

Giant limpets in southern Iberian coastal and continental archaeological sites, from Neanderthals to Copper Age

Miguel Cortés-Sánchez^a, M. Carmen Lozano-Francisco^{b,*}, María D. Simón-Vallejo^a,
Francisco Jiménez-Espejo^c, Carlos Odriozola Lloret^a, Sara Macías Tejada^a,
Arturo Morales Muñoz^d

^a Departamento de Prehistoria y Arqueología. Universidad de Sevilla, Sevilla, Spain

^b Departamento de Ecología y Geología. Facultad de Ciencias. Universidad de Málaga, Málaga, Spain

^c Instituto Andaluz de Ciencias de La Tierra, CSIC-Universidad de Granada, Granada, Spain

^d Departamento de Biología, Universidad Autónoma de Madrid, Madrid, Spain

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ABSTRACT

The use of coastal resources has been crucial for human diet and social behaviour evolution has been extensively documented since the Middle Palaeolithic, mainly in the western Mediterranean and southern Africa. In southern Iberia, the mollusc assemblages associated with archaeological sites show a continuous record regardless of palaeoclimatic conditions. Among these, limpets are uninterruptedly abundant from the Middle Palaeolithic to the Bronze age with the giant limpets (*Cymbula safiana* and *Patella ferruginea*) being present since MIS6. To assess their distribution, predominance, and cultural significance this paper presents the results from an exhaustive archeozoological survey of the southern Iberian region. A total of 1628 specimens have been analysed, including 425 modern (333 *C. safiana* and 91 *P. ferruginea*) and 1203 from 60 archaeological deposits deriving from 36 sites, both coastal and continental. Giant limpets' context also has been described and it has been related with a wide variety of deposits ranging from food refuse accumulations to occupations and burials.

Detailed morphological and surface analysis allowed us to determine extraction methods and anthropic transformations. On coastal sites, the giant limpet record starts with Neanderthal populations from the Middle Palaeolithic and continues throughout the Upper Palaeolithic, Mesolithic, Neolithic, and Copper Age. On inland sites, giant limpets appear first in reduced numbers during the Late Neolithic and have been often worked into elliptical contours with polished, rib-free, external shell surfaces. In this study, we focus on the Copper Age, when giant limpet use becomes common, and records include tholoi, dolmens and other funerary contexts. The data indicate that the use of *P. ferruginea* is associated with Los Millares and El Argar cultures. Giant limpets use declines during the Bronze Age probably due to the major cultural shift that occurred during the Chalcolithic to Bronze transition.

The data suggest that giant limpets should be considered as proxies of long-range trade during the Chalcolithic. We propose a new hypothesis linking giant limpets symbology with orbital/tidal variations and the ubiquitous use of marine elements as symbolism during this period.

Our study highlights the relevance of shells in the reconstruction of the symbolic evolution of prehistoric cultures, as well as their connections with local ecosystem resources and regional commerce networks.

1. Introduction

Molluscs, as animals exhibiting deep interactions with humans through space and time, bear a bio-cultural relevance that proceeds beyond the level of subsistence and into the social and symbolic spheres

of society (Claassen, 2009). One reason for this is that shells exhibit a variety of morphologies, colours and sculpturing that served a range of utilitarian purposes and appealed to humans for their aesthetic values since prehistoric times (Vermeij, 1995). Mollusc shells, including those of fossil specimens, have been also used as containers, hooks, musical

* Corresponding author.

E-mail addresses: mcortes@us.es (M. Cortés-Sánchez), mclozano@uma.es (M.C. Lozano-Francisco), msimon@us.es (M.D. Simón-Vallejo), francisco.jimenez@iact.ugr-csic.es (F. Jiménez-Espejo), codriozola@us.es (C.O. Lloret), smacias1@us.es (S.M. Tejada), arturo.morales@uam.es (A.M. Muñoz).

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instruments, coins, adornments, amulets, and symbols of prestige to name but the best documented cases (e.g. [Cuenca-Solana et al., 2016](#); [Cortés-Sánchez et al., 2020](#); [Fritz et al., 2021](#)). In most instances, and partly due to their more intensive mineralization and wider variety of shapes, it is marine shells that have been preferentially used as raw materials. This is fortunate since access to marine shells has been restricted until recent times to the coasts and fossil outcrops. For such reason, marine shells on inland sites allowed archaeologists to infer and reconstruct regional and long-distance contacts, define trade networks, and even monitor language dissemination ([Botha, 2008](#); [Bajnóczi et al., 2013](#)).

Southern Iberia is a particularly interesting site for the study of molluscs not only because of the continuity and abundance of the archaeological record and especially the early exploitation of marine resources ([Cortés-Sánchez et al., 2011, 2019](#)), but also because the western Mediterranean acts as a passageway and sometimes as a refuge for both warm fauna (i.e., Senegalese fauna) and north Atlantic fauna elements in addition to its endemics ([Rodríguez, 1982](#)). In this study we will focus on the use of two species of limpets, the so-called “giant limpets”, members of the family Patellidae [Subclass Patellogastropoda] that reach beyond 100 mm and may have played yet-to-be-determined roles in past societies ([Espinosa and Rivera - Ingraham, 2017](#); [WORMS, 2020](#)). Of the seven limpet species presently found in the Iberian Peninsula, the two qualifying as giant are restricted to the easternmost sector of the Mediterranean known as the Sea of Alborán ([Figs. 1 and 2](#)). The first one is the Black limpet (BL hereafter), *Cymbula safiana* (Lamarck, 1819), often referred to in the archaeological literature by its invalid synonyms of *Patella nigra* (Da Costa 1771) and *Cymbula nigra* (Da Costa, 1771). The second species is the ferruginous limpet (FL hereafter), *Patella ferruginea* Gmelin 1791), [WoRMS Editorial Board \(2021\)](#). Both species have rather different distributions yet happen to overlap in the Sea of Alborán ([Fig. 1](#)).

In Iberian archaeology, knowledge of giant limpets develops following those of natural history studies within archaeological research programs ([Morales Muñoz and Peña Chocarro, 2020](#)). Their records start with the seminal monograph of the Siret brothers on the “Argar” Bronze Age societies of SE Spain ([Siret and Siret, 1887](#)). From the end of the 19th century and until American and German archaeologists resumed with the study of archaeological faunas in the 1960s, in the Spanish and Portuguese literature molluscs were mostly reported as “shells” without any further specification. Such situation owed much to a divorce that took place within Spanish anthropology at the start of the 20th century that sent the naturalist-oriented scholars to the realm of Paleontology and the “traditional” archaeologists to that of History ([Morales Muñoz and Peña Chocarro, 2020](#)). This explains why in a comprehensive compilation of archaeological molluscs from more than 50 Iberian sites in the 1970s, limpets were at best referred to by their Genus (i.e., *Patella*) ([Martín, 1978](#)). This inertia constitutes one major hindrance to assess limpet records in the literature, a problem compounded by the fact that few studies to this day incorporate illustrations ([Sangmeister and Schubart, 1981:133](#)). During the past 40 years, faunal studies have been carried out on a systematic manner and on sound scientific bases. These studies reveal that the archaeological record of giant limpets starts in Middle Palaeolithic (i.e., Neandertal) coastal sites on southern Iberia (Bajondillo, 128 ka and Figueira Brava, 105 ka) and become common items on Upper Palaeolithic coastal assemblages ([Gutiérrez-Zugasti, 2009](#); [Cortés-Sánchez et al., 2011](#); [Colonese et al., 2011](#); [Zilhão et al., 2020](#)). No limpet remain has been ever reported on Iberian inland sites prior to the Neolithic period, and this fact seems baffling if limpets had been transported inland as food items. Indeed, giant limpets have been repeatedly associated with ritual (i.e., non-subsistence) activities. In the case of the Iberian Copper Age, for example, their shells routinely occur in deposits with luxury items such as amber, ivory, ostrich eggshell, rare mineral and large flint blades, revealing long-distance trade are recorded ([Table 1](#)) ([Alfonso et al., 2011](#); [Costa et al., 2011](#); [Morgado et al., 2011](#); [Domínguez-Bella, 2012](#); [Odriozola et al., 2016](#); [Villalobos and](#)

[Odriozola, 2017](#)).

The lack of an integral ecological, taphonomical, spatial and biogeographic approach for these giant limpets has not allowed an in-depth interpretation of the economic, societal relevance, as well as their environmental significance. To increase the information content that giant limpets can provide, this paper surveys the pertinent information in southern Iberia, a key area for coastal resource exploitation during prehistoric times. In addition, we aim at determining.

- when does the inland transport of giant limpets started in Iberian prehistory,
- whether just one or the two giant limpets were involved in this transport, and in what proportion,
- whether proportions of the two species differ on coastal as opposed to inland sites at any given time, and
- whether shells transported inland exhibit a similar range and/or frequencies of sizes, shapes and manipulative traces as the specimens that remained on the coastal deposits through time. Those data allow us to explore to what extent giant limpets can be taken as proxies of former trade networks and symbolic items. Lastly, given the long record available, we evaluate the use of these thermophilic (warmth-loving) limpets as stratigraphic markers in this region.

2. The biology and ecological constraints of the iberian giant limpets

Inferences on human behavior emerge when contextual data provided by archaeological specimens are confronted with the biology of species, in particular their life cycles and biogeography.

To reach proper inferences a detailed ecological knowledge is required of the ecology and the life cycles and biogeography of these two species. From a biological standpoint, limpets can live above sea level because of physiological and behavioural adaptations that allow them to tolerate desiccation, adaptations that involve a tight interlock with their substrate (i.e., the so-called home scar) and very restricted movement when outside this scar (Luque, verb. com.). The FL is a western Mediterranean endemism, reaching from Sicily to the Strait of Gibraltar, that has been never recorded in the colder central Atlantic waters. Even under the best possible conditions (i.e., transport in a portable freezer), FL specimens start to die after ~48 h (Luque, verb. com.). BL is instead a West African denizen ranging from the western Cape/Angola to the Sea of Alborán, that is also found on islands such as the Azores and Cape Verde ([Nordsiek and Garcia-Talavera, 1979](#); [Gofas et al., 2011](#); [Rolán, 2005](#); [Espinosa and Rivera-Ingraham, 2017](#)). The overlap of the two species in this westernmost tip of the Mediterranean is most intensive in productive up-welling zones ([Espinosa and Rivera-Ingraham, 2017](#)).

In the case of FL, information has been accumulating at an ever-faster pace on account of its status as a species in danger of extinction ([Luque et al., 2018](#)). In Mediterranean waters, for example, the largest specimens have been documented on the eastern façade of the Gibraltar Strait, in areas combining high marine productivity with low human demography. This would be the case of the Alborán and Chafarinas islands (maximum length (MD, [Fig. 2](#)) 114 mm and ~75 mm, respectively), and the city of Ceuta (MD: 107 mm). A third factor dictating size is density, an inverse correlation documented between mean MD and the number of specimens/m² ([Guallart and Templado, 2016](#)).

In terms of shell morphology, FL is readily identified from other species European by the extreme development of its ribs that reach well beyond the shell disc, conferring its perimeter a characteristic serrated profile ([Fig. 2B](#)). Two different morphs, *rouxi* [Payraudeau \(1826\)](#), and *lamarcki* [Payraudeau \(1826\)](#) that were previously granted species or subspecies status, nowadays genetic analyses consider eco-morphotypes at best ([Espinosa and Ozawa, 2006](#)). Although *rouxi* would feature a more pyramidal (i.e., higher) shell with a more eccentric apex and attenuated ribs than *lamarcki*, intermediate morphologies render a tight ecotypic characterization of FL specimens far from straightforward, an

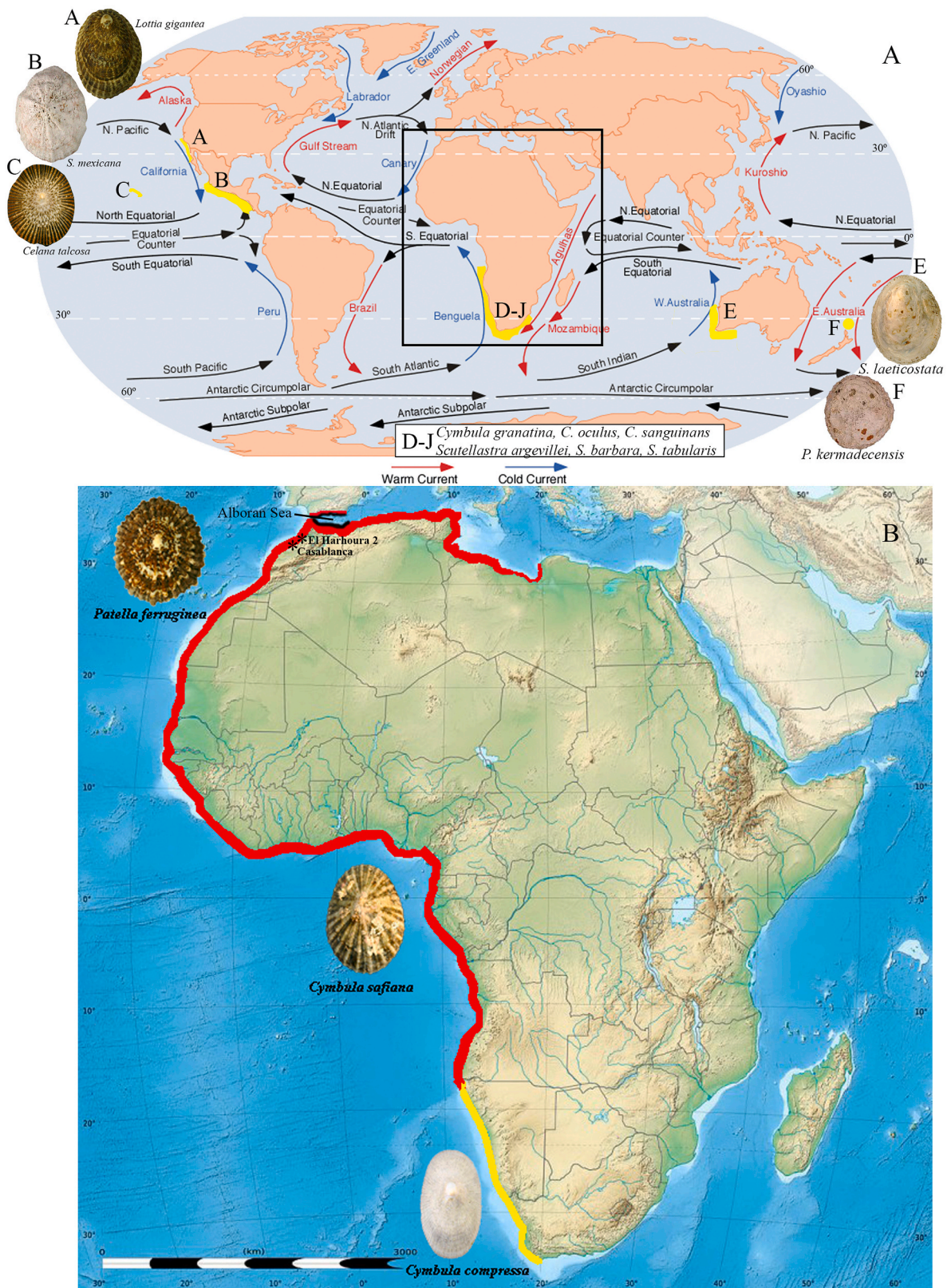


Fig. 1. Global distribution of the species of giant limpets: A. Other species of giant limpets. The arrows indicate the direction of the sea currents. B. Global distribution of discussed giant limpets in this study (made from Espinosa and Rivera-Ingraham, 2017). *Cymbula safiana* (red), western Mediterranean Sea endemic *Patella ferruginea* (black) and *Cymbula compressa* another species of giant South African limpet. Limpet photos from WoRMS (<http://www.marinespecies.org/>).

Table 1

Summary of the use of giant limpets in the Prehistory of southern Iberia. During the Upper Pleistocene (UP) giant limpets are cited in the MIS 6, MIS 5e, Early UP, Solutrean and Magdalenian (Magd.). In the Holocene the record is continuous from the Epipalaeolithic (Epipaleol.) to Bronze Age.

Location/Use	Upper Pleistocene					Holocene			
	MIS 5e	4–3	3	2	1				
Human	<i>H. neanderthalensis</i>		<i>Homo sapiens</i>						
Period	Middle Palaeolithic		Early UP	Solutrean	Magd.	Epipalaeol.	Neolithic	Copper Age	Bronze Age
Coast	Bajondillo	Bajondillo	Gorham	Nerja	Nerja	Nerja	Nerja	Nerja	Nerja
Alimentary	Gorham's Devil's Tower Abrigo3/Humo					Hoyo Mina	Bajondillo HoyoMina Higuérón		Gavilanes
Hinterland							Cave	Settlement	Settlement
Symbolic							Negative structures	Negative structure	
Functional								Artificial cave	
Funerarial								Dolmen, Tholos	
[53]							Incipient	Giant limpets (BL&FL > 60 mm)	More frequent use of FL
Settlement [6]									SE Spain

issue that will also be explored here (Payraudeau, 1826; Luque et al., 2018). For zooarchaeologists, the most useful discriminant trait these morphs feature involves the habitat they preferentially settle. Indeed, although FL at large finds its optimum in areas of moderate exposure on the upper fringes of the littoral zone (Fig. 3), *rouxi* (Fig. 2B4) is purportedly more frequent on sub-vertical substrates (cliffs and walls) above tide level whereas *lamarcki* (Fig. 2B3) prefers sub-horizontal substrates closer to sea level, being found underwater more often than *rouxi* (Bouzaza and Mezali, 2019).

Much has been written on the reasons for the low frequency of FL. Many of these have to do with biological traits that Laborel-Deguen and Laborel (1990) associate to a restricted dispersal capacity of the species. This would be the case of (a) large (i.e., 200 µm): ovocytes, (b) a short reproductive period, (c) low fecundity, and (d) low growth rate. FL is a typical broadcast spawner, with a single spawning season and a short-lived larval development in the water column that lasts between 3 and 7 days. Spawning, however, occurs at a time of the year (October/November) when storms in the Western Mediterranean are common, granting larvae the possibility to settle down at considerable distances from spawning grounds (i.e., ≥10 km) (Frenkiel, 1975). This fact alone would suggest that factors unrelated to dispersal capacity may be the cause of the current low frequency of FL populations (Espinosa et al., 2006).

Similar contention applies to reproductive biology. Traditionally, FL is characterized as a protandrous hermaphrodite, maturing as male when reaching 20 mm, then shifting to female within the 35–45 mm MD range. Recent studies, however, evidence a more labile strategy where, for reasons that are not totally clear at this point, females can occasionally switch sex later in life, so that large males of up to 90 mm have been now documented (Espinosa et al., 2006; Rivera-Ingraham, 2010). For such reason, FL more properly typifies as an alternating hermaphrodite *sensu* Hoagland (1984). Alternating hermaphroditism renders questionable the traditional practice of “sexing” archaeological FL specimens using size.

In the case of BL (*Cymbula safiana*, Fig. 2A), it is a western African species that apparently never managed to proceed far beyond the Alborán Sea (Poppe and Goto, 1991; Rivera-Ingraham, 2010; Gofas et al., 2011). On the southern shore of this sea (Fig. 1), BL ranges from Tangier to Oran and on the Iberian littoral from the provinces of Cádiz to Granada, including the island of Alborán (Poppe and Goto, 1991; Templado et al., 2004; Rivera-Ingraham et al., 2011). Although catalogued as an endangered species and several BL populations are

presently in decline, others seem to be on the increase (Templado et al., 2004). What seems clear is that in present days the presence of BL in the Mediterranean appears to be associated with warm water pulses. BL is the largest of the Mediterranean limpets, reaching MD of up to 130 mm (Gofas et al., 2011), although the specimens we collected over the years in the Cádiz and Málaga coasts reached ~100 mm at most. This species features a distinctive oblong shell that is rather flattened by comparison with FL (more similar to the *lamarcki* ecotype), along with a marked eccentricity, its apex lying clearly closer to the anterior margin of the shell than to the posterior margin (Fig. 2A). The external sculpturing features fine radial striae, and on fresh specimens, dark radial bands on the smooth margins of the inner shell are conspicuous. Three morphotypes are presently recognized for *C. safiana* by Rivera-Ingraham et al. (2011) (Table 2). Specimens with shell lengths below 50 mm (morphotype 1) represent non-mature limpets, easily identified by their dark and white stripped pattern on the outer shell, a lobulated contour (perimeter) and radial ribs (Fig. 4.1). Medium to large individuals with shell lengths above 70 mm represent mature specimens with higher and more solid shells than those of morphotype 1. Within this size category, morphotype 2 specimens feature flat shells with a lobulated contour and radial ribs whereas morphotype 3 shells lack the latter two features and feature an extremely thick and high, almost conical, shell (Fig. 4.2, Table 2). Rivera-Ingraham et al. (2011) reported that in the shores of Ceuta, the largest individuals belonged to morphotype 2 suggesting that, as happens with other limpet species, development of flat and conical shell in the adult is mediated by yet to be determined agents.

Very little is known about the biology of BL although the species is typified as a protandrous hermaphrodite and a broadcast spawner with two spawning seasons, one at the start of autumn and the other during spring (Frenkiel, 1975). BL ranges from the upper fringe of the sublittoral zone, some 5 m below water, to the lower levels of the littoral zone in areas of moderate hydro-dynamism, as is often the case for FL (Fig. 3). For the most part, juveniles (≤20 mm) range from the splash zone to slightly below sea level, whereas adults would be less accessible as they occupy deeper waters, over essentially sub-horizontal substrates of lower hydro-dynamism (Gofas et al., 2011; Espinosa and Rivera-Ingraham, 2017; Rivera-Ingraham, 2010). Another factor that would restrict accessibility is the fact that adult limpets are frequently covered by macroalgae/algae and grasses, rendering their visual location difficult (Rivera-Ingraham, 2010). BL has a clear preference for significant smoother substrates than those of other Iberian limpets.

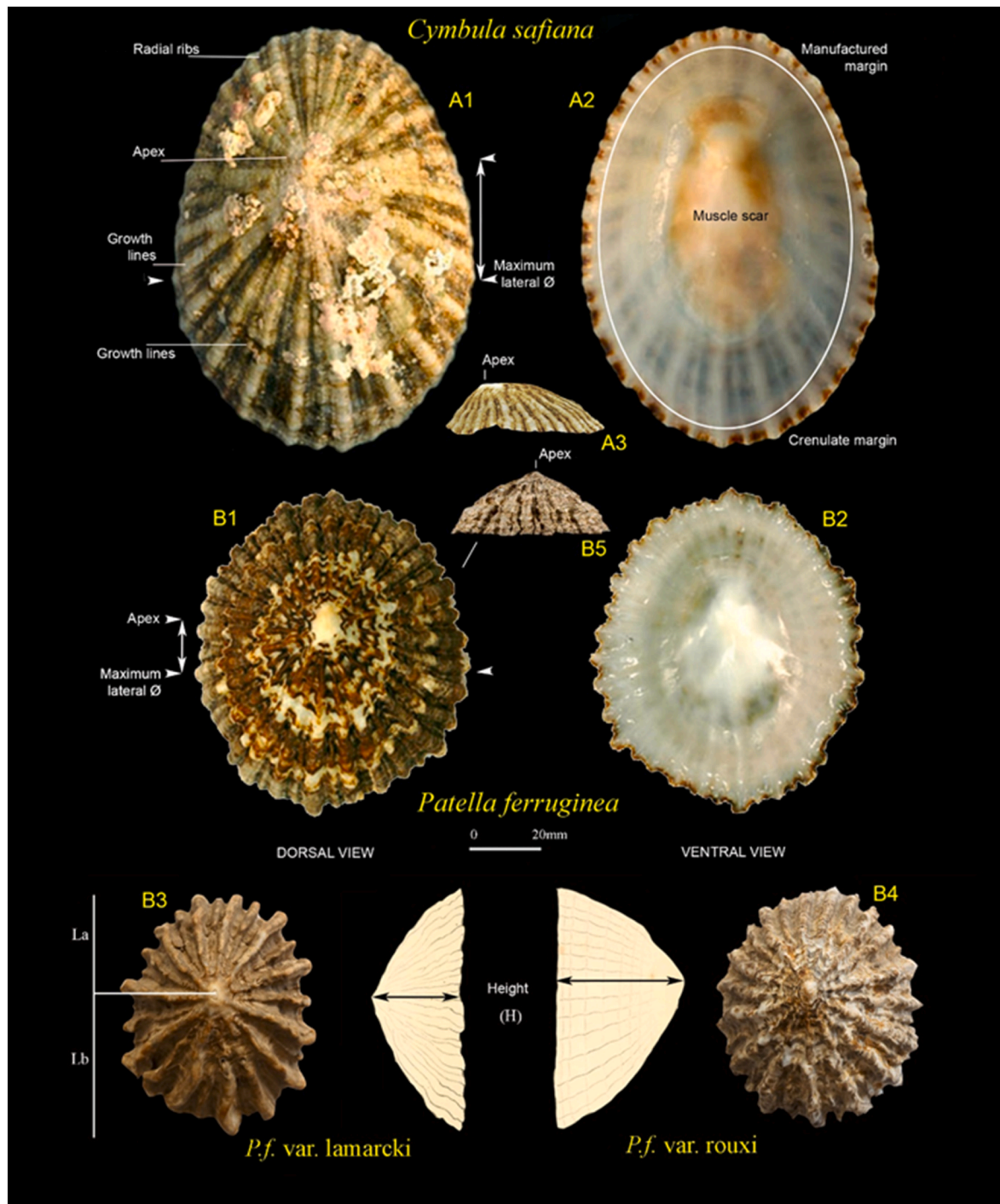


Fig. 2. A1: *Cymbula saffiana* dorsal view; A2: *Cymbula saffiana* ventral view, it is observed crenulated and manufactured margins; A3: *Cymbula saffiana* lateral view; B1: *Patella ferruginea* dorsal view; B2: *Patella ferruginea* ventral view; B3: *Patella ferruginea* var. *lamarcki* dorsal view and lateral view; B3: *Patella ferruginea* var. *rouxi* dorsal view and lateral view; B5: *Patella ferruginea* lateral view. MW: maximum width; MD: maximum diameter; La: length from apex to anterior end; Lb: length from apex to posterior end; H: shell height.

3. Materials and methods

Southern Iberian sites have been split into three sectors (western, central, eastern) on account of sub-regional cultural parallels during the Chalcolithic and Bronze Age (Siret and Siret, 1887, Fig. 5). The eastern sector includes sites from the province of Almería and the Granada plateau, a region that is taken as the cradle of the “El Argar” culture (Siret and Siret, 1887). The central sector incorporates settlements from the provinces of Málaga, Granada -other than the plateau- and Jaén.

Sites from the provinces of Seville and Huelva, along with sites found in the Portuguese Algarve constitute the western sect.

Two groups of limpets were analysed.

- Archaeological samples. These collections include 60 assemblages from 37 sites (8 coastal and 29 inland) ranging from the Middle Palaeolithic to the Bronze Age (see Table 3). Of these, 18 contexts -deriving from 13 sites- have been studied by us. A further 18 assemblages from another 13 sites have been studied

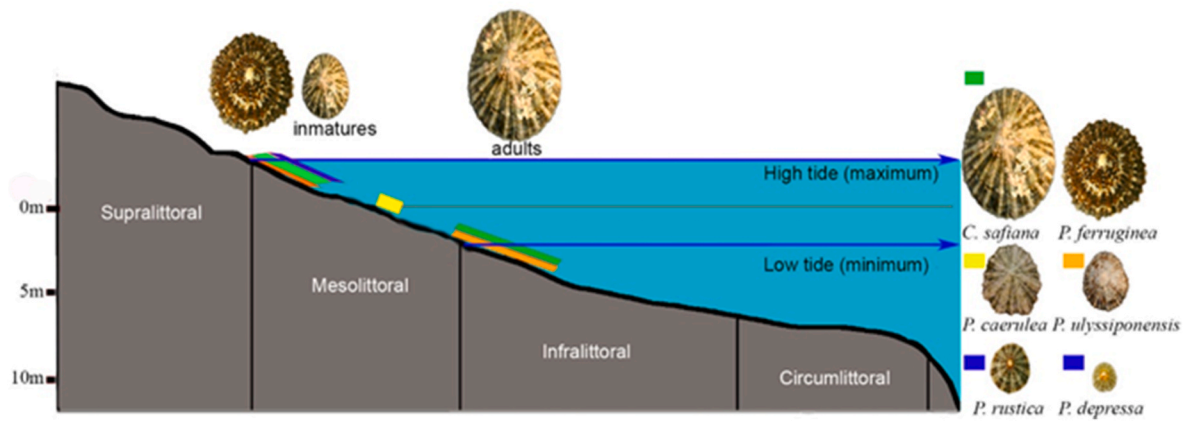


Fig. 3. Distribution by littoral zones of the Alboran Sea Patellidae in relation to the maximum and minimum level of the tides. Size of the different limpets scaled between the maximum sizes of each one of them.

Table 2

Biometrical characterization of *Cymbula safiana* (BL) morphotypes (taken, with modifications, from Rivera-Ingraham et al., 2011) and *Patella ferruginea* (FL) (taken, with modifications, from Bouzaza and Mezali, 2019) in terms of their maximum length (MD) and the height/length (H/MD) coefficient; see Fig. 2 for explanation of measurements). All measurements in mm.

Morphotype BL	MD	H/MD	Morphotype FL	H/MD	H/MD
1	45.2 ± 0.89	0.18	lamarcki	67.27 ± 1.27	0.28
2	73.6 ± 1.11	0.27	rouxii	70.35 ± 1.31	0.35
3	87.1 ± 0.99	0.35			

from graphic material, i.e., for which a photograph or drawing is included in the bibliography and the remaining collections (i.e., 24 assemblages from 11 sites) were data compiled from other authors. For operative purposes, 5 km has been taken as the threshold distance to set apart coastal from inland sites (vid. Bigalke, 1973; Erlandson, 2001 and references therein).

b) Modern shells. A total of 333 *C. safiana* and 91 *P. ferruginea* specimens have been used as reference material to develop the biometrical, taphonomical and trace analyses to assess the archaeological samples. These specimens have two origins, namely:

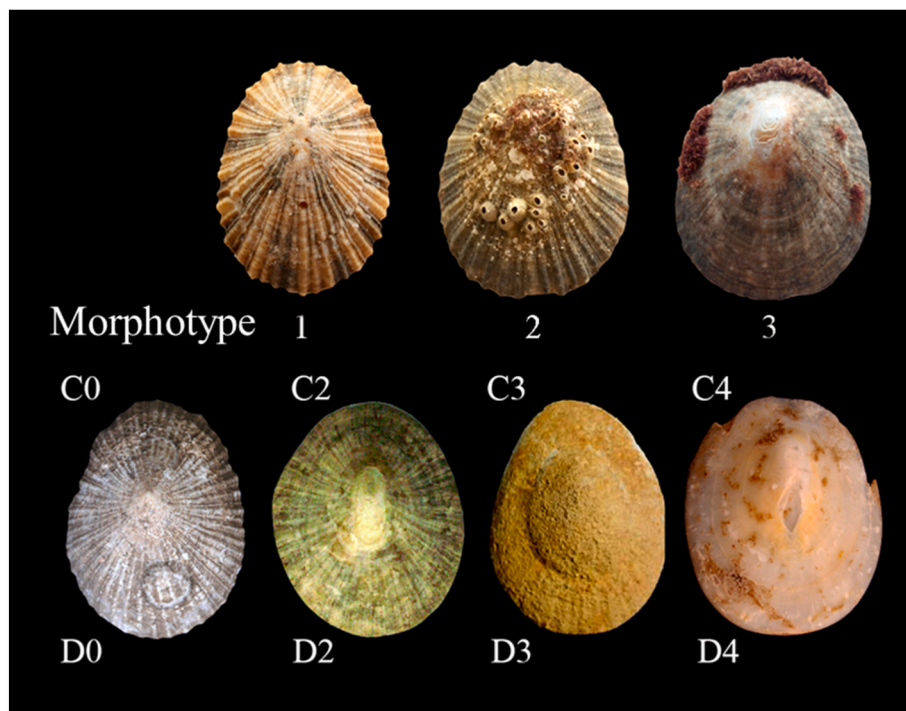


Fig. 4. Above: Morphotypes of adult, Black limpet (*Cymbula safiana*) specimens (Rivera-Ingraham et al., 2011). Below: Archaeological specimens from: (1) Nerja, (2) La Pileta, (3) Panoría, and (4) Carmona exhibiting the four polishing categories for the contour (C0–C3) and dorsal surface (D0–D3).

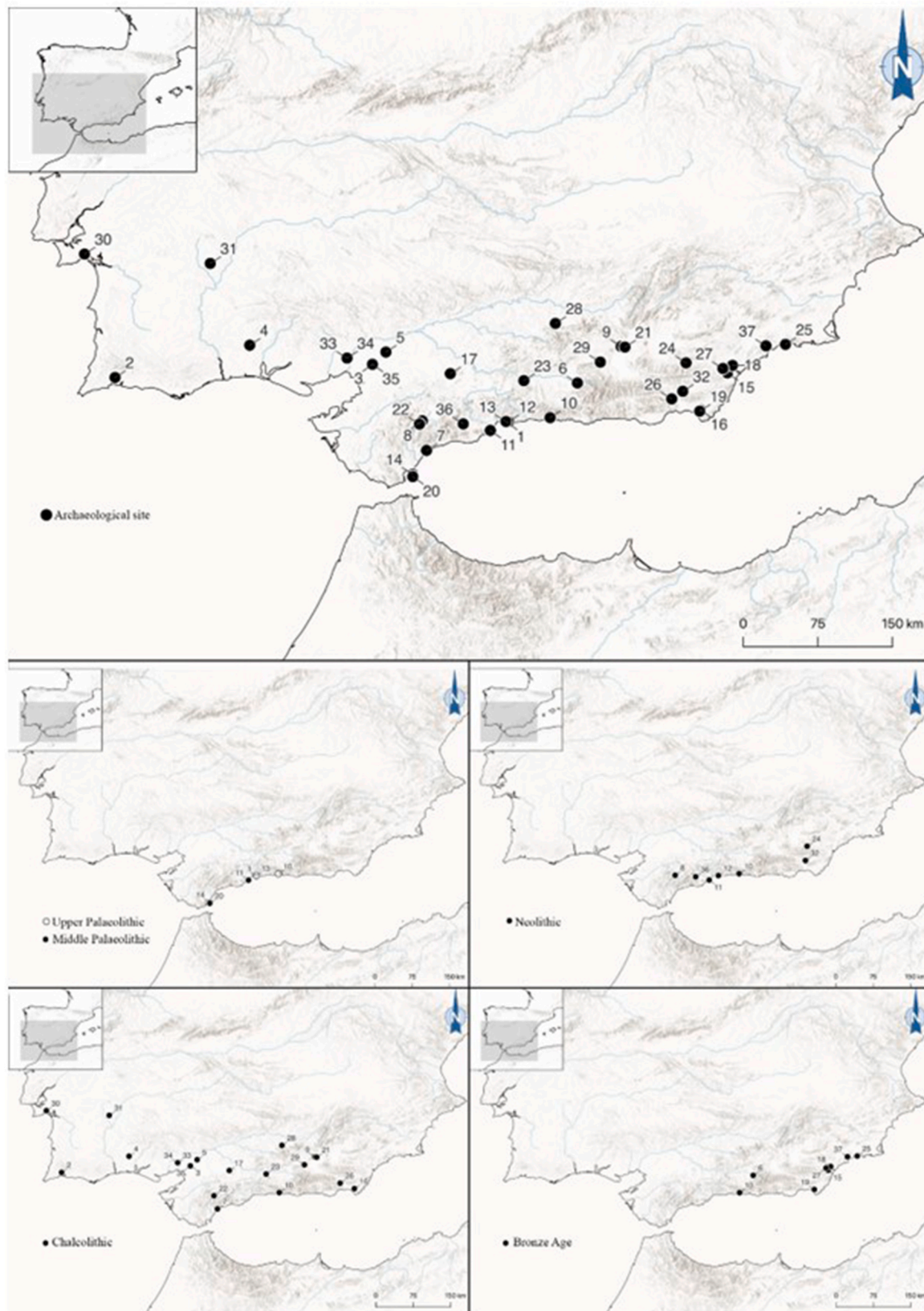


Fig. 5. Map with distribution of deposits of which giant limpets have been analysed by chronocultural stage. 1) Abrigo 3, 2) Alcalar, 3) Bencarrón, 4) Cabezo Juré, 5) Carmona, 6) Cerro de la Encina, 7) Corominas, 8) Cueva del Gato, 9) Cuesta de la Sabina, 10) Cueva de Nerja, 11) Cueva Bajondillo, 12) Cueva del Higerón, 13) Cueva del Hoyo de la Mina, 14) Devil's Tower, 15) El Argar, 16) El Barranquete, 17) El Negrón, 18) Fuente Álamo, 19) Fuente Amarguilla, 20) Gorham's cave, 21) Hoyas del Conquín, 22) Cueva de La Pileta, 23) Covacha de La Presa, 24) Loma de la Atalaya, 25) Los Gavilanes, 26) Los Millares, 27) Lugarico Viejo, 28) Marroquíes Bajos, 29) Panoría, 30) Pedrão, 31) Perdigoães, 32) Terrera Ventura, 33), Valencina. PP4 Montelirio, 34) Valencina. C/ Dinamarca 3.5, 35) Vaquero, 36) Villares de Algane, 37) Zapata.

Table 3

Giant limpets on Southern Iberian sites, context and distance to the coast. In addition, the number of individuals from BL (*Cymbula safiana*) and FL (*Patella ferruginea*) (BL: FL); the percentage of total limpets in the site compared to total molluscs (% add Mollusc) and the percentage of the total number of giant limpets in relation to the total number of limpets in the site (% Giant Limpet).

	No. *	Site	Context	Coast (km)	BL: FL	% add mollusc*	% Giant limpet	Note Reference
C o	1–2	Bajondillo	Cave	0.25	1:3	0.5	6.55	A, 1, 2
a	3	Abrijo 3/Humo	Rock shelter	<0.1	6:0			A, 2, 3
s	4–5	Gorham's	Cave	0.02	0:70			C, 4
t	6	Devil's Tower	Cave	0.02	0:1			C, 4
a	7	Hoyo de la Mina	Cave	0.6	2:0	0.29	3.44	A, 2
l	8–12	Nerja	Cave	1.4	619:338	5.56	14.51	A, 2
	13	Higuerón	Cave	0.7	0:1			B, 5
	14	Gavilanes	Settlement	<0.1	0:57	98.8	42.8(limpets) 1.2(molluscs)	A, 2, 6
I n	19	Terrera Ventura	No data	23.5	2:0			B, 2, 5
l	20–26	El Barranquete	Settlement, Tholos 1–4, 8	7	7:2			B, 2, 7
a	27–30	Los Millares	Tholos 8–10, 40	15	12:2			B, 5, 8
n	38	Panoría	Dolmen	68	1:0			B, 2, 9
d	39	Hoyas del Conquín	Dolmen	78	0:1			B, 2, 10
	40	Cuesta de la Sabina	Dolmen	78	1:0			B, 2, 10
	15	Gato	Cave	34	1:0			B, 2, 5, 11
	16	Loma de la Atalaya	Negative structure	52	1:0			A, 2
	17–18	Villares de Algane	2 Negative funerary structures	22	4:0	9.52	100	A, 12
	31	La Presa	Cave	34	1:0			B, 13
	32	La Pileta	Cave	33	1:0			A, 2
	33	Marroquíes Bajos	Settlement	114	2:0	0.024	50	A, 2, 14
	34–37	Corominas	Tholos 1, 4–5, Others	5	20:6	18.67	19.25	A, 2, 17
	41	Carmona/D. Quintanilla	Settlement	32	1:0			B, 2, 18
	42–45	Valencina/Montelirio	4 Negative structures	2.6	4:0			B, 2, 19
	46–47	Valencina/ C. Dinamarca	2 Negative structures	4	2:0			B, 2, 20
	48	Vaquero	Tholos	17	1:0	14.28	100	A, 2, 21
	49	Bencarrón	Dolmen	18	2:0	18.75	100	A, 2, 21
	50	Cabezo Juré	Settlement	39.8	1:0			B, 2, 22
	51	El Negrón	Artificial cave	74	2:0			B, 2, 23
	52	Perdigões	Tholos	100	2:0			B, 2, 24
	53	Pedrao	Settlement	2.7	1:0			C, 2, 25
	54	Alcalar	Tholos	9	1:0			C, 26
	55	Lugarico Viejo	Settlement	14	1:0			C, 27
	56	Fuente Amarguilla	Settlement	4.5	1:0			C, 28
	57	Zapata	Settlement	35	1:0			B, 2, 5, 27
	58	El Argar	Settlement	10.7	0:1			B, 2, 5, 27, 28
	59	Fuente Álamo	Settlement	12	1:49	12	100	C, 29
	60	Cerro de la Encina	Settlement	43	0:4			C, 29

1) Cortés-Sánchez et al., 2011, 2) this paper, 3) Fernández et al., 2005, 4) Fa et al., 2016, 5) <http://ceres.mcu.es/pages/Main>, 6) Roselló et al., 1995, 7) Almagro, 1973, 8) Almagro and Arribas, 1963, Leisner and Leisner, 1943, 9) Díaz-Zorita et al., 2017, 10) García and Spahni, 1959, 11) Mora, 1976, 12) Márquez and Fernández, 2002, Lozano-Francisco and Vera-Peláez, 2002 13) Carrasco et al., 1977, 14) Lozano-Francisco and Rodríguez Ariza, 2014, 17) Fernández et al., 2005, 18) Collins, 2003, 19) , 20) Pajuelo and López, 2013, 21) Bullen, 1905, 22) Abril, 2012, 23) Cruz-Auñón et al., 1990 and personal communication, 24) Evangelista, 2014, Valera and André, 2017, 25) Soares and Silva, 1975, 26) Leisner and Leisner, 1943, 27) Siret and Siret, 1887, 28) Navarro, 2013, 29) Manhart et al., 2000, 30) Milz, 1986, Friesch, 1987. Note: A) Material studied for this paper (1–3, 7–12, 14, 16–18, 32–37, 48–49); B) material identified by graphic material (13, 15, 19–31, 38–47, 50–52, 57–58); C) Data from other authors (4–6, 53–56, 59–60).

b1) 101 specimens were collected during fieldwork carried out at the Maro-Cerro Gordo Natural Park (provinces of Málaga and Granada) during the years 2004 and 2005.

b2) 232 specimens beachcombed on the provinces of Málaga and Cádiz.

In addition, 35 specimens (24 FL and 11 BL) from the reference collection of one of the authors (AMM), housed at the Laboratory of Archeozoology (Universidad Autónoma de Madrid), deriving from various locations of the western Mediterranean, have been used for complementary purposes.

Taxonomy follows the nomenclature of WORMS (<http://www.marinespecies.org/>) and the criteria provided by Nicklès (1950), Lecoivre (1952), Poppe and Goto (1991), Gofas et al. (2011) and Rivera-Ingraham et al. (2011). Since in worked limpets, anatomical features are often difficult to ascertain, biometrical/statistical tools were developed to aid with identification. These measurements should help one recognize the various morphotypes of the two species for shells in good condition.

Five measurements were taken: (a) Maximum width (MW),

corresponding to the largest transverse (i.e., latero-lateral) diameter of the shell, (b) Maximum length (MD), corresponding to the largest anterior-posterior diameter of the shell, (c) Length from the apex to the anterior margin (AA), (d) Length from the apex to the posterior margin (AP), and (e) Maximum height (H) (Fig. 2). The MW/MD ratio provides an estimation of how round or oblong a shell is; the AA/AP ratio was used to provide an estimation of how eccentric the apex on a given shell was and the H/MD ratio gave us an approximation of the conicity of the shell. In the case of archaeological specimens, whenever illustrations allowed, measurements were taken directly on the depicted specimens correcting values in accordance with the graphic scale data provided in Fig. 2. Measurements were taken with a Mitutoyo Powerfix® digital caliper (estimated error ± 0.01 mm). All values are given in millimeters. The MD and MW provided for the *lamarcki* and *rouxi* morphotypes of FL were taken from Bouzaza and Mezali (2019). For the estimation of measurements in fragmented or otherwise damaged specimens, whenever possible, we used the model or equation generated from the lineal regression among biometrical variables that were taken on modern limpet populations. In this way, the equation used for BL was $MD = 1,293MW + 1,5442$ (Pearson's r between MD & MW = 0,9893; p -value <

0,001) and the equation used for FL was $MD = 1,1447MW + 3,6367$ (Pearson's r between MD & MW = 0,9890; p -value <0,001). Likewise, AA and AP were estimated whenever MD and either AA or AP (depending on which one is available), are known.

The statistical analyses, as well as the infographics derived from them, were done with the EXCEL Office 365 package and the SPSS statistics' v.26 program, respectively. Each of the biometrical variables was characterized through conventional descriptive statistics routines. The statistical analyses include Shapiro-Wilk's Normality test, One-way ANOVA (Tukey's pairwise; Dunn's post hoc). In all cases the confidence level was set at 95%.

Quantification of the archaeological specimens was accomplished by estimating the MNI (Minimum Number of Individuals) following Reitz and Wing (2008). In our case, only shell apices were taken into consideration.

The assignment of a given specimen as either evidence of consumption or more elaborate use relies on a combination of contextual data and traces. Contextual clues include presence of isolated vs. grouped shells, consumption (i.e., refuse tip, shell midden) vs. non-consumption features (e.g., graves, rooms, etc.) of the deposits, and manipulative marks (Table 4). Traces on shells can be of several kinds. Coloration (traces of pigment) and thermo-alterations are anthropic in nature and readily spotted in most cases. Anthropic alterations such as chipping scars on the margins of the shell, produced when detaching a limpet from its substrate with a chisel, may be clear in some cases but in others may resemble natural fragmentation (Cuenca Solana et al., 2016). Much the same happens with perforations, polishing on the shell's external surface and levelling of contours (Cuenca Solana et al., 2016). Table 4 details the features of the marks explored in this study and the codes each one of them received. Some of these marks are depicted in Fig. 6.

All dates are expressed as cal ka BP or cal BC. We used the raw data from the literature to calibrate them using the intcal20 curve. These calibrated data were used to calculate the Summed Probability Density (SPD). This was done using the rcarbon package. The rcarbon package for R was used for date calibration and SPD calculation (Bevan and Crema, 2020).

4. Results

4.1. Distribution

4.1.1. Biogeographical

The total of 1203 giant limpets recorded in our survey and analyses include 690 BL (57.3%) and 500 FL (41.6%) specimens. An additional MNI = 13 from inland sites, representing 1% of the total sample, could only be classified as "unspecified giant limpet" (GL hereafter). Since FL is an endemic an BL a western African invader whose presence one would deem intermittent in these past 128 ka (i.e., Bajondillo, Bj/18 = MIS 5) due to temperature shifts, the higher abundances of BL vs. FL in both the specimens we beachcombed in the coast of Málaga and in the

archaeological sites constitute one first remarkable feature worth noting (1.4:1 in the archaeological collections vs. 2.6:1 in modern collection; see Table 5).

4.1.2. Archaeological and geographic context of giant limpets

Giant limpets derive from 60 Southern Iberian archaeological deposits. The area covered ranges from the Bay of Mazarrón in the province of Murcia (Spanish Levant coast) to Lisbon in central Portugal (Fig. 5). The sites are rather evenly distributed since 13 of them (35.1%) appear on the Eastern sector, a further 14 (37.9%) in the central sector, and the last 10 (27%) in the western sector. 21.6% of the sites (8) lie on either the coast or its vicinity, and the remaining 29 (78.4%) are inland sites (i.e., >5–114 km) (Tables 3 and 6). Only 19% of the studied sites, representing 24.2% of the deposits, are coastal yet the giant limpets recorded in them amount to ca. 88.5% records (i.e., 1064 specimens). For such reason, whereas FL and BL average an anecdotic 4 specimens per inland site (2.7 specimens per inland deposit), on coastal assemblages that mean value rises to ca. 149 specimens per site (ca. 80 specimens per assemblage). These coastal site averages are misleading in that ca. 90% of the giant limpets (957 specimens) appear on the cave of Nerja, where FL represents 35.3% of the total MNI for that species on our coastal sites (338 specimens) and ca. 65% in the case of BL (619 specimens) (Table 7). The 3 caves and single artificial cave, featuring one deposit each, barely amount to 10% of the contexts documented on inland sites. In contrast, the 11 settlements one-deposit-strong each, represent 40% of the sites and 26% of the giant limpet inland assemblages, whereas those numbers in the case of the 16 tholoi would reach over 42% (in terms of sites) and 30% (in terms of assemblages), and in the four dolmens ca.14% (in terms of sites) and +9% (in terms of assemblages) (Table 8).

Differences among coastal and inland sites are more marked when numbers of specimens are considered since 88.4% of the giant limpets (MNI = 1064) appear on coastal assemblages whereas the 139 specimens from the hinterland represent 11.6% of the total sample. The proportions of each species also differ between the coast and hinterland. In the former, 629 specimens are BL (59.1% of the total sample), and 435 (40.9%) are FL; on the hinterland sites, the proportion of BL is not only higher than on the coast (74 specimens representing 53.2% of

the total hinterland samples) and that of FL lower (65 specimens representing 46.8%) but these values could be misleading since of the further 13 that remained unidentified, those incorporated to the biometrical analysis appear to be BL as well (Table 5). FL also appears restricted to sites from the eastern sector.

4.1.3. Chronocultural distribution

The archaeological record of BL and FL starts with Neandertals and in the Upper Palaeolithic is recurrent in coastal sites (Bajondillo [Marine isotopic stage (MIS) 5, 128-78 ka: 1 BL], Gorham's [MIS 5-3: 9 FL], Devil's Tower [MIS 3: 1 FL] and Abrigo 3 [MIS 3: 6 BL]). During the Middle Palaeolithic, FL exhibits a 10:1 dominance over BL, yet during the Upper Palaeolithic and Neolithic, BL dominates FL in proportions

Table 4

Giant limpets: applied anthropic modification analysis. 0: unchanged and 3: maximum change.

Degrees	0	1	2	3
Outline	Natural (unmodified) (Fig. 6.1) Crenulate (Fig. 6.4)	Reduction of serrated edge by partial elimination of the crenulate from the margin of the base of the shell (Fig. 6.4). Pseudoelipsoidal delineation. Micro-irregular contour (Figs. 6–4).	Elimination of denticulation or even the margin of the base from the shell (Fig. 6.2) Oval Delineation. Removal of several mm from the base margin of the shell. Reduction of diameter (Fig. 6.2)	Modification of the contour creating appendices or recesses that break the oval line (Fig. 7.3) Oval delineation. Elimination full margin of the base the shell. Deep reduction of diameter (Fig. 6.3)
Dorsal face	Unmodified (Fig. 6.1) Ribs (6.1)	Shallow abrasion and polishing (Fig. 6.2) Rib smoothing (Fig. 6.4)	Abrasión y pulido intenso. (Fig. 6.4) Regularization of the heights of the ribs (Fig. 6.2)	Very intense polishing and abrasion. (Figs. 6.6 and 11) Complete removal of ribs have to bring out the layer internal lamellar of the shell (Fig. 6.3)
Boring	No	One	Double parallel	Two non-parallel

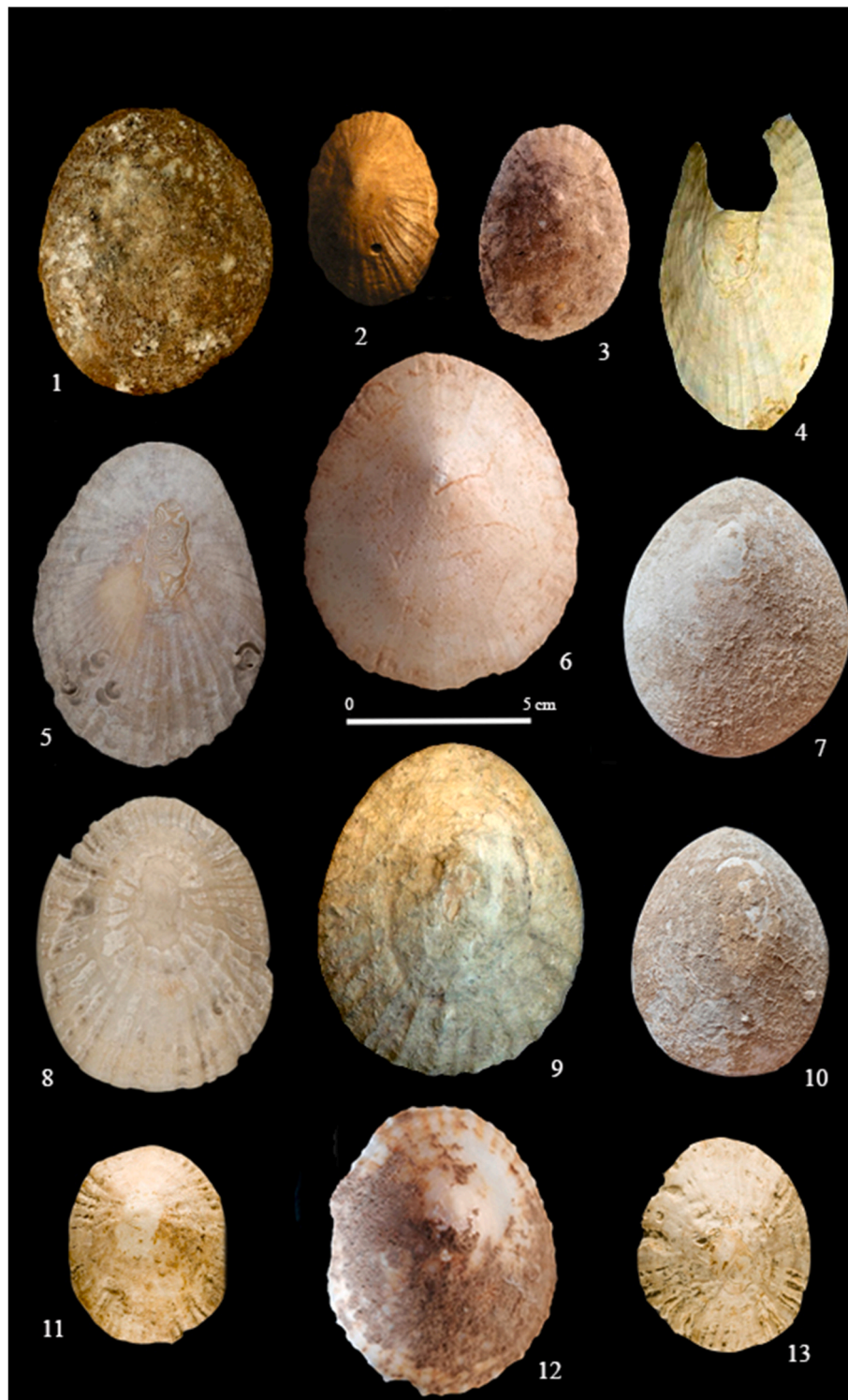


Fig. 6. *Cymbula safiana*. (1) Perdigões, (2) Gato, (3) Bencarrón (4) Cabezo Juré, (5 y 8) Los Millares/Grave 40 (photos MAN/1976/1/MILL/40/201-2), (7 and 10) Valencina/C. Dinamarca, (8) Los Millares (Museo de Almería DE1976/1/ill/6/9, (9) Valencina/Montelirio (11 y 13) *Patella ferruginea*, Los Millares (Museo de Almería, DE1976/1/Mill/6/8), (12) Acebuchal.

that range from 1.5:1 to 6:1 (Table 7). In the hinterland, giant limpets first appear during the Late Neolithic (i.e., the 4th-3rd millennia BCE transition), at places such as Gato and Viera (Mora, 1976; Mergelina, 1922).

During the Copper Age (~5000 - 4100 ka BP) a disproportion favoring BL over FL occurs on inland sites. Whereas on the coast BL = 59.5% and FL = 40.5%, the trend accentuates inland (BL = 84%; FL =

16%). The Chalcolithic marks the zenith of occurrences also in terms of the variety of deposits. The 38 archaeological contexts, including 16 tholoi (42.1% of all records during the Chalcolithic), are listed on Table 8. Although these megalithic constructions reach to the first millennia BC, limpet records date mostly from the 4th-3rd millennia BC (Figs. 7 and 8).

Table 5

Summary coastal and inland sites: minimum number of individuals (MNI), number of individuals totals of BL (*Cymbula safiana*), FL (*Patella ferruginea*) and giant limpet (GL) number of individuals per chronocultural segment and percentage of total number of giant limpets.

		Middle Palaeolithic		Upper Palaeolithic		Epipalaeolithic		Neolithic		Copper Age			Bronze Age	
		BL	FL	BL	FL	BL	FL	BL	FL	BL	FL	GL	BL	FL
A) Coastal(1–14)														
MNI = 1064	%	7	70	28	15	18	3	173	50	392	267	–	11	30
BL = 629	59.1	9.1%	–	65.1%	–	85.7%	–	77.5%	–	59.5%	–	–	26.8%	–
FL = 435	40.9	–	99.9%	–	34.9%	–	14.3%	–	22.5%	–	40.5%	–	–	73.2%
	100	MNI = 77 (7.2%)		MNI = 43 (4.1%)		MNI = 21 (2%)		MNI = 223 (20.9%)		MNI = 659 (61.9%)			MNI = 41 (3.8%)	
B) Hinterland(15–60)														
MNI = 139	%	–	–	–	–	–	–	6	–	50	12	13	5	53
BL + GL = 74	53.2	–	–	–	–	–	–	100%	–	66.6%	–	17.3%	8.6%	–
FL = 65	46.8	–	–	–	–	–	–	–	–	–	16%	–	–	91.4%
	100	MNI = 0		MNI = 0		MNI = 0		MNI = 6 (4.3%)		MNI = 75 (54%)			MNI = 58 (41.7%)	
C) Total A + B														
MNI = 1203	%	7	70	28	15	18	3	179	50	442	279	13	+16	83
BL + GL = 703	58.4	9.1%	90.9%	65.1%	34.9%	85.7%	14.3%	78.2%	21.8%	60.2%	38%	1.8%	16.2%	83.8%
FL = 500	41.6	MNI = 77 (6.4%)		MNI = 43 (3.6%)		MNI = 21 (1.7%)		MNI = 229 (19.0%)		MNI = 734 (61.0%)			MNI = +99 (8.3%)	

4.2. Biometry

For the comparative taxonomic and size analyses, BL and FL have been grouped into two categories: 1) modern and thanatocoenosis populations from present day beaches, and 2) archaeological specimens, subdivided into coastal and inland sites (Tables 9 and 10, Fig. 5). The following categories have been considered.

- For BL: current and archaeological coastal (Nerja cave) populations, manipulated or not, and manipulated archaeological (inland).
- For FL: current populations without considering morphotype (*lamarcki* and *rouxi*), coastal archaeological limpets (Nerja cave and Cerro de los Gavilanes), both manipulated and unmanipulated, and manipulated archaeological (inland).

Tables 9 and 10 show the results of the descriptive statistics for each of the groups, as well as the ratio between the different biometric variables that characterize each species.

To determine whether a pattern of selection between the *lamarcki* and *rouxi* morphotypes existed, and how similar the shells were to those of BL, we obtained biometric data from the collections and used the data of current specimens from Bouzaza and Mezali (2019). Data were only available for the variables MD and MW. The results are provided in Table 2 and will be discussed in section 5.1. When grouped, once the length of the archaeological specimens is estimated from the linear regression data for incomplete specimens the thanatocoenosis and present-day length distributions fit a normal distribution (Figs. 9 and 10; Shapiro-Wilk normality test [S-WT], p -value = 0.6613; α = 0.05). For coastal archaeological sites the size distribution does not fit a normal distribution (S-WT p -value = 0.04394; α = 0.05) whereas this is the case for inland sites specimens (S-WT p -value = 0.2404; α = 0.05).

In order to determine whether a selection in the shape and size of the specimens through the different chronocultural stages took place, we used the following ratios (see sections 2): a) the MW/MD ratio (indicates how oval or rounded a shell is); b) the AA/AP ratio (how displaced the apex is in relation to the center of the shell) and, c) the H/MD ratio (how conical the height of the shell looks).

The differences between the means of the MW/MD and AA/AP parameters in coastal and inland specimens has been obtained by a One-way ANOVA analysis (Tukey's pairwise; Dunn's post hoc, with significance level α = 0.005) (Tables 11 and 12). One can see that no significant differences between the means of the MW/MD ratio amongst the BL groups exist, so that the shape or ellipse representing the contour is always similar. Nevertheless, the MW/MD ratio is significantly different with respect to the different groups of FL, allowing us to clearly

differentiate between the species in the modern populations (p -value = 1.60×10^{-17} , α = 0.005). In contrast, there are no differences between archaeological FL and BL (Table 12). Consequently, there seems to be a selection of FL in terms of shape and size that mimic the shape and size of BLs. With respect to morphotypes, *rouxi* and *lamarcki*, do not show significant differences between the means of the MW/MD ratio. The AA/AP ratio could only be obtained for the current populations of both species and the set of inland BL (with significant differences between the current FL and inland BL) (Table 13).

Comparison of the mean MD values reveals that the specimens recovered in archaeological contexts on the hinterland (mean MD: 69.13 mm) have a clearly different range from those found in coastal sites, which are generally smaller (mean MD: 57.60 mm). From the Upper Palaeolithic to the Bronze Age there is an increase in the size of the specimens for the two species. For BL, the mean MD in the Palaeolithic: 42.60 mm; mean MD for the Neolithic: 66.68 mm and mean MD for the Chalcolithic-Bronze: 72.85 mm; for FL the mean MD for the Palaeolithic: 32.58 mm; mean MD for the Neolithic: 48.51 mm and mean MD for the Copper- Bronze Age: 54.94 mm (Fig. 11, Table 11).

4.3. Taphonomy

If one were to assess use by the presence of manipulative marks other than those reflecting capture, only 7.2% of the studied samples (NISP = 85) could be taken to reflect non-subsistence items (Table 8). The only marks recorded on coastal site limpets are chipped margins characteristically produced by firing pins when detaching the animal from its substrate. Such "extraction" marks are recorded on all species of limpets, not just giant ones, and appear to be of two kinds Table 4).

- Expeditive extraction marks. These are profound, helicoidal scars that follow growth lines and reflect a strong blow on the margin of the dorsal face of the shell.
- "Meticulous" extraction marks. These are small scars (denticulations) on those borders of the mantle that allow the limpet to be detached while leaving the shell almost intact.

On coastal sites, such dominance of unmodified giant limpet shells and others exhibiting these extractive marks appears on mixed faunal assemblages (including smaller limpet species) and bone accumulations taken to represent offal. This is most evident on the large limpet assemblage at Nerja cave but seems to be a recurrent pattern of giant limpet occurrences throughout the temporal window our study covers (i. e., Middle Palaeolithic-Bronze Age) (Cortés-Sánchez et al., 2012, 2019). Worth remarking are also the mean sizes of these giant limpets, in

Table 6

Giant limpets in archaeological sites in southern Iberia, context and distance to the coast. In addition, the minimal number of individuals (MNI) from BL (*Cymbula safiana*), FL (*Patella ferruginea*) and giant limpet (GL).

—	Nº	Archaeological site	Type	km →coast	MNI		
					BL	FL	GL
C o a s t	1–2	Bajondillo	Cave	0.25	1	3	–
	3	Abrigo 3	Rock shelter	<0.1	6	–	–
	4–5	Gorham's	Cave	0.02	–	70	–
	6	Devil's Tower	Cave	0.02	–	1	–
	7	Hoyo de la Mina	Cave	0.6	2	–	–
	8–12	Nerja	Cave	1.4	619	338	–
s i t e s	13	Higuerón	Cave	0.7	1	–	–
	14	Gavilanes	Settlement	<0.1	–	25	–
H i n t e r l a n d	15	Gato	Cave	34	1	–	–
	16	Loma de la Atalaya	Negative structure	52	1	–	–
	17–18	Villares de Algane	2 Negative funerary structures	22	4	–	–
r e g i o n	19	Terrera Ventura	No data	23.5	2	–	–
	20–26	El Barranquete	Settlement, Tholos 1–4, 8	7	5	2	2
a l l i e s	27–30	Los Millares	Tholos 8–10, 40	15	3	2	9
	31	La Presa/Cave	Cave	34	–	–	1
d i s t r i c t	32	La Pileta/Cave	Cave	33	1	–	–
	33	Marroques Bajos	Settlement	114	2	–	–
e s	34–37	Corominas	Tholos 1, 4–5, Others	5	20	6	–
	38	Panoría	Dolmen	68	1	–	–
s	39	Hoyas del Conquín	Dolmen	78	–	1	–
	40	Cuesta de la Sabina	Dolmen	78	–	–	1
e s	41	Carmona	Settlement	32	1	–	–
	42–47	Valencina (PP4-Montelirio. C/Dinamarca)	6 Negative structures	2.6–4	6	–	–
a l l i e s	48	Vaquero	Tholos	17	1	–	–
	49	Bencarrón	Dolmen	18	2	–	–
e s	50	Cabezo Juré	Settlement	39.8	1	–	–
	51	El Negrón	Artificial cave	74	2	–	–
a l l i e s	52	Perdigões	Tholos	100	2	–	–
	53	Pedrao	Settlement	2.7	1	–	–
e s	54	Alcalar	Tholos	9	–	1	–
	55	Lugarico Viejo	Settlement	14	1	–	–
a l l i e s	56	Fuente Amarguilla	Settlement	4.5	1	–	–
	57	Zapata	Settlement	35	1	–	–
e s	58	El Argar	Settlement	10.7	1	–	–
	59	Fuente Álamo	Settlement	12	1	49	–
a l l i e s	60	Cerro de la Encina	Settlement	43	–	4	–

Table 7

Limpets in Nerja Cave. Minimum number of individuals (MNI) and percentage of the species out of the total number of limpets (%) in each chronocultural segment.

MNI	Upper Palaeolithic	%	Epipal.	%	Neolithic ~2.5ka	%	Copper Age~1ka	%	Bronze Age~0.5ka	%
<i>C. safiana</i>	28	3.8	16	4.4	172	4.3	392	6.6	11	34.4
<i>P. ferruginea</i>	14	1.9	3	0.8	49	1.2	267	4.5	5	15.6
Other limpets	695	94.3	347	94.8	3772	94.5	5236	88.8	16	50
Σ11,023	737	100	366	100	3993	100	5895	100	32	100

particular BL, that do not deviate significantly from the values of smaller-sized species (BL MD (Ȳ): 57.60 mm; FL MD (Ȳ): 32.58 mm; other limpets (pooled Ȳ): 36.1 mm).

Abrasive marks bearing traces of manufacturing were only recorded

on Neolithic and Chalcolithic specimens from inland locations (Table 5). Of the 61 specimens in this category, only 37 could be studied. These include 13 shells and a further 24 specimens analysed from graphic material. The traceological analyses evidenced that people tried to

Table 8

Hinterland. Giant limpets. Data summary from Neolithic-Copper Age sites with context information. Minimum number of individuals (MNI) and percentage of the giant limpets species out of the total number of limpets (%) in each chronocultural segment.

Type	Sites	%	MNI	%	Context	MNI	%
Settlement	4	10.5	6	11.8	Settlement	6	9.8
Cave	4	10.5	3	5.9	Funerary context	53	86.9
Artificial cave/Negative structure	10	26.3	9	17.6	No data	2	3.3
Dolmen	4	10.5	5	9.8	Add	59	100
Tholos	16	42.1	28	54.9			
Σ	38	100	51	100			

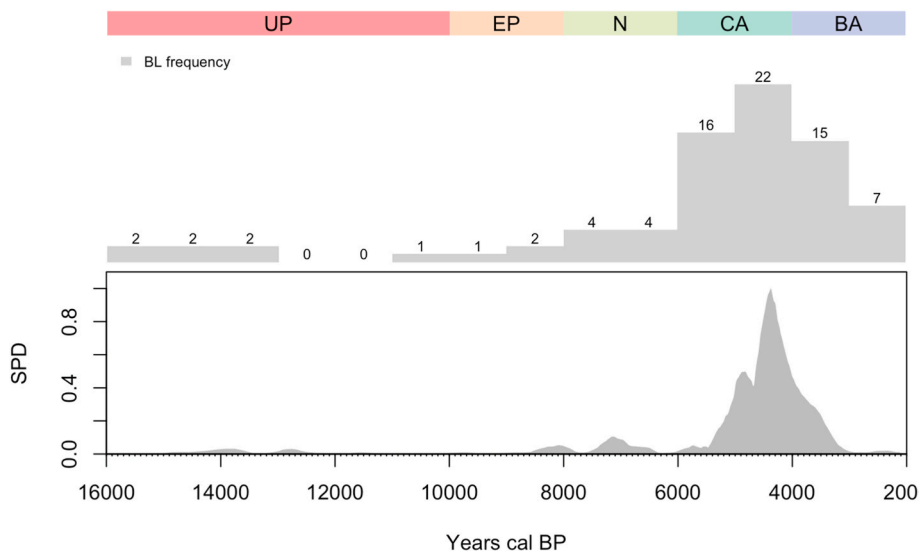


Fig. 7. ^{14}C dates on sites with giant limpets. Only directly dated contexts and short-lived samples on anthropic contexts with margins of error <100 years have been considered. No date derives from limpets analysed in this paper. BL (*Cymbula safiana*) frequency in absolute values. UP: Upper Palaeolithic; EP: Epipalaeolithic; N: Neolithic; CA: Chalcolithic; BA: Bronze Age. BL Frequency Histogram (1000-year bin) compared to SPD (Summed Probability Density) for the available ^{14}C dates. The rcarbon package for R was used for date calibration and SPD calculation (Bevan and Crema, 2020).

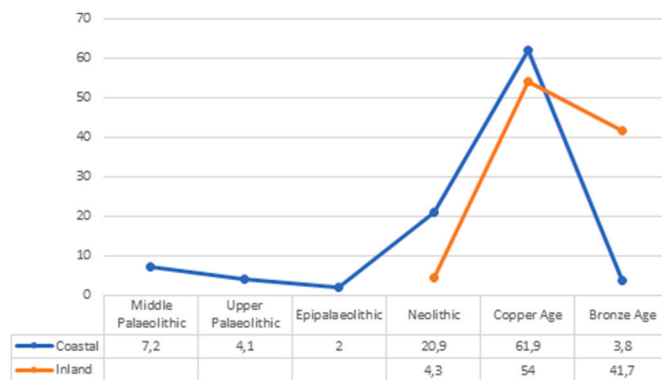


Fig. 8. Representation of the percentage of giant limpets (BL + FL + GL) on the Coast and in the Interior with respect to the total on the coast and the total in the interior. It is observed how it is from the Neolithic when the giant limpets begin to be transported inland. (BL: *C. safiana*, FL: *P. ferruginea*, GL: giant limpets unidentified).

abrade the external sculpturing of these shells to produce a smooth surface (Fig. 4C4). In addition, the marginal crenulations (denticulations) were also eroded, generating an ovoid profile/contour (Fig. 2B.2, 4C4). On several cases, the smoothening of the shell margins also affected the extraction scars, an operation that required a more intense smoothening of the altered surface (Morphotype 3, Fig. 4). One should remark that this manipulation was only recorded on inland sites from the westernmost sector (i.e., sites of Valencina (3 specimens), Negrón [2 specimens], Pedrao [1], and probably also Perdígones and Vaquero).

5. Discussion

5.1. Giant limpets' identification, biogeography, selection and modifications

In the sites of the south Iberian Peninsula we find references to the presence of limpets in both coastal and inland archaeological sites (e.g., Márquez and Fernández, 2002; Lozano-Francisco and Vera-Peláez, 2002; Collins Hayes, 2003; Fernández et al., 2005; Cortés-Sánchez et al., 2011; Abril, 2012; Navarro, 2013; Pajuelo and López, 2013; Lozano-Francisco and Rodríguez Ariza, 2014; Liesau et al., 2014; Evangelista, 2014; Lozano y Rodríguez, 1982; Fa et al., 2016; Valera and André, 2017; Díaz-Zorita et al., 2017). Some material has been studied by the

authors of this paper although a significant fraction was tracked down from the literature, including grey literature and reports not readily accessible, as well as museum collections (see Table 3). As has been often the case of faunal remains in Spain, prior to the 1990s archaeological molluscs were neither systematically retrieved nor adequately reported. The latter includes a scarcity of illustrations, which are in many cases faulty and of poor quality, and no data on specimen biometrics or scales bars, as well as misleading nomenclature. This includes not only synonyms and invalid names but also the use of very coarse categories (i.e., "molluscs", "snails"). In our case this included references to giant or very large limpets for which we needed to develop a third category for this study (GL) (e.g., García and Spahni, 1959; Carrasco et al., 1977; Abril, 2012; Díaz-Zorita et al., 2017).

When considering the maximum dimensions of all the limpet species present in Alborán Sea, we find that, in the archaeological collections, the specimens are at least 20 mm smaller than the maximum sizes reported for each species (based on modern data according to Gofas et al. (2011)). Thus, neither in +11,000 limpet specimens analysed in Nerja cave (Table 7) nor the observations of the biocenoses and thanatocenoses of the Malaga coast has any specimen been documented that reaches the maximum dimensions recorded for each limpet species (Tables 9–11). In this way, among 5158 complete specimens of *P. caerulea*, the mean maximum size is ~50 mm, except for a single specimen from Ner of 58 mm (the maximum size cited in the literature for *P. caerulea* is 55 mm (Gofas et al., 2011)). Consequently, it is very likely that, without considering identification criteria, any limpet recovered from inland archaeological contexts in southern Iberia with a size >55 mm corresponds to one of the two giant limpets. From a taxonomic point of view, BL and FL are both easy to set apart on well-preserved shells and applying biometric criteria characterizing each species (see section 2) (Poppe and Goto, 1991; Templado et al., 2004; Gofas et al., 2011; Luque et al., 2018) (Fig. 2).

Comparison of the mean MD value b in each chronological segment shows a trend of increasing size in selected limpets over time in the case of BL (Fig. 11). In coastal sites, where we find mainly unmodified specimens, the range 30–40 mm predominates in BL, but the center of the bell (i.e., 60–80 mm) is "missing", whereas on inland sites the size range preference is precisely 60–90 mm (Fig. 9). This is a very interesting and can be taken to indicate that Nerja cave, a presumably core site on account of previous archaeological evidence could have functioned as an export site of sorts. In the case of MD for FL, the smaller range (<60 mm) is missing on inland sites (Fig. 10). Nevertheless, in all cases, FL sizes are distributed according to a normal distribution (S-WT: current FL p-value = 0.5762; coastal archaeological FL p-value = 0.8890

Table 9

Summary of the descriptive statistics for *Cymbula safiana* (BL) (modern, coastal (Nerja) and hinterland). Maximum width (MW), Maximum length (MD), Maximum height (H), length from the apex to the anterior margin (AA), length from the apex to the posterior margin (AP), length from the apex to the length (AL). All measurements in mm.

<i>Cymbula safiana</i> Modern	MD	MW	H	AA	AP	MW/MD	AA/AP	H/MD
N	333	333	251	251	253	333	251	251
Mean	45.07	33.66	13.09	18.06	34.71	0.75	0.52	0.25
Standard error of the mean	1.05	0.81	0.36	0.53	0.73	0.00	0.01	0.00
Deviation	19.25	14.73	5.69	8.46	11.62	0.06	0.18	0.05
Range	82.31	68.53	27.35	59.21	57.12	0.52	1.89	0.31
Minimum	10.00	7.00	2.53	3.29	6.64	0.42	0.19	0.08
Maximum	92.31	75.53	29.88	62.50	63.76	0.94	2.08	0.40
<i>Cymbula safiana</i> . Coastal	MD	MW	H	AA	AP	MW/MD	AA/AP	H/MD
N	26	26	16	16	17	26	16	15
Mean	57.60	45.45	11.17	13.50	25.49	0.79	0.54	0.31
Standard error of the mean	4.93	3.93	0.59	0.71	1.98	0.01	0.03	0.00
Deviation	25.14	20.03	2.37	2.86	8.18	0.06	0.11	0.01
Range	78.55	60.47	7.83	9.87	32.54	0.29	0.48	0.06
Minimum	26.45	21.53	8.29	8.14	16.78	0.58	0.19	0.27
Maximum	105.00	82.00	15.67	18.01	49.32	0.88	0.67	0.33
<i>Cymbula safiana</i> . Hinterland	MD	MW	H	AA	AP	MW/MD	AA/AP	H/MD
N	47	46	10	33	33	46	33	10
Mean	69.13	51.75	16.90	26.27	43.08	0.75	0.65	0.25
Standard error of the mean	2.60	1.99	2.49	1.61	2.11	0.01	0.06	0.02
Deviation	17.82	13.52	7.88	9.24	12.12	0.09	0.32	0.07
Range	72.00	51.65	22.23	47.43	44.03	0.48	1.58	0.24
Minimum	30.00	24.35	6.27	12.57	20.76	0.52	0.33	0.17
Maximum	102.00	76.00	28.50	60.00	64.79	1.00	1.90	0.41

Table 10

Summary of the descriptive statistics for *Patella ferruginea* (FL) (modern, coastal (1: Nerja, 2: Cerro de los Gavilanes), and hinterland). Individual number (N), maximum width (MW), Maximum length (MD), Maximum height (H), length from the apex to the anterior margin (AA), length from the apex to the posterior margin (AP), and length from the apex to the length (AL). All measurements in mm.

<i>Patella ferruginea</i> Modern	MD	MW	H	AA	AP	MW/MD	AA/AP	H/MD
N	21	21	21	21	21	21	21	21
Mean	54.68	44.59	17.74	21.35	34.89	0.81	0.61	0.32
Standard error of the mean	3.58	3.09	1.63	1.62	2.48	0.01	0.02	0.01
Deviation	16.40	14.16	7.46	7.42	11.35	0.04	0.07	0.06
Range	57.13	48.09	24.30	23.83	39.66	0.14	0.33	0.21
Minimum	29.63	23.37	9.11	11.09	17.76	0.75	0.38	0.23
Maximum	86.76	71.46	33.41	34.92	57.42	0.89	0.71	0.44
<i>Patella ferruginea</i> Coastal-1	MD	MW	H	AA	AP	MW/MD	AA/AP	H/MD
N	15	15	12	12	12	15	12	12
Mean	32.58	26.23	9.85	11.52	20.04	0.81	0.59	0.30
Standard error of the mean	1.50	1.10	0.78	0.65	1.40	0.02	0.03	0.01
Deviation	5.80	4.27	2.69	2.27	4.86	0.07	0.10	0.05
Range	20.27	17.02	9.67	8.10	17.48	0.28	0.39	0.17
Minimum	21.77	16.52	5.94	7.71	11.70	0.75	0.44	0.21
Maximum	42.04	33.54	15.61	15.81	29.18	1.03	0.83	0.38
<i>Patella ferruginea</i> Coastal-2	MD	MW	H	AA	AP	MW/MD	AA/AP	H/MD
N	20	24	20	25	25	18	20	20
Mean	58.29	49.73	23.42	32.70	41.12	0.83	0.79	0.40
Standard error of the mean	1.78	1.59	1.03	1.31	1.39	0.01	0.02	0.01
Deviation	7.96	7.79	5.15	5.84	6.93	0.03	0.08	0.06
Range	27.50	28.50	19.00	20.00	25.50	0.11	0.27	0.27
Minimum	45.50	37.50	14.50	25.00	29.50	0.77	0.67	0.29
Maximum	73.00	66.00	33.50	45.00	55.00	0.88	0.94	0.56
<i>Patella ferruginea</i> Hinterland	MD	MW	H	AA	AP	MW/MD	AA/AP	H/MD
N	12	12	1	5	5	12	5	1
Mean	51.07	41.22	36.00	23.11	31.02	0.81	0.74	0.72
Standard error of the mean	3.45	2.62	–	2.28	2.85	0.01	0.01	–
Deviation	11.96	9.07	–	5.10	6.37	0.07204	0.02	–
Range	35.39	25.73	–	13.39	16.00	0.12	0.06	–
Minimum	34.61	28.27	36.00	14.61	20.00	0.77	0.72	0.72
Maximum	70.00	54.00	36.00	28.00	36.00	0.89	0.78	0.72

in Nerja and 0.6491 at Cerro de los Gavilanes and inland archaeological FL p-value = 0.1121, for $\alpha = 0.005$ in all cases). Summarizing, we find a selection of FL from >50 mm maximum diameter during the Chalcolithic, and a complementary size distribution between Nerja cave and

inland sites, that point to this site as a “source” for this giant limpet species (Fig. 11, Table 9).

As discussed above (see section 2.1), FL more properly qualifies as an alternating hermaphrodite (Hoagland, 1984). Such circumstance

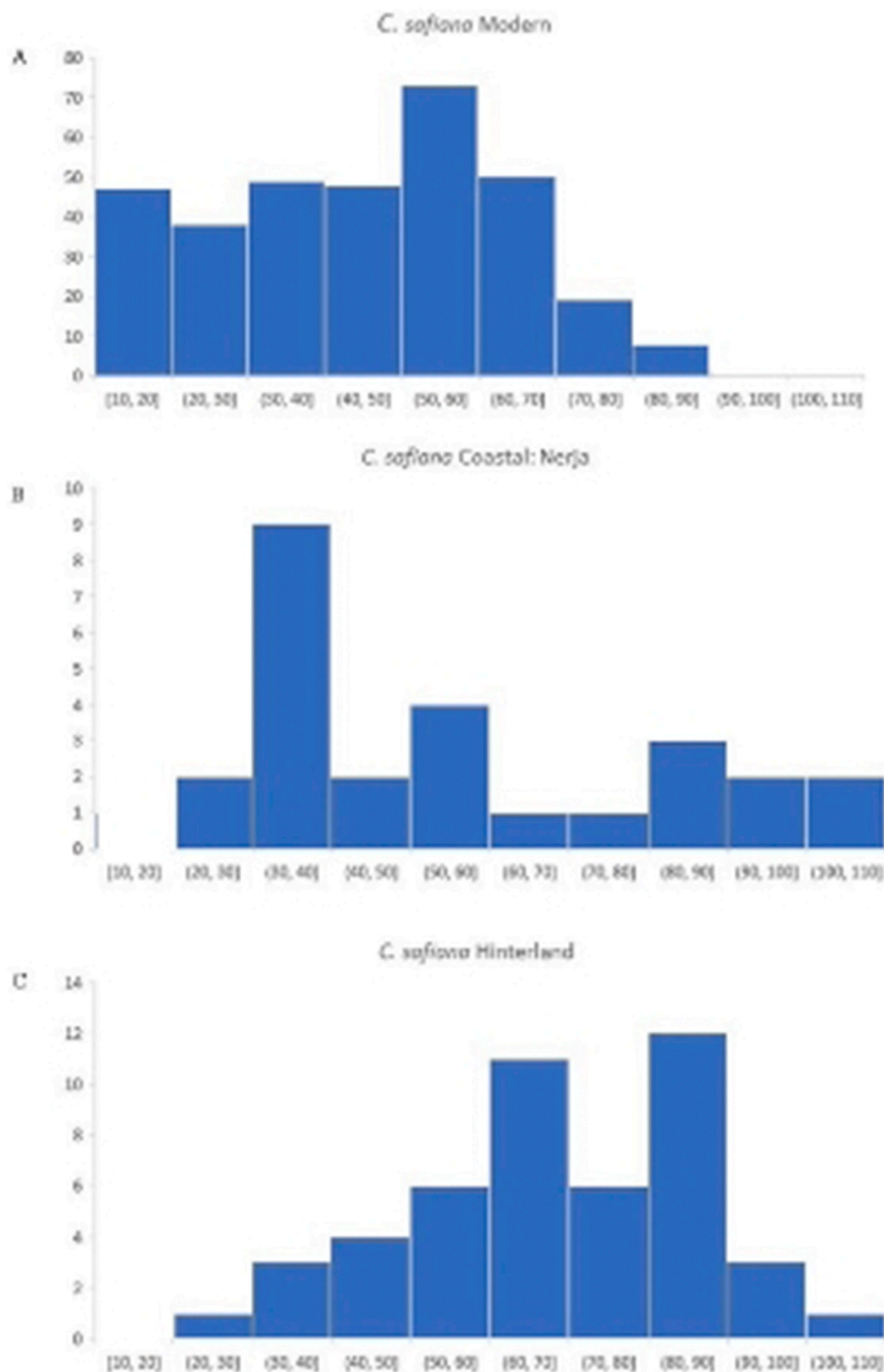


Fig. 9. *Cymbula safiana*. Distribution of the sizes (mm) of the current reference population (A) and the archaeological ones studied here. It is observed how, in the coastal samples (B), there are "missing" sizes of specimens recovered in inland sites (C).

renders questionable the traditional practice of "sexing" archaeological FL specimens by using size (Espinosa et al., 2006; Guallart and Templado, 2016). As a corollary, an overabundance of specimens above 45 mm MD can no longer be taken as evidence for a preferential harvesting of females in archaeological collections, a threat to the long-term viability of populations or explanations for stock depletion (Rivera-Ingraham et al., 2011). All these are issues that need to be taken into consideration when assessing the archaeological record of FL.

For prehistoric coastal foragers, BL would not have been as accessible as FL since it ranges from the upper fringe of the sublittoral zone, some 5 m below water, to the lower levels of the littoral zone in areas of

moderate hydro-dynamism, where FL is often found (Rivera-Ingraham et al., 2011) (Fig. 3). For the most part, juveniles (≤ 20 mm) range from the splash zone to slightly below sea level, whereas adults would be less accessible as they occupy deeper waters, over essentially sub-horizontal substrates of lower hydro-dynamism (Gofas et al., 2011; Espinosa and Rivera-Ingraham, 2017; Rivera-Ingraham, 2010). Another factor that would restrict accessibility is the fact that adult limpets are frequently covered by macroalgae/algae and grasses, rendering their visual location difficult (Rivera-Ingraham, 2010).

In terms of shape, there seems to exist a preference for more elliptical individuals, with the (intentionally modified) FL from the hinterland

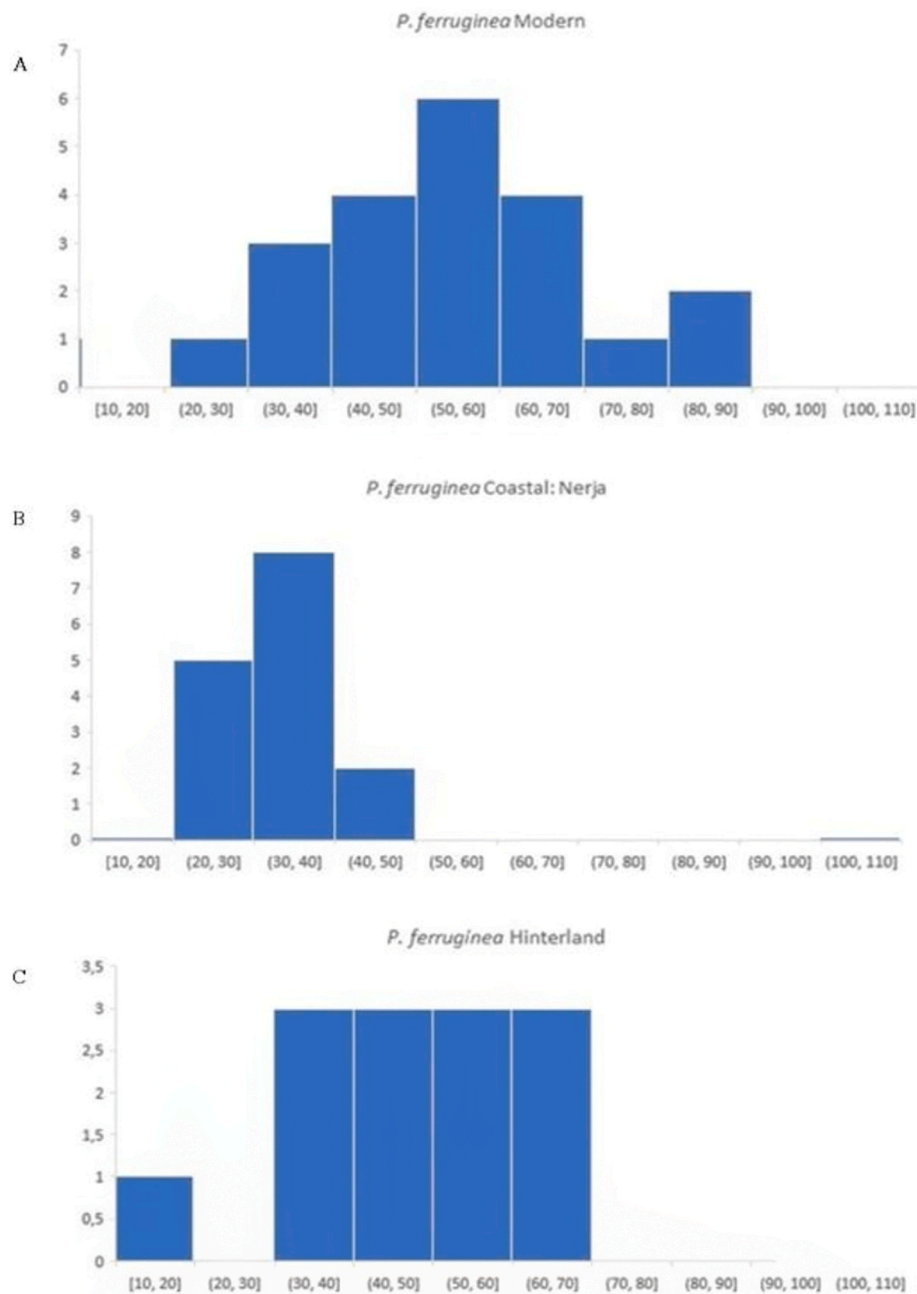


Fig. 10. *Patella ferruginea*. Distribution of the sizes (mm) of the current reference population (A) and the archaeological ones studied here. It is observed that among the coastal specimens (taking Nerja as models) (B) there is a greater range of sizes than in those from the interior (C) where the range of sizes is generally between 40 and 70 mm, coinciding with the sizes of *C. safiana* in these same deposits.

Table 11

Arithmetical mean of the biometric variables of the two giant limpet species for different chronocultural segments. Maximum width (MW), Maximum length (MD), Maximum height (H), length from the apex to the anterior margin (AA), length from the apex to the posterior margin (AP), and length from the apex to the length (AL), *Patella ferruginea* (FL), *Cymbula safiana* (BL). All measurements in mm.

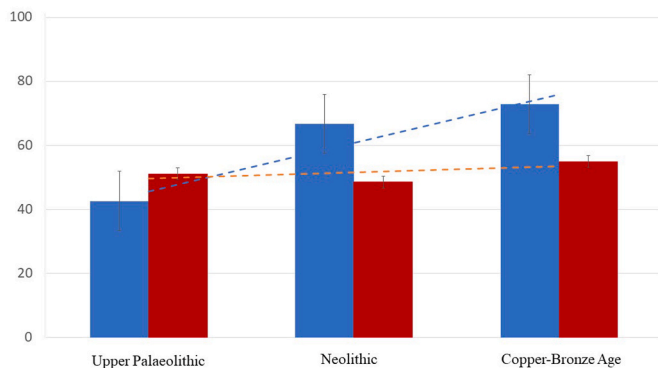
Period	MD	MW	H	AA	AP	AL	MW/MD	AA/AP	H/MD
Palaeolithic BL	42.61	33.70	12.49	13.99	27.33	30.12	0.79	0.54	0.31
Neolithic BL	66.68	50.56	16.99	21.07	36.45	42.99	0.76	0.59	0.27
Copper Age-Bronze Age BL	72.85	54.64	15.98	27.03	44.30	49.91	0.76	0.66	0.24
Upper Palaeolithic FL	51.07	41.22	36.00	23.11	31.02	41.85	0.81	0.74	0.72
Neolithic FL	48.51	40.03	–	–	31.39	42.55	0.83	0.73	–
Copper Age-Bronze Age FL	54.94	41.45	36.00	23.13	30.93	41.67	0.81	0.75	0.72

Table 12Results of One-way ANOVA for the ratio maximum width/Maximum length (MW/MD). p-value for Dunn's post hoc, significance level $\alpha = 0.005$.

Black limpet					Ferrugineous limpet				
	MW/MD	Modern	Coastal	Hinterland	Modern	lamarcki	rouxi	Coastal	Hinterland
BL	Modern		1.41E-05	0.0249	1.76E-09	7.99E-29	7.61E-29	2.71E-05	0.001869
	Coastal	1.41E-05		0.01663	0.332	0.102	0.1989	0.8747	0.6395
	Hinterland	0.0249	0.01663		0.0002345	1.39E-08	9.44E-08	0.01522	0.0397
FL	Modern	1.76E-09	0.332	0.0002345		0.6348	0.9357	0.4481	0.8445
	lamarcki	7.99E-29	0.102	1.39E-08	0.6348		0.529	0.1861	0.624
	rouxi	7.61E-29	0.1989	9.44E-08	0.9357	0.529		0.3216	0.7935
	Coastal	2.71E-05	0.8747	0.01522	0.4481	0.1861	0.3216		0.7316
	Hinterland	0.001869	0.6395	0.0397	0.8445	0.624	0.7935	0.7316	

Table 13Results of One-way ANOVA for the ratio length from the apex to the anterior margin/length from the apex to the posterior margin (AA/AP). p-value for Dunn's post hoc, significance level $\alpha = 0.005$.

AA/AP	BL Modern	BL Hinterland	FL Modern
BL Modern		2.86E-08	1.39E-13
BL Hinterland	2.86E-08		0.79
FL Modern	1.39E-13	0.79	

**Fig. 11.** Increase in the mean value of MD (maximum length) in the different chronocultural segments: 1: Upper Palaeolithic, 2: Neolithic, 3: Chalcolithic-Bronze Age (the SE of the mean is expressed with a confidence level of 95%). In blue *C. safiana*, in red *P. ferruginea*. The trend lines for the average length are shown in dotted lines. *C. safiana* (blue) ($y = 15,121x + 30,471$; $R^2 = 0,8954$) and *P. ferruginea* (red) ($y = 1,935x + 47,637$; $R^2 = 0,3573$).

approximating the shape of BL. Also, among BLs, those closer in shape to morphotype 2 appear to be preferentially selected, except in the coastal collections that are closer to morphotype 3, the former being more flattened and oval than the latter (Table 1, Fig. 4). The giant limpets from our archaeological sites are mostly considered “unmodified” and rarely reported as worked. However, visual inspection of some specimens and illustrations reveals that many, particularly those retrieved on inland sites, exhibited traces of work/manufacturing processes. This is, for example, the case when the serrated borders of the FL appear smooth. These modifications were studied through experimental work and biometrical analyses (Figs. 9 and 11).

5.2. Dynamics of the biogeography of southern Iberian giant limpets

The thermophilic FL species has been described from the early Pleistocene onwards in the western Mediterranean (Malatesta, 1960; Cuerda and Sacares, 1970; Cuerda, 1987; Lario et al., 1993; Forli et al., 2004; Andreucci et al., 2009). In all cases, FL has been interpreted as a proxy of the Senegalese warm-water faunas that penetrate the Mediterranean during interglacial periods (Cuerda and Sacares, 1970; Cuerda, 1987). However, this consideration is incorrect, as this is a species endemic to the western Mediterranean, that appeared during the

Lower Pleistocene. In southern Iberian sites this species has been described during the last interglacial (MIS 5) in Gorham's and Bajondillo (Baden-Powell, 1964; Cortés-Sánchez et al., 2019) and during the last glacial period (MIS 3 and 2) (Fischer, 1928; Fa et al., 2016; Cortés-Sánchez et al., 2019; this study) (Table 1). This resilience can relate to the fact that FL is adapted to the supralittoral zone the survival of the adults depends more on on-air temperature and humectation, and therefore than sea water temperature proper. FL genetic studies indicate a population bottleneck at the end of the Pleistocene (Espinosa and Ozawa, 2006). The survival of decimated populations during the cold conditions associated to the last glacial stage can be related to the presence of sunny shallow waters in climatic refugia (Maier, 2020). Based on new and reviewed archeozoological and paleozoological one must refrain of using FL as a warm-water faunal proxy when no other data thermophilic species are recorded (e.g., *Strombus bubonius*, *Cantharus viverratus*).

BL originated in southwest Africa and diverged from the Genus *Patella* during the Neogene (Ridgway et al., 1998; Koufopanou et al., 1999; Nakano and Ozawa, 2007). During the Middle- Late Pleistocene, BL crossed latitude 23°N (Fig. 1) and reached Morocco (Lefèvre and Raynal, 2002) (e.g., site of El Harhoura 2, ~120-74ka, Nouet et al., 2015) and southern Iberia (MIS 5, Lario et al., 1993; Zazo et al., 2002; archaeological sites (MIS 5, Bajondillo/18), ~128 ka (1 BL); Cortés-Sánchez et al., 2019) (Table 1). During the MIS-3 we find punctuated evidence of BL (Bajondillo/15 (3 BL), Abrigo 3 (6 BL)) (Table 1), becoming a recurrent item in the archaeological record of the Sea of Alborán region during the last deglaciation (e.g., Nerja cave). Data indicate that when both limpets coexisted during interglacials, BL was markedly more abundant than FL in all coastal sites (Table 5). This links with a) an easier access to BL juvenile specimens (the sizes of the archaeological sites), because they are located mainly in easy access locations as tidal ponds and cracks with moderate hydrodynamics, and b) a persistent low density of FL populations during interglacials. Present day low density has been associating to population decline associate to human activities (Guallart and Templado, 2016), but archaeological records could indicate that FL reach lower numbers when coexisting with others Patellidae during interglacials.

5.3. Limpets: nutritional, utilitarian, or symbolic uses

From the data obtained, a systematic consumption of BL and FL can be documented in the coastal deposits that is not different from the exploitation of other limpet species. The fractures that most of them feature is utilitarian, a result of detaching the animals from the rock. This explains why one could not measure many specimens. However, there is a second group that were detached by a percussion restricted to the edge of the mantle, allowing the deactivation of the animal's vacuum effect barely fracturing the shell edge. The limpets that are the most difficult to detach and are the largest specimens and it is precisely these that appear in the hinterland sites. Ethnographic parallels indicate that, even today, marine molluscs seldom proceed inland more than 5 km from the coast (i.e. Bigalke, 1973; Erlandson, 2001), a circumstance that occurs in 88.5% (46) of the 52 sites analysed in this paper. Most of the

Table 14

Taphonomic traces in giant limpets in Archaeological sites. A) Shellfishing traces: No data (0), 1 (notched/denticulate), 2 (helical fracture), 3 (eliminated by manufacture), B) Dorsal face polish: No data (0), 1 (unworked), 2 (attenuated ribs), 3 (eliminated ribs), 4 (perforation); C) Contour polish: No data (0), 1 (unworked), 2 (crenulate removed), 3 (Aimin/appendage); D) Pigments: (–) no data, 0 (no pigment), 1 (ochre), 2 (cinnabar).

Archaeological site	A	B	C	D
Gato	0	4	–	–
Loma de la Atalaya 2.Grave 4	¿2?	2	2	–
Terrera Ventura 1	0	0	1, 1	–
Terrera Ventura 2	0	0	1	–
El Barranquete 1 Settlement	0	3	2,3	–
El Barranquete 2 Tholos 1	0	2	2	–
Los Millares 1. Tholos 6	0	3	2	–
Los Millares 2. Tholos 6	0	1	1	–
Los Millares 3. Millares 1. Tholos 6	0	3	2	–
Los Millares 4. Tholos 6	2	3	2	1?
Los Millares 5. Tholos 8	0	2	2	–
Los Millares 6. Tholos 9	0	0	0	–
Los Millares 7 Tholos 9	0	0	0	–
Los Millares 8. Tholos 9	0	0	0	–
Los Millares 9. Tholos 9	0	0	0	–
Los Millares 10. Tholos 9	0	0	0	–
Los Millares 11. Tholos 10	0	3	2	–
Los Millares 12. Tholos 40	0	3	2	–
Los Millares 12. Tholos 40	0	2	2	–
La Presa	1	0	2	–
La Pileta	0	3	2	–
Marroquíes Bajos 1	0	2	2	–
Marroquíes Bajos 2	0	2	2	–
Panoría	0	2	2,3	–
Hoyas del Conquín	0	¿2?	¿2?	–
Cuesta de la Sabina	0	0	0	–
Carmona	0	3	2,3	–
Valencina 1	–	3	2,3	–
Valencina 2	1,3	2	2,3	1?
Valencina 3	0	0	0	–
Valencina 4	1	0	0	–
Valencina. C/ Dinamarca 3	3	3	2,3	–
Valencina. C/ Dinamarca 5	0	3	2,3	–
Vaquero	0	2	3	–
Bencarrón 1	0	2	2	–
Bencarrón 2	3	2	2	–
Cabezo Juré	0	3	2,3	–
El Negrón 1	0	0	0	–
El Negrón 2	3	3	2,3	–
Perdigões 1	3	3	2,3	–
Perdigões 2	3	3	2	–
Pedrao	0	3	3	–
Argar	1	1	1	0
Gavilanes	1	1	1	0

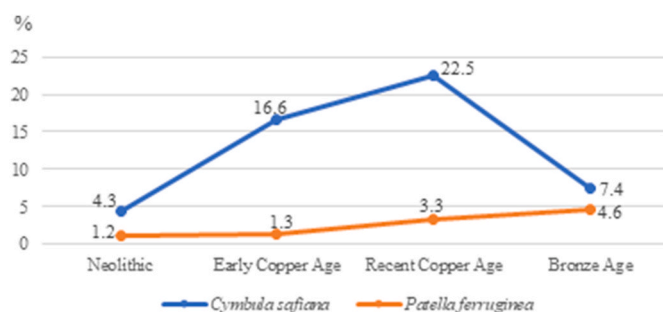


Fig. 12. Nerja excavation of 1965–1968. The figure shows the percentage of giant limpets >55 mm in diameter (y-axis) by period with respect to the total limpets for each period (x-axis).

limpets recovered on inland sites (>5 km) are associated with funerary contexts (53 of 59, Table 8), thus their symbolic connotations seem compelling.

5.4. Giant limpets during the Chalcolithic period (~5000–4100 cal BP)

5.4.1. Hinterland and coastal sites, implications for trade networks

Giant limpets appear in several of the main hinterland sites during the Chalcolithic (e.g., Los Millares, Marroquíes Bajos, Valencina Table 3, Fig. 5), allowing us to conduct a more in-depth analysis than in other periods. Limpet size can often exceed 60 mm (Table 1, Figs. 9–10), despite anthropic abrasion which could reduce the original size by 2–4 mm (Fig. 2A2, i.e., Carmona site, Fig. 4.D4). On hinterland sites giant limpets are mostly complete, the fractures often associated with post-depositional processes. In addition to their big size (>55 mm), they feature careful abrasion and are deposited isolated or with a few other limpets in funerary contexts (86%). Following the established criteria one can safely assume that these shells were used for symbolic purposes.

In terms of frequencies, BL is the most frequent species (~88% of all individuals) likely due to aesthetic reasons. Chalcolithic societies appear to have selected the biggest limpets, with flattened and eccentric apices that reach a perfect elliptical base once the shell border was polished. BL samples show an apex more displaced towards the anterior margin (≥25%), and this generates an oblique cone with a very flattened profile (Fig. 2A) and smooth surface (Fig. 10). This “ideal” elliptical base is hard to obtain from an FL whose more irregular shape demands more abrasion and thus a smaller final product. When FL was used it appears that the selected specimens belong to the *lamarckii* morphotype, most similar to BL because of its flattened form (Tables 4 and 14, Fig. 6.13). Despite intensive abrasion, FL samples preserved enough features to set them apart from BL (Fig. 2).

Giant limpet present at the coastal site of Nerja cave is contemporaneous to hinterland sites but with a different use. At this site, giant limpets first appear in the Late Neolithic (end of 4th millennium BC; 3.6%) and reach their maximum frequencies during the Copper Age (first half of the 3rd millennium BC [39.3%] and second half of the 3rd millennium BC [57.1%]), vanishing in the Bronze Age (Fig. 12). Nevertheless, among the 26 individuals recovered at Nerja cave between during the described period (Pellicer and Acosta, 1997: 155), none of the giant limpets were associated to burials. In contrast, BL between 60 and 110 mm are mostly found near the western Malaga coast, inland and in some of the main Chalcolithic megalithic funerary contexts in southern Iberia (Tables 2 and 4, Fig. 12). Surprisingly, giant limpets at Nerja exhibit the same abrasion treatments of hinterland specimens pointing to that site as the source of manufactures of utilitarian use (e.g., containers). The comparative low number of giant limpets in this presumed “factory site” resemble that of sites where raw materials are obtained but whose elaborated elements are exported (e.g., Pétrequin et al., 2012). This evidence hints that coastal site responded to this generalized use of limpets as symbolic items, although in a different way to that documented on hinterland sites.

This different use among hinterland and coastal sites implies that giant limpets could be part of 3rd millennium BCE commercial networks. Indeed, limpets found inland are associated with other products with marked symbolic or prestige connotations (e.g., amber, ivory, ostrich egg, rare minerals or large flint blades) (Alfonso et al., 2011; Costa et al., 2011; Morgado et al., 2011; Domínguez-Bella, 2012; Odriozola et al., 2016; Villalobos and Odriozola, 2017), sharing oddity or abnormal size with studied giant limpets. Our limpet records combined with those of exotic materials allows us to make an approach to circulation networks (Fig. 5). Assuming the Sea of Alborán coastline was the nearest and most probable source of giant limpet shells these were transported at least 100 km inland (i.e., Marroquíes Bajos or Gorafe) the limpet from Pedrao perhaps exceeded 600 km either through continental or maritime transport. At this point one cannot discard the possibility that limpets were exported from the North African coast and were associated with populations crossing through the Gibraltar Strait during ~6.5–6 cal ka (Olalde et al., 2019) and the 6th–5th millennium BC (González et al., 2019). Several authors have suggested a Canary Island or Moroccan connection for the giant limpets found in the Portuguese

coast. A specimen from Pedrão (reported as "*P. safiana*"), and another one from Perdigões ("*P. candei*") were associated with North-African ivory trade (Cardoso and André, 2017: 202). One can discard a Canarian origin since *C. safiana* is presently absent from these islands and was devoid of humans during the 3rd millennium BC.

5.4.1.1. A new hypothesis: giant limpets as tidal/lunar phase symbols during the Chalcolithic? Based on detailed ecological knowledge of FL/BL and the cultural development of Chalcolithic societies we want to put forward a hypothesis to test further. As said, large FLs can be collected on the mesolittoral zone, whereas larger BLs (>50 mm) are found on the infralittoral. Size distribution along the northern coast of the Sea of Alborán shows a trend of diminishing average size as one approaches the Strait of Gibraltar and larger sizes in connection with the thermicity of the Cabo de Gata waters (Arroyo et al., 2011: Fig. 5.8). Interestingly, FL has been documented only in hinterland sites of south-eastern Spain (Los Millares, El Barranquete or Hoyas del Conquín) (Fig. 5). This phenomenon could reflect the scarcity of BL in the South-eastern Iberian coast, the easternmost boundary or the preference for local varieties (Cortés-Sánchez et al., 2020) or simply that FL features were not suitable for Atlantic circulation network demands.

The mean size of BL increases with depth with respect to tide level. Accordingly, the most easily collected and represented specimens in coastal sites are smaller because they are more accessible (see Fig. 3). Thus, the presence of large BL in coastal and inland archaeological sites can be explained through three possible alternatives.

- Collected on the beach thanatocoenoses. Today, a few large specimens may be occasionally collected. However, most of them are damaged after being washed ashore during storms. A deep polishing of the shells would indicate shell repair with this origin. Thus, the Carmona specimen shows such an intense abrasion of the dorsal face that the inner lamellar layer of the shell surface has been removed (Fig. 4C4). However, this treatment is exceptional in the analysed collection and may also respond to aesthetic criteria, not necessarily linked to the repair of a damaged shells. On the other hand, it is possible to identify limpets from the thanatocoenoses of the beaches through taphonomic signatures such as bioerosion or biogenetic construction on the inner face. However, no such signs have been found in the collections we analysed directly, nor have such marks ever been described in the publications we consulted or the graphic material we reviewed.
- Capture when diving. Limpets are often colonised by algae, making them difficult to see when underwater. If this ever happened, the difficulties involved in this way of acquisition could possibly endow such shells with a unique "value".
- Capture through conventional shellfishing. The absence of biological traces and the anthropic evidence point to this origin. Thus, the large giant limpets analysed at Nerja cave show unequivocal taphonomic traces of shellfishing. Some specimens could have been extracted expeditiously with strong percussions that would have fractured the shell. However, they were instead extracted with small blows, which deactivated the suction effect with which the animal fixes to the rock allowing the shell to be preserved almost in its entirety. The same traces appear in archaeological specimens from the hinterland (e.g., Fig. 6). In other cases, the notches or breaks are deeper and seem to be the result of blows applied to the dorsal face of the shell, but in more interior areas (percussion on the apex area is very rare), resulting in longitudinal helical fractures on the edge of the limpet or partially following the growth lines of the shell. Careful percussion on the mantle edge is difficult to execute and to control underwater, so this suggests that it was carried out in a subaerial environment and with the use of possibly stone percussion tools.

At this point, it should be remembered that large BLs normally live in

submerged sites, except during special periods of the year. In the coast of Malaga, the main window of opportunity when specimens are exposed to subaerial conditions are the low tides of perigee (every 27 days, 13 h and 18 min) and the equinoctial tides (19th–21st March and 21st–24th September), when the Earth-Moon-Sun alignment causes the maximum tidal amplitude. The tidal range in the Alborán Sea in general, and on the coast of Malaga in particular, is small (0.5–1.5 m) (Ellenberg, 1981), when compared to the Atlantic coasts of Iberia, but enough because, during tidal stopovers, these decimetric descents bring to the surface the gently sloping rock flats that adult BL fashion. Being territorial, they stay put until the water submerges them. If we add the low-energy regime of the Malaga coast, with a distribution of predominantly small waves (Malvárez et al., 1998), the low turbidity of the water in rocky areas and the shallow submerged areas (<50 cm), we have the ideal conditions for accessing very large BLs which, although camouflaged by algae, are then easy to locate and detach from the rock with the help of stone hammers.

From a functional point of view, during the 3rd millennium BC, the largest collection of giant limpets of our samples (70.6%) took place. Some large sized specimens later moving to inland locations are finally placed in funerary contexts (~85%), among which the tholoi stand out (~39%), and to sites of "political-economic-symbolic" attraction (i. e., Los Millares, Valencina, Marroquíes Bajos, Perdigões, etc.), possibly associated with burials and perhaps used as pigment containers (Almagro and Arribas, 1963; Liesau et al., 2014; Lozano-Francisco and Rodríguez Ariza, 2014; Evangelista, 2014).

The symbolic value of giant limpets, along with other marine molluscs (i.e., *Pecten* and *Glycymeris*), may perhaps be related to an apotropaic (magical or supernatural object which staves off evil) use or to other complex social codifications. Thus, it is worth recalling the importance that solar and lunar cycles had in the cosmogonies of recent prehistoric communities (i.e., Hoskin, 2001, Belmonte and Hoskin, 2002). In this sense, for populations linked to marine resources, accumulated observations of the coast must have been essential, so this amassed knowledge of the correlation between tidal and lunar cycles enabled them, among other things, to collect exceptionally large black limpets on specific days of the year, perhaps endowing them with an evocative charge of this regular and predictable phenomenon. An indication of this knowledge could be found in the close link between lunar phases and fish activity, an appreciation that has been used for centuries by coastal fishing communities and, in this sense, the particularly large sizes of rockfish at Nerja during the 3rd millennium BC might also reflect access to resources not accessible most of the year (Roselló et al., 1995). Some of the main cultural poles of the Copper Age in southern Iberia are articulated around estuaries (Tagus, Guadalquivir or Almanzora). The importance of coastal communications justifies the presence of the main archaeological areas (Vila Nova de São Pedro, Valencina or Los Millares) and could be identified through the abundant exotic products present at these sites (ostrich eggs, ivory, etc.). Navigation in these areas traditionally required a deep knowledge of the tides to access or leave the landing areas, especially in the Atlantic façade. On the other hand, the existence of navigation in the Mediterranean is evident from the Neolithic in both the eastern and western Mediterranean (e.g., obsidian), so that, presumably, during the Copper Age, in the aforementioned sites of southern Iberia, knowledge of tidal cycles must have played a well-established role in the articulation of mobility.

At this point, one can only speculate on the way in which the large BL were collected, (i.e., only exposed when the sea retreats noticeably). This fact is cyclical, since it occurs during special low tides, such as the perigee tides (every ~28 days), the equinoctial tides (the strongest of the year and lasting for 3 days) or, in the longer term, during the maximum equinoctial tide (every 18.5 years, when the sun passes through its perihelion and the moon through its perigee). These predictable processes may have had a strong regulating and evocative character of seasonal and vital cycles (annual distribution of marine resources, agricultural cycles, life-death, etc.), including the occasional/tidal collection of BL.

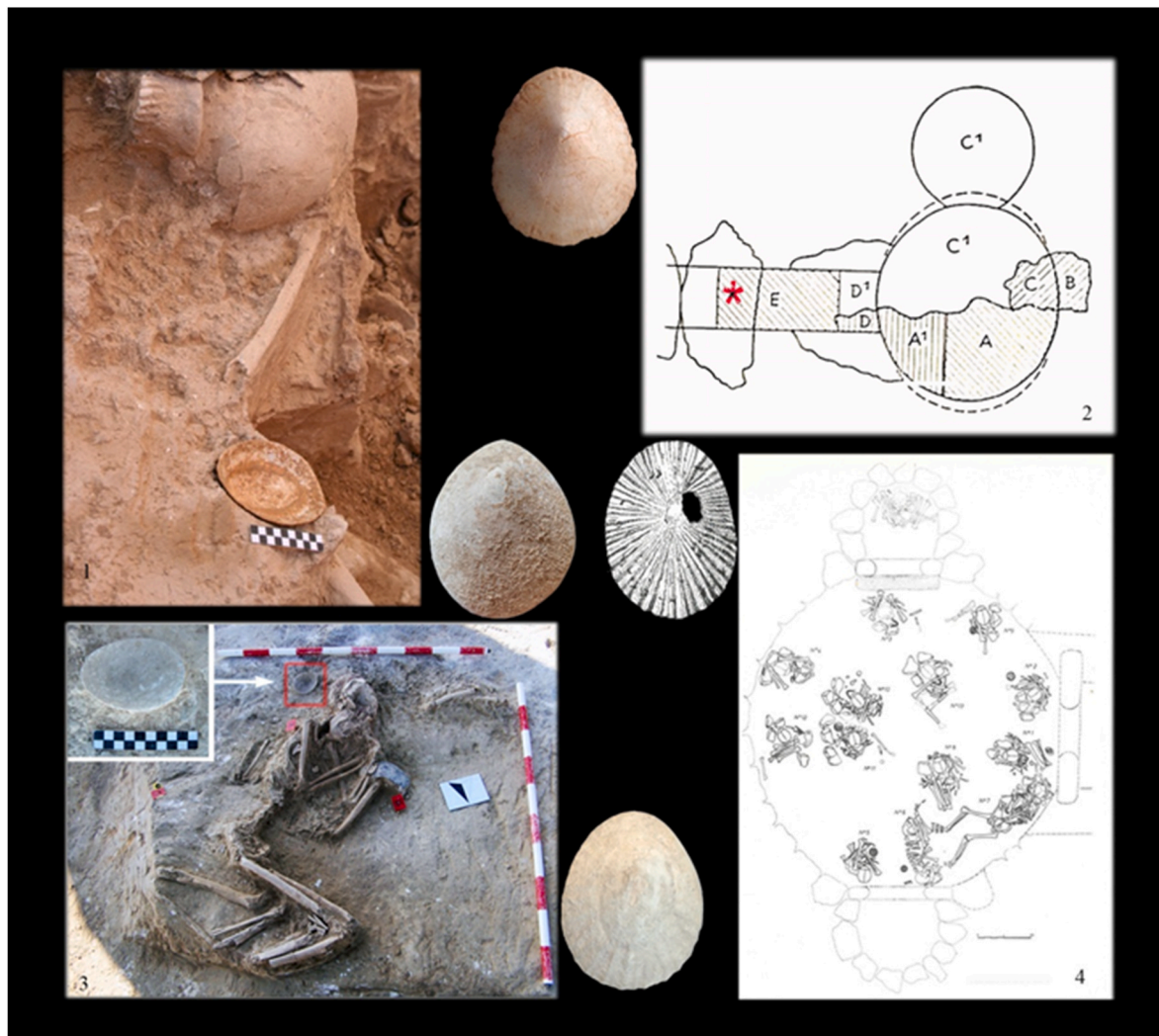


Fig. 13. Context of location of the giant limpets. 1. Valencina/Dinamarca, 2. Tholos Vaquero, 3. Valencina/Montelirio, 4. El Barranquete/Tholos 4.

Along these same lines, the funerary contexts artificially built during the 3rd millennium BC in southern Iberia are defined by clear patterns of astronomical orientation SE and have been linked to the rising or ascending sun, during the winter solstices (Hoskin, 2001; García Sanjuán et al., 2023) or else linked to lunar cycles (Belmonte and Hoskin, 2002). The possible collection of giant limpets during low tides would fit in well with populations that have astronomical observations as one of their cosmogonic expressions.

From the standpoint of micro-contextualisation, we only have the example of structure 10073 at Valencina de la Concepción, where a BL was recovered resting on its dorsal face and deposited near the back of a skull (Liesau et al., 2014) and with general references to the deposition of limpets next to skeletons in funerary contexts (Valencina, Los Millares, Gorafe or Barranquete) (Siret and Siret, 1887; García and Spahn, 1959; Alfonso et al., 2011; García Sanjuán et al., 2018) (Fig. 13).

As for functionality, structure 10081 of sector PP4 Montelirio at Valencina de la Concepción, features a BL preserved with red dye stains on its ventral surface (Liesau et al., 2014), as in Los Millares-Tomb 63 (Leisner and Leisner, 1943: 52). None of these pigments have been analysed thus far, so their use as dye containers remains incomplete.

Recent studies on the aggregation pattern of some of the main Chalcolithic sites in southern Iberia (Valencina or Los Millares) indicate that their earliest stages correspond to funerary uses that precede, often by several centuries, other types of structures (García Sanjuán et al., 2018; Aranda et al., 2020). In this context, it is worth asking whether

individuals/groups from the coastal areas of the Sea of Alborán could not have participated in the process of creating and maintaining these sites, and whether the marine molluscs could have served as an ethnic identity item and an ancestral symbolic link with their source areas. This aspect of aggregation on inland areas has been incipiently addressed from certain archaeometric aspects of the ceramics (Dias et al., 2008). In this sense, although it is true that the Copper Age developed, for example, in Nerja cave with particular features (e.g., no metallic elements have been documented), it is no less true that there are numerous elements of material culture that show its links with the most important poles of the period, both the eastern (Southeast) and western, on the Iberian Atlantic façade (Pellicer and Acosta, 1997). Marine elements abound in dolmens and in different structures. Within such context, giant limpets could represent the cultural contribution of the Alborán coastal sites to the regional macro-networks of exchanges existing in the south of the Iberian Peninsula during the 4th-3rd millennium BC. In any case, this aspect needs to be tested and quantitatively assessed by geochemical and isotopic analysis that could offer information about the season when they are recollected (e.g., Graniero et al., 2017a,b; Milano et al., 2022).

5.4.2. Giant limpets during the Early Bronze age (~4200-3500 cal BP)

The available data on giant limpets for this period are limited and come from Argaric settlements in the SE (Table 3, Fig. 5).

For the Bronze Age as a whole, the most frequent is FL (Table 5). This

data would link with the development of this period mainly in the Iberian SE, an area that represents the limit for the distribution of BL which is more frequent on its coasts.

The absence of taxonomic, biometric and taphonomic data or details on their location in the sites prevents us from going into more detail on whether if they are still used in funerary contexts or are symbolic in nature. The proposed genetic renewal that might have occurred during the Bronze Age in the Iberian Peninsula (Olalde et al., 2019) and the establishment of highly hierarchical societies seem to have definitively changed the role attributed to giant limpets in the communities of southern Iberia between the late 4th and early 3rd millennium BC, from an object of high symbolic value to a source of food or occasionally tools. However, we should be aware of the fact that the quality of the contexts studied was not the best for more in-depth considerations.

6. Conclusions

The 1203 specimens studied constitute a relevant assemblage on which palaeoecological and archaeological inferences can be made. From a chronocultural perspective, giant limpets were collected for consumption on southern Iberian margin by both Neanderthals (from 128 ka) and modern humans. At a diachronic level, an increase in the number of specimens collected can be seen during the Neolithic and especially during the 3rd millennium BC (Copper Age).

Our data do not indicate a straightforward use of BL and FL as climatic proxies in the westernmost Mediterranean Sea, despite their thermophilic nature. From a demographic point of view, archaeological and paleontological records indicate that FL populations, have always been quantitatively smaller than any of the remaining limpet species in the northern Sea of Alborán.

The overabundance of large specimens (over 45 mm MCD) in archaeological collections is not evidence of a preferential harvesting of females, always a threat to the long-term viability of populations or an explanation for population depletion. These are all issues that need to be considered when assessing the archaeological record of FL.

On inland archaeological sites, BL and some FL appear during the Neolithic and show clear evidence of shell modification. These limpets appear to be integrated as yet another element in the network of goods at a regional scale in which exotic or prestige materials and products are moved, which is established in the south of the Iberian Peninsula from the end of the 7th millennium BP, reaching its apogee during the 3rd millennium BC and seems to contract in the Bronze Age. Based on the common presence of limpets but the different size distribution and symbolic use, the site of Nerja appears to be a “factory site” for giant limpets in southern Iberia. Based on their ecological distribution and the particular use by Chalcolithic societies we propose a new hypothesis about the symbolism likely associated with giant limpets. In essence we propose that they could represent a link with the tidal/moon cycles that can relate to shellfishing. This hypothesis requires additional studies to be quantitatively assessed.

Footnotes

(1) Two species of limpets in Iberian waters reach up to 70 mm. These are *Patella caerulea* Linnaeus, 1758 (≤ 72 mm), and *P. ulysiponensis* Gmelin, 1791 (≤ 70 mm). *Patella rustica* Linnaeus, 1758, and *P. vulgata* Linnaeus, 1758 only reach to ≤ 50 mm whereas for *P. depressa* Pennant, 1777 the maximum size is set at ≤ 30 mm (Gofas et al., 2011). Since mollusks grow through life, size alone is not sufficient to set apart juveniles of the two “giant” species from the other limpets thus morphological features need to be taken into consideration.

Author contributions

Miguel Cortés-Sánchez: Archaeology, Middle Palaeolithic, Upper Palaeolithic, Symbolism, M. Carmen Lozano-Francisco: Zooarchaeology,

Biology, Ecology, Palaeoecology, Statistical analysis., María D. Simón-Vallejo: Archaeology, Middle Palaeolithic, Upper Palaeolithic, Symbolism., Francisco Jiménez-Espejo: Paleoclimatology, Climate Variability, Palaeoecology, Stable Isotope Analysis, Carlos Odriozola: Statistical analysis, Historiography, Sara Macías Tejada: Historiography and data analysis. Arturo Morales Muñoz: Zooarchaeology, Biology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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