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Analysis of archaeological fish remains provides new insights into seasonal mobility in Eastern Arabia during the mid-Holocene. The subsistence fisheries of UAQ36, Umm al-Quwain lagoon (United Arab Emirates).

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Highlights

- Analyses of archaeological fish remains provide substantial information on ancient coastal adaptation.
- The capture of small fish outlines the use of beach seines in intertidal and shallow waters.
- Fishing techniques and strategies vary greatly between Neolithic sites occupying the study area.
- Ecological data and fish growth parameters could be used to investigate archaeological seasonality.
- Differences in subsistence strategies could be related to intergroup conflicts or distinct mobility patterns.

Abstract

The site of UAQ36 is a shell midden located on top of a sand dune on the eastern edge of the Umm al-Quwain lagoon, United Arab Emirates. The first radiocarbon dates suggest that the site was inhabited from the mid-5th millennium, and possibly part of the 4th millennium BCE. While the site was surprisingly poor in material culture, its stratigraphy reached almost 2 m deep. The abundant faunal remains collected during the excavations allow a detailed analysis of the subsistence economy of the site. Out of 2985 fish remains, 607 were taxonomically identified. The assemblage is almost entirely composed of small inshore fish including seabreams (Sparidae), rabbitfish (Siganidae), emperors (Lethrinidae), and mojarras (Gerreidae). The fishing grounds exploited and the

diversity of the strategies used by the fishermen in the UAQ lagoon are discussed by comparing data from the neighboring sites of UAQ2 and Akab. This paper gives the first indication of a summer occupation of a coastal site during the Neolithic in this area, and provides new insights on the seasonality and mode of occupation of Neolithic sites, not only in the Persian Gulf, but across Eastern Arabia.

Keywords: Coastal adaptation; Subsistence strategies; Seasonality; Archaeo-ichthyology; Ancient fishing; Neolithic; Arabia

1. Introduction

In Eastern Arabia, the Neolithic period (ca. 6500–3300 BCE) corresponds to a cultural phase characterized by the development of mixed economies, principally based on pastoralism, hunting, and the exploitation of marine resources (shellfish, fish, crustaceans, and marine mammals). Unlike in the Fertile Crescent, rainfall is not sufficient to support the development of rain-fed agriculture in the area. Therefore, oasis agriculture only developed from the Bronze Age onwards in Eastern Arabia, based on the occurrence of irrigation techniques. Since the 1970s, a great number of Neolithic sites have been discovered and excavated along the coastline and on the coastal islands of both the UAE and the Sultanate of Oman. Conversely, only a few examples of inland sites are known to date. The numerous shell middens concentrated around lagoons and mangroves highlight an original case of 'coastal adaptation' (Beaton, 1995) during the mid-Holocene. However, mobility patterns and stages of sedentarization of Neolithic cultures established from Kuwait to the Sultanate of Oman remain essentially undetermined.

The Umm al-Quwain lagoon is a semi-enclosed basin of about 80 km², located about 100 km southwest of the Strait of Hormuz (Figure 1). The water depth varies greatly inside the lagoon, depending on location and tides. It oscillates between 2 and 8 m in the non-dredged areas (Department of Fisheries, 1984). It is a shallow lagoon offering secure moorage and hosting for extensive mangrove stands and seagrass bed areas. Off the lagoon, the water depth gradually increases, reaching 15 m deep at 2 nautical miles offshore (Service Hydrographique de la Marine, 1904). Both archaeological and paleoenvironmental studies have outlined that mangrove existed here from at least the Neolithic period (6th to the 4th millennium BCE) (Méry et al., 2019). The ancient presence of loop-root mangroves (*Rhizophora mucronata*) and mud creeper snails (*Terebralia palustris*)—now both extinct in the area—clearly indicates higher moisture conditions at that time and higher productivity of the coastal ecosystems (see, for instance, Tengberg 2005; Berger et al., 2013). As a result, for a long time, the human groups inhabiting the vicinity of the UAQ lagoon exploited a variety of key resources for their subsistence, such as marine shells, crustaceans, and fish. Past foraging activities are clearly highlighted by the presence of numerous shell middens on top of the surrounding sand dunes.

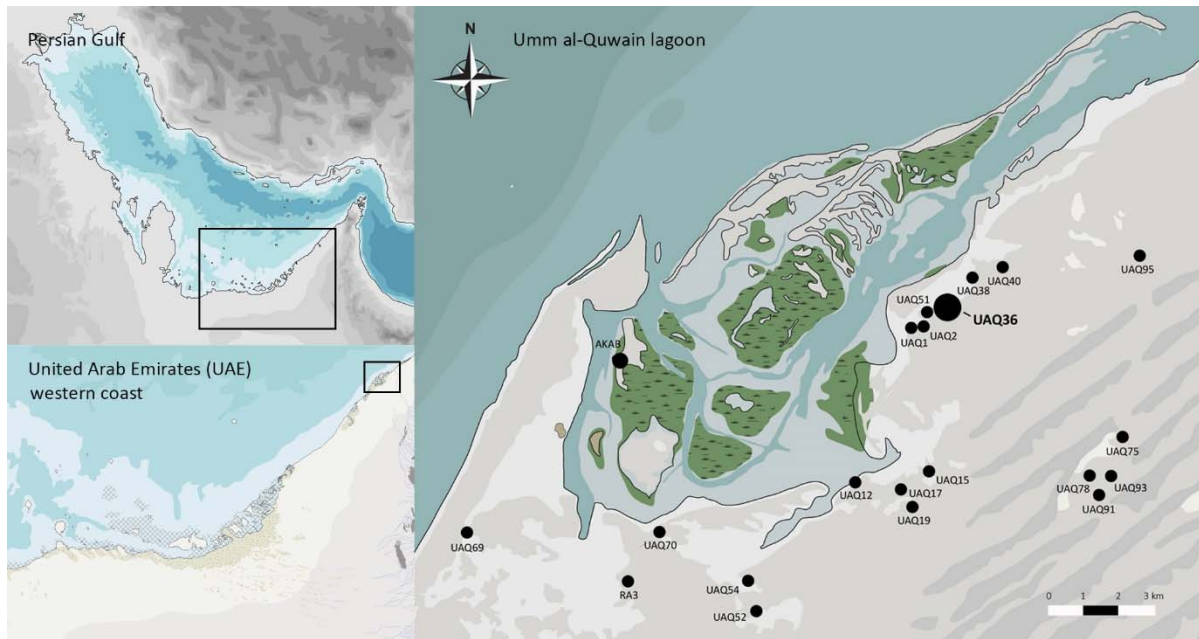


Figure 1. Location of the Umm al-Quwain lagoon (United Arab Emirates) and the Neolithic sites (black spots) recorded in the area (data: Méry et al. 2019).

2. Site location and archaeological settings

UAQ36 (25°34'57"N; 55°39'35"E) is a Neolithic shell midden located on top of a sand megadune on the eastern edge of the Umm al-Quwain lagoon. Field operations conducted during the past two decades, by the French Archaeological Mission in the United Arab Emirates in collaboration with the Department of Tourism and Archaeology of Umm al-Quwain, led to the discovery and the excavation of several Neolithic sites in the area such as UAQ2 (1 km southward of UAQ36) and Akab (ca. 9 km southwest across the lagoon) (Méry et al., 2019).

First surveyed in 2011 and sounded in 2013, UAQ36 was excavated in 2018. Several trenches were opened on top of the dune in order to observe the continuity and the slope of the stratigraphic layers. The deepest layers (ca. 2 m deep) were only preserved in Sector 1 (3x2 m² trench). The stratigraphy consisted of an alternation of shell rich layers and cleaner sand deposits. Housing and domestic activities at UAQ36 are suggested by the discovery of several postholes and hearths. However, the material culture was scarce in comparison to other Neolithic sites in the area, such as UAQ2 and Akab. Artifacts almost entirely consisted of lithic debitage (20 items) including two splintered pieces as the only tools. Likewise, a single shell scraper made of *Callista erycina* was found. The most distinctive artifact was an unfinished soft-stone cylinder bead of the 'Akab-type' found on the surface. This type of ornament is well attested at Akab from 4300 BCE, as well as during the 4th millennium (Charpentier & Méry, 2008: 130). Although it is not yet possible to assert, it can be assumed that UAQ36 seems to have been less frequently occupied than Akab and UAQ2 (Méry et al., 2019: 230).

Charcoal and marine shells (*Marcia* spp.) were collected from several layers for radiocarbon dating and evaluating the local reservoir effect. The first results confirm that the site was inhabited from the middle of the 5th millennium BCE. It is thus roughly contemporaneous with the Akab settlement and the uppermost levels of UAQ2 (levels 4-8) (Méry et al., 2019). While it remains to be confirmed by further radiocarbon dating, it is possible that the uppermost part of the stratigraphy belongs to the 4th millennium BCE. Despite the small number of recovered artifacts, a significant quantity of faunal remains was collected during the excavations. This provides the opportunity to improve our knowledge of the subsistence strategies during the Late Neolithic (ca. 4500–3300 BC) in this study area. The present study focuses on the analysis of fish bones.

3. Material and method

All the excavated sediments were systematically dry sieved using a 3 mm mesh. From each context, a sample of 10 L was taken for sieving with a smaller mesh (1 mm)—this will provide the basis for a future statistical evaluation of the faunal components. The residues were mostly composed of fragments of marine shells (*Marcia* spp., *Saccostrea cucullata*, and *Terebralia palustris*), crab claws, fish bones, and a few fragments of mammal bones (bovids) (N = 89; WISP = 24 g). Note that a small gecko vertebra (Gekkonidae) was also identified (S. Bailon, pers. comm.) in one of the uppermost layers.

Anatomical and taxonomic identifications were conducted according to the methods of comparative anatomy, using the osteological collection of Arabian Gulf fishes housed at the National Museum of Natural History (MNHN) of Paris. Quantifications were based on the number of identified specimens (NISP), the minimum number of individuals (MNI), and the weight of identified specimens (WISP) (Table 1). MNI estimates were achieved according to the combination method: the frequency of bones combined with laterality and size/weight estimations (Chaplin, 1971). We estimated the lengths of fish after visual comparisons of archaeological bones with reference specimens (Wheeler & Jones, 1989: 141).

4. Results

A total of 2985 fish bone fragments were retrieved and recorded of which 607 (NISP) could be identified to the level of family, genus or species (including Sparoidea superfamily¹)—the identification rate thus reaches 20.4%. However, identifications at the species level were only possible in a few cases (7.6%) due to the extreme bone fragmentation and a number of taxonomic problems with closely related fish species of the Indo-West Pacific. The assemblage included sardines (Clupeidae), milkfish (Chanidae), mullets (Mugilidae), needlefish (Belonidae), flatheads (Platycephalidae), groupers (Serranidae), jacks and trevallies (Carangidae), snappers (Lutjanidae), mojarras (Gerreidae), grunts (Haemulidae), threadfin breams (Nemipteridae), emperors (Lethrinidae), seabreams (Sparidae), drums (Sciaenidae),

¹ The superfamily Sparoidea (i.e. sparoid fish) includes Nemipteridae, Lethrinidae, and Sparidae.

goatfish (Mullidae), grunters (Terapontidae), rabbitfish (Siganidae), and barracudas (Sphyraenidae), corresponding at least to 25 genera and 29 species. Non-fish remains possibly associated with fishing activities included several cuttlebone fragments (NISP = 4).

According to NISP, the assemblage was dominated mainly by seabreams (39.7%), rabbitfish (14.5%), emperors (8.2%), mojarras (7.2%), mullets (5.1%), and barracudas (4.3%) (Figure 2). Seabreams were almost entirely represented by the haffara seabream (*Rhabdosargus haffara*) and species belonging to the genus *Acanthopagrus* (Table 1). Emperors were represented by at least two species: the pink-ear emperor (*Lethrinus lentjan*) and the smalltooth emperor (*Lethrinus microdon*). The strongspine silver-biddy (*Gerres longirostris*) was also identified. Identifications at species level were, however, not possible for mullets, rabbitfish or barracudas. Almost all the specimens represented in the assemblage were small-sized fish: seabreams, mojarras, and emperors, generally estimated to be between 15 and 22 cm in total length (TL). Likewise, rabbitfish rarely exceeded 10 cm. Only a few specimens were estimated over 30 cm in length, such as some flatheads, snappers, and trevallies of the genus *Carangoides*.

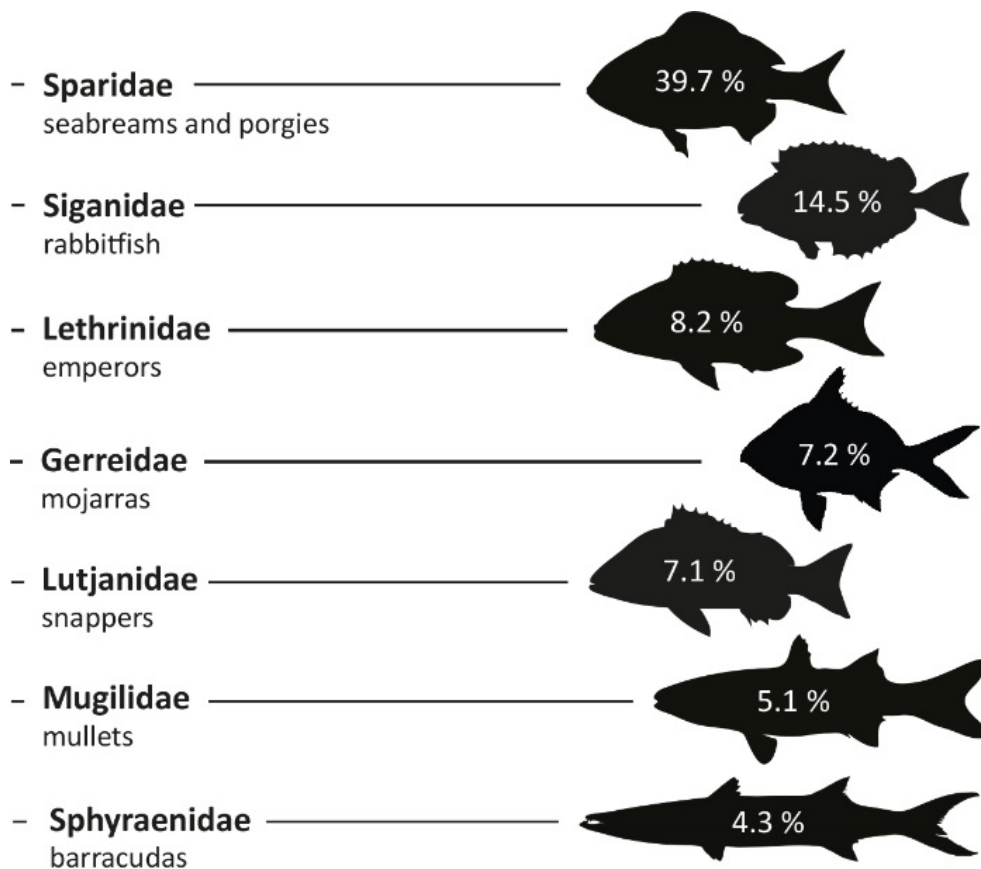


Figure 2. Proportions of the main fish families identified at UAQ36. NISP = 607; other fish taxa 14.9%

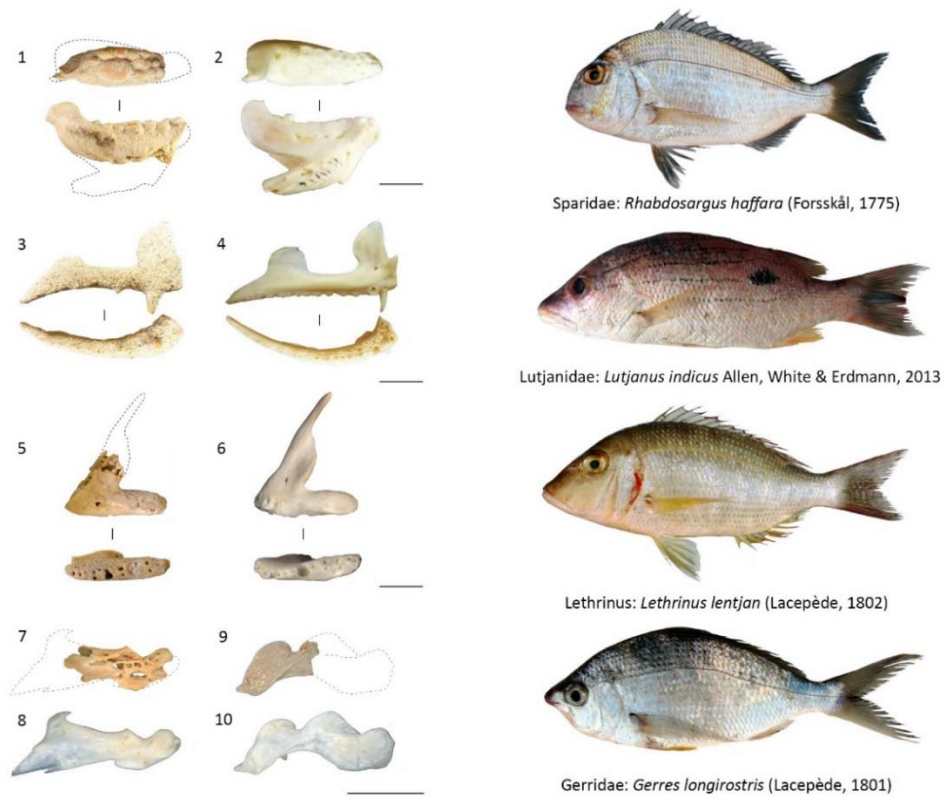


Figure 3. Sample of remains belonging to bony fish (Teleostei) from UAQ36 compared to analogue bones from the MNHN osteological reference collection, and corresponding live pictures of the species (© P. Béarez, S. Kerneur & K. Lidour): 1–2. Right dentaries of haffara seabream, *Rhabdosargus haffara* (MNHN-ICOS-01098); 3. Right premaxilla of an indeterminate snapper, *Lutjanus* sp.; 4. Right premaxilla of Indian snapper, *Lutjanus indicus* (MNHN-ICOS-00390); 5–6. Left premaxillae of pink-ear emperor, *Lethrinus lentjan* (MNHN-ICOS-00274); 7–8. Left angulo-articulars of strongspine silver-biddy, *Gerres longirostris* (MNHN-ICOS-00251); 9–10. Left maxillae of strongspine silver-biddy, *Gerres longirostris* (MNHN-ICOS-00251). Scale: 5 mm.

Family	Genus	Species	NISP	MNI	WISP (g)
Clupeidae	<i>Sardinella</i>	<i>Sardinella</i> sp.	1	1	0.002
	ind.		5	5	0.06
Chanidae	<i>Chanos</i>	<i>Chanos chanos</i>	3	3	0.034
Mugilidae	ind.		31	13	3.295
Belonidae	<i>Tylosurus</i>	<i>Tylosurus choram</i>	3	2	0.329
		<i>Tylosurus</i> sp.	2	1	0.509
	ind.		1	1	0.006
Platycephalidae	<i>Platycephalus</i>	<i>Platycephalus indicus</i>	7	6	1.163
Serranidae	<i>Cephalopholis</i>	<i>Cephalopholis hemistiktos</i>	2	2	0.074

	<i>Epinephelus</i>	<i>Epinephelus coioides</i>	2	2	0.403
		<i>Epinephelus</i> sp.	5	1	0.154
	ind.		2	1	0.1
Carangidae	<i>Carangoides</i>	<i>Carangoides</i> sp.	3	2	0.038
	<i>Caranx</i>	<i>Caranx</i> sp.	3	3	1.149
	<i>Gnathanodon</i>	<i>Gnathanodon speciosus</i>	1	1	0.012
	<i>Scomberoides</i>	<i>Scomberoides</i> sp.	6	1	1.6
	ind.		4	1	0.211
Lutjanidae	<i>Lutjanus</i>	<i>Lutjanus coeruleolineatus</i>	1	1	0.065
		<i>Lutjanus indicus</i>	1	1	0.065
		<i>Lutjanus</i> sp.	41	13	2.825
Haemulidae	<i>Diagramma</i>	<i>Diagramma pictum</i>	1	1	0.066
Gerreidae	<i>Gerres</i>	<i>Gerres longirostris</i>	1	1	0.05
		<i>Gerres</i> sp.	43	20	2.346
Nemipteridae	<i>Scolopsis</i>	<i>Scolopsis</i> sp.	1	1	0.002
Lethrinidae	<i>Lethrinus</i>	<i>Lethrinus lentjan</i>	4	3	0.231
		<i>Lethrinus microdon</i>	1	1	0.2
		<i>Lethrinus</i> sp.	45	16	5.17
Sparidae	<i>Acanthopagrus</i>	<i>Acanthopagrus arabicus</i>	1	1	0.2
		<i>Acanthopagrus berda</i>	2	1	0.05
		<i>Acanthopagrus sheim</i>	4	1	1.227
		<i>Acanthopagrus</i> sp.	59	25	6.743
	<i>Argyrops</i>	<i>Argyrops</i> sp.	1	1	0.05
	<i>Boops</i>	<i>Boops lineatus</i>	1	1	0.05
	<i>Rhabdosargus</i>	<i>Rhabdosargus haffara</i>	46	26	11.952
	ind.		127	16	8.366
ind. Sparoidea			7	-	0.041
Sciaenidae	ind.		5	2	0.042
Mullidae	ind.		2	1	0.04
Terapontidae	<i>Terapon</i>	<i>Terapon</i> sp.	18	7	0.19
Siganidae	<i>Siganus</i>	<i>Siganus</i> sp.	88	19	0.974
Sphyraenidae	<i>Sphyraena</i>	<i>Sphyraena</i> sp.	26	11	1.439
ind. Perciformes			35	-	1.615
ind. Teleostei			2343	-	70.054
		Total determined Teleostei	607	216	51.432
		Grand Total	2985	216	123.142

Table 1. Table of identified fish from UAQ36. Quantifications in NISP, MNI and WISP.

All the main anatomical elements belonging both to the skull and the backbone were represented (Table 2). The assemblage was almost entirely composed of vertebrae (75.5%), while the bones belonging to the mandibular arch were also well represented (Figure 3): premaxillae (5.9%), dentaries (4.1%), maxillae (2.3%), angulo-articulars (2%), and quadrates (1.8%). Since no butchery marks were observed, it is likely that the fish was directly brought to the site and consumed in a relatively complete form. Charring on spines and soft rays suggest that whole fish were probably grilled on coals. However, fire marks remain rare on the bone assemblage (less than 2% of the global NISP).

	Teleostei		Sparidae		<i>Lethrinus</i> spp.		<i>Gerres</i> spp.		<i>Siganus</i> spp.		<i>Lutjanus</i> spp.	
	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%
Vomers	5				1		1					
Basioccipitals	12		5		2						1	
Otoliths	3				1							
Palatines	10		6		2							
Maxillae	32		10		2		7	15.9%			9	20.9%
Premaxillae	81	5.9%	66	27.4%	1		3	6.8%			9	20.9%
Dentaries	56		42	17.4%	2		4	9.1%	3			
Ang.-articulars	28		14	5.8%	3	6%	8	18.2%			1	
Quadrates	25		17	7.1%	1		1				3	7%
Hyomandibulas	7		3		1							
Opercles	5		2		1				1		1	
Preopercles	4		3									
Cleithra	3		1								1	
Scapulae	14		5		3	6%	3	6.8%			1	
Post-temporals	4		2									
Ceratohyals	11		1		2							
Vertebrae	1039	75.8%	56	23.2%	28	56%	17	38.6%	80	90.9%	17	39.5%
Other	31		8						4			
Total NISP	1370		241		50		44		88		43	
Grand total	2985											

Table 2. Distribution of anatomical elements for some of the main taxa identified.

The abundance of fish greatly fluctuated within the stratigraphy. The richest units were SU 1808, 1823, 1824, and 1825 in the upper part of the stratigraphy, and SU 1818, 1819, 1839, and 1840 in the lower part (for the stratigraphic matrix see Méry et al., 2019: fig. 5). However, the small surface excavated did not allow concluding that fish was less consumed within the other stratigraphic units. Indeed, food remains were typically concentrated in lenses or shallow pits and were not homogeneously distributed on archaeological soils. The main taxa identified were represented in different parts of the stratigraphy and do not suggest a particular pattern of distribution. We noted, however, that rabbitfish and mojarras were concentrated in SU 1818, while seabreams and barracudas were concentrated in SU 1825.

5. Discussion

5.1. Fishing grounds and techniques

All the taxa identified during this study can be caught inside the UAQ lagoon or in its vicinity (Department of Fisheries, 1984; Lidour 2019: ann. 3).

The haffara seabream mainly occurs in the Red Sea and the Persian Gulf, while the distribution of the goldlined seabream (*Rhabdosargus sarba*) remains imprecise. The former was the only one identified in the UAQ36 sample. It is encountered in a variety of coastal habitats such as around coral reefs and soft bottoms where it can feed on small benthic invertebrates (Sommer et al., 1996). The haffara seabream is abundant in the modern fisheries of UAE, including in the Umm al-Quwain waters. It commonly measures about 20 cm TL, up to 35 cm, and thus traditionally constitutes an important food fish (Fischer & Bianchi, 1984). Several other species of seabreams are also encountered and greatly consumed, including the Arabian yellowfin seabream (*Acanthopagrus arabicus*), the goldsilk seabream (*Acanthopagrus berda*), and the spotted yellowfin seabream (*Acanthopagrus sheim*) (Iwatsuki, 2013). Seabreams are traditionally caught in the area using stake nets (*sakkar* in local Arabic) which are stretched across estuaries and the gaps in lagoons (Beech, 2004: 46).

The white-spotted spinefoot (*Siganus canaliculatus*) is the most abundant species of rabbitfish encountered along the UAE coastline. It is especially caught in the Umm al-Quwain area where it is regarded as a valuable food fish despite its relatively small size—commonly about 20 cm TL (Department of Fisheries, 1984). It is mostly caught using intertidal traps and dome-shaped cage traps (known as *gargūr* in local Arabic) which are baited with bread or dried algae. Juveniles aggregate in schools over algal flats and seagrass beds, feeding mainly on filamentous algae, while adults generally move into shallow areas with the tides to feed on benthic plants (Randall et al., 1997).

Emperors are also abundant and utilized in the UAE. The most frequently encountered species are the spangled emperor (*Lethrinus nebulosus*), the pink-ear emperor, and the smalltooth emperor. While adult specimens are typically found in reef areas, juveniles mainly inhabit sheltered waters where soft bottoms and seagrass meadows predominate (Randall, 1995). Mojarras (or silver-biddies) and grunters can also be found around seagrass beds close to estuaries, mangroves, and inside lagoons influenced by freshwater (Iwatsuki et al., 2001). Mulletts are even more tolerant of fresh and brackish waters. They are thus encountered inshore, around estuaries, mangroves, and even in rivers. Mangroves act as hosts for many other fish species, especially during their first stages of life (Manson et al., 2005). This is the case, for instance, for several snappers, trevallies, and barracudas. However, bigger individuals can also enter into shallow lagoons and mangroves through channels to hunt, depending on the tide. Barrier traps are well adapted to be used in intertidal flats and in shallow lagoons where seagrass beds generally occur.

Since catches made with intertidal traps are not restricted to a certain size range, it is unlikely that such a fishing device has been used by the UAQ36 inhabitants. Indeed, the fish caught at UAQ36 were generally small. Likewise, there is scant possibility that small mulletts, mojarras, and rabbitfish were caught with lines and cage traps. Hence, we assume that, at UAQ36, fishing was essentially carried out in very shallow waters with beach seines. Traditionally, different types of beach seines were in use along the coast of the UAE. Small mesh nets can be set on foot at least by 2–3 fishermen in the shallow waters—this technique was known as *idfarah* in local Arabic (Heard-Bey, 1986: 175). In Mayotte (Comoro Islands), a similar technique known as *djarifa* (in Shimaore) is typically conducted by women and children. They generally use large pieces of cloth as small-mesh nets. *Djarifa* fishing is essentially carried out

at the back of the bays, close to seagrass beds and in front of mangrove stands (Jamon et al., 2010).

5.2. Comparisons

Two distinct modes of fishing are attested during the Neolithic in the Persian Gulf, concomitantly:

- A non-selective fishing carried out in shallow and inshore waters, based on the exploitation of rich ecosystems including mangroves, seagrass beds, and reefs with small mesh devices such as beach seines and intertidal traps. Catches were generally composed of seabreams, emperors, mojarras, and grunts, as well as small planktivorous fish such as sardines, anchovies (Engraulidae), and silversides (Atherinidae). This pattern was highlighted at the majority of the sites. It could have been carried out all year round in addition to other foraging activities. The seasonal aggregations of certain fish could also have been deliberately exploited, such as the spawning of emperors in the UAQ lagoon (Beech, 2004: chap. 7; Lidour et al., 2018) or those of groupers in the Delma reef system (Lidour & Beech, 2019a).

- A mode of fishing oriented toward the exploitation of offshore pelagic fish schools (typically tunas and large trevallies) from boats with more specialized techniques such as the use of encircling nets and fishing lures (with mother-of-pearl fish hooks). This pattern directly depends on the intermittent and unpredictable occurrences of schools close to the shore. It has been highlighted at only a few Neolithic sites in the Persian Gulf where non-selective fishing activities carried out inshore were also attested (Akab, Delma, and Dosariyah) (Uerpmann & Uerpmann, 2018; Lidour et al., 2019; Lidour & Beech, 2019a).

	UAQ2 (lvl. 9–15)	UAQ2 (lvl. 4–8)	Akab	UAQ36
	Middle Neolithic	Late Neolithic	Late Neolithic	Late Neolithic
NISP	5006	351	12 550	607
Sparidae	49.7%	73.5%	13.5%	39.7%
Siganidae	-	-	-	14.5%
Lethrinidae	37.1%	8%	5.6%	8.2%
Gerreidae	0.1%	0.6%	0.1%	7.2%
Mugilidae	0.5%	1.1%	5.2%	5.1%
Sphyraenidae	2.9%	3.1%	1.2%	4.3%
Carangidae	1.5%	3.7%	38.1%	2.8%
Serranidae	2.4%	4%	0.3%	1.8%
Scombridae	2.8%	-	19.8%	-

Table 3. Comparison of proportions of the main fish families identified at the major Neolithic sites of the UAQ lagoon (data: Mashkour et al., 2016; Lidour et al., 2019; present study).

It seems clear that UAQ36 can be included in the first mode of fishing presented above. UAQ2 and Akab are the only Neolithic sites of the UAQ lagoon providing current comparative data

(Table 3). Their assemblages show dissimilarities from a number of perspectives. At UAQ2, fishing was concentrated on obtaining seabreams and small emperors. Since almost all the emperors were identified from otoliths at UAQ2, their lesser presence at UAQ36 and Akab may have been due to taphonomic bias. Dissolution processes affect fish bones and otoliths differently since they are made of distinct crystal forms of calcium carbonate: calcite and aragonite respectively. The levels of pH in shell middens depend on a wide range of factors such as the proportion of shell versus sand deposits within the stratigraphy. It could also depend on the dissolution degree and the chemical composition of the shell taxa represented. Only 3 otoliths were identified in the UAQ36 assemblage despite the careful retrieval practices adopted. Conversely, a total of 111 otoliths were registered at Akab versus 2438 at UAQ2 (Lidour 2019: fig. 6.1.8; M. Beech, pers. comm.). Given their abundance in the shallow waters of the UAQ lagoon (Department of Fisheries, 1984), emperors probably constituted a large part of the catches at UAQ36 and Akab too. Besides, open-sea fishing was also carried out at Akab, more moderately at UAQ2, as suggested by the occurrence of tunas and large trevallies in the assemblages of these two sites. This involves the use of specialized techniques associated with the second mode of fishing described above—something which does not seem to have existed at UAQ36. More broadly, catches at UAQ36 are generally only small fish, in comparison to UAQ2 and Akab. This suggests that fishing was restricted to very shallow grounds such as intertidal seagrass beds, tidal creeks, and the edge of the mangrove. Fishing expeditions were probably done on foot by only a few people.

5.3. Seasonality

The mode of occupation of the Neolithic sites has been widely discussed for many years. Various mobility models have been suggested, alternatively based on degree of seasonal nomadism versus sedentism (e.g. Rice, 1994: 75; Cleuziou & Tosi, 1998: 126; Cavulli & Scaruffi, 2013; Méry, 2015). The question lies in how to integrate inland cemeteries such as Buhais BHS18 and Faya FAY-NE15 (Emirate of Sharjah, UAE) (Uerpmann & Uerpmann, 2000; Uerpmann et al., 2012) into a coherent model of mobility at a regional scale, knowing that almost all the residential sites identified to date are located on the coast and on coastal islands. It was frequently suggested that the Neolithic communities from Eastern Arabia followed a seasonal mobility pattern in a similar way to certain traditional Bedouin tribes of the Ash-Sharqiyyah Region (Sultanate of Oman). During winter, people could have focused on coastal fishing, and then moved back to inland oases during the summer for the date harvest season (Lancaster & Lancaster, 1995; el-Mahi, 2000). However, several transdisciplinary studies have pointed out evidence indicating low residential mobility during the Neolithic (Biagi & Nisbet, 2006; Zazzo et al., 2014; Kutterer & Uerpmann, 2017). For instance, according to Mashkour et al. (2016), the UAQ2 inhabitants could potentially fish almost all year round, taking advantage of the occurrence of tuna close to the shore during winter and of the spawning of emperors in the lagoon in spring and autumn (Table 4). The occupation of the site during the spring months is also well supported by the consumption of very young caprines whose birth generally occurs at the beginning of the year in this part of the world. Occupation during the hotter months of summer, however, remained uncertain. One can expect that coastal groups were involved in pastoral movements into the mountains during summer as it has been suggested by Uerpmann and Uerpmann (2000). Seasonal pastures could have grown at that particular time of year as a result of the significant rainfalls associated with the summer

monsoon, as is the case in Dhofar (south of the Sultanate of Oman) (el-Mahi, 2001). Indeed, during the Neolithic, the monsoonal conditions affected a larger part of the Arabian Peninsula since the Intertropical Convergence Zone (ITCZ) was situated further north than today (Fleitmann et al., 2007).

Certain scholars have pointed out that the marine waters off Eastern Arabia are more productive during winter and thus generally preferred for professional fishing, which especially targets highly profitable taxa such as tunas and kingfish during their seasonal migration close to the shore (e.g. Ali & Cherian, 1983; Van Neer & Gautier, 1993). Such winter fishing was probably carried out at Akab, Delma (Emirate of Abu Dhabi, UAE), and Dosariyah (Saudi Arabia) where large numbers of tunas have been registered (Uerpmann & Uerpmann, 2018; Lidour et al., 2019; Lidour & Beech, 2019a). However, several archaeo-ichthyological studies indicate that during the Neolithic fishing could have been carried out almost all year round close to certain rich coastal ecosystems, such as mangroves, seagrass beds, and reefs, where numerous smaller fish are encountered (Desse, 1988; von den Driesch & Manhart, 2000; Beech, 2004: 201-207; Lidour et al., 2018; Lidour & Beech, 2019a; 2019b). Therefore, with the contribution of other diet components such as shellfish, crustaceans, and the meat derived from both hunting and herding, fishing activities were able to ensure the daily subsistence of small communities throughout the year (Table 4).

		J	F	M	A	M	J	J	A	S	O	N	D
LIVESTOCK	Lambing	x	x	x									
	Presence of young caprines			x	x	x	x						
FISHING	Tuna fishing season	x	x									x	x
	Pink-ear emperor spawning					x	x			x	x		
	Spangled emperor spawning			x	x								
	Presence of juvenile rabbitfish							x	x				

Table 4. Reconstruction of the 'UAQ calendar' showing the seasonal cycle of food resources (data: Mashkour et al., 2016; Lidour et al., 2018; present study). Among the studied archaeological sites, UAQ2 has the longest cycle of probable occupation (all months of the year, except July and August). UAQ36 is the only site so far with a summer occupation including July and August.

While the white-spotted spinefoot is highly abundant in the UAQ lagoon, the other species of rabbitfish encountered in the Persian Gulf, the streaked spinefoot (*Siganus javus*) and the dusky spinefoot (*Siganus luridus*) are barely present (Department of Fisheries, 1984). This makes sense, since the latter ones mainly prefer rocky habitats (Carpenter et al., 1997). Although the taxonomic identification of the rabbitfish remains from UAQ36 were not possible at species level, it is quite likely that they mostly belong to white-spotted spinefoots (Figure 4).

It has been outlined that the white-spotted spinefoots' main spawning period occurs from March to early June, with a peak in April in the southern Persian Gulf (Department of Fisheries,

1984: 29, fig. 12; al-Ghais, 1993; el-Sayed & Bary, 1994; Wassef & Abdul Hady, 1997; Grandcourt et al., 2007). Hatching occurs about one day after spawning (May et al., 1974), and according to Laviña and Alcalá (1974) the white-spotted spinefoot grows up to 10 cm (TL) in about 3 months in Philippines. Hasse et al. (1977: fig. 4) also found that juveniles grow up to 7–9 cm (TL) over the same period of time in Palau, Micronesia. Similar results have been obtained for the southern Persian Gulf by modelling the von Bertalanffy growth function (von Bertalanffy, 1938) with the parameters given by Grandcourt et al. (2007: tab. 1) (Figure 5.a): rabbitfish grow up to 8 cm (TL) in 3 months and about 10 cm (TL) in 4 months. Standard length (SL) and fork length (FL) given in original publications were converted into total length (TL) using length–length relationships from Gumanao et al. (2016). Assuming that sea water temperatures were similar to today's, and that neither reproductive seasons nor growth parameters have changed for the white-spotted spinefoot during the past 7000 years, it is more than likely that most of the small rabbitfish from UAQ36 (8–10 cm TL in Figure 5.b) were caught about 3–4 months after hatching, i.e. mostly during the summer months, July and August (Table 4). Small strongspine silver-biddies could have also been targeted at this particular time of the year in the shallowest areas of the lagoon (see Grandcourt et al., 2006). It is thus interesting to note that small rabbitfish and mojarras were both well represented in SU 1818. Conversely, most of the other taxa identified in the assemblage could have been caught throughout the year. Precise evidence of activity during other seasons, however, remains elusive, since fishing was only restricted to shallow areas of the lagoon.



Figure 4. Sample of remains belonging to rabbitfish from SU 1818, UAQ36, and corresponding live picture of the white-spotted spinefoot, *Siganus canaliculatus* (© P. Béarez, K. Lidour): 1. Precaudal vertebra of indeterminate rabbitfish, *Siganus* sp.; 2. Caudal vertebra of indeterminate rabbitfish, *Siganus* sp. Scale: 1 mm.

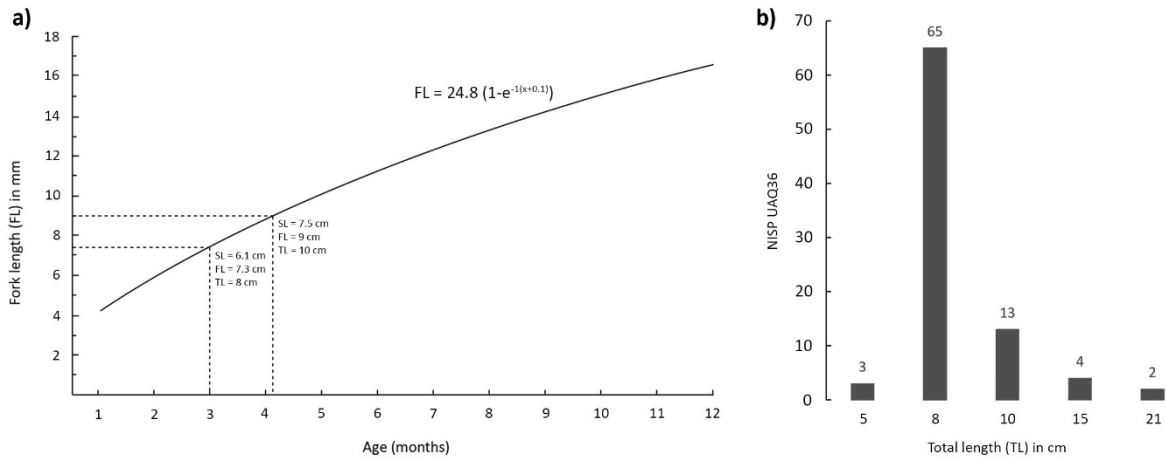


Figure 5. a) von Bertalanffy growth function for *Siganus canaliculatus* from the southern Gulf according to parameters given by Grandcourt et al. (2007: tab. 1). Interpolations of fish age at about 7.3 and 9 cm (FL) – conversion from 8 and 10 cm (TL) using length-length relationships from Gunamao et al. (2016); b) Estimated total lengths (TL) of rabbitfish caught at UAQ36 (NISP = 87).

Future fieldwork at UAQ36 should focus on extending the excavation trench, especially from layers where summer activities have been detected (i.e. SU 1818). The main aim should be to specify what type of occupation (residential versus logistical) define this site.

More identifications at the species level should be obtained by supplementing existing reference collections of Persian Gulf fishes. ZooMS analyses (Richter et al., 2011) could also be planned soon. However, first laboratory tests were inconclusive due to a lack of molecular material (M. Buckley, pers. comm.). Just as it is the case for human remains (Zazzo et al., 2014), it is likely that the lack of collagen in ancient fish bones is due to arid conditions occurring in Eastern Arabia.

6. Conclusion

It is unlikely that fish played as important a role in the UAQ36 subsistence as at Akab or UAQ2. One can assume that the UAQ36 inhabitants were less invested technologically and logistically in fishing activities than the other neighboring Neolithic sites. In this sense, Lancaster and Lancaster (1995: 227) indicate that, in the Ash-Sharqiyyah Region, each tribe was traditionally concentrated on distinct subsistence strategies (i.e. herding, fishing, etc.). Using the model of *djarifa* fishing from Mayotte, it is possible that fishing at UAQ36 was only carried out as a secondary activity during foraging trips for shellfish gathering. Malacological studies are, however, necessary to assert this. One is also tempted to say that the foraging radii were restricted in a context of competition for resources between the different sites inhabiting the UAQ lagoon. The sharing of fishing grounds could have led to intergroup conflicts, which is in line with evidence of violence from a number of burials excavated at UAQ2, BHS18, and Ra's al-Hamra 5 (Santini, 2002; Kiesewetter, 2006; Salvatori, 2007; Méry et al., 2016). An increase in population and the intensification of foraging activities in the UAQ lagoon during the 5th

millennium BCE could have led to the strengthening of ownership claims over key resources. This is assumed to be associated with territoriality and violence between groups inhabiting the same area (Fitzhugh, 2003: chap. 10; Zangrando, 2009: 603), which could explain why the fisheries from UAQ36, UAQ2, and Akab are so different. However, more research is required to clarify this idea.

The large occurrence of small rabbitfish and mojarras suggests that fishing was partly carried out during the summer months by the UAQ36 inhabitants. This discovery could change our assumptions on the seasonal pattern of mobility during the Neolithic and underlines that certain coastal sites could have been occupied all year round. This clearly demonstrates the importance of archaeo-ichthyological studies to help resolve issues regarding seasonality and mobility. At this point, we need to remain cautious and continue to seek further evidence of summer activities with the help, for instance, of sclerochronology applied to marine shellfish and the analysis of domestic mammal tooth enamel oxygen isotope ratios.

UAQ36 is a Neolithic site whose data on fisheries contrast with most other sites in Eastern Arabia. The comparative study of sites situated in the UAQ lagoon is of great interest for studies about climate change during the Holocene and the associated evolution of subsistence strategies. Therefore, the recent excavations conducted at UAQ38, a newly discovered Neolithic site only 1 km northeast of UAQ36, are of particular interest (Degli Esposti et al., 2019): zooarchaeological analyses are in course on the retrieved faunal material and will provide substantial comparative data on coastal subsistence strategies and mobility during the mid-Holocene in Eastern Arabia.

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