentation categories for molluscs, crustaceans and echinoderms. The fragmentation categories used for molluscs were based on the morphology of the shells: a) for non-spiralled gastropods (e.g., limpets) we considered complete individuals, fragmented individuals, apical fragments and non-diagnostic fragments; b) for spiralled gastropods (e.g., top shells) we used complete individuals, fragmented individuals, apical fragments, stoma fragments, umbilical fragments and non-diagnostic fragments; and c) the bivalves (e.g., mussels) were separated into complete valves, fragmented valves, complete hinge fragments, anterior and posterior hinge fragments and non-diagnostic fragments. The fragmentation categories used to calculate the MNI in the case of echinoids are based on the different anatomical parts of the buccal area (the so-called Aristotle's lantern): semi-pyramids (complete, apical and basal, separated in right and left), epiphyses, *rotulae*, compasses and teeth. For crustaceans, we considered the dactilopods and propods (separated in right and left) in the case of crabs, and the larger plates (*carina*, *scutum* and *tergum*, separated in right and left) for goose barnacles. Previous research has reported significant changes in MNI calculation for sea urchins when material found in the finer mesh screen (i.e. 1 mm) is also used (García-Escárzaga et al. 2015). Following this approach, all the sea urchin remains recovered in the 1 mm mesh screens were used to calculate the MNI.

Taphonomic processes affecting the shells were also recorded. The fragmentation index was calculated by applying the fragmentation coefficient assigned by Gutiérrez-Zugasti (2009; 2011c) to each category. The estimation of the fragmentation index (FI) was carried out using only the archaeological remains recovered in the 4 and 2 mm mesh screens.

Collection areas were defined through the synthesis elaborated on by

Taxon	SU 114			SU 115		
Marine bivalves	**MNI**	**MNI%**	**MNI/dm³**	**MNI**	**MNI%**	**MNI/dm³**
Mytilus galloprovincialis	4	0.95	2	22	1.05	2.2
Total	**4**	**0.95**	**2**	**22**	**1.05**	**2.2**
Marine gastropods	**MNI**	**MNI%**	**MNI/dm³**	**MNI**	**MNI%**	**MNI/dm³**
Melarhaphe neritoides	2	0.47	1	0	0	0
Bittium latreillei	0	0	0	1	0.05	0.1
Phorcus lineatus	217	51.3	108.5	1000	48	100
Gibbula sp.	6	1.42	3	7	0.33	0.7
Nassarius reticulatus	0	0	0	2	0.10	0.2
Patella vulgata	87	20.6	43.5	297	14.2	29.7
Patella depressa	9	2.13	4.5	96	4.59	9.6
Patella ulyssiponensis	2	0.47	1	10	0.48	1
Patella sp.	62	14.7	31	414	19.8	41.4
Total	**385**	**91.02**	**192.5**	**1827**	**87.37**	**182.7**
Terrestrial gastroplds	**MNI**	**MNI%**	**MNI/dm³**	**MNI**	**MNI%**	**MNI/dm³**
Cepaea nemoralis	1	0.24	0.5	14	0.67	1.4
Cochlostoma sp.	0	0	0	2	0.10	0.2
Family Clausiliidae	0	0	0	2	0.10	0.2
Order Stylommatophora	1	0.24	0.5	6	0.29	0.6
Pormatias elegans	1	0.24	0.5	2	0.10	0.2
Total	**3**	**0.71**	**1.5**	**26**	**1.24**	**2.6**
Crustaceans	**MNI**	**MNI%**	**MNI/dm³**	**MNI**	**MNI%**	**MNI/dm³**
Brachyura sp.	1	0.24	0.5	4	0.19	0.4
Pollicipes pollicipes	0	0	0	1	0.05	0.1
Balanus sp.	1	0.24	0.5	1	0.05	0.1
Total	**2**	**0.47**	**1**	**6**	**0.29**	**0.6**
Echinoids	**MNI**	**MNI%**	**MNI/dm³**	**MNI**	**MNI%**	**MNI/dm³**
Paracentrotus lividus	29	6.86	14.5	210	10.04	21
TOTAL	**423**	**100**	**211.5**	**2091**	**100**	**209**

Table 2: Species representation in units 114 and 115 of El Mazo.

MNI: Minimum Number of Individuals.

Gutiérrez-Zugasti (2009) for the preferential habitat of each species in the region, our observations in Langre Beach, and the regression equations and Length/Height (L/H) ratios established by Bailey and Craighead (2003) for *Patella vulgata* (Linné 1758). These equations, developed through the study of modern populations, are based on the relation between shell morphology and habitat. Regression equations are used to establish the degree of exposure of the coast (sheltered or exposed) where the shells were collected. L/H ratios are usually used to establish the zone of the intertidal (high or low) where limpets were gathered. Biometrical analyses were performed using standardised measurements (length, width, height) for each species (Gutiérrez-Zugasti 2009; 2010) and statistics were carried out using the PAST program (Hammer et al. 2001).

Results

The study of the shell assemblages from units 114 and 115 produced nineteen taxa: one bivalve, nine marine gastropods, five terrestrial gastropods, three crustaceans and one echinoid (**Table 2**). The most abundant taxa are the limpets of the *Patella* genus and the top shell *P. lineatus*, which together represent about 88% of the total MNI in both units. Among the limpets, the species *P. vulgata* is largely the most abundant. The presence of the sea urchin *Paracentrotus lividus* (Lamarck 1816) is also significant, reaching between 6 and 8% of the MNI in both units respectively. The numbers of the rest of the taxa are marginal.

Fragmentation is the main taphonomic process recorded at the site. Other processes were also identified, including cementation (precipitation of calcium carbonate), burning (in different degrees, from shells slightly burnt to carbonification) and biodegradation (loss of proteins). The land snail *C. nemoralis* presented the highest fragmentation in both units (**Fig. 3**). Among the marine species, the mussel *Mytilus galloprovincialis* (Lamarck 1819) showed higher fragmentation, although the FI is similar to that observed for this species within other sites. This is not the case for *P. lineatus*, which had similar levels of fragmentation in units 114 and 115, but was
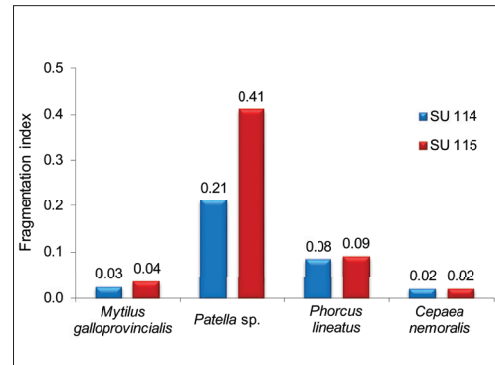
Figure 3: Fragmentation indices of the main species of molluscs (lower values reflecting higher fragmentation).

significantly higher than at other Mesolithic sites in the region (Gutiérrez-Zugasti 2011c). Finally, *Patella* sp. fragmentation indices are different between units. The index from unit 115 is similar to those from other Mesolithic sites, while the index from unit 114 showed a higher fragmentation.

The majority of the shells (99%) recorded in both stratigraphic units were collected on the rocky shore. Most of the species were captured in different areas of the intertidal zone (i.e. high, medium and lower zones) (**Fig. 4**). The higher percentages of high and medium zones on both units are related to the higher amounts of the top shell *P. lineatus*, which do not inhabit the lower zone. Length/Height
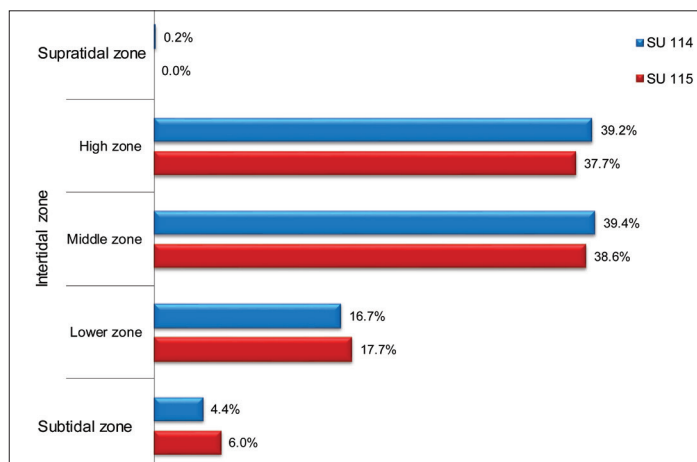
Figure 4: Collection areas in units 114 and 115 regarding littoral zonation: supratidal, intertidal (high, middle, low) and infratidal.

(L/H) ratios calculated for *P. vulgata* reflected that ~75–80% of the individuals of this species recovered from both units were captured in the lower zone of the intertidal. The MNI of the different taxa recovered on units 114 and 115 and the preferential zones of habitat exploited suggested that humans occupying El Mazo during the early Mesolithic preferentially targeted exposed shores (**Fig. 5**). Moreover, the regression equation described by Bailey and Craighead (2003) reflected that 97.8 and 99.3% of *P. vulgata* shells from units 114 and 115, respectively, were collected from exposed areas.

The biometric study provided information about the size of the main species recorded in units 114 and 115 (**Table 3**). A normality test (Shapiro-Wilk) showed normal size distributions for *P. lineatus* ($p = 0.67$) and *P.*
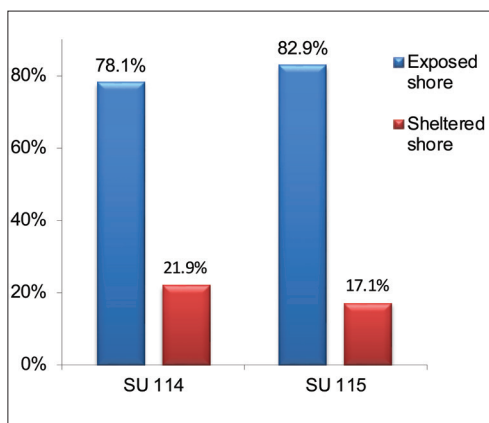
Figure 5: Collection areas in units 114 and 115 regarding coastal exposure (exposed or sheltered).

vulgata from unit 114 ($p = 0.76$), while distributions from unit 115 were found not to be normal for both taxa ($p < 0.0001$ & $p < 0.0001$). However, the size distribution of *P. depressa* from unit 115 (sample size from unit 114 was not significant) was normal ($p = 0.99$). Finally, the normality test showed that size distributions of both *rotulae* and semi-pyramids from the sea urchin *P. lividus* were not normally distributed in both units ($p < 0.0001$).

Discussion
Environmental conditions deduced from the shell assemblages
The composition of the shell assemblage has provided general information on the environmental conditions in the region *c.* 9 kys ago. Previous research identified a change of taxa between the late Pleistocene (colder conditions) and the early Holocene (warmer conditions). Cold-loving species such as the periwinkle *L. littorea* and the limpet *P. vulgata* were the most abundant in shell assemblages belonging to the late Pleistocene, whilst species adapted to warmer conditions such as *P. lineatus*, *P. depressa* and *Patella ulyssiponensis* (Linné 1758) were predominant in Holocene sites (although *P. vulgata* was also present in significant amounts) (Gutiérrez-Zugasti 2009; Gutiérrez-Zugasti and Cuenca-Solana 2014; Álvarez-Fernández 2011; 2013). A similar pattern is visible today in the Cantabrian coast, with a predominance of warmer species. Therefore, the presence of *P. lineatus* and the absence of

Taxon	SU 114				SU 115			
	Length		Width		Length		Width	
	n	Size (mm)	n	Size (mm)	n	Size (mm)	n	Size (mm)
P. lineatus	186	16.5	158	16.6	841	16.4	707	16.3
P. vulgata	51	24.7	61	19.6	176	24.4	198	19.8
P. depressa	5	23.8	7	19.6	50	24.7	60	20.3
P. lividus (Semi-Pyramid)	98	9.6	98	4.5	619	9.7	619	4.6
P. lividus (Rotula)	125	4.7		–	981	4.7		–

Table 3: Biometrical data (length and width) of the most abundant species at El Mazo.

L. littorea in units 114 and 115 suggest that climatic conditions during the formation of these units were typical of the Holocene in the region. The high percentage of *P. vulgata* within these units, in comparison with *P. depressa*, can be explained by the formation of these assemblages at the beginning of the Holocene, when the sea surface temperatures were still increasing. Although the amount of land snails is marginal and their presence at El Mazo is not related to human activity (except perhaps in the case of *C. nemoralis*), these taxa can also provide information about environmental conditions. The assemblage found at El Mazo, and especially the presence of *C. nemoralis* and *Pomatias elegans* (Müller 1774), suggests the existence of temperate conditions at the time of the occupation (André 1975). Therefore, species representation (both marine and terrestrial) at El Mazo suggests the existence of climatic and environmental conditions similar to today. This hypothesis is consistent with evidence from isotopic analyses previously undertaken on *C. nemoralis* recovered from the site (Yanes et al. 2012), which showed that the environmental conditions were more humid than during the late Pleistocene and were similar to the present day. These data are also consistent with other proxies used to reconstruct the environmental conditions during the Mesolithic in the Cantabrian region (mammals, pollen, seeds, charcoal, ostracods, foraminifera, etc.), which have documented a temperature increase from the start of the Holocene (Cuenca-Bescós et al. 2009; Fano 2007; Martínez-García et al. 2015; Rofes et al. 2015).

A comparison between modern shell assemblages from exposed rocky shores (Gutiérrez-Zugasti 2009) and those from El Mazo showed that the same species predominate (mainly limpets and top shells). Therefore, species representation and collection patterns also suggest that, despite the rising sea level until *c.* 7 kys cal BP, Holocene coastal areas were very similar to current littoral zones in the central area of the Cantabrian region, which is characterised by the occurrence of exposed shores and a limited existence of estuaries.

Shellfish exploitation patterns

The species representation shows that the exploitation during the formation of units 114 and 115 at El Mazo was focused on three taxa (the top shell *P. lineatus*, the limpets of the *Patella* genus and the sea urchin *P. lividus*), whilst the rest of the taxa were collected in limited amounts (**Table 2**). The predominance of limpets and top shells has been previously recorded in other Mesolithic shell midden sites in northern Iberia, located either in the Asturian area, such as Mazaculos II (Gutiérrez-Zugasti and González-Morales 2010), La Llana (Gutiérrez-Zugasti 2009), Poza l'Egua (Arias et al. 2007), El Toral III (Bello-Alonso et al. 2015) and unit 108 from El Mazo (García-Escárzaga et al. 2015), or in other parts of the Cantabrian region, such as La Garma A (Álvarez-Fernández 2013), El Truchiro (Álvarez-Fernández et al. 2013), La Trecha and La Fragua (Gutiérrez-Zugasti 2009). In all of these sites and within units 114 and 115 at El Mazo, limpets and top shells always account for more than 80% of the MNI of the shell midden. However, despite the clearly established pattern in species representation, there are changes in the abundance of the predominant taxa. In general terms, limpets from the *Patella* genus are the most exploited species, but the amount of *P. lineatus* in units 114 and 115 at El Mazo is unusually high when compared to other sites in the region, and only at La Llana does the %MNI reach similarly high proportions (Gutiérrez-Zugasti 2009). These changes could be related to differences in resource availability due to: 1) environmental factors (warmer conditions inducing abundance of warm loving species, such as *P. lineatus*), 2) human pressure on the limpets (reduced stocks of limpets promoting the collection of alternative species), or 3) human decisions on shell selection at different times (collection of *P. lineatus* is easier as no tools are needed to

detach the shells from the rocks, and they usually inhabit more accessible areas of the shorefront).

The presence of sea urchin as one of the most exploited species is not commonly observed archaeologically in the region. Sea urchins have rarely been documented in any considerable quantity at late Pleistocene and early Holocene sites dated within Cantabrian Spain, with the exception of the late Magdalenian and Azilian levels in Santa Catalina (Gutiérrez-Zugasti 2014), the Mesolithic midden in Arenillas (Gutiérrez-Zugasti 2009) and unit 108 at El Mazo (García-Escárzaga et al. 2015). However, %MNI and MNI/dm^3 from units 114 and 115 are considerable larger than in any other assemblage previously reported. The limited numbers of echinoderms compared to molluscs has usually been interpreted from a quantitative perspective, implying that they were opportunistic resources contributing to the survival of the group (Gutiérrez-Zugasti 2011c). However, given the pattern of continuous exploitation exhibited by these resources in northern Iberia (Álvarez-Fernández 2011; Gutiérrez-Zugasti 2011c), some scholars have recently stated that they could be interpreted from a qualitative perspective, and so they should be considered as stable resources with a significant social value (Gutiérrez-Zugasti et al. 2016). Nevertheless, recent studies have demonstrated that the interpretation of the role of echinoderms in subsistence strategies of prehistoric populations is clearly biased.

Investigations of sea urchins have not usually relied on remains recovered from mesh screens smaller than 2 mm. Recently, two different investigations have studied the material coming from the 1 mm mesh in order to test the MNI that would have been lost if only 2 and 4 mm mesh were used (Álvarez-Fernández et al. 2010; García-Escárzaga et al. 2015). However, these investigations reached different conclusions. The results obtained by Álvarez-Fernández et al. (2010) suggested that the MNI would not increase by using remains recovered in the 1mm mesh screen. However, the limited sample size used in that study was probably biasing the results. In contrast, results presented by García-Escárzaga et al. (2015) from unit 108 at El Mazo, where the presence of sea urchins was significant, suggested that the MNI loss would have been considerable (31.5%) if remains recovered in the 1 mm mesh screen were not used. This could explain the lower quantity of sea urchin remains found in other previously analysed shell assemblages. Results presented here confirm that the amount of MNI loss would be higher if only the material recovered in the mesh screen of 2–4 mm were used, and this is especially true for unit 115 where 23.3% of the total sea urchins would have been lost (**Table 4**). Therefore, using 1 mm mesh screen has been demonstrated to be helpful (and necessary) to increase the accuracy of the MNI calculations and not undervalue the role of sea urchins in human diet. In our case, a correct estimation of the amount of sea urchins was crucial to establish that sea

Mesh screen sizes	*Paracentrotus lividus* MNI					
	SU 114		SU 115		Total	
	n	Total%	n	Total%	n	Total%
4 mm	9	31	85	40.5	94	39.3
2+4 mm	27	93.1	161	76.7	188	78.7
1+2+4 mm	29	100	210	100	239	100

Table 4: Comparison of Minimum Number of Individuals (MNI) of the sea urchin *Paracentrotus lividus* obtained in units 114 and 115 using 4, 2 and 1 mm mesh screens.

urchins probably were much more important for human populations than previously thought.

Very few land snails were present within units 114 and 115. The occurrence of these organisms at archaeological sites can have a natural or anthropogenic origin (Lubell 2004; Fernández-López de Pablo 2011; Gutiérrez-Zugasti 2011d). When edible species such as *C. nemoralis* appear in small numbers they are usually considered as natural accumulations and this is probably the case at El Mazo.

In terms of shell collection locations, the human populations occupying El Mazo during the early Mesolithic exploited intertidal areas of rocky exposed shores (**Fig. 4** and **5**). The most commonly exploited species, the limpets *P. vulgata* and *P. depressa* inhabit all levels of the intertidal zone, whereas *P. ulyssiponensis* occupies the lower zones; top shell *P. lineatus* inhabits the high-medium areas of the intertidal; and the sea urchin *P. lividus* is usually found within lower intertidal and subtidal locations, although they can also be found in rock pools located in higher zones of the intertidal range (Fechter and Falkner 1993; Gutiérrez-Zugasti 2009). Data from El Mazo show that high-medium areas of the intertidal were exploited (e.g. collection of *P. lineatus*), but information obtained from *P. vulgata* indicates heavy exploitation of lower exposed zones, which is consistent with other Mesolithic sites, contrasts with the exploitation patterns observed during the Upper Palaeolithic in the region, when this species was mainly collected in higher and sheltered shores (Gutiérrez-Zugasti 2009; 2010).

Shellfish gathering and intensification in northern Iberia during the Mesolithic

Intensification in the use of coastal resources is thought to have occurred in northern Iberia from the late Palaeolithic to the Mesolithic (Gutiérrez-Zugasti 2011b; Straus and Clark 1986). In the case of El Mazo, taphonomy (high shell fragmentation), chronology (units formed in a short period of time) and shell abundance suggest an intensive use of the cave for exploitation of coastal resources. Data relating to shell biometry and collection areas are also needed to confirm the existence of intensification. Thus, decrease in shell size and exploitation of lower and more exposed areas than in the Upper Palaeolithic have been suggested as potential indicators of intensification during the Mesolithic in the region (Gutiérrez-Zugasti 2011b).

Results based on shell sizes from El Mazo showed that *P. lineatus*, *P. vulgata* and *P. depressa* (**Table 3**) were smaller than top shells or limpets recovered in Magdalenian and Azilian assemblages from the Cantabrian region (Álvarez-Fernández 2013; Álvarez-Fernández et al. 2011; Gutiérrez-Zugasti 2011b; Ortea 1986). However, shell sizes measured from units 108, 114 and 115 are slightly smaller than those from other Mesolithic assemblages of similar chronology, and are more similar to the sizes recorded from late Mesolithic and Neolithic assemblages (Arias et al. 2007; Álvarez-Fernández et al. 2011; Gutiérrez-Zugasti 2011b). Reduced shell size at El Mazo *c.* 9 kys cal BP could be related to the intensification in the exploitation of marine resources stated for the Mesolithic by previous research (Gutiérrez-Zugasti 2011b; Straus and Clark 1986), but at the same time the presented data do not fit the model of gradual decreasing sizes through time, with smaller sizes at the late Mesolithic and Neolithic. The explanation could be related to collection strategies and resource management, and periods of intense shell collection could have alternated with times of shell stock recovery through the Mesolithic.

Collection areas could also potentially be linked to the coastal resource intensification proposed for the Mesolithic in the region (Gutiérrez-Zugasti 2009; 2010; 2011b; 2011e). Accessing lower and exposed areas can be a complicated task as these areas are continually wave-beaten, and are therefore more dangerous than higher intertidal zones. A trend exists towards the exploitation of these areas (probably due to depletion of

shellfish in higher zones of the intertidal) during the Mesolithic, and data from El Mazo comply with this model. The intensification hypothesis is also consistent with the size-able amount of sea urchins recovered in these stratigraphic units, as they inhabit the lower intertidal and subtidal zones and the procurement of this species is more complex than other coastal resources. However, with the available information, other explanations (e.g., collection in intertidal rock pools) cannot be discarded.

Differences in size distributions of *P. lineatus* and *P. vulgata* between unit 114, and units 108 and 115, suggest the existence of two different collection strategies. Whilst normal distributions were recorded in unit 114, distributions from units 108 and 115 were not normally distributed. Data from the normality test plus data from the univariate statistics (e.g. skewness) clearly demonstrated that larger sized shells were collected during the formation of units 108 and 115, whereas all sizes of shells were collected within unit 114, reflecting that more intense exploitation was performed. However, data on *P. depressa* from units 108 and 115 (normal distribution and slightly negative skewness) suggest intensive collection within both units. Conversely, distributions of *P. lividus* were not normal, indicating some kind of size selection. Diversity in size selection between units reflect the existence of changes in collection strategies through time, while differences in size selection strategies between species suggest differential treatment, in terms of intensity of exploitation, depending on the species targeted.

Therefore, although information recovered from species representation, collection areas and biometry from the units analysed at El Mazo reflect some evidence of intensification (reduced shell size, collection in lower areas of exposed shores, no size selection in some units and species), the results suggest the existence of a mixture of strategies, with periods of higher and lower level of intensity in the collection of coastal resources.

Conclusions

Mesolithic human groups that occupied El Mazo cave ~9 kys cal BP systematically exploited molluscs, sea urchins and crustaceans. The limpets from the genus *Patella*, the top shell *P. lineatus* and the sea urchin *P. lividus* were the preferred taxa. Using 1 mm mesh screen allowed for a more precise recovery of sea urchin remains, increasing the accuracy in MNI calculation. A better estimation of the amount of sea urchins was crucial to establish their role in shellfish exploitation patterns. Environmental conditions deduced from shell assemblages indicated that temperate conditions prevailed at the time of the occupation and that coastal morphology was similar to today (rocky exposed shores). Collection was carried out predominantly in exposed and lower areas of the intertidal zone. Information recovered from species representation, collection areas and biometry from the units analysed at El Mazo showed some evidence of intensification (reduced shell size, collection in lower areas of exposed shores, no size selection in some units and species) in the exploitation of coastal resources through time. However, the results do not fully fit the intensification model, suggesting the existence of changes in collection strategies and resource management, and so periods of intense shell collection could have alternated with times of shell stocks recovery through the Mesolithic.

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