Research Article

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Why Mesolithic Populations Started Eating Crabs on the European Atlantic Façade Only Over the Past 15 Years?

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Abstract: Mesolithic populations from coastal areas are known as hunter-gatherer-fishers. This way of life is visible in the landscape owing to the presence of large accumulations of shells named shell middens. These anthropogenic refuse heaps are composed of high proportions of marine resources, yet studies dedicated to marine components are relatively recent. Efforts have been made to record marine molluscs, but other minorities are still invisible as a result of the small sizes of archaeological remains. Crustaceans are one of these minorities and this article will focus on one of them: crabs. Why are these decapods persistently ignored by most of archaeologists? Is this due to the scant presence of their remains in Mesolithic shell middens? An overview of published data on crabs is presented here for the Mesolithic period on the European Atlantic façade. The proportions of shell middens comprising these crustaceans is evaluated, as well as quantities and identified species. We endeavour to identify the potential impact of excavation methods and sampling on our knowledge of this marine resource. We present the methods developed to extract data from small archaeological crab remains and show how, from a fragment of a crab finger extremity, we can identify the species and estimate the original size of crabs. This methodological challenge has a major impact on our knowledge of past maritime populations.

Keywords: Mesolithic, crabs, methodology, taphonomy, palaeoenvironment

1 Introduction

Along the Atlantic coast of Europe, shell middens are emblematic anthropogenic Mesolithic constructions (Aldeias & Bicho, 2017; Astrup et al., 2021; Gutiérrez-Zugasti et al., 2011; Roksandic, Mendonça de Souza, Eggers, Burchell, & Klokler, 2014) and elsewhere. Their relative abundance in the Mesolithic, and especially in the Late Mesolithic period, is still a formidable “playground” for archaeologists. Numerous studies have shown that this shell boom, especially at the end of the Mesolithic, is largely linked to the stabilisation of the rise in sea level that began thousands of years earlier (Astrup, 2018; Dupont, 2006, pp. 8–9; Gutiérrez-Zugasti et al., 2011; Milner, Craig, & Bailey, 2007). These archaeological sites left their mark on archaeologists on account of the sheer quantities and imposing mounds of waste that they represent. However, in

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some countries, part of their attraction lies in the angle of approach to the cultural sphere (for example, see Dupont & Marchand, 2021). Indeed, many of these shell middens are actually necropolises and therefore places where populations may have returned on a recurring basis. Thus, these sites are places where people lived, but also, where they buried their dead. For a long time, the presence of burials in these sites relegated the informative potential of the shell midden components to the background. In this way, the shell layer was considered as a kind of sediment in which burials were built.

Whether or not these accumulations are associated with burials, lithics and large mammal bones attracted archaeologists' attention much earlier than other components of these waste mounds. There are several reasons for this. On the one hand, the technical aspects of lithics can be used to attribute approximate dates to sites, and on the other hand, they are associated with a valued activity for these hunter–gatherer populations: hunting. It is undoubtedly on account of this latter activity that large mammal remains are so highly valued by research. The fishing and consumption of shellfish may even have conveyed a negative image (Dupont, 2021). As for large mammal bones, their size and immediate legibility on the ground also undoubtedly contributed to their collection during the excavation. Milner (2009) summarises this idea in a single sentence in the article dedicated to the study of the crabs from Sand: "Consequently, Mesolithic dialogue often retains an androcentric bias with a proliferation of 'boys and arrows' narratives directed on the importance of the deer hunt (Finlay, 2000)."

These various elements suffice to explain why Mesolithic populations have only eaten crabs for the past 15 years. Simply because archaeologists were not interested in them before that. They did not look for them and when they did find them, they did not describe them. There are, however, some published data on ancient excavations. The first mention we found is in 1874 when Grieve described "a portion of the claw species of crab" at Inveravon (Scotland). In 1898, Anderson wrote that "crabs were represented only by the claws of their great toes" at the site of Druimvargie Rock shelter (Scotland). In 1900, Madsen and colleagues proposed the first determination of a single crab finger extremity with *Carcinus maenas* at Havnø (Madsen et al., 1900, p. 110). In 1914, Bishop proposed a second one with *Necora puber* and *Cancer pagurus* associated with Mesolithic levels at Cnoc Sligeach (Scotland). It was not until 1958 that Roche described the abundance of *Carcinus maenas* and the rarity of *Uca tangeri* at Moita do Sebastião (Portugal).

These hunter–gatherer populations were subsequently reconsidered in the 1980s and the impact of their food resources was finally taken into account as a potential aspect of societal organisation (Erlandson, 1988; Price & Brown, 1985; Straus, 1981; Testart, 1982; Yesner, 1980; Zvelebil, 1986). This slow evolution of shell midden perceptions in prehistory has recently been described more specifically for the French Atlantic coast (Dupont & Marchand, 2021). It has led to the development of studies combining archaeological and palaeoenvironmental disciplines on the scale of the European Atlantic coast. They were initiated in Scotland (Mellars, 1978, 1987), Denmark (Andersen & Johansen, 1986), and then developed at the scale of Atlantic Europe (Milner et al., 2007). This awareness of the informative power of shell midden components has led to the multiplication of studies and even re-studies, such as for example in Ireland (O'Sullivan & Breen, 2011; Woodman, Anderson, & Finlay, 1999), Portugal, (Arnaud, 1989; Bicho, Detry, Price, & Cunha, 2015; Soares & Tavares da Silva, 2004; Valente & Carvalho, 2009), Denmark (Andersen, 2013; Astrup et al., 2021), Spain (González Morales, 1982; Gutiérrez-Zugasti et al., 2013, 2016), and France (Dupont et al., 2009, 2010; Gruet, 2002; Tresset, 2000, 2005).

Marine molluscs thus eventually made their mark on prehistory. They now contribute to various archaeological issues applied to the Mesolithic period, such as the territory, mobility, rituals, the human diet, and the diversity of activities related to the ocean (Dupont & Gutiérrez-Zugasti, in press). The crab did not undergo the same fate (Milner, 2009). The slow development of crab studies in archaeological contexts is partly related to the misappreciation, on one hand, of the possibility of determining crabs from their claws, and on the other hand, of their archaeological potentialities.

Using the database presented by Dupont (2016) and updated, more than 330 Mesolithic shell middens are currently known along the European Atlantic façade. Some of them seem to be temporary camps with a low volume of refuse; others are more voluminous and may correspond to more prolonged or repeated occupations. The aim of our article is to assess the input of crabs in these shell middens, both quantitatively and in terms of their scientific contribution. In this article, we only take into account the shell-middens, because, to our knowledge, crabs have not been found in prehistoric sites outside of shell deposits. First, we propose an overview of known data on crabs in all the Mesolithic shell middens on the European Atlantic façade. Second, we summarise potential developments for archaeological applications.

2 State of the Art: A Quantitative Assessment

2.1 Where Are the Crabs?

The assessment of the presence of crabs on Mesolithic shell middens on the scale of Atlantic Europe requires a database. The one used here was presented by Dupont (2016) and is based on published data. It lists the archaeological components of all the Mesolithic and Neolithic sites along the European Atlantic arc (extending from Norway to the south of Portugal) where molluscs were consumed. For crabs, in this database, for each archaeological site and represented period we list: the determined species, their quantities in number of identifiable specimens (NISP), and minimum number of individuals (MNI) and their weight in grams. When crabs are present but not identified or quantified, we indicate their presence with a tick. When quantification is given without species determination, we use the Decapoda category. Information about the conservation status of crabs, consumption patterns, or palaeo-biogeographic data is added in the comments box. References are also quoted for each data entry.

As a result, we can first synthesis our knowledge on Mesolithic crabs (Figure 1). Our census of Mesolithic shell accumulations indicates a total of 338 levels. Among them, crabs are described in 60 levels for 55 archaeological sites (Figure 2, Tables 1–4). Quantitative values are published for 29 levels and if we combine determination and quantification, only 15 Mesolithic sites present published data. If we only take species

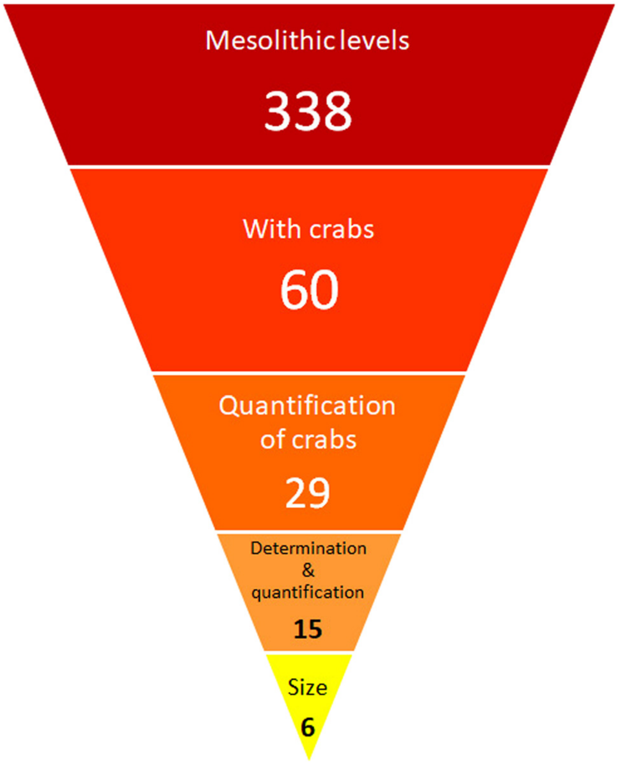

Figure 1: Published data describing crab remains from Mesolithic shell middens along the European Atlantic façade (CAD C. Dupont).

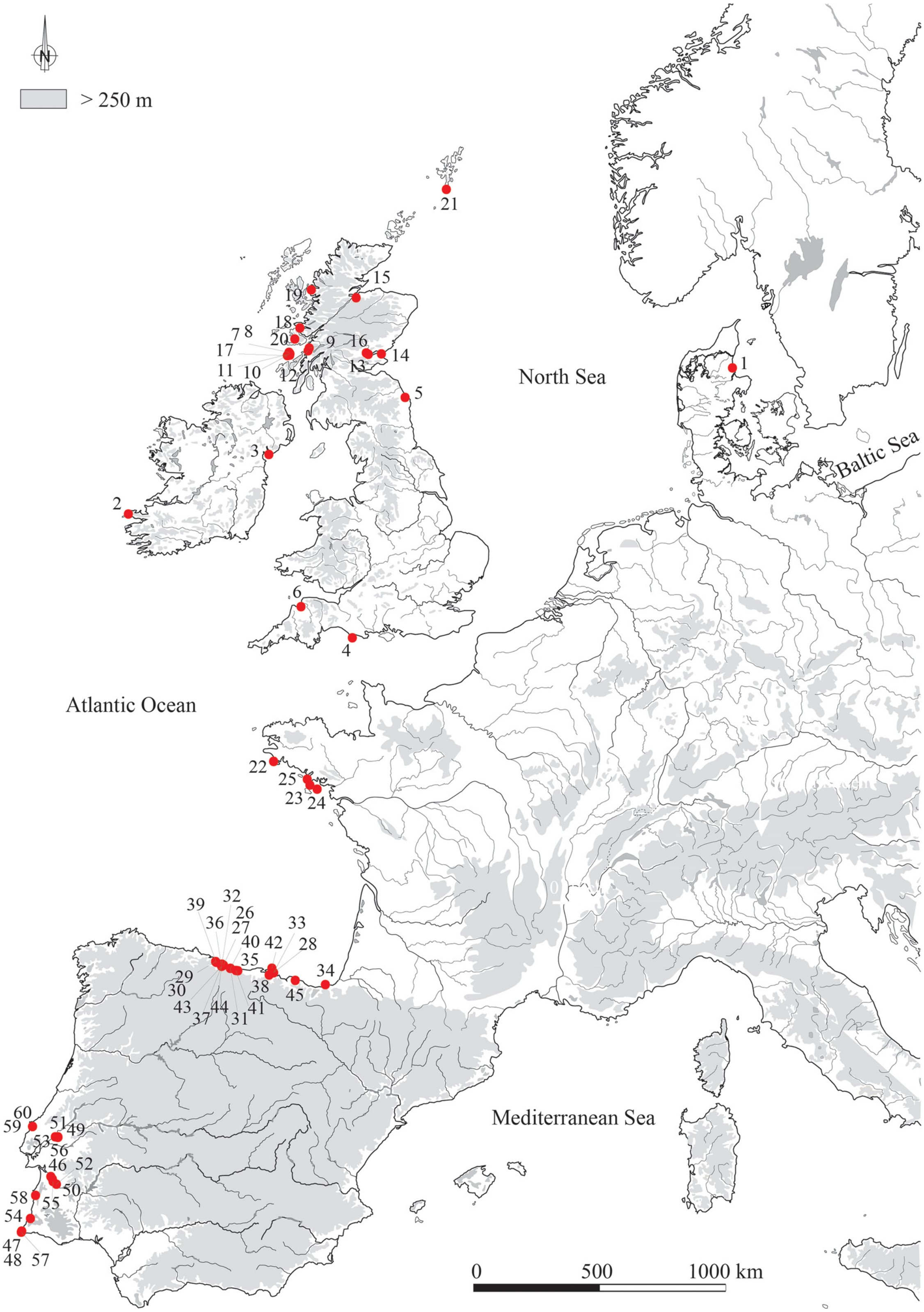

Figure 2: Mesolithic shell middens with crabs (number of sites in Tables 1–4, CAD C. Dupont and L. Quesnel).

Table 1: Mesolithic shell middens located on the map in Denmark, Ireland, England, and Scotland with crab species and quantification

Number on the map	Site	Country	Species	NISP	MNI	Weight (g)	References
1	Havnø	Denmark	*Carcinus maenas*	1	1	—	Madsen et al. (1900)
2	Ferriter's Cove	Ireland	Decapoda (undetermined)	+			Woodman et al. (1999)
3	Rockmarshall		Decapoda (undetermined)	+			Woodman (1978)
4	Culverwell	England	*Cancer pagurus*	+			Mannino, Spiro, and Thomas (2003)
5	Howick		Decapoda (undetermined)	1			Bailey and Milner (2007)
6	Westward Ho!		Decapoda (undetermined)	64		>0.11	Bell (1987)
7	Caisteal nan Gillean I	Scotland	Decapoda (undetermined)	+			Mellars (1978)
8	Caisteal nan Gillean II		Decapoda (undetermined)	+			Mellars (1978)
9	Carding Mill Bay		*Cancer pagurus*	+			Connock, Finlayson, and Mills (1993)
			Carcinus maenas	+			
10	Cnoc Coig		Decapoda (undetermined)	+			Mellars (1978)
11	Cnoc Sligeach		*Cancer pagurus*	+			Bishop (1914); Mellars (1978)
			Necora puber	+			
12	Druimvargie Rock shelter		Decapoda (undetermined)	+			Anderson (1898)
13	Inveravon		Decapoda (undetermined)	+			Grieve (1874)
14	Morton		*Cancer pagurus*	+			Coles (1971)
15	Muirtown		Decapoda (undetermined)	+			Myers and Gourlay (1991)
16	Mumrills		*Cancer pagurus*	+			Stevenson (1946)
17	Port Lobh		*Cancer pagurus*	+			Finlay et al. (2019)
18	Risga		Decapoda (undetermined)	+			Pollard, Atkinson, and Banks (1996)
19	Sand		*Cancer pagurus*	+			Milner (2009)
			Carcinus maenas	+			
			Macropipus tuberculatus or *Liocarcinus depurator*	+			
20	Ulva Cave		*Atelecyclus rotundatus*	1	1		Pickard and Bonsall (2009)
			Cancer pagurus	165	17		
			Carcinus maenas	59	9		
			Corystes cassivelaunus	2	1		
			Inachus dorsettensis	1	1		
			Maja squinado	3	1		
			Necora puber or *Liocarcinus depurator*	165	12		
21	West Voe (lower midden)		Decapoda (undetermined)	+			Melton and Nicholson (2004)

+: presence.

Table 2: Mesolithic shell middens located on the map in France with crab species and quantification

Number on the map	Site	Country	Species	NISP	MNI	Weight (g)	References
22	Beg-an-Dorchenn (D/M)	France	*Cancer pagurus*	15	12	6.80	Dupont et al. (2010)
			Carcinus maenas	2	2	0.04	
			Eriphia verrucosa	6	6	1.10	
			Xantho sp.	15	11	1.60	
	Beg-an-Dorchenn (K)		*Cancer pagurus*	16		17.83	
			Eriphia verrucosa	2	0	0.65	
			Maja squinado	1		0.13	
			Xantho sp.	1		0.08	
23	Beg-er-Vil (K)		*Cancer pagurus*	64	39	13.60	Dupont and Gruet (2005); Gruet (2002)
			Carcinus maenas	6	5	0.20	
			Decapoda (undetermined)	294		69.31	
			Eriphia verrucosa	21	19	2.40	
			Necora puber	11	7	1.30	
	Beg-er-Vil (M/D)		*Cancer pagurus*	2,389	353	140.94	Dupont et al. (in press)
			Carcinus maenas	182	73	1.34	
			Decapoda (undetermined)	735		1.29	
			Eriphia verrucosa	378	114	5.28	
			Maja squinado	17	9	0.49	
			Necora puber	131	39	1.07	
			Pachygrapsus marmoratus	28	11	0.27	
			Xantho sp.	98	26	0.93	
24	Hoëdic (Péquart)		Decapoda (undetermined)	+			Péquart and Péquart (1954)
25	Téviec		Decapoda (undetermined)	+			Péquart, Boule, and Vallois (1937)

+: presence.

determination into account, this number drops to 20 Mesolithic levels. Only six of them yield data on crab size: Havnø, Ulva Cave, Beg-an-Dorchenn, Beg-er-Vil, El Mazo, and Toledo (Dupont et al., 2010; Dupont, 2011; Dupont, Gruet, Arthur, & Digard, in press; Gruet, 2002; Gutiérrez-Zugasti et al., 2016; Madsen et al., 1900; Pickard & Bonsall, 2009). For Beg-an-Dorchenn, Beg-er-Vil, El Mazo, and Toledo, an estimation of size is given in millimetres, for Havnø the presence of a single tall crab is specified and for Ulva Cave, the one of juvenile or adult specimens.

2.2 The Impact of Methodology and Taphonomy on the Visibility of Mesolithic Crabs

Crabs have only been detected at 18% of the published Mesolithic shell middens along the European Atlantic façade. It is unclear as to whether this marine resource was exploited at all sites, but the fact that sieving is only mentioned for 6% of the published sites may be one explanation for their rarity. For example, the diversity of identified species seems to be linked to sampling methods. One of the obstacles encountered in demonstrating this point is that excavation techniques are not always mentioned in publications. For sites where crabs were mentioned, we were only able to find the excavation technique used for 40% of them (Figure 3).

Thus, 77 % of the archaeological sites where more than two species have been identified correspond to samples sieved with fine meshes varying between 1 and 6 mm. Claws are the main element discovered in

Table 3: Mesolithic shell middens located on the map in Spain with crab species and quantification

Number on the map	Site	Country	Species	NISP	MNI	Weight (g)	References
26	Balmori (D-1)	Spain	Decapoda (undetermined)	1			González Morales (1982)
27	Balmori (E-1; C-1)		*Cancer pagurus*	1			Clark (1971)
28	Chora		*Carcinus maenas*	1	1		Gutiérrez Zugasti (2009)
			Decapoda (undetermined)	11	1	1	
29	Coberizas A		Decapoda (undetermined)	+			Clark (1971)
30	Coberizas B-1		Decapoda (undetermined)	1+			Clark (1971)
31	El Mazo cave		*Cancer pagurus*		21		Gutiérrez-Zugasti et al. (2016)
			Carcinus maenas		27		
			Eriphia verrucosa		121		
			Necora puber		41		
			Pachygrapsus marmoratus		39		
			Xantho sp.		26		
32	Fonfría B		*Cancer pagurus*	+			Clark (1976); Fano Martínez (1998)
			Decapoda (undetermined)	2			
			Necora puber	+			
33	Fragua		*Carcinus maenas*	4	1		Gutiérrez Zugasti (2009)
			Decapoda (undetermined)	26	1		
			Necora puber	10	3		
			Portunidae	5	2		
34	J3 (Jaizkibel 3)		Decapoda (undetermined)	12	1	1.00	Álvarez-Fernández, Iriarte, and Arrizabalaga (2010)
			Eriphia verrucosa	+			
			Pachygrapsus marmoratus	+			
35	la Franca (B)		*Cancer pagurus*	+			Clark (1971)
36	La Mina (Cueto de)		*Cancer pagurus*	+			Clark (1971)
			Necora puber	+			
37	La Riera		*Carcinus maenas*	+			Ortea (1986)
38	La Trecha		*Cancer pagurus*	1	1		Gutiérrez Zugasti (2009)
			Carcinus maenas	1	1		
			Decapoda (undetermined)	2	1	2	
39	Les pedroses cave		*Cancer pagurus*	1			Zilhão (2000); Arias Cabal (1991)
40	Llana		*Cancer pagurus*	3	1		Gutiérrez Zugasti (2009)
			Decapoda (undetermined)	37	3	10.00	
			Necora puber	1	1		
			Lophozozymus incisus	1	1		
41	Mazaculos II		Decapoda (undetermined)	1	1	1.00	Gutiérrez Zugasti (2009)
42	Pico Ramos		Decapoda (undetermined)	19			Moreno Nuño (2017); Zapata, Milner, and Roselló (2007)
43	Poza l´Egua		*Eriphia spinifrons*	1	1		Álvarez-Fernández (2011)
44	Riera B		*Cancer pagurus*	1	1		Clark (1971)
45	Santimamiñe		Decapoda (undetermined)	1	1	1.00	Gutiérrez Zugasti (2009)

+: presence.

Table 4: Mesolithic shell middens located on the map in Portugal with crab species and quantification

Number on the map	Site	Country	Species	NISP	MNI	Weight (g)	References
46	Arapouco	Portugal	*Carcinus maenas*	+			Arnaud (1989); Arnaud (2000)
47	Barranco das Quebradas I		Decapoda (undetermined)	7			Valente (2008); Valente and Carvallo (2009)
48	Barranco das Quebradas IV		Decapoda (undetermined)	6			Valente (2008); Valente and Carvallo (2009)
49	Cabeço da Amoreira		*Carcinus maenas*	>170	>93	>24.44	Dupont and Bicho (2015); Lentacker (1986); Roche (1965)
			Decapoda (undetermined)	>10426			
			Afruca tangeri	7	>3	>0.69	
50	Cabeço da Amoreira		Decapoda (undetermined)	+			Arnaud (2000)
51	Cabeço da Arruda		*Carcinus maenas*	+			Lentacker (1986)
			Decapoda (undetermined)	1041			
			Afruca tangeri	+			
52	Cabeço do Rebolador		*Carcinus maenas*	+			Arnaud (1989)
53	Moita do Sebastião		*Carcinus maenas*	+			Roche (1958)
			Afruca tangeri	+			
54	Montes de Baixo		Decapoda (undetermined)	+		3.10	Tavares da Silva and Soares (1997)
55	Poças de São Bento		Decapoda (undetermined)	+			Arnaud (2000)
56	Quinta da Sardinha		Decapoda (undetermined)	+			Ribeiro (1884)
57	Rocha das Gaivotas		Decapoda (undetermined)	2			Valente (2008)
58	Samouqueira I		Decapoda (undetermined)	+			Lubell, Jackes, Sheppard, and Rowley-Conwy (2007)
59	Toledo		*Carcinus maenas*	59	32	18.08	Dupont (2011)
			Eriphia verrucosa	1	1	0.57	
			Pachygrapsus sp.	6	4	1.62	
60	Vale Frade		Decapoda (undetermined)	>145			Araujo (personal communication)

+: presence.

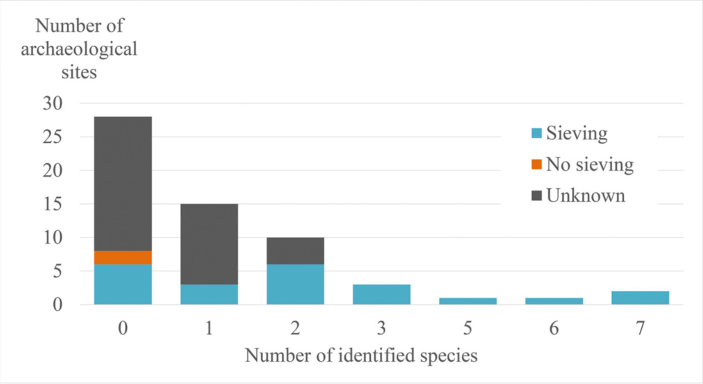

Figure 3: Number of identified crab species according to the published excavation technique for the Mesolithic shell middens in Atlantic Europe (CAD C. Dupont).

shell middens (Anderson, 1898; Arnaud, 1989; Clark, 1976; Coles, 1971; Dupont & Gruet, 2005; Dupont, 2011; Grieve, 1874; Gruet, 2002; Madsen et al., 1900; Valente & Carvalho, 2009; Woodman et al., 1999), but sediment sieving has resulted in the identification of some carapace fragments (Dupont et al., 2010; Gutiérrez-Zugasti et al., 2016; Melton & Nicholson, 2004; Milner, 2009; Myers & Gourlay, 1991, p. 21; Pickard & Bonsall, 2009). Fragments of crab mandibles have also been detected (Figure 4). This discovery is possible on condition that sediments are sieved with a fine mesh (<2 mm), and sorted by qualified individuals.

But sieving is not the only factor affecting the detection of the exoskeleton, as mineral content increases from the carapace to the claw to the finger (Bosselmann, Romano, Fabritius, Raabe, & Epple, 2007, p. 67), taphonomic biases can impact the preservation of crab remains (Rick et al., 2015). We observed this *in situ* at the archaeological site of Beg-er-Vil in the north-western part of France (Dupont et al., in press). The size of crab fragments at this Mesolithic site seems to vary depending on their position in the shell level, in relation to the variability of soil acidity. The average weight of a crab fragment for the 2010 excavations at Beg-er-Vil is 0.15 g (Dupont et al., in press). Thus, their generally lighter weight is one of the likely reasons for their poor visibility in the archaeological record.

At the scale of Atlantic Europe, 53% of the crustaceans found have been determined. In some cases, crustaceans have been deemed indeterminable (Péquart & Péquart, 1954). This assessment is clearly related to their small size, but also to the historical context of the discovery of these archaeological remains. In 1954, archaeozoological studies were rare. Another assertion is perhaps currently more accurate: the diversity of potential analyses on an archaeological site, such as the shell midden, does not allow archaeologists to recognise all the possibilities of specialised analysis.

2.3 Who are the Mesolithic Crabs?

In total, 13 species have been determined along the European Atlantic façade in a Mesolithic context: *Afruca tangeri* (Eydoux, 1835), *Atelecyclus rotundatus* (Olivi, 1792), *Cancer pagurus* (Linnaeus, 1758), *Carcinus maenas* (Linnaeus, 1758), *Corystes cassivelaunus* (Pennant, 1777), *Eriphia spinifrons* (Forskål, 1775), *Inachus dorsettensis* (Pennant, 1777), *Lophozozymus incisus* (Milne Edwards, 1834), *Macropipus tuberculatus* (Roux, 1830 [in Roux, 1828–1830]), *Maja squinado* (Herbst, 1788), *Necora puber* (Linnaeus, 1767), *Liocarcinus depurator* (Linnaeus, 1758), and *Pachygrapsus marmoratus* (Fabricius, 1787) (Tables 1–4). Some remains could not be specifically determined. Thus, we can add two genera (*Pachygrapsus* Randall, 1840 and *Xantho* Leach, 1814 [in Leach, 1813–1815]) and one family (Portunidae Rafinesque, 1815) to these species. Other names appear in publications, such as *Gelasimus tangeri, Uca tangeri* (Lentacker, 1986; Roche, 1958, 1965), and *Xantho incises* (Gutiérrez-Zugasti, 2009). We chose to use the valid name at the

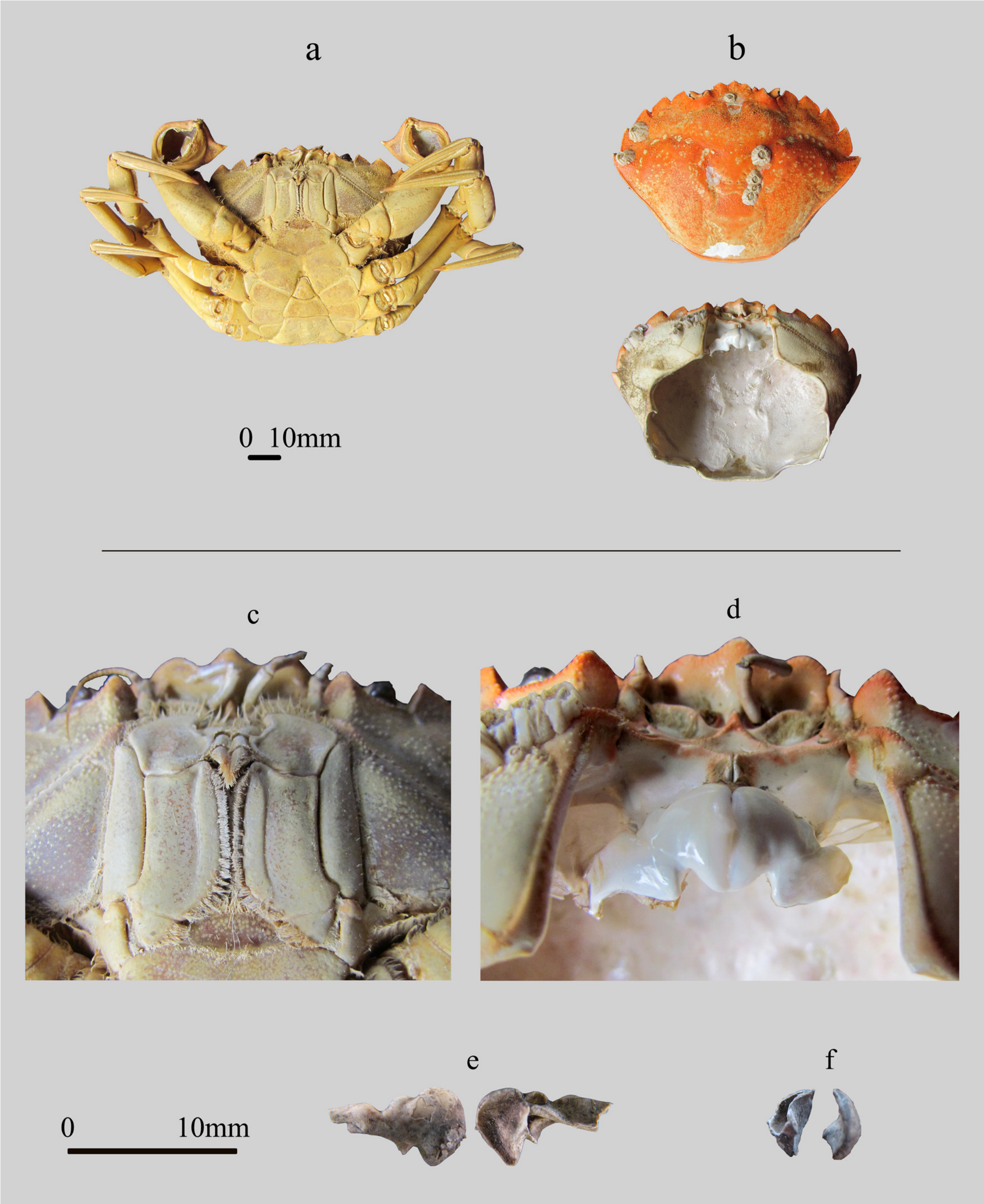

Figure 4: Comparison between modern crabs (a–d) and archaeological mandible fragments from Cabeço da Amoreira (e) and Beg-er-Vil (f) (photos and CAD C. Dupont).

time of writing our article (WoRMS, 2022). Some determinations can only be made at the genus level and doubts have been voiced concerning the presence of *Liocarcinus depurator* and *Macropipus tuberculatus* (Milner, 2009; Pickard & Bonsall, 2009) and the potential presence of lobster at Sand (Scotland) (Milner, 2009).

Here we summarise the identified species from the most abundant to the least recurrent: European edible crab *Cancer pagurus* (19 sites), green crab *Carcinus maenas* (16 sites), velvet swimming crab *Necora puber* (7 sites), warty crab *Eriphia verrucosa* (6 sites), fiddler crab *Afruca tangeri* (3 sites), spider crab *Maja* *squinado* (3 sites), and marbled rock crab *Pachygrapsus marmoratus* (3 sites). The others have only been detected at a single site. Size does not seem to be the only factor affecting species representation. The spider crab, *Maja squinado,* for example, is a tall crab but its carapace and claws seem to be more porous than those of the edible crab *Cancer pagurus*. The spider crab is also a difficult species to catch all year round. Taphonomic biases, accessibility, and gustative preference may also be factors affecting crab representativeness.

In brief, this indicates that crabs are not systematically examined, quantified, or determined. They do however provide data on the Mesolithic way of life. We will thus expound the archaeological methodology and its repercussions in order to encourage archaeologists to take crabs into consideration.

3 Archaeological Interest of Mesolithic Crabs

3.1 From Archaeological Crumbs to Complete Mesolithic Animals

In order to arouse the interest of archaeologists, we thought it would be interesting to present what can be done with the small remains of crabs found in Mesolithic shell middens.

Although other skeletal parts are found on Mesolithic sites (see above), the fingertips of the crab claw are the most recurrent (Figure 5).

The determination of these remains is possible by comparison with a reference collection. Indeed, each species is composed of two propods and right and left dactylopods that can be identified according to their size, shape, the aspect of their more or less granular surface, and the presence of more or less large-sized pores with a specific arrangement. Some of these pores form localised alignments on the surface of the finger. The presence of tubercles on the inner surfaces of propods and dactylopods is also very useful for identification. Their shapes, numbers, and sizes are specific to each species.

Quantification is then based on three units: NISP, MNI, and weight applied to sieved samples. Sieving is essential here as selection by sight in the field tends to overlook most crabs' fragments, which are often less than a centimetre long. The NISP and weight correspond to all the detected crab remains. The MNI varies among authors. The simplest method consists in counting all the fingers and dividing the total by four (Milner, 2009). A more detailed MNI can be obtained by taking into account the dactyl and propodus remains (Pickard & Bonsall, 2009). A more detailed combined MNI can be obtained by taking into account the lateralisation of both propods and dactylopods (Gruet, 2002). Lateralisation is determined by taking into account the curvature of the fingers towards the animal's body (Figure 5). The accuracy of this number can be increased by adding the size of the crab to calculate the MNI. In spite of the low frequency of counts in Mesolithic contexts, we note that crab remains are said to be as abundant as the remains of marine shells in some Mesolithic sites: Culverwell (Mannino et al., 2003) and Téviec (Péquart et al., 1937). They also seem to be relatively abundant in all the Oronsay middens (Mellars, 1978), but also at Arapouco (Arnaud, 1989), Cabeço da Amoreira (Pinto, 1986), Cabeço do Rebolador (Arnaud, 1989), and Sand (Milner, 2009). Three mentions are made of rare quantities of crab at Samouqueira I (Lubell et al., 2007), Hoedic (Péquart & Péquart, 1954), and Howick (Bailey & Milner, 2007). Some authors only use complete claws to reconstruct crab size (Milner, 2009; Pickard & Bonsall, 2009). But with a comparative collection it is possible to correlate partial segments of claws (propods and dactylopods) with the original breadth of the carapace (Dupont et al., in press; Gruet & Laporte, 1996; Gutiérrez-Zugasti et al., 2016). This approach requires many samples of each potentially fished species comprising a range of small to large-sized individuals. These correlations can be obtained by two methods: by close visual comparison or by establishing a correlation equation with systematic measurements taken between identifiable points. We can obtain approximate values of crab size by using a comparative collection with grades of propods and dactylopods from small to tall specimens by visual comparison (Dupont & Gruet, 2005; Dupont et al., 2010). The second method, which consists in establishing correlation equations, shows very good results, with correlation coefficients

Figure 5: Finger fragments of crabs from shell middens – edible crab *Cancer pagurus*: (1) Beg-er-Vil, (a) left dactylus and (b) left propodus; Warty crab *Eriphia verrucosa*: (2) Beg-er-Vil, (a) right dactylus, (b) left dactylus, and (c) right propodus; (3) Toledo, right propodus; Velvet swimming crab *Necora pube*r: (4) Beg-er-Vil, (a) left dactylus, (b) right dactylus, and (c) right propodus; Green crab *Carcinus maenas:* (5) Beg-er-Vil, (a and b) right dactylus; (6–8) Toledo, right propodus, right dactylus, and left propodus; (9) Cabeço da Amoreira, left dactylus; *Afruca tangeri*: (10) Cabeço da Amoreira; Spider crab *Maja squinado:* (11) Beg-er-Vi; Furrowed crab *Xantho* sp.: (12) Beg-er-Vil, left dactylus; *Pachygrapsus* sp.: (13) Toledo, right dactylus; Marbled rock crab *Pachygrapsus marmoratus*: (14) Beg-er-Vil, (a and b) right dactylus (Photos Beg-er-Vil: O. Digard (1) and M. Arthur (2, 4, 5, 12, 14), Toledo and Cabeço da Amoreira C. Dupont, CAD: C. Dupont).

often exceeding 0.90 (Dupont et al., in press; Gruet & Laporte, 1996). Therefore, using claw fragments, it is possible to identify the distribution of crab size in a shell midden.

Theoretically, the obtained size can be related to the mass of meat of the animal (Dupont & Gruet, 2005) and therefore to the potential quantity of food. The yield is more than 50% if we consider the weight of meat in relation to the weight of the animal (Dupont & Gruet, 2005). Crabs, for example, have a higher yield than most shellfish, with the exception of the limpet. Thus, claw tips could well be "the tip of the iceberg" and may represent a significant part of the diet of Mesolithic populations. These quantities of crabs would also have contributed to the diversity of the Mesolithic diet and could have prevented vital deficiencies. They are rich in omega-3 fatty acids (Anacleto, Maulvault, Barbosa, Nunes, & Marques, 2016) and "essential elements such as K, Ca, Cu, Zn, Se, and n – 3 PUFA, namely, EPA and DHA" (Maulvault et al., 2012, p. 6).

3.2 Only Food?

Some animals are known to eat crabs, such as mammals (foxes, sea otters, etc.) or birds (European sea eagle, gulls, etc.; Erlandson & Moss, 2001). In the same way as for small proportions of shells in anthropogenic shell middens, some crab accumulations can be due to natural agents.

The presence of crabs at the archaeological sites can result from different human activities. The most visible is catching crabs for human consumption. Many cooking methods are associated with crabs; they can be grilled, roasted on heated stones, steamed, or boiled. They can also be used in soups. The main method of Mesolithic cooking is presumed to be grilling, because of the localised presence of burns on the tips of the claws, such as at Sand (Milner, 2009). This hypothesis is, however, often difficult to confirm because very often the burnt parts are the only preserved parts (the fingertip). The rate of calcination can often be high for crab remains: between 25 and 77% El Mazo, (Gutiérrez-Zugasti et al., 2016), 45% of the 3,049 fragments observed in the 2013 survey of Beg-er-Vil (Dupont et al., in press). For example, at Beg-er-Vil, due to fragmentation, it is not always possible to ascertain whether these burns are localised. Furthermore, hearths were often located on or in Mesolithic shell middens. Thus, most archaeologists remain cautious in their conclusions as many scenarios could potentially explain the origin of these burns, such as use as fuel, accidental burning, and burning in cooking (Milner, 2009). Possible markers of crab consumption include breakage types (Zilhão et al., 2020). In most cases, claws are crushed to gain access to their flesh (Milner, 2009). However, these anthropogenic breaks are often combined with those of natural origin, rendering identification difficult (Milner, 2009). In a site such as Beg-er-Vil where, as we have already mentioned, a crab fragment weighs on average 0.15 g (2010 excavation, NISP = 3,262; Dupont et al., in press), it seems impossible to differentiate between natural and anthropogenic breaks. In our comparison collection, we observed that the simple drying of crab fingers in the sun causes them to crack and break vertically and horizontally. The microwear analysis of the macro-tools left at sites could perhaps contribute to identifying the deliberate crushing of crab claws. For example, a significant number of pebbles were left at the Beg-er-Vil site (Marchand, Calvo Gomez, Cuenca Solana, Henin, & Nukushina, 2019) and they may have been used for this purpose.

Some authors also suggest the possible use of crustaceans as bait (Lentacker, 1986; Milner, 2009). This activity is difficult to prove in archaeology as the carapace and claws were probably crushed and laid as bait on the seashore or in the sea. Crabs can also be accessorily transported to a settlement with other marine materials, such as rocks or seaweed. For example, seaweed can be used as food, but also to keep molluscs or fish in a wet and fresh atmosphere. These marine plants can be used for transport from the sea to the settlement, but also inside the settlement itself prior to consumption. It is a means for keeping food fresh for several hours or days, depending on the season. This method is still used on the Atlantic coast of France. Crabs can also be intrusive when the site is near the seashore (Connock et al., 1993). Some parts of the crab skeleton may have been reused, such as the carapace of tall specimens as receptacles (Milner, 2009), or the extremity of huge crab fingers as pipes (Datta & Ghosh, 2013). The first use is difficult to detect on Mesolithic sites due to the porosity and the fragility of crab carapaces. However, the use of crab claws as pipes could potentially be identified on archaeological remains. The size of the chosen crab finger is tall. The tip is broken and the extremity should show evidence of localised burning. To our knowledge, no such finds have been documented in Europe but crab pipes are known in Australia (Kuipers, 1986) and India (Datta & Ghosh, 2013), for example.

Most of these activities can be differentiated on the basis of carcinological analysis. What do the Mesolithic remains along the European Atlantic coast tell us?

Using the abovementioned methodology, we can advance hypotheses on the rare Mesolithic sites that have been studied from the crab point of view. This methodology is, of course, dependent on the techniques used during excavation. Recently, we showed that sieve mesh size can have an impact on the representativeness of the smallest species and individuals (Dupont et al., in press). It may even impact the pattern of Mesolithic crab exploitation deduced by archaeologists (Dupont et al., in press). At Toledo, sieve rejects on a 2 mm mesh indicated that crabs were selected for their large size (Dupont, 2011). This selection of large individuals generally indicates human consumption. This is also the case at El Mazo, which shows a certain preference for the selection of larger specimens (Gutiérrez-Zugasti et al., 2016). For the latter example, the authors infer non-intensive crab collection as similar mean sizes were recorded throughout the shell layer sequence (Gutiérrez-Zugasti et al., 2016). A different scenario was observed at Ulva Cave (Pickard & Bonsall, 2009) and at Beg-er-vil (Dupont et al., in press), where both juveniles and adults were collected for the main species. This composition may correspond to the combination of two activities: consumption and seaweed collection for food and fuel (Pickard & Bonsall, 2009). The planned spatial analysis of a large area of the Beg-er-Vil shell midden will probably be able to verify this hypothesis in the long term. For the latter site, natural crab intrusion can be ruled out as it was more than 500 m from the coastline during the Mesolithic.

The composition of the malacofaunal spectrum can also reveal behavioural aspects of coastal hunter-gatherer-fishers populations. For example, at Beg-er-Vil, the most consumed crab species seem to be linked to a combination of two factors: species with the largest individuals, and accessibility on the foreshore at low tide (Dupont et al., in press).

Estimates of the food supply that these tiny crab finger fragments could represent have already been tested. Based on the reconstructed size of the original carapace, we can calculate the fresh mass of the animal (Dupont et al., 2010). Some calculations have been made in the shell midden of Beg-an-Dorchenn. A square metre of the midden, which yielded 9.55 g of crab remains, can be evaluated as equivalent to 13 kg of fresh whole crab (Dupont et al., 2010). Lentacker (1986, p. 18) judged at Cabeço da Arruda that “Their meat amount is too small to be of any economic value. If, however these crab claws are the remains of part of the diet, they could indicate a scarcity of other more valuable or more palatable food.” The consumption of *Carcinus maenas* can be linked to its abundance. Adult breadth of this species is around 73 mm (Hayward & Ryland, 2007). This size can be judged small, but this type of crab is not only confined to poor populations. It has already been reported on the London market and in American restaurants (Crothers, 1968).

3.3 From Biotopes to Palaeoenvironments

The determination of crabs opens up access to a whole range of known data on their biotopes, including the substrate, tolerance to salinity, and bathymetry. It can provide an indirect picture of the environments near the site but also of human behaviour. Indeed, populations may simply have fished crabs on foot at low tide, or they may have used more sophisticated techniques.

Bathymetry provides a first indication of rhythms of capture. Amongst the determined species, only two live in the subtidal zone: *Atelecyclus rotundatus* and *Macropipus tuberculatus* (Table 5). They can be collected after a storm on the seashore or maybe in tidal pools on the lower shore. Species accessible on lower shores can only be caught during low spring tides while those living on the high and middle shore can be caught virtually all year round. Both species are poorly represented in Mesolithic shell middens on the European Atlantic coast. The quantities of *Macropipus tuberculatus* identified at Sand are not specified

Table 5: Seasonal availability and crab biotopes in Mesolithic sites (after Bouvier, 1940; Hayward & Ryland, 2007; Ingle, 1997; Latrouite, 1992; Pickard & Bonsall, 2009)

Latin name	Common name	Shoreline availability	Substrate
Atelecyclus rotundatus (Olivi, 1792)	Circular crab	Difficult alive, subtidal zone	Sandy and gravelly substrates
Cancer pagurus (Linnaeus, 1758)	European edible crab	Year round for juveniles, more frequent from April until November for adults, middle shore to subtidal zone	Rocky shores under stones
Carcinus maenas (Linnaeus, 1758)	Shore green crab	More accessible from spring to autumn, all the seashore to subtidal zone	All marine substrates, tolerance for brackish waters, absent from exposed coasts
Corystes cassivelaunus (Pennant, 1777)	Masked crab	Year round, lower shore to subtidal zone	Burrows in sandy to soft substrates
Eriphia spinifrons (Forskål, 1775)	Warty crab	Year round, middle and lower shore to subtidal zone	On rocky substrates under stones and in crevices
Afruca tangeri (Eydoux, 1835)	Fiddler crab	Year round, all the seashore	Burrows in sandy and muddy substrates
Inachus dorsettensis (Pennant, 1777)	Scorpion spider crab	Year round, lower shore to subtidal zone	On sandy and muddy shores, among seaweed on rocky shores
Liocarcinus depurator (Linnaeus, 1758)	Sandy swimming crab	Year round, lower shore to subtidal zone	On sand, muddy sand, and gravel
Macropipus tuberculatus (Roux, 1830 [in Roux, 1828–1830])	—	Difficult alive, subtidal zone	Rocky substrates
Maja squinado (Herbst, 1788)	Common spider crab	Year round, lower shore for juveniles. From April to summer, lower shore for adults. Year round, subtidal zone for all specimens.	Rocky substrates among seaweed on sandy bottoms
Necora puber (Linnaeus, 1767)	Velvet swimming crab	Year round, lower shore to subtidal zone	Rocky substrates under stones and in crevices
Pachygrapsus marmoratus (Fabricius, 1787)	Marbled rock crab	Year round, high shore to subtidal zone	Rocky substrates under stones and in crevices in sandy and muddy bottoms
Lophozozymus incises (Milne Edwards, 1834)	Furrow crab	Year round, lower shore to subtidal zone	On stony substrates

and this species can be confused with *Liocarcinus depurator* (Pickard & Bonsall, 2009). As for *Atelecyclus rotundatus* at Ulva Cave, only one individual has been determined (Milner, 2009).

Adult *Maja squinado* are also subtidal most of the year. These crabs come close to the coast from spring to summer. They can then wash up on the beach in large numbers or be caught safely by walking in shallow water. Such species are recorded at Ulva Cave, Beg-an-Dorchenn, and Beg-er-Vil (Dupont et al., 2010, in press; Pickard & Bonsall, 2009). Again, this predominantly subtidal species is poorly represented in the assemblages of these sites.

Although edible crabs are accessible all year round on the foreshore, adult *Cancer pagurus* are currently more accessible from spring to autumn, when they return to shallower conditions.

A mention of *Cancer pagurus* behaviour is also evoked for the Morton site (Coles, 1971). This could be the case at Beg-an-Dorchenn where 8 edible crabs show a size superior to 120 mm (Dupont et al., 2010). Such dimensions are currently accepted as being related to subtidal specimens (DORIS, 2021). It is also possible that some current conditions differ slightly from the biotope of these animals in the Mesolithic. One example is the modern overexploitation of foreshores, which means that, over a human life span, some of the sizes accessible at low tide are smaller than in the past.

It must be noted that these species are difficult to access due to the depth of the water in which they live, and seem to have been collected in smaller quantities. They are also absent from other sites for which quantification is given (Tables 1–4). The correlation between accessibility and the proportion of species was noted at Beg-er-Vil (Dupont et al., in press). The multiplication of these quantitative analyses would indicate whether or not this behaviour can be generalised on the scale to the whole of Atlantic Europe. In the current state of knowledge, it tends to show fishing for these seafoods at low tide, with more abundant species from high and medium tidal ranges. This type of fishing is still carried out by populations along the French Atlantic coast. It only requires a simple curved pole to dislodge the crabs from their cavities (Figure 6). This type of fishing is handed down from generation to generation. Information on the location of holes in the rocks with abundant crabs is thus passed on, depending on the tidal range. Not all holes are accessible at every tide. Some species lodge in holes, others hide under rocks that are also regularly turned over and repositioned by fisherfolk.

Of course, we cannot exclude the possible use of nets or traps for the capture of crabs, but in the light of current data, these more elaborate capture techniques do not seem to have been required on the foreshore for archaeological sites with quantified data.

Biotopes are of interest in that they help us to understand modifications to the palaeoenvironment or to Mesolithic territories. Some species tolerate brackish waters and can point to the presence of huge and sheltered estuaries in the past. If we take into account all the Portuguese shell middens from the Muge and Sado complexes (Arnaud, 1989; Dupont & Bicho, 2015; Lentacker, 1986; Roche, 1958), and also the less known Early Mesolithic sites such as Toledo and Vale Frade, the species *Carcinus maenas* is present in most of them (Dupont, 2011; Araujo, personal communication). It could be interesting to assess the proportions of this species in combination with malacological, and ichthyological studies in order to attempt to measure salinity levels at the foot of each settlement. These studies can help to recreate the morphology of such estuaries. At an archaeological site, they would also indicate if crabs were collected from one or several areas of the coast and point to selective or opportunistic exploitation of the seashore. Such analyses have been carried out simultaneously at Beg-er-Vil and at Cabeço da Amoreira (Dupont & Bicho, 2015). We were able to compare the diversity of malacofaunal spectra with that of carcinological spectra. At Beg-er-Vil, diverse biotopes were exploited with a dominance of rock species for both molluscs and crustaceans, whereas at Cabeço da Amoreira, shellfish collection and crab fishing target a single environment: mudflats. These differences between the two sites can be explained by the accessibility of the environments near the sites. They show that Mesolithic hunter-gatherer-fishers adapted their foraging to environments in the vicinity of the site. The search for marine resources seems to represent opportunistic behaviour.

We also need to draw attention to climatic data. If we compare the modern biogeographical distribution of each species to its occurrence at Mesolithic sites, we observe some interesting distortions (Figures 7 to 9). One, published by Roche (1965), concerns *Afruca tangeri*. Its present northern limit is

Figure 6: Crab fisherfolk on the French Atlantic coast with his tool (Photo C. Dupont 2021).

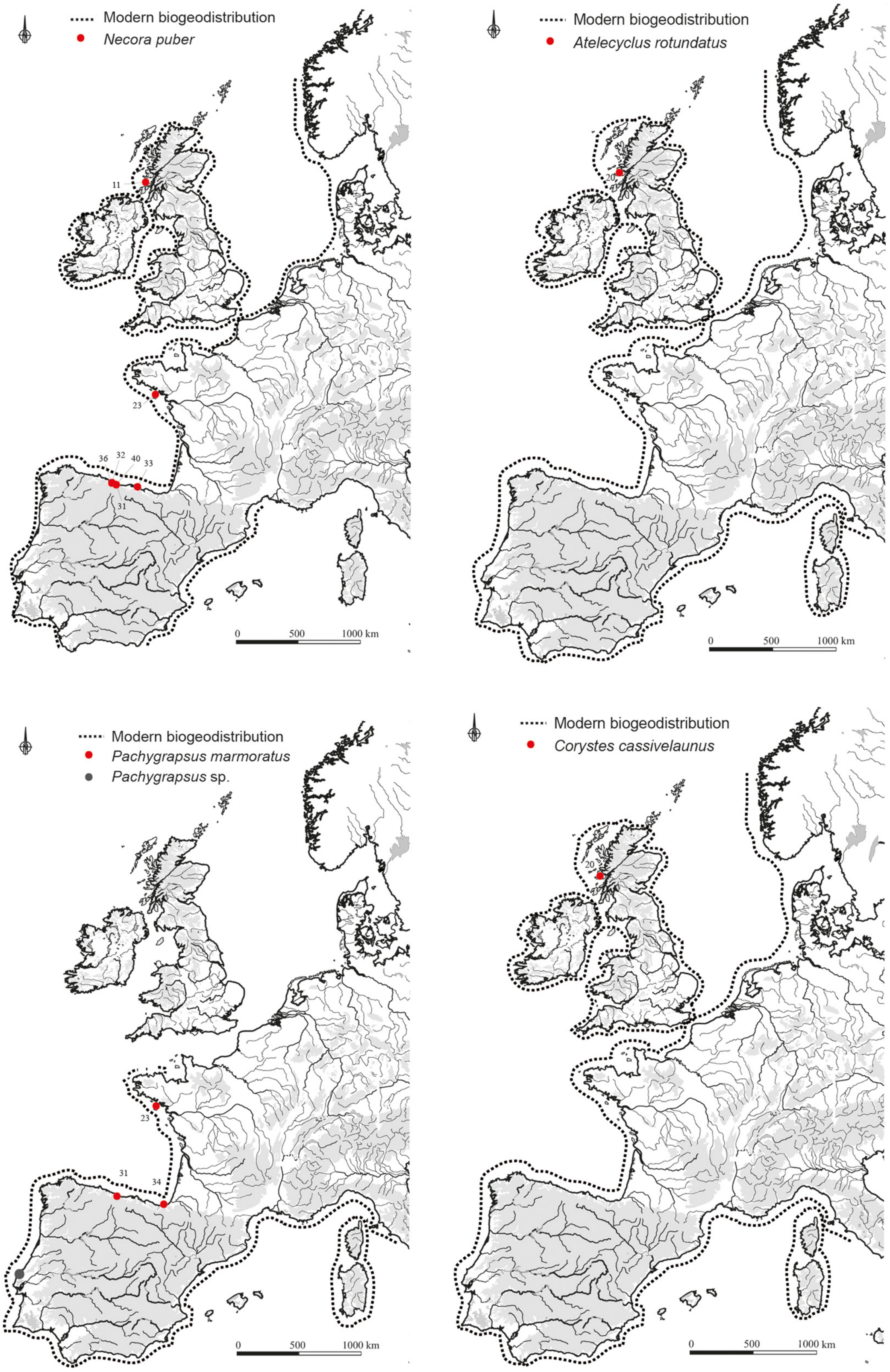

Figure 7: Mesolithic shell middens with *Necora puber, Atelecyclus rotundatus, Pachygrapsus marmoratus* and *P.* sp., *Corystes cassivelaunus*, and limits of their modern biodistribution (CAD C. Dupont and L. Quesnel).

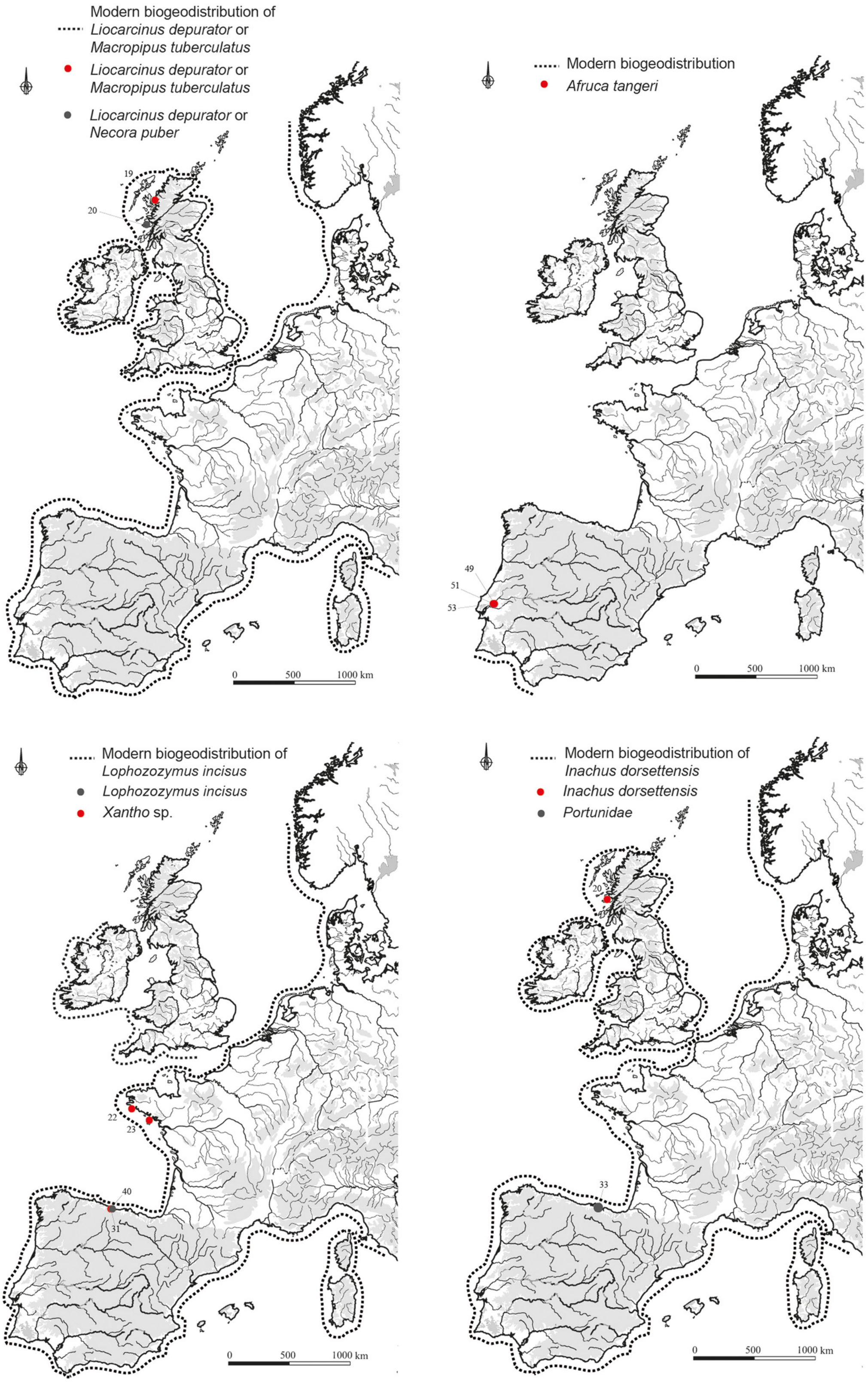

Figure 8: Mesolithic shell middens with *Macropipus tuberculatus, Portunidae, Afruca tangeri, Lophozozymus incises, Xantho* sp., *Inachus dorsettensis*, and limits of their modern biodistribution (CAD C. Dupont and L. Quesnel).

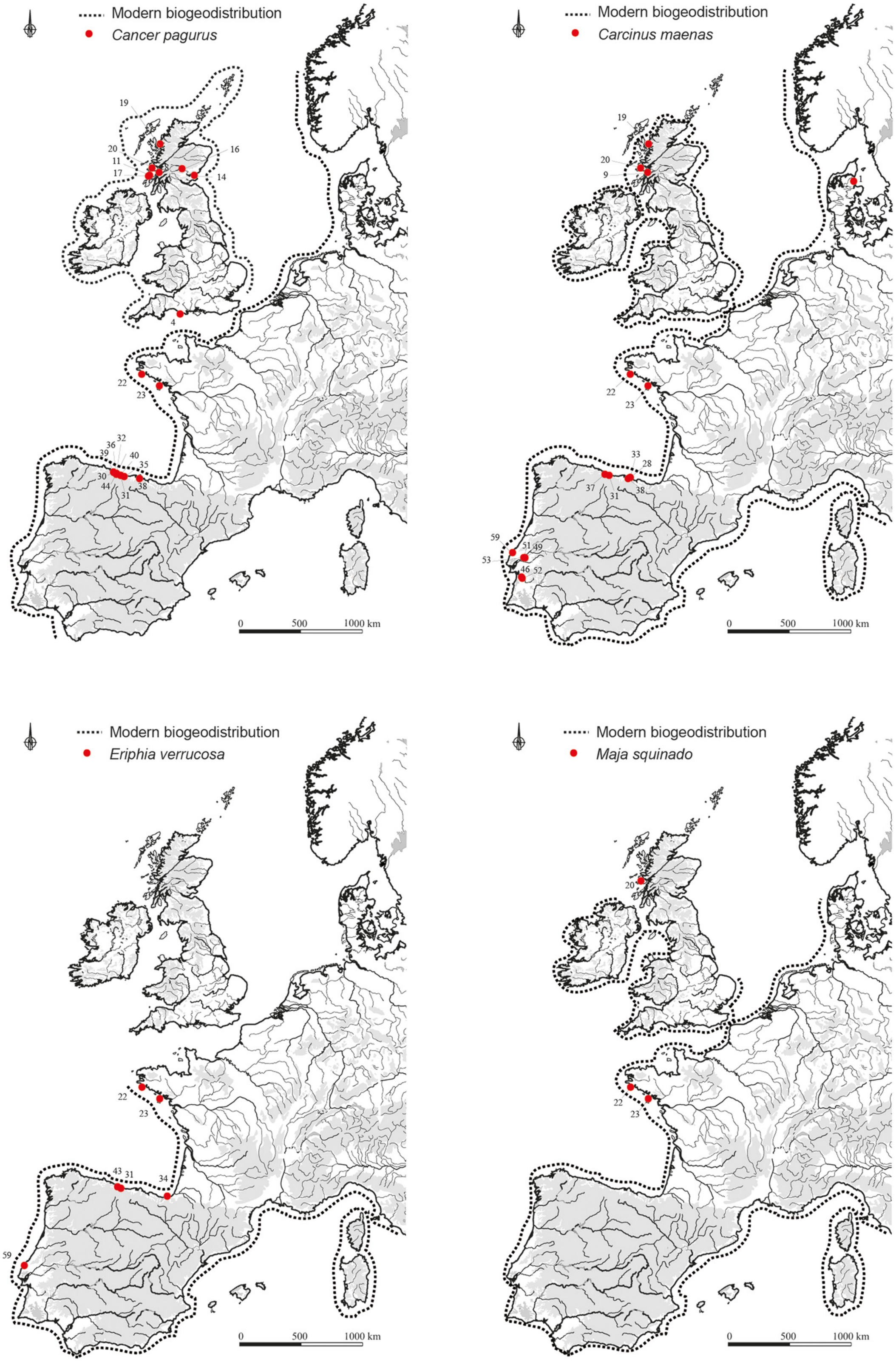

Figure 9: Mesolithic shell middens with *Cancer pagurus, Carcinus maenas, Eriphia verrucosa*, *Maja squinado*, and limits of their modern biodistribution (CAD C. Dupont and L. Quesnel).

around "Cabo de Sõa Vicente" (South Portugal) and the archaeological records indicate warmer conditions during the Mesolithic. Its presence does not seem to be coincidental since this species is recorded on three shell middens attributed to the Mesolithic: Cabeço da Amoreira (Dupont & Bicho, 2015; Lentacker, 1986; Roche, 1965), Cabeço da Arruda (Lentacker, 1986), and Moita do Sebastião (Roche, 1958; Figure 8). This tendency is also published with the presence of *Maja squinado* at Ulva Cave (Pickard & Bonsall, 2009), in an area where the spider crab is currently rare (Quéro & Vayne, 1998; Figure 9). We also note the presence of *Eriphia verrucosa* close to its current northern limit at Beg-an-Dorchenn (Dupont et al., 2010; Figure 9).

All these cases need to be studied in detail in the future because they are not strictly contemporaneous. The case of the fiddler crab is the most indicative, but two other species seem to confirm a tendency towards warmer or mild conditions during the Mesolithic, similar to the present day climate.

4 Discussion: From Crab to Thinking

This overview points out the fact that the presence of crab remains in the archaeological record is largely underestimated. They are rarely identified and only occasionally quantified. However, these specific and quantitative data open up access to topical discussions concerning Mesolithic populations. Were these people dependent on the marine environment for their diet? Did crabs make a real contribution to the diet of Mesolithic populations? If so, in what proportions? What is the relationship between the sea and Mesolithic societies? Is contact with the marine environment a way of maintaining a stable residence? What type of environment surrounded the site during site occupation? Have climatic conditions induced changes in coastal settlements? Did the available marine resources vary during the Mesolithic?

Crab remains can provide us with information on these topics, but sampling methods need to be adapted to excavation strategies in order to contribute to the archaeological record. Sieving large volumes of sediment with a fine mesh (around 2 mm) seems to be an answer. With a finger, it is now possible to gain access to the exploited species, their biotopes, the original size of the crab, and a quantification of the meat yield. All data on crabs are particularly relevant if they can be combined with studies of other marine resources (shells, urchins, fish, marine mammals, birds, etc.) and incorporated into the larger archaeological picture.

"Once natural resources are transformed into food through processing and cooking, food becomes a form of material culture which is bound up inextricably with symbolism, ritual, and cultural identity" (Milner, 2009). Crab is undoubtedly one of those resources that can tell us more about human populations from the time of capture to abandonment in waste heaps. Crab fishing may only have been reserved for part of the population (De Oliveira Côrtes, Zappes, & Beneditto, 2014; Magalhães, Barbosa, & Py-Daniel, 2006). For example, it is reserved for women and children among the Yanomami Indians of South America, who are familiar with crabs' hiding places (Magalhães et al., 2006). This memory of places of capture has also been described on the French Atlantic coast. There is also a generational transmission of periods of abundance of certain crabs on the coast (De Oliveira Côrtes et al., 2014). This crab acquisition phase can also be regulated depending on the available resources. There may thus be rotations of exploited areas throughout the year (De Oliveira Côrtes et al., 2014).

Most of the foreshore crabs identified in Mesolithic levels can be caught by hand, although there are many different ways of catching them. They can be baited in a trap using a line, a scale, or a trap. Other tools are also known to trap them such as nets or dredges.

Crab moulting may also have intrigued people. The animal leaves its carapace to start a new life and is a symbol of regeneration and immortality in many countries (Vadon, 2013). Thus, the crab is used in rituals to symbolise the passage to adulthood among Yanomami women (Magalhães et al., 2006). In addition to its moult, its appearance, its life in the sea, and the way it walks have given rise to many legends and popular beliefs throughout the world. For example, it is used as a totem (Rivers, 1909) or as a "homem-caranguejo" God (Arcuri, 2009). The representation of the Roman god "Océan" is characterised by crab or lobster claws on the head (Fuchs, 2010). It is also particularly sought after in China as a delicacy for its “Yin” effect (Halsey, 2021).

Crustaceans were and are a highly prized food item in the diet of several populations around the world, whether they are consumed in small or large quantities. They are described in both ethnological and archaeological records (for examples Baudry et al., 2018; Gruet & Laporte, 1996; Keegan, Carlson, Delancy, & Hayes, 2018; Lavallée & Béarez, 2012; Lidour, Béarez, Beech, Charpentier, & Méry, 2021; Magalhães et al., 2006; Mougne, 2015; Rick et al., 2015; Serrand, Vigne, & Guilaine, 2005; Zilhão et al., 2020). In many cases, coastal populations catch them for food and differentiate species by their taste (for example Magalhães et al., 2006). In some populations, food taboos surround these crustaceans (Rivers, 1909; Vadon, 2013). As scavengers, they consume corpses, which means that they have sometimes been associated with death or bad omens. Some populations also developed specific tools for shelling crabs. Some of these tools are currently available on tables. For example, the Ming dynasty in China has eight different tools for eating crabs (Vadon, 2013).

Crabs are not absent from funerary contexts either. Representations of them have been found in such contexts (Bodson, 1989; del Solar Velarde, 2015).

These few examples have been listed to illustrate the contrast between the possibilities of thematic development in archaeology and the lack of interest shown by archaeologists. We hope that this review will arouse archaeologists’ interest and prompt them to include the search for these ten-legged animals in their excavations.

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