



**Rice, lamb and tuna. Food processing and acquiring strategies  
in the medieval harbour city of Qalhât (Oman):  
Bioarchaeological evidence from the twin houses' building  
(B94)**

Vladimir Dabrowski, Anaïs Marrast, Hervé Monchot, Axelle Rougeulle

► **To cite this version:**

Vladimir Dabrowski, Anaïs Marrast, Hervé Monchot, Axelle Rougeulle. Rice, lamb and tuna. Food processing and acquiring strategies in the medieval harbour city of Qalhât (Oman): Bioarchaeological evidence from the twin houses' building (B94). *Archaeological Research in Asia*, 2024, 40, pp.100561. <10.1016/j.ara.2024.100561>. <hal-04870259>

**HAL Id: hal-04870259**

**<https://hal.science/hal-04870259v1>**

Submitted on 7 Jan 2025

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

# Rice, lamb and tuna. Food processing and acquiring strategies in the medieval harbour city of Qalh<sup>^</sup>at (Oman): Bioarchaeological evidence from the twin houses' building (B94)

Vladimir Dabrowski<sup>1</sup>, Anaïs Marrast<sup>1</sup>, Hervé Monchot<sup>2</sup>, Axelle Rougeulle<sup>2</sup>

<sup>1</sup>UMR 7209 Archéozoologie, Archéobotanique : Sociétés, pratiques et environnements – Sorbonne Universités, Muséum National d'Histoire Naturelle, CNRS

<sup>2</sup>UMR 8167 Orient et Méditerranée : Textes, Archéologie, Histoire – Université Paris Sorbonne (Paris 4), CNRS

[vladimir.dabrowski@gmail.com](mailto:vladimir.dabrowski@gmail.com)

[anaïs.marrast@mnhn.fr](mailto:anaïs.marrast@mnhn.fr)

[herve.monchot@wanadoo.fr](mailto:herve.monchot@wanadoo.fr)

[arougeulle@aol.com](mailto:arougeulle@aol.com)

## *Abstract*

The rise of the kingdom of Hormuz during the 13th–15th c. CE led to the development of harbour cities such as Qalh<sup>^</sup>at (Sultanate of Oman), considered as the kingdom's second capital. However, although some textual sources are available, a lack of bioarchaeological analysis means that the food-processing activities and subsistence strategies set up to feed this urban population are still largely unknown. Multi-proxy analyses, including zoological, ichthyological, and botanical, have therefore been undertaken on the twin houses building (B94) at the site of Qalh<sup>^</sup>at. Cross-referencing these data allowed for the identification of several food processing activities and the function of some rooms due to their spatial distribution. In addition, these data give new insights into fishing practices (intensively exploited pelagic zone) and the composition and management of agropastoral systems (in the form of oasis date palm gardens, using a combination of crops, weeds and livestock), as well as food acquiring strategies that relied on the importation of plant products via the long-distance maritime trade networks of the western Indian Ocean. The study of building (B94) has provided major data to understand the way of life of the inhabitants of this region for this period, still too little studied.

## *Key-words*

Bioarchaeology, Arabian Peninsula, Medieval period, Food-processing practices, Oasis agropastoral systems, Fishing techniques, Maritime trade

## 1. Introduction

Despite the increase of archaeological initiatives focusing on the Islamic period, analysis of bioarchaeological remains (faunal, fish, plant) are still limited for Eastern Arabia, although they can contribute to provide useful data on food-processing and supply strategies during these periods of urban development and human migration (e.g. Power, 2017; Kennet, 2012; Velde, 2012). Indeed, written sources (e.g. travellers such as Ibn Baṭṭūṭa, Marco Polo, Ma Huan) have already provided valuable information about the economic and social aspects of everyday life activities in this part of the Arabian Peninsula; unfortunately, they still remain relatively scarce and incomplete (often qualitative, imprecise).

For Eastern Arabia, initial archaeobotanical studies have focused on the regression of mangrove ecosystems during the medieval Islamic period at the site of Kush (Ra's al-Khaimah, U.A.E.) (Tengberg 2005). Later, the early Islamic levels of Fulayj (Batinah, Oman) yielded the first well-identified and directly radiocarbon dated evidence of sorghum and highlighted the extension of a fuel catchment area in the foothill and low mountainous zones (Priestman et al., 2023; Dabrowski et al., 2021) (Fig. 1). In contrast, vertebrate (mammal, bird, fish) archaeozoological studies from the Islamic period remain scarce. Nevertheless, we can point out those from the monastery of al-Qusur (Monchot et al., in press) and Khara'ib al-Dasht (Iwaszczuk et al., 2021) on Failaka island in Kuwait; Qal'at al-Bahreïn (Vorenger, 2017) and Bilad al-Qadim (Insoll, 2005) in Bahrain; the fort of Lululyyah in the Sharjah's Emirate (Uerpmann, 2017); the harbour city of Julfar in the Ra's al-Khaimah's Emirate (Beech, 2004); and Khor Rori/Sumhram (Dhofar) in the Sultanate of Oman (Carenti and Wilkens, 2008). These sites reveal that diverse fishing activities were in place, and that even sites on the Arabian Persian Gulf were focused on the exploitation of coastal areas, especially lagoons. The faunal assemblages are also often dominated by sheep/goats and camels, showing specific herding practices and involvement in long-distance caravan trade activities.

Excavations at the medieval harbour city of Qalhât – within the framework of the *Qalhât Project* in 2008-2016 (Omani Ministry of Heritage and Culture, now Heritage and Tourism/CNRS/French Ministry of Foreign Affairs) (Rougeulle, 2010; Rougeulle et al., 2012) and the *Qalhât Development Project* in 2013-2016 (Omani Ministry of Heritage and Tourism/CNRS/Eveha International) under the direction of A. Rougeulle (CNRS) – gave a unique opportunity to gather new information about subsistence strategies for ensuring the safety of food supplies aimed at a large urban population. The *Qalhât Development Project* aimed to extensively excavate buildings that were planned to be restored as part of an archaeological park, as well as to increase our knowledge about the spatial organization of the city, the chronological evolution of the urban settlement and the economic and everyday activities of the inhabitants (Rougeulle et al., 2014; Rougeulle, 2016, 2017, 2023).

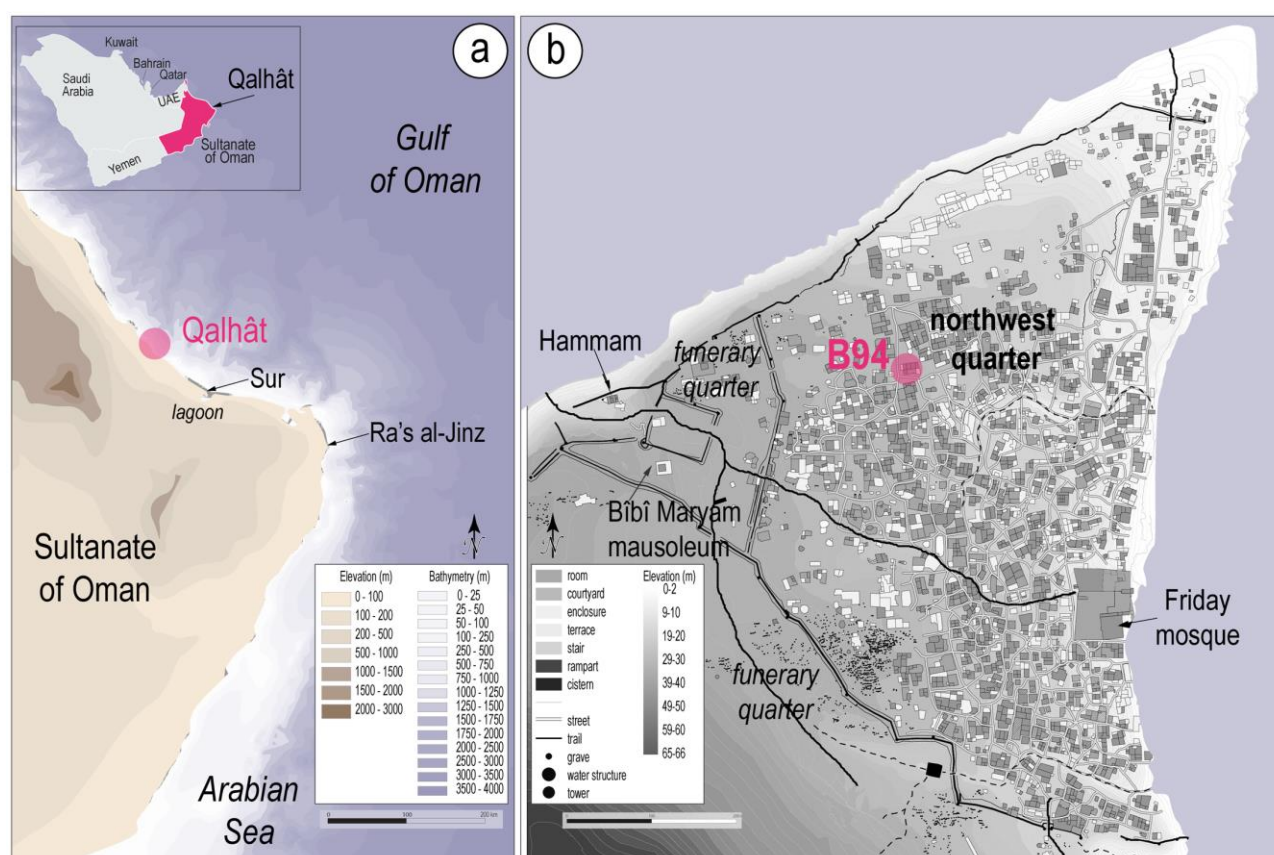
As a result, the twin house building (B94), extensively excavated in 2013, provided a large diversified bioarchaeological assemblage, giving us the opportunity to study food-acquiring systems in conjunction with land-use systems and long-distance trade networks.

## 2. The archaeological site of Qalhât

### 2.1. Environmental setting

The site of Qalhât (22°41'40''N–59°22'30''E) is situated on the Ash-Sharqiyyah coast, 20 km north of the lagoon of Sur and about 60 km from Ra's al-Jinz, the most eastern point of the Arabian Peninsula (Fig. 1). This coast is constituted of limestone terraces, sandy beaches and coastal cliffs, interrupted regularly by wadi mouths. The archaeological site lies partially on a calcareous terrace 10 m above sea level on the east side and is bordered by the mouth of Wadi Hilm on the north-west and

the slopes of the Al-Hajar Mountains to the south-west (Fig. 2) (Desruelles and Beuzen-Waller, 2013). At the wadi mouth, the water from precipitation at high altitude, still contained in the mountains, infiltrates underground before discharging into the sea, allowing for the irrigation of small date palm gardens against the wadi banks, thanks to water extracted from wells (Wilkinson 1977, 47). The climate is arid with high summer temperatures and an average annual precipitation of less than 100 mm, unequally distributed throughout the year (Kwarteng et al. 2009; Sanlaville 2000, 49). Palaeoclimatological analyses have revealed that climatic conditions in the region were globally similar to those of today, although minor climatic oscillations (episodes of aridity, alluvial deposits) seem to have taken place at the end of the medieval Islamic period in the Oman Peninsula (Parker and Goudie, 2008). For example, episodes of aridity have been highlighted by the presence of *Ephedra* pollen 600 years ago at Maqta (Sultanate of Oman) (Urban and Buerkert, 2009) or, in contrast, phases of fluvial deposits in the Musandam Peninsula (Vita-Finzi, 1978) and near Al-Aïn (Abu Dhabi, U.A.E.) (Gebel et al., 1989).



**Fig 1:** Localisation of Qalhât in the Arabian Peninsula (A) and of the twin houses' building B94 in the archaeological site (B)

Vegetation cover at the site is characterized by open thorny formations of xerophilous taxa, represented mostly by *Acacia tortilis* and *Ziziphus spina-christi*, completed by a few shrubby species (*Thephrosia purpurea*, *Heliotropium brevilmbe*, *Pulicaria glutinosa*, *Senna holocerisea*). Halophilous (salt-tolerant) trees and shrubs can also be observed, notably on high-salinity soils due to the proximity of the sea, such as *Tamarix aucheriana*, *Limonium stocksii*, *Heliotropium bacciferum* and *Suaeda fruticosa* (König and Fried 2015; Ghazanfar 1999). Furthermore, these landscapes are represented by grazing livestock composed of sheep and goats, forming herds of mixed species, and dromedaries, moving back and forth between the modern city fringe and rural settlements (Fig. 2). Today in Sur, fishing activities take place throughout the year, although with two peak periods: between October and December and, more importantly, between March and April. According to the Sharqiyah Governorate, landings are mainly from net and line fishing from small motorboats. Fishing is concentrated on different tunas and tuna-like fish (yellowfin, longtail, kawakawa, kingfish) and

sardines (M.A.F., 2018).

## 2.2. Historical and archaeological background

Qalhât is a harbour city which occupied a central part within the international trade networks of the western Indian Ocean during the medieval Islamic period and was a pivotal element of the kingdom of Hormuz (Rougeulle 2016, 2017, 2023). According to several textual sources, the city was founded around 1100 CE during a migration of the 'Azd tribe from Southern Arabia to Iran where they founded the Hormuz kingdom (Ulrich, 2008; Bhacker and Bhacker, 2004). Qalhât later became its second capital and, in 1330 CE, Ibn Baṭṭūṭāʾi witnessed the notable urban expansion of the city realised under the governance of Ayaz and Bībī Maryam (Rougeulle et al., 2012). The harbour's prominence led to it driving international trade in the western Indian Ocean as testified by numerous archaeological data, such as pottery sherds, connecting regions such as Yemen, Iran, the Indian subcontinent, China, and South-East Asia (Renel 2023, Rougeulle 2016, 2017; Simsek et al. 2015). In the 13<sup>th</sup> c., Marco Polo (2011: 498-99) emphasized its pivotal role in trading Arabian horses for Indian merchandise. However, in the 15<sup>th</sup> c., Qalhât began to decline due to an earthquake and the rise of Muscat as Oman's primary harbor. The Portuguese army, led by Afonso de Albuquerque, devastated the city in 1508 and used it as a maritime base after the fall of the Kingdom of Hormuz in 1515. This led to a swift decline in the latter half of the 16th c. (Rougeulle 2016, 2017). By 1592, a traveller described Qalhât as completely abandoned (Agius 1999).

The archaeological site of Qalhât is today a large area of 35 ha covered by ruins surrounded by fortification walls with great concentrations of buildings, including the so-called mausoleum of Bībī Maryam, other mausoleums and two cisterns. At the beginning of archaeological research, a preliminary survey (1998) and few soundings (2003) have been conducted before the launch of the Qalhât Project (2008-2016) and the Qalhât Development Project (2013-2016) in collaboration with the Ministry of Heritage and Culture of Oman, now of Heritage and Tourism, under the direction of Dr Axelle Rougeulle (UMR 8167, CNRS). After an extensive survey, a general map of the medieval city has been drawn, allowing to determine the layout of the fortification walls, funerary zones, streets and different types of buildings such as houses, storehouses, public buildings, mosques, mausoleums, cisterns, a public bath, and workshops. The eastern part of the city is composed by the most ancient quarter which includes the Great Mosque, the sūq and several public buildings. Peripheral quarters with less dense urban networking are distributed northward and westward of the most ancient sector of the site, installed during the extension of the city at the end of the 13<sup>th</sup>-the beginning of the 14<sup>th</sup> c. At the northeast, a complex building with several courtyards which may correspond to the governor residence has been tested. The western part of the site is composed of craft neighbourhoods with pottery and jewellery workshops. The site is bordered on the western side by funerary districts with thousands of graves and several mausoleums. In the northwestern part of city, three buildings have been excavated such as a small mosque, a storehouse (B21) and the twin houses' complex (B94) that is the object of this paper (Rougeulle 2016, 2017, 2023). Excavations have highlighted the connection of the harbour within regional and long-distance networks with the discovery of imported potteries from Yemen, Iran, the Indian subcontinent, China and South-East Asia (Vietnam, Thailand, Birmanya), alongside local productions (Rougeulle et al. 2014, Simsek et al. 2015).





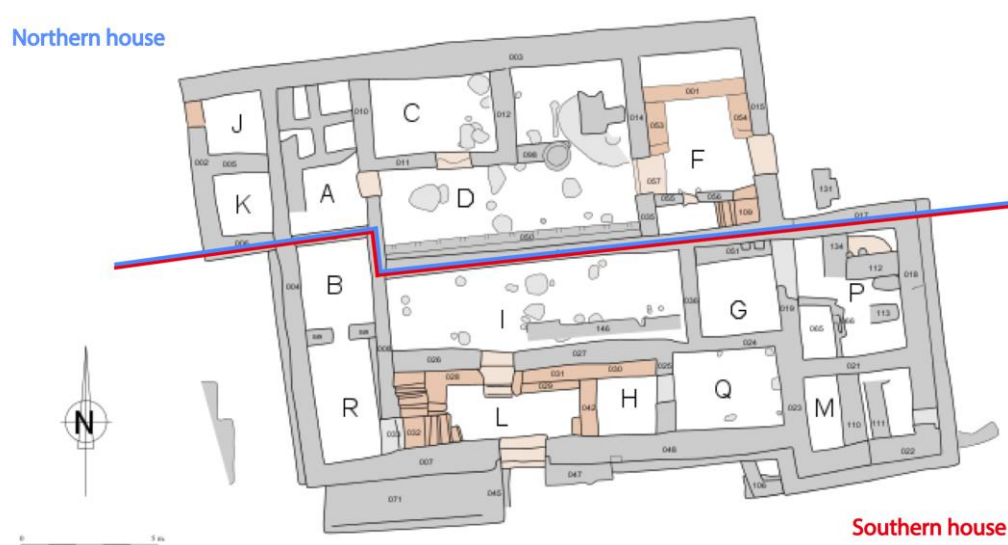
**Fig. 2:** The archaeological site of Qalhât and its surroundings. A= Aerial view of the site before excavations (Rougeulle 2016: 99); B= Acacia trees standing among archaeological ruins of the site with foothills of the Omani mountains behind; C= Mouth of the Wadi Hilm north to the site; D= Date palm gardens maintained in the mouth of the Wadi Hilm with livestock grazing local vegetation.

Bioarchaeological investigations from Qalhât have already been published. The study of seed/fruit remains from a workshop (B39) has allowed to identify the first plant components of diet, to reconstruct the type of agrosystems maintained for produce them and to underline the importation of African/Indian products (Dabrowski et al. 2018). The study of cat bones found in different buildings of the site permits to document the interactions between humans and pets and the taphonomic processes that led to their deposit (Monchot 2022).

### 2.3. The twin house complex (B94)

The twin house complex (B94), which provided the bioarchaeological material studied in this paper, is situated in the north-western quarter of the site (Fig. 1B). Two architectural phases were identified in this area. An early building was first erected directly on the bedrock at the end of the 13th-beg. of the 14th c. (phase 1), before being erased for the construction and occupation of a second building during the 14th c. (phase 2) until its definitive abandonment in the second half of the 16th c. (phase 3). This second building was composed of two unconnected houses (northern and southern) covering approximately 310 m<sup>2</sup> and has been interpreted as a probable community-based habitat in which domestic and craft activities took place, and which yielded the most important part of the zooarchaeological and archaeobotanical material presented here. It is constituted of two distinct habitat units, each composed of one central courtyard bordered by three wings (Fig. 3). Both houses had an entrance leading to a hallway (B94-F in the northern house and B94-L in the southern one) including benches and stairs leading to the upper floors. Two small exterior rooms against the north-

western part of the houses (B94-K and J) may correspond to a shop and its back. The upper floors probably represented the reception and living rooms, while the ground floor was dedicated to domestic and craft activities. In the northern house, the central courtyard (B94-D) evidenced a raised gully all along the southern wall and a rocky billot in the northern part, as well as a marine anchor, suggesting activities relating to fishing in this part of the building (Fig. 4: D and E). In the adjacent rooms, storage jars (B94-C) were recovered, as well as coated basins (B94-A) that had been quickly covered by a floor (Fig. 4: A and C). Room A also yielded evidence of fire at the beginning of the 16<sup>th</sup> c. The southern house yielded fireplaces in the courtyard (B94-I) probably linked to culinary activities, as well as several grindstones (B94-R) and one *madbasa* (B94-B) for making date syrup (Fig. 4: B) (Rougeulle 2016, 2017). Rooms M, P and Q are difficult to understand: the former may have been part originally of an empty wind tower; room Q yielded three superposed floors, the last one likely covered by a wooden structure on poles; and room P includes several backfills and squat occupations.



**Fig. 3:** Plan of the houses' complex of the building 94



**Fig. 4:** Structures and artefacts found in the building 94. A= Four quadrangular basins carved in the floor in room A; B= Madbasa in room B; C= Jar set in the ground of room C; D= Gully with cavities as a workstation for fish processing in courtyard D; E= Marine anchor found in courtyard D.



Throughout the excavation of this structure, a multitude of organic remains, including seeds, fruit, charcoal, as well as mammal, bird and fish bones, were unearthed (Fig. 5). Although they clearly indicate that food-processing activities took place here, we were not able to precise the building's exact function, which cannot be considered as a domestic dwelling, at least at ground level. Thus, the discovery of these abundant bioarchaeological artefacts has raised a series of questions: can this organic material provide new information about the spatial distribution of the daily-life activities of the inhabitants? Can it help to define the function of the building? Could it offer new insights into food acquiring strategies regarding interactions between agropastoral systems and fishing practices set up for feeding an entire urban medieval population?



**Fig. 5:** Graphic representation of the spatial distribution of the material through the building.



### 3. Material and Methods

#### 3.1. Zooarchaeological remains

Identifications were attempted for all bone fragments. Specimens were identified to the lowest possible taxonomic category and anatomical element, or portion thereof. Sheep and goats were distinguished using morphometrical criteria (Salvagno and Albarella, 2017 and references therein); however, despite the extensive literature, specific separation is not always easy, a large majority of the criteria are not 100% reliable and highly diagnostic elements, such as horncores, are generally poorly preserved. Sheep and goat remains were therefore placed in a combined sheep/goat category, i.e. caprine. The quantification of bone remains was based on the total number of identified specimens (NISP) and the minimum number of individuals (MNI). To estimate the age at death, the stages of tooth eruption and dental wear analysis was used (Payne, 1973) alongside epiphyseal fusion (Barone, 1986). Butchering consists of a set, or series of sets, of human activities (skinning, dismemberment, disarticulation, meat removal) directed towards the extraction of consumable resources from a carcass (i.e. butchering pattern, Lyman, 1987; Binford, 1981; Monchot, 1996). Two categories of damage resulting from tool use were identified, namely cut marks (cutting movement of a sharp-edged implement) and chop marks (broad, deep and relatively linear depressions that often have a V-shaped cross-section) (Horwitz and Monchot, 2002). The degree of burning visible on bones was classified by colour on an ordinal scale from 0 to 6. These visible grades of burning range from unburnt (code 0) to intermediate burning stages centring on carbonization (100% carbonized or pure black = code 3) to the most advanced phase known as calcination (100% calcined or pure white = code 6) (Stiner et al. 1995).

#### 3.2. Archaeoichthyological analysis

Fish bones came mainly from hand-picking from almost all the rooms (A, B, C, D, F, G, H, I, J, K, M, P, Q, R) and the exterior areas. In a chronological distribution, 19 contexts were associated with phase 1, 89 for phase 2, 60 for phase 3 and 11 for the interphase contexts (Tab. 1, Supplementary material-A). The fish bones had already been sorted when this study was carried out. Comparative anatomy study was carried out based on the reference collection of the National Museum of Natural History (MNHN) in Paris (France). Identifications were attempted for all bone fragments and each bone was counted (NR). Due to the large presence of vertebrae in the corpus, and the fact that the bones are from occupation layers and not from closed contexts, the MNI was not calculated. Ideally, each bone was identified to species rank, but when it was too fragmented or when some taxa had very similar skeletons (such as for sharks), identification was stopped at genus, family or order (Desse et al., 2002). The weight estimation of the living specimens was made by comparison with our reference specimens (Wheeler and Jones, 1989); though not very precise, it enabled us to determine the minimum and maximum (Béarez et al., 2012). For information on ecological behaviour and fishing practice, we mainly used the FishBase sheets (Froese and Pauly 2022), Randall's (1995) manual on fish biodiversity in Oman and data (monthly artisanal fisheries landings for the governorate of Muscat) from the Ministry of Agriculture and Fisheries of the Sultanate of Oman (M.A.F., 2013, 2015, 2016, 2018). Cut marks were recorded, as were traces of burning. Two different kinds of burning were assigned: burnt, when the bones were black or partially black; and calcified, when the bones become white after longer exposure (Nicholson 1995). To simplify our interpretations, the fishes have been classified into two main categories: pelagic fish, which include all species living in the water column (up to 200 m deep) and demersal fish, which are associated with coastal substrates.

#### 3.3. Archaeobotanical analysis

Two types of archaeobotanical samples (handpicked and sediment) were made during the excavations in six rooms (A, C, D, I, M, P) and two external sectors close to the building (eastern and western) (Tab. 1).

The handpicked samples were found in backfills, destruction/collapse layers, soil levelling and

the abandonment level distributed in rooms A, I, M, P, as well as the external western sector. Six handpicked samples (5 contexts) were dated to phase 3, while three samples each (3 contexts) came from phases 1 and 2. Most of the 29 sediment samples (21 contexts) were realized within courtyards I and D where hearths, thermic soil alterations, refuse and pits, have been processed. Room C yielded a single sample from a hearth. The external eastern sector included two samples from a dump and soil deposit. Phase 2 is the most represented chronological phase of the building with 25 samples from 19 contexts, while phase 1 is documented by 4 samples from 2 contexts.

The handpicked samples (n=12, 11 contexts) consist of clusters of merged carbonized grains. As these were visible to the naked eye they were removed prior to sieving to avoid degradation. The average volume of sediment samples (n=29, 21 contexts)<sup>1</sup> processed was 5 litres, with a minimum of less than 1 litre to a maximum of 35 litres. In total, 155 litres were processed during one field campaign in February/March 2014. All the samples were sieved using a flotation machine that had been built in the field; the methodology is explained in Dabrowski et al. (2018). Samples were then exported for analysis to the archaeobotanical platform (UMR AASPE) of the MNHN, Paris (France). The macro-botanical remains (seeds, fruits, wood charcoal) were extracted with the help of a binocular stereo microscope (Nikon SMZ645). Identification of the seed and fruit remains was made possible by comparison with modern reference collections and an atlas of photographs (Cappers et al., 2006, 2009, 2012; Jacomet, 2006; Van Zeist and Bakker-Heeres, 1982). The number of remains were all counted (NR) as whole and fragmented items. The MNI was evaluated by adding the estimation of original whole items from the fragmented remains to the number of whole remains. This estimation was obtained for cereals and pulses by dividing the number of fragments by two, or in the case of fruits by reconstructing using the naked eye. Percentages were calculated based on the MNI, determinate and indeterminate remains combined, when it is not specified. The clusters of merged carbonized grains sampled by handpicking in the field were studied against the description protocol already set by Dabrowski et al. (2021b). Any botanical remains that were visible on the surface were identified and described to determine their taxa and nature (caryopsis, spikelet, lemma and palea for cereals and Gramineae; cotyledon for pulses) in the same way as the individual seed and fruit remains. Insect damage as circular holes was also noticed. For each cluster, the remains were quantified according to a counting system evaluating their abundance in each cluster (1=1 to 5 remains; 2=6 to 10; 3=11 to 20; 4=more than 20). Some photographs of them have been made with SEM Hitachi SU3500 at the SEM platform of the National Museum of Natural History in Paris (France).

---

<sup>1</sup> In addition, 28 more sediment samples (v= 186,5 l.) from 26 contexts have been processed from several rooms (B=1, C=4, D=2, F=1, G=1, I=8, P=4, Q=1, Ext. West=3, Ext. East=1, Est. South=2) (Table 1, Supplementary material-A), but as they were revealed to be sterile, they have not been taken into consideration.

	Animal bones	Fish bones	Seeds and fruits
A	4	5	3
B	7	8	0 (+1)
C	14	13	2 (+3)
D	24	25	6 (+1)
F	10	10	0 (+1)
G	18	15	0 (+1)
H	7	4	0
I	16	25	14 (+5)
J	3	3	0
K	2	1	0
M	5	5	1
P	16	15	2 (+2)
Q	10	9	0 (+1)
R	19	12	0
Ext. East	11	10	2 (+2)
Ext. North	2	1	0
Ext. SE	1	1	0
Ext. South	14	9	0 (+2)
Ext. West	3	4	0 (+2)
Ext. SW	1	1	1
SURF.	1	1	0
?	3	3	0 (+1)

**Tab. 1:** Synthetic table with the number of contexts taken in consideration per room and for each discipline. Number in brackets indicate the number of contexts in which only hand-picked samples have been made.

## 4. Results

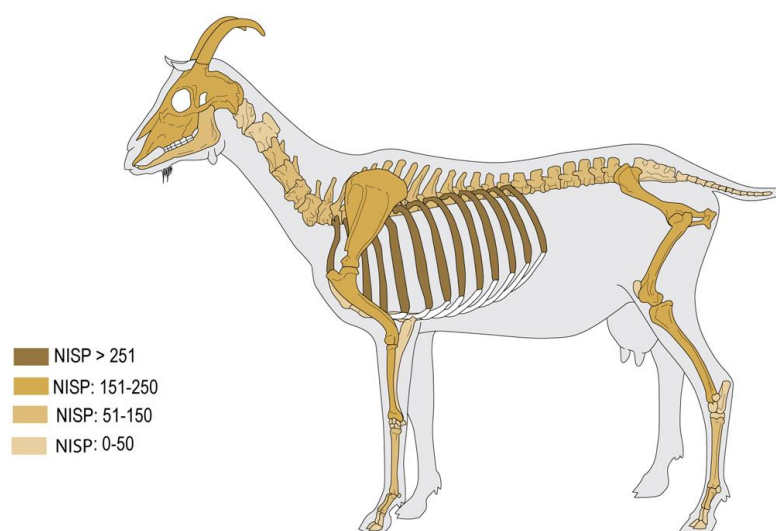
### 4.1. Animal bones (mammals and birds)

Vertebrate remains (mammals and birds) were scattered throughout the building and 16 taxa were identified (NR=5528, NISP=4356, 78.8% of NR). Room P yielded the largest number of faunal remains, followed by room I and, to a lesser degree, rooms R, G, A and courtyard D (Tab. 2, Supplementary material B). In a chronological distribution, 19 contexts were associated with phase 1, 89 with phase 2, 60 with phase 3 and 11 to the interphase contexts.

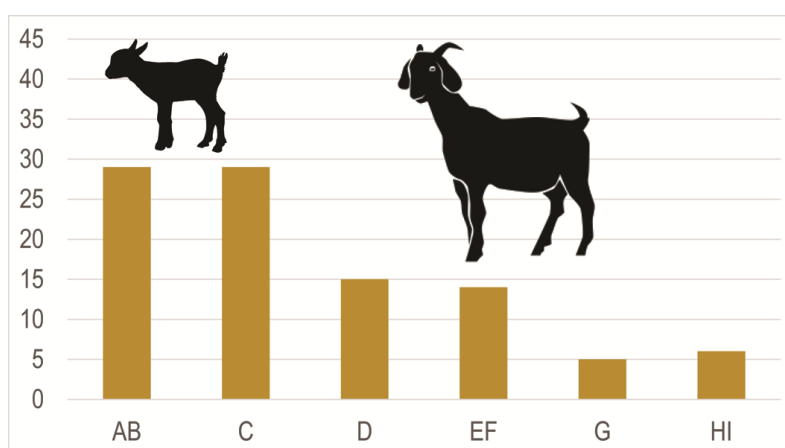
	A	B	C	D	F	G	H	I	J	K	L	M	P	Q	R	Ext. N	Ext. S	Ext. E	Ext. SE	Ext. W	SURF	Total
Caprine	237	237	96	256	122	333	108	610	27	23	2	405	710	288	340	39	42	48	15	25	18	3981
Cattle						2	3					1	12	1	5							24
Gazelle													1	1								2
Donkey/Horse						1		2				1	1		1	1	1					8
Dog						3							3	1					2	1		10
Cat	2		3			3							6	11	25		1	1				52
Hare								1						1								2
Black rat	37		7	10	3	1	1	8						18	1							86
Whale													1									1
Dolphin													1									1
Chicken	12	5	6	17	2	16	4	6	5			12	29	37	12	1	2	9	3		1	179
Rock dove			1	1																		2
Gull								2						1								3
Cormorant													1									1
Ostrich													1									1
Aves sp.				1	1			1														3
Indeterminate	72	36	44	68	61	100	47	289	7	23		58	211	14	90	15	4	16	7	2	8	1172
<b>Total</b>	<b>360</b>	<b>278</b>	<b>157</b>	<b>353</b>	<b>189</b>	<b>459</b>	<b>163</b>	<b>919</b>	<b>39</b>	<b>46</b>	<b>2</b>	<b>477</b>	<b>977</b>	<b>373</b>	<b>474</b>	<b>56</b>	<b>50</b>	<b>74</b>	<b>27</b>	<b>28</b>	<b>27</b>	<b>5528</b>
<b>% Total</b>	<b>6.5</b>	<b>5.0</b>	<b>2.8</b>	<b>6.4</b>	<b>3.4</b>	<b>8.3</b>	<b>2.9</b>	<b>16.6</b>	<b>0.7</b>	<b>0.8</b>	<b>0.0</b>	<b>8.6</b>	<b>17.7</b>	<b>6.7</b>	<b>8.6</b>	<b>1.0</b>	<b>0.9</b>	<b>1.3</b>	<b>0.5</b>	<b>0.5</b>	<b>0.5</b>	<b>100</b>

**Tab. 2:** Zooarchaeological results per room by Number of identified specimens (NISP)

With 91.4% of the NISP, caprine dominated the bone assemblage. If all the skeletal parts are assumed to be present, a dominance of the trunk and the meaty part of the limbs was observed, with a clearly under-representation of the feet bones (i.e. carpal, tarsal and metapodial) (Fig. 6). According to teeth wear and attrition stages, more than half the individuals (62.7%) were juvenile, including many yearlings (suckling lambs). The rest was made up of 27.9% adults and 9.4% old individuals (Fig. 7). However, this proportion of juveniles was not found using the long bones – for example, a minimum of 50 adults were identified from the distal end of the humerus. The presence of cut and chop marks (NR=273) were noted on the entire skeleton, reflecting butchery activities (e.g. skinning, dismemberment, filleting). Finally, only 23 bones showed traces of calcination, but it is impossible to know if these traces are the result of culinary preparations (roasting) or related to the elimination of rubbish by fire.



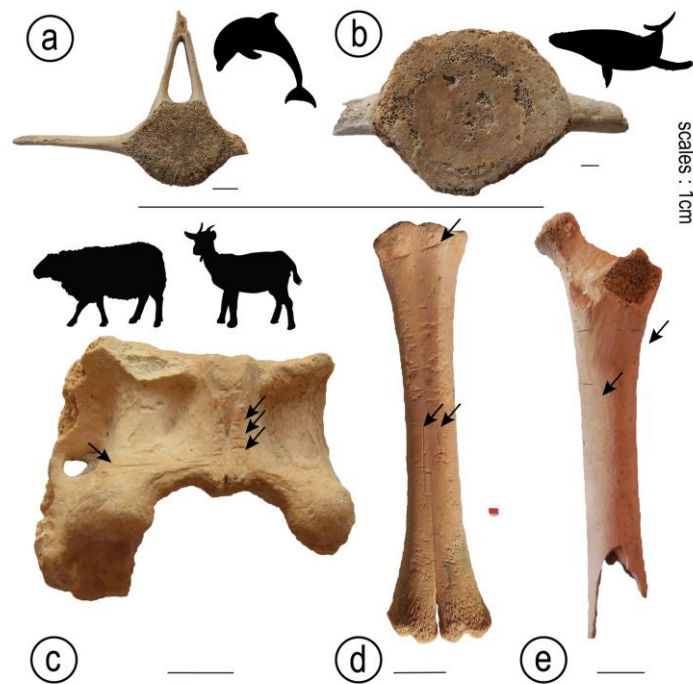
**Fig. 6:** Caprine skeletal representation in NISP (Number of identified specimens).



**Fig. 7:** Mortality profile of caprine in NISP (Number of identified specimens) (according to Payne, 1973)

With only 179 remains (4.1% of NISP), domestic fowl (chicken, *Gallus gallus domestica*) was the second most represented species on the site. The remains included bones from roasters (presence of spurs), females (presence of medullary bones, De Cupere et al., 2005) and chicks (immature bones, 23.9%). If all the skeletal elements were identified, we observed a clear predominance of leg and wing bones. The anatomical profile indicated that the bones represented the waste from entire birds. Butchery was confirmed by the presence of cut marks, identified on one femur, three humeri and three tibiotarsus. Eggshell fragments were identified in B94 1746 (room G), 1830 (room Q) and 1681 (room B) (Fig. 8).





**Fig. 8:** Illustration of (a) vertebra of a dolphin, (b) vertebra of a whale, (c) cut marks on a sheep axis, (d) cut marks on a sheep metapod, (e) cut marks on a sheep femur.

For the other represented species, few cattle remains were identified (NISP=21, 0.48%), consisting essentially of long bone shaft fragments (e.g. femur, tibia, metapodial). Eight remains, mostly isolated teeth, attested the presence of equids (*Equus* sp.) (0.18% NISP). Identifying equid bones specifically is not easy with the recurrent distinction between horse (*Equus caballus*), donkey (*Equus asinus*) and hybrid mules (Hanot et al., 2017; Hanot and Bochaton, 2018). The dog (*Canis lupus familiaris*), a commensal species, was also presented in B94 (NISP=2, 0.05% NISP), with young individuals attested.

Several domestic cat remains (*Felis catus*, NISP=52, 1.19% NISP) were identified, representing six adults and three immature individuals (kittens), with an almost complete skeleton identified (UF 1723, 25 remains) (Monchot and Guintard, 2017; Monchot, 2022). The size of the long bones show that immature juveniles belonged to different age ranges. No traces of cut marks were found on any of the cat bones, so it seems likely that the animals were not skinned.

Two bones evidenced the presence of a hare (*Lepus capensis*): a right humerus belonging to an adult with butchery cut marks (UF 1408) and a left scapula from a juvenile individual (UF 1830). The black rat (*Rattus rattus*) was present in many rooms (NISP= 86, 1.97%). In addition, numerous bones showed gnaw marks, a sign of intense rodent activity on the site.

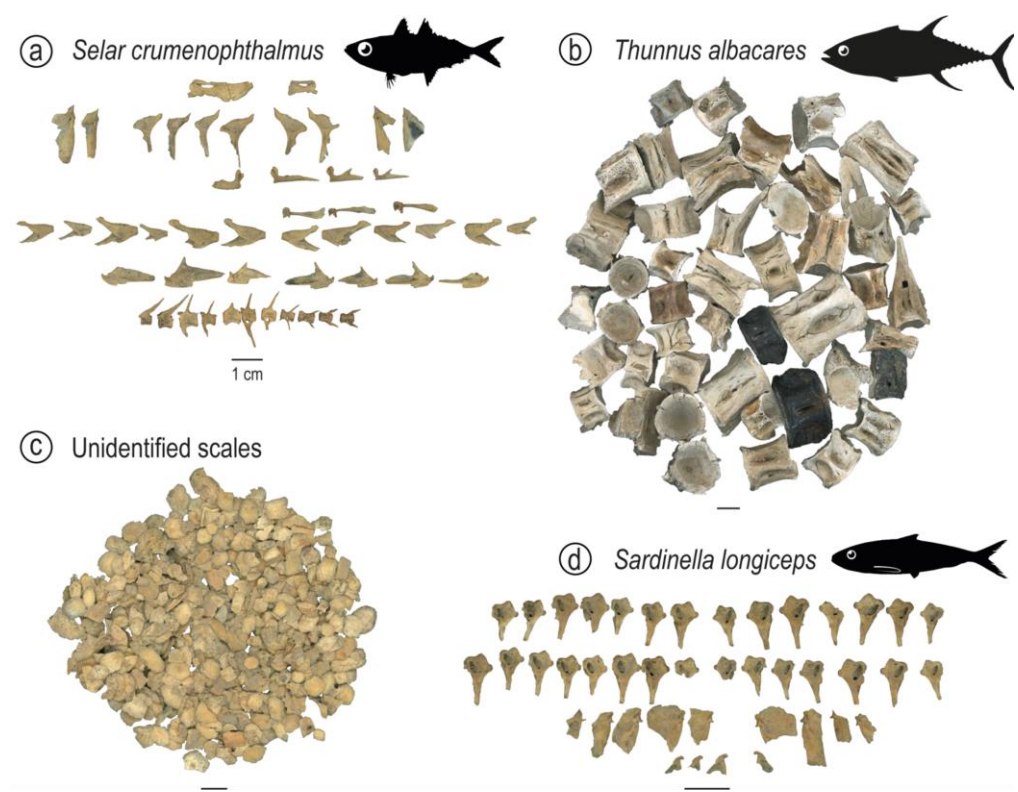
For the wild taxa, two bones were identified as belonging to a gazelle (*Gazella* sp.): a right proximal metatarsal (US 1835) and a distal metatarsal (US 1898); however, it was not possible to precise the exact species. One vertebra belonging to a dolphin (unidentified) and another belonging to a whale were also discovered. With regards birds, a right carpometacarpus testified to the presence of a cormorant (*Phalacrocorax* sp.), the rock dove (*Columba livia*) was attested by two bones (a left proximal humerus and a furcula), gulls (*Larus* sp - morphology and size of these bones are close to those observed in the European Herring gull/*Larus argentatus*.) was testified by three bones (two coracoids and one proximal humerus), and finally one eggshell fragment from an ostrich (*Struthio camelus*) was present. For the cormorant, it was not possible to determine if the bone belonged to the Great cormorant (*Phalacrocorax carbo*) or the Socotra cormorant (*Phalacrocorax nigrogularis*).

These two species are widely present along the coastal area and were commonly hunted in the past (Tomé, 2003). As for the rock dove, it lives on cliffs and rocks, mountains and hillsides, where it nests in rock crevices or caves.

## 4.2. Fish bones

For the fish corpus, 34 families and 80 species were identified (18 865 NR, 4855 NR identified). Most of the bones were vertebrae (n=4416), although a large quantity of scales (n=6005) were also recorded. Head bones were well represented (n=1204). The other remains were unidentified fragments. Fish bones were found in almost all the rooms of the building with a high concentration in the eastern exterior and rooms D, I, Q, and R (Tab. 3, Fig. 5). The bones were primarily associated with phase 2, followed by phase 3, while phase 1 was poorly represented. Scales were strongly represented during phase 2 of the occupation (n=5990) in the northern part of the building (room-C - n=222, room-D - n=817, eastern exterior - n=4903). Only 11 scales were counted for phase 3 from the entire building. For the cranial remains, during phase 2, room I evidenced the most cranial remains, while during phase 3, rooms B and M showed a large proportion.

The most important category of fish were pelagic fish (Supplementary material-C, Marrast, 2024). The tuna family (57%, Scombridae) was the most important with the yellowfin tuna species (26.2%, *Thunnus albacares*) and the longtail tuna (8%, *Thunnus tonggol*) (unidentified *Thunnus* spp. represented 12.5% and Scombridae 4.7%). A very common fish in today's fisheries, the kawakawa (3%, *Euthynnus affinis*) and narrow-barred Spanish mackerel (or "kingfish", 0.7%, *Scomberomorus commerson*) was of minor importance. Large specimens of yellowfin tuna, up to 70 kg were identified, while the longtail tunas could reach 40 kg, even the mean weigh was between 9 and 13 kg. According to the number of remains, bigeye scad (6.51%, *Selar crumenophthalmus*) (Fig. 9) was the most important of the Carangidae family, followed by trevallies (3.4%, *Carangoides* spp.) and jacks (3.4%, *Caranx* spp.). Seabreams (4.8%, Sparidae) were primarily represented by the king soldierbream (3.56%, *Argyrops spinifer*), a demersal fish that can reach 450 m deep (Froese and Pauly 2022). This species is highly recognizable in archaeological remains due to the characteristic features of its skull, teeth and premaxilla. Seabreams were following by emperors (3.9%, Lethrinidae). These were represented by several species (mainly *Lethrinus microdon*, *L. nebulosus*), but generally we stopped our identification at the genera *Lethrinus* because the bones can be very similar between species. In last position came requiem sharks (3.5%, Carcharhinidae). One specimen of tiger shark (*Galeocerdo cuvier*, UF 2573, room P, phase 2) was particularly huge with a vertebra measuring 52.2 mm. Excepting for tuna and some sharks, all the fish were estimated to be of medium size. In addition, minor demersal species (7.3%) were also represented, such as snappers (Lutjanidae), parrotfish (Scaridae), rabbitfish (Siganidae), groupers (Serranidae), nurse sharks (Ginglymostomatidae) and grunts (Haemulidae). In the minor pelagic fish category (4.5%), sardines (Clupeidae) (Fig. 9), barracudas (Sphyraenidae), hammerheads (Sphyrnidae), few specimens of white/mackerel sharks (Lamnidae) and dolphinfish (*Coryphaena hippurus*) were identified. Sailfish (Istiophoridae) were also noted, with mentions of Indo-Pacific sailfish (*Istiophorus platypterus*) and black marlin (*Istiompax indica*) (Supplementary material C, Marrast, 2024).



**Fig. 9:** Illustration of different bones from (a) big eye scad (ceratohyal, cleithrum, opercula, dentary, maxillary, articular, vertebrae), (b) yellowfin tuna (burned vertebrae) (c) unidentified fishes (various scales), (d) Indian oil sardine (hyomandibular, opercular, palatine).

Family/Room	A	B	C	D	F	G	H	I	J	K	M	P	Q	R	Ext East	Ext North	Ext South	Ext West	Total
Scombridae	4	173	27	530	90	131	212	285	13	6	84	110	326	199	198	17	338	7	2750
Carangidae	1	15	17	87	9	67	16	49		1	26	30	83	57	464	2	11	3	938
Lethrinidae	1	13	6	33	3	16		39			3	3	26	20	24		1		188
Sparidae	2	9	17	27	2	36	3	35	1		9	10	34	18	29		1		233
Carcharhinidae		7	3	12	3	24	4	33		3	7	22	14	28	9	1	1		171
Other pelagic	0	9	2	6	8	13	0	16	0	3	6	8	26	29	90	0	4	1	221
Other demersal	0	11	7	141	1	22	1	21	0	0	2	6	51	23	65	0	0	3	354
Unidentified		371	398	2539	162	260	18	663	151	3	52	86	1506	814	6892	8	82	5	14010
Total	8	237	79	836	116	309	236	478	14	13	137	189	560	374	879	20	356	14	4855

**Tab. 3:** Archaeoichthyological results per room by Number of remains (NR) and Weight of Remains (WR). (results)

As for the butchery marks, very few were observed, maybe because the bones were so poorly conserved after their deposition (Willis et al., 2008). In the corpus, only 7 were noted: 5 on a requiem shark's vertebrae and 2 on a greater amberjack (*Seriola dumerili*). With regards fire exposure (Fig. 9), 10% (n=1878) of the total remains had been exposed to different levels: burnt (n=849) and calcified (n=1027) (Fig. 9) (Nicholson, 1995). The burnt bones came mainly from phase 2 (n=1654) and were mostly vertebrae, especially from yellowfin tuna (n=573) and other tuna (Fig. 9). For *Thunnus* bones, the burnt and calcified vertebrae were mainly from rooms D, H, southern exterior, B and F (Fig. 9). The head bones and spines did not appear to be affected by this taphonomic effect.

### 4.3. Seeds and fruits

In total, the 364 botanical remains (MNI=191) recovered from sediment samples (Tab. 4, Fig. 10 and 11, Supplementary material-D) mostly corresponded to whole and fragmented seeds and fruits, with some fragments of pericarp. Other types of remains such as perianth, leaf, and straw fragments were occasionally attested. Of the 23 taxa, 13 were identified to the species or subspecies level, 4 to the genus level and 5 to the family or subfamily level. Almost all the botanical remains (96%) were found in contexts belonging to phase 2, with rooms D and I yielding the most numerous remains (respectively, 48% and 47%).

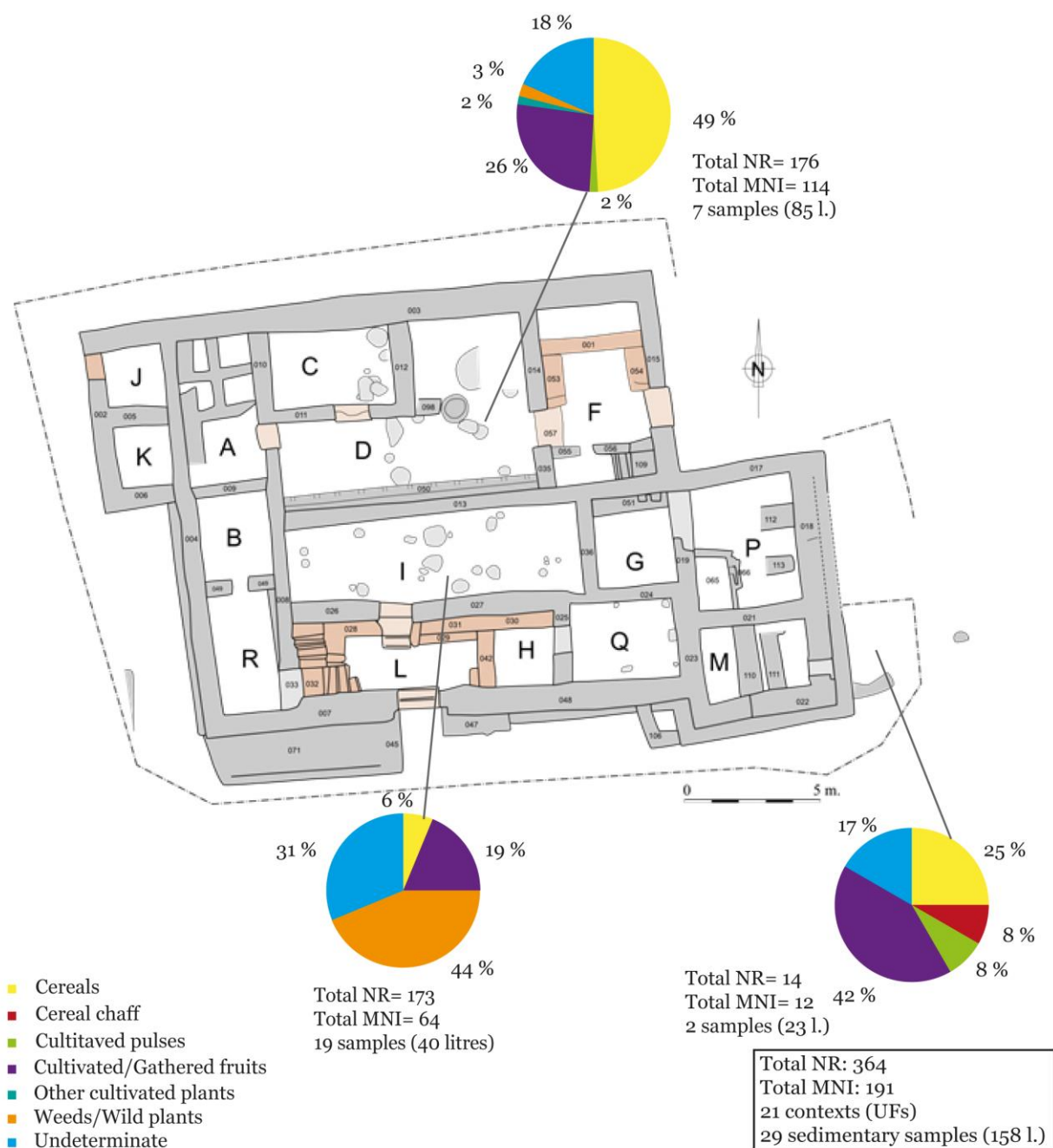
Several categories of plants were attested within the assemblage, with cereals (34%) and fruits (25%) being the most represented. Free-threshing wheat (*Triticum aestivum/turgidum/durum*) corresponded to the most attested taxon (19%) followed by Asian rice (7%, *Oryza sativa*), finger millet (3%, *Eleusine coracana* ssp. *coracana*) and hulled barley (3%, *Hordeum vulgare*). Most of cereals came from two hearths (UF 1658, UF 1661) and one pit (UF 1956) in room D: free-threshing wheat was mostly attested in this room (in particular, UF1658), while Asian rice and hulled barley was only recovered from this room. Finger millet is the only cereal represented in contexts dated to both phases 1 and 2. Fruits from cultivated/wild trees were mostly evidenced by the date palm (13%, *Phoenix dactylifera*), followed by jujube (9%, *Ziziphus* sp.). Other fruits were occasionally attested in the assemblage, such as pomegranate (*Punica granatum*) and grapevine (*Vitis vinifera* ssp. *vinifera*), as isolated seeds (1% each). Cultivated pulses were only attested in very minor proportions: mung/urid bean (*Vigna radiata/mungo*) and cowpea (*Vigna unguiculata*) (1% each); the former in room D and the latter in the eastern exterior. This is also the case for spices and condiments, represented by pepper (*Piper nigrum*) and celery (*Apium graveolens*) (1% each), both of which were attested as single fruits in one hearth (UF 1658) of room D. Wild plants (16%) included several taxa that could correspond either to weeds incorporated with harvests and eliminated by fire inside the building or wild plants growing in the surroundings and brought in accidentally by wind, for example. They belong mostly to the Poaceae family: Bermuda grass (10%, *Cynodon dactylon*) (10%); Sawa millet (*Echinochloa colona*); the Malvaceae family, such as mallow (*Malva* sp.) and Indian mallow (*Abutilon* sp.); and the Amaranthaceae family, such as amaranth/chenopod (*Amaranthus/chenopodium*). The majority of wild plants were found in room I, especially in one hearth (UF 1719) and one thermal degradation level (UF 1751) in the form of seeds, caryopses and a single leaf. Substantial amounts of indeterminate remains (23%) and occasional animals droppings and insects were also attested in the assemblage.



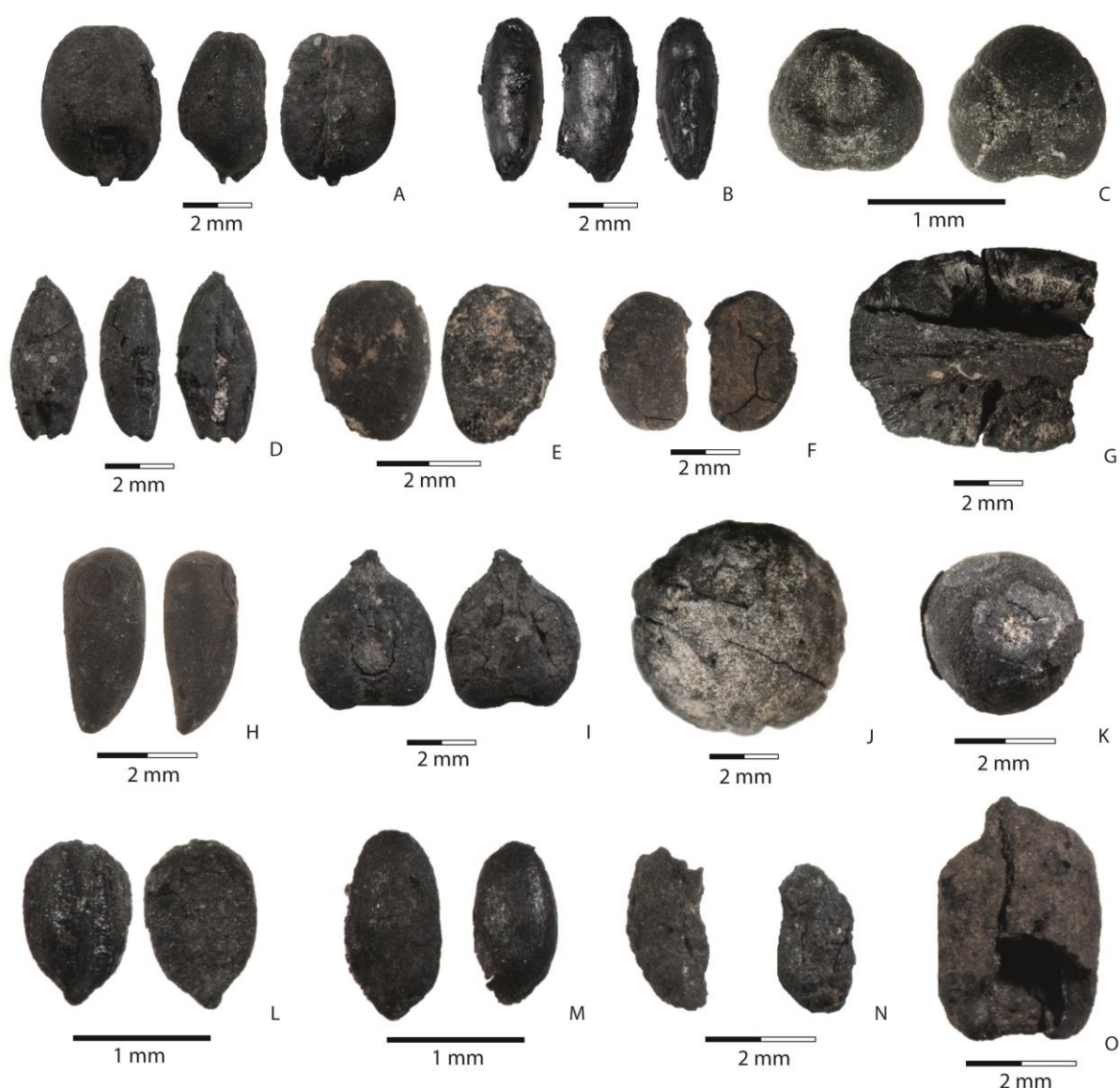
Phase		Phase 1		Phase 2								Total	
Room		I		C		D		I		Ext. East			
Number of contexts		2		1		7		9		2		21	
Number of samples		4		1		7		15		2		29	
Total of volume sieved (litre)		8		10		85		32		23		158	
		NR	MNI	NR	MNI	NR	MNI	NR	MNI	NR	MNI	NR	MNI
Vernacular name	Latin name												
<b>Cereals</b>													
Finger millet, seed	<i>Eleusine coracana</i> ssp. <i>coracana</i>	1	1	-	-	4	4	1	1	-	-	6	6
Hulled barley, caryopsis	<i>Hordeum vulgare</i>	-	-	-	-	4	4	-	-	-	-	4	4
Hulled barley, fg. caryopsis		-	-	-	-	1	1	-	-	-	-	1	1
Asian rice, caryopsis	<i>Oryza sativa</i>	-	-	-	-	10	10	-	-	-	-	10	10
Asian rice, fg. caryopsis		-	-	-	-	2	1	-	-	-	-	2	1
Probable Asian rice, fg. caryopsis		-	-	-	-	3	2	-	-	-	-	3	2
Free-threshing wheat, caryopsis	<i>Triticum aestivum/durum/turgidum</i>	-	-	1	1	27	27	1	1	3	3	32	32
Free-threshing wheat, fg. caryopsis		-	-	-	-	7	4	2	1	-	-	9	5
Und. cereal, fg. caryopsis	<i>Cerealia</i>	-	-	-	-	5	3	-	-	-	-	5	3
Und. cereal, straw fragment		-	-	-	-	-	-	-	-	1	1	1	1
<b>Cultivated pulses</b>													
Urd/Mung bean, cotyledon	<i>Vigna mungo/radiata</i>	-	-	-	-	2	2	-	-	-	-	2	2
Cowpea, cotyledon	<i>Vigna unguiculata</i>	-	-	-	-	-	-	-	-	2	1	2	1
<b>Fruit trees/vines</b>													
Date, seed	<i>Phoenix dactylifera</i>	-	-	-	-	3	3	1	1	-	-	4	4
Date, fg. seed		-	-	-	-	38	9	75	8	1	1	114	18
Date, fg. seed with pericarp		-	-	-	-	2	1	-	-	-	-	2	1
Date, frag. of pericarp		-	-	-	-	1	-	-	-	-	-	1	-
Date, fg. of endocarp		6	1	-	-	14	-	34	-	-	-	54	1
Date, perianth		-	-	-	-	1	1	-	-	-	-	1	1
Pomegranate, seed	<i>Punica granatum</i>			-	-	1	1	-	-	1	1	2	2
Grape, seed	<i>Vitis vinifera</i> ssp. <i>vinifera</i>			-	-	2	2	-	-	-	-	2	2
Jujube, endocarp	<i>Ziziphus</i> sp.			-	-	5	5	-	-	1	1	6	6
Jujube, half endocarp				-	-	12	6	-	-	2	2	14	7
Jujube, fg. endocarp		1	1	-	-	6	2	-	-	1	1	10	5
<b>Other cultivated plants</b>													
Celery, achene	<i>Apium graveolens</i>	-	-	-	-	1	1	-	-	-	-	1	1
Pepper, drupe	<i>Piper nigrum</i>	-	-	-	-	1	1	-	-	-	-	1	1
<b>Weedy/Wild plants</b>													

Phase		Phase 1		Phase 2								Total	
Room		I		C		D		I		Ext. East			
Number of contexts		2		1		7		9		2		21	
Number of samples		4		1		7		15		2		29	
Total of volume sieved (litre)		8		10		85		32		23		158	
		NR	MNI	NR	MNI	NR	MNI	NR	MNI	NR	MNI	NR	MNI
Indian mallow, seed	<i>Abutilon</i> sp.	-	-	-	-	-	-	1	1	-	-	1	1
Amaranth/Chenopod, seed	<i>Amaranthus/Chenopodium</i>	-	-	-	-	1	1	-	-	-	-	1	1
Amaranthaceae, leaf	Amaranthaceae	-	-	-	-	1	1	-	-	-	-	1	1
Brassicaceae, seed	Brassicaceae	1	1	-	-	-	-	1	1	-	-	2	2
Bermuda grass, caryopsis	<i>Cynodon dactylon</i>	-	-	-	-	-	-	13	13	-	-	13	13
Probable Bermuda grass, caryopsis	cf. <i>Cynodon dactylon</i>	-	-	-	-	-	-	5	5	-	-	5	5
Sawa millet, caryopsis	<i>Echinochloa colona</i>	-	-	-	-	-	-	1	1	-	-	1	1
Probable euphorb, seed	cf. <i>Euphorbia</i>	-	-	-	-	-	-	1	1	-	-	1	1
Pulse, cotyledon	Fabaceae	-	-	-	-	-	-	2	2	-	-	2	2
Mallow, seed	<i>Malva</i> sp.	-	-	-	-	-	-	2	2	-	-	2	2
Millet, caryopsis	Panicoidae	-	-	-	-	1	1	1	1	-	-	2	2
<b>Indeterminate</b>													
Indeterminate, seed/fruit/other		4	4	-	-	17	17	11	11	-	-	32	32
Indeterminate, fruit		-	-	-	-	-	-	2	2	-	-	2	2
Indeterminate, fg. of pericarp		-	-	-	-	4	4	-	-	2	2	6	6
Indeterminate, fg. of endocarp		-	-	-	-	-	-	3	3	-	-	3	3
Organic amorphous remains		-	-	-	-	×	×	×	×	-	-	×	×
<b>Coprolites</b>													
Coprolites, sheep/goat pellet		-	-	-	-	1	1	-	-	-	-	1	1
Coprolites, rodent dropping		1	1	-	-	-	-	7	7	-	-	8	8
cf. Coprolites, rodent dropping		-	-	-	-	-	-	2	2	-	-	2	2
<b>Total of determined carpological remains</b>		9	4	1	1	155	93	144	40	12	10	320	148
<b>Total of undetermined carpological remains</b>		4	4	-	-	21	21	16	16	2	2	43	43
<b>Total of carpological remains</b>		13	8	1	1	176	114	160	56	14	12	363	191

Tab 4: Distribution of seed/fruit remains per phase and per room.



**Fig. 10:** Distribution of the different categories of seed/fruit remains from sediment samples in the building B94. Results from room C have not been illustrated since a single remain is concerned.



**Fig. 11:** Seed/fruit remains identified in the houses' building 94. A= Caryopsis (grain) of free-threshing wheat (*Triticum aestivum/turgidum/durum*) in dorsal, lateral and ventral views; B= Caryopsis (grain of Asian rice (*Oryza sativa*) in dorsal, lateral and ventral views; C= Seed of finger millet (*Eleusine coracana* ssp. *coracana*), in dorsal and ventral views; D= Caryopsis (grain) of hulled barley (*Hordeum vulgare*); E= Cotyledon of mung/urid bean (*Vigna radiata/mungo*), in dorsal and ventral views; F= Cotyledon of cowpea (*Vigna unguiculata*), in dorsal and ventral views; G= Fragment of date seed (*Phoenix dactylifera*), in ventral view; H= Seed of pomegranate (*Punica granatum*), in two different views; I= Grape pip (*Vitis vinifera* ssp. *vinifera*), in dorsal and ventral views; J= Jujube endocarp (stone) (*Ziziphus* sp.), in dorsal view; K= Seed/fruit of pepper (*Piper nigrum*); Achene of celery (*Apium graveolens*), in dorsal and ventral views; M= Two caryopses of barnyard grass (*Cynodon dactylon*), in lateral views; N= Two rodent coprolites; O= One goat/sheep coprolite.

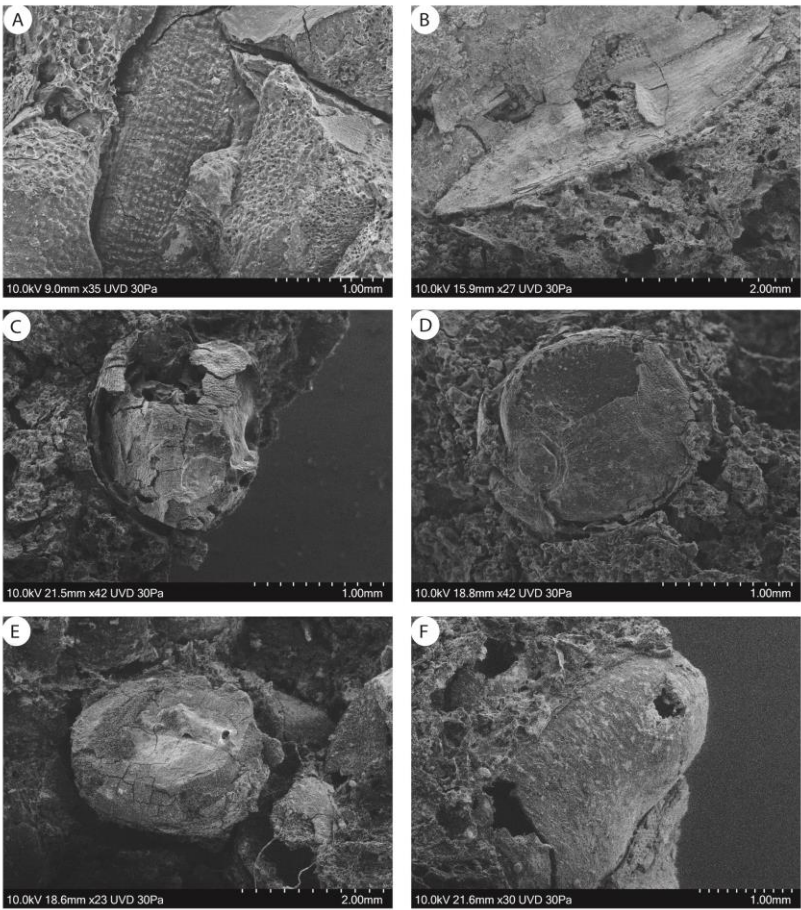


In total, 130 clusters of grains merged by carbonization were handpicked from several rooms in the two houses (Supplementary material-E). Most of the handpicked samples were recorded from three different contexts of room A distributed within four samples dated to phase 3 (Tab. 5), while others were found in rooms C, I, M, P and the southern exterior (Supplementary material-E). For room A, three distinct groups have been defined among the 97<sup>2</sup> clusters described (Fig. 12 & 13): the first set constituted of only whole rice grains (57%), the second one of rice spikelets, chaff and/or Panicoidae (27%) and the last one of mung bean (10%); some clusters samples correspond to a mix of the three groups (5%). These groups may correspond to different assemblages prior to the destruction fire: the first to whole rice grains ready for consumption/transformation, which include most of the clusters; the second to less cleaned storage with still by-products (spikelets, fragments of chaff, weeds); and the third to culinary preparations corresponding to a mix of rice grains and split cotyledons of mung bean. A mix of these elements seems to result from mutual contaminations between these three groups, probably during the destructive fire. The other rooms also yielded clusters of grains. In room C, three clusters of rice grains were found in one destruction level dated to phase 3, probably linked to the other destruction levels of room A. In room I, 16 clusters of whole rice grains, some of them still with Panicoidae as weeds, were unearthed from backfill levels dated to phase 1, likely from burnt down buildings whose material had been reused for the construction of the building. In room P, five clusters of rice grains were unearthed from backfill levels. In the western exterior, eight clusters of rice grains were found in one abandonment deposit and one cluster of free-threshing wheat was noted in one backfill deposit in room M. As datation needs to be confirmed for the samples from rooms P, M and the western exterior, they have not been taken into consideration.

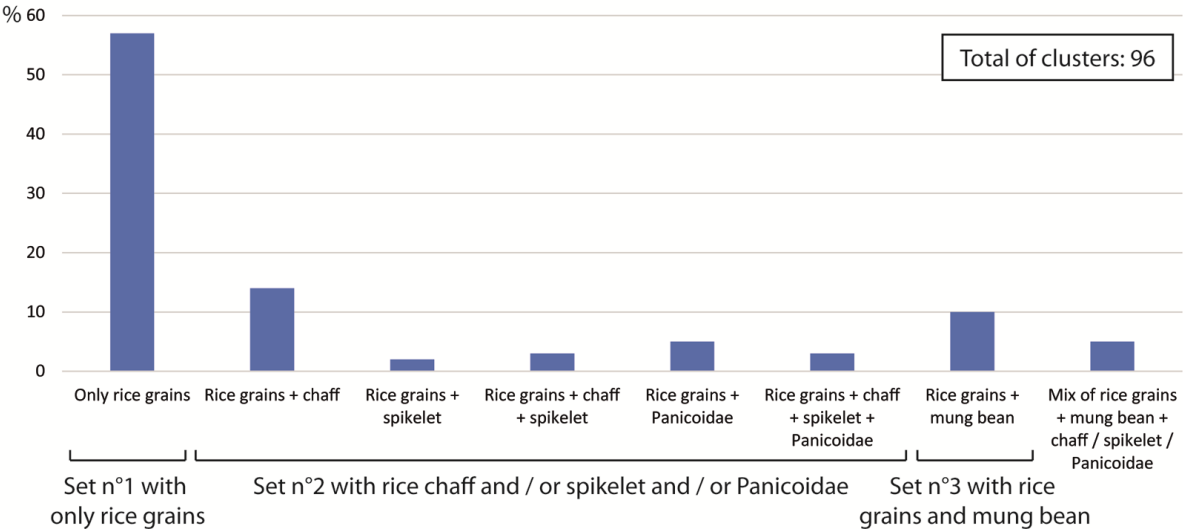
Room		A										
Contexts		1411,1414,1419										
Samples		215, 217, 255, 267										
Phase		3										
Total number of clusters		96										
Taxa	Scale of abundance	0	%	1	%	2	%	3	%	4	%	Total
<i>Asian rice (Oryza sativa)</i>	Caryopsis	-	-	6	6	16	17	31	32	43	45	96
	Whole caryopsis	-	-	13	14	34	35	26	27	23	24	96
	Fg. caryopsis	8	8	71	74	13	14	4	4	-	-	96
	Spikelet	87	91	9	9	-	-	-	-	-	-	96
	Fg. of chaff	75	78	21	22	-	-	-	-	-	-	96
	Infested caryopsis	92	96	4	4	-	-	-	-	-	-	96
<i>Urd/Mung bean (Vigna mungo/radiata)</i>	Cotyledons	81	84	3	3	6	6	1	1	5	5	96
<i>Millet (Panicoidae)</i>	Caryopsis	87	91	9	9	-	-	-	-	-	-	96
Fibres	-	82	85	14	15	-	-	-	-	-	-	96

**Tab. 5:** Description of rice clusters found in room A.

<sup>2</sup> Only one cluster was not composed of rice grains, but of free-threshing wheat. It has not been included in the percentages of the different groups. In addition, 185 other clusters constituted probably of rice grains were counted but their very bad state of preservation lead us to not include them in the study.



**Fig. 12:** Details of rice clusters found in room A. A= Whole rice spikelet; B= Rice fragmentary chaff (*lemma/palea*); C= Caryopsis of indeterminate millet within its chaff; D= Caryopsis of Sawa millet partially in its chaff; E= Split cotyledon of mung bean; F= Rice grain with circular perforation maybe due to a pest beetle. © Plateforme de Microscopie Electronique du Muséum National d'Histoire Naturelle



**Fig. 13:** Distribution of rice clusters from room A according to their taxonomical and anatomical composition.

## 5. Discussion

Analysis of the three categories of organic remains has enabled us to garner new information about the nature and spatial distribution of the food-processing activities that took place inside the building and propose a hypothesis for its function. More globally, it allowed us to reconstruct the dietary habits of the urban population of Qalhāt via the reconstruction of agropastoral systems, fishing strategies and regional maritime trade.

### 5.1. From the spatial distribution of archaeobiological remains to the function of rooms

The spatial distribution of the archaeobiological remains (Fig. 5) and the composition of the different assemblages, alongside architectural features, and archaeological artefacts, enabled us to characterize the food-processing activities and propose potential functions for the different rooms within the building. As almost all the assemblages came from phase 2, and to a lesser extent phase 3, both linked to the occupation and abandonment of the second building, only this data was considered.

#### 5.1.1. The northern house

##### 5.1.1.1. *Courtyard D*

The northern house included numerous evidence of fish-processing activities, with large quantities of fish scales and heads being recovered from courtyard D and adjacent rooms C and F, although in lesser proportions. These remains testify that scaling and gutting activities primarily took place in this part of the building. Additionally, structures in the courtyard, similar to a gutter with regular cavities in the lower part (for storing tools?) and a rocky billot, may also be linked to the processing of fish – for blood and guts evacuation, as well as cutting heads and filleting. However, there still remains the problem of water evacuation due to the absence of drain holes, although any perishable elements that could have helped explain these structures have disappeared. Today in Qalhāt, medium-sized fish are typically sold whole and fresh to customers with scaling or filleting done upon request (Iddison, 1998, pers. obs), but the few cranial bones from large fish (like tunas) that were discovered in building (B94) indicates the removal of heads and tails away from the site, either on the boat or at the harbour. Contrary to the Khor Rori remains, which showed numerous butchery marks on various fish (Carenti and Wilkens, 2008), only a few were found here. However, the presence of so many butcher marks seems to be unusual, as these cut marks can also appear on fragmented bones, which are usually set aside in fish bones. (Willis et al., 2008).

The association of fish bones and rice grains in this courtyard may testify to meal preparations, described in textual sources such as Ibn Battūṭāʾī (1982, p. 93): “*I ate fish at Kalhāt such as I have never tasted in any other country; I preferred it to all kinds of meat, and that was my only food. The inhabitants roast it on tree leaves, put it on rice, and eat it; ...*”. Moreover, the analysis of seeds and fruit remains underlines that meal preparation and/or consumption probably took place in courtyard D. Indeed, most of the cereals, fruits, other than date (grape, pomegranate, jujube) and all the pulses and spices linked with hearths and pits were found in this part of the building. There was also an absence of weeds and chaff, suggesting cleaned crops that were ready for cooking and consumption.

##### 5.1.1.2. *Eastern exterior*

The composition of fish assemblages dominated by scales, and to a lesser extent botanical dataset including pulses and jujubes, in the eastern exterior implies that this dump area was heavily used for discarding by-products relating to processing activities in the northern house. In addition, the presence of numerous small fishes, attested by heads and bones together, may suggest that rotting fishes were also dumped here. During phase 3, fish bone quantities decrease significantly in the

northern house and related dumping areas, highlighting changes surrounding the processing activities that took place inside the building at the end of the occupation. However, the eastern exterior was still used as a dump during this period, as suggested by the high concentration of wood charcoal and desiccated fly pupae indicating decayed organic matter.

### 5.1.1.3. *The storage rooms: A and C*

At the beginning of the occupation, room A was composed of four quadrangular basins covered by a plaster floor. This room was probably used initially for salting fishes for conservation purposes; the fish flesh (ElMahi, 2000) prepared in the next courtyard were stored. During phase 3, at the end of the occupation, several assemblages of rice grains (Tab. 5, Fig. 12 & 13; Supplementary material-E), some less clean than others and some mixed with split mung beans, had been preserved by the destructive fire. This indicates that this room was used for storing different kinds of food preparations; in addition, some fibres were also observed, demonstrating that the rice had been stored in bags. The mix of rice grains and split mung beans seems to correspond to a meal preparation originating from the Indian subcontinent. Ethnographic works mention the preparation of a traditional meal called *khîcrî* in Rajasthan (India), made of rice and mung beans cooked together in salted boiled water with curcuma powder, but there is no mention of split mung beans (Cousin, 2010: 327-8). The consumption of pulses as split cotyledons with the testa removed is not surprising, since it is still seen today in the Indian subcontinent in the form of *dhal* (Reddy, 2006). This preparation of rice grains and split mung beans is also mentioned by Ibn Baṭṭūṭāʾ (1982: 288) in India: rice and mung beans are cooked together and eaten with butter for lunch, known as *kichry*. This mix may have been prepared directly in the room or have been stored already in this form: the 13<sup>th</sup> c. traveller Ibn al-Muğāwir (2008: 162) testifies that this kind of preparation, called *kedgerie*, was imported from the Indian subcontinent. In room C, the presence of three charred rice clusters seems to indicate links with room A at the end of the occupation. Some jars that were still in place correlate to the function of this room as a storage place for a time, especially given that some fish scales were also found here, as in courtyard D.

## 5.1.2. The southern house

### 5.1.2.1. *The courtyard I*

In the southern house, differences among the zooarchaeological and archaeobotanical assemblages, alongside the archaeological structures, compared to the northern house gave new insights into the food-processing activities that took place here. Almost all the weeds and wild plant taxa were attested from the hearths situated in courtyard I. This distribution shows the elimination of harvest by-products by throwing them into the fire: the cleaning of crops may have taken place directly in the courtyard or may have occurred outside before bringing the waste products in to use as fuel (Van der Veen, 1999). Fish bone evidence demonstrates that fish processing was also undertaken in this courtyard. Differences concerning the composition of the fish assemblages between courtyards D and I were noticed, with the southern house presenting much more biodiversity. This may be due to differences in fisher supplies, using divergent fishing techniques or by exploiting a variety of environments.

### 5.1.2.2. *The madbasa rooms: B and R*

In room B, the presence of a *madbasa* demonstrates the preparation of date syrup in this house. This structure, attested in the Persian Gulf region at least during the medieval period, is composed of parallel channels, on which bags of dates were overlaid, leading to one earthenware jar that collected the date syrup (Rougeulle, 1982). Evidence of charred date seeds and fruits fragments in connexion with hearths suggests that, once the date syrup was made, the by-products from *madbasa* activities were reused as fuel. At the end of the occupation, the accumulation of mammal and fish bones in the

*madbasa* room (B) and entrance (R) shows that these rooms were ultimately used as a dump.

### 5.1.2.3. *The dump rooms: M, P and Q*

High quantities of animal bones in rooms M, P and Q whose functions are difficult to determine demonstrate that these areas were used as dumps, notably for food remains after processing and consumption, at least at the end of the occupation of the building. The presence of such a large concentration of animal bones in room Q may be difficult to understand; however, the inhabitants of the building may have thrown their meal waste through an upstairs opening.

### 5.1.3. Synthesis

To summarise, the northern house seems to have been used for various food-processing activities, particularly fishing products, but included plant products and animal meat that were either consumed by the building's inhabitants or sold through the "shop" on the western side of the building. In addition, throughout the building, rodent bones assert the presence of stored food products, as suggested by the botanical assemblages.

Variations among the plant and fish assemblages from the northern house allowed us to discern that different activities had taken place in the southern house. In courtyard I, the presence of weeds and a wide diversity of fish suggests that crop-processing, such as harvest cleaning, and specific fishing practices maybe be due to different suppliers. Rooms B and R were devoted to the production of date syrup, as testified by the presence of a *madbasa*, before being abandoned as dumps. Finally, rooms M, P and Q were used as dumps at the end of the occupation of the building, as evidenced by the accumulation of animal bones. It is interesting to notice that food-processing activities documented seem to have been concentrated on each house in courtyards, in some extent similarly to building B39 where they were mostly attested in room E (Dabrowski et al. 2018), although other room were also dedicated to other activities linked to food products.

## 5.2. Food-processing and consumption activities throughout the building

### 5.2.1. Animal and plant consumption practices

With regards animal bones, building (B94) mainly contained the most substantial parts of the carcass, with foot bones being notably absent. This scarcity could be attributed to two possible hypotheses: either these bones were left attached to the skin during the skinning process, or (more plausibly) only the meatier sections were brought into the building. The less-nutritious parts were probably discarded outdoors, most likely during the initial butchery phase following the slaughter. In addition, alongside sheep and goats, chicken was one of the most prevalent meals, occasionally supplemented by other options like eggs or gazelle. Indeed, although never abundant, the gazelle is often mentioned in archaeological sites of the Arabian Peninsula.

The presence of numerous diversified fish bones belonging to several taxa, with evidence of burning linked to hearths in courtyard D, suggests that these assemblages resulted from various preparations. Historical and ethnographic testimonies indicate several methods of fish processing, such as drying, salting and grilling, also took place (Costa, 1988; ElMahi, 2000). The four basins of room A could be related to one of these activities, probably salting. Marco Polo (1991: ii, 496) described baking fish biscuits, which involved boiling, pressing and adding flour to fish in order to preserve it for extended periods. Finally, oil could have been another of the numerous by-products derived from fish, as for coating boats (Hardy-Guilbert and Maguer, 2010). Small fishes are under-represented in this assemblage, although we know that sardines were one of the primary resources for the inhabitants of the Omani coast, often eaten with fennel seeds (Iddison, 1998) or consumed dried by humans and cattle (ElMahi, 2000). After drying, the sardines can be crushed for



incorporation into various preparations, which may explain the absence of anchovies and the low presence of whole/fragmented sardines in the assemblage.

The nature and state of preservation of plant remains testifies to meal preparation and consumption practices. The charred seeds/fruits of cereals and pulses correspond to accidental losses in the fire during culinary activities, such as cooking, roasting, stewing and baking (Hillman, 1973, 1981, 1984; Van der Veen, 2007). For example, rice grains can be eaten after steaming and boiling in water, sometimes alongside pulses (as previously mentioned), vegetables, meat and fish (Vergara and de Datta, 1996). Free-threshing wheat and finger millet can be reduced to flour for making leavened/non-leavened breads or porridge (Jansen and Ong, 1996). Pulses such as cowpea may be consumed as seeds or pods, with vegetables, meat and fish (steamed or dried) (Pandey and Westphal, 1989). Mung beans are prepared by cooking and milling and can be eaten whole, split as in *dhal*, as sprouted seeds or as flour (Arora and Mauria, 1989). The dried fruit of pepper appears to have been one of the most popular spices and would have been used in various culinary preparations (Utami and Jansen, 1999). The presence of charred pomegranate seeds can be explained by its incorporation into meals - pomegranates can be eaten fresh or dried with their aril (pulp around the seed); the latter can be observed today in the *anardana* technique, attested in the Indian subcontinent and quoted in classical sources as spice (Pruthi and Saxena, 1984; Singh et al. 2011; Jacomet et al. 2014). Besides, the importance of dates in the plant diet can be deduced also with the Venitian traveller of the 13<sup>th</sup> c. Marco Polo (2011: 499) who indicates that the people of Qalhât ate dates since the great quantities available. Regarding fruit remains, such as date seeds, jujube stones and grape pips, these were probably thrown into the fire as waste or directly used as fuel, as attested at other sites in the Arabian Peninsula (Bouchaud, 2013).

#### 5.2.2. Burnt fish bones: waste thrown into the fire or a valuable source of fuel?

In Qalhât, fish bones, especially tuna vertebrae from the northern house, were thoroughly burnt, often white and distorted, implying prolonged direct exposure (Fig. 9). This aspect does not seem to be correlated with smoking or grilling practices, such as in Kharā'ib al-Dasht (Mierzejewska 2019); indeed, the size of the burnt specimen in Qalhât contrasts with the type of small fish typically used for grilling (Iwaszczuk et al., 2021). Burning fish/tuna bones may be related to sanitation needs – to char the fatty tuna bones, preventing odour or decay – or as an alternative source of fuel as in the hammam and the pottery kilns of the city (Lesguer and Renel 2018, Rougeulle 2023, Rougeulle and Lesguer 2019). This practice has been already attested in Al-Shir (Yemen) (Hardy-Guilbert et al., 2002) and Kharā'ib al-Dasht (Iwaszczuk et al., 2021; Mierzejewska, 2019). It is challenging at this stage to confirm any hypothesis definitively, necessitating further analysis to shed light on the reuse of fishing waste.

#### 5.2.3. Dogs, cats, rats and mice: commensals or how to manage with unwanted companions?

Commensal animals, including cats, dogs and rats, were commonly found in previous analyses, although in limited quantities. The presence of rodents in building (B94) is also confirmed by droppings in the sediment samples, asserting the use of some rooms (A, C) as storage places for food products. Stable isotope analysis of the animal bones from the building indicates that cats primarily consumed fish, either provided by humans or scavenged. These cats consumed diverse fish types, including those not easily accessible to larger mammals, sheep/cattle, such as marine fish. Approximately  $41 \pm 21\%$  of the cats' protein intake came from marine resources, suggesting a close human-cat relationship (Brozou et al. 2023). Cats were probably popular pets, but they would also have fulfilled an important role in controlling rats and other small rodents (Brickner-Braun et al., 2007; Hamilton-Dyer, 2013; Onar et al., 2021; Monchot 2022).

### 5.3. Oasis as food agropastoral system

#### 5.3.1. Composition and organisation of oasis agropastoral systems for feeding the population

The nature and management of the agropastoral systems set up to feed the urban population is highlighted within the composition of the botanical and faunal assemblages. Indeed, the simultaneous presence of dates, fruits (grape, pomegranate, jujube) and annual crops such as cereals and condiments seem to reflect the vertical composition of date palm gardens, which are composed of date palms in the upper level (providing shadow for the crops below), fruits trees in the intermediate level and annual and perennial crops (cereals, pulses, aromatics) below (Munier 1973; Battesti 2005; Tengberg 2012). This is a very well-adapted agrosystem for arid environments since it allows the optimization of water by concentrating several types of crops in the same place inside delimited plots, irrigated by channel networks (Battesti 2005; Tengberg 2012). Moreover, the predominance of Bermuda grass (10%) among the weeds in the assemblage is considered as irrigation evidence, due to its ecological requirements (Ghazanfar 1992: 132). This type of agrosystem is attested by the association of date seeds and charcoal with cereals in Eastern Arabia, since at least the end of the 4<sup>th</sup> millennium BCE (Tengberg 2012). The fruit tree composition in the date palms gardens in the region of Qalhât, deduced by the botanical analysis, are asserted by the description of Arab geographer al-Idrīsī in the 12<sup>th</sup> c. who stated that the countryside was fertile with fruits from warm climates, such as dates, figs, bananas, pomegranates and grapes (Jaubert, 1836: 151).

The composition of the faunal assemblage indicates a large predominance of caprine – the main supplier of meat, milk and wool – alongside cattle and equids in lesser proportions, supporting the hypothesis of the installation and maintenance of date palm gardens for feeding the urban population of Qalhât, as they represent the animal component of this agropastoral system. Indeed, livestock constitutes a significant part of oasian agropastoral systems, with cattle being used as a pulling force for agrarian labour and water extraction from the ground (Dollé 1990). Multiple oasian products can also be used as fodder resources, such as crops, chaff or weeds and, in the same way, help prevent the development of the latter (Tisserand 1990; Ferry and Toutain 1990). Animal dung can be also gathered and used as a fertilizer for renewing soil nutrients (Dollé 1990).

#### 5.3.2. Evidence for lambing: evidence for production of dairy products and/or consumption by high-social status inhabitants?

The presence of a significant number of young animals (lambs/kids) might be attributed to the potential existence of a nearby sheepfold or butchery area (slaughterhouse), which could have conveniently supplied the inhabitants of building (B94) with young animals. Moreover, since this building was not a breeding farm, we can assume that these meat products may have been intended for sale or consumption *in situ*, as attested by the over-presentation of meaty parts like shanks. The importance of juveniles certainly correlates with herding management that is also dedicated to dairy production, where young males are slaughtered to preserve females, as has been observed for the Neolithic period (Helmer and Vigne 2004; Blaise 2005). According to the material of this building, breeders appear not to have been interested in rearing large numbers of juveniles, as they reduce milk production and require greater feed availability. In addition, even if we were not able to separate goats from sheep, ecological and environmental affinities suggest a larger number of goats. The reason for preferring goats to sheep is quite clear: sheep yield about half the annual milk of goats and lactate for about three months, while goats can be milked for up to five months (Palmer, 1998). Moreover, due to the tenderness of lamb meat, it is usually considered as meat products dedicated to high-social status populations that might be the case here with the concentration of such juveniles although it is difficult to determine it precisely.

### 5.3.3. Localization of oasis agropastoral systems: local- and regional-scale supply?

These agropastoral systems, maintained for feeding the entire harbour population, may have been partially situated nearby in the mouth of the Wadi Hilm just north of the site, as is still the case today. As mentioned previously, on the ash-Sharqiyyah coast, water from precipitations in the mountainous is contained underground before discharging into the sea, allowing small date palm gardens to be irrigated by extracting water from the wells (Wilkinson 1977: 47). Thus, Al-Idrisi (1836: 151) mentions that the water supply of the population relied on its extraction through wells in the wadi bed during the 12<sup>th</sup> c. More recently, Miles (1919: 527) indicates that people from the small village got water from shallow wells and pits while Lorimer (1908: 971) noticed the presence of few wells but no dates and no cultivation areas. In addition, archaeological survey revealed contemporaneous occupation with the city north of the Wadi Hilm where several ruined structures, probably connected with gardens, have been noted (Rougeulle 2023: 31-32, 49). Therefore, if small agricultural systems located north to the site may have participated to food supply of the city, they were very probably marginal in their strategy.

Textual sources, and even archaeological evidence, suggest the existence of such agropastoral systems along the banks of the Wadi Hilm and connected wadis upstream during the occupation of the site. The 13<sup>th</sup> c. Arab traveller Ibn al-Muğāwir (2008: 265) specifies that “there, there is the river of Socrates [identified as the Wadi Hilm], the water of which is from the mountains, flowing among palm groves and cultivated areas, light, healthy and sweet to the taste”. Today, Kabda is one of the most important oasis in the area, 6 km upstream Wadi Manqāl (anciently known as “Wadi Kabdi”) as last tributary to Wadi Hilm; besides, Lorimer (1908) shows that this oasis included 350 date palms, 100 camels, 150 donkeys, 80 cattle and 600 sheeps and goats during his visit. Thus, this oasis may have contributed to supply the city with agricultural products (Rougeulle 2023: 51). Anyway, water supplying of the city was relying on catching systems located further upstream of the Wadi Hilm. Miles (1919: 529) points that several hydraulic features were attested in several locations in the Wadi Hilm upstream during his journey in 1874, such as a “pools” among which a big one called “Maida”, half a mile to the mouth of Wadi Hilm, and presumably an aqueduct called “Ghala” leading to a reservoir at a place named Sakherat, at the junction of Wadi Manqāl. However, several of them are not visible anymore although a small *qanat* leading to a cistern, apparently ancient but of uncertain dating, for distributing water to small agricultural terraces at Sakherat is still standing (Rougeulle 2023: 51). Therefore, it is more than likely that several agropastoral systems located further upstream were dedicated during the time of Qalhât to the food supply of the city, with small date palm gardens in the mouth of Wadi Hilm as complementary sources.

Moreover, such large populations would have relied on diversified sources of fruit production as suggested by al-Idrisi (see 5.3.1.) and Ibn Baṭṭūṭa (1982: 93), the latter who mentions the importation of fruits from the small city of Thîby, identified nowadays as Tiwi, situated 15 km to the north, which had numerous orchards. Furthermore, dates are brought from Oman which designates areas located south from the Al-Hajar Mountains. This testifies that the fruit supplying strategies of the city of Qalhât relied not only on local date palm gardens close to the site and further upstream, but also on other sources of production available at a regional scale.

## 5.4. Relations of the city and the sea: from offshore fishing strategies to maritime regional trade

### 5.4.1. Offshore fishing strategies

Due to the fish spectrum highlighted in building B94, it can be deduced that Qalhât had highly-skilled sailors and a strong control of sea navigation techniques (Camelin, 1995, 2006; Lancaster and Lancaster, 1995; Al Jabri et al., 2013). Indications point towards a range of fishing practices,

demonstrating the exploitation of diverse marine environments. Likely methods encompassed handlines, nets and, potentially, the *gargour*, a technique common to Eastern Arabia, specifically used for capturing coastal fish. These traps excel in seizing fish in the Arabian Peninsula (Tharwat and Al-Gaber, 2006; Al Jabri et al. 2013). As for small pelagic species, they can be easily caught offshore because of the large schools that are pushed towards the shore, particularly after strong winds (Al-Jufaili and Al-Jahwari, 2011; Al-Jufaili, et al., 2006; pers. obs). Regarding pelagic fishing, the species and sizes targeted strongly suggest the use of large boats, such as the traditional *dhow*. In 1507, Albuquerque mentions that tuna was caught from large boats (Albuquerque, 1875 quoted in Lancaster and Lancaster, 1995: 231). Nowadays, tuna, sharks and swordfish are mainly targeted from *dhow*s in the same region as Qalhât (M.A.F., 2013, 2015, 2016, 2018). Finally, the demersal zone was less represented, and mainly by king soldierbrems and emperors (M.A.F., 2013, 2015, 2016, 2018). However, a high biodiversity of demersal fish was identified, which testifies to the variety of fish in these inshore waters, observable nowadays in fish markets. Such demersal fishery characterizes the sites of Khara'ib al-Dasht (Iwaszczuk et al., 2021), Qal'at al-Bahrain (Vorenger, 2017) and Khor Rori/Sumhuram (phase 4) (Carenti and Wilkens, 2008), with the king soldierbreem being mentioned at Siraf (phase 4) (Beech, 2004). Most of these fish could be consumed simply grilled or in a stew. The zooarchaeological analysis also revealed the presence of dolphin and whale indicating the possible consumption of marine mammals, even if attested as only occurrences. More likely, these fish and marine mammal assemblages imply that experienced, highly-skilled fishing crews, organized socially and hierarchically, took part in the fishing strategies, equipped with the necessary knowledge of the sea, fishing techniques, navigation technologies and expertise in catching various species (Camelin, 1995, 2006; Lancaster and Lancaster, 1995; Al Jabri et al., 2013).

#### 5.4.2. Maritime trade of plant products

Several foreign plant products were found, including Asian rice, finger millet, mung beans, cowpeas and pepper. But do these really correspond to imported products by long-distance trade or have they been adapted locally into oasis agrosystems? Asian rice, finger millet, mung beans and cowpeas most likely come from the Indian subcontinent, although Eastern Africa may also be considered for finger millet and cowpea; however, as these products have already been discussed in detail in Dabrowski et al. (2018), we will focus on pepper. Pepper cannot be grown locally because it only grows in very warm and humid climates with important precipitations throughout the year (2000–4000 mm per year) and a mean atmospheric humidity of 65%–95%, all conditions that cannot be met in arid environments. Pepper originates from the western Ghats of the Kerala state in South-West India where it is still attested in a wild state (Purseglove, 1981; De Waard and Anunciado, 1999). For Qalhât, pepper was most certainly imported, probably from the southern part of the Indian subcontinent, testifying to trade circulation of this product in the western Indian Ocean, as quoted by written sources. Indeed, Marco Polo (2004: 498) precises that Arab horses were exported from Qalhât to the Indian subcontinent in exchange for various spices, although pepper was not explicitly mentioned it is likely to be part of this trade. It was probably exported from the harbour city of Calicut (present-day Kozhikode), founded in the 11<sup>th</sup> c., as this corresponds to the main exportation centre of pepper during the 15<sup>th</sup> c. (Vallet, 2011). Ma Huan (1970: 151), a Muslim sailor accompanying the Chinese expeditions of Zeng He in the 15<sup>th</sup> c., mentions that this harbour exported its merchandise into Hormuz. Moreover, numerous textual and archaeobotanical evidence demonstrate that pepper was a largely traded food commodity in the Indian Ocean during the medieval period, with great quantities sent to the Mediterranean Sea and Europe (Van der Veen, 2011: 41, Van der Veen et al., 2015; Vallet, 2010: 156, 202, 454, 637; Goitein and Friedman, 2008: 24, 65; Freedman, 2008: 125; Dalby, 2000: 92; Barendse, 2000: 193-94). The importation of pepper into Qalhât from the southern part of the Indian subcontinent was part of a wider maritime trade organized according via regional and long-distance networks.

Other plant products such as Asian rice and mung beans may also have been imported from the Indian subcontinent, as testified by textual evidence mentioning the importation of such products to Qalhât. This may also be the case for finger millet and cowpea, both African crops that were introduced into India during the 2<sup>nd</sup> millennium BCE. As Indian ceramics are the most represented on the site between the 13<sup>th</sup> and 15<sup>th</sup> c. and very few African sherds have been found, we favour an Indian origin for these crops. Archaeobotanical evidence at a site scale (e.g. dominance in the assemblage), ethnographic observations and written testimonies revealed that it is not impossible to consider the local cultivation of Asian rice and finger millet, but further strontium isotopic investigations are necessary to assert or refute this hypothesis (Dabrowski et al., 2018).

## 6. Conclusion

The analysis of archaeobiological remains from building (B94) of the harbour city of Qalhât gives new insights into the food-processing activities and the subsistence strategies that the inhabitants of the city implemented to ensure their food supply, for the less-documented bioarchaeological Islamic period. The composition and the spatial distribution of animal and plant assemblages, alongside the archaeological structures and artefacts, allowed us to identify specific practices related to these remains and propose hypothesis about the function of the rooms. For example, in the northern house, courtyard D was used for fish processing (heading, scaling) and meal preparation (seeds and fruits) ready for consumption/selling, with the external eastern sector being used as a dump for these activities; the initial purpose of adjacent room A may have been linked to those of courtyard D (salting fishes?) before being converted to a storage room with different sets composed of rice and mung beans. In the southern house, courtyard I was possibly used for crop-processing activities (harvest cleaning) and different fish processing activities than the other courtyard (maybe due to a different fish supply); room B was initially devoted to date syrup before being used as dump, in the same way as several other rooms (M, P, Q).

The archaeobiological analysis allowed us to highlight the nature and organization of oasis agropastoral systems set up for ensuring the food supply of the inhabitants, corresponding to date palm gardens composed of cereals, fruits and condiments, with a prominent component of livestock (sheep, goat, cattle). The predominance of lambs in the faunal assemblage underlines specific herding practices (e.g. production of dairy products and/or supplying of high-quality meat). Date palm gardens seem to have been localized north of the city, in the mouth of the Wadi Hilm, thanks to groundwater tables. However, written evidence shows that the importation of fruits at a regional scale would also have been necessary for ensuring a continuous food supply. Fishing offshore strategies included various marine taxa (fish and mammals), which implies advanced techniques and socially organized groups. Maritime trade allowed the population to obtain tropical plant products (e.g. pepper, rice) through regional and long-distance trade networks from the Indian subcontinent.

However, much work is still required in this region. A comparison with other medieval buildings in Qalhât would help us to better understand the organization of the city through the spatial distribution of specific activities, and a study of samples from the pottery kilns would allow us to reconstruct the fuel management practices for maintaining fire over a long period. Further research (charcoal, shell) is required to acquire a more global and comprehensive view of the subsistence strategies of the city. Strontium isotopic analysis on plant remains would provide us with the possibility to ascertain if tropical taxa (e.g. rice, finger millet) were imported or in fact cultivated locally within oasis date palm gardens. Finally, further investigations could be realised on the burnt fish bones to determine the reason for their burning and their specific association with craft contexts (pottery kilns, hammam) needs to be investigated.



## Acknowledgments

Archaeological research at Qalhāt has been conducted since 2008, initially as part of the *Qalhāt Project* (2008–2016) and then as the *Qalhāt Development Project* (2013–2016), by a team from the CNRS (UMR 8167 Orient & Méditerranée) and the Eveha International agency, directed by Axelle Rougeulle and mainly supported by the Ministry of Heritage and Culture, now Heritage and Tourism of the Sultanate of Oman. These projects were carried out under the high authority of the then Minister of Heritage and Culture of Oman, His Majesty Sayyid Haitham bin Tarik Al-Said. Our warmest thanks go to the current Minister, at the time Undersecretary for Heritage, H.E. Salim Mohammed Al-Mahrooqi, and to all the members of the General Directorate for their involvement and support. We are particularly grateful to Sultan Saif Nasser Al-Bakri, Director General of Archaeology, and to H.E. Hassan bin Mohammed bin Ali Al-Lawati, former Advisor to the Minister for Heritage Affairs. Also, our thanks to the National Museum of Natural History, Paris (France) for giving us access to the laboratories and heritage collections of fish bones. Finally, we would like to thank Jérôme Ros (UMR 5554/CNRS) for having taken part in the sieving and sorting of archaeobotanical remains during the February/March 2014 fieldwork.

## Funding

This work was supported by the doctoral committee of PRES-Sorbonne Universités [Contrat doctoral CRP N°EGB 027/15]; LabEx Resmed; ATER of National Museum of Natural History (Paris, France).

## References

- Agius, D., 1999. Medieval Qalhat: travellers, dhows and stone anchors in south-east Oman. *Archaeology of Seafaring* 173–220.
- Al-Jufaili, S.M., Al-Azri, A.R., Al-Shuaily, S.S., 2006. A Preliminary Investigation on the Omani Sardines and Anchovies Stock Fluctuation; Recommendations for Future Studies. *Pakistan J. Biol. Sci.* 9, 1073–1082.
- Al-Jufaili, S., Al-Jahwari, O.S., 2011. The Omani coastal traditional sardine fishery 1994-2007: a review. *Journal of Agricultural and Marine Sciences [JAMS]* 16, 1–12.
- Albuquerque, A. de, 1875. The commentaries of the great Afonso Dalboquerque, second viceroy of India. Vol. 3.
- Arora, R.K., Mauria, S.S., 1989. *Vigna radiata* (L.) Wilczek, in: Mausen, L.J.G.V. der, Somaatmadja, S. (Eds.), *Plant Resources of South-East Asia N°1: Pulses*. Pudoc / Prosea, Wageningen, pp. 71–74.
- Barendse, R.J., 2000. Trade and state in the Arabian seas: A survey from the fifteenth to the eighteenth century. *Journal of World History* 173–225.
- Barone, R., 1986. *Anatomie comparée des mammifères domestiques*. Tome 1: Ostéologie. Vigot Frères Eds.
- Battesti, V., 2005. *Jardins au désert: Evolution des pratiques et savoirs oasiens - Jerid tunisien*, A travers champs. I.R.D., Paris.
- Béarez, P., Gay, P., Lunniss, R., 2012. Sea Fishing at Salango (Manabí Province, Ecuador) During the Middle Formative Machalilla Phase. *Lat. Am. Antiq.* 23, 195–214. <https://doi.org/10.7183/1045-6635.23.2.195>
- Beech, M., 2004. In the land of the ichthyophagi: modelling fish exploitation in the Arabian Gulf and Gulf of Oman from the 5th millennium BC to the Late Islamic period, BAR International Series. Archaeopress, Oxford.
- Bhacker, M.R., Bhacker, B., 2004. Qalhāt in Arabian history: context and chronicles. *Journal of Oman Studies* 13, 11–55.
- Binford, L.R., 1981. *Bones: ancient men and modern myths*. Academic press, New York / London.
- Blaise, E., 2005. L'élevage au Néolithique final dans le sud-est de la France: éléments de réflexion sur la gestion des troupeaux. *Anthropozoologica* 40, 191–216.
- Bouchaud, C., 2013. Exploitation végétale des oasis d'Arabie: Production, commerce et utilisation des plantes. L'exemple de Madâ'in Sâlih (Arabie Saoudite) entre le IV<sup>e</sup> siècle av. J.-C. et le VII<sup>e</sup> siècle

- apr. J.-C. Revue d'ethnoécologie. <https://doi.org/10.4000/ethnoecologie.1217>
- Brickner-Braun, I., Geffen, E., Yom-Tov, Y., 2007. The Domestic Cat as a Predator of Israeli Wildlife. *Israel Journal of Ecology & Evolution* 53, 129–142. <https://doi.org/10.1560/IJEE.53.2.129>
- Brozou, A., Fuller, B.T., De Cupere, B., Marrast, A., Monchot, H., Peters, J., Van de Vijver, K., Lambert, O., Mannino, M.A., Ottoni, C., Van Neer, W., 2023. A dietary perspective of cat-human interactions in two medieval harbors in Iran and Oman revealed through stable isotope analysis. *Sci Rep* 13, 12316. <https://doi.org/10.1038/s41598-023-39417-7>
- Camelin, S., 1995. Les pêcheurs de Shihr. Transmission du savoir et identité sociale. *Arabian Humanities. Revue internationale d'archéologie et de sciences sociales sur la péninsule Arabique/International Journal of Archaeology and Social Sciences in the Arabian Peninsula*. <https://doi.org/10.4000/cy.80>
- Camelin, S., 2006. Pêcheurs du Yémen: organisation et transformation d'une communauté de pêcheurs de la côte de l'Océan indien. Maisonneuve & Larose, Paris.
- Cappers, R.T.J., Bekker, R.M., Jans, J.E.A., 2006. Digitale zadenatlas van Nederland, Groningen archaeological studies. Barkhuis Publishing; Groningen University Library, Eelde; Groningen.
- Cappers, R.T.J., Neef, R., Bekker, R.M., 2012. Digital atlas of economic plants in archaeology, Groningen archaeological studies. Barkhuis & Groningen University Library, Groningen.
- Cappers, R.T.J., Neef, R., Bekker, R.M., 2009. Digital atlas of economic plants, Groningen archaeological studies. Barkhuis & Groningen University Library, Groningen.
- Carenti, G., Wilkens, B., 2008. Terrestrial fauna and marine produce in Sumhuram, in: Avanzini, A. (Ed.), *A Port in Arabia between Rome and the Indian Ocean, 3rd C.BC-5th C.AD: Khor Rori Report 2, Arabia Antica*. L'Erma di Bretschneider, Roma, pp. 477–547.
- Costa, P.M., 1988. Fishing Stations of the Coast of Oman: A Theme of Ethno-Archaeological Research. *Proceedings of the Seminar for Arabian Studies* 18, 3–13.
- Cousin, F., 2010. Les céréales au Rajasthan (Inde), in: Couscous, Boulgour et Polenta. Transformer et Consommer Les Céréales Dans Le Monde. Khartala, Paris, pp. 317–340.
- Dabrowski, V., Tengberg, M., Creissen, T., Rougeulle, A., 2018. Plant Supplying Strategies in an Islamic Omani Harbour City: Archaeobotanical Analysis from a Workshop (B39) in Qalhât (XIVth-XVIth c. AD). *Journal of Islamic Archaeology* 5, 17–38.
- Dabrowski, V., Bouchaud, C., Tengberg, M., Mouton, M., 2021a. Crop processing, consumption and trade of Asian rice (*Oryza sativa* L.) in the Arabian Peninsula during Antiquity: earliest evidence from Mleiha (third c. AD), United Arab Emirates. *Archaeological and Anthropological Sciences* 13, 1–19. <https://doi.org/10.1007/s12520-021-01277-5>
- Dabrowski, V., Bouchaud, C., Tengberg, M., Zazzo, A., Priestman, S., 2021b. Archaeobotanical analysis of food and fuel procurement from Fulayj fort (Oman, 5th-8th c. CE) including the earliest secure evidence for sorghum in Eastern Arabia. *Journal of Arid Environments* 190, 104512. <https://doi.org/10.1016/j.jaridenv.2021.104512>
- Dalby, A., 2000. *Dangerous tastes: the story of spices*. British Museum Press, London.
- De Cupere, B., Van Neer, W., Monchot, H., Rijmenants, E., Udrescu, M., Waelkens, M., 2005. Ancient breeds of domestic fowl (*Gallus gallus* f. *domestica*) distinguished on the basis of traditional observations combined with mixture analysis. *Journal of Archaeological Science* 32, 1587–1597.
- Desruelles, S., Beuzen-Waller, T., 2013. Rapport sur l'étude géomorphologique, Programme d'étude géoarchéologique du secteur côtier Sur-Quriyat (Oman).
- Desse, J., Desse, G., Desse-Berset, N., 2002. L'Archéozoologie, in: Miskovsky, J.-C. (Ed.), *Géologie de la Préhistoire (Réédition)*. Association pour l'étude de l'environnement géologique de la préhistoire, Paris, pp. 815–822.
- Dollé, V., 1990. Elevage intensif en oasis, une composante importante du système de production. *Options Méditerranéennes. Serie A: Séminaires Méditerranéens (CIHEAM)*. no. 11. 195–204.
- ElMahi, A.T., 2000. Traditional fish preservation in Oman: the seasonality of a subsistence strategy. *PSAS* 30, 99–113. <https://doi.org/10.2307/41223700>
- Ferry, M., Toutain, G., 1990. Concurrence et complémentarité des espèces végétales dans les oasis. *Les systèmes agricoles oasiens*.
- Freedman, P., 2008. *Out of the East: Spices and the Medieval Imagination*. Yale University Press.

- Froese, R., Pauly, D. (Eds.), 2022. FishBase.
- Gebel, H.G., Hanss, C., Liebau, A., Raehle, W., 1989. The Late Quaternary environments of 'Ain al-Faidha/Al-'Ain, Abu Dhabi Emirate. *Archaeology in the United Arab Emirates* 5, 9–48.
- Ghazanfar, S.A., 1999. Coastal Vegetation of Oman. *Estuarine, Coastal and Shelf Science* 49, 21–27. [https://doi.org/10.1016/S0272-7714\(99\)80004-3](https://doi.org/10.1016/S0272-7714(99)80004-3)
- Ghazanfar, S.A., 1992. An annotated catalogue of the vascular plants of Oman and their vernacular names. *Scripta Botanica Belgica* 2.
- Goitein, S.D., Friedman, M.A., 2008. India traders of the middle ages documents from the Cairo Geniza India book, *Études sur le judaïsme médiéval*. Brill, Leiden; Boston.
- Hamilton-Dyer, S., 2013. Pampered puss? Cats from the Roman port of Myos Hormos at Quseir, Egypt, in: De Cupere, B., Linseele, V., Hamilton-Dyer, S. (Eds.), *Archaeozoology of the Near East X. Proceedings of the Tenth International Symposium on the Archaeozoology of South-Western Asia and Adjacent Areas*. Peeters, Ancient Near East Studies, Supplement 44, 357–371.
- Hanot, P., Guintard, C., Lepetz, S., Cornette, R., 2017. Identifying domestic horses, donkeys and hybrids from archaeological deposits: a 3D morphological investigation on skeletons. *Journal of Archaeological Science* 78, 88–98.
- Hanot, P., Bochaton, C., 2018. New osteological criteria for the identification of domestic horses, donkeys and their hybrids in archaeological contexts. *Journal of Archaeological Science* 94, 12–20.
- Hardy-Guilbert, C., Le Guennec-Coppens, F., Mery, S., 2002. Al-Shihr, un port d'Arabie face à l'Afrique. *Journal des Africanistes* 72, 39–53. <https://doi.org/10.3406/jafr.2002.1305>
- Hardy-Guilbert, C., Maguer, S.L., 2010. Chihr de l'encens (Yémen). *Arabian Archaeology and Epigraphy* 21, 46–70. <https://doi.org/10.1111/j.1600-0471.2009.00322.x>
- Helmer, D., Vigne, J.-D., 2004. La gestion des cheptels de caprinés au Néolithique dans le midi de la France, in: *Approches Fonctionnelles En Préhistoire (Actes XXVe Congrès Préhistorique de France Nanterre, 24–26 Novembre 2000)*, Paris: Société Préhistorique Française Édition. pp. 397–407.
- Hillman, G., 1973. Crop husbandry and food production: modern basis for the interpretation of plant remains. *Anatolian studies* 23, 241–244.
- Hillman, G., 1981. Reconstructing crop husbandry practices from charred remains of crops. *Farming practice in British prehistory*.
- Hillman, G., 1984. Interpretation of archaeological plant remains: the application of ethnographic models from Turkey, in: Zeist, W.V., Casparie, W.A. (Eds.), *Plants and Ancient Man*. Balkema, Rotterdam, pp. 1–41.
- Horwitz, L.K., Monchot, H., 2002. Choice cuts: hominid butchery activities at the Lower Paleolithic site of Holon, Israel, in: Buitenhuis, H., Choyke, A.M., Mashkour, M., Al-Shiyab A.H. (Eds.), *Archaeozoology of the Near East V: Proceedings of the fifth international symposium on the archaeozoology of southwesern Asia and Adjacent areas*. Gröningen, ARC publication, 48–62.
- Ibn al-Muğāwir, Y. ibn Y., 2008. A traveller in thirteenth-century Arabia Ibn al-Mujāwir's *Tarīkh al-mustabṣir*, Works issued by the Hakluyt Society. Ashgate, Aldershot.
- Ibn Baṭṭūṭa, M. ibn 'Abd A., 1982. *Voyages*. F. Maspero, Paris, France.
- Iddison, P., 1998. A fish suq in the UAE desert. *Fish: Food from the Waters* 163–170.
- Idrīsī, M. ibn M. al-Š.A. 'Abd A. al-, 1836. *Géographie d'Edrisi*. Paris.
- Insoll, T., 2005. *The land of Enki in the Islamic era : pearls, palms, and religious identity in Bahrain*. Kegan Paul, London.
- Iwaszczuk, U., Pieńkowska, A., Wouters, W., Gręzak, A., Mierzejewska, M., 2021. Fishing at the Late Islamic settlement in Kharā'ib al-Dasht, Failaka Island, Kuwait. *Archaeol Anthropol Sci* 13, 211. <https://doi.org/10.1007/s12520-021-01434-w>
- Jacomet, S., 2006. Identification of cereal remains from archaeological sites.
- Jacomet, S., Kučan, D., Ritter, A., Suter, G., Hagendorn, A., 2014. *Punica granatum* L. (pomegranates) from early Roman contexts in Vindonissa (Switzerland). *Veget Hist Archaeobot* 11, 79–92. <https://doi.org/10.1007/s003340200009>
- Jansen, P.C.M., Ong, H.C., 1996. *Eleusine coracana* (L.) Gaertner cv. group Finger Millet, in: Grubben, G.J.H., Partohardjono, S. (Eds.), *Plant Resources of South-East Asia N°10: Cereals*. Prosea

- Foundation, Bogor, pp. 90–95.
- Jaubert, P.A., 1836. Recueil de voyages et de mémoires publié par la Société de géographie: Géographie d'Edrisi, traduite de l'arabe en français d'après deux manuscrits de la Bibliothèque du roi et accompagnée de notes. Imprimerie royale.
- Kennet, D., 2012. Archaeological History of the Northern Emirates in the Islamic Period: An Outline, in: Potts, D.T., Hellyer, P. (Eds.), *Fifty Years of Emirates Archaeology*. Motivate Publishing, Abu Dhabi, Dubaï, Londres, pp. 188–202.
- König, P., Fried, O., 2015. Plant communities on the NE coast of Oman and their site conditions. *Phytocoenologia* 45, 269–290.
- Kwarteng, A.Y., Dorvlo, A.S., Vijaya Kumar, G.T., 2009. Analysis of a 27-year rainfall data (1977–2003) in the Sultanate of Oman. *International Journal of Climatology* 29, 605–617.
- Lancaster, W., Lancaster, F., 1995. Nomadic fishermen of Ja'alân, Oman. *Nomadic Peoples* 227–243.
- Lesguer, F. and Renel, H., 2018. Un atelier de potier de la période médiévale découvert à Qalhât (Oman). In C. Hardy-Guilbert, H. Renel, A. Rougeulle & E. Vallet eds, *Sur les chemins d'Onagre. Histoire et archéologie orientales. Hommage à Monique Kervran*. Archaeopress Archaeology, 85–105.
- Lorimer, J. G.. 1908. *Gazetteer of the Persian Gulf, 'Omân, and Central Arabia*. Vol. 2. Irish Academic Press.
- Lyman, R.L., 1987. Archaeofaunas and Butchery Studies: A Taphonomic Perspective. *Advances in Archaeological Method and Theory* 10, 249–337.
- Ma Huan, 1970. Ying-yai sheng-lan = The overall survey of the ocean's shores [1433]. At the University Press, Cambridge.
- M.A.F., 2013. Fisheries Statistics Book. Ministry of Agriculture and Fisheries - General directorate of Planning and Development Fisheries Statistic Department, Mascate.
- M.A.F., 2015. Fisheries Statistics Book. Ministry of Agriculture and Fisheries - General directorate of Planning and Development Fisheries Statistic Department, Mascate.
- M.A.F., 2016. Fisheries Statistics Book. Ministry of Agriculture and Fisheries - General directorate of Planning and Development Fisheries Statistic Department, Mascate.
- M.A.F., 2018. Fisheries Statistics Book. Ministry of Agriculture and Fisheries - General directorate of Planning and Development Fisheries Statistic Department, Mascate.
- Mierzejewska, M., 2019. Hearths, ovens and fishery: Kharaib al-Dasht as a case of Late Islamic fishing village (Jazirat Faylaka). *Arabian Archaeology and Epigraphy* 30, 263–279. <https://doi.org/10.1111/aae.12125>
- Marrast, A., 2024. "I ate fish at Kalhât such as I have never tasted": Fishing practices in the medieval harbour of Qalhât of the Sultanate of Oman, *Journal of Archaeological Science: Reports* 54, 104444, <https://doi.org/10.1016/j.jasrep.2024.104444>
- Miles, S. B. 1919. *The countries and tribes of the Persian Gulf*. London: Harrison and Sons.
- Monchot, H., 1996. La consommation du Mouflon (*Ovis antiqua*, Pommerol, 1879) au Pléistocène moyen à la Caune de l'Arago (Tautavel, Pyrénées-Orientales). *Géologie Méditerranéenne* 23, 101–115.
- Monchot, H., 2022. Stray cats: Pets or pests? Cats and kittens everywhere in the medieval harbour site of Qalhât (Oman). *Arab Archaeol Epigr* 33, 226–240. <https://doi.org/10.1111/aae.12204>
- Monchot, H., Guintard, C., 2017. Chronic diseases in cats from the medieval site of Qalhât (Oman). *International Journal of Paleopathology* 17, 1–9.
- Monchot, H., Wouters, W., Van Neer, W., In press. The vertebrate remains from Al-Qusur (Failaka Island, Kuwait), in: Bonnéric J. (Ed.), *Al-Qusur, a Christian settlement from Early Islam off Kuwait Bay*, vol. 1. Final publication of the French-Kuwaiti Archaeological Mission in Failaka (2011–2018), Kuwait City: NCCAL & IFPO.
- Munier, P., 1973. Le palmier-dattier. G.-P. Maisonneuve et Larose, Paris.
- Nicholson, R.A., 1995. Out of the frying pan into the fire: what value are burnt fish bones to archaeology? *Archaeofauna* 47–64.
- Onar, V., Köroğlu, G., Armutak, A., Öncü, Ö.E., Siddiq, A.B., Chrószcz, A., 2021. A cat skeleton from the Balatlar Church excavation, Sinop, Turkey. *Animals* 11, 288.
- Palmer, C., 1998. 'Following the plough': the Agricultural Environment of Northern Jordan. *Levant* 30,



- 129–165. <https://doi.org/10.1179/lev.1998.30.1.129>
- Pandley, R.K., Westphal, E., 1989. *Vigna unguiculata* (L.) Walp, in: Maesen, L.J.G.V. der, Somaatmadja, S. (Eds.), Plant Resources of South-East Asia N°1: Pulses. Pudoc / Prosea, Wageningen, pp. 77–81.
- Parker, A.G., Goudie, A.S., 2008. Geomorphological and palaeoenvironmental investigations in the southeastern Arabian Gulf region and the implication for the archaeology of the region. *Geomorphology, Geoarchaeology and Geomorphology: Soils, Sediments, and Societies* 101, 458–470. <https://doi.org/10.1016/j.geomorph.2007.04.028>
- Payne, S., 1973. Kill-off patterns in sheep and goats: the mandibles from Aşvan Kale. *Anatolian studies* 23, 281–303.
- Polo, M., 1991. Le devisement du monde: le livre des merveilles. La Découverte, Paris, France.
- Polo, M., 2011. Le devisement du monde. Le livre des Merveilles. Paris : La Découverte.
- Power, T., 2017. Julfar and the Ports of Northern Oman, in: Al-Salimi, A., Staples, E. (Eds.), The Ports of Oman. Georg Olms Verlag, Hildesheim, pp. 219–244.
- Priestman, S., Al-Jahwari, N., MacDonald, E., Derek Kennet, Alzeidi, K., Andrews, M., Dabrowski, V., Kenkadze, V., MacDonald, R., Mamalashvili, T., al-Maqbali, I., Naskidashvili, D., Rossi, D., 2023. Fulayj: a Sasanian to Early Islamic Fort in the Sohar Hinterland. *Proceedings of Seminar for Arabian Studies* 52, 291–304.
- Pruthi, J.S., Saxena, A.K., 1984. Studies on Anardana (dried pomegranate seeds). *Journal of food science and technology* 21, 296–299.
- Purseglove, J.W., 1981. Spices. Longman, London.
- Reddy, B.S., 2006. Indigenous technical knowledge on pulses storage and processing practices in Andhra Pradesh.
- Randall, J.E., 1995. Coastal fishes of Oman. University of Hawaii press, Honolulu.
- Renel, H., 2023. The ceramics. In Rougeulle, A., 2023, Qalhāt, a medieval port city of Oman. From a field of ruins to UNESCO. The Archaeological Heritage of Oman 11. Oxford, Archaeopress/Oman Ministry of Heritage and Tourism, 165–170.
- Rougeulle, A., 1982. Des “étuves” à dattes à Bahraïn et en Oman: le problème de l’apparition des techniques de transformation de la datté. *Paléorient* 8, 67–77.
- Rougeulle, A., 2010. The Qalhāt Project. New researches at the mediaeval harbour site of Qalhāt, Oman 2008. *Proc. Semin. Arab. Stud* 40, 315–332.
- Rougeulle, A., 2016. Le Projet Qalhāt : étude archéologique et valorisation d’un site médiéval omanais. *Routes de l’Orient, Hors-série* 95–115.
- Rougeulle, A., 2017. Medieval Qalhāt, historical vs archaeological data. *Arabian Humanities. Revue internationale d’archéologie et de sciences sociales sur la péninsule Arabique/International Journal of Archaeology and Social Sciences in the Arabian Peninsula*. <https://doi.org/10.4000/cy.3442>
- Rougeulle, A., 2023. Qalhāt, a medieval port city of Oman. From a field of ruins to UNESCO. The Archaeological Heritage of Oman 11. Oxford, Archaeopress/Oman Ministry of Heritage and Tourism.
- Rougeulle, A., Creissen, T., Bernard, V., 2012. The Great Mosque of Qalhāt rediscovered. Main results of the 2008–2010 excavations at Qalhāt, Oman. *Proceedings of the Seminar for Arabian Studies* 42, 341–356.
- Rougeulle, A., Renel, H., Simsek, G., Colomban, P., 2014. Medieval ceramic production at Qalhāt, Oman, a multidisciplinary approach, in: *Proceedings of the Seminar for Arabian Studies*. Archaeopress, pp. 299–315.
- Rougeulle, A. and Lesguer, F., 2019. Public bathing in medieval Oman: the Qalhāt *hammâm*. *Journal of Oman Studies* 20, 177–200.
- Sanlaville, P., 2000. Le Moyen-Orient arabe: le milieu et l’homme, Collection U. Armand Colin, Paris.
- Salvagno, L., Albarella, U., 2017. A morphometric system to distinguish sheep and goat postcranial bones. *PloS one* 12, e0178543.
- Simsek, G., Colomban, P., Wong, S., Zhao, B., Rougeulle, A., Liem, N.Q., 2015. Toward a fast non-destructive identification of pottery: The sourcing of 14th–16th century Vietnamese and Chinese ceramic shards. *Journal of Cultural Heritage* 16, 159–172.



- Singh, R.S., Sharma, B.D., Bhargava, R., More, T.A., 2011. Introduction and evaluation of anardana type pomegranate under hot arid conditions. *Acta horticulturae* 239.
- Stiner, M.C., Kuhn, S.L., Weiner, S., Bar-Yosef, O., 1995. Differential burning, recrystallization, and fragmentation of archaeological bone. *Journal of archaeological science* 22, 223–237.
- Tengberg, M., 2012. Beginnings and early history of date palm garden cultivation in the Middle East. *Journal of Arid Environments, Ancient Agriculture in the Middle East* 86, 139–147. <https://doi.org/10.1016/j.jaridenv.2011.11.022>
- Tengberg, M., 2005. Les forêts de la mer. Exploitation et évolution des mangroves en Arabie orientale du Néolithique à l'époque islamique. *Paléorient* 31, 39–45.
- Tharwat, A.A., Al-Gaber, A.R., 2006. Fishery Traps (Gargours) in Saudi Territorial Waters of the Arabian Gulf. *JKAU : Mar. Sci.* 17, 13–31. <https://doi.org/10.4197/mar.17-1.2>
- Tisserand, J.-L., 1990. Les ressources alimentaires pour le bétail. Options méditerranéennes Série A: Séminaires méditerranéens 237–248.
- Tomé, C., 2003. Les mammifères et les oiseaux dans l'économie des sociétés protohistoriques et historiques du golfe Arabo-Persique (III<sup>e</sup> millénaire avant J.-C.-VII<sup>e</sup> siècle après J.-C.). PhD Thesis, Université Aix-Marseille 1.
- Uerpmann, M., 2017. Faunal remains from the Islamic fort at Luluyyah (Sharjah, UAE). *Arab Archaeol Epigr* 28, 2–10. <https://doi.org/10.1111/aae.12081>
- Ulrich, B., 2008. The Azd migrations reconsidered: narratives of 'Amr Muzayqiya and Mālik b. Fahm in historiographic context. *Proceedings of the Seminar for Arabian Studies* 38, 311–318.
- Urban, B., Buerkert, A., 2009. Palaeoecological analysis of a Late Quaternary sediment profile in northern Oman. *Journal of arid environments* 73, 296–305.
- Utami, D., Jansen, P.C.M., 1999. Piper L., in: Guzman, C.C.D., Siemonsma, J.S. (Eds.), *Plant Resources South-East Asia N°13. Spices*. Backhuys Publishers, Leiden, pp. 183–188.
- Vallet, E., 2010. L'Arabie marchande: Etat et commerce sous les sultans rasūlides du Yémen (626-858/1229-1454). Publications de la Sorbonne.
- Vallet, E., 2011. Le marché des épices d'Alexandrie et les mutations du grande commerce de la mer Rouge (XIV<sup>e</sup>-XV<sup>e</sup> siècle), in: Décobert, Ch., Empereur, J.-Y., Picard, Ch. (Eds.), *Alexandrie médiévale* 4. Centre d'Etudes Alexandrines, Alexandrie.
- Van der Veen, M., 1999. The economic value of chaff and straw in arid and temperate zones. *Veget Hist Archaeobot* 8, 211–224. <https://doi.org/10.1007/BF02342721>
- Van der Veen, M., 2007. Formation processes of desiccated and carbonized plant remains – the identification of routine practice. *Journal of Archaeological Science* 34, 968–990. <https://doi.org/10.1016/j.jas.2006.09.007>
- Van der Veen, M. (Ed.), 2011. Consumption, trade and innovation exploring the botanical remains from the Roman and Islamic ports at Quseir al-Qadim, Egypt, *Journal of African Archaeology, Monograph Series*. Africa Magna Verlag, Frankfurt am Main.
- Van der Veen, M., Morales, J., 2015. The Roman and Islamic spice trade: new archaeological evidence. *Journal of Ethnopharmacology, Potent Substances: On the Boundaries of Food and Medicine* 167, 54–63. <https://doi.org/10.1016/j.jep.2014.09.036>
- Van Zeist, W., Bakker-Heeres, J.A.H., 1982. Archaeobotanical studies in the Levant: I. Neolithic sites in the Damascus basin: Aswad, Ghoraife, Ramad. *Palaeohistoria* 165–256.
- Velde, C., 2012. The Geographical History of Julfar, in: Potts, D.T., Hellyer, P. (Eds.), *Fifty Years of Emirates Archaeology*. Motivate Publishing, Abu Dhabi, Dubai, Londres, pp. 212–222.
- Vergara, B.S., Datta, S.K.D., 1996. *Oryza sativa* L., in: Grubben, G.J.H., Partohardjono, S. (Eds.), *Plant Resources of South-East Asia N°10: Cereals*. Prosea Foundation, Bogor, pp. 106–115.
- Vita-Finzi, C., 1978. Recent alluvial history in the catchment of the Arabo-Persian Gulf, in: Brice, W.C. (Ed.), *The Environmental History of the Near and Middle East since the Last Ice Age*. Academic Press, London, pp. 255–274.
- Vorenger, J., 2017. Fish exploitation at Qal'at al-Bahrain from the Early Dilmun period (3rd millennium BC) to the Middle Islamic period (13th-16th centuries AD): preliminary results, in: Mashkour, M., Beech, M.J. (Eds.), *Archaeozoology of the Near East* 9. Presented at the Proceedings of the 9th

- Conference of the ASWA (AA) Working Group archaeozoology of Southwest Asia and adjacent areas : in honour of Hans-Peter Uerpmann and François Poplin, Oxbow Books, Oxford, pp. 320–330.
- De Waard, P.D., Anunciado, I., 1999. *Piper nigrum* L., in: Guzman, C. de, Siemonsma, J. (Eds.), *Plant Resources of South-East Asia N°13: Spices*. Backhuys Publishers, Leiden, pp. 189–194.
- Wheeler, A., Jones, A.K.G., 1989. *Fishes*, Cambridge manuals in archaeology. Cambridge University Press, Cambridge, New York.
- Wilkinson, J.C., 1977. *Water and tribal settlement in South-East Arabia: a study of the Aflāj of Oman*. Clarendon press, Oxford, Royaume-Uni de Grande-Bretagne et d'Irlande du Nord.
- Willis, L.M., Eren, M.I., Rick, T.C., 2008. Does butchering fish leave cut marks? *J. Archaeol. Sci.* 35, 1438–1444. <https://doi.org/10.1016/j.jas.2007.10.010>