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Shellfish consumption in the Early Upper Palaeolithic on the Mediterranean coast of the Iberian Peninsula: The example of Foradada Cave

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ABSTRACT

Foradada Cave is an archaeological site located in the Mediterranean coast of the Iberian Peninsula (Xàbia, Spain). Marine molluscs have been recovered in the Early Upper Paleolithic archaeological levels (VI, V and II) of the site. This assemblage is composed by a high diversity of marine taxa, however the majority of them are represented by few individuals (in many cases, just one). The presence of different species from rocky shores and sandy/gravel shores has been documented, but the most important species are mussels (*Mytilus galloprovincialis* Lamarck, 1819), limpets (*Patella* spp. Linnaeus, 1758) and top snails (*Phorcus* spp. Risso, 1826). The three taxa were consumed as food. In the same levels (V and II) some shell ornaments have been recovered as well. This study shows that the consumption of marine resources (used for diverse purposes) is usual since very ancient chronologies, and they must be considered to reconstruct the diet, the economy and the social organization of hunter-gatherer societies in the Early Upper Paleolithic and especially in the Aurignacian.

1. Introduction

The number of examples of the consumption of marine resources in old chronologies is increasing. This is proof that these resources have been part of the subsistence of human societies since very ancient times. The earliest evidence of the consumption of marine molluscs has been found in South Africa (Pinnacle Point) and dates back to 164 ka (Marean et al., 2007; Jerardino and Marean, 2010; Jerardino, 2016).

In the Iberian Peninsula (IP), the use and consumption of littoral resources (molluscs, fish and mammals) is documented since the Middle Palaeolithic (MP) (Montes Bernárdez, 1988, 1993; Antunes, 2000; Callapez, 2000; Baena Preysler et al., 2004; Álvarez Fernández, 2005; Morales-Muñiz and Roselló-Izquierdo, 2008; Zilhão et al., 2010; Colonese et al., 2011; Cortés-Sánchez et al., 2011; Aura Tortosa et al., 2016; Fa et al., 2016). Bajondillo Cave has yielded the oldest record (150 ka) (Cortés-Sánchez et al., 2011) and the record of these remains increases progressively in later times (Álvarez-Fernández, 2011; Colonese et al., 2011). During the Upper Palaeolithic in the IP and in other Mediterranean areas, there are numerous examples of the consumption of molluscs at archaeological sites located near the coast. Molluscs were used for different purposes as they were consumed as food and used as ornaments or as tools (*e.g.* Martínez Andreu, 1989; Montes Bernárdez, 1993; Stiner, 1999; Álvarez Fernández, 2005; Colonese et al., 2011; Gutiérrez-Zugasti et al., 2013; Cuenca-Solana, 2015; Aura Tortosa et al., 2016; Fa et al., 2016). According to the archaeological data, the consumption of marine resources and especially molluscs in these chronologies do not seem to be massive. However, we might say that it was usual among hunter-gatherer societies from the MP. Moreover, in this period, the presence of other small resources has also been proved (*e.g.* Stiner et al., 2000; Bicho and Haws, 2008). As some scholars propose, this could be interpreted as an early diversification of the diet probably since, at least, the beginning of the Upper Palaeolithic (or even MP). This leads us to think that the diet of hunter-gatherer societies was probably made up of all the available resources in the area where they lived and accessible with the technology that they had from the Early Upper Palaeolithic (EUP) onwards.

The hypothesis of the marginality of small resources (molluscs among them) has been questioned for some time (*e.g.* Stiner et al., 2000; Brugal and Desse, 2004). In this way, owing to the recent increase in the number of studies, the secondary role of these resources is becoming outdated and they are being considered an important part of the diet. The human body, especially the brain, needs different essential nutrients besides calories (principally from meat) to develop (Hocket and Haws, 2003; Haws and Hocket, 2004). Some of these essential nutrients are present in marine resources: vitamins (A, B12, C, D, E), iron, folate, potassium, calcium and omega-3 fatty acids (Bosch et al., 2017). Following Hocket and Haws (2003), diverse diets are more efficient and are associated with lower infant mortality rates and a longer average life expectancy.

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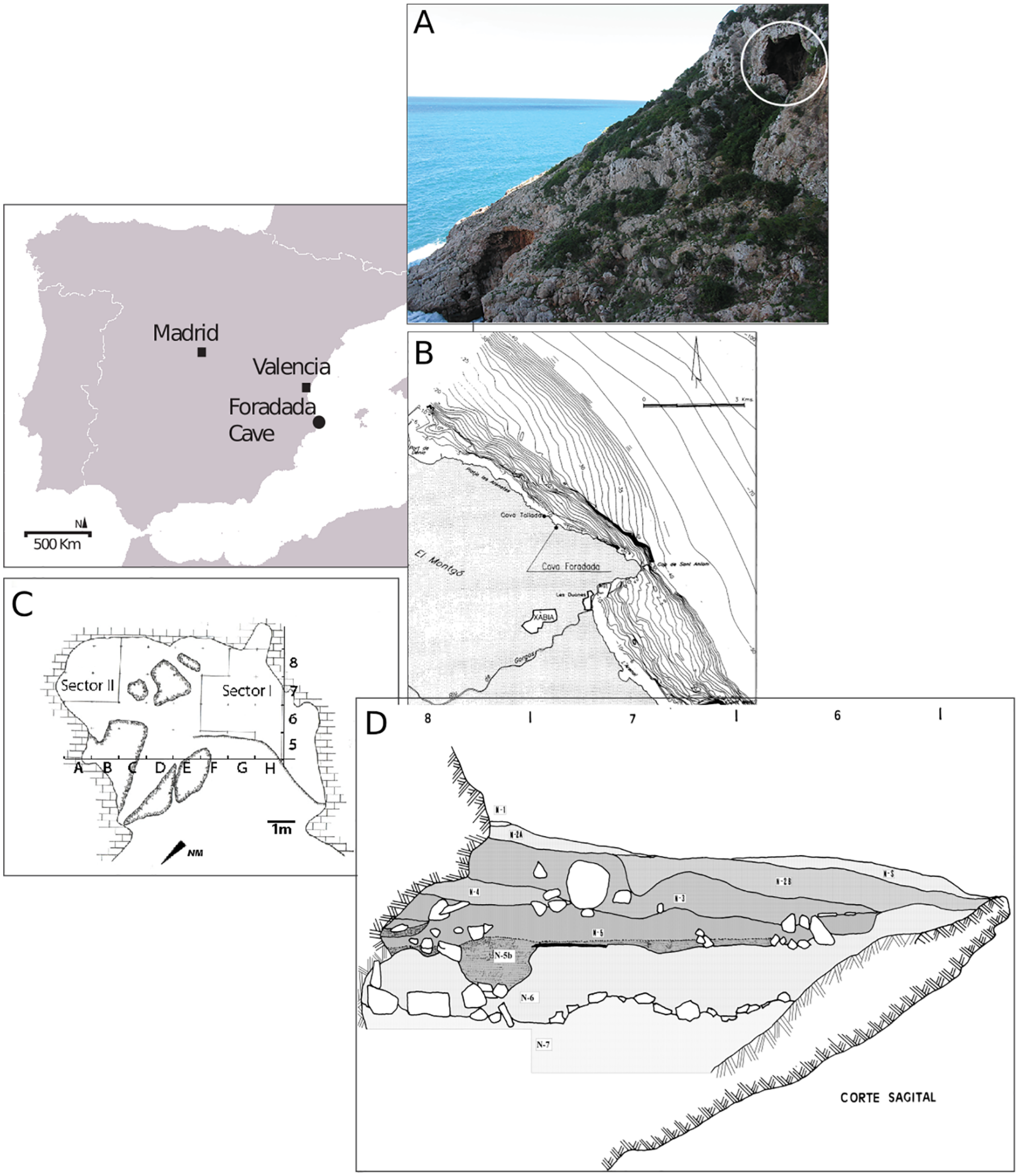

Fig. 1. Location and plan of Foradada Cave: A. Foradada Cave nowadays; B. Reconstruction of the coastal geomorphology (obtained from Fumanal and Olmo, 1997); C. Plan of the archaeological site; D. Stratigraphic sequence of the eastern section of the excavation in Sector I.

Considering the importance of small resources in the socio-economic organization of hunter-gatherer societies, the main objective of this work is to afford new information about the consumption of molluscs in the EUP through the study of malacofaunistic non-ornamental marine remains from Foradada Cave (Xàbia, Spain). This study complements the preliminary analysis published in a previous work (Casabó i Bernad, 1997a, 1997b). The study of these remains will contribute to a better understanding of: a) the role of marine resources in the economies of hunter-gatherer societies in the EUP and b) the relationship between these groups and the sea.

2. Foradada Cave: the site

Foradada Cave is a rock-shelter of c. 60 m^2, located at 40mamsl, in the cliff of the Sant Antoni Cape (Xàbia, Spain) (Fig. 1). During the EUP occupations, the cave was located at c. 2 km of the nearest coast, where the shore was steep and rocky. Studies on the ancient coastline and submarine bottom relief show that there is another cliff at $-30/-35$ m off the current coastline near Foradada Cave. This tends to get narrower towards the point of Sant Antoni Cape. Between both cliffs there is a funnel-shaped space that might have been a natural trap for animal herds. Towards the north, this cliff loses height and it turns into a coastal sandy plain. For this reason, the emerged platform in this area during the Pleistocene was c. 4 km wide (Casabó i Bernad, 1997a, 1997b; Fumanal, 1997; Fumanal and Olmo, 1997).

Throughout the fieldwork, different successive phases with some intermediate gaps were identified. The stratigraphy does not consist of a continuous sequence but is formed by occasional short occupation events which have taken place separated in time since the EUP until recent times (Casabó i Bernad, 1997, 2014; Fumanal and Olmo, 1997).

During the excavation of the site, two sectors were differentiated on each side of the cave (Sector I and Sector II). They had a similar stratigraphic sequence, although in Sector II the recent levels were absent because the site had been plundered and it has not been totally excavated (Casabó i Bernad, 1997). In the Sector I eight archaeological levels have been identified. Calibrated age estimates are provided at the 68% probability level (Casabó i Bernad, 2014). The stratigraphic sequence is briefly described below but the aurignacian levels on which this work focuses (Levels VI and V-Sector I and Level II-Sector II) are described in more detail (Fumanal and Olmo, 1997; Casabó i Bernad, 1997a, 1997b, 2014; Pantoja et al., 2011):

Sector I:

- Level VIII: it lays on a stalagmitic surface. It contains some remains of fauna and charcoal. Due to the scarcity of remains, the chronology is uncertain.
- Level VII: it is composed of clays and blocks from the breaking down of the karst. Like the previous level, the archaeological remains are scarce as well. Only some lithic, fauna and charcoal remains have been recovered. It has been dated to 33,900 ± 310 BP (40,506–38,481 cal BP).
- Level VI: it has been dated to 29,950 ± 150 BP (34,409–34,081 cal BP). The palynological studies indicate cold and dry conditions (by the presence of Asteraceae). Some remains have been documented (lithics, fauna and charcoal). The archaeozoological study shows the presence of red deer (*Cervus elaphus),* wild goat *(Capra pyrenaica),* wild boar (*Sus scrofa*) and some felines: leopard (*Panthera pardus*), lynx (*Lynx pardinus)* and wildcat (*Felis silvestris*).
- Level V: it is the main occupation phase at the site and the archaeological remains are more abundant. Five hearths and lithic (which correspond to the Aurignacian), charcoal and faunal remains have been recorded. The identified vertebrate species are red deer, wild goat, horse equid (*Equus hydruntinus* and *Equus ferus*), a big bovine (probably *Bos primigenius)*, wild boar and some carnivores (lynx, leopard and wildcat). Two radiocarbon dates have been obtained: 29,440 ± 190 BP (34,122–33,497 cal BP) and 27,190 ± 150 BP (32,015–31,727 cal BP). A variation is documented in the course of Level V: the first palynological samples, from the bottom of the level, were sterile but the presence of *Pinus* and *Juniperus* is recorded in progressively higher samples. This reveals an arboreal landscape that expands towards the top of the level. The presence of xeric and steppe plants is also documented. At the top of the level the presence of bushes, *Pinus* and *Juniperus,* is higher which suggests greater climate stability. In addition, the presence of taxa that indicates a major availability of water and greater thermal regularity (*Alnus* and Ericaceae) is also recorded (Pantoja et al., 2011). This description corresponds to Heinrich Event 3 (HE3) (c. 31,000 BP), which is characterized by a relative slow cooling of the sea surface temperature (SST) (3.7 °C in 1300 years) and a final sharp warming (4 °C in 500 years) in the Alboran Sea (Cacho et al., 1999).
- Level IV: the faunal and lithic remains are similar to those obtained in level V. There are no radiocarbon dates.
- Level III: abundant faunal remains have been obtained. Although the radiocarbon date, 6,130 ± 140 BP (7,182–6,838 cal BP), corresponds to the Epicardial Neolithic, the lithic assemblage and the lack of ceramics suggest that it corresponds to the Mesolithic.
- Level II and I: both levels are sedimentologically similar, although the sediment is darker towards the top. The obtained remains correspond to the Eneolithic. There are no radiocarbon dates.

Sector II:

- Level III: practically, it has not been excavated. Some faunal and lithic remains have been documented. Lithics correspond to EUP but there are no radiocarbon dates.
- Level II: the top of the level was plundered by furtive. This is the reason of the differences among the obtained dates 28,310 ± 170 BP (33,041–32,384 cal BP), 26,610 ± 460 BP (31,749–30,813 cal BP), 20,620 ± 80 BP (24,866–24,358 cal BP) and 7770 ± 50 BP (8593–8482 cal BP). It is chronologically very similar to Level V-Sector I. Some faunal and lithic remains have been documented but there is no detailed information about the vertebrate fauna. However, the find of a spherical piece of limestone can be noted. The palynological studies show a very open landscape with low taxonomic variability.
- Level I: although this level was highly altered due to the action of the looters, some faunal and lithic remains corresponding to the Paleolithic have been recovered. The dates are altered as well: 2820 ± 80 BP (3063–2853 cal BP) and 310 ± 40 BP (441–327 cal BP).

It should be noted that in the studied levels continental molluscs (Levels VI and V-Sector I and Level II-Sector II) and ornaments (Levels V and II) made from marine and freshwater mollusc shells have also been documented in addition to marine mollusc remains (Casabó i Bernad, 1997a, 1997b, 2014; Pantoja et al., 2011). The continental species documented in level V are: *Melanopsis* sp., *Pomatias elegans*, *Abida polyodon*, *Ferrussacia follicula*, *Rumina decollata*, *Sphincterochila* sp., *Cernuella cespitum*, *Trochoidea barcinensis*, *Trochoidea barceloi*, *Xerotricha apicina*, *Helicella* sp., *Oestophora boscae jeresae*, *Iberus alonensis*, *Pseudotachea splendida* and *Otala punctata* (Casabó i Bernad, 1997a, 1997b). The assemblages from levels VI and II are still under study.

3. Material and methods

Marine mollusc remains from the Aurignacian levels (VI, V and II) in Foradada Cave have been analysed. The larger specimens were systematically collected manually during the excavation and their provenance were registered (level, square and depth). The smaller ones were recovered after wet sieving the sediments by square meter every 5 mm depth. The size of the mesh was 1 mm. The analysis included the taxonomic identification of the remains, the count of the remains (NR and NISP), the estimation of the minimum number of individuals (MNI) and the taphonomic, biometric and morphometric analyses.

3.1. Taxonomy, NR and MNI estimation

The taxonomic identification of the remains has been carried out with the reference collections in the Laboratoire méditerranéen de préhistoire Europe Afrique (LAMPEA) (Aix-Marseille Université) and the Laboratory of Archaeozoology (Universitat Autònoma de Barcelona) and by consulting guides, manuals, specialized bibliography (D'Angelo and Gargiullo, 1978; Martinell et al., 1986; Lindner, 2000) and the on-line catalogue World Register of Marine Species (WoRMS) (www.marinespecies.org) (WoRMS Editorial Board, 2017). Identifications refer to the lowest possible taxonomic level following the nomenclature proposed in this register.

The MNI has been estimated according to the number of whole individuals and diagnostic and unrepeated parts of shells, adapting the proposals of Moreno (1994) and Gutiérrez-Zugasti (2009). For bivalves, the parts used are as follows: umbo (whole or anterior, central or posterior part) and the whole ventral margin. The laterality of the valves or fragments has also been taken into account to calculate the MNI, which was based on the side with the largest number of fragments. For gastropods, the parts of the shell taken into account were as follows: the apex, the peristome, the umbilicus and the operculum. The MNI was calculated by the number of whole individuals plus the part with the largest number of specimens.

3.2. Taphonomy

The most important taphonomic processes that affect mollusc remains from Foradada Cave (pre- and post-deposition) have been identified. This will make it possible to identify, to characterize and to discriminate intentional human actions from non-intentional or natural actions. In order to do this, the proposals of Gutiérrez Zugasti (2008–2009) and Bosch et al. (2015) have been followed. The former explains each of the taphonomic processes that can affect shells in archaeological deposits and the agents that may cause them. The latter work includes a detailed taphonomic study of mollusc remains.

Pre-deposition processes include: abrasion by sedimentary particles transported by seawater and the presence of natural perforations (caused by a predator or by natural erosion of the shell) and/or the presence of serpulids. Post-deposition processes are seen in the degree of fracture of the remains, signs of burning, the presence of calcareous concretion, the decalcification of the remains and the presence of perforations caused by natural erosion of the shell. The pre-deposition processes (abrasion and the presence of natural perforations caused by a predator or serpulids in the inner part of the shell) indicate that shells have been collected post-mortem.

Calcareous concretion affects a large number of the remains from Foradada Cave. In some cases it affects the complete shells and the taxonomic identification of some remains was hampered by this taphonomic alteration. In the most of the remains it covers only a part of the shell, so the cases where the pre-deposition damage could be concealed by the calcareous concretion are not significant.

3.3. Biometry

The size of molluscs of archaeological sites can afford information about the management of these resources (Mannino and Thomas, 2001; Gutiérrez-Zugasti, 2011; Verdún Castelló, 2014a, 2014b). For this reason, all the complete individuals and the fragments capable of offering any data have been measured. The measurements have been taken with a Vernier digital calliper and recorded in millimetres to two decimal points. The measurements taken in gastropods are: length (from the apex to the base of the peristome), width (W) and height (H) (in limpets). For bivalves, the measurements taken were the maximum length (L) (from the margin to the umbo) and the maximum width (W). A more detailed study has been carried out for the most abundant taxa: *Mytilus galloprovincialis* and *Patella* spp. (*Patella caerulea*, *Patella rustica* and *Patella* sp.). The measurements obtained from the third most abundant taxon (*Phorcus* spp.) are not enough to offer unbiased information. The statistical analyses were performed with the software *R-statistics*: Shapiro-Wilk test of normality and Wilcoxon test to compare the results between levels. Statistical results are considered significant when $P < 0.05$.

3.4. Morphometric analysis

The morphology of the shells is directly correlated to the characteristics of the coast where these animals lived. Therefore, its study can provide information about the coastal areas where these animals were obtained and, indirectly, about the management implemented by human societies (Bailey and Craighead, 2003; Cabral and da Silva, 2003; Campbell, 2008; Cabral, 2010; Colonese et al., 2014; Verdún Castelló, 2015). Morphometric analysis has been carried out in order to obtain information about the area where molluscs were collected. This analysis has been implemented for the species *Mytilus galloprovincialis* and *Patella caerulea*. These taxa have been chosen because: a) they are the most abundant in the site and b) there is already previous information about the variation of the morphology of their shells in the Mediterranean (Adriatic Sea).

A study about the variation of the morphology of *Mytilus galloprovincialis* shells carried out on the north coast of the Adriatic Sea shows that their shape varies in relation to their position in the intertidal zone (as a consequence of the action of waves) (Moschino et al., 2015). This variation could be evaluated by the rate obtained between width and length (W/L) (from here on, robustness index). The highest values indicate a more robust shape of the shell (wider and less high, in proportion). According to this study, in the north of the Adriatic Sea the highest indexes correspond to the lowest area of the intertidal zone (subtidal), which is always submerged. In order to obtain data about the area where the mussels in Foradada Cave were collected, the morphometric indices of the archaeological individuals have been compared to the values of modern individuals in this study.

A similar study was applied to *Patella caerulea* in the same area (in the Gulf of Trieste) in the northern Adriatic Sea (Battelli, 2016). The variation in the morphometry of this limpet is reflected in the ratio between height and length (H/L) (conicity index). In this study, the higher values correspond to the individuals collected in the area above mean sea level, as a mechanism to avoid dehydration. The values obtained from the archaeological limpets have been compared to the values obtained in this study of modern individuals.

4. Results

4.1. Taxonomy, NR and MNI estimation

A total of 6876 malacofaunistic remains have been documented (gastropods and bivalves) in the three studied levels. In Level VI, 213 remains were recovered, of which 42% have been identified taxonomically (NISP = 89). They correspond to 13 individuals, of which 69.2% are bivalves. The most abundant species is *Mytilus galloprovincialis* Lamarck, 1819 (MNI = 7; 53.8%) (Table 1, Fig. 2).

In Level V, 3032 malacofaunistic remains have been documented, of which 98% have been identified (NISP = 2958). The estimated MNI is 344, of which 52.3% are bivalves. Although the taxonomic diversity is high, most of the taxa are represented by only one or two individuals. The most abundant species are *Mytilus galloprovincialis* (MNI = 164; 47.7%), *Patella* spp. (*Patella caerulea*, *Patella rustica* and *Patella* sp.) (MNI = 92; 26.7%) and *Phorcus* spp. (*Phorcus turbinatus* and *Phorcus* sp.) (MNI = 29; 8.5%). Besides the molluscs, remains of other marine invertebrate have also been recovered: cirripedia (NR = 2; MNI = 1), echinodermata (NR = 32; MNI = 1) and a crustacean (NR = 3; MNI = 1).

In Level II 3631 malacofaunistic remains have been documented, of which 97% have been identified (NISP = 3532), corresponding to 308 individuals (84.4% of them are bivalves). Like in Level V, the taxonomic diversity is high, but most of the taxa are represented by few individuals. The most abundant species in this level are the same as those in Level V: *Mytilus galloprovincialis* (MNI = 243; 78.9%) and *Patella* spp. (*Patella caerulea*, *Patella rustica* and *Patella* sp.) (MNI = 18; 5.8%). The presence of *Buccinum undatum* and *Neptunea contraria* should be highlighted (Fig. 3). Both are species from cold waters, especially *Neptunea contraria*. Geological studies of würmian submarine sediments prove the presence of these species in different areas in the Mediterranean (Domènech and Martinell, 1982; Martinell et al., 1986; Vicens et al., 2001). Other marine invertebrate remains have been documented: cirripedia (NR = 1; MNI = 1), echinodermata (NR = 12; MNI = 1) and a crustacean (NR = 4; MNI = 1).

The most important taxa in the three levels (*Mytilus galloprovincialis*, *Patella* spp. and *Phorcus* spp.) live on intertidal rocky shores (D'Angelo and Gargiullo, 1978).

4.2. Taphonomy

In general, the degree of fragmentation of the remains is very high and similar in the three levels. In Level VI, only 3.8% of the remains are complete, 3.2% in Level V and 3% in Level II. It should be highlighted that *Patella* spp. have marks on their edges that were caused by the instrument used to pry them off the rock (Fig. 4). Table 2 shows the other taphonomic processes observed on the remains from Foradada Cave. The results of the taphonomic study indicate some differences between the three levels.

As can be observed in Table 2, Levels V and II present very similar results which are different from those obtained in Level VI. The clearest

Table 1
Taxonomic composition of the marine mollusc assemblage recovered in the Aurignacian levels at Foradada Cave: Number of remains (NR) and Minimal number of individuals (MNI).

	Level											
	VI				V				II			
	NR	%	MNI	%	NR	%	MNI	%	NR	%	MNI	%
Gastropods												
Bittium reticulatum (da Costa, 1778)					1	0.03	1	0.3	1	0.03	1	0.3
Bittium sp. Gray, 1847									1	0.03	1	0.3
Cerithium vulgatum Bruguière, 1792					8	0.26	5	1.4	7	0.19	4	1.3
Cerithium sp. Bruguière, 1789					2	0.07	1	0.3				
Turritella communis Risso, 1826	5	2.3	1	7.7	47	1.55	14	4.1	18	0.50	4	1.3
Melarhaphe neritoides (Linné, 1758)									1	0.03	1	0.3
Euspira sp. Agassiz, 1837					1	0.03	1	0.3				
Naticidae Guilding, 1834					2	0.07	2	0.6	2	0.06	2	0.6
Aporrhais sp. da Costa, 1778									1	0.03	1	0.3
Trivia sp. Gray, 1837					1	0.03	1	0.3	1	0.03	1	0.3
Buccinum undatum Linné, 1758					82	2.70	11	3.2	16	0.44	5	1.6
Neptunea contraria (Linné, 1771)									2	0.06	1	0.3
Columbella rustica (Linné, 1758)					1	0.03	1	0.3	1	0.03	1	0.3
Tritia cuvierii (Payraudeau, 1826)					1	0.03	1	0.3				
Nassariidae Iredale, 1916 (1835)					1	0.03	1	0.3	1	0.03	1	0.3
Ocenebra edwardsii (Payraudeau, 1826)					3	0.10	3	0.9	1	0.03	1	0.3
Stramonita haemastoma (Linné, 1767)					2	0.07	1	0.3	1	0.03	1	0.3
Patella caerulea Linné, 1758					23	0.76	23	6.7	7	0.19	6	1.9
Patella rustica Linné, 1758					33	1.09	27	7.8	8	0.22	5	1.6
Patella sp. Linné, 1758	5	2.3	1	7.7	254	8.38	42	12.2	45	1.24	7	2.3
Gibbula sp. Risso, 1826									3	0.08	1	0.3
Phorcus turbinatus (Born, 1778)	1	0.5	1	7.7	266	8.77	26	7.5	44	1.21	4	1.3
Phorcus sp. Risso, 1826	7	3.3	1	7.7	30	0.99	3	0.9	6	0.17	–	–
Gastrop. ND	18	8.5	–	–	41	1.35	–	–	16	0.44	–	–
Bivalves												
Acanthocardia tuberculata (Linné, 1758)					11	0.36	1	0.3	13	0.36	2	0.6
Acanthocardia sp. J.E. Gray, 1851	1	0.5	1	7.7	1	0.03	1	0.3	2	0.06	1	0.3
Cerastoderma sp. Poli, 1795					6	0.20	2	0.6	1	0.03	1	0.3
Cardiidae Lamarck, 1809					28	0.92	–	–	16	0.44	–	–
Mactra sp. Linné, 1767									1	0.03	1	0.3
Chamelea gallina (Linné, 1758)					3	0.10	1	0.3	3	0.08	2	0.6
Ruditapes decussatus (Linné, 1758)									2	0.06	1	0.3
Venus verrucosa Linné, 1758					1	0.03	1	0.3				
Veneridae Rafinesque, 1815									1	0.03	–	–
Lembulus pella (Linné, 1758)									1	0.03	1	0.3
Glycymeris sp. da Costa, 1778					6	0.20	3	0.9	2	0.06	2	0.6
Modiolus sp. Lamarck, 1799									1	0.03	1	0.3
Mytilus galloprovincialis Lamarck, 1819	69	32.4	7	53.8	2113	69.69	164	47.5	3279	90.31	243	78.9
Ostreidae Rafinesque, 1815					1	0.03	1	0.3				
Pecten sp. O.F. Müller, 1776					22	0.73	5	1.4	29	0.80	2	0.6
Aequipecten opercularis (Linné, 1758)									1	0.03	1	0.3
Mimachlamys varia (Linné, 1758)					5	0.16	1	0.3	6	0.17	2	0.6
Pectinidae Rafinesque, 1815	1	0.5	1	7.7	3	0.10	–	–	7	0.19	–	–
Bivalve ND	106	49.8	–	–	33	1.09	–	–	83	2.29	–	–
Total	**213**		**13**		**3032**		**344**		**3631**		**308**	
Cirripedia					2		1		1		1	
Crustacea					3		1		4		1	
Echinoidea					32		1		12		1	
Total					**37**		**3**		**17**		**3**	

differences between them are in the percentages of remains affected by abrasion caused by the sedimentary particles transported by seawater (pre-deposition) and the remains affected by calcareous concretion (post-deposition).

The most important taphonomic process in Level VI is abrasion. It affects 50.7% of the remains. Due to this, many remains could not be identified taxonomically. The other processes recorded in this level are due to post-deposition actions: the calcareous concretion that affects 5.2% of the remains, and burning, observed in 2.3% of the remains (all of them *Mytilus galloprovincialis*).

In Levels V and II, the post-deposition alterations are those which most affect the conservation of malacofaunistic remains: calcareous concretion is the most frequent. It is documented on 20.9% of the remains from Level V (especially on *M. galloprovincialis*, *Buccinum undatum* and *Patella* spp.). Evidence of burning is present on 6.8% of the remains, principally *M. galloprovincialis*, *Patella* spp. and *Phorcus* spp. The presence of natural perforations (that can be due to pre- or post-deposition processes) or serpulids in the internal side of the shell is observed in 0.8% of the remains. They are present in the taxa *Turritella communis* and Naticidae (with perforations produced by the natural erosion of the shell), *M. galloprovincialis* (with serpulids on the internal side of the shell). Finally, the pre-deposition process of abrasion affects 2.1% of the remains (especially Cardiidae, bivalves ND and gastropoda ND).

In Level II calcareous concretion is documented on 23% of the remains (mainly on *M. galloprovincialis* and *Pecten* sp.). Some of the remains display evidence of burning (5.6%). The most affected taxa are *M. galloprovincialis*, *Patella* spp. and *Phorcus* spp. (the same taxa as in Level V). Decalcification affects two Naticidae fragments (0.1% of the remains). Some of the remains display natural perforations or serpulids (0.2%). The taxa affected by these processes are *M. galloprovincialis* and

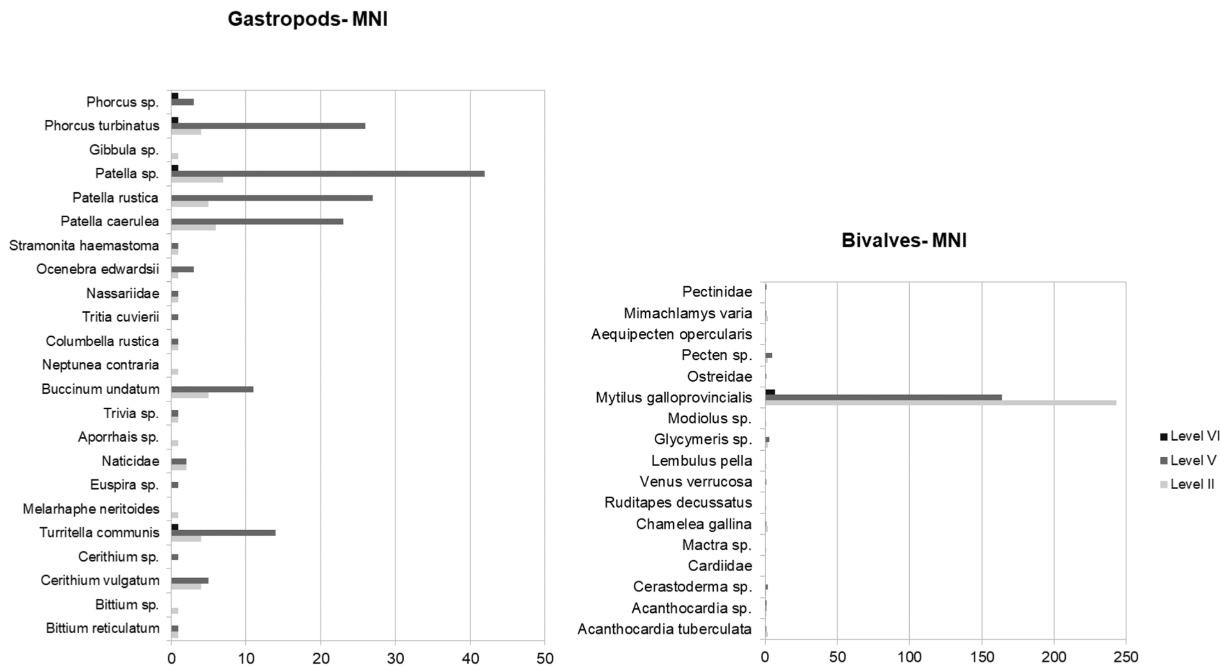

Fig. 2. MNI of molluscs retrieved in Levels VI, V and II at Foradada Cave.

Pecten sp. (with serpulids on the internal side of the shells), a fragment of *Chamelea gallina* (with a perforation caused by another mollusc) and *Turritella communis* (with natural perforations produced as a consequence of natural erosion of the shells, probably due to post-deposition actions). Abrasion affects 2.8% of the remains (especially bivalve ND, *Acanthocardia* spp., Cardiidae and *Pecten* sp.).

4.3. Biometry

All the complete specimens and some fragments from Levels VI, V and II have been measured (Table 3 and Table 4 for descriptive statistics). As can be observed in the table, many of the measured individuals are small (*e.g. Bittium reticulatum*, *Bittium* sp., *Melarhaphe neritoides*, Naticidae, *Ocenebra edwardsii*, *Lembulus pella*, *Modiolus* sp.). An exhaustive analysis has been performed for the most abundant taxa (*Mytilus galloprovincialis* and *Patella* spp.).

4.3.1. *Mytilus galloprovincialis*

Only 3 individuals in Level VI could be measured (Table 3). The length obtained from only one individual is 26.5 mm. The mean width obtained from the three specimens is 15.8 mm. Data obtained from left valves (the most abundant) have been used in Level V. The mean measurements are: L = 29.0 mm (N = 26) and W = 17.3 mm (N = 30) (Table 3). Only the length has been used to perform tests and comparisons between levels. The Shapiro-Wilk normality test shows the normal distribution of data (Table 3). It should be highlighted that the coefficient of variation (CV) shows high variability in the data (L: CV = 0.48).

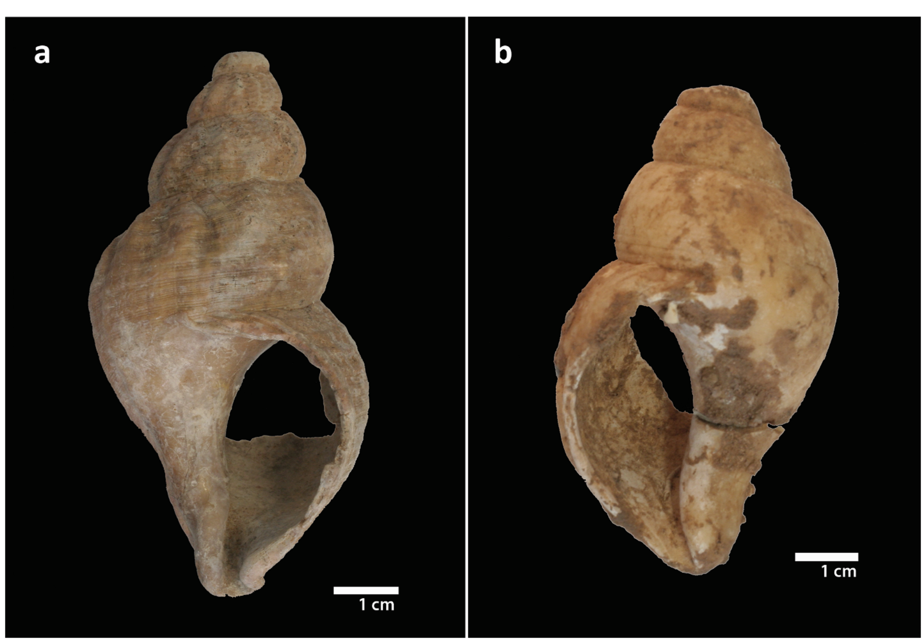

Fig. 3. a) *Buccinum undatum* and b) *Neptunea contraria*.

Fig. 4. *Patella* spp. with prying marks.

Table 2
Remains affected by taphonomic alterations (number of remains and percentages).

Level	Pre-deposition		Pre and post-deposition		Post-deposition					
	Abrasion		Natural perforations/serpulids		Burning		Concretion		Decalcification	
	NR	%	NR	%	NR	%	NR	%	NR	%
VI	108	50.7			5	2.3	11	5.2		
V	63	2.1	24	0.8	206	6.8	634	20.9		
II	102	2.8	7	0.2	202	5.6	836	23	2	0.1

The right valves have been used in Level II. The length (L) and width (W) have been obtained. The mean sizes are: L = 30.9 mm (N = 41) and W = 16.9 mm (N = 47) (Table 3, Fig. 5). The Shapiro-Wilk test on the length data shows the non-normal distribution of data As in Level V, also in this level, the CV shows high variability in the data (L: CV = 0.50).

The results for Levels V and II have been compared using the Wilcoxon test and there are no significant differences between them (L: p-value = 0.69 > 0.05). Level VI has not been considered in this comparison because it has not provided enough data. In both levels, the CV shows that there are mussels of different sizes, but most of them are between 20 and 40 mm in length. The smaller individuals are scarce.

4.3.2. *Patella spp.*

In order to optimise the biometric results, the data of *Patella caerulea*, *Patella rustica* and *Patella* sp. have been grouped. Only the length was considered for the comparisons. In Level VI no biometric data was obtained for limpets. In Level V the mean sizes obtained for *Patella* spp. are: L = 22.4 mm (N = 30) and W = 18.4 mm (N = 35) (Table 3, Fig. 5). Even if the probability is low, the Shapiro-Wilk test indicates the normal distribution of the length sizes. The CV shows that the data are homogeneous (L: CV = 0.19). In Level II, the obtained sizes are: L = 21.5 mm (N = 10), W = 18.0 mm (N = 11). The result of the Shapiro-Wilk normality test applied to length measurements reveals a normal population. The CV indicates homogeneity in length sizes (L: CV = 0.24). Like the results obtained for mussels, the Wilcoxon test shows that there are no significant differences in limpet sizes in the two levels (L: p-value = 0.7939 > 0.05). The CV for both levels indicates uniformity in *Patella* spp. sizes: the limpets mainly measure 17–25 mm in length. There is only one smaller specimen.

4.4. *Morphometry*

The morphometric analysis has been carried out on the species *Mytilus galloprovincialis* and *Patella caerulea* from Levels V and II, since Level VI does not offer enough data.

4.4.1. *Mytilus galloprovincialis*

In Level V, the ratio between the variables width and length (W/L) is 0.54 (N = 24) (Table 3, Fig. 5). The Shapiro-Wilk test confirms the normal distribution of data. The CV indicates the high homogeneity in the data (CV = 0.10). In Level II, the obtained ratio is also 0.54 (N = 36) (Table 3, Fig. 5). The Shapiro-Wilk normality test shows the normal distribution of data (p-value = 0.6085 > 0.05). As in Level V, the CV indicates high homogeneity in the data (CV = 0.09).

The results obtained in both levels are very similar to each other. The Wilcoxon test does not detect significant differences between them (p-value = 0.7249 > 0.05).

The comparison between the W/L ratio obtained for the mussels from the Aurignacian Levels V and II at Foradada Cave and the one obtained for the modern mussels on the north coast of the Adriatic Sea (Moschino et al., 2015) shows that the archaeological data are similar to those from the low intertidal zone-sublittoral. The information about the modern mussels has been obtained from a graph (Moschino et al.,

Table 3
Sizes (mm) of the specimens from Levels VI, V and II. Mean measurements are presented for taxa with more than 10 individuals. S-W: results of the normality test Shapiro-Wilk. CV: coefficient of variation.

Gastropods	Level									
	VI		V				II			
	L (mm)	W (mm)	L (mm)	W (mm)	H (mm)	H/L	L (mm)	W (mm)	H (mm)	H/L
Bittium reticulatum							13.0	4.2		
Bittium sp.							5.4	2.0		
Turritella communis			15.9	4.6			19.4	5.5		
			21.6	6.8						
			16.1	4.8						
			27.3	8.0						
			–	7.8						
			–	8.0						
			–	6.4						
			–	8.6						
			–	6.0						
			–	3.3						
			–	6.0						
			–	4.3						
			–	6.3						
Melarhaphe neritoides							5.1	3.7		
Euspira sp.			–	24.7						
Naticidae			8.6	8.3			8.3	7.9		
			7.8	–			9.8	8.7		
Trivia sp.			8.9	6.7						
Buccinum undatum							12.8	7.4		
							10.4	6.5		
							9.2	5.8		
							81.3	47.2		
Neptunea contraria							–	39.1		
Columbella rustica			14.8	9.2			14.9	9.3		
Ocenebra edwardsii			7.3	4.7			–	8.3		
Patella caerulea			$\bar{X}$ = 23.1 N = 14	$\bar{X}$ = 19.1 N = 15	$\bar{X}$ = 6.4 N = 16	$\bar{X}$ = 0.28 N = 14 S-W p-value = 0.4693 > 0.05 CV = 0.14	24.0	20.8	8.3	$\bar{X}$ = 0.30 N = 5 S-W p-value = 0.03271 < 0.05 CV = 0.22
							16.4	11.7	3.7	
							31.5	25.4	7.2	
							21.8	17.9	7.8	
							24.8	19.9	8.6	
							–	23.6	9.7	
Patella rustica			$\bar{X}$ = 21.2 N = 11	$\bar{X}$ = 17.4 N = 14	$\bar{X}$ = 7.4 N = 15		23.2	17.9	7.3	
							20.7	16.9	6.7	
							21.6	18.6	7.8	
							–	18.0	8.2	
							19.5	–	6.6	
Patella sp.			25.0	21.4	7.0		21.0	16.4	7.3	
			22.4	19.5	8.8		12.4	9.9	3.8	
			25.1	21.2	9.4					
			22.5	18.7	6.8					
			20.8	16.0	7.0					
			–	17.7	7.9					

(*continued on next page*)

Table 3 (*continued*)

Gastropods	Level									
	VI		V				II			
	L (mm)	W (mm)	L (mm)	W (mm)	H (mm)	H/L	L (mm)	W (mm)	H (mm)	H/L
Patella spp. (*P. caerulea*, *P. rustica*, *Patella* sp.)			X̄ = 22.4 N = 30 S-W p-value = 0.07831 > 0.05 CV = 0.19	X̄ = 18.4 N = 35			X̄ = 21.5 N = 10 S-W p-value = 0.8502 > 0.05 CV = 0.24	X̄ = 18.0 N = 11		
Phorcus turbinatus	23.2	21.3	15.5	17.3			20.4	22.4		
			17.9	18.9			–	19.5		
			18.6	14.7						
			17.4	19.8						
			18.7	19.5						
			15.9	16.6						
			–	17.8						
			–	14.7						
			–	18.9						
			13.4	–						
			–	14.0						

Bivalves	Level										
	VI			V				II			
	Valve	L (mm)	W (mm)	Valve	L (mm)	W (mm)	W/L	Valve	L (mm)	W (mm)	W/L
Acanthocardia tuberculata								l	58.3	56.1	
Cerastoderma sp.				r	27.1	29.6					
Lembulus pella								r	5.0	8.6	
Modiolus sp.								r	9.2	4.2	
Mytilus galloprovincialis	r	26.4	15.2	l	X̄ = 29.0 N = 26 S-W p-value = 0.2359 > 0.05 CV = 0.48	X̄ = 17.3 N = 30	X̄ = 0.54 N = 24 S-W p-value = 0.2848 > 0.05 CV = 0.10	r	X̄ = 30.9 N = 41 S-W p-value = 0.02983 < 0.05 CV=0.50	X̄ = 16.9 N = 47	X̄ = 0.54 N = 36 S-W p-value = 0.6085 > 0.05 CV = 0.09
	r	–	16.6								
	r	–	15.6								
Pecten sp.				r	–	70.1					
				r	114.0	–					
Mimachlamys varia				r	31.0	26.2		r	25.1	18.7	

Table 4
Descriptive statistics for the metric data (additional information for Table 3).

Gastropods	Level						
	V				II		
	L (mm)	W (mm)	H (mm)	H/L	L (mm)	W (mm)	H/L
Patella caerulea	N 14 Min 15.57 Max 31.58 Sum 323.74 Mean 23.1243 Std. Error 1.25837 Variance 26.9196 Stand. dev 5.18841 Median 23.325 25 prcntil 18.9725 75 prcntil 26.225 Skewness 0.435197 Kurtosis-0.837783 Geom. mean 22.5959	N 15 Min 12.43 Max 29.77 Sum 286 Mean 19.0667 Std. Error 1.38653 Varianc 32.6819 Stand. Dev 5.71681 Median 17.5 25 prcntil 14.87 75 prcntil 20.21 Skewness 1.06016 Kurtosis − 0.0371443 Geom. Mean 18.3599	N 16 Min 3.87 Max 8.62 Sum 102.4 Mean 6.4 Std. error 0.32276 Variance 1.77096 Stand. dev 1.33077 Median 6.385 25 prcntil 5.4525 75 prcntil 7.4375 Skewness −0.102543 Kurtosis-0.577223 Geom. mean 6.26337	N 14 Min 0.231948 Max 0.356198 Sum 3.93667 Mean 0.281191 Std. error 0.00947559 Variance 0.00152638 Stand. dev 0.0390689 Median 0.277329 25 prcntil 0.245616 75 prcntil 0.312551 Skewness 0.505263 Kurtosis −0.723101 Geom. mean 0.278738			N 5 Min 0.22439 Max 0.358257 Sum 1.50219 Mean 0.300439 Std. error 0.0301074 Variance 0.00453227 Stand. dev 0.0673221 Median 0.344583 25 prcntil 0.226957 75 prcntil 0.351848 Skewness −0.581743 Kurtosis −3.26498 Geom. mean 0.293994
Patella rustica	N 11 Min 17.5 Max 29.07 Sum 233.36 Mean 21.2145 Std. error 0.932492 Variance 13.0431 Stand. dev 3.61152 Median 20 25 prcntil 18.58 75 prcntil 22.68 Skewness 1.35058 Kurtosis 1.14852 Geom. mean 20.9621	N 14 Min 13.77 Max 24.63 Sum 243.91 Mean 17.4221 Std. error 0.912407 Variance 12.4873 Stand. dev 3.53374 Median 15.905 25 prcntil 15.035 75 prcntil 20.4925 Skewnes 1.03722 Kurtosis −0.255625 Geom. mean 17.1195	N 15 Min 6.3 Max 9.39 Sum 111.6 Mean 7.44 Std. error 0.249727 Variance 0.935457 Stand. dev 0.96719 Median 7.48 25 prcntilm6.42 75 prcntil 8.1 Skewness 0.583388 Kurtosis −0.415083 Geom. mean 7.38314				
Patella spp. (*P. caerulea, P. rustica, Patella* sp.)	N 30 Min 15.57 Max 31.58 Sum 672.82 Mean 22.4273 Std. error 0.686591 Variance 17.9135 Stand. dev 4.23243 Median 21.855 25 prcntil 19.0325 75 prcntil 24.835 Skewness 0.716804 Kurtosis −0.115178 Geom. mean 22.0612	N 35 Min 12.43 Max 29.77 Sum 644.37 Mean 18.4106 Std. error 0.71698 Variance 19.5343 Stand. dev 4.41976 Median 17.5 25 prcntil 15.31 75 prcntil 20.21 Skewness 1.21324 Kurtosis 1.0804 Geom. mean 17.9554			N 10 Min 12.38 Max 31.5 Sum 215.17 Mean 21.517 Std. error 1.47268 Variance 26.0255 Stand. dev 5.10152 Median 21.4 25 prcntil 18.7025 75 prcntil 24.195 Skewness 0.150129 Kurtosis 1.38507 Geom. mean 20.9433	N 11 Min 9.88 Max 25.41 Sum 198.4 Mean 18.0364 Std. error 1.31432 Variance 20.7292 Stand. dev 4.55294 Median 17.92 25 prcntil 16.41 75 prcntil 20.8 Skewness −0.259239 Kurtosis 0.11902 Geom. mean 17.4569	

Bivalves	Level							
	V				II			
	Valve	L (mm)	W (mm)	W/L	Valve	L (mm)	W (mm)	W/L
Mytilus galloprovincialis	l	N 26 Min 8.8	N 30 Min 5.1	N 24 Min 0.45	r	N 41 Min 5.85	N 47 Min 4	N 36 Min 0.46

(*continued on next page*)

Table 4 (*continued*)

Bivalves	Level							
	V				II			
	Valve	L (mm)	W (mm)	W/L	Valve	L (mm)	W (mm)	W/L
		Max 58.6 Sum 752.95 Mean 28.9596 Std. error 2.46372 Variance 194.238 Stand. dev 13.9369 Median 24.97 25 prcntil 17.3525 75 prcntil 39.3425 Skewness 0.443488 Kurtosis −0.745338 Geom. mean 25.5941	Max 41.57 Sum 518.04 Mean 17.268 Std. error 1.51157 Variance 73.1155 Stand. dev 8.55076 Median 14.655 25 prcntil 12.51 75 prcntil 21.5525 Skewness 0.991472 Kurtosis 0.980693 Geom. mean 15.3292	Max 0.63 Sum 12.87 Mean 0.53625 Std. error 0.00899596 Variance 0.00258967 Stand. dev 0.0508888 Median 0.545 25 prcntil 0.4925 75 prcntil 0.58 Skewness −0.202145 Kurtosis −0.970019 Geom. mean 0.533894		Max 69.45 Sum 1264.94 Mean 30.8522 Std. error 2.15031 Variance 240.44 Stand. dev 15.5061 Median 28 25 prcntil 21.075 75 prcntil 36.74 Skewness 0.736048 Kurtosis 0.228681 Geom. mean 26.8111	Max 34.26 Sum 793.11 Mean 16.8747 Std. error 1.01575 Variance 53.6511 Stand. dev 7.32469 Median 15.87 25 prcntil 11.77 75 prcntil 20.87 Skewness 0.673449 Kurtosis 0.0782588 Geom. mean 15.2769	Max 0.67 Sum 19.58 Mean 0.543889 Std. error 0.00663224 Variance 0.0022873 Stand. dev 0.0478257 Median 0.54 25 prcntil 0.51 75 prcntil 0.58 Skewness 0.435259 Kurtosis0.101523 Geom. Mean 0.541876

2015: 1444) and therefore the precise values cannot be offered. Although the two areas are distant from each other, we can only suggest that the mussels at Foradada Cave were probably mostly obtained in this zone, which is usually submerged.

4.4.2. *Patella caerulea*

The morphology of this species is associated with the characteristics of the area where they live. Changes in the morphology are reflected in the conicity index (H/L). In Level V, the mean value of the conicity

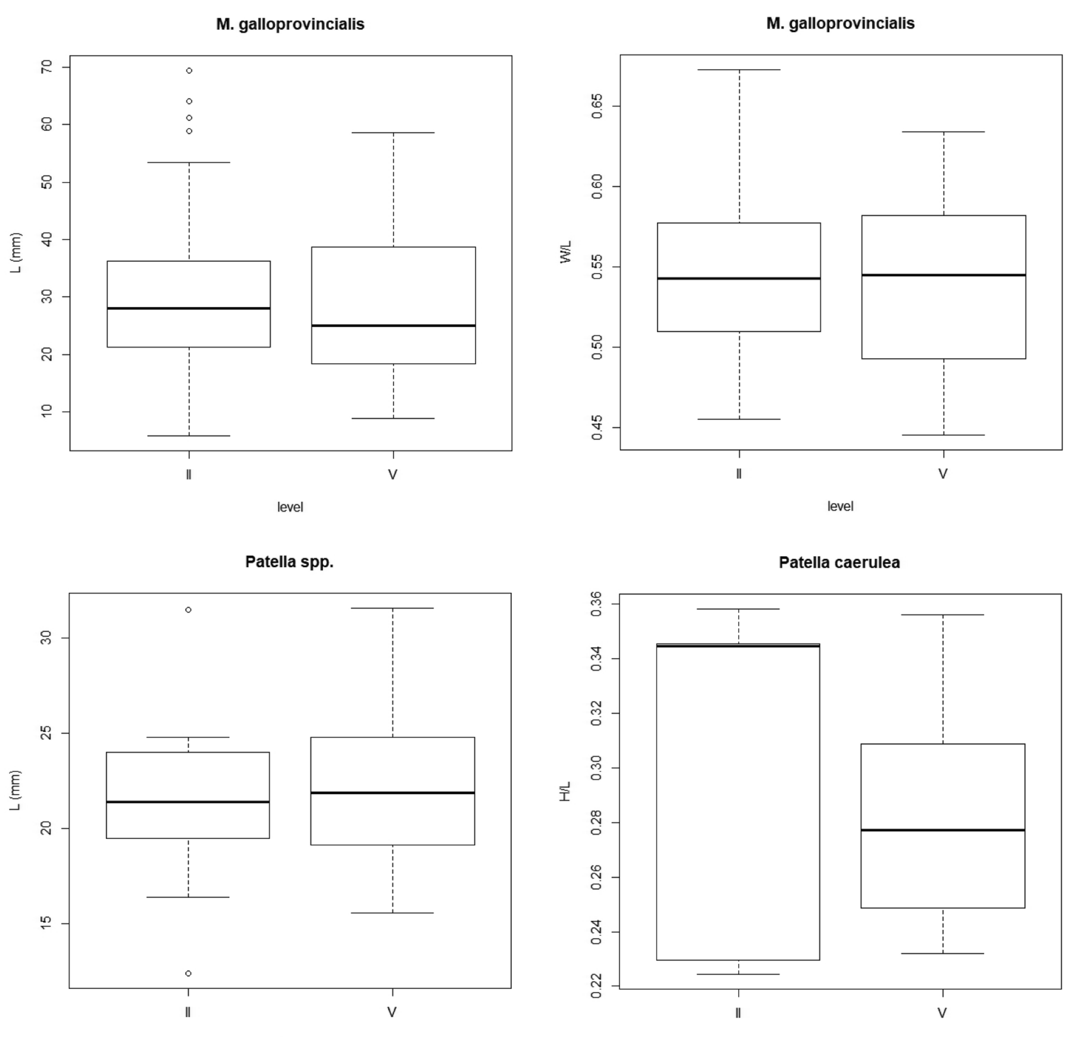

Fig. 5. Box plot of the length (L) and morphometry index of *Mytilus galloprovincialis* (W/L) and *Patella* spp./*Patella caerulea* (H/L) from Levels V and II at Foradada Cave.

index is 0.28 (N = 14) (Table 3, Fig. 5). The Shapiro-Wilk test indicates the normal distribution of data (p-value = 0.4693 > 0.05). The CV shows the high homogeneity of data (CV = 0.14). The mean of the conicity index of the individuals from Level II is 0.30 (N = 5) (Table 3, Fig. 5). The Shapiro-Wilk test indicates a non normal distribution of data. It should be highlighted that the sample is too small and the data could be biased. The CV indicates a high homogeneity of data (CV = 0.22). The comparison between the conicity indexes in the two levels (Wilcoxon test) suggests that there are no significant differences (p-value = 0.6868 > 0.05).

Conicity indexes of the archaeological individuals have been compared with those of modern individuals from the north coast of the Adriatic Sea (Battelli, 2016) (Fig. 6). The values of the archaeological limpets are much higher than the values of the modern individuals; therefore it is not possible to make a direct correlation between them. However, the values of the modern limpets can be used as points of reference and it can be suggested that the limpets from Foradada Cave were probably obtained in the upper intertidal zone, where the highest indices are recorded. It should be highlighted that the CV of mussels and limpets from both archaeological levels indicates high homogeneity. This probably shows that most of the specimens of each species were gathered in the same area or in areas with similar characteristics.

5. Discussion: marine molluscs in Cova Foradada, implications for hunter-gatherer societies

5.1. Palaeoecological implications

Buccinum undatum has been documented in Levels V and II and *Neptunea contraria* in Level II. Both species live in cold waters and currently, they are not present in the Mediterranean. This proves that when Foradada Cave was occupied, the seawater temperature was colder than today, which agrees with the climatic conditions of Heinrich Event 3. According to Cacho et al. (1999), in the Alboran Sea, HE3 was characterized by slow cooling of the sea surface temperature (SST) (−3.7 °C over 1300 years) followed by abrupt warming (+4°C in 500 years). A palaeoclimate reconstruction for a terrestrial area in northeastern Iberia (Galls Carboners cave, Tarragona) offers similar results. It suggests that the mean annual temperature at that time would be −3.72 °C lower than today. The mean annual precipitation was higher than at present (+437 mm). The mean temperature of the coldest month was −3.77 °C lower than the current mean, like the mean temperature of the warmest month (−2.2 °C) (López-García et al., 2014). These data agree with the palynological information from Level V that shows the predominance of xeric and steppic taxa at the bottom of the level. This aridity in the first phase of HE3 is equally observed in marine surveys (Cacho et al., 2006; López-García et al., 2014). *Pinus* and *Juniperus* have been documented at the top of Level V, which suggests greater climatic stability, while other species indicate wetter and milder conditions.

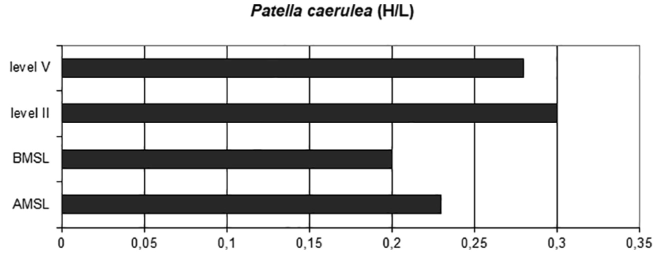

Fig. 6. Conicity index (H/L) of *Patella caerulea* from Levels V and II at Foradada Cave and of modern individuals (Battelli, 2016). AMSL = Above mean sea level, BMSL = Below mean sea level.

5.2. Socio-economic implications

5.2.1. Use and consumption of molluscs

A total of 665 marine molluscs corresponding to a wide diversity of taxa have been documented in the Aurignacian levels VI, V and II at Foradada Cave. Nevertheless, most of them are represented by very few individuals, in many cases only one. Level VI has yielded few individuals (MNI = 13). They are more abundant in Levels V and II (344 and 308 respectively), which present similar taxonomic compositions. The most abundant species in the three levels is *Mytilus galloprovincialis*, followed by *Patella* spp. and *Phorcus* spp. (in Levels V and II). It can be highlighted that in Level II the MNI of mussels is higher than in Level V whereas in this latter level, *Patella* spp. and *Phorcus* spp. are more abundant than in Level II. The three taxa live on intertidal rocky shores, although species from sandy bottoms have also been documented (*e.g. Acanthocardia* sp., *Cerastoderma* sp.). This agrees with the reconstruction of the morphology of the ancient coastline close to the cave when it was occupied (Casabó i Bernad, 1997a, 1997b; Fumanal and Olmo, 1997). It should be recalled that the nearest coastline was located c. 2 km away during the Aurignacian occupations of Foradada Cave, (Casabó i Bernad, 1997a, 1997b; Fumanal and Olmo, 1997). This could explain why the amount of molluscs is not very high. Moreover, the site was interpreted as a succession of occasional and short occupation events (Casabó i Bernad, 1997a, 1997b), which contributes to the fact that the number of remains is not high. The predominant taxa (*Mytilus galloprovincialis, Patella* spp. and *Phorcus* spp.), and probably *Buccinum undatum*, *Stramonita haemastoma*, *Gibbula* sp., *Mimachlamys varia*, *Aequipecten opercularis*, *Ruditapes decussatus*, and the echinoidea and the crustaceans, would be consumed as food.

In Level VI the number of unidentified and extremely eroded small fragments is especially large. The wide variety of small-size taxa, represented by very few individuals, should be noted in Levels V and II. Most of the fragments in Level VI, the small molluscs in Levels V and II, and the remains displaying natural erosion (by natural causes) (*e.g. Turritella communis*), probably reached the site unintentionally, attached to other species or mixed in algae or seagrass brought to the settlement by the human groups. Some of these taxa (*Bittium reticulatum*, *Bittium* sp., Nassariidae, *Gibbula* sp., *Modiolus* sp.) can live in seaweed or marine plants (D'Angelo and Gargiullo, 1978; Urra et al., 2013). Casabó i Bernad (1997b) pointed to the transportation of algae to the site as an explanation for the presence of small pebbles in different archaeological levels. Although in this case we can only suggest this idea as a hypothesis, examples are known in which the presence of kelp, seagrass and sponges in archaeological contexts has been inferred indirectly from the presence of non-dietary molluscs (Stiner, 1999; Ainis et al. 2014). It should be stressed that some fragments of *Acanthocardia* sp., *Glycymeris* sp. and *Pecten* sp. display abrasion on their surface, especially in Level II. This indicates that these taxa were not collected as food but for other purposes that cannot be specified. Remains in the three levels were altered by exposure to heat. In Level VI, burning affects 2.3% of the remains (all of them *M. galloprovincialis*). In levels V and II, this phenomenon affects principally the three most abundant taxa (*M. galloprovincialis, Patella* spp. and *Phorcus* spp.) consumed as food. The burning marks would be due to an intentional action (throwing the molluscs on the fire in order to open the shells, to roast the meat or as a cleaning activity) or an unintentional action if the remains were previously in the place where a hearth was built (Bosch et al., 2015). Five hearths have been documented in Level V.

5.2.2. The management of molluscs as a resource

The size of the most abundant molluscs in Foradada Cave offers information about the management of the resource. Only one length measurement was obtained for Level VI. For this reason, this level was not compared with the others. The sizes of *M. galloprovincialis* are similar in Levels V and II. The CV in both levels indicates diversity in sizes, but it should be noted that most of the individuals are larger than

Fig. 7. Archaeological sites cited in the text: 1 El Conde; 2 Covalejos; 3 El Castillo; 4 Cueva Morín, El Ruso I, La Garma A, El Cuco; 5 El Otero; 6 Aitzbitarte IV; 7 L'Arbreda; 8 Cova Gran; 9 Foradada Cave; 10 Cova Beneito; 11 Monte Miral; 12 Cueva Perneras; 13 Riparo Mochi; 14. Klissoura Cave 1; 15 Üçağızlı Cave; 16 Ksar 'Akil.

20 mm in length. Smaller mussels are very scarce. This suggests a selection of the larger individuals, rejecting the smaller ones. *Patella* spp. presents similar results in Levels V and II (there are no data for Level VI). The sizes of the limpets are very homogeneous since they generally measure 17–25 mm in length and only one specimen is smaller. Considering that limpets must be gathered one by one, the individuals with a suitable size to be consumed as food were clearly selected. The morphometric study provided information, in general terms, about the place where mussels and limpets (*Patella caerulea*) were collected. Data for modern individuals in the Mediterranean are scarce, but the comparison with data from the Adriatic Sea (Moschino et al., 2015; Battelli, 2016) suggests that the mussels from Levels V and II were gathered mostly in the low intertidal-subtidal zone and the limpets in the upper intertidal zone. According to this, it seems that the whole intertidal zone would be exploited in order to obtain different species. Moreover, some species as *Cerastoderma* sp. or *Ruditapes decussatus* live in brackish water areas, which also shows the exploitation of both salt and brackish water areas.

5.2.3. Other animal resources in Foradada Cave

Other animal resources were consumed in Foradada Cave besides the molluscs. In order to obtain a general idea about the subsistence strategies of the hunter-gatherer societies that occupied the cave during the Aurignacian, these resources must be considered too.

In Level VI the following species have been recorded: red deer (MNI = 1), wild goat (MNI = 2), wild boar (MNI = 1) and some felines: leopard (MNI = 1), lynx (MNI = 1) and wildcat (MNI = 1). These remains display burning and cut marks, which could suggest the consumption of some species as food and the use of the carnivores' fur. In Level V, the predominant species are red deer (MNI = 5) and wild goat (MNI = 6). The other species in this level are: equines (MNI = 5), a large bovine (MNI = 1), wild boar (MNI = 1) and some felines: lynx (MNI = 2), leopard (MNI = 1), and wildcat (MNI = 1). Many remains are burnt and some remains of ungulates and carnivores also have cut marks. There is no detailed information for Level II. The study of bone fracture patterns in Levels VI and V suggests the consumption of the marrow. Moreover, some bones were used as raw material to make tools (Pantoja et al., 2011).

These data, together with the results of the study of malacofaunistic remains, indicate the exploitation of different landscapes in order to procure the different resources in the area, according to the reconstruction of the ancient coastline (Fumanal, 1997; Fumanal and Olmo, 1997): resources from the hills (*e.g.* wild goat, lynx and wildcat) and meadows (*e.g.* equines and the large bovine) in the surroundings of the settlement and coast (rocky and sandy). In addition, the consumption of marrow suggests an intensive exploitation of the resources (Pantoja et al., 2011).

5.3. Foradada Cave and other contemporary sites

Besides Foradada Cave, the consumption of marine molluscs as food and/or their use as ornaments or tools during the Aurignacian have been recorded in other archaeological sites in the IP and other Mediterranean areas. On the Mediterranean façade of the IP marine molluscs have been documented in L'Arbreda, Cova Gran, Cueva Perneras, Monte Miral and Cova Beneito (Martínez Andreu, 1989; Montes Bernárdez, 1993; Vanhaeren and d'Errico, 2006; Martínez-Moreno et al., 2010). On the Cantabrian coast, they have been recorded in Cueva Morín, El Castillo, El Conde, El Ruso I, Covalejos, La Garma A, El Otero, Aitzbiarte IV and El Cuco (Álvarez Fernández, 2005, 2006, 2010; Vanhaeren and d'Errico, 2006; Gutiérrez-Zugasti et al., 2013). In other Mediterranean areas, marine molluscs have been recorded in Riparo Mochi (Liguria, Italy), Klissoura Cave 1 (Peloponnese, Greece), Üçağızlı Cave (Hatay, Turkey) and Ksar 'Akil (Lebanon) (Stiner, 1999, 2010; Kuhn et al., 2001; Bosch et al., 2015) (Fig. 7). Except in El Cuco, Riparo Mochi and Ksar 'Akil, the malacofaunistic assemblages are generally formed by very few individuals principally used as adornments. In these three cases, molluscs were consumed as food and used as ornaments, and in Ksar 'Akil, some remains were used as tools. The most abundant species consumed as food come from rocky shores. In El Cuco, the predominant taxon is *Patella* spp.; in Riparo Mochi, *Patella* spp., *Phorcus turbinatus* and *Mytilus galloprovincialis* and in Ksar 'Akil, *Phorcus turbinatus*. These same species have been recorded in Foradada Cave (Stiner, 1999; Álvarez Fernández, 2010; Gutiérrez-Zugasti et al., 2013; Bosch et al., 2015).

Regarding the size of molluscs, no other biometric analyses of the species studied in detail in Foradada Cave (*M. galloprovincialis* and *Patella* spp.) have been carried out in the Mediterranean. Morphometric data from El Cuco show that most *Patella vulgata* in the Aurignacian levels were collected in the upper intertidal zone (Gutiérrez-Zugasti et al., 2013), like in Foradada Cave.

Even though archaeological sites with molluscs are not very abundant in this chronology, they testify that this resource was part of the hunter-gatherers' diet. The scarcity of malacofaunistic remains is probably due to the fact that the archaeological sites that were next to the coast are now under the sea (Bailey and Flemming, 2008).

6. Conclusions

The data afforded by the study of the malacofaunistic remains from the Aurignacian levels in Foradada Cave (VI, V and II) are of special interest because they attest the exploitation and consumption of coastal resources in the EUP. In Level VI, 13 individuals were recovered, 344 in Level V and 308 in Level II. The predominant species in all the levels are *Mytilus galloprovincialis*, *Patella* spp. and *Phorcus* spp. and they were consumed as food. The three taxa come from intertidal rocky shores. The limpets (*Patella caerulea*) were probably collected mainly in the upper intertidal zone, while the mussels would be gathered in the lower intertidal zone. This suggests an exploitation of the whole intertidal area. The sizes of mussels and limpets indicate a selection of the larger individuals since there are no smaller ones. Other species (*Acanthocardia* sp., *Glycymeris* sp. and *Pecten* sp.) which are eroded by seawater were collected for other purposes that we cannot specify. Finally, it should be noted that the individuals of small-size species probably reached the cave due to non-intentional actions (attached to mussels or to seaweed).

Some remains, especially *Mytilus galloprovincialis*, *Patella* spp. and *Phorcus* spp. consumed as food, display burning marks. They could have been produced intentionally (to open the valves, to roast the meat or as a cleaning action) or non-intentionally (if the valves were previously in the place where the fire was located).

Bones from other animal resources have been documented in Foradada Cave as well as molluscs. They were exploited for their meat, fur and bones (used as raw material to make tools). The recorded species suggest the exploitation of different areas: hills, meadows and coast. It should be noted that the nearest coast was c. 2 km from the cave during the Aurignacian occupations of the site. This is also evidence of the importance of coastal resources as part of the diet, together with other animal resources, in the EUP.

Although not very abundant, there are other examples of Aurignacian archaeological sites in the Iberian Peninsula and in other Mediterranean areas which testify the use and consumption of molluscs for different purposes (food, ornaments and tools). As explained in the introduction, the consumption of coastal resources as food is indicative of a diversified diet in the EUP, since Foradada Cave is an example of the consumption of different kinds of resources. This study together with other recent papers about the consumption of coastal resources in ancient chronologies contributes to a progressive change in the consideration of these resources from "marginal" to "usual" in the hunter-gatherers' economy. For this reason, they must be considered in explanations of these groups' strategies of socio-economic organization.

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