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Intensive exploitation of marine crabs and sea urchins during the Middle Holocene in the Eastern Arabian Peninsula offers new perspectives on ancient maritime adaptations.

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Abstract

Maritime adaptation is a key component of the Neolithization process in Eastern Arabia. It is expressed by the development of diversified fishing techniques, the exploitation of hard marine animal materials (e.g., seashells, shark teeth, stingray's barbs, etc.) for both tools and personal adornments production, advanced seafaring, and colonization of offshore islands. Although a diet based mainly on the consumption of marine fish and molluscs, the importance of other seafood have been greatly underestimated in previous zooarchaeological studies. Large quantities of marine crabs (NISP = 10,619) and sea urchins (NISP = 2454) have been retrieved from newly excavated Neolithic sites in the United Arab Emirates. These data highlight local developments of interest for specific seafood and their intensive exploitation over several centuries of human occupation. This study focuses on methods for identifying the main edible marine crab and sea urchin species retrieved from archaeological sites in Eastern Arabia. Results from the Neolithic sites of Delma island and the Umm al-Quwain lagoon are discussed.

Keywords: Neolithic; Maritime adaptation; Coastal Archaeology; Zooarchaeology; Marine crab; Sea urchin

1. Introduction

In coastal Eastern Arabia, the Neolithization process (ca. 6500-3300 BCE) is characterised by the development of subsistence economies that were primarily based on herding and the exploitation of marine resources. The long-term occupation of islands and coastal areas and the intensive foraging activities are evidenced by the large number of archaeological sites that have been surveyed and excavated to this day from Kuwait to the Sultanate of Oman. Nevertheless, the discovery of inland sites including important cemeteries in the foothills of the Western Hajar also provides a more complete view of the range of mobility patterns – possibly linked with pastoral movements. Despite wetter climatic conditions at that time (e.g. Parker et al., 2004; Berger et al., 2013), the rainfalls were not sufficient to allow the development of rain-fed agriculture that is the case as in the Fertile Crescent. Therefore, an original form of oasis agriculture developed from the 3rd millennium onwards in the UAE and the Sultanate of Oman supporting the emergence of more complex societies within a regional Bronze Age.

At the last glacial maximum (ca. 18,000 BP), sea level in the Persian Gulf was about 120–130 m lower than it is today, resulting in the retreat of the sea to the Strait of Hormuz and exposure of a vast dry land. Then, the Flandrian transgression was a period of rapid sea level rise: sea level is assumed to have been fairly close to modern sea level by about 5000 BCE but continued to rise until the middle of the fourth millennium BCE, reaching ca. 2–3 m asl. Thereafter, it gradually dropped at an average rate of ca. 40 cm per millennium until the present (Lambeck, 1996; Sanlaville & Dalongeville, 2005). The association of a marine transgression and a wetter climate during the Neolithic in Eastern Arabia has greatly contributed to the development of coastal eco systems, including not only mangroves (Berger et al. 2013) but presumably also seagrass meadows and coral reefs. According to Safarkhani et al. (2021), about 3000 BCE (which corresponds to the end of the Neolithic in Eastern Arabia) the mean sea surface temperature (SST) was ca. 3°C lower than that of today in the Persian Gulf. A cooler SST has probably contributed to creating less harsh hydrological conditions, helping sustain the coastal ecosystems. Neolithic people settled along the coast and on islands had access to a wide range of resources provided by these highly productive ecosystems, including large quantities of marine fish, mollusks, and crustaceans. In that respect, the Eastern Arabian Neolithic constitutes an original case of "coastal adaptation" (Beaton, 1995) by human groups of the Saharo-Arabian arid belt during the Middle Holocene.

Zooarchaeological investigations conducted in Arabia during the last couple of decades have demonstrated that Neolithic groups feed on a variety of seafood products, including shellfish, fish, marine mammals, and sea turtles. The consumption of fish and shellfish has been particularly emphasised within hunter-gatherer studies that focused on calorific and energetic inputs. Conversely, marine crabs and sea urchins has been little considered by researchers to this date. Nonetheless, they can be easily collected in large numbers in highly productive marine environments such as those encountered in Eastern Arabia – in particular mangroves and reef systems. Detailed studies have significant interest for such seafood in

other parts of the world. For crabs, in Western Europe (Gruet & Laporte, 1996; Gruet, 2002; Dupont & Gruet, 2005; Milner, 2009; Pickard & Bonsal, 2009; Mougne, 2015; Gutierrez-Zugasti et al., 2016; Dupont, 2017), in Northern America (Bender, 2019; Losey et al., 2004; Rick et al., 2015), in the Caribbean (Wing, 1995; Grouard 2001; 2002; Serrand, 2002; Newsom & Wing, 2004), in Southern America (Lavallée et al., 1999; Lavallée & Béarez, 2012) as well as in the Levant (Ashkenazi et al., 2005). For sea urchins, in Western Europe (Campbell, 2008; Mougne & Dupont, 2011; Gutierrez-Zugasti, 2011; Bejega García et al., 2014; Mougne et al., 2014; Gutierrez-Zugasti et al., 2016; García-Escárzaga et al., 2017), in Northern America (Ainis, 2020; Erlandson et al., 2005; Bender, 2019), in Southern America (Jerardino et al., 1992; Lavallée et al., 1999), and quite abundantly in Oceania: Kisar Island (O'Connor et al., 2019), New Ireland (Allen et al., 1989), New Caledonia (Sand et al., 2002), Norfolk Island (Campbell & Schmidt 2001), New Zealand (Walter et al., 2011), and Hawaii (Weisler et al., 2020). However, this thematic remains greatly un-investigated in the Indian Ocean.

Recent excavations conducted at Neolithic sites located on Delma Island (Emirate of Abu Dhabi, UAE) and in the Umm al-Quwain lagoon (Emirate of Umm al-Quwain, UAE) have provided large numbers of sea urchin and marine crab remains respectively. The occurrence of numerous crab remains have been previously reported within other Neolithic assemblages of Eastern Arabia such in the Suwayh-Ruwayz area (Sultanate of Oman) (Charpentier et al., 2000), but has never before been examined in detail. Crab consumption has been also reported during the Iron Age at Rafaq and from the Sassanian to the Islamic periods in Kush (both situated in the Emirate of Ra's al-Khaimah, UAE) (Kennet, 1997; Beech & Hogarth, 2002; Beech, 2004: 155, 163), as well as more recently from the Kalba fort (16-18th centuries AD, Emirate of Sharjah, UAE) (Callapez & Dinis, 2020). The occurrence of long-spined sea urchin (*Diadema setosum*) has been reported at the Neolithic site of as-Sabiyah H3 (Kuwait) (Beech, 2010: 135, tab. 7.2). *Diadema* urchins are edible despite being small and capable of causing pain with their long mildly venomous spines. Note also that fossilised urchins are frequently found within archaeological sites in the Oman peninsula, such as in the Jebel Buhais area (Emirate of Sharjah, UAE) and the Bani Bu Ali Wilayat (Ash-Sharqiyah, Sultanate of Oman).

The present paper is intended to provide identification keys of the main edible marine crab and sea urchin species encountered in coastal Arabia. It includes the study of crab remains retrieved from the sites of UAQ2, UAQ36, and Akab (Umm al-Quwain lagoon) and of urchins from DA11 (Delma Island) (Figure 1). The discussion will focus on identifying the natural habitats which were exploited, foraging strategies and techniques, as well as cooking methods.

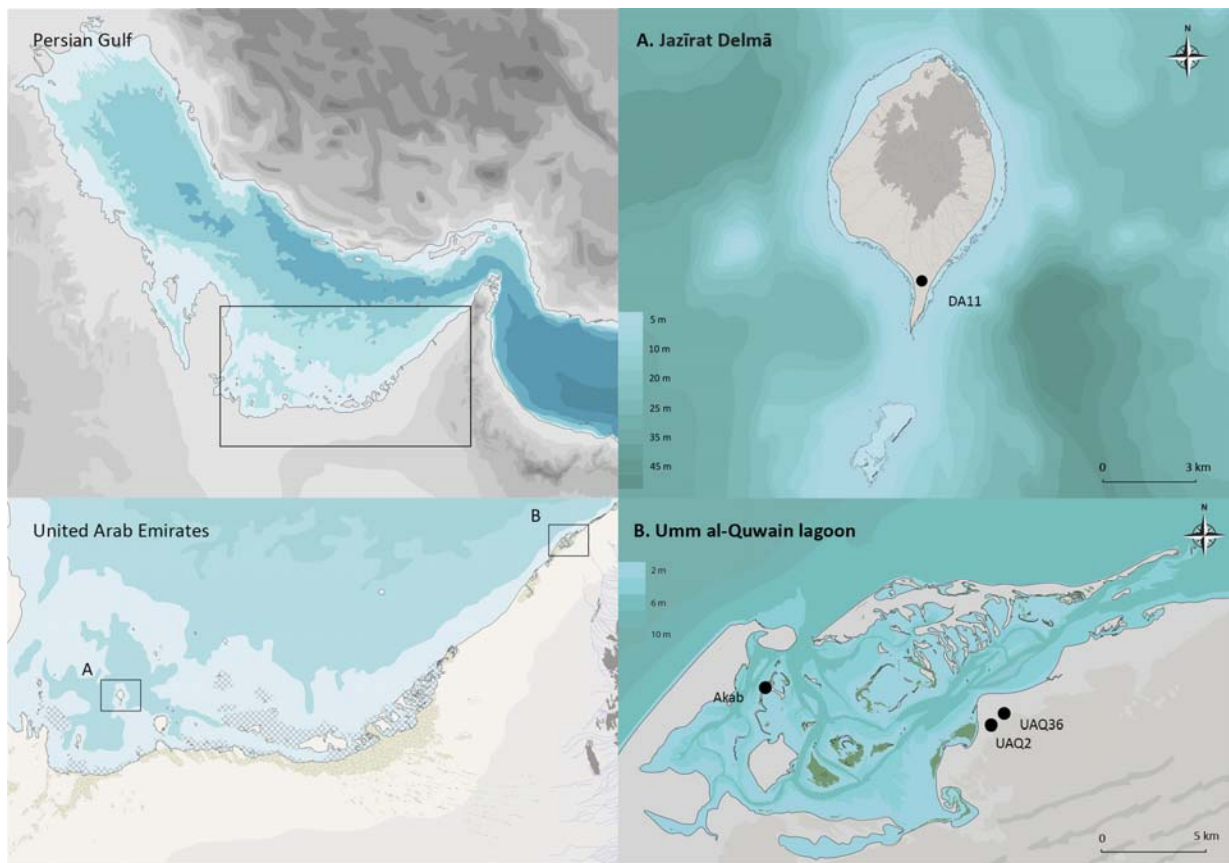


Figure 1. Localization of the sites studied in this article. **A.** Delma Island, site DA11; **B.** Umm al-Quwain lagoon, sites Akab, UAQ2, and UAQ36. Coastline drawing based on 1965-1972 CORONA satellite imagery (USGS-EROS). CAO: © K. Lidour.

2. Environmental and archaeological settings

Delma island, Emirate of Abu Dhabi

Delma Island lies about 50 km off the coastline of the Emirate of Abu Dhabi and 30 km in the northwest of Sir Bani Yas Island (Figure 1.A). The island is composed of a rocky core reaching about 100 m above sea level and surrounded by a rim of marine sediments and reef. The coastline is bordered by a wide fringing reef extending seaward for several hundred metres and which is, at low tide, accessible on foot. Beyond the reef edge, deeper reefs are accessible by boat. Coral assemblages thriving in the area are mainly composed of *Porites* and *Acropora* species. On the island, brackish sources of water are provided by artesian aquifers. They support the establishment of a few mangroves in mudflats and small lagoons.

DA11 (24°30'38"N; 52°18'37"E) is a Neolithic settlement located in the city center of Delma town, close to the leeward coast of the island (King, 1998; Beech & Elders, 1999; Beech et al., 2016). It is likely that the ancient inhabitants of the site have opted for such particular location since it is offering a secure moorage for their boats. Archaeological deposits continue from the surface down to 1.7 m deep and grouped into several phases. The earliest

occupational phase is directly settled on ancient sand beach, suggesting that the site was closer to the shoreline in the past. Radiocarbon dating indicate that the site was inhabited at least between the mid-6th millennium and the mid-5th millennium BCE (Supplementary Material 1). Evidence of housing and domestic activities consists of post-holes and several ashy lenses which have provided a large amount of faunal remains (Beech & Glover, 2005; Lidour & Beech, 2019). They essentially consist of marine shells, fish bones, and sea urchins (Figure 2.C). Remains of sea turtles, dolphins, and terrestrial mammals (from both herding and hunting) are also reported. The lithic assemblage is composed of a few tools in flint (arrowheads, drills, and knives) obtained locally and ground-stone artefacts made from beach pebbles (hammerstones, anvils or burnishing tools). Small pierced pebbles could have been used as net sinkers (Beech, 2004: 63). Personal ornaments include beads in marine shell and softstone. A number of pottery sherds were found – they almost all belong to Mesopotamian wares (Ubaid/Middle Chalcolithic) which were circulating in the Persian Gulf during the 6th and 5th millennium BCE (Oates et al., 1977; Méry et al., 2016). Plaster vessels were made by the site inhabitants from local sources.

Umm al-Quwain lagoon

The Umm al-Quwain lagoon is a semi-enclosed basin about one hundred kilometers southwest of the Strait of Hormuz (Figure 1.B). The water depth greatly varies inside the lagoon: between 2 and 8 meters depending on areas and tides (Department of Fisheries, 1984). Off the lagoon, the water depth gradually increases: reaching 15 meters deep at 2 nautical miles offshore (Service Hydrographique de la Marine, 1904). Sandy, muddy, and rocky substrates occur in the lagoon, supporting the development of tropical coastal marine ecosystems (mangrove forests, seagrass meadows, and sparse coral reefs). The shallowness of the waters allows roaming a wide bare area at low tide, facilitating extensive shellfish collection. According to local fishermen, important coral reefs are accessible by boat a few miles off the lagoon (K.L.).

UAQ2 (25°34'37"N; 55°39'16"E) is a Neolithic shell-midden located on the eastern edge of the Umm al-Quwain lagoon. The site is on the top of a Pleistocene sand mega-dune overhanging a wide *sabkhah*, a salt-crushed depression corresponding to an ancient lagoon area. The site is composed of a settlement and an important cemetery where the remains of at least 47 individuals were found (Phillips, 2002; Méry, 2015; Méry et al., 2016). Radiocarbon dating indicated that occupation took place from the mid-6th millennium BC to the end of the 5th millennium BCE (Supplementary Material 1). Remains of architectural structures on post, hearths, and food wastes were mainly found in the settlement area. Faunal remains are mostly belonging to marine shells, terrestrial mammals, fish, and crabs (Mashkour et al., 2016). Herds were mainly composed of caprines (goats and sheeps) and, more moderately, of cattle. Hunting was conversely little practiced: a few gazelle and oryx bones were identified. The material culture is rich and well diversified at this site. It is composed of a number of lithic tools and debitage: arrowheads, scrapers, knives as well as drills and splintered pieces which were used for the confection of personal ornaments in stone and marine shell (beads, pendants, earrings). The tool kit also includes shell scraper made from large clams (*Callista* spp.) and ground-stone implements such as stone adzes, crushing stones, grinding stones, polishing stones as well as net sinkers made from pebbles.

Shell fish hooks were found in the upper levels corresponding to the late 5th millennium occupation. A great number of pottery sherds have been found during the excavations – they all belong to Mesopotamian wares.

The site of UAQ36 (25°34'57"N; 55°39'35"E) is a shell-midden located about 1 km northward of UAQ2 (Méry et al., 2019). Archaeological deposits extend from the surface to a depth of two meters. Radiocarbon dating indicate that the site was inhabited from the mid-5th millennium BCE onwards (Supplementary Material 1). It is thus roughly contemporaneous with the Akab settlement and the upper levels of UAQ2 (levels 4-8). The uppermost part of the stratigraphy possibly belong in part to the 4th millennium BCE. Housing and domestic activities are evidenced by several post-holes and hearths. However, the material culture is scarce in comparison to UAQ2 and Akab (see below). It consists of a small amount of lithic debitage (20 items, including two tools), a shell scraper, and a few beads. On the other hand, a significant quantity of faunal remains was collected: mostly marine shells, fish bones, and crab remains (Lidour et al., 2020b) (Figure 2.D). Remains of terrestrial mammals consist of a few fragments of bone shafts.

Akab (25°34'09"N; 55°34'31"E) is located on the top of a Pleistocene sand dune, which is situated on a sandy islet (Jazirat al-Ghallah) of the Umm al-Quwain lagoon. The site is composed of a settlement of the second part of the 5th millennium BCE (Charpentier & Méry, 2008) (Supplementary Material 1) and a ceremonial structure built in dugong skeletal elements dating from the mid-4th millennium BCE (Méry et al., 2009; Méry & Charpentier, 2012). Archaeological deposits are 25-35 cm thick and directly accumulated on wind-borne sands. Faunal assemblages mainly come from the settlement area, where remains of architectural structures on post (including circular houses, fences, and possible wind-barriers) were found. Domestic activities are evidenced by burned areas, food wastes as well as artefacts scattered over the soils. The faunal assemblage is composed of large quantities of marine shells, fish bones, and crab remains (Lidour et al., 2020a) (Figure 2.A-B). Dugong bones were not only found in the ceremonial structure but also frequently within the settlement. Conversely, remains of terrestrial mammals are only little represented. They however evidenced that both bovid herding and hunting were practiced by the ancient inhabitants of the site. Lithic tools are mainly splintered pieces and drills which were used in the local fabrication of personal ornaments in stone and marine shells, in particular disc beads in spondyle shell. The tool kit also includes shell implements such as scrapers in valves and fish hooks in mother-of-pearl. Fishing activities are also highlighted by the discovery of several net sinkers made from pebbles. A few pottery sherds belonging to Mesopotamian wares were found.



Figure 2. **A.** Concentration of Arabian blue crab (*Portunus segnis*) pincers, Akab settlement (© V. Charpentier); **B.** Broken pincer of giant mud crab (*Scylla serrata*), Akab settlement (© V. Charpentier); **C.** Concentration of burrowing urchin (*Echinometra* sp. EZ) remains at DA11, Trench 1 – Context 128 (© M. J. Beech); **D.** Sample of crab remains from Akab, Sector 1, Level 3 (© K. Lidour).

3. Material and methods

Sampling strategies are similar on the different sites discussed in this paper. All the excavated sediments were systematically dry sieved using a 3 mm mesh (1/8 inch). At UAQ36, additional samples of 10 L of deposit were punctually taken for sieving with a smaller mesh (1 mm), allowing the retrieving of very small faunal remains. Fine sievings were conducted systematically for each excavated context at UAQ36. The residues were overall composed of fragments of marine shells and fish bones.

Anatomical and taxonomic identifications were conducted according to the methods of comparative anatomy, using modern specimens collected during field campaigns conducted since 2015 in the UAE and the Sultanate of Oman – specimens are housed at the National Museum of Natural History (MNHN) of Paris. Identification of collected crabs was essentially conducted using species diagnoses given by Apel and Spiridonov (1998) and Naderloo (2017). Specimens of the MNHN Crustacean collection were also examined: *Portunus sanguinolentus* (B-15921 3 specimens, B-6061 3 specimens, B-6048 2 specimens, EC-906 3 specimens), *Leucosia anatum* (MNHN-IU-2016-9158 1 specimen).

Quantifications were based on the number of identified specimens (NISP), the minimum number of individuals (MNI), and the weight of identified specimens (WISP). Since crab remains were highly fragmented, a minimum number of elements (MNE) was used for quantifying crab fingers according to the occurrence of distal and proximal fragments. Hence, a MNI calculation for crabs was possible by dividing the MNE by four (given a pair of fingers by pincer) (Lavallée & Béarez, 2012) (Figure 3.B). Echinoids have a complex chewing apparatus (the Aristotle's lantern) which is composed of five calcium carbonate plates called pyramids (Brusca & Brusca, 1990: 468-469, 808) (Figure 3.A). Each pyramid is itself composed of two hemipyramids bearing a tooth (Figure 4 n°2-3, 5). An MNI calculation for urchins is thus possible by dividing the number of hemipyramids by ten.

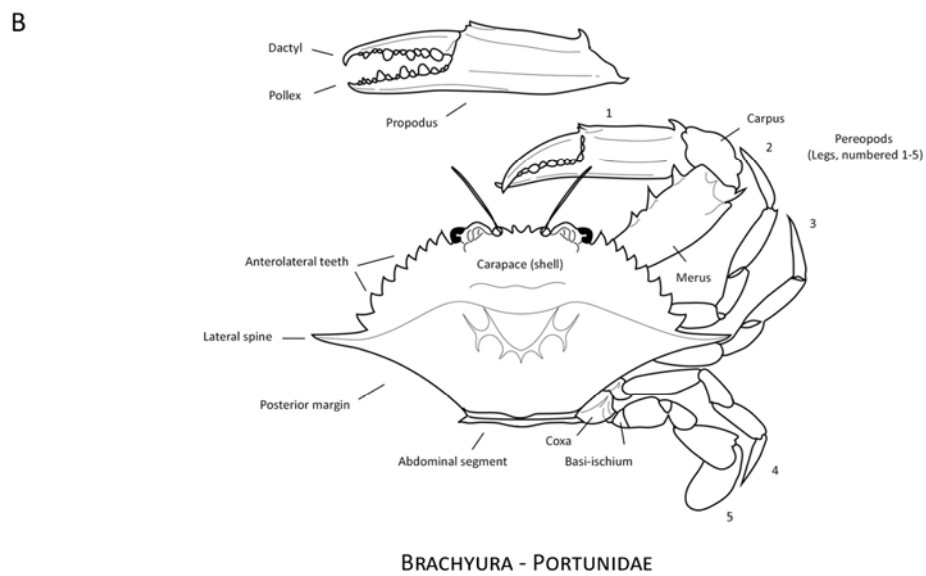
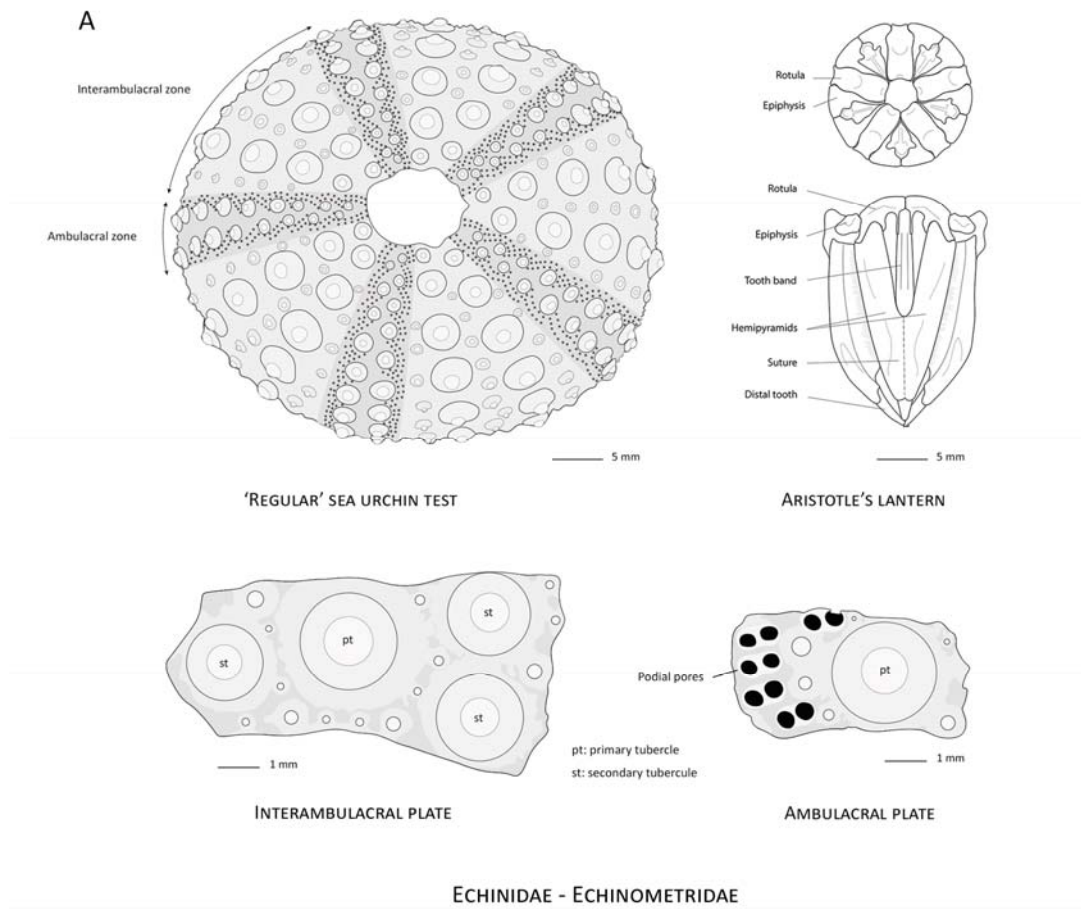


Figure 3. A. External anatomy of a burrowing urchin (*Echinometra* sp. EZ) collected in the UAQ area. **B.** Blue crab (*Portunus* sp.) general anatomy. Drawings: © K. Lidour.

4. Results

Marine crabs

A total of 10,619 crab remains were registered from the sites of the UAQ area, corresponding to a MNI of 1403 specimens. At least, 8 distinct taxa are represented. However, the assemblage is dominated by two species: the Arabian blue crab (*Portunus segnis*) (95%) and the giant mud crab (*Scylla serrata*) (3% on the NISP basis, 5% on the MNI basis) (Table 1) (Supplementary Material 3). Other identified taxa include fiddler crabs (*Cranuca inversa*), pilumnid crabs (*Eurycarcinus orientalis*), pebble crabs (Leucosiidae), ghost crabs (*Ocypode* sp.), and the mangrove swimming crab (*Thalamita crenata*). The proportions of Arabian blue crabs and giant mud crabs are highly similar at UAQ2 and Akab, respectively 97% and 2.5%. A slightly larger proportion of giant mud crab is observed at UAQ36 (6.6%). Crabs are represented throughout the whole stratigraphic sequences of studied sites. A few crab remains were also identified in the Delma assemblage (N = 43; not presented here): they all belong to the Arabian blue crab.

UAQ2			NISP	MNI	WISP (g)
Portunidae	<i>Portunidae</i>	<i>Portunus segnis</i>	2310	339	1027.78
	<i>Scylla</i>	<i>Scylla serrata</i>	62	13	103.32
	<i>Thalamita</i>	<i>Thalamita crenata</i>	3	1	0.13
		<i>Thalamita</i> sp.	1	1	0.68
Ocypodidae	<i>Cranuca</i>	<i>Cranuca inversa</i>	1	1	1.2
			2377	355	1132.01
UAQ36					
Portunidae	<i>Portunidae</i>	<i>Portunus segnis</i>	1119	98	234.66
		<i>Portunus</i> sp.	161	-	10.43
	<i>Scylla</i>	<i>Scylla serrata</i>	93	14	76.49
	ind.	ind.	45	1	2.32
			1418	113	323.89
Akab					
Portunidae	<i>Portunidae</i>	<i>Portunus segnis</i>	6629	882	2781.04
	<i>Scylla</i>	<i>Scylla serrata</i>	172	42	290.86
		<i>Eurycarcinus</i>	9	5	0.48
Pilumnidae	<i>Eurycarcinus</i>	<i>orientalis</i>			
Ocypodidae	<i>Ocypode</i>	<i>Ocypode</i> sp.	8	2	0.987
Leucosiidae	<i>Leucosia</i>	<i>Leucosia</i> cf. <i>anatum</i>	2	2	0.722
	<i>Phylira</i>	<i>Philyra</i> sp.	1	1	0.419
	ind.	ind.	3	1	0.085
			6824	935	3074.60

Table 1. Table of identified crab from the UAQ area. Quantifications in NISP, MNI, and WISP (in gram).

Swimming crabs (Portunidae) are characterised by a hexagonal carapace and flattened paddles on their last pair of pereopods (walking legs) (Figure 3.B). Fingers generally bear large molar-like tubercles (sometimes designated as "teeth") very useful for taxonomic determinations. However, the development of tubercles is generally reduced on regenerated claws: it makes sometimes the determinations tough. Portunids reach their highest diversity in the Indo-West Pacific, where several species are economically valued, including blue crabs (*Portunus* spp.) and the giant mud crab.

The Arabian blue crab fingers are straight and elongated, especially for the male specimens (Figure 5 n°1-4). Several crab species show darker areas on their fingers, generally around the tips. It corresponds to a bromine-rich material which strengthens the shell and prevents it from fracture (Schofield et al., 2009). This anatomical feature generally depends on species (D. Guinot, pers. com. for K.L.). For blue crabs, this area is restricted to the tip of each finger, close to or after the last tubercle.

Dactyls bear a single line of 14-17 tubercles (Figure 5 n°1, 3), including 3 repetitions of a tubercle triplet, whose organization always follows the same scheme: a large and high tubercle surrounded by two smaller secondary ones (one located proximally, and the other one distally). Pollexes can bear from 16 to 18 tubercles depending on the size of the crab: two small tubercles arranged in a pair tend to fuse together when they get bigger (e.g. Gruet 2002: 131). Therefore, tubercles are arranged as it follows: from 1 to 3 pairs of medium-sized tubercles (the second and third pairs become a single large tubercle respectively with time), and a single line of either 11-14 tubercles for the crushing pollex (Figure 5 n°4) or 14-16 tubercles for the cutting pollex (Figure 5 n°2). As for dactyls, we observed the same repetition of 3 tubercle triplet on pollexes.

Fingers are curved and distinctively shorter for mud crabs and mangrove swimming crabs (Figure 5 n°5-12). The dark color pattern generally covers the tips and almost all the tubercles for both mud crabs and mangrove swimming crabs. For giant mud crabs, dactyls bear a single line of about 11-12 molar-like tubercles (Figure 5 n°5, 7) whereas pollexes bear from 1 to 3 pairs of tubercles followed by a single line of 8-10 tubercles (Figure 5 n°6, 8). As for blue crabs, the second and third pairs of tubercles found on pollexes tend to become 2 single large tubercles with time. On both dactyls and pollexes, we observe only 2 tubercle triplets. There is no difference between crushing and cutting fingers in the organization of their tubercles.

For mangrove swimming crabs, crushing and cutting claws greatly differ. The crushing dactyl bear a single line of about 10-12 discernible tubercles: the first and most proximal one is prominent, the other tubercles are significantly smaller (Figure 5 n°9). Three tubercle triplets can be distinguished. The cutting dactyl bear a single line of 16-17 tubercles, including 3 tubercle triplets (Figure 5 n°11). The crushing pollex bear a pair of tubercles followed by a single line of 10-11 tubercles, including two tubercle triplets (Figure 5 n°10). The cutting pollex bear a unique pair of proximal tubercles followed by a single line of 12-14 small tubercles, including 2-3 tubercle triplets (Figure 5 n°12). Note that a few minute tubercles sometimes precede the tubercle series on pollexes.

Decapod crustaceans have an exoskeleton essentially composed of chitin mineralised with calcium carbonate. Chelipeds and mandibles are generally well preserved since their shell is thicker and more calcified than other parts of the exoskeleton (Reitz & Wing, 2008: 50). Therefore, recorded anatomical elements are almost entirely composed of finger fragments within archaeological contexts (Table 2) (Figure 6 n°1-4, 6-9). However, despite the careful retrieval practices adopted, no crab mandible was identified in the studied assemblage. Small carapace fragments and apodemes¹ (Figure 6 n°5) were more frequently found at UAQ36 thanks to systematic fine sievings and careful sortings. Fragments of thick carapace shell were more commonly retrieved, in particular from giant mud crabs (whose shell thickness can reach up to 5 mm). Fire marks were frequently observed on fingers (ca. 3-4% of the total NISP) – in particular on the tips (Figure 6 n°2).

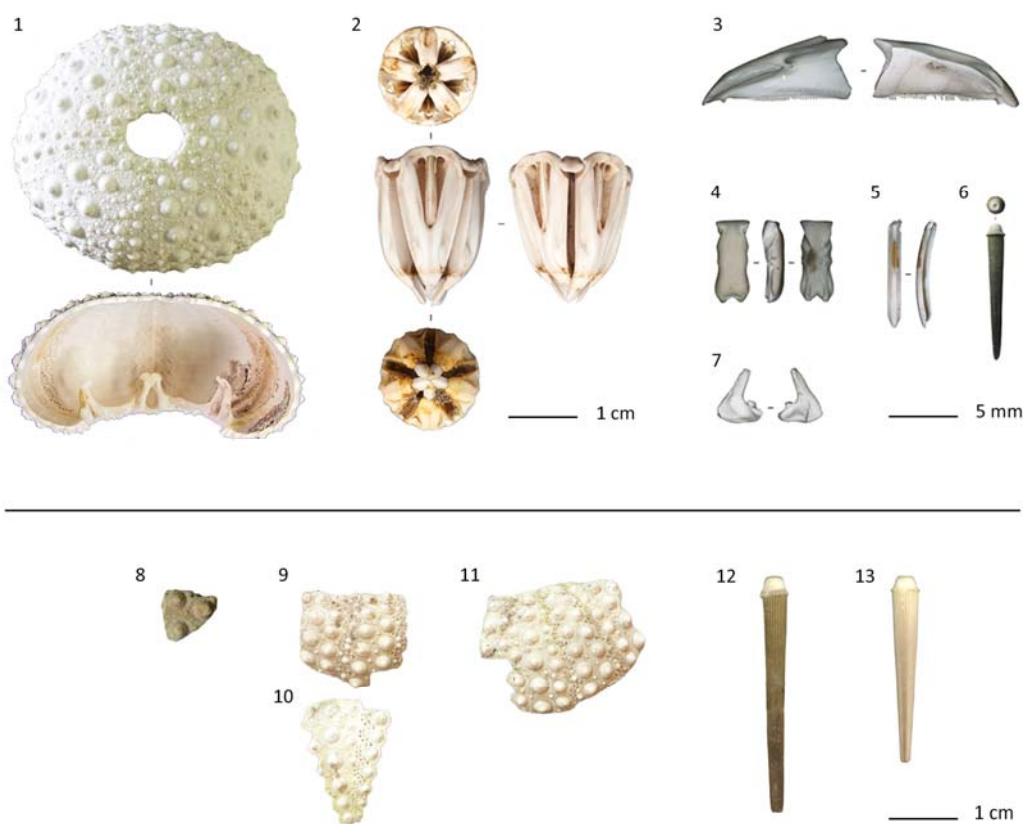


Figure 4. 1-7. Reference anatomical elements of the burrowing urchin, *Echinometra* sp. EZ; 8-13. Archaeological specimens from sites studied in the present paper – **1.** Upper (aboral) and internal views of the reference test (without spines); **2.** Reference Aristotle's lantern; **3.** Reference hemipyramid; **4.** Reference rotula. **5.** Reference tooth; **6.** Reference spine; **7.** Reference epiphysis; **8.** Test fragment from Akab; **9-11.** Test fragments from Delma DA11; **12.** Spine from Delma; **13.** Spine from UAQ2. Images: © K. Lidour.

¹ The apodeme is a ridge-like structure articulated to the finger bases and providing attachment points for opener and closer muscle tendons.

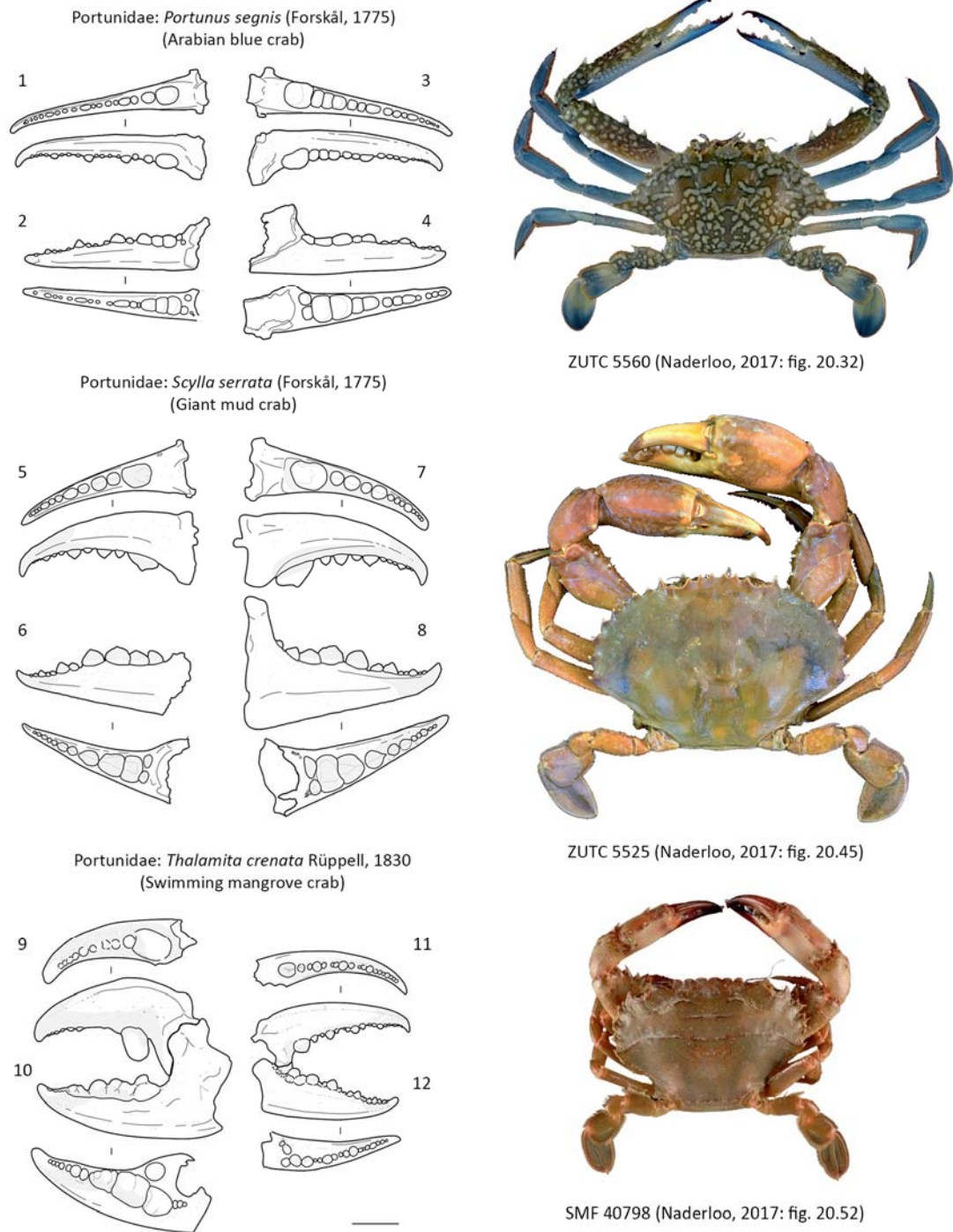


Figure 5. Determination drawings of crab fingers for the main edible crab identified. Fingers are represented in cranial/ventral and mesial views. **1.** Right dactyl of the Arabian blue crab, *Portunus segnis*. **2.** Right pollex of the Arabian blue crab, *Portunus segnis*. **3.** Left dactyl of the Arabian blue crab, *Portunus segnis*. **4.** Left pollex of the Arabian blue crab, *Portunus segnis*. **5.** Right dactyl of the giant mud crab, *Scylla serrata*. **6.** Right pollex of the giant mud crab, *Scylla serrata*. **7.** Left dactyl of the giant mud crab, *Scylla serrata*. **8.** Left pollex of the giant mud crab, *Scylla serrata*. **9.** Right

dactyl of the swimming mangrove crab, *Thalamita crenata*. **10.** Right pollex of the swimming mangrove crab, *Thalamita crenata*. **11.** Left dactyl of the swimming mangrove crab, *Thalamita crenata*. **12.** Left pollex of the swimming mangrove crab, *Thalamita crenata*. Drawings: © K. Lidour; Live specimens photos: Naderloo, 2017; Scale: 1 cm.

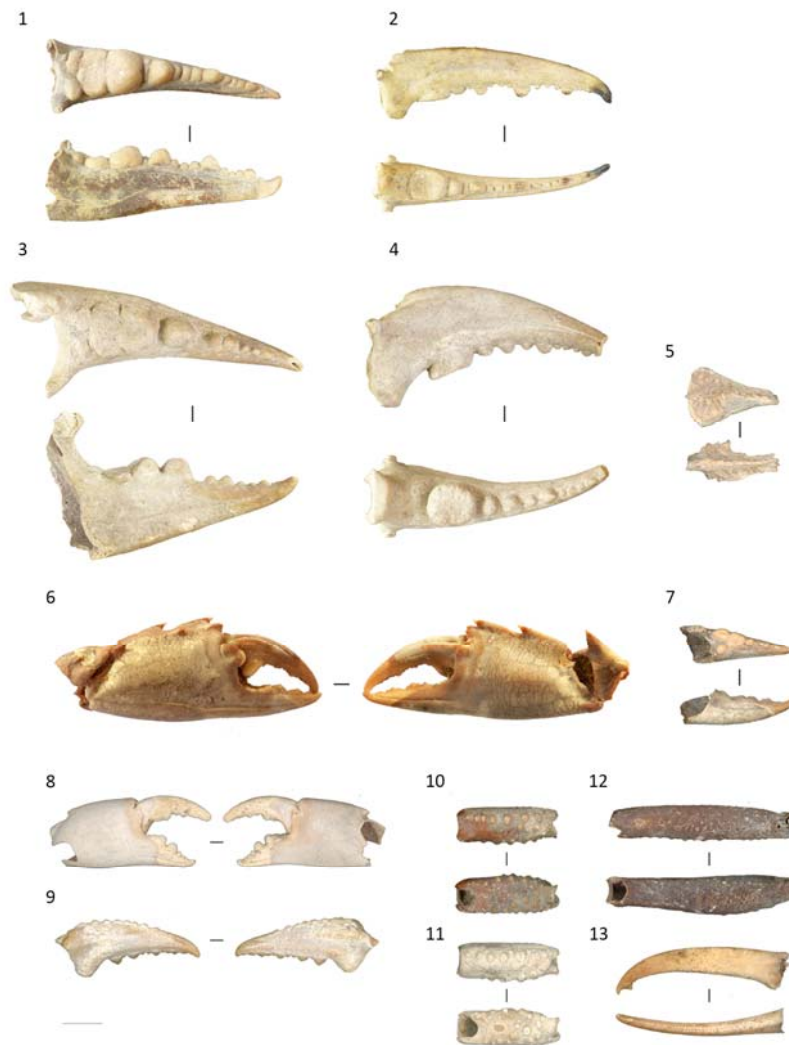


Figure 6. Archaeological specimens of marine crab remains retrieved from the studied sites: **1.** Left pollex of the Arabian blue crab, *Portunus segnis*, UAQ2; **2.** Left dactyl of the Arabian blue crab, *Portunus segnis*, UAQ36; **3.** Left pollex of the giant mud crab, *Scylla serrata*, Akab; **4.** Left dactyl of the giant mud crab, *Scylla serrata*, UAQ2; **5.** Apodeme of portunid crab, Portunidae, UAQ36; **6.** Right claw (carpus, propodus, dactyl, and pollex) of the mangrove swimming crab, *Thalamita crenata*, UAQ2; **7.** Right pollex of the mangrove swimming crab, *Thalamita crenata*, Akab; **8.** Right claw (propodus, dactyl, and pollex) of the pilumnid crab *Eurycarcinus orientalis*, Akab; **9.** Right dactyl of a ghost crab, *Ocypode* sp., Akab; **10-11.** Right meri of the leucosiid crab, *Leucosia* cf. *anatum*, Akab; **12.** Left merus from a leucosiid crab, *Philyra* sp., Akab; **13.** Right dactyl of the fiddler crab, *Cranuca inversa*, UAQ2. Images: © K. Lidour; Scale: 1 cm.

Sea urchins

A total of 2454 sea urchin remains were recorded from the Delma assemblage. Urchins occurred in all the occupational phases but mostly came from contexts dating from the end of the 6th and the beginning of the 5th millennium BCE: 80% from Phase 4, 4% from Phase 3, and 11% from Phase 2 (for the description of the phases, see Beech & Elders, 1999). All the identified pieces belong to the burrowing urchin (*Echinometra* sp. EZ). Remains retrieved from UAQ2 Level 14 (N = 1) and Akab Level 3 (N = 1) also belong to this species.

The urchin test is a rigid structure divided in five ambulacral and interambulacral areas. Each area is composed of rows of plates bearing several tubercles – where spines (or radiolae) are attached. For *Echinometra* species, each ambulacral and interambulacral plate bears one large primary tubercle (Figure 3.A). Interambulacral plates generally bear 2-3 medium-sized secondary tubercles. Ambulacral plates bear 5-7 pairs of podial pores arranged in arcs and separated by adradial small tubercles. Tubercles are never perforated, unlike for *Diadema* species. Spines are stout, pointed, and elongated. But their length generally does not exceed the test diameter. They bear a fluting ornament very distinct from the spine-like verticillate pattern of *Diadema* species.

CRAB	UAQ2	UAQ36	Akab	URCHIN	DA11
Distal finger frag. (tip)	375	142	1005	Spine	1278
Proximal finger frag. (basis)	1197	340	3548	Test frag.	919
Ind. pincer fragment	790	687	2253	Hemipyramid	241
Carpus	-	-	1	Epiphysis	11
Merus	-	1	5	Rotula	5
Apodeme	1	45	-		2454
Carapace fragment	13	203	12		
Lateral spine	1	-	-		
	2377	1418	6824		

Table 2. Anatomical elements recorded.

Urchin test and spines are composed of calcium-organic composite materials favoring their good preservation within archaeological contexts (Figure 4). Recorded pieces are mostly spines (52%), fragments of test (37%) which include madreporites, ambulacral, interambulacral, buccal, ocular, and genital plates (not separated in the general counting here). Hemipyramids are also represented (about 10%). Conversely, epiphyses, teeth, and rotulae are little found (Table 2), possibly lost by lack of fine sievings. A NMI of 33 urchins was obtained given the number of hemipyramids from each archaeological context. However, given the large amount of spines and test fragments collected, it is likely that this number is greatly underestimated. Fire marks were only observed on a few test fragments (N = 10; 0.4% of the total NISP).

5. Discussion

Taxonomy and ecology of the main taxa recorded

A recent revision of the *Portunus pelagicus* (Linnaeus, 1758) species complex outlined that blue crabs encountered in Arabian peninsula all belong to the species *Portunus segnis* (Forskål, 1775) (Lai et al., 2010) – also native in the Red Sea and Pakistan. Males are generally bright blue in color (especially on their legs), whereas females are beige and greenish. Both bear numerous white spots on their bodies. Males are also characterised by quite longer chelipeds than females. The Arabian blue crab inhabits shallow coastal marine habitats (2-15 m) such the fore-reef zone, seagrass beds, and mangroves. It is mainly found in shallow bays with sandy and muddy bottoms (Dai & Yang, 1991; Carpenter et al., 1997: 38). Shrimp trawls, seine nets, and stake nets are used to catch this species nowadays. It can reach up to 17.5 cm in CW (Carapace Width), corresponding to a maximum weight of 275 g (Kamrani et al., 2010; Hosseini et al., 2014: tab. 1). The Arabian blue crab mainly feeds on shrimps, molluscs (mostly small bivalves such as clams and carditas), small and juveniles fish as well as vegetal debris (Guinot, 1966: 88; Zainal, 2013). It is the most important edible crab caught and traditionally consumed in the Arabian Peninsula (Iddison, 1998).

Keenan et al. (1998) have pointed out that *Scylla serrata* is a species complex grouping four valid taxa native from the Indian Ocean: *Scylla serrata* (Forskål, 1775), *Scylla olivacea* (Herbst, 1796), *Scylla tranquebarica* (Fabricius, 1798), and *Scylla paramamosain* Estampador, 1949. However, up to date, only *S. serrata* has been reported in the Arabian Peninsula (Alberts-Hubatsch et al., 2016). While well present in Yemen and Sultanate of Oman, the giant mud crab is only little documented on the Arabian shores of the Persian Gulf – in the emirates of Umm al-Quwain and Ra's al-Khaimah (Department of Fisheries, 1984; Hogarth & Beech, 2001). Conversely, specimens are well present in coastal South-East Iran, in particular on Qeshm and Hormuz islands (Naderloo et al., 2013). Giant mud crabs is also reported from Khor Kalba, in UAE Eastern Provinces, along the Gulf of Oman (Apel & Spiridonov, 1998: 313). The giant mud crab is one of the Indo-West Pacific's most important edible crab and is particularly valued because of its suitability for aquaculture (Shelley & Lovatelli, 2011). In the UAE, the majority of crabs sold in the fish markets are blue crabs, with no giant mud crab being sold. This may be due to a number of factors: mangrove areas may be less extensive now than they were in the past. They are not currently intensively exploited because some of them are designated protected areas. The giant mud crab inhabits coastal marine habitats characterized by brackish or fresh waters such as swamps, mangroves, estuaries, and tidal rivers. This species is well known for burrowing and hiding into mud (Motoh, 1979; Brown, 1993). It mainly feeds on crustaceans (shrimps and smaller crabs), small fish, molluscs, and vegetal debris. On Europa Island (Mozambique Channel), giant mud crabs are reported to live between mangrove's aerial roots and inside large crevices in rocks (Fourmanoir 1952: 174). It is medium to large in size and can reach a maximum CW of 22-23 cm. Largest specimens can weight over 2 kg (Estampador 1949: 101). Doubtful larger sizes are however reported by certain sources (for a review, see Guinot 1966: 55).

The mangrove swimming crab has little economic value. It is encountered in the intertidal zone: mostly in tide pools and tidal creeks located in the vicinity of seagrass areas and mangroves (Fourmanoir, 1954: 10; Crosnier, 1962: 132). Specimens generally do not exceed 8 cm CW,

corresponding to a few dozen grams only. This small species of portunid crab is frequently bycaught with blue crabs (*Portunus* spp.) in Indonesia (Hamid et al., 2020). The other crab species identified in the present assemblage are small burrowing crabs mostly encountered in the intertidal area. They are little represented and of little interest – it is likely that they are intrusive within the archaeological contexts since they are only found in the uppermost layers.

Burrowing urchins belonging to the species *Echinometra mathaei* (Blainville, 1825) show a high morphological variation in their test shape and spines color (Arakaki et al., 1998). Recent DNA and mitogenomic sequencings (Bronstein & Loya, 2013; Ketchum 2018) have suggested that burrowing urchins from the Persian Gulf belong to an undescribed species *Echinometra* sp. EZ – sequenced specimens were originated from Dhabiya reefs (Emirate of Abu Dhabi, UAE). Burrowing urchins are abundant in reef environments of the Indo-West Pacific area (Mortensen, 1943). They are encountered in shallow subtidal waters (from the low tide line down to 10 m deep) (George, 2005; McClanahan & Muthiga, 2006), colonising hard substrates including corals by boring (Shoppe 2000). Sea urchins generally feed on benthic algae and other invertebrates, in particular living corals – sometimes resulting in a reducing of their survival (Lawrence, 1975; Glynn et al., 1979). The burrowing urchin is the most abundant species of sea urchins encountered in the Persian Gulf (Riegl & Purkis, 2012: 28): population densities are estimated of 4-5 individuals by m² on Delma Island (Ibid: 61, fig. 4.9). The highest densities are reported in Kuwait reef systems (e.g. Qaro Island, Kubbar Island, and Umm al-Maradem) where Downing and Robert (1993) estimated from 20 to 80 individuals by m². Specimens can reach up to 6 cm in diameter, and about 100 g in weight (Muthiga & McClanahan, 1987).

Collecting areas and potential foraging techniques

In Eastern Arabia, the fishing activities are traditionally gendered: the professional fishing industry is exclusively carried out by men, whereas the women (sometimes with the help of children) are involved in small-scale exploitations of marine invertebrates such as shellfish, cuttlefish, sea cucumbers (holothurian), and blue crabs (Bose et al., 2013; al-Rashdi & McLean, 2014). So far, there is no clear evidence that foraging tasks were gendered within Neolithic communities in Arabia. Although the relationship of grave goods to Neolithic social structure is uncertain, it is interesting to note that fishing tools (shell fishhooks and stone net sinkers) are reported from both female and male burials at Ra's al-Hamra RH5 (Sultanate of Oman) (e.g., Graves 66 and 82 are female burials) (Salvatori 2007: 126, 149). Although objects of common use are rarely present in Neolithic graveyards, individuals are frequently adorned with seashell and stone jewelry regardless of age or sex (De Beauclair 2008, 148; Bortolini & Munoz 2015: 63).

On both sides of the Oman peninsula, sea snails, bivalves, and sea cucumbers are directly gathered by hand, while cuttlefish and blue crabs are usually speared in shallow waters (Supplementary Material 4). In Umm al-Quwain, resort hotels are used to organise crabbing trips in shallow waters after dusk – crabs are easily speared when dazzled by headlamps. Catches are mainly composed of blue crabs, a few cuttlefish, and more rarely giant mud crabs (K.L.). One could imagine that Neolithic fishermen already used torches for crabbing at night. In the Persian Gulf, blue crabs are also frequently caught in traditional dome-shaped cage traps (local Arabic: *gargūr*) (Chen et al., 2012), as well in intertidal barrier traps (local Arabic: *ḥāḍra*; *skār*) (McEwan et al., 2001; al-Baz et al., 2007). Archaeo-ichthyological investigations conducted on the studied sites have outlined the

potential use of such fishing devices (Mashkour et al., 2016; Lidour et al., 2020a; 2020b).

Techniques of capture for giant mud crabs could be trapping, spearfishing or bare hands (in particular when crabs are resting on the mud, among the mangroves). In West Bengal and South-East Asia (e.g. Thailand, Philippines, Java, and Northern Australia) giant mud crabs are traditionally dislodged from their burrows using a long hook. In New Caledonia, a simple mangrove root or branch was traditionally used in this way (Rocklin, 2006). In Eastern Arabia, amateur fishermen generally wrap an arm with rags prior to introduce it in the burrow (V.C.). The crab instinctively grabs and squeezes the intrusive arm. In this way, the fishermen can pull the crab out of its burrow without injuries. Indeed, being able to crush thick seashells (such as *Terebralia palustris*), mud crab claws are particularly harmful (Williams, 1978).

Giant mud crabs thus could have been caught in such ways by Neolithic inhabitants of the UAQ lagoon during shellfish collections in the mangrove. It is also likely that individuals were speared alongside blue crabs during their routine movements between their burrows and the sea. Note that giant mud crabs can also be occasionally bycaught using fishing lines, beach seines, and gill nets. However, considering the large number of crab remains found at the different sites of the UAQ area, it is more than likely that crabs were deliberately exploited using specialised techniques. In the absence of metal, Neolithic spearheads could have been made using fire hardening wood, flint or possibly stingray's barbs.

Field observations have confirmed that burrowing urchins can be encountered just below the low tide line, among rocks. It is likely that urchins were collected by hand alongside seashells such as crowned turban shells (*Lunella coronata*) among intertidal rocks in the fore-reef zone (Beech & Glover, 2005).

Although sea urchins could have been gathered all year round by Neolithic people, *Echinometra mathaei* has better nutritional value in late spring, prior to its spawning season. In the months prior to spawning, sea urchins replenish their nutritional reserves, resulting in the growth of their gonads. During spawning, the release of eggs and sperm reduces gonad size, resulting in lesser nutritional value during this period. Alsaffar and Lone (2000: 847, fig. 2) found a single peak of spawning for *E. mathaei* in Kuwait, occur ring in late June-July. Therefore, the gonads are the biggest between April and early June. Another study conducted in South-West Iran (Keshavarz et al. 2017) confirms that the gonads develop mainly in spring in the Persian Gulf. Interestingly, Lidour and Beech (2019, 216) have suggested that the DA11 inhabitants could have captured large orange-spotted groupers (*Epinephelus coioides*) on the occasion of seasonal aggregations during their spawning season (peaking in May according to Grandcourt et al. 2005). In that respect, data from archaeological sea urchins and fish remains corroborate each other and support the idea that the DA11 site was inhabited at least during late Spring.

Dietary considerations

For crab remains, fire marks are often seen on finger tips, where the shell is the thinnest. Experimentations suggest that crabs were directly cooked on burning coals before to be eaten (K.L.). The presence of numerous small fragments of carapaces (when they are retrieved by fine sieving and identified, such as at UAQ36) suggest that crabs were brought to the site and consumed in a relatively complete form. Indeed, traces of charring were also

often observed on carapace fragments. Interestingly, at Akab, Arabian blue crab fingers were frequently found by pairs (Figure 2.A.; Charpentier & Méry, 2008: 131). It is likely that the dactyls and the pollexes have undergone bending in order to be separated from the propodus. Callapez and Dinis (2020: 317) report that, at Kalba Fort, the mud crab claws were probably broken using stones or other hard tools to access the edible flesh. Indeed, mud crab claws are generally too thick to be broken directly by hand. Observations of urchin tests on archaeological soils suggest that they were split open to access the edible parts (urchin roe or corals, which corresponding to gonads). The latter were probably eaten raw since no fire marks was observed on test fragments and spines.

Crabs and sea urchins are important sources of vitamins and minerals, in particular in phosphorus, sodium, and potassium. The meat yield is situated about 39-43% for blue crabs (Brown, 1986; Rasheed & Mustaqim, 2014: tab. 11) while about only 16-29% for giant mud crabs (Georges et al., 1986) (Supplementary Material 2).

Sea urchin gonads are gourmet seafood delicacy in many parts of the world including in Japan, in the Mediterranean, in the West Indies, in Chile, for Native Americans in California and for Māori in New Zealand (Andrew et al., 2002; Sun & Chiang, 2015). Eating sea urchin is popularly assumed to induce a slight euphoria as it contains anandamide (N-arachidonylethanolamine or AEA) (Bisogno et al., 1997) – an endocannabinoid neurotransmitter responsible for modulating, among others, pleasure and pain signals (Devane et al., 1992). Further specialised research is however necessary to determine if this chemical compound is directly involved in the alleged 'addictive behavior' of the sea urchin consumers. Keshavarz et al. (2017: 927, tab. 1) found that the gonads represent 8.25% of the mean total body weight for *Echinometra mathaei* in Bandar-e Lengeh, South-West Iran (Supplementary Material 2).

Marine crabs and sea urchins are easy to collect and quite abundant along the shores of the Arabian Peninsula. However, their exploitation is rarely documented within archaeological sites. For instance, we noted an abundance of Arabian blue crabs on the Marawah Island seashores (Emirate of Abu Dhabi, UAE) (K.L.), although crab remains are only little attested at the MR11 site (Lidour & Beech, 2020). Therefore, the consumption of marine crab and sea urchins seems does not seem to depend on their local availability. It is likely that Neolithic peoples have developed their own local dietary preferences and have adapted their subsistence strategies accordingly. The construction of group identity can find expression in the consumption of unusual food or food with a very pronounced taste (Smith, 2006). Indeed, food and gastronomy are staple components of group identity and social cohesion which are put into practice in everyday life through commensality or ritual events., such as feasts (Hamilakis, 2008: 15). Interestingly, Carter (2010: 195–197) has linked the possession, trade, and use of Mesopotamian pottery by the Arabian Neolithic groups with the putative existence of "social intercourse, concerned with feasting and display [...] at communal events." He based his assumption mainly on the predominance of highly decorated cups, bowls, and small jars, which are more suitable for displaying and serving food and beverages than for bulk storage. However, we believe that greater attention should be paid to the spatial distribution of faunal remains on archaeological floors prior to discussing this issue in more detail.

Conclusion

In coastal Eastern Arabia, the Neolithic diet was based mainly on marine fish and molluscs. They provide an inexhaustible staple food for small and traditional coastal communities. However, seafood with lesser dietary value (in terms of calorific and proteinic inputs) such as marine crabs and sea urchins was also abundantly consumed at some sites. They could have been consumed for special occasions such as social or religious ceremonies, as El-Mahi (2000: 108) reported for mammal meat in traditional Oman. Likewise, mammal meat seems to have only played a secondary importance in the daily diet of the Neolithic coastal groups. Zooarchaeological investigations have suggested that husbandry was foremost oriented toward the production of animal milk (Mashkour et al., 2016: fig. 6). In this sense, it is also possible that hunting and marine mammal fishing were carried out more as prestigious activities than for procuring a staple food.

The sea did not only have a nurturing role, but has also greatly contributed to the construction of sustainable culinary cultures during the Neolithic. : the consumption of sea urchin is attested over several centuries of human occupation at Delma (Supplementary Material 1). However, it does not seem to have continued during the following periods. The situation is comparable in the UAQ lagoon, where the exploitation of marine crabs remains important all along the mid-6th and the 5th millennium BCE while only little attested afterward despite no apparent local disruption in the natural stocks: only a few crab remains are reported from Tell Abraq (c. 2300-300 BC) (Stephan, 1995: tab. 2) and ed-Dur (1st-4th centuries AD) (Van Neer & Gautier, 1993: tab. 1). Conversely, Arabian blue crabs are exploited in abundance in the UAQ area nowadays, mostly consumed by Filipino expatriates. Interestingly, in the Arabian Gulf states, at the present day, marine crabs are for the most part not eaten by the native coastal communities due to, in some cases, religious taboos, although they are consumed in some numbers by expatriate workers (Carpenter et al. 1997: 36–40).

Further research is needed to examine potential changes in mean sizes of harvested crabs and sea urchins through time. A potential reduction in mean sizes over time should be correlated to intensive fishing by past societies or as a result of environmental changes. However, constructing osteometric models is complicated by difficulties collecting small specimens due to fishery restrictions regarding size limits, in particular for crabs. Furthermore, the strong sexual dimorphism among Arabian blue crabs also complicates both the construction and the exploitation of regression curves.

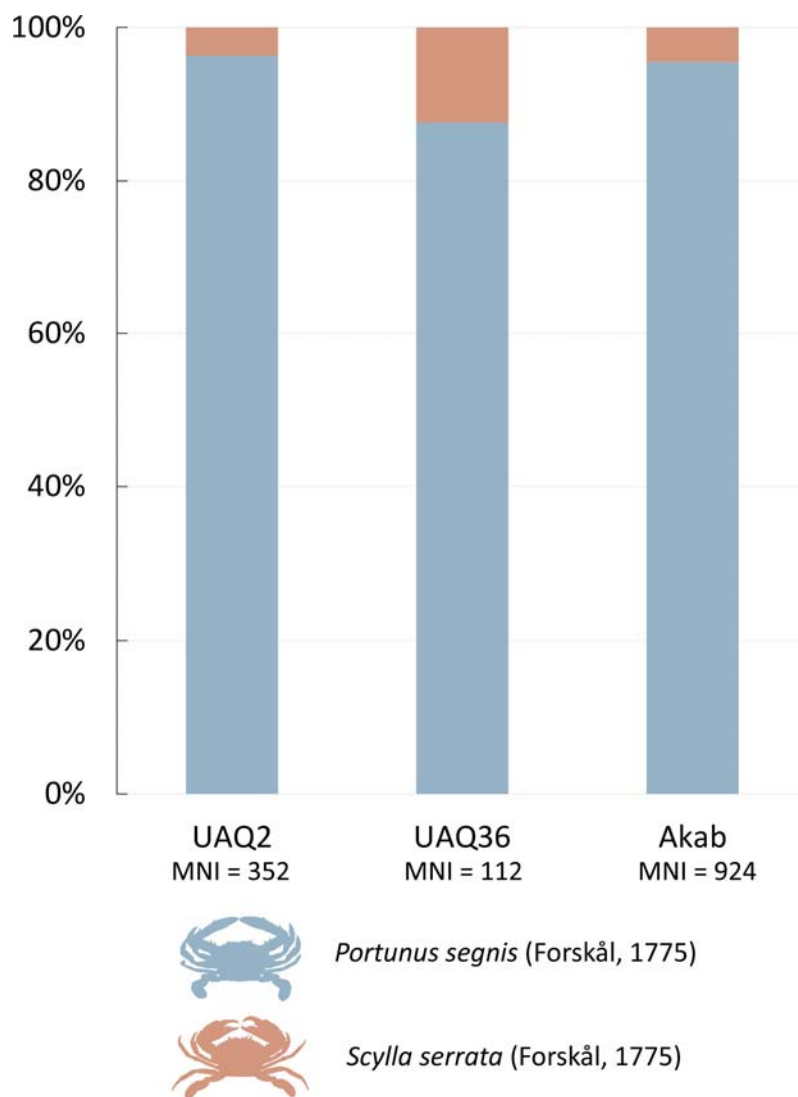
This study highlights the importance of marine crabs and sea urchins in the diet and the cultural definition of some Neolithic groups of Eastern Arabia. It shows how important it is that zooarchaeologists should pay attention to the study of fauna usually assumed as a secondary concern.

Site	Context	Sample	Type of sample	BP datations	2 σ cal. BC	Curve
Delma DA11	Trench 2, Context 1043	AA-52544 (GU-10609)	Ashy sand/charcoal	6395 +/- 60	5477-5297 BC (0.91); 5260-5220 BC (0.09)	Intcal20
Delma DA11	Trench 2, Context 1027	AA-52545 (GU-10610)	Ashy sand/charcoal	6230 +/- 45	5308-5199 BC (0.44); 5187-5050 BC (0.56)	Intcal20
Delma DA11	Trench 2, Context 1053	AA-52543 (GU-10608)	Charcoal	6220 +/- 45	5305-5239 BC (0.23); 5230-5045 BC (0.77)	Intcal20
Delma DA11	Trench 1, Context 15	AA-32032	Carbonized datestone	6165 +/- 55	5294-5263 BC (0.04); 5219-4977 BC (0.94); 4976-4952 BC (0.02)	Intcal20
Delma DA11	Trench 2, Context 1014	AA-32031	Carbonized datestone	5830 +/- 55	4830-4817 BC (0.01); 4799-4543 BC (0.99)	Intcal20
Delma DA11	Trench 2, Context 14	AA-52546 (GU-10611)	Charcoal	5830 +/- 45	4792-4580 BC (0.96); 4573-4550 BC (0.04)	Intcal20
UAQ2 settlement	Sector 1, Level 3	LOC-165	Marine shell: <i>Marcia cf. hiantina</i>	5677 +/- 32	4121-3611 BC (1)	Marine20
UAQ2 settlement	Sector 1, Level 10	LOC-166	Marine shell: <i>Hexaplex kuesterianus</i>	6555 +/- 21	5070-4536 BC (1)	Marine20
UAQ2 settlement	Sector 1, Level 10	LOC-164	Marine shell: <i>Marcia cf. hiantina</i>	6741 +/- 30	5283-4766 BC (1)	Marine20
UAQ2 settlement	Sector 2, Level 9	LOC-235	Marine shell: <i>Marcia cf. hiantina</i>	6692 +/- 25	5217-4703 BC (1)	Marine20
UAQ2 settlement	Sector 2, Level 11	LOC-236	Marine shell: <i>Marcia cf. hiantina</i>	6921 +/- 29	5455-4969 BC (1)	Marine20
UAQ2 settlement	Sector 2, Level 12	LOC-237	Marine shell: <i>Marcia cf. hiantina</i>	6974 +/- 29	5485-5013 BC (1)	Marine20
UAQ2 settlement	Sector 2, Level 15	LOC-238	Marine shell: <i>Marcia cf. hiantina</i>	6961 +/- 26	5475-5005 BC (1)	Marine20
UAQ36	SU 1819/104	MAMS-35678	Charcoal	5574 +/- 25	4450-4353 BC (1)	Intcal20
UAQ36	SU 1819/104 M1	P-17769	Marine shell: <i>Marcia cf. hiantina</i>	5946 +/- 15	4375-3910 BC (1)	Marine20
UAQ36	SU 1819/104 M2	P-17770	Marine shell: <i>Marcia cf. hiantina</i>	5943 +/- 17	4373-3905 BC (1)	Marine20
UAQ36	SU 1836 M1	P-17771	Marine shell: <i>Marcia cf. hiantina</i>	5980 +/- 15	4412-3946 BC (1)	Marine20
UAQ36	SU 1836 M2	P-17772	Marine shell: <i>Marcia cf. hiantina</i>	5977 +/- 17	4409-3943 BC (1)	Marine20
UAQ36	SU 1840/104	MAMS-35679	Charcoal	5667 +/- 24	4450-4446 BC (0.99); 4416-4408 BC (0.01)	Intcal20

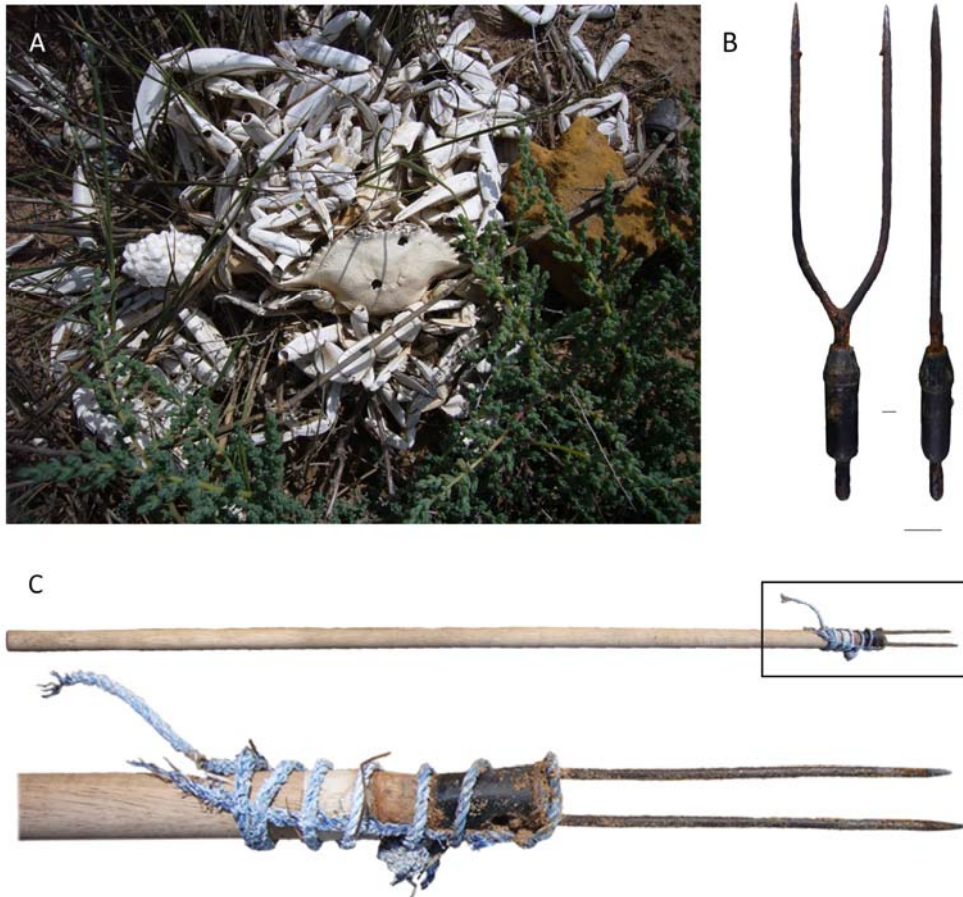
Supplementary Material 1. Radiocarbon and 2σ calibrated dates from the study sites. Radiocarbon datations: Beech and Glover 2005; Charpentier and Méry 2008; Méry et al. 2019; Méry et al. 2016. Calibration program : CALIB Rev 8.2 (Stuiver et al. 2020). Marine20 calibration curve (Stuiver and Reimer 1993) with $\Delta R=68 \pm 91$ for the UAQ area according to Méry et al. (2019, fig. 6).

Species	Common name	Max. size	Max. weight	Meat yield	Preferred habitat	Main catching techniques in the area study
<i>Portunus segnis</i>	Arabian blue crab	17.5 cm CW	275 g	39-43%	Intertidal and shallow subtidal (close to seagrass beds)	Spearing; Set nets; Cage traps; Fish weirs
<i>Scylla serrata</i>	Giant mud crab	22-23 cm CW	ca. 2000 g	16-29%	Associated to mangrove environments (in swamps and among mangroves)	Hand catching; Trapping; Spearing (occasionally)
<i>Thalamita crenata</i>	Mangrove swimming crab	8 cm CW	ca. 120 g	12-19%	Intertidal in tide pools and creeks (close to mangrove and seagrass beds)	Hand catching; Cage traps
<i>Echinometra mathaei</i>	Burrowing urchin	6 cm (test diameter)	ca. 100 g	ca. 8%	Among shallow subtidal rocks	Hand gathering; Diving

Supplementary Material 2. Ecological aspects and catching methods of the main marine crab and sea urchins species identified in the present study. CW stands for ‘Carapace Width’.



Supplementary Material 3. Proportion of the main crab species identified at the sites of the UAQ area. Percentages based on the MNI data.



Supplementary Material 4. A. Discarded crabs in the vicinity of JH9 site, Jazirat al-Hamra (Ra's al-Khaimah Emirate, UAE); B. Modern fishing spearhead found in the Umm al-Quwain area (UAE). C. Modern crab spear found in the vicinity of JH11 site, Jazirat al-Hamra (Ra's al-Khaimah Emirate, UAE). Images: © V. Charpentier, K. Lidour; Scale: 1 cm.

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