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A Bronze to Iron Age fishing economy at Kalbāʾ 4 (Emirate of Sharjah, United Arab Emirates)

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Abstract

This paper represents a study of archaeological fish remains retrieved from the excavations conducted by C. S. Phillips between 1993 and 2001 at Kalbāʾ 4 (Emirate of Sharjah, UAE). Kalbāʾ 4 is a major coastal site that was continuously occupied from the Umm an-Nar period to the Iron Age (c. 2700–600 BCE). The site is of particular interest regarding monumental architecture, pottery studies and exchange networks across Arabia and its neighbouring regions from the Bronze Age onwards. A corpus of about 5500 fish remains provides information on fishing economies during the entire occupation of the site. Data regarding fish complement results previously obtained from the study of other fauna including marine molluscs, sea turtles, terrestrial and marine mammals. They allow us to document a fishing-based economy at Kalbāʾ 4. The results highlight the exploitation of a quite limited range of fish taxa associated mostly with reef areas (groupers, trevallies, snappers, spangled emperors, King soldierbreams), brackish waters (mullets) and the open sea (scombrids). The techniques seem to have mainly involved the use of baited lines from boats, fishing nets and possibly cage traps. The discussion includes comparisons with the other main fish studies conducted for the Bronze Age and the Iron Age in Eastern Arabia.

KEYWORDS

Bronze Age, fishing, Gulf of Oman, Iron Age, Kalbāʾ, zooarchaeology

1 | INTRODUCTION

1.1 | Site location and environmental settings

Kalbāʾ site 4 (K4) is a Bronze Age–Iron Age mound located on the east coast of the United Arab Emirates in an exclave of Sharjah Emirate (Figure 1: Left). The site was first discovered in 1993 by C. S. Phillips during surveys undertaken with the authorisation and support of the Sharjah Ministry of Culture and Information and the Archaeological Authority of the Emirate of Sharjah (SAA). The size of the mound and the large quantities of pottery and soft-stone vessels that have been found on the surface during the survey rapidly demonstrated the great archaeological potential of this site. Excavations were undertaken by a team of the University College London (UCL) under the responsibility of C. S. Phillips every year between 1993 and 2001. New campaigns of excavations are currently being conducted by a joint initiative of the Austrian Archaeological Institute (QeAI) of the Austrian Academy of Sciences (QeAW) and the Römisch-Germanisches Zentralmuseum in Mainz (RGZM)—Leibniz Research Institute for Archaeology (Schwall et al., 2022; Schwall & Jasim, 2020).

The Kalbāʾ region is a small coastal plain overlooking the Gulf of Oman and is located about 150 km

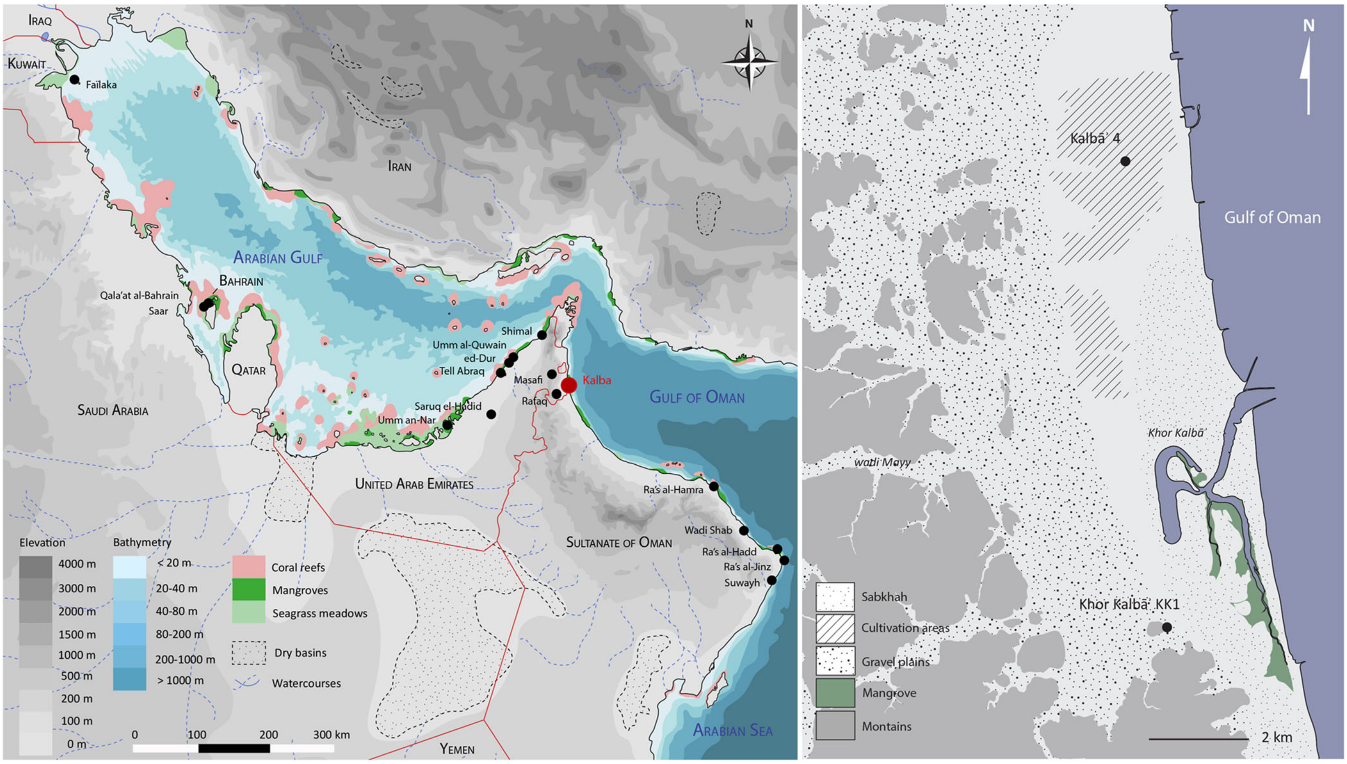

FIGURE 1 Left, Map of the Arabian Gulf showing the location of the different sites and areas mentioned in the present paper; Right, Map of the area of Kalbāʾ showing the location of Kalbāʾ 4 (Bronze Age and Iron Age) and Khor Kalbāʾ KK1 (Neolithic). CAD: K. Lidour. [Color figure can be viewed at wileyonlinelibrary.com]

south of the Strait of Hormuz. The plain extends about 3–5 km from the Shamaliyyah mountains to the sea and is crossed by several wadis. Denser saline seawater in the groundwater table has led to the rise of freshwater nearer to the surface and has directly promoted the growth of numerous acacia trees in the plain as well as the development of tropical coastal ecosystems, including mangroves. Therefore, for a long time, the area has been particularly suitable for agriculture by well irrigation. Although little information is available on the fishing grounds in this area, the local geological configuration suggests the presence of submerged rocky formations, consisting of reef habitats for several fish species. The water depth is about 10 m in the nondredged areas within 2 km off the coast. Then, it rapidly increases by several tens of metres each kilometre offshore. Deep open-sea waters close to the coast favour the occurrence of pelagic fish schools within a radius accessible by short boating trips.

The Khor Kalbāʾ mangrove constitutes a major marine ecological reserve for the whole South-East Arabia. Charcoal samples retrieved from Kalbāʾ 4 testify to the presence of both *Avicennia marina* and Rhizophoreae mangrove species during the third millennium BCE (Schwall et al., 2022, p. 339). The suspected presence of *Rhizophora* charcoals would confirm that the Khor Kalbāʾ mangrove ecosystem benefitted, at that time, from stronger freshwater inputs, whether from higher rainfall or from Wādī Hām surface streaming. Moreover, the local Khor Kalbāʾ landscape is characterised by a wide sabkha, which indicates a previously more extensive lagoon environment and, possibly, a greater extent of mangrove. Mangroves played a key role in the subsistence and the cultural development of ancient Arabian populations established along the coasts of the UAE and the Sultanate of Oman during the regional Neolithic (c. 6500–3300 BCE). The intensive exploitation of marine molluscs and fish has resulted in the formation of large shell middens within the coastal landscapes, in particular, in the northern UAE (from Sharjah to Ra's al-Khaimah) and in the Ash-Sharqiyyah region in the Sultanate of Oman (the Ruways–Suwayh area).

A large fifth millennium BCE shell-midden is also known in the Kalbāʾ area: Khor Kalbāʾ KK1 (Figure 1: Right), which was surveyed and test pitted by C. S. Phillips in the early 1990s (Phillips & Mosseri-Marlio, 2002). Preliminary investigations on this site have shown the importance of shell gathering in its economy, in particular, species associated with swamp and mangrove ecosystems, including giant mangrove whelks (*Terebralia palustris*), ark shells (*Anadara uropigimelana*) and true oysters (*Saccostrea cucculata*), showing mangrove root imprints on their left valves. Almost no fish remains have been found during the excavations, but it is very likely that this is linked to the sieving process and, in particular, the use of a 4 mm mesh, which would not have been fine enough to retrieve small fish remains. Indeed, when carried out in mangroves, fishing generally focuses on the catching of small fish species and juveniles—see, for instance, the study conducted on UAQ36 (Lidour et al., 2020).

1.2 | Archaeological setting

Kalbāʾ 4 is a c. 50 m across mound, rising about 2.5 m high above the surrounding fields. It is located in the vicinity of present-day cultivated date gardens, 2 km inland from the Gulf of Oman coastline (Figure 1: Right). Archaeological levels occur from the surface down to 6.7 m below the present ground level (Schwall et al., 2022, p. 334). They provide architectural features from Early Bronze Age (EBA)/Umm an-Nar period (2700–2000 BCE) through the Middle Bronze Age (MBA)/Wadi Suq period (2000–1600 BCE), the Late Bronze Age (LBA) (1600–1300 BCE) and Iron Age I (IA I) (1300–1000 BCE) and Iron Age II (IA II) (1000–600 BCE) (Eddisford & Phillips, 2009). Radiocarbon dating undertaken by Lindauer et al. (2017, 2018) has partly confirmed this chronology. Additionally, new absolute dates of the EBA and MBA periods were published recently (Schwall et al., 2022, p. 338, fig. 7b).

During the first campaigns of excavations conducted by C. S. Phillips, the earliest levels of occupation were reached at the bottom of a 5.5 m deep trench excavated in the central part of the mound. The earliest phase of the site occupation is marked by the construction of a massive EBA subcircular mud-brick tower (Tower 1) showing a series of small internal compartments (c. 20 × 21 m in plan, with walls surviving to a height of 4 m in some places). A mud-brick pavement (22.143) and a series of terrace walls (wall features) were identified around the tower. The presence of Baluchi incised grey ware and Omani red sandy wares in the pottery assemblage retrieved from the tower compartments suggests an occupation of the late third millennium BCE for these deposits (Eddisford, 2022; Eddisford & Phillips, 2009). This dating is also supported by the presence of an Umm an-Nar "Série Récente C" (David, 1996)-type soft-stone vessel, whose production took place between c. 2300 and 2000 BCE. Burial mounds (i.e., K1.A, K1.B and K2) found in the vicinity of the site have also provided rich material culture including pottery and "figurative-style" soft-stone vessels testifying to connections with Mesopotamia, Bahrain, Kerman-Hormozgan, Sistan-Baluchestan and Indus during the mid-third millennium BCE.

Despite the fact that several campaigns of excavations have been conducted on the site, the stratigraphy remains quite complex, including massive and numerous architectural features that restrain access to the earliest phases of the site occupation, particularly to the EBA levels. During the following periods, until the IA II period, subsequent fortifications and repair works took place around the EBA tower. However, because of the long and intense human activity at the site, the uppermost parts of the oldest structures have been progressively truncated, then eroded and mixed with later deposits, making their excavation and interpretation quite hard.

Changes in the quality of mud-bricks and the alignment of internal walls suggest that the tower underwent rebuilding during the MBA/Wadi Suq period (2000–1600 BCE). During the second millennium BCE, a 2 m high mudbrick platform was also built (composed of a 4 m-thick mud-brick retaining wall [23.050] and a 1.5 thick mud-brick capping). The construction of this mud-brick wall was associated with a significant amount of "Classic Wadi Suq" (as described by Carter, 1997) pottery. Some "Late Wadi Suq" (Carter, 1997) pottery have been found in deposits accumulated against the mud-brick wall, suggesting that the platform was still in use during the LBA (1600–1300 BCE).

During the Iron I period (c. 1300–1000 BCE), a large clay-faced stone revetment wall (32.014) was built on top of the Wadi Suq platform. The latter was enlarged and accompanied by a small tower and deep ditch flanked by a retaining wall (42.017). More recently, after the ditch was silted up, a new encircling clay-faced stone wall (42.009) was built. During the IA II period (c. 1000–600 BCE), the final phase of occupation, the main function of the site seems to have shifted from a defensive purpose to a metallurgic activity, specialised in the smelting of copper or bronze.

1.3 | Overview of the economic activities at the site

A few small pieces of copper slag have been found within the EBA contexts, indicating that some metalworking activities have occurred at the site since the beginning of its occupation. This assertion is supported by the presence of a mining–smelting site further inland, at Hilo (Kutterer & Jasim, 2009; Kutterer et al., 2013). Further copper slags and indirect evidence for metallurgy at Kalbāʾ 4 in the form of crucibles and moulds have been found in the subsequent periods of occupation (Schwall et al., 2022, pp. 341–343). The production of soft-stone vessels seems to have played a major role in the site economy as well throughout its occupation.

Despite being the strategic location of Kalbāʾ 4 for agriculture, there is little evidence of consumption of plants at the site, apart from dates—which is probably due to taphonomic processes. In fact, plant remains have been identified in the fabric of many mudbricks composing the architectures, but none have been identified so far. Recent archaeobotanical data suggest the importance of mangrove wood as fuel for the site inhabitants (Schwall et al., 2022, pp. 337–341, fig. 7a). Subsistence is almost entirely documented by faunal remains, including marine molluscs (mostly *T. palustris* shells), crabs, fish, sea turtles and both terrestrial and marine mammals (dolphins and dugongs). Preliminary zooarchaeological analyses indicate that caprines (sheeps and/or goats) were consumed mainly at Kalbāʾ 4 among terrestrial mammals. Cattle and equid remains have also been identified in the bone assemblage (Phillips & Mosseri-Marlio, 2002). A detailed study of the mammal remains retrieved from Kalbāʾ 4 is currently being undertaken by J. Robert (University of New England, Australia).

This article focuses on the fishing economy at Kalbāʾ 4. The identification of the fish taxa that have been consumed at the site allows us to discuss the nature of fishing grounds exploited within the local environment and the appropriate strategies and equipment deployed for this purpose. The determination of the fishing seasons also takes its part in the general discussion of the organisation of the site economy. This research focuses on the study of fish remains retrieved during excavations conducted between 1993 and 2001 by C. S. Phillips, including a reanalysis of the assemblage published by Beech (2004, pp. 164–173, tabs. 156–161). The material also includes some crab remains, which are briefly presented here.

2 | MATERIALS AND METHODS

The retrieval of fish and crab remains was undertaken mostly by dry-sieving using a 4 mm mesh screen. Some remains have also been hand-collected. However, the 4 mm mesh does not allow the recovery of small remains such as otoliths and bones belonging to very small fish such as sardines, anchovies or juveniles of other species.

The abundance of fish fluctuates considerably within the different stratigraphic units. However, all the main cultural phases represented at the site have provided significant amounts of fish remains, allowing a diachronic analysis and comparisons with other sites (Table 1). The phasing of the contexts was performed on the basis of previous work on pottery by Carter (1997) and Eddisford (2022). The richest stratigraphic units correspond to hearths and post-holes associated with the MBA–LBA structures, used during the second millennium BCE (e.g., contexts 24.063, 24.064 and 34.018). Most of the remains associated with the IA I period were retrieved from layers associated with the clay-faced stone revetment wall (e.g., contexts 34.009 and 34.013). However, the complex stratigraphy does not allow a detailed analysis of the spatial distribution of the fish remains. This issue can be solved by studying further material retrieved on the occasion of new campaigns of excavations.

TABLE 1 Repartition of fish remains among the main cultural phases at Kalbāʾ 4.

Cultural phase	NISP
Umm an-Nar period (Early Bronze Age)	1400
Middle Bronze Age (Wadi Suq) and Late Bronze Age	2386
Iron Age I	594
Iron Age II	321
Surface or mixed	730
Total	5431

Abbreviation: NISP, number of identified specimens.

Anatomical and taxonomic identifications were conducted by K. Lidour according to the methods of comparative anatomy, using M. J. Beech's personal comparative osteological collection of Arabian Gulf fish during a visit in Abu Dhabi (UAE). Quantifications were based on the number of identified specimens (NISP), the minimum number of individuals (MNI) and the weight of identified specimens (WISP). MNI estimates were achieved according to the combination method: the frequency of bones combined with laterality and size estimations (Chaplin, 1971). However, the NISP is commonly preferred because of the significant bias in MNI calculation due to both taphonomic processes and sampling methods (Grayson, 1984; Morales Muñiz, 1984). We estimated the lengths of fish after visual comparisons of archaeological bones with reference specimens (Wheeler & Jones, 1989, p. 141).

Identifications for crab remains are based on descriptions, illustrations and the methodology detailed in Lidour et al. (2021).

In 2019, samples of archaeological fish remains were sent to M. Buckley (Manchester Institute of Biotechnology, University of Manchester, UK) for trial Zooarchaeology by Mass Spectrometry (ZooMS) analyses. ZooMS exploits the peptide sequence in the bone collagen as a molecular barcode (spectra) to identify the taxa. Although ZooMS has previously been proven to be successful for taxonomic determination of archaeological fish remains (Richter et al., 2011), no organic materials have been found within the Kalbāʾ 4 samples, making it impossible to perform analyses using collagen, DNA or lipids (M. Buckley, personal communication in September 2019). As has been explained for ancient human bones (Zazzo et al., 2014), the bone collagen generally does not preserve in Eastern Arabia due to arid conditions.

3 | RESULTS

A total of 5431 fish bone fragments (c. 5 kg) were retrieved and recorded, of which 2309 can be identified to the level of family, genus or species—the identification rate thus reaches 42.2%. It includes a minimum of 16 families, 26 genera and 31 species of marine fish. Fish families are represented by requiem sharks (Carcharhinidae), sawfish (Pristidae), milkfish (Chanidae), marine catfish (Ariidae), mullets (Mugilidae), needlefish (Belonidae), groupers (Serranidae), trevallies (Carangidae), snappers (Lutjanidae), grunts (Haemulidae), emperors (Lethrinidae), seabreams (Sparidae), spadefish (Ephippidae), barracudas (Sphyraenidae) and tunas (Scombridae) (Table 2).

According to the NISP, the whole assemblage is dominated mainly by tunas (40.4%), trevallies (25.2%), seabreams (13.0%), snappers (6.0%), requiem sharks (4.4%) and groupers (4.0%) (Figure 2). Tunas are almost entirely represented by the kawakawa (*Euthynnus affinis*) (Figure 3) and trevally species belong mostly to the genus *Carangoides*. The longnose trevally (*Carangoides chrysophrys*) is the species that is most commonly represented within the Carangidae family. The King soldierbream (*Argyrops spinifer*) is the main species of seabream encountered at Kalbāʾ 4 (c. 80% of the Sparidae). Snapper remains belong mainly to the Malabar blood snapper (*Lutjanus malabaricus*) and the mangrove red snapper (*Lutjanus argentimaculatus*). The orange-spotted grouper (*Epinephelus coioides*) is the only species of serranids clearly identified in the assemblage. At least two genera of requiem sharks are represented: *Carcharhinus* and *Rhizoprionodon* (sharpnose sharks).

Almost all the specimens represented in the assemblage are medium- to large-sized fish: specimens of tunas, trevallies, seabreams, snappers and groupers are frequently estimated to be about 50–70 cm in total length (TL)—corresponding to about 2–4 kg in weight (Figure 4). Smaller fish consist mostly of mullets, emperors and some small seabreams and scombrid species such as the Indian mackerel (*Rastrelliger kanagurta*).

For cartilaginous fish (Chondrichthyes), only vertebrae ($N = 120$) and elements composed of vitrodentine (enamel-like tissue) such as shark teeth ($N = 1$) and stingray's barbs ($N = 1$) are preserved. For bony fish (Teleostei), all the main anatomical elements belonging both to the skull and the backbone are represented. Vertebrae and other postcranial remains (such as pterygiophores and urostyles) represent about 74% of the remains for bony fish. Cranial remains are represented mostly by bones belonging to the mandibular arch including dentaries (17.9%), maxillae (14.1%), premaxillae (13.1%), angulo-articulars (7.2%) and quadrates (5.1%) (Figure 5; Table 3). Hyperostotic supraoccipitals (14.4%) are also well represented within cranial remains. They belong to the longnose trevally, the King soldierbream and the longfin batfish (*Platax teira*). Hyperostotic bones (swollen bones) are frequently species-diagnostic for bony fish and thus quite helpful for archaeo-ichthyological studies (von den Driesch, 1994) (Figure 6).

A single cut mark was clearly identified in the whole assemblage, coming from a hearth (context 34.014) dated from the MBA–LBA phase (Figure 7)—it suggests a fish beheading. It is known that fish butchering often does not leave visible traces (Desse & Desse-Berset, 2000, p. 131). Charring on fish remains is quite uncommon, and observed on both cranial bones and vertebrae. Even when fish are directly cooked on coals, fire marks generally only appear on bones in contact with the less fleshy parts of the body (i.e., external tips of the jaw bones, opercle series, last vertebrae, spines, rays, etc.).

Trevallies and scombrids represented about 60%–70% of the catches, being the main catches throughout the site occupation (Table 4). Nevertheless, we can notice that the proportion of scombrids tends to decrease, whereas trevallies are taking on greater importance during the Iron Age. However, we must be careful not to overvalue the representativeness of the later phases—which have provided fewer quantities of material. The proportions in snappers and breams are significantly higher during the EBA than during the later periods. A greater presence of emperors is observed during the MBA/Wadi Suq and the LBA. It is also worth noting that mullets take on importance between the end of the Bronze Age and the IA I. Groupers are more represented during the IA II than during the earlier phases.

About 820 g of crab remains have been sorted: they consist of a total of 184 fingers (65% of the NISP) and crab carapace fragments (35%). An MNI of 104 has been calculated. More than 99% of the specimens belong to the mangrove-associated species *Scylla serrata*. Other species include the Arabian blue crab (*Portunus segnis*) and the violet mud crab (*Eurycarcinus orientalis*). The crab remains will be studied in more detail in a separate paper.

4 | DISCUSSION

4.1 | Archaeological evidence of fishing tackle

So far, there is no evidence of fish hooks or net sinkers at Kalbāʾ 4. In a general way, there are little published data regarding fishing equipment after the Neolithic in Eastern Arabia.

Net sinkers have quite a simple shape and were essentially made of locally available materials. A large amount of fishing sinkers was found in the third millennium BCE Umm an-Nar settlement (Figure 8: 9–12)—mostly found in House 227–228 and Area 499. Most of these are made of limestone; they are flattish, roughly circular and perforated in the middle (Frifelt, 1995, figs. 130, 329). They measure up to 10 cm in diameter and range from 1.5 to 5 cm in thickness. Their weight ranges from less than 100 to 500 g, but most specimens are between 100 and 200 g (Beech, 2004, fig. 33), which suggests that fishing nets were quite light. Such light nets are easily movable and could have been used for seine

TABLE 2 Table of identified fish from Kalbāʾ 4, quantifications in NISP, MNI and WISP.

Family	Genus	Species	NISP	MNI	WISP (g)
Carcharhinidae	*Carcharhinus*	*Carcharhinus* sp.	81	51	138.93
	Rhizoprionodon	*Rhizoprionodon* sp.	20	6	4.57
Pristidae	*Pristis*	*Pristis* sp.	7	6	23.86
ind. Myliobatiformes			14	8	3.02
Chanidae	*Chanos*	*Chanos chanos*	3	3	11.02
Ariidae	*Netuma*	*Netuma bilineata*	2	2	3.1
	ind.		14	8	3.31
Mugilidae	ind.		72	26	11.9
Belonidae	ind.		9	7	0.83
Serranidae	*Epinephelus*	*Epinephelus coioides*	17	9	31.27
		Epinephelus sp.	73	28	107.87
	ind.		1	-	0.99
Carangidae	*Carangoides*	*Carangoides bajad*	7	4	13.99
		Carangoides caeruleopinnatus	4	4	29.19
		Carangoides chrysophrys	56	44	448.872
		Carangoides sp.	380	97	574.82
	Caranx	*Caranx* sp.	8	3	34.34
	Gnathanodon	*Gnathanodon speciosus*	3	3	5.31
	Scomberoides	*Scomberoides commersonnianus*	34	16	52.71
		Scomberoides sp.	7	6	2.38
	ind.		78	10	123.74
Lutjanidae	*Lutjanus*	*Lutjanus argentimaculatus*	10	4	7.65
		Lutjanus malabaricus	44	19	66.63
		Lutjanus sp.	83	25	83.77
Haemulidae	*Plectorhinchus*	*Plectorhinchus schotaf*	1	1	0.32
Lethrinidae	*Lethrinus*	*Lethrinus nebulosus*	2	2	3.3
		Lethrinus sp.	39	22	27.78
Sparidae	*Acanthopagrus*	*Acanthopagrus arabicus*	1	1	1.63
		Acanthopagrus bifasciatus	2	1	1.2
		Acanthopagrus sheim	4	4	7.35
		Acanthopagrus sp.	1	1	0.56
	Argyrops	*Argyrops spinifer*	237	124	793.95
		Argyrops sp.	38	3	45.89
	Rhabdosargus	*Rhabdosargus haffara*	5	3	2.72

TABLE 2 (Continued)

Family	Genus	Species	NISP	MNI	WISP (g)
	ind.		10	3	8.94
ind. Sparoidea			23	7	18.43
Epiphiidae	*Platax*	*Platax teira*	2	1	24.11
Sphyraenidae	*Sphyraena*	*Sphyraena jello*	3	2	3.53
		Sphyraena sp.	7	6	2.8
Scombridae	*Auxis*	*Auxis sp.*	16	3	2.62
	Euthynnus	*Euthynnus affinis*	875	162	891.59
	Rastrelliger	*Rastrelliger kanagurta*	11	2	0.29
	Scomberomorus	*Scomberomorus commerson*	6	4	13.2
	Thunnus	*Thunnus tonggol*	16	7	42.3
		Thunnus sp.	1	1	1.6
ind. Thunnini			5	2	1.36
ind. Perciformes			86	5	46.55
ind. Teleostei			3013	20	1270.89
		Total identified	2309	744	3.517.612
		Grand Total	5431	776	4.853.482

Abbreviations: ind., indeterminate; MNI, minimum number of individuals; NISP, number of identified specimens; WISP, weight of identified specimens.

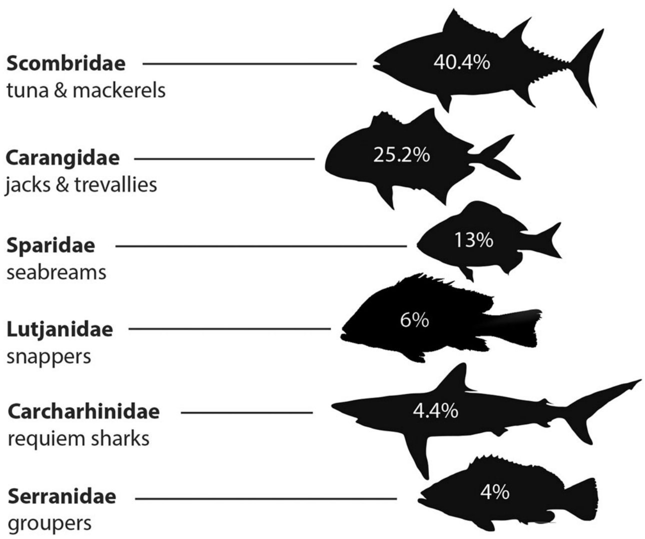

FIGURE 2 Proportions of the main fish families identified at Kalbāʾ 4. NISP = 2309; other fish taxa = 7%. NISP, number of identified specimens.

fishing in shallow waters on foot or from boats. This method of fishing is not selective and, therefore, results in a catch containing a large variety of fish encountered close to the shore, including stingrays and sea turtles, frequently. Seine fishing allows nets to be moved in a more controlled manner to encircle specific fish schools or cross through them. A few other net sinkers found at Umm an-Nar are made of stone pebbles (Frifelt, 1995, figs. 297–298). They show a central waistline made by picketing. These are similar to older Neolithic specimens frequently found in the Northern Emirates. It is also noteworthy that the discovery of calcified ropes and fabrics, which have been interpreted as potentially belonging to fishing nets, was made at Ra's al-Hadd HD6 (Cleuziou & Tosi, 2020, p. 105, fig. 80).

Copper and bronze fish hooks are documented on a number of late-fourth and third-millennium BCE sites in Eastern Arabia (Figure 8: 1–8). These include Ra's al-Hamra RH10 and Wadi Shab GAS1 for the late-fourth millennium BCE (Giardino, 2017, figs. 5.2 and 5.6). Umm an-Nar (Frifelt, 1995, figs. 108, 115, 209, 217, 269, 270), Tell Abraq (Potts, 2000, p. 63), Ra's al-Hadd HD1 (Cattani et al., 2019; Reade, 1990, p. 35, fig. 8), HD5 (Borgi et al., 2012, p. 33), HD6, Ra's al-Jinz RJ2 (Cleuziou & Tosi, 1986, fig. 19 no. 2–4; Cleuziou & Tosi, 1988, fig. 18 no. 6, fig. 19, fig. 20 no. 2) and Suwayh SWY3 (Méry & Marquis, 1998, fig. 9 no. 13–14) have provided numerous specimens for the third millennium BCE. One rare specimen of iron fish hook has been reported from RJ2 (Giardino, 2017, p. 65, fig. 7.3). Note that a fish hook can be easily made by bending a long metal stem in a semicircular shape, suggesting that many

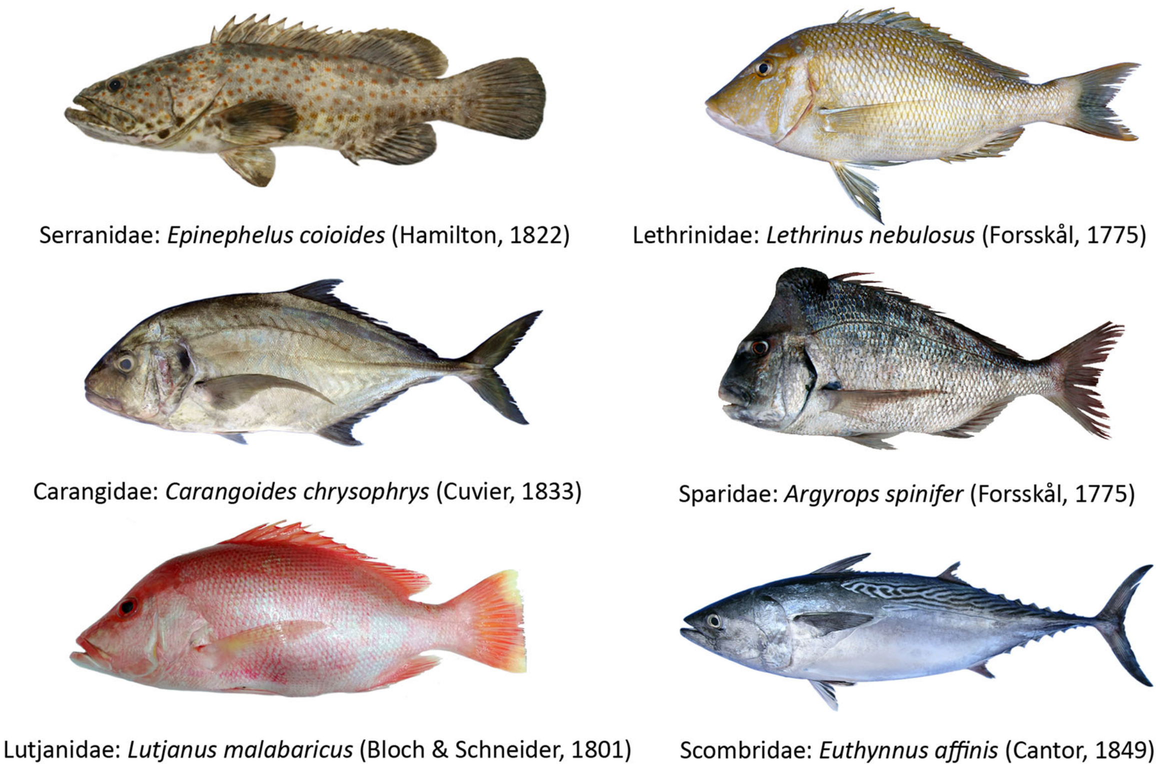

FIGURE 3 Live pictures of some of the main fish taxa identified at Kalbāʾ 4. Images: K. Lidour, P. Béarez. [Color figure can be viewed at wileyonlinelibrary.com]

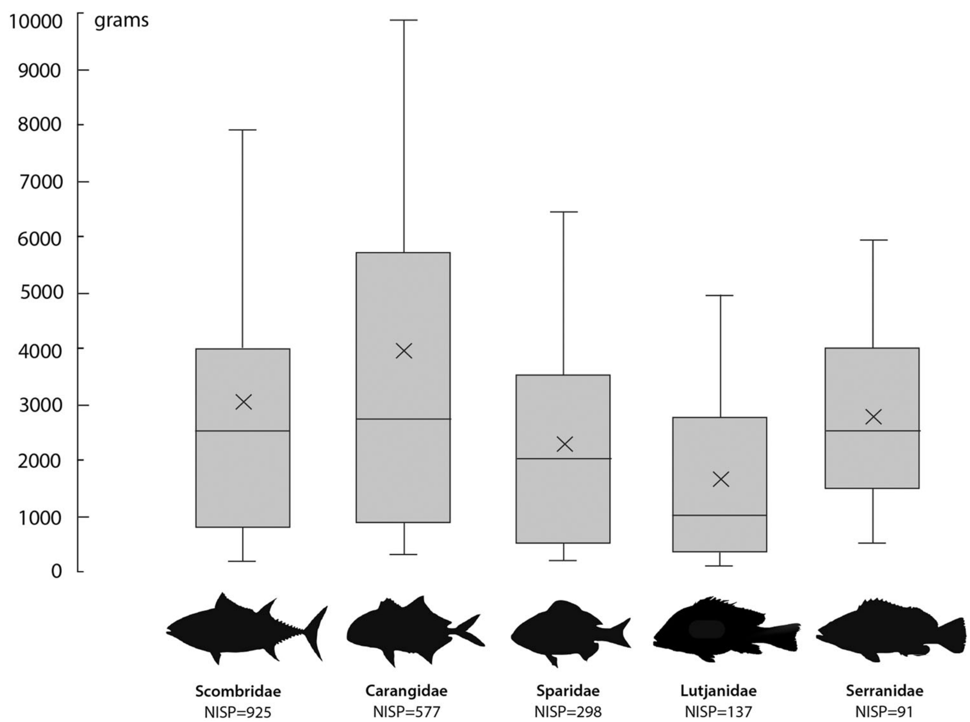

FIGURE 4 Box plots of fresh weights (in grams) for the main bony fish families identified at Kalbāʾ 4 (based on estimations according to visual comparisons with reference specimens).

FIGURE 5 Sample of archaeological remains belonging to the main fish taxa identified at Kalbāʾ 4: 1, right dentary of kawakawa, *Euthynnus affinis*; 2, right dentary of orange-spotted grouper, *Epinephelus coioides*; 3, right dentary (heavily burned) of Malabar blood snapper, *Lutjanus malabaricus*; 4, right dentary of trevally, *Carangoides* sp.; 5, right dentary of King soldierbream, *Argyrops spinifer*; 6, vertebra caudalis of mullet (Mugilidae: cf. *Crenimugil* sp.)—the presence of a cut mark is unclear; 7, vertebra of requiem shark, *Carcharhinus* sp.; 8, vertebra of sawfish, *Pristis* cf. *zijsron*; 9, tooth of requiem shark, *Carcharhinus* sp.; 10, stinger of a stingray, Dasyatoidea. Images: K. Lidour (scale: 2 cm). [Color figure can be viewed at wileyonlinelibrary.com]

metal pins found at archaeological sites can be potentially interpreted as preforms of fish hooks (for instance, see Magee, 2014, fig. 4.11 no. 5–6).

The fish hooks encountered during the Bronze Age and the Iron Age are quite variable in size: from 1.5 to 11.5 cm in length at HD6 according to Giardino (2017, p. 47), showing that they were adapted to various sizes of fish and, more than likely, to various species. Although Cartwright (2004, pp. 45–46) has expressed doubts over their solidity for catching some very large fish, in particular tuna, one can imagine that copper hooks could have been used for luring in combination with boat seining. The fish hooks are generally barbless and of the J-shaped type: the shank is quite long and extends up in parallel to the point. In this way, J-shaped hooks can be used for rigging up live baits (like small fish). A long shank also tends to prevent the line from being cut by fish with sharp teeth like kingfish or barracudas. Note also such barbless hooks come out easily, and are thus preferred for fast fishing like exploitation of tuna schools on the surface.

TABLE 3 Distribution of anatomical elements for the main bony fish families identified in the assemblage.

NISP	General 2733	Scombridae 930	Carangidae 577	Sparidae 298	Lutjanidae 137	Serranidae 91
Cranial	625	50	186	235	72	31
Premaxilla	82 (13.1%)	5 (10%)	13 (7.0%)	39 (16.6%)	13 (18.1%)	7 (22.6%)
Maxilla	88 (14.1%)	10 (20%)	18 (9.7%)	37 (15.7%)	15 (20.8%)	2 (6.5%)
Palatine	18 (2.9%)	–	2 (1.1%)	12 (5.1%)	–	–
Dentary	112 (17.9%)	25 (50%)	19 (10.2%)	38 (16.2%)	17 (23.6%)	10 (32.3%)
Angulo-articular	45 (7.2%)	6 (12%)	10 (5.4%)	18 (7.7%)	9 (12.5%)	2 (6.5%)
Quadrate	32 (5.1%)	4 (8%)	14 (7.5%)	7 (3.0%)	5 (6.9%)	1 (3.2%)
Cleithrum	12 (1.9%)	–	11 (5.9%)	–	–	1 (3.2%)
Opercle	22 (3.5%)	–	8 (4.3%)	11 (4.7%)	2 (2.8%)	–
Supraoccipital	90 (14.4%)	–	48 (25.8%)	40 (17.0%)	–	–
Frontal	15 (2.4%)	–	–	14 (6.0%)	–	–
Others	108 (17.3%)	–	43 (23.1%)	19 (8.1%)	11 (15.3%)	8 (25.8%)
Postcranial	2108	880	391	63	65	–
Vertebra praecaudalis	606 (28.7%)	111 (12.6%)	82 (21.0%)	26 (41.3%)	37 (56.9%)	50 (83.3%)
Vertebra caudalis	1313 (62.3%)	765 (86.9%)	288 (73.7%)	33 (52.4%)	28 (43.1%)	10 (16.7%)
Others	189 (9.0%)	4 (0.5%)	21 (5.4%)	4 (6.3%)	–	–

Note: Other postcranial elements include spines, ribs, pterygiophores and so on. Unidentified fragments ($N = 2576$) not included.
Abbreviation: NISP, number of identified specimens.

Other potential fishing tools could have included harpoons, spears or tridents. Copper spears are reported from the third millennium BC settlements of Umm an-Nar and Ra's al-Jinz. This type of spear (type "Harpon 2.B" from Gernez, 2007, p. 387) is well documented in the Lower Mesopotamia during the Early Dynastic III (2600–2350 BCE) and the Akkadian period (2350–2150 BCE).

One can imagine that other fishing devices that generally do not leave remains within archaeological contexts could have been used by the Kalbāʾ 4 fishers, such as cage traps and intertidal devices. Cage traps are traditionally used in Eastern Arabia, especially in the Arabian Gulf, where they are called *qarāqir* (sing. *qarqūr*) in local Arabic. They are basket-like traps with one or two funnel-like entrances. They are nowadays made of fine galvanised wire mesh, but were woven out of date palm (*Phoenix dactylifera*) leaflets and stems (midribs) in the past. They are particularly efficient for the capture of large fish encountered in reef areas, in particular, groupers (Hartmann, 2014, 2016) and King soldier-breams (Chen et al., 2012, tab. 1). Intertidal barrier traps are also among the traditional fishing devices still in use in Eastern Arabia. The most common one is the *ḥāḏra* (or *ḥaẓra*), which consists of lines of semipermanent intertidal fences vertically fixed and supported by stones projecting out perpendicular to the shoreline. These form a V-shaped structure that acts as a funnel for fish at the falling tide. Other intertidal traps traditionally used in the region include nets on stakes (*sakkār*) and stone dams (*miskar*). Intertidal barrier traps allow to catch a wide spectrum of fish encountered in shallow coastal waters—varying from one area to another. In this region, the main catches generally include seabreams, mullets, little snappers and sardines and anchovies (al-Baz et al., 2007, 2013; Beech, 2004, p. 46).

4.2 | Fishing grounds and fishing strategies

Although specimens can often be caught individually close to the shore, schools of large scombrids are only encountered in open waters. Kawakawas, longtail tunas (*Thunnus tonggol*) and frigate tunas (*Auxis* sp.) can constitute large multispecific schools (Collette & Nauen, 1983), suggesting that they could have been exploited simultaneously. Large kingfish (or narrow-barred Spanish mackerels, *Scomberomorus commerson*) are usually solitary, whereas small- and medium-sized specimens occur in small schools (Collette, 2001). Scombrids usually prey on schools of smaller pelagic fish including anchovies, sardines and mackerels, whose proximity close to the shore is dependent on seasonally based parameters. However, the localisation of scombrid schools is fairly unpredictable and hard to track without using radars. Traditionally, schools can be detected by

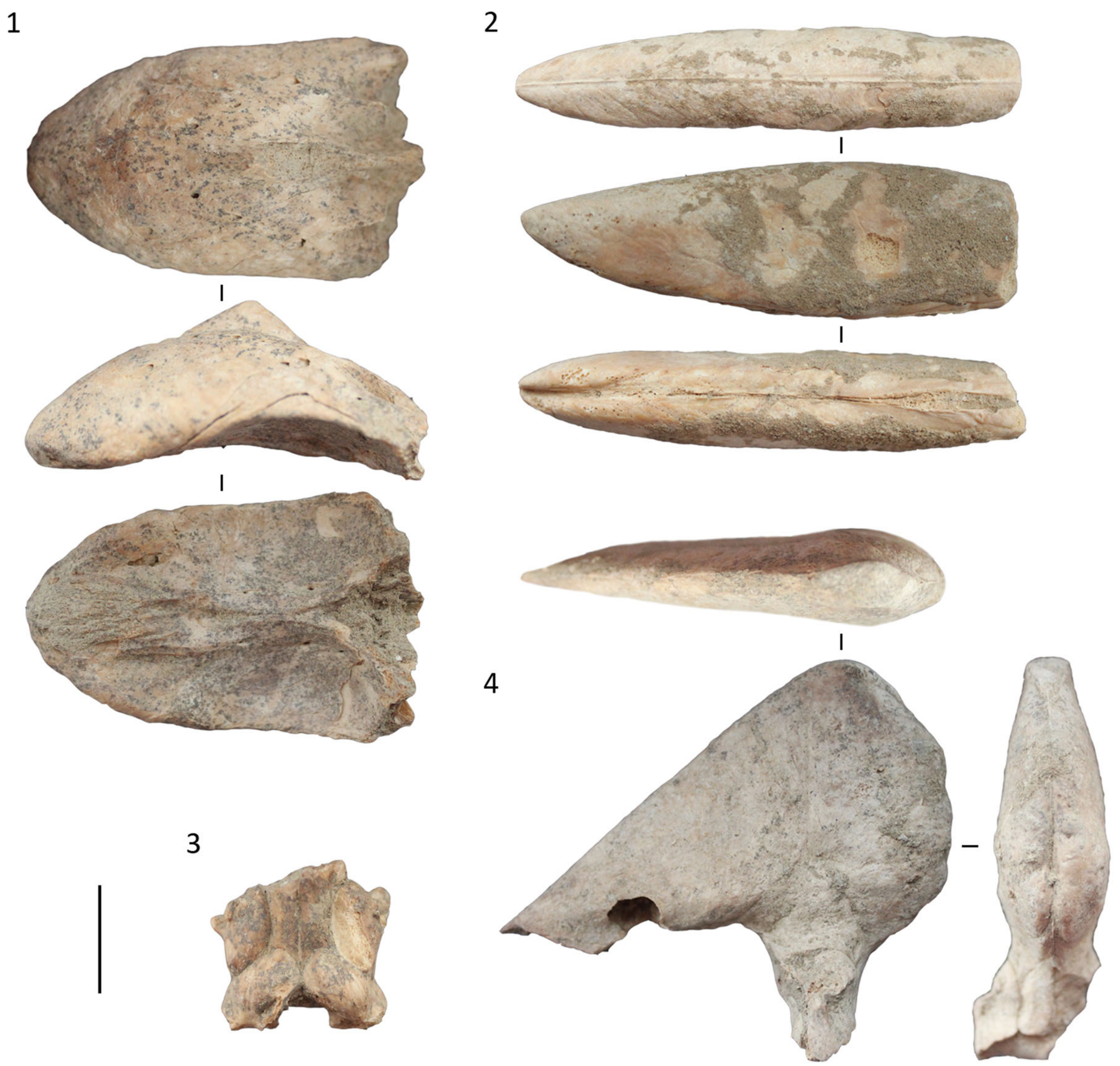

FIGURE 6 Sample of hyperostosed fish remains identified at Kalbāʾ 4: 1, fused frontals of King soldierbream, *Argyrops spinifer*; 2, supraoccipital of longnose trevally, *Carangoides chrysophrys*; 3, fused exoccipitals (caudal view) of King soldierbream, *Argyrops spinifer*; 4, supraoccipital of King soldierbream, *Argyrops spinifer*. Images: K. Lidour; (scale: 2 cm). [Color figure can be viewed at wileyonlinelibrary.com]

FIGURE 7 Hyperostosed dorsal process of posttemporal of Talang queenfish, *Scomberoides commersonnianus*, showing an oblique cut mark (arrow to the left). Images: K. Lidour (scale: 2 cm). [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 4 Proportions of the main fish families identified at Kalbāʾ 4 by cultural phases—based on %NISP.

NISP	EBA 632	MBA–LBA 968	IA I 246	IA II 134
Carcharhinidae	4.9%	3.5%	4.1%	2.2%
Mugilidae	0.5%	3.9%	5.3%	–
Serranidae	4.3%	2.9%	4.1%	9.0%
Carangidae	**20.4%**	**16.8%**	**35.8%**	**53.7%**
Lutjanidae	**11.7%**	4.0%	5.3%	4.5%
Lethrinidae	1.1%	**11.1%**	1.6%	3.0%
Sparidae	**16.1%**	4.0%	8.9%	**10.4%**
Scombridae	**38.8%**	**50.6%**	**32.5%**	**14.9%**
Others	2.2%	4.4%	2.4%	2.2%

Note: Bold values are highlighting the main fish families represented for each period.

Abbreviations: EBA, Early Bronze Age; IA I, Iron Age I; IA II, Iron Age II; LBA, Late Bronze Age; MBA, Middle Bronze Age; NISP, number of identified specimens.

fishers because of the turbulence that they create on the surface of the sea when hunting or by tracking marine birds (e.g., seagulls and gannets) that are looking for the same prey. In the Kalbāʾ region, scombrid schools cannot have been exploited directly from the shore by using lines—fishing them involves the use of boats, either to deploy large beach seines from the shore or to access deeper waters. From boats, fishing could have been carried out with seines for encircling or crossing through schools or using lines (e.g., baited lines, trolling). As already discussed, J-shaped hooks are convenient for baited lines and could have been particularly efficient to catch scombrids during their hunt if sardines or anchovies were used as bait.

Groupers are solitary and territorial fish living alone or in small groups near caves and crevices found in reefs. These are a major food fish in the Arabian Gulf; today, it is caught using cage traps (*qarāqir*) baited with cuttlefish or pieces of fish. Catches include other reef-associated taxa such as large King soldierbreams, spangled emperors (*Lethrinus nebulosus*), trevallies and

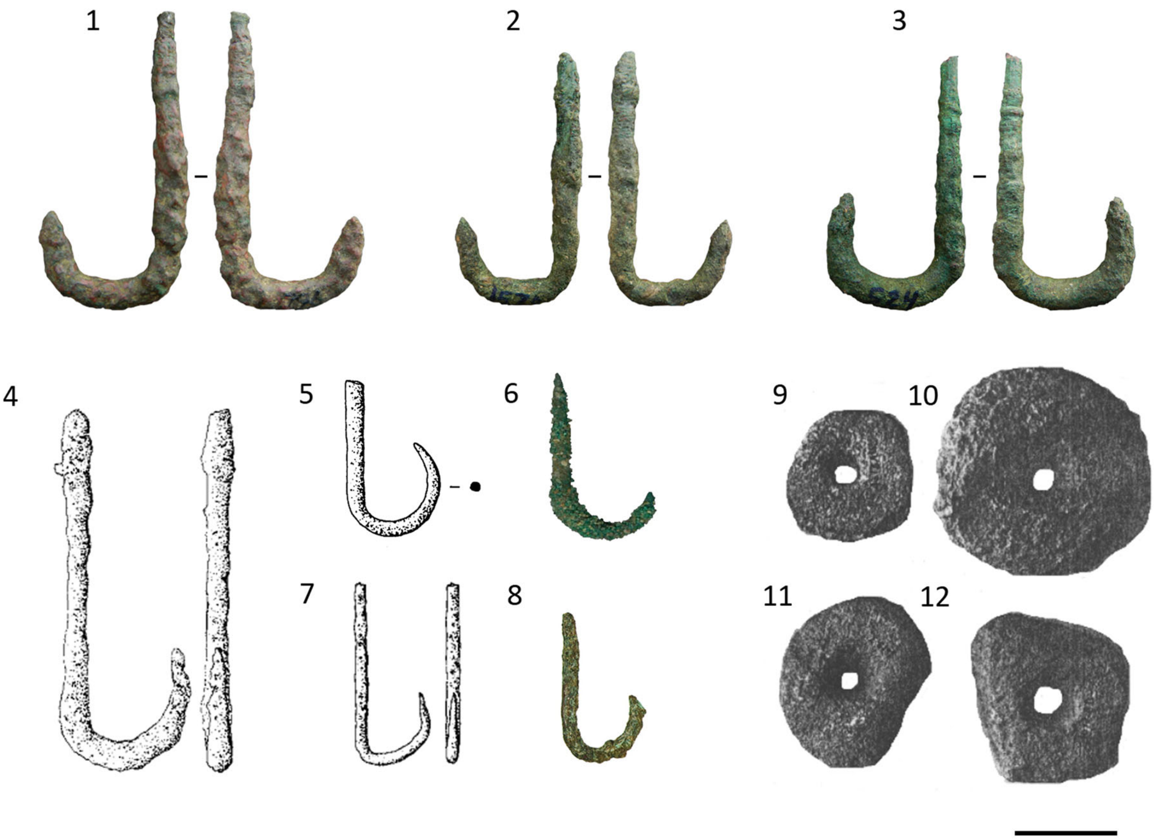

FIGURE 8 Specimens of fishing tools from Bronze Age and Iron Age contexts of Eastern Arabia. 1–3, Copper alloy fish hooks from Tell Abraq (DTA Umm al-Quwain courtesy); 4, Copper alloy fish hook from Umm an-Nar (Frifelt, 1995, fig. 270); 5, copper alloy fish hook from Suwayh SWY3 (Méry& Marquis, 1998, fig. 9, no. 13–14); 6, copper alloy fish hook from Ra's al-Hadd HD1 (Cattani et al., 2019, fig. 8a), copper alloy fish hook from Umm an-Nar (Frifelt, 1995, fig. 270); 8, copper alloy fish hook from Ra's al-Jinz RJ2 (Giardino, 2017, fig. 7.14, DA12474); 9–12, limestone net sinkers from Warehouse 1013, Umm an-Nar (Frifelt, 1995, fig. 325) (scale: 1 cm). [Color figure can be viewed at wileyonlinelibrary.com]

sweetlips (*Plectorhinchus* spp.). The Talang queenfish (*Scomberoides commersonnianus*) is also encountered near the reef (Sommer et al., 1996) and can occasionally be caught in such traps (Chen et al., 2012, tab. 1). Large snappers are not reported from landings made with cage traps in the Arabian Gulf, but one can expect that specimens can also be caught in that way in other areas, including in the Gulf of Oman. Indeed, both Malabar blood snappers and mangrove red snappers are reported to live near coral and rocky reefs (Allen, 1985; Lieske & Myers, 1994; Sainsbury, 1987). The mangrove red snapper is also reported as being tolerant to brackish habitats and even freshwater, indicating that specimens can be encountered in mangroves as well (Allen et al., 2002; Sommer et al., 1996). The use of baited lines—with weights—is also conceivable as most of the reef-associated taxa identified are carnivore fish.

Although trevallies belonging to the *Carangoides* genus are frequently reef-associated, many species are reported to move into other habitats for hunting, including coastal mangroves on the occasion of high tides (Bogorodsky et al., 2017). This may be the case, for instance, of the longnose trevally, which is the main carangid species identified at Kalbāʾ 4. In Queensland (Australia), fishermen set gillnets across entrances of mangroves to specifically catch this fish (Grant, 2014). This technique has already been suggested for the Neolithic at Akab (Emirate of Umm al-Quwain) (Lidour et al., 2020). Although longnose trevallies are also available in reef areas, one could suggest that a similar technique could have been used off the Khor Kalbāʾ mangrove.

Spangled emperors are encountered mostly in reef areas, whereas juveniles are inhabiting seagrass beds and mangroves that consist of nurseries for many fish species (Downing, 1987). Mature specimens (over 27 cm in fork length) are reported to spawn in shallow coastal waters around April in Eastern Arabia (Grandcourt et al., 2010), favouring inlets, as these seem to be advantageous for egg dispersion (Egretaud, 1992). In a previous study (Lidour et al., 2018), it has been suggested that large spangled emperors were caught by the Akab fishers on the occasion of their spawning season in the vicinity of the Umm al-Quwain lagoon. A similar scenario is possible at Kalbāʾ 4. Indeed, modern catches of spangled emperors concentrate in March and April in the area of Kalbāʾ (Ali et al., 1980; see also Lidour et al., 2018, fig. 2).

As has been explained by C. E. Mosseri-Marlio (2000), cetacean remains are rarely abundant on archaeological sites since these large and heavy animals are usually butchered on the shore just after being captured. Indeed, most edible flesh can be sliced along the backbone without removing any skeletal elements. The skull could eventually be collected as a trophy. Strong bones, fat and leather should be considered as raw material as well. Indeed, dugong bones (seven ribs) and a fragment of tusk have been identified at Saruq al-Hadid (from LBA to LBA contexts), as well as at Umm an-Nar, indicating their use for nonalimentary purposes (Hoch, 1979; Roberts et al., 2019, p. 186, fig. 8). Although dolphins can sometimes be bycaught in nets alongside scombrids when fishing is carried out on pelagic schools, the presence of dugong remains at Kalbāʾ 4 is more surprising. In the Arabian Peninsula, dugongs are restricted to the Red Sea and the Arabian Gulf (Sheppard et al., 1992). Nowadays, no specimens are reported in the Gulf of Oman, or along the coastline bordering the Arabian Sea. It has been suggested that dugongs could have frequented the Khor Kalbāʾ lagoon in the past if its surface was wide enough to host extensive seagrass beds (Phillips & Mosseri-Marlio, 2002). Indeed, as they are exclusively grazing animals, dugongs can migrate over long distances between seagrass meadows. A wider relict lagoon could correspond to the extent of the *sabkhah* surrounding the actual mangrove of Kalbāʾ. However, this remains to be confirmed in more detail by geomorphological studies.

Sea turtles (Cheloniidae) can be speared in shallow waters, but they are also frequently caught in large nets set from the shore, such as beach seines (K. Lidour, personal observation in November 2017). Adult specimens can also be captured when they slowly drag themselves on the beaches during the laying season. They are herbivorous and coral-grazers—they usually occur in shallow seagrass and near coral reefs.

4.3 | Comparisons with modern landings and thoughts on seasonality

In the district of Kalbāʾ, modern landings are composed mainly of trevallies (24.1% of the total annual tonnage), emperors (10.7%), tuna (10.4%), snappers (9.1%), grunts (6.3%), groupers (5.7%) and barracudas (4.2%) (Ali et al., 1980, Part III.2). Fishing activities are performed all year round (46% of the landings are registered during the winter months; 54% during summer). The best fishing seasons are in September–November (for groupers and snappers) and in March–April (for emperors and kingfish). However, modern landings result from professional fishing relying on the exploitation and sale of cost-effective commercial fish and, consequently, do not reflect the local biodiversity.

Catches are in some ways similar between modern landings and archaeological records: trevallies, tuna and snappers are predominant, although some variations can be observed in the proportions of other taxa. For instance, seabreams represent only 2.4% of modern landings, while emperors, grunts and barracudas are almost absent from the zooarchaeological data set. Trevallies are composed mainly of *Carangoides* spp. and the Talang queenfish. The longnose trevally as well as other close *Carangoides* species present at Kalbāʾ 4

such as the coastal trevally (*Carangoides coeruleopinnatus*) could have been misidentified as Malabar trevally (*Carangoides malabaricus*) by fisheries officers who were part of the study mentioned above. Similarly, one can assume that Malabar blood snappers and mangrove red snappers have been misidentified with large John's snappers (*Lutjanus johnii*) and humphead snappers (*Lutjanus sanguineus*)—which are not represented in the archaeological assemblage. Surprisingly, modern scombrid catches consist mostly of kingfish as opposed to kawakawas and tunas. Note that longtail tunas are caught almost all year round in Khor Fakkan (c. 40 km north of Kalbāʾ), while kawakawas are exploited exclusively in September–October (Ali & Thomas, 1979, fig. 3).

Nothing would suggest that fishing was carried out during a particular season at Kalbāʾ 4. Although schools of pelagic fish tend to be present along the coast on a seasonal basis, tropical ecosystems such as coral reefs and mangroves provide high and persistent biodiversity and biomass that could support fishing throughout the year—within certain limits. Year-round fisheries would promote sedentarisation of the habitat on the coast. Indeed, groupers, trevallies and snappers are reported to be available throughout the year in Khor Fakkan (Ali & Thomas, 1979, figs. 4–6).

4.4 | Comments on diachronic changes

During the EBA, fisheries focused on schools of scombrids located in the open sea and reef-associated fish, namely, breams, snappers and trevallies—although it is known that particular species, such as the longnose trevally, also enter coastal mangroves on occasions of high tides.

The exploitation of scombrids takes on importance during the MBA and the LBA, whereas the greater presence of emperors in the assemblage can result either from changes in the reef fish populations or from the targeted exploitation of spawning events in the vicinity of the lagoon inlet. The idea that fishing has been further oriented towards the exploitation of estuarine waters at that time is also supported by a significant increase in the proportion of mullets.

The situation is different during the IA I, as we observe the near disappearance of the emperors in the assemblage, whereas the mullets are still present in moderate quantities. This tends to confirm that the capture of emperors was mainly allowed by the exploitation of episodic events, namely, their spawning season. On the other hand, fishing still relies mainly on the capture of scombrids and trevallies, as was already the case during the preceding period. Mullets concentrate in contexts dated from the end of the Bronze Age to the IA I. This might be explained by greater estuarine conditions potentially supported by increased rainfall at that time. In this sense, palaeoclimatic studies have identified a short-lived wet phase between c. 2000 and 1000 BCE in Eastern Arabia (Lückge et al., 2001; Parker et al., 2004).

The scheme seems to change greatly by the IA II with a significant increase in trevallies, followed distantly by scombrids, breams and groupers—mullets are absent. Although trevallies can also be caught during their routine movements to coastal mangroves, they were likely exploited mainly alongside breams and groupers in reef areas. Scombrids are still present among the primary catches, although in fewer quantities. However, the IA II results have to be interpreted with caution as they are based on a pretty small sample of fish remains ($N = 134$).

It is worth noting that the variations observed in the proportion of the different reef-associated fish families throughout the occupation might not necessarily be linked to changes in the fishing strategies. As shown by Sale (1978), the composition of the reef fish populations is more dependent on the randomness of the larval recruitment rather than on ecological requirements and competition among mature individuals.

4.5 | Regional perspective

The main studies documenting fishing economies during the Bronze Age and the Iron Age have been conducted on material retrieved from Qala'at al-Bahrain and Saar (in Bahrain), as well as from Umm an-Nar, Tell Abraq and Shimal (in the UAE) (von den Driesch, 1994; Uerpmann & Uerpmann, 2005; Vorenger, 2016) (Table 5). Although Saruq el-Hadid and Rafaq 2 (in the UAE) (Beech et al., 2008; Roberts et al., 2019) have provided fewer quantities of remains, they consist of good comparison sites and allow discussion regarding the circulation of fish between coastal and inland areas. Conversely, assemblages from Failaka F6 (in Kuwait), Tomb 2 in Umm an-Nar, ed-Dur North and Tomb 602 in Shimal (in the UAE) did not provide enough exploitable data (i.e., NISP < 100) (Beech, 2004; Desse & Desse-Berset, 1990, pp. 150, 159–162).

On the majority of sites, main catches include groupers, trevallies, emperors and seabreams. Sites located in Bahrain are evidencing the exploitation of shallow coastal habitats, mostly reefs, as shown by the strong presence of groupers, trevallies and King soldierbreams in the catches. Comparable results have been obtained from Kalbāʾ 4 as we have seen above. There is thus a certain consistency in the exploitation of reef-associated fish at the regional scale during the Bronze Age and the Iron Age.

The habitats exploited seem to be more diversified along the UAE coastline as we observe greater proportions of mullets: about 9%–10% at Umm an-Nar and Shimal and up to 20% at Tell Abraq. At Kalbāʾ 4, this proportion is more modest (4%–5%). This highlights the

TABLE 5 Proportions of the main fish families identified within other main Bronze Age–Iron Age assemblages from Eastern Arabia: UAN for Umm an-Nar, QAB for Qala'at al-Bahrain; SAH for Saruq el-Hadid, TA for Tell Abraq (data from Beech, 2004; von den Driesch 1994; Roberts et al., 2019; Uerpmann & Uerpmann, 2005; Vorenger, 2016)—based on %NISP.

NISP	UAN EBA 894	Saar MBA 2917	QAB MBA 4106	QAB Early Dilmun (2200–1750 BCE) 3246	SAH Horizon IV (1750–1300 BCE) 185	QAB Middle Dilmun (1500–1250 BCE) 2110	TA BA-IA (2200–300 BC) 14751	Shimal BA-IA (2300-80– BCE) 2143	QAB Late Dilmun (1000–450 BCE) 3589	Rafaq 2 IA III 120
Carcharhinidae	–	0.1%	0.8%	0.5%	0.5%	0.6%	2.8%	0.6%	0.2%	**11.7%**
Dasyatidae	–	–	–	–	–	–	0.5%	0.9%	–	–
Mugilidae	9.6%	<0.1%	–	–	–	0.2%	**19.7%**	9.0%	0.1%	–
Ariidae	0.1%	0.1%	0.5%	0.6%	–	<0.1%	1.1%	7.5%	0.8%	–
Belonidae	3.4%	0.1%	–	0.1%	**17.3%**	–	1.5%	0.3%	0.1%	–
Serranidae	**14.1%**	**13.3%**	**34.0%**	**36.2%**	**9.2%**	3.7%	2.3%	1.0%	**13%**	5.8%
Carangidae	**23.8%**	7.4%	**15.5%**	**15.2%**	6.5%	**8.0%**	**15.6%**	**35.9%**	**23.3%**	0.8%
Lutjanidae	0.6%	<0.1%	–	<0.1%	–	–	0.3%	0.3%	–	1.7%
Lethrinidae	**33.1%**	**60.2%**	**31.6%**	**29.7%**	7%	**80.1%**	**24.6%**	0.8%	**33.8%**	0.8%
Sparidae	**14.7%**	**15.4%**	**15.2%**	**15.7%**	**57.8%**	**5.7%**	**22.1%**	**12.1%**	**23.7%**	1.7%
Scombridae	–	<0.1%	0.6%	0.6%	0.5%	0.5%	0.2%	**26.5%**	0.5%	**75.8%**
Others	<0.1%	3.3%	1.8%	1.4%	1.1%	1.2%	9.2%	5.3%	5.0%	1.7%

Note: Bold values are highlighting the main fish families represented for each period.
Abbreviations: EBA, Early Bronze Age; IA III, Iron Age III; MBA, Middle Bronze Age; NISP, number of identified specimens.

exploitation of brackish habitats supported by the presence of wadi estuaries and sheltered waters in these areas. Apart from Shimal, Rafaq 2 and Kalbāʾ 4, scombrids are almost absent from all the assemblages. This is quite surprising when considering their considerable exploitation during the Neolithic in various areas of the Arabian Gulf such as at Dosariyah, Delma and Akab (Lidour, 2023; Lidour et al., 2020; Lidour & Beech, 2019; Uerpmann & Uerpmann, 2018). This feature has already been pointed out by Uerpmann and Uerpmann (2005, p. 114), but its causes remain greatly unknown.

The assemblage of Saruq el-Hadid shows a greater similarity to those of sites located in the Arabian Gulf, whereas the association of scombrids, requiem sharks, but also mud crabs at Rafaq 2 more closely matches the assemblage found at Kalbāʾ 4. In both cases, it seems that only a limited range of fish taxa were circulating inland. These comparisons are related to the respective geographical location of the sites: Rafaq 2 is located about 15 km from the Gulf of Oman (along the Wādī al-Qawr) and only 20 km from Kalbāʾ, whereas Saruq el-Hadid is about 40 km from Jebel Ali, Dubai. It is not impossible that fish were processed at Kalbāʾ 4 to be exported towards other sites, particularly inland, such as Rafaq 2. The circulation of seafood from Kalbāʾ to an inland site has been previously suggested by a study of marine shells retrieved from the LBA site of Masāfī 5 (Decruyenaere et al., 2022; Lidour et al., 2023). However, no fish remains have been found on the latter site. Further research must be conducted at Kalbāʾ 4 to localise potential areas and structures that could have been dedicated to fish processing tasks (for butchering, salting, drying, storage, etc.). These areas are expected to have been located in the site's periphery, somehow distantly from housings—because of the smell and the potential presence of pests.

Although no quantitative data are currently available, assemblages from the Sultanate of Oman document fishing activities during the Bronze Age along the Arabian Sea. The assemblages of the third millennium sites of Ra's al-Hadd HD1 and Ra's al-Jinz RJ2 reflect the exploitation of both reef areas and the open sea, where catches consist mainly of large scombrids, dolphins and sea turtles (Cartwright, 1994, p. 240; Cartwright, 1998, p. 99; Cleuziou & Tosi, 2000, p. 42; Mosseri-Marlio, 2000). These preliminary results show similarities to the fisheries highlighted at Kalbāʾ 4 in the present study.

5 | CONCLUSION

Fishing was focused mainly on the capture of both reef-associated and large pelagic fish throughout the Bronze Age and the Iron Age in South-East Arabia. The capture of mullets as well as of other taxa with a certain freshwater tolerance (e.g., groupers, trevallies, snappers, emperors, seabreams) also indicates that some fishing activities were conducted in brackish environments, either in the vicinity or inside the lagoon. Some of the natural channels crossing through the Kalbāʾ mangrove are wide and deep enough to be frequented by large fish including barracudas as well as by sea turtles (K. L., personal communication). Conversely, Neolithic fisheries documented at Khor Kalbāʾ KK1 seem to have focused mainly on the exploitation of small and juvenile specimens in the shallow and sheltered waters of the lagoon—however, this remains to be confirmed by a proper analysis of faunal samples obtained from this site. If confirmed, this evolution in the fishing strategies would clearly indicate a shift from non-selective exploitation of coastal waters to specialised fishing activities targeted at some key species. This would have been linked to a redefinition of the socioeconomical organisation: during the Neolithic, the fishing effort was probably more or less equally distributed among the site population, whereas, from the Bronze Age onwards, it would have been delegated to specialised fishers.

This shift into more specialised fisheries from the Bronze Age onwards is suggested on other coastal sites of Eastern Arabia. In Bahrain, fishing was mainly carried out in reef areas, where it has focused on the exploitation of large carnivorous taxa such as groupers, trevallies, spangled emperors and King soldierbeams. The latter could have been caught by using either baited lines or cage traps. Along the western coast of the UAE, the assemblages reflect more diversified local environments including not only reefs but also sheltered lagoons where the development of seagrass and mangrove ecosystems was supported by stronger freshwater inputs—by surface streaming and resurgences of the groundwater. These local specificities allow the capture of a greater variety of fish including both reef-associated and euryhaline species. Schools of mullets occurring in shallow waters could have been quite easily exploited using seines or trapped in intertidal devices set in the lagoon. At Shimal, like at Kalbāʾ 4, deeper waters would have facilitated the occurrence of schools of scombrids close to the shore. The latter could have been exploited using baited lines or seines. Similarly, Bronze Age fisheries documented at Ra's al-Hadd and Ra's al-Jinz seem to have focused on the exploitation of both reef-associated fish and schools of scombrids in open water. They are also characterised by the development of specialised exploitations of other marine fauna, including sea turtles and dolphins.

Previous zooarchaeological studies have shown that seafood was exchanged between coastal and inland sites, in significant quantities, from the LBA onwards. Studies conducted on different lithic raw materials have shown that Kalbāʾ 4 was actively involved in regional trade as early as the Umm an-Nar period (Schwall et al., 2022). The procurement of rock types in the direct vicinity of the site and more distant regions in and beyond the Ḥajar Mountains emphasises the importance of the local resources for nutrition and craft activities. Moreover, imports from Mesopotamia, Iran and the Indus region underline that Kalbāʾ 4 was integrated in far-reaching trade networks as early as the Umm an-Nar period and has functioned as the node between trade maritime and land-based caravan routes. Although no clear evidence of fish processing has been observed in the material studied, there is little doubt that Kalbāʾ 4 has played a role in the export of seafood towards hinterlands and sites such as Masāfī 5 during the LBA (for marine molluscs), and Rafaq 2 at the end of the Iron Age (for fish and mud crabs). Of course, one can expect that fish processing did not take place at the centre of the site and where the excavations have concentrated but, more than likely, on its periphery and closer to the shore.

The present study highlights a well-developed fishing economy at Kalbāʾ 4 from the EBA onwards. The analysis of material retrieved from further well-dated contexts would allow to discuss in more detail the chronological evolution of fisheries at the site in the future. Regarding the quantity of material studied and the information that it provides, the site of Kalbāʾ 4 should be considered as a major site for the discussion of fisheries, and more generally, the maritime economy during the Bronze Age and the Iron Age in Eastern Arabia.

New excavations that are ongoing at Kalbāʾ 4 will probably provide new material to be studied in the future. This will allow us to have a better understanding of the spatial distribution of fish remains according to the nature of the architectural structures and the site plan. If conducted, fine sieving (2–4 mm mesh) will permit the collection of smaller fish remains, whose analysis is necessary for a more complete reconstruction of the fishing strategies.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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