The Prehistoric Fisheries of Akab Island (United Arab Emirates): New Insights into Coastal Subsistence during Neolithic in Eastern Arabia

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Abstract

The Neolithic period in Eastern Arabia (especially from 5500 to 3100 BC) is better understood due to recent excavations of stratified sites stretching from Kuwait to the Sultanate of Oman. When oasis agriculture developed from the Bronze Age onwards, herding, shellfish gathering, and fishing became the primary modes of subsistence, and despite strong regional aridity, coastal shell middens provide the best preservation conditions in the Persian Gulf. Akab, one of the many Neolithic shell middens of the United Arab Emirates coastline, is situated in the Umm al-Quwain lagoon. This settlement is dated to the second part of the fifth millennium BC and has provided more than 37,000 fish remains, derived from over 50 fish species. Ichthyofaunal analysis underlines the predominance of coastal pelagics, such as kawakawas and trevallies, and the exploitation of several coastal fishes, mostly seabreams and emperors. Inhabitants fished over a wide aquatic territory, which included shallow-water biotopes, situated inside the lagoon, and the open sea. The associated fishing gear, composed of stone sinkers and shell fishhooks, indicates that nets and lines were used. Here, we review the seasonal organization of activities and mobility schemes from an archaeo-ichthyological perspective.

Keywords: Archaeo-ichthyology; Eastern Arabia; fishing; Neolithic; Persian Gulf

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Introduction

Archaeological research – which for a long time concentrated on the Bronze Age and the relationship between Mesopotamia, Iran and the Indus Valley – has recently developed a particular interest in the Late Prehistory and Neolithic of Eastern Arabia. However, only a few Neolithic sites, mostly shell middens, have been excavated between Kuwait and the Sultanate of Oman during the last few decades.

Fishing and shell harvesting have long been an important subsistence activity among Arabian coastal societies, being first documented by classical Graeco-Roman authors such as Diodorus Siculus, Ptolemy and Pliny who described them as 'fish-eaters' or *ichthyophagi*. This reliance on marine resources is still highlighted by contemporary authors (e.g. Beech 2004; Charpentier 2002), and has been corroborated by recent zooarchaeological investigations (Beech 2010a; Beech & Glover 2005; Mashkour et al. 2016; von den Driesch & Manhart 2000).

Akab is a famous archaeological site in the United Arab Emirates (UAE) known for its unprecedented ceremonial structure made of dugong bones, presented as one of the oldest ritual sites in Arabia (Méry et al. 2009). Excavation of the settlement area has provided dense occupation layers containing a huge amount of faunal deposits, mostly seashells, crabs and fish remains. The site is dated from the Late Neolithic (ca. 4500-3100 BC), which is a period currently under-represented in the Persian Gulf (Uerpmann 2003). Therefore, Akab is a cornerstone for understanding the regional Neolithic, and the study of Akab fish bones provides an opportunity to investigate Late Neolithic fisheries and compare them with what is known for the Middle Neolithic (ca. 5500-4500 BC), especially at the nearby site of Umm al-Quwain 2 (Mashkour et al. 2016).

Two preliminary studies were done on the fish bones of Akab: one concerning a small sample from the 1990-1992 excavations (Jousse et al. 2002) and one concerning the material collected in 2002 (Beech et al. 2017; Méry et al. 2008). This study presents a complete analysis of all the material from that site focusing on the detailed identification of the fish remains, the potential fishing techniques used and on the probable fishing grounds and seasons.

Site discovery and localisation

In 1989, the former French Archaeological Mission in Umm al-Quwain conducted a series of surveys (Boucharlat et al. 1991). During these surveys, the site of Akab (25°34'9.94"N; 55°34'31.67"E) was discovered on Jazirat al-Ghallah, a small island situated in the Khor al-Beidah, a vast lagoon bordering the modern city of Umm al-Quwain (Figure 1). The surface of the site, on the top of the flattened sand dune forming the central part of the island, was covered with lithic flakes, shell beads and faunal remains, which mostly included seashells, fish and dugong bones.

The lagoon formation dates back to the Early Holocene (Sanlaville & Dalongeville 2005). During this period, a marine transgression cut through the pre-existing dunes aligned along the coast to form some large sheltered embayments. This longshore drift subsequently established a sand barrier, which enclosed the lagoon. Nowadays, this lagoon comprises an important mangrove whose brackish waters are maintained by continuous infiltrations of the water table into the sea. However, due to the wetter climate in the Early Holocene (Berger et al. 2013; Preston et al. 2015), the seasonal surface streams (sing. *wadi*, pl. *wudiyan*) were probably able to flow more continuously. And while the lagoon was also probably smaller than today, the presence of the mangrove is well attested since the middle 6th millennium BC. Many mudcreeper shells (*Terebralia palustris*) were discovered in the earliest levels of the UAQ2 settlement site (Figure 1), dated from ca. 5500-5300 BC (Méry et al. 2015: 360). This gastropod is known as a typical symbiont of the Indo-West-Pacific mangals.

The lagoon itself is shallow (max. depth: 10 m) and provides profitable habitat for marine life: seagrass beds grow over the soft bottom areas and sparse corals are established on the subtidal rocky flats. Locally called *farush*, the beach rocks result from the slow cementation of fine sediments. The tidal range is low (between 0.2 m and 1.5 m) but the foreshore slope is gentle, exposing a wide bare area during low tides, which could be particularly suited to traditional fish trapping devices. Nowadays, the water temperature range inside the lagoon is 18-20°C during winter, increasing to 25°C in mid-spring and frequently exceeding 30°C during the summer. For that reason, salinity may exceed 40 ppt during the hotter months (> 45 ppt in the shallowest areas), whereas it remains roughly close to the Persian Gulf mean during the rest of the year (Ali & Cherian 1983; Shriadah & al-Ghais 1999; UAQ Fisheries 1984). Because high temperatures and salinities can become limiting factors for the occurrence of certain fishes in the lagoon, modern fishermen have turned to deeper waters for their year-round activities.

The Persian Gulf is also shallow (35 m mean). Just off the coast of Umm al-Quwain, the depth is about 7.3 m at 450 m offshore, and about 15 m at 2 nautical miles offshore (Service Hydrographique de la Marine 1904: 111-112).
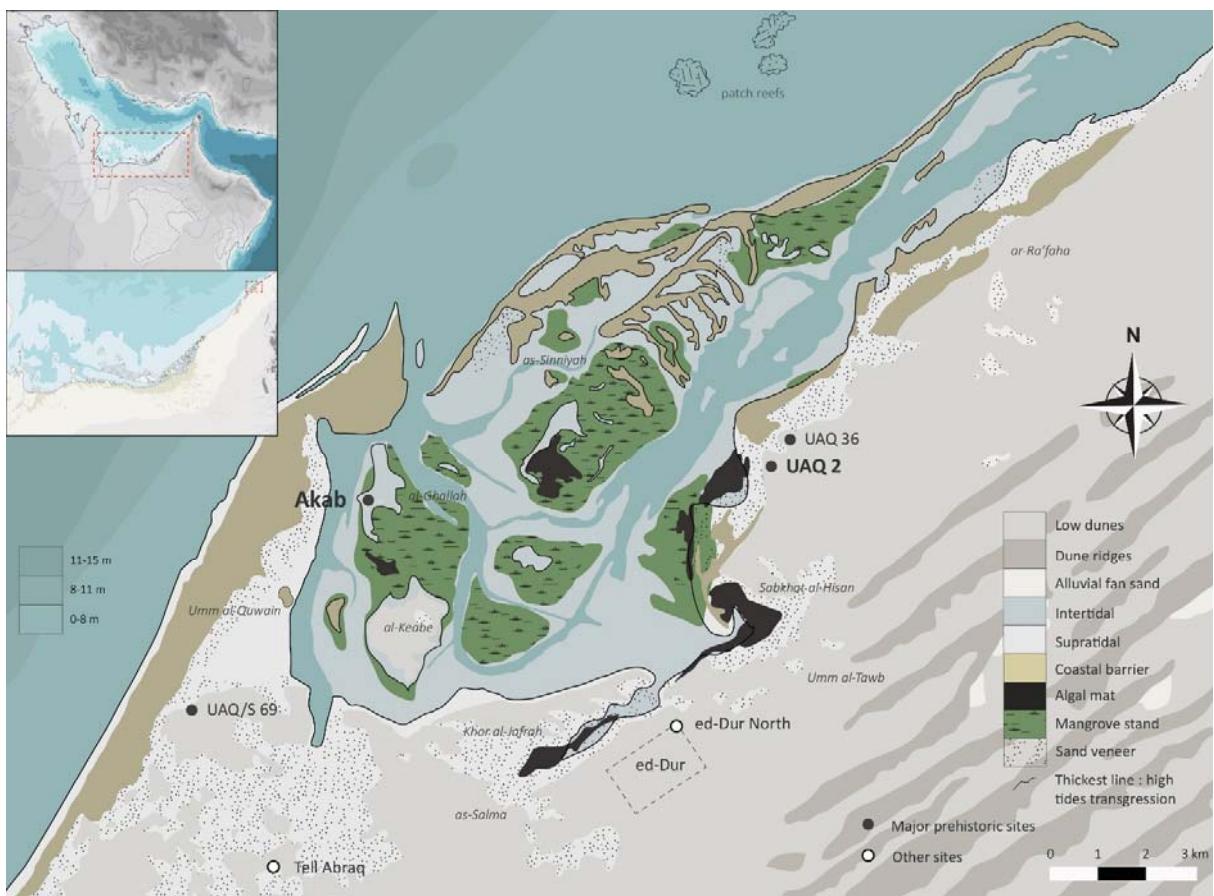
Figure 1. Map of the Umm al-Quwain lagoon (Khor al-Beidah) and localisation of the major archaeological sites (modified from Ministry of Energy, UAE, 2006)

Site description

Excavations and material culture

The site was first excavated in 1990-1992 and was described as a small butchery camp which had specialised in dugong fishing (Jousse et al. 2002); it was dated to the Late Neolithic period, ca. 4500-3100 BC.

From 2002 until 2009, a new series of excavations were conducted by a team from the French Archaeological Mission to the UAE (Charpentier & Méry 2008). Six test trenches (2 x 4 m) were excavated in order to define the extension of the settlement site. The excavated area represented 60 m².

The oldest occupation layer was dated to ca. 4600 BC in Trench 2 (Table 1: Pa-2355). Trench 5 offered well-preserved levels ranging from 4300 to 4000 BC (Table 1; Figure 2). The archaeological horizons (25-35 cm thick), directly accumulated on the Pleistocene wind-borne sand were sealed

by an uppermost layer of sterile sand, more than 70 cm thick. The settlement area delivered over 250 post holes (possibly corresponding to round houses, wind barriers and fences), numerous hearths and domestic waste from where most of the faunal material was obtained (see part 2.2).

Sample	Type of sample	BP			2σ cal. BC			Context
Pa-2433	Dugong bone	5140	+/-	55	3522	-	3226	Dugong accumulation
Pa-2355	*Marcia*cf. *hiantina*	6275	+/-	50	4710	-	4461	Trench 2, Layer 6
Pa-2440	*Marcia*cf. *hiantina*	5970	+/-	35	4353	-	4207	Sector 1, base
Pa-2356	*Marcia*cf. *hiantina*	5900	+/-	50	4316	-	4056	Trench 5, Layer 6
Pa-2439	*Marcia*cf. *hiantina*	5710	+/-	30	4062	-	3914	A/B/C/21

Table 1. Radiocarbon and 2r calibrated dates from the Akab site. Radiocarbone ages according to Charpentier & Mery 2008. Calibration program : Calib Rev 7.0.4.; Marine13 calibration curve (Stuiver & Reimer 1993). ΔR = 163 according to Saliège et al. 2005; Southon et al. 2002.
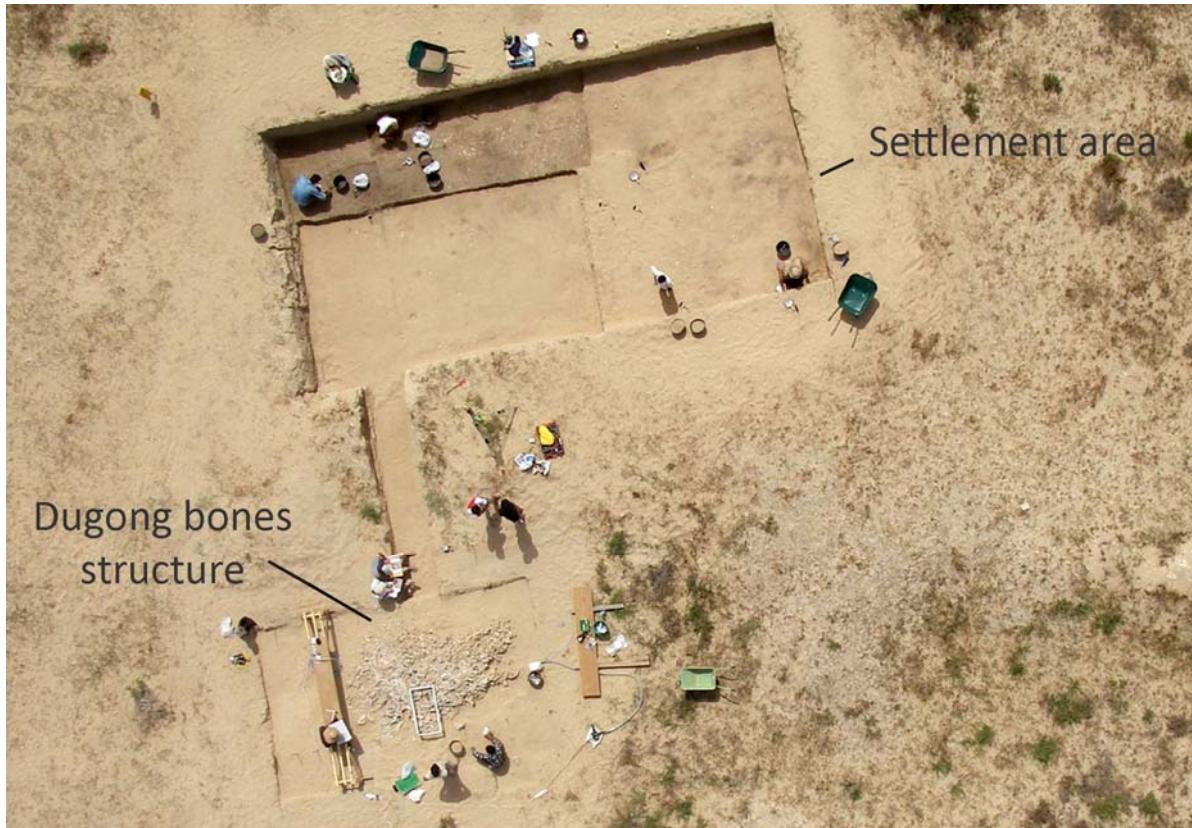
Figure 2. Kite photo of the 2002-2009 excavations: top, the settlement area from trench 5, sector 1 & 2; bottom, the dugong bone mound © T. Sagory.

The material culture is clearly related to the Late Neolithic period in Eastern Arabia, due to the presence of shell fish-hooks and miniature stone sinkers (Cleuziou & Tosi 1998: 124-127; Méry &

Charpentier 2013; Uerpmann 1992). It also comprises several "splintered pieces" and drills made from chert or flint that were primarily involved in the local manufacturing of personal ornaments: perforated gastropod beads (e.g. *Ancilla* spp.), *Spondylus* sp. and Pteriidae (pearl oysters) shells disc beads, *Conomurex persicus* or *Conus* sp. apex ring beads, and *Hexaplex kuesterianus* columella or soft stone tubular beads. Shell scrapers made from the valves of large clams (*Callista* spp.), and sheep bone points were also found, as were flint tile knives. All the pottery corresponds to the standard 'Ubaid ware (Méry et al. 2016: 162) which comes from southern Iraq; a few painted sherds have 'Ubaid 3 period decoration (Charpentier & Méry 2008; Méry & Charpentier 2012).

The fishing gear of Akab is typical of the Neolithic period as defined in the Oman peninsula (see Uerpmann 1992 for a review). Several stone sinkers were found (N = 22) (Figure 3, n°1-2). These are generally used by fishermen to weigh their nets, fishing lines or cage traps. At Akab, we distinguished two different types:

- Type A: Sinkers are made from siliceous stone pebbles roughly fist sized (5-10 cm) and about 100-200 g (Charpentier & Méry 2008: fig. 8). Type A1 sinkers are generally rounded with a picked or grooved central waistline, used to tie a headline (Figure 3, n°1). Type A2 sinkers, less common, are flattened with notched edges – many are made in fine sandstone pebbles. Because of their moderate weights, it is likely that Type A sinkers were mostly used to weight medium-sized fishing nets such as gill nets and small seines.

- Type B (Figure 3, n°2): Sinkers are made from small round pebbles (diameter ca. 2.5-3 cm; weight less than 20 g). A coiling waistline is generally grooved around it. These sinkers were probably used to weight light gear such as cast nets or hook-and-line (Charpentier & Méry 2012: fig. 19-20). Type B sinkers appear during the Late Neolithic.

Note that other classifications also exist: the Akab Type B sinkers correspond well to the small thick pebbles from Saruq (Uerpmann et al. 1992: 94-95) and the fourth class from Ra's al-Khabbah 1 (Cavulli & Scaruffi 2011: fig. 2), in coastal Oman.

Shell fish-hook technology has been abundantly documented in the Sultanate of Oman (Bavutti et al. 2015; Charpentier & Méry 1997) and, more recently, in the Persian Gulf (Méry et al. 2008). Few northern UAE sites provide Neolithic fish-hooks: Akab, UAQ2 upper levels (Méry 2015), and out of context in Shimal (SH501 Wadi Suq tomb, Kästner 1991). At Akab, both final pieces and preforms, made from mother-of-pearl valves (mostly *Pinctada persica*) were found (Charpentier & Méry 2008: fig. 9; Méry et al. 2008: fig. 2). Complete shell fish-hooks generally do not exceed 3-4 g. According to the classification suggested by Bavutti et al. (2015), the Akab fish-hooks belong to various types:

- Type 1B (Figure 3, n°3-4): Fish-hooks are small and slender (up to 5 cm in length) with the point curved toward the shank (Méry et al. 2008: fig. 2). A well-preserved piece shows two eyelet perforations, used to tie the line. This one is of the sub-category 1Be.

- Type 2A: One example of a large (> 5 cm in length), thick fish-hook is attested at Akab (Méry et al. 2008: fig. 2). The point, despite being broken, seems to have been roughly parallel to the shank.


Figure 3. Neolithic fishing gear (selection of stone sinkers and shell fish-hooks) from Akab # French Archaeological Mission in UAE.

Recent excavations have also revealed that the dugong bones accumulation follows a designed structure of about 10 m² (Charpentier & Méry 2008; Méry et al. 2009). It was built in different stages by assembling the skulls, ribs and mandibles of at least forty dugongs (Figure 2), and was constructed on packed sandy soil which included fragmented shells and bones reddened by ochre and artefacts similar to those found in the settlement area. Within the dugong structure, a kit of tools was also found which included a bone point, a tile knife made from tabular flint, a miniature stone sinker and two shell fish-hooks (Méry & Charpentier 2012). It was probably protected and enhanced by walls or fences, as suggested by a closed array of post holes, and dates from the end of the Neolithic period (Table 1: Pa-2433). It has no parallel in Eastern Arabia but is comparable to the dugong bone mounds in Torres Strait (Northern Australia), which, however, are not older than the 14th century AD (David et al. 2009; McNiven & Feldman 2003). Each of these structures are linked to totemic ceremonies and propitiatory rites (Haddon 1904-1912).

The latest levels of the settlement area and the dugong accumulation are separated by an episode of wind-blown sand, possibly corresponding to a phase of aridification. It remains unclear if the dark millennium, as defined by Uerpmann (2003), between 3800/3700 and 3300/3100 BC

in the northern UAE, is due to poor preservation of the archaeological layers (owing to the sandy winds and dunal destabilisation), a shift in the mobility of Neolithic populations toward a more nomadic life, or the difficulty for archaeologists in identifying low invested technologies and minimally diversified material cultures.
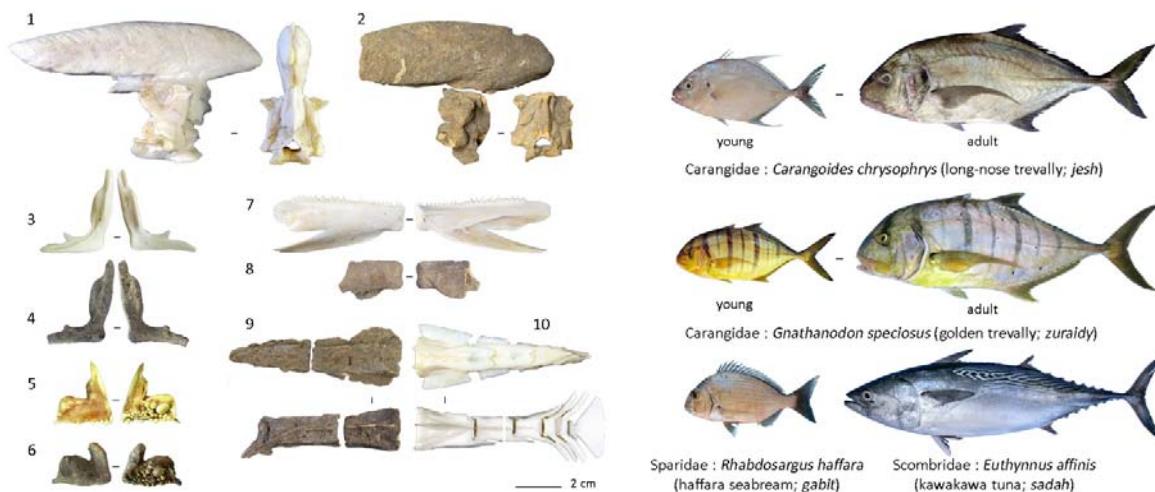
Figure 4. Sample of the fish remains collected from Akab compared to analogue bones from the MNHN osteological reference collection, and corresponding live-pictures of the species (photos © P. Béarez and K. Lidour). 1-2. Hyperostotic supraoccipital and exoccipitals of longnose trevally, *Carangoides chrysophrys*; 3-4. Right premaxillae of golden trevally, *Gnathanodon speciosus*; 5-6. Right premaxillae of Haffara seabream, *Rhabdosargus haffara*; 7-8. Right dentaries of kawakawa, *Euthynnus affinis*; 9-10. Series of caudal vertebrae of *Euthynnus affinis* (dorsal and lateral view).

Faunal material

While the inhabitants of Akab also consumed livestock (sheep/goats, cattle, and possibly dogs) and wild game (gazelles and donkeys) their food economy came essentially from the sea (Charpentier & Méry 2012: 71); indeed, this settlement has provided a large amount of faunal material, of which the majority are fish bones and seashells.

Apart from fish, the marine fauna comprises dugongs (*Dugong dugon*), sea turtles (e.g. *Chelonia mydas*), crabs (mostly *Scylla serrata* and *Portunus segnis*) and shellfish, which could be directly gathered from the surrounding shores, mangal roots or shallow patch reefs. Molluscs are mostly represented by mudcreepers (*Terebralia palustris*), murexes (*Hexaplex kuesterianus*), venus clams (*Marcia* spp.) and oysters (*Saccostrea cuccullata* and *Pinctada* spp.). Dugongs and sea turtles are slow swimmers and are not particulary difficult to catch even with simple techniques involving ropes, nets or harpoons (Jousse et al. 2002; Zacot 2009). Other sites have provided numerous dugong bones within the Persian Gulf from Neolithic to the pre-oil era (Beech 2010b).

Because of the relatively few number of specialists working on fish osteology in Eastern Arabia, fishing practices (techniques, seasons, grounds and the risk taking to access them) have remained poorly known until now, especially for the Neolithic period. This has been exacerbated by the underrepresentation of faunal material due to the lack of precise contextual data and the absence of sieving – a situation which is obviously problematic for the study of coastal societies. However, because the site of Akab was an open-area excavation (with a detailed stratigraphy) and all the material was sieved, a detailed study of the fish remains was possible.

Material and methods

After drying, all the excavated sediments were systematically dry sieved using a 3 mm mesh. Fine sieving was also punctually conducted with a 1 mm mesh to test for the presence of small fauna. The faunal material came from the six levels (plus the inter-level 4/5) identified in two sectors of the same settlement area (Trench 5).

The bones were poorly preserved and often heavily encrusted with carbonates, which often obliterated their diagnostic parts; however, some anatomical connections were well preserved (Figure 4, n°9). Concretions such as these are a common phenomenon observed at several sites in Eastern Arabia (Beech 2004: 174; Mashkour et al. 2016: 199) and as they generally resist brushing or scrapping, acid treatments have to been used.

Anatomical and taxonomical identifications were conducted according to the methods of comparative anatomy, using the reference collection of the Muséum National d'Histoire Naturelle (MNHN). Quantifications (Table 2) were based on the number of identified specimens (NISP), the minimum number of individuals (MNI) and the weight of identified specimens (WISP). Estimated fresh weights of fishes presented in Figure 6.C were obtained after visual comparisons of their bones with the reference collection. Estimated fresh weights were preferred for their particular interest in diet studies. However, fine estimates of fish sizes should be preferred for fishing techniques reconstructions or ecological interpretations (Lidour et al. 2018). The MNI (Table 2) was calculated using the frequency of bones and combined with laterality and size (Chaplin 1971; Poplin 1981). However, the NISP is commonly preferred for archaeological fish bones because of the important bias in MNI calculation, which are due to both taphonomic processes and methods of sampling (Grayson 1984; Morales-Muñiz 1984). In this study, N refers to the total number of remains while NISP refers to the number of identified specimens within both taxonomical and anatomical counts.

Results

A total of 37 612 fish bone remains were studied and recorded, of which 12 550 were identified to family level, at least, and to species level where possible. This fine grain identification was made possible due to the high proportion of species-diagnostic bones. In some cases, higher taxa levels have been used: the superfamily Sparoidea for seabreams (Sparidae) and emperors (Lethrinidae) and the superorder Batoidea for rays (Table 2). Only a few remains were retrieved within the 1-3 mm fraction (N = 229; NISP = 95). This low number has no impact on the >3 mm assemblage analysis or the taxonomic spectrum. From a qualitative perspective, it informs on the presence of certain taxa wich could not be identified with a 3 mm mesh or larger, such as silversides (*Atherinomorus lacunosus*), indian oil sardines (*Sardinella longiceps*), plus numerous juveniles of sparoids (grouping Sparidae and Lethrinidae), needlefishes (Belonidae) and mullets (Mugilidae). At Akab, fine sieving also allows to collect many otoliths, in particular from mullets.

Almost all the fish bones come from the two main excavated residential areas: Sector 1 (32 493 remains) and Sector 2 (5074 remains) and are therefore related to the Late Neolithic 1 (LN1) settlement, i.e. 4300-4000 BC (Table 1). At Akab, this period is represented by different levels of occupation for which precise dates are not yet established.

Only a few remains (N = 45) came from the dugong accumulation: the ritual structure of Akab dated to the second part of the 4th millennium BC (Late Neolithic 2 period). According to their diversity and spatial dispersion, it is unlikely that fishes were deliberately deposited here, as, for example, in the case of First Fruits ceremonies (Mauss 1967: 197-204).

A total of 56 teleost species were identified, distributed across 42 genera and 22 families including, in order of importance, trevallies (Carangidae), tunas (Scombridae) and seabreams. These are followed by emperors, catfishes (Ariidae), mullets, needlefishes and barracudas (Sphyraenidae). Few cartilaginous fishes were reported: these were identified as requiem sharks (Carcharhinidae) and stingrays (Dasyatidae).

Non-fish remains were also punctually recorded, consisting of fragments of cuttlebone (*Sepia* sp.) and sea urchin shell (*Echinometra* sp.).

Family	Genus	Species	NISP	MNI	WISP (g)
Carcharhinidae	*Carcharhinus*	*Carcharhinus* sp.	4	1	1.209
Dasyatidae	*Himantura*	*Himantura* sp.	1	1	?
Superorder Batoidea (ind. 'ray')			1	1	0.09
Clupeidae	*Sardinella*	*Sardinella longiceps*	3	1	0.02
	ind.		6	1	0.06
Chanidae	*Chanos*	*Chanos chanos*	1	1	0.66
Ariidae	*Netuma*	*Netuma bilineata*	191	81	318.734
		Netuma thalassina	41	27	97.315
		Netuma sp.	338	11	338.112
	Plicofollis	*Plicofollis* sp.	3	3	2.73
	ind.		21	2	9.12
Mugilidae			655	94	132.082

Family	Genus	Species			
Atherinidae	*Atherinomorus*	*Atherinomorus lacunosus*	1	1	0.01
Belonidae	*Ablennes*	*Ablennes hians*	14	5	2.124
	Tylosurus	*Tylosurus choram*	277	17	25.069
		Tylosurus crocodilus	15	10	13.76
		Tylosurus sp.	54	10	29.077
	ind.		236	2	75.283
Platycephalidae	*Platycephalus*	*Platycephalus indicus*	16	13	5.15
Serranidae	*Cephalopholis*	*Cephalopholis hemistiktos*	1	1	0.37
		Cephalopholis sp.	5	2	0.51
	Epinephelus	*Epinephelus coioides*	17	11	41.013
		Epinephelus sp.	6	5	7.961
	ind.		3	3	1.619
Rachycentridae	*Rachycentron*	*Rachycentron canadum*	32	21	33.776
Echeneidae	*Echeneis*	*Echeneis naucrates*	1	1	0.322
Carangidae	*Alectis*	*Alectis indica*	13	6	42.93
		Alectis sp.	3	1	5.11
	Alepes	*Alepes vari*	3	2	0.45
		Alepes sp.	2		0.1
	Carangoides	*Carangoides bajad*	9	6	14.429
		Carangoides chrysophrys	827	335	2316.972
		Carangoides fulvoguttatus	7	7	11.31
		Carangoides orthogrammus	1	1	0.44
		Carangoides sp.	1705	42	1317.987
	Caranx	*Caranx ignobilis*	5	3	20.482
		Caranx sexfasciatus	163	80	141.542
		Caranx sp.	189	5	67.48
	Gnathanodon	*Gnathanodon speciosus*	632	92	541.476
	Megalaspis	*Megalaspis cordyla*	9	6	2.659
	Scomberoides	*Scomberoides commersonnianus*	74	29	55.958
		Scomberoides lysan	1	1	0.11
		Scomberoides sp.	8	3	0.649
	Seriola	*Seriola dumerili*	1	1	0.5
	Ulua	*Ulua mentalis*	4	3	12.61
	ind.		1125	11	947.228
Lutjanidae	*Lutjanus*	*Lutjanus argentimaculatus*	4	3	3.82
		Lutjanus sp.	13	8	1.627
	ind.		1	1	1.29
Gerreidae	*Gerres*	*Gerres acinaces*	5	3	1.1
		Gerres sp.	3	1	0.29
Haemulidae	*Plectorhinchus*	*Plectorhinchus schotaf*	3	5	2.702
		Plectorhinchus sp.	4		1.912
	Pomadasys	*Pomadasys argenteus*	6	4	3.328
		Pomadasys commersonnii	1	1	0.4
		Pomadasys sp.	3	3	0.62
	ind.		1	1	0.417
Lethrinidae	*Lethrinus*	*Lethrinus borbonicus*	3	2	1.05
		Lethrinus lentjan	32	23	10.265

Family	Genus	Species	NISP	MNI	WISP
		Lethrinus cf. mahsena	1	1	2.419
		Lethrinus nebulosus	158	65	90.561
		Lethrinus sp.	508	77	95.661
Sparidae	Acanthopagrus	Acanthopagrus berda	43	22	20.56
		Acanthopagrus bifasciatus	12	5	7.356
		Acanthopagrus sp.	5	1	0.83
	Argyrops	Argyrops cf. caeruleops	1	1	0.81
		Argyrops spinifer	14	9	18.571
	Crenidens	Crenidens indicus	2	2	0.12
	Rhabdosargus	Rhabdosargus haffara	1231	439	710.329
	Sparidentex	Sparidentex hasta	6	4	7.94
	ind.		374	13	37.691
Superfamily Sparoidea (ind. Lethrinidae or Sparidae)			721		42.341
Sciaenidae	Otolithes	Otolithes ruber	5	2	0.392
	ind.		9	2	0.595
Mullidae	Parupeneus	Parupeneus sp.	1	1	0.12
Terapontidae	Terapon	Terapon jarbua	1	1	0.11
		Terapon sp.	3	2	0.064
Sphyraenidae	Sphyraena	Sphyraena acutipinnis	1	1	2.968
		Sphyraena jello	3	2	5.097
		Sphyraena putnamae	70	29	26.732
		Sphyraena sp.	73	8	16.458
Scombridae	Auxis	Auxis thazard	34	8	5.86
		Auxis sp.	20	2	1.294
	Euthynnus	Euthynnus affinis	2333	166	3094.116
	Rastrelliger	Rastrelliger kanagurta	2	1	0.632
	Scomberomorus	Scomberomorus cf. commerson	1	1	0.36
	Thunnus	Thunnus tonggol	5	4	18.686
		Thunnus sp.	7	3	15.331
	ind.		82	1	38.44
Triacanthidae	Triacanthus	Triacanthus biaculeatus	21	11	13.57
ind.			25062		6727.492
		Total determined	**12550**		**10939.388**
		Grand Total	**37612**	**1899**	**17666.88**

**Table 2.** Table of identified fish from Akab, quantifications in NISP, MNI and WISP.

Anatomical representation

The systematic attribution of the fish remains was based on osteological comparisons (see part 3). Hyperostoses are species-specific swollen bones and have a special usefulness in archaeo-ichthyological analyses (von den Driesch 1994) and figured prominently among the several keys of determination used during this study. The longnose trevally (*Carangoides chrysophrys*) shows a diagnostic hyperostosis on the supraoccipital which is elongated in the cranio-caudal axis (Figure 4, n°1-2), while hyperostoses of Indian threadfish (*Alectis indica*) and king soldier bream (*Argyrops*

spinifer) are sub-triangular shaped in the lateral view. The hyperostoses of the island trevally (*Carangoides orthogrammus*) and the Indian pompano (*Trachinotus mookalee*) are more similar and might be confused with the longnose trevally; however, the latter also possesses hyperostotic epiotics and exoccipitals that tend to fuse together and are easily recognizable.

In the Akab assemblage, the anatomical representation was equilibrated with regard to the different occupation levels. The bones of the mandibular arch (in particular dentaries and premaxillae) were the most recorded cranial pieces (Figure 6.A and B), and were represented in similar proportions throughout the different settlement levels.

No evidence of a particular anthropogenic process in the fishes was observed and there were no butchery marks. A high proportion of vertebrae was prevalent in the assemblage and a number of articulated vertebrae were found during the excavation, but cranial bones were limited as they are often more sensitive to decomposition, generally because of their weakness – a typical case of differential preservation as noted on many archaeological sites. The number of vertebrae ranges from 24 to 27 for Carangidae and roughly 37 to 41 for Thunnini (tunas and kawakawas), which may explain their greater proportion in the assemblage compared to single and paired bones, especially skull bones. It is more likely that kawakawas were not headed at Akab since certain strong cranial bones, such as maxillae and dentaries (Figure 6.B), were also found. Cranial pieces from other taxa are generally well represented.

A Cranial skeleton ca. 30% NISP = 5326 | Post-cranial skeleton ca. 70% NISP = 11 825

1-3% | 4-10% | 10-50% | > 50%

Pterygiophore
Supraoccipital
Maxilla
Premaxilla
Dentary
Articular
Quadrate
Preopercle Opercle Cleithrum
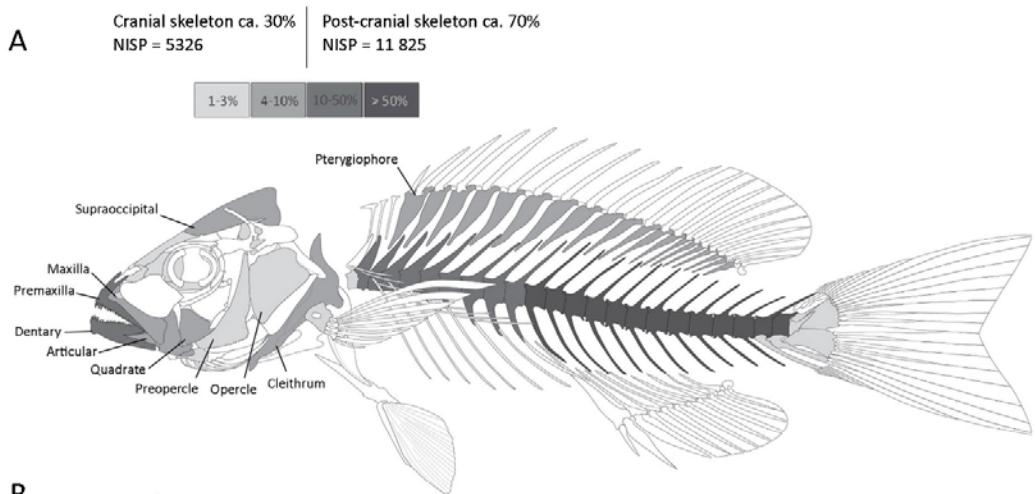
B

	Global		Euthynnus affinis		Carangoides spp.		Gnathanodon speciosus		Rhabdosargus haffara	
	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%
Supraoccipitals	311	1.8%			308	12.1%				
Epiotics	92	0.5%			92	3.6%				
Exoccipitals	48	0.3%			48	1.9%				
Quadrates	219	1.3%	6	0.3%	107	4.2%	26	4.1%	1	0.1%
Maxillae	423	2.5%	107	4.6%	118	4.6%	28	4.4%	8	0.6%
Premaxillae	1269	7.4%	21	0.9%	93	3.6%	72	11.4%	578	47.0%
Angulo-articulars	224	1.3%	21	0.9%	95	3.7%	20	3.2%	11	0.9%
Dentaries	1218	7.1%	73	3.1%	128	5.0%	74	11.7%	625	50.8%
Hyomandibulas	116	0.7%	2	0.1%	36	1.4%	26	4.1%		
Opercles	139	0.8%	9	0.1%	70	2.7%	25	4.0%	1	0.1%
Cleithra	200	1.2%	4	0.2%	35	1.4%	2	0.3%		
Ceratohyals	108	0.6%			63	2.5%	14	2.2%		
Precaudal vertebrae	2192	12.8%	420	18,0%	183	7.2%	108	17.1%	4	0.3%
Caudal vertebrae	5165	30.1%	1604	68.0%	373	14.6%	138	21.8%		
Total NISP	17151		2333		2549		632		1231	

C

	Min	Q1	Median	Q3	Max
Carangoides chrysophrys	500	2000	2500	2600	8000
Gnathanodon speciosus	200	2000	2100	2500	8000
Rhabdosargus haffara	50	150	200	250	800
Euthynnus affinis	500	2500	3000	4000	10000

Euthynnus affinis | Carangoides chrysophrys | Gnathanodon speciosus | Rhabdosargus haffara
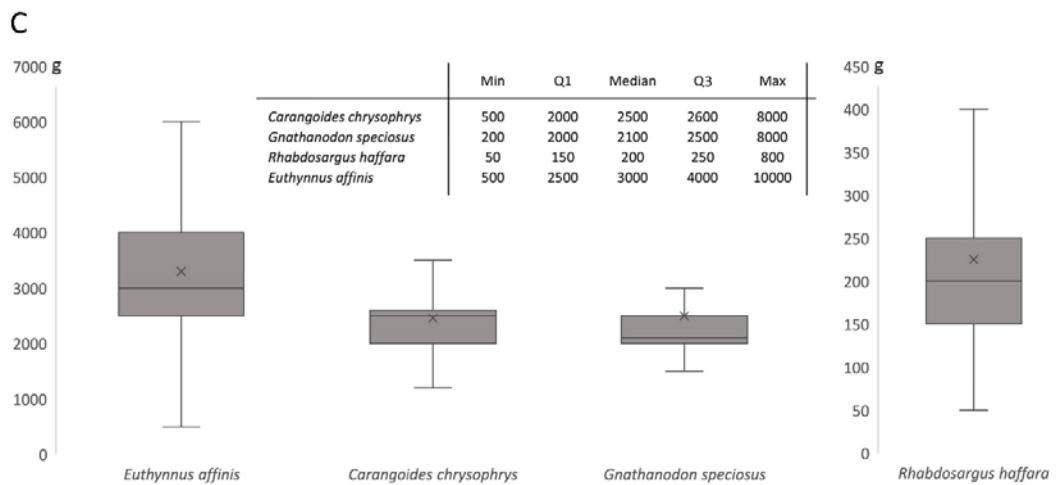
Figure 5. A) Anatomical representation of the fish bones from Akab (modified from Coutureau & Béarez 2012). B) Detailed representations for the main taxa identified. C) Boxplots of fresh weights for the main taxa at Akab (based on estimations according to visual comparisons with the MNHN Paris collection).

Taxonomic quantification

According to the NISP data (Table 2), the assemblage is dominated by trevallies (38%) with a high representation of the genus *Carangoides* (21%), mostly *Carangoides chrysophrys*. Golden trevallies (*Gnathanodon speciosus*) are less frequent (5%) and are directly followed by bigeye trevallies (*Caranx sexfasciatus*) and talang queenfishes (*Scomberoides commersonnianus*). Tunas and mackerels (20%) constitute the second most important taxon, largely dominated by kawakawas (*Euthynnus affinis*). Seabreams (Sparidae, 13.5%) are dominated by the Haffara seabream (*Rhabdosargus haffara*). Since it is often difficult to differentiate seabreams from emperors (5.6%) using some bone elements, especially caudal vertebrae, both families were grouped into the Sparoidea superfamily, which counts for ca. 25% (Figure 5).

A disparity was noted between levels 5-6 and 4-1 due to an increase in the proportion of seabreams. This observation could not be interpreted in terms of seasonality because kawakawas and Haffara seabreams, which were abundantly represented in these levels, are today available in large amounts during the same period of the year (mostly during winter). Thus, a change in the fishing grounds, offshore fishing versus lagoon exploitation, and fishing techniques might explain this slight variation in fish proportions.
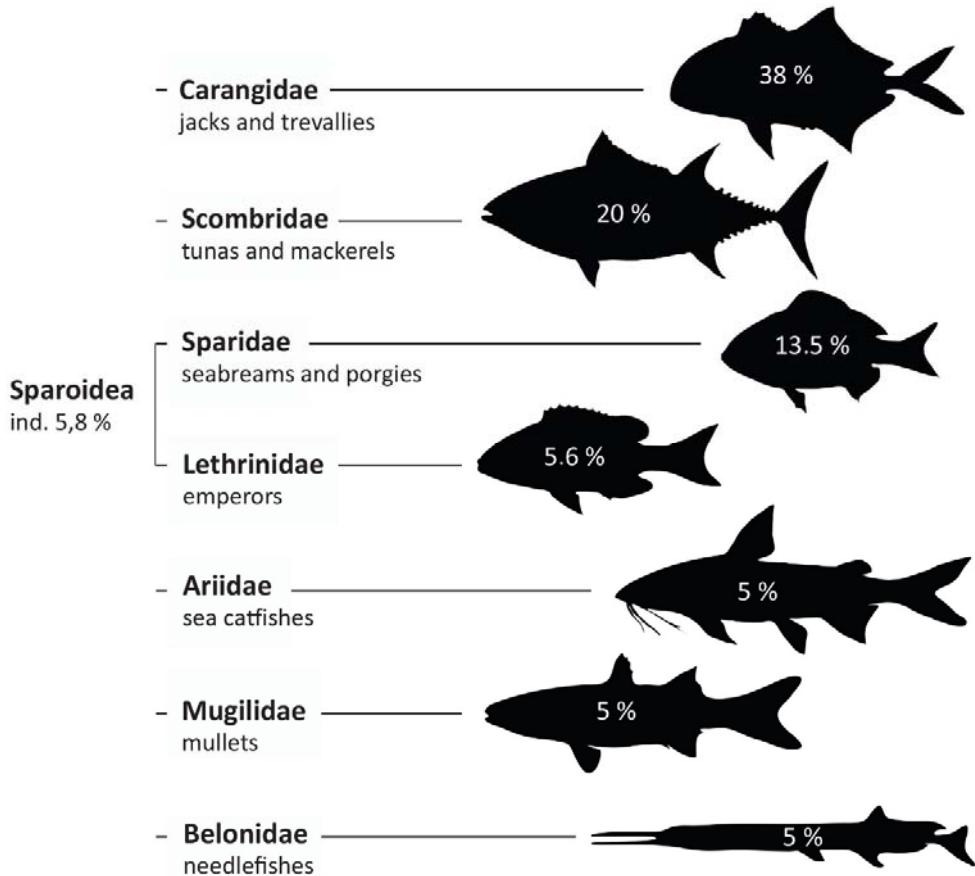
Figure 6. Proportions of the main families identified at Akab. NISP = 12 550; other fish taxa = 2.1%

Discussion

The majority of fishes identified at Akab can currently be caught in the vicinity of Umm al-Quwain. An ecological survey done in 1984 (UAQ Fisheries 1984: tab. 9) permits the estimation that 90% of the taxa identified at Akab could have been directly caught inside the lagoon, including small sparoids, sea catfishes, mullets, young barracudas and needlefishes.

Mangroves are well known to act as nurseries for many species, like young trevallies (*Carangoides* spp.); however, according to fishermen from Cairns (Queensland, Australia), even adult individuals are able to enter into shallow lagoons and coastal mangroves to hunt using the opportunity of high tides (Grant 2014; Lieske & Myers 1994). Therefore, although the longnose trevallies from Akab weigh around 2-3 kg (Figure 6.C), it is highly likely that they frequent the proximity of lagoons and coastal mangroves to feed, and that lagoon entrances or inlets were good locations to place nets or traps to catch them. Golden trevallies or *zuraidy* are principally

encountered over and around offshore reefs, but they could also enter sheltered lagoons for feeding. Adults generally adopt a solitary behaviour – sometimes seen among other trevally schools – while the younger ones are widespread and commensal of large fish, sharks and even dugongs.

Kawakawas, locally known as *sadah*, are epipelagic fishes which often remain close to the shore. They tend to form multi-species schools with others scombrids (Collette & Nauen 1983) like longtail (*Thunnus tonggol*) and frigate tunas (*Auxis thazard*) – which were also identified at Akab, although in low numbers (Table 2) – and prey on small pelagics like sardines and silversides when feeding near the surface (Fischer & Bianchi 1984). These small fishes are also consumed by marine birds like seagulls whose flights fishermen track to find the fish schools. Tuna schools are also easily visible because they bust-up the surface of the sea (Figure 7.A). They are therefore an easy and profitable catch for traditional fisheries using nets or hook-and-line, as kawakawas commonly attain lengths of 60 cm to 1 m; however, it is necessary to use boats to catch them.
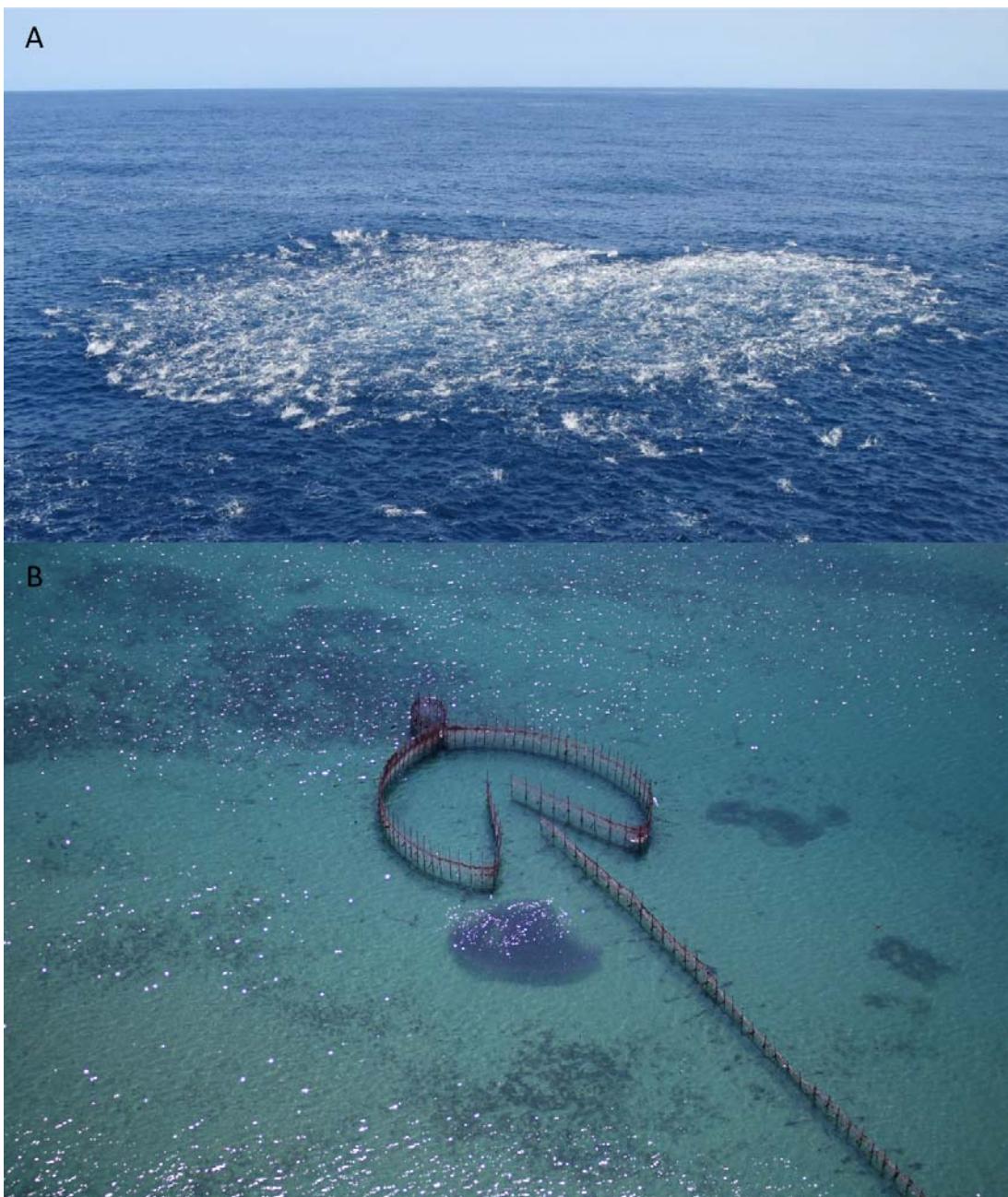
Figure 7. A. Example of a tuna bust-up off the Ivory Coast. Creative Commons BY-NC-ND 4.0 © 2013 Wm Adams. B. Aerial view of traditional haddrah trap in Kuwait. Note the fish shoal at the trap's entrance. © 2016 Paulo Oliveira.

King soldier breams or *kofar* (*Argyrops spinifer*) are bentho-pelagic fishes restricted to deep waters when adults. They could have been caught with long lines or with basket traps, locally called *gargoor* (pl. *garagir*), according to modern fisheries in the Gulf. These traditional dome-shaped traps, built in the recent past with palm leaves and fronds (Chen et al. 2012), might have

been in use for a long time. Within the Sparoidea, the main taxon is the Haffara seabream or *gabit*, which is encountered in shallow coastal waters, especially over soft bottoms. Young emperors or *sheary* also form large agglomerations in mangroves and over grass beds. These small sparoids can be easily caught with a hook-and-line or *gargoor*. Tidal traps were formerly attested by classical authors like Diodorus Siculus (II, 22) and were probably among the first techniques used by prehistoric fishermen in the area (Cleuziou & Tosi 2007: 53). These traps, called *haddrah*, are semi-permanent intertidal fences (Figure 7.B) vertically fixed and supported by stones; this forms a bottleneck that encloses fish at the falling tide. The variant *sakkar* consists of intertidal barrier nets or net stakes which are more easily installed in lagoons or estuaries (Beech et al. 2005; Nedelec & Prado 1999: 41). These techniques are non-selective and are able to catch a wide variety of fishes frequenting the shallow inshore waters; in this way they are similar to beach seines (*yaroof*) and provide similar landings (Bangsgaard & Yeomans 2016). In the Persian Gulf, the main taxa caught using the coastal barrier traps are seabreams, mullets, young barracudas, needlefishes and trevallies, as well as moderate quantities of benthic fishes like sea catfishes, flatheads and tripod fishes (Abou-Seedo 1992; al-Baz et al. 2007; 2013). It should also be noted that several marine invertebrates like cuttlefishes and pelagic crabs can also be caught with tidal traps (McEwan et al. 2001), which supports the hypothesis of this technique being used by Akab fishermen.

The main fishes caught at Akab were listed and correlated with the most popular traditional fishing techniques used in Eastern Arabia (see Supplementary Information: S2). The data suggest a joint utilization of hook-and-line, gill nets and beach seines, or barrier traps. It is likely that fishing was carried out inside the lagoon with low selective techniques like beach seines and tidal traps, allowing for a wide variety of coastal taxa to be caught, especially seagrass bed and soft bottom dwellers. In addition, at least two other specialised techniques are likely to have been used: one focusing on open water Thunnini schools, mostly kawakawas, probably caught with hook-and-lines or nets; the other focusing on trevally schools with tidal traps or gill nets deployed close to the inlets during high tides.

Seasonality

Seasonality is a recurring subject in Neolithic archaeology. It was initially suggested that Neolithic societies in Eastern Arabia followed a mobility scheme similar to that of traditional Bedouin tribes, alternating between summer and winter settlements (see Scholz 1980: fig. 2). The validity of this model was enhanced by characteristics of our modern climate: the summer is very hot and windy on the coast, making boat fishing dangerous and poorly efficient. Seasonal mobility between coastal and inland settlements has been recently suggested in the case of the study of Buhais BHS18 site (Kutterer & Uerpmann 2017; Uerpmann & Uerpmann 2008). However, recent studies indicate that some Neolithic sites could have been inhabited throughout the year (Biagi & Nisbet 2006; Mashkour et al. 2016; Méry 2015). Moreover, other studies have demonstrated that the climate was wetter during the Neolithic (Berger et al. 2013; Preston et al. 2015) which suggests that their summers were not as harsh as one might expect. Nowadays, it is possible to fish during all seasons, although winter is clearly more productive (UAQ Fisheries 1984; Van Neer & Gautier

1993). A sedentary life, therefore, did not implicate any food storage as the local waters provided enough fish throughout the year to feed the entire settlement.

Beech (2004) analysed the growth marks on emperor otoliths from the Neolithic site of UAQ2 (ca. 5500-4000 BC) close to Akab (Figure 1) and suggested that these fishes were caught during the spawning seasons, May-June and September-October (see also von den Driesch & Manhart 2000). Lidour et al. (2018) also propose that Akab people took advantage of the spawning season of emperors during spring. Conversely, scombrid fishing and livestock slaughtering are considered as winter activities at UAQ2 by Mashkour et al. (2016). Indeed, within the modern climate, tunas and kingfishes (*Scomberomorus commerson*) are mostly caught during the winter months, because late spring and summer are generally too hot for these fish.

Until now, there has been little evidence of summer activities at Neolithic sites in the Gulf. According to Desse (1988) observations of otoliths from Khor P and Shagra (Qatar) indicate that fishing could have also been carried out during the summer, although less intensively than during the rest of the year. Unfortunately, the sclerochronology and ecology of fishes in Eastern Arabia and Indo-West-Pacific are not sufficiently understood to firmly extrapolate their seasonality. For example, tropical fish can spawn during a period of several months in warmer waters (Lowe-McConnell 1979) and the spawning season can vary between regional populations of the same fish species (Grandcourt et al. 2010). These biological characters, combined with the problem of applying actualist data to ancient climates, prevents any clear statement about seasonality based on fishing activities in the area being determined. To improve this knowledge, it will be necessary to embrace a broader ecosystemic view and to model the ecological studies on both ancient environments and palaeoclimatic data.

Fish processing

Current knowledge of Eastern Arabian Neolithic sites has not yet clearly provided any evidence of fish processing linked to drying, salting or even smoking. Desse (1988) observed an overrepresentation of fish cranial elements at Khor P (Qatar), suggesting heading practices. The body, containing the rachis, could have been diffused on roads to supply inland sites (Tosi & Cleuziou 1998: 125). However, the published cranial remains from Khor P were mostly composed of seabream teeth and the otoliths of seabreams and silversides. And because enameloid and dentin from teeth and aragonite from otoliths make these remains more resistant than bones in certain contexts, there could be a taphonomic bias; therefore, the hypothesis of fish processing suggested at Khor P is clearly unconvincing.

This hypothesis was also proposed for Akab (Charpentier & Méry 2008: 131) but, unfortunately, as scombrid skull bones are particularly fragile (Béarez 1996: 135-136), except for certain jaws elements, only a few were preserved. Moreover, until now, no inland site dated from the Neolithic period (e.g. Buhais BHS18) has provided fish bones. Dried fish consumption is however suggested on later sites, especially at Mleiha (2nd-3rd centuries AD), in inland UAE (Van Neer et al. 2013).

	UAQ2	UAQ2	Akab	Tell Abraq	Ed-Dur North	Ed-Dur
	Middle Neolithic	Late Neolithic	Late Neolithic	Bronze Age	Iron Age	150 BC-150/250 AD
NISP	**5006**	**351**	**12550**	**14988**	**75**	**4429**
Mugilidae	0.5%	1.1%	5.2%	19.4%	-	4.5%
Serranidae	2.4%	4%	0.3%	2.2%	6.7%	4.7%
Carangidae	1.5%	3.7%	38.1%	15.4%	29.3%	11.6%
Lethrinidae	37.1%	8%	5.6%	24.2%	12%	9.3%
Sparidae	49.7%	73.5%	13.5%	21.7%	32%	15.4%
Scombridae : Thunnini	2.7%	-	19.1%	0.2%	4%	29.1%
Scombridae : others	< 0.1%	-	0.7%			17.4%

Table 3. Comparison of proportions of the main fish families identified at Akab and different UAQ sites (data from Beech 2004; Mashkour et al. 2016; Uerpmann & Uerpmann 2005; Van Neer 2017).

Comparisons with other assemblages

The exploitation of shallow coastal environments using generalist techniques is the typical scheme of Neolithic fisheries in the Persian Gulf. Indeed, high proportions of seabreams are noted at several sites, such as as-Sabiyah H3 (36% - Kuwait, Beech 2010a), Dosariyah DOS11 (77% - Saudi Arabia, Beech 2004), al-Markh J19 (83% - Bahrain, von den Driesch & Manhart 2000), Khor P (78% - Qatar, Desse 1988) and Dalma DA11 (34% - UAE, Beech 2004; Glover & Beech 2005). Groupers (Serranidae) are another of the main taxa identified at as-Sabiyah (17%), al-Markh (4%) and Dalma (15%), suggesting that fishing was also carried out over reefs.

Fishing in open waters is also attested by the occurrence of Thunnini – while few - at as-Sabiyah (N = 36), Dosariyah (N = 5), al-Markh (N = 2) and Dalma (N = 215). Some of these sites have also provided few remains of king soldier breams, which is consistent with fishing in deeper waters. Strikingly, until now, none of these sites has provided proportions of trevallies similar to those at Akab (i.e. 38%): remaining always lower than 10%. Proportions of pelagic fishes including Thunnini and trevallies are, however, prevalent on several sites situated in coastal Oman (> 60%): Ra's al-Hamra sites 4, 6, 10, and Khor Milkh 1 (Uerpmann & Uerpmann 2003; Wilkens 2005). This area benefits from the proximity of deeper bottoms that could be advantageous for the living and the transit of pelagic fishes.

Because of the occurrence of Thunnini (N = 137), king soldier breams (N = 111) and even a tooth of tiger shark (*Galeocerdo cuvier*) at UAQ2, we know that fishing in open waters was practiced during the Middle Neolithic (MN) in the Gulf, i.e. from the mid-6th to the end of the 5th millennium. The assemblage is, however, mainly dominated by small sparoids (ca. 90% of the MN assemblage, and mostly 10-30 cm long) (Table 3), whose proportion increases during the following periods.

Mashkour et al. (2016) suggest that fishing 'became even more focused on local exploitation of the shallow waters of the neighbouring lagoon'. Emperors represent the prevalent taxa at UAQ2, about 40% during the MN but only ca. 6% during LN1 at Akab. This proportion decreases during the transitional MN-LN (10%) and LN1 (2%) at UAQ2 – despite the differential NISP. Nowadays, small emperors are numerous in the lagoon of Umm al-Quwain and are available all year round (UAQ Fisheries 1984), which raises the question of their disappearance in LN levels. Emperors were mainly identified through their otoliths at UAQ2 (85% of their remains, Beech pers. com.) but, unfortunately, before 2015, otoliths were not systemically collected due to the methods of separating material: otoliths were often confused with shell fragments. Subsequently, because the site was excavated before 2015, the upper levels of UAQ2 are otolith depleted and we can assume that the proportion of emperors is greatly underestimated at Akab. Such a bias is common in field archaeology, but it could be eradicated with the use of fine sieving and further training for field archaeologists by faunal remains experts.

LN1 is currently marked by the occurrence of the shell fish-hooks and small stone sinker types (Cleuziou & Tosi 2007), which advocates for their joint use. They were mainly discovered along the coast of Oman on sites dated from the mid-5th to the end of the 4th millennium (Bavutti et al. 2015; Charpentier & Méry 1997). Only a few were found in northern UAE, at Akab (Méry et al. 2008) and in the Late Neolithic levels at UAQ2 (Méry et al. 2015). While the efficiency of hand-lines is theoretically lower than gill nets, the first technique requires less time, effort and people (Jennings et al. 2001); the reflection of the mother-of-pearl shell makes the fish hook function as a lure that tricks surface predators, in particular Thunnini (Anell 1955: 146; Béarez et al. 2012: 209). Shell fish-hooks represented an important innovation, and were likely the results of long and fruitful observations of the surface predator's behaviour and forms of hunting. The use of shell fish-hooks, therefore, was probably motivated by, and linked to, the fishing of pelagics.

Later fisheries are known from two other archaeological sites at Khor al-Beidah (Figure 1): Tell Abraq (Early Bronze Age) and ed-Dur (Early Iron Age and the Late pre-Islamic period) (Table 3). The large amounts of fish remains include significant quantities of sparoids and mullets, which indicate a perseverance of fishing in the shallow coastal waters, including the lagoon (Uerpmann & Uerpmann 2005; Van Neer et al. 2017). Overall, open water fishing is attested at both sites through the occurrence of pelagic fishes such as Thunnini, king soldier breams, amberjacks (*Seriola* spp.) and eagle rays (Myliobatidae). The Iron Age and pre-Islamic site of ed-Dur provides a closer taxonomic spectrum to Akab: it is quite diversified and shows notable proportions of trevallies and kawakawas (Table 5). The occurrence of rabbitfishes (Siganidae, 3.6%) at Tell Abraq and groupers (4.7%) at ed-Dur may suggest the use of *garagir* traps in reef areas situated offshore.

Large proportions of trevallies and kawakawas are registered on later sites of the northern UAE coast: Kush, Jazirat al-Hulaylah, Julfar, and Siraf, which are dated from the Islamic period. Small coastal fishes such as sparoids (mainly Haffara seabreams) and mullets were also identified in abundance on these sites (Badstöber 2000; Beech 1998; 2004; Desse & Desse-Berset 2000). The presence of tuna (*Thunnus* spp.) is more important at these later sites – e.g. at Julfar (8.19%) –, considering that fishermen were more able to fish in deeper waters due to an amelioration of their fishing gear and boats.

Conclusion

Although the local environment of UAQ has probably changed significantly during the past 7500 years, current archaeo-ichthyological data confirms that the lagoon and its mangrove were already well established during the Neolithic, allowing a wide variety of fishes – commonly associated with the lagoonal environments as shallow sheltered bays, mangroves and estuaries – to be caught (see Supplementary Information: S1). Fishing expeditions were also carried out by boat, in open waters, in order to catch kawakawas and other pelagic fish.

In the UAE, Neolithic offshore seafaring is well attested by the insular occupations of Marawah and Dalma (Beech 2004; Beech et al. 2016), some tens of kilometres offshore. At as-Sabiyah (Kuwait) boating technology is documented by fragments coated in bitumen (Carter & Crawford 2010). Reed imprints on these fragments suggest that ancient boats were comparable to traditional *shoosh*/*shashah*: rowboats made of palm fronds and commonly operated with paddles, or less frequently with a small sail. Such small crafts could only carry a restricted fishing crew and a limited cargo, making them not particularly safe for fishing offshore schools. Net fishing can also be difficult in open waters, as an overloaded net can cause the fishermen to fall overboard, or even to sink the boat. Hand-lining and especially luring with shell fish-hooks are much easier alternatives to catch surface predators like tunas, kingfishes and trevallies.

In the Trobriand archipelago, Malinowski (1948) noted that open water fishing generated superstitious behaviours among the fishermen, while fishing inside the lagoon did not. Fishing and seafaring in these deep waters creates anxiety because of the fear of bad landings and drowning risks (Homans 1941; Poggie et al. 1976; Poggie & Pollnac 1988), and often produces superstitious behaviours including taboos and apotropaic or propitiatory ceremonies. Beliefs associated with totemism commonly originate from hunting or fishing stories (Leblic 1989; Mauss 1967: 47-48; McNiven 2003). In some respects, fishing in open waters probably presented a high degree of risk, and therefore a certain amount of anxiety, for the Neolithic Akab fishermen; and may have resulted in superstitious behaviours or beliefs linked to the construction and maintenance of the dugong bone mound for specific ritual ceremonies. It remains impossible, however, to specify the nature of the superstitions/beliefs and their link with the belief system of the community.

Because of its predefined and predesigned structure and the specific set of associated deposits (mostly adornments), the dugong bone mound at Akab has been interpreted as a ceremonial site. And despite the fact that the parallels mentioned here reflect other cultures, countries, and periods, it is possible that at Akab these rites were probably not only dedicated to the dugong figure and its symbolism, but also to fishing and, in particular, to the expeditions carried out in the open sea.

This study provides new insights into Neolithic fisheries, regarding the marine resources exploited, the fishing gear used and strategies developed in accordance with the natural environment of Akab. Alongside generalist fishing inside the lagoon, the fishing of trevallies was probably organised near the inlet, while kawakawas were captured in the open sea, only accessible by boat. The evidence presented here suggests that the shell fish-hooks, weighted with miniature sinkers, that arose during the Late Neolithic, were specifically used as shining lures to catch selected pelagic predators.

This study also opens up the discussion on fish processing and seasonality, which was formerly oriented – based on local ethnographic data – toward semi-nomadism; it also provides evidence of a more balanced pattern, with a site occupation that extended at least from winter to late spring. Further work at Akab, especially schlerochronologic investigations, should contribute to resolve this issue. As data on the other faunal remains (seashells, crabs, terrestrial mammals and dugongs) are still not available, the relative part of fish consumption in the Neolithic diet is unclear. Nevertheless, according to other contemporaneous sites, both in the UAE and the Sultanate of Oman, fishes have significantly contributed to the human subsistence economy here during both Neolithic and later periods.

Supplementary Information S1. Synthetic and simplified repartition of the main fish taxa identified at Akab among the Umm al-Quwain coastal environments.

| | | Angling | Baited basket trap | Nets | | |
| | | | | Cast net | Beach seine | Gill net |
		hadaq	gargoor	saleyah	yaroof	asharee; hayal
Carcharhinidae		x				x
Superorder Batoidea (ind. 'ray')		x			x	x
Clupeidae	*Sardinella longiceps*			x	x	x
Chanidae	*Chanos chanos*	x	x			
Ariidae	*Netuma* spp.	x	x	x	x	x
Mugilidae				x	x	x
Atherinidae	*Atherinomorus lacunosus*				x	x
Belonidae		x		x	x	x
Platycephalidae	*Platycephalus indicus*	x			x	
Serranidae	*Cephalopholis hemistiktos*		x			
	Epinephelus coioides	x	x			x
Rachycentridae	*Rachycentron canadum*	x			x	x
Echeneidae	*Echeneis naucrates*	x			x	x
Carangidae	*Alepes* spp.	x			x	x
	Carangoides spp.	x			x	
	Caranx ignobilis	x				x
	Gnathanodon speciosus	x			x	x
	Megalaspis cordyla				x	x
	Scomberoides commersonnianus	x			x	x
	Scomberoides lysan	x			x	
	Seriola nigrofasciata		x			x
Gerreidae	*Gerres* spp.	x		x	x	

Family	Species					
Haemulidae	*Plectorhinchus schotaf*	x	x		x	
	Pomadasys argenteus	x	x		x	
	Pomadasys commersonnii	x	x			x
Lethrinidae	*Lethrinus* spp.	x	x			x
Sparidae	*Acanthopagrus berda*	x			x	x
	Acanthopagrus bifasciatus	x	x		x	x
	Crenidens indicus			x	x	x
	Rhabdosargus haffara	x		x	x	x
Mullidae	*Parupeneus* sp.		x	x	x	x
Terapontidae	*Terapon theraps*	x	x		x	x
Sphyraenidae	*Sphyraena* sp.	x		x	x	x
Scombridae	*Euthynnus affinis*	x				x
	Rastrelliger kanagurta	x				x
	Scomberomorus commerson	x			x	x
	Thunnus sp.	x				x
Triacanthidae	*Triacanthus biaculeatus*	x			x	

Supplementary Information S2. Species-associated techniques traditionally used in Eastern Arabia (data were collected from several references mentioned in the text: Abou-Seedo 1992; al-Baz et al. 2007; 2013; Beech 2004; UAQ Fisheries 1984; Vorenger 2016.)

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