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First archaeozoological evidence of freshwater fish on the island of Delos (Greece): fishing and resource management in the Sacred Lake during the Hellenistic period

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Abstract: This paper proposes new evidence about the management of fish resources in the Sacred Lake on the island of Delos (Greece) based on unpublished archaeo-ichthyological data. The specificity of this assemblage lies in the presence of freshwater fish identified for the first time by an archaeozoological study. In agreement with the epigraphic data attesting to fish breeding in the lake, the hypothesis that these fish were acclimatized in this fresh water pond is advanced through the study of historical, archaeological and geomorphological data. The management of these fish resources (species selection, acclimatization, seasonal management, capture) presupposes a degree of proficiency in freshwater fish breeding in Hellenistic times and is the only case study of its kind in terms of the set of sources mobilized.

Keywords: Archaeo-ichthyology; Fishing; Fish breeding; Delos; Greece; Hellenistic period

1. Introduction

Delos lies in the centre of the Cyclades and is one of the smallest islands of the Aegean archipelago (Fig. 1). The island was believed to be the birthplace of the god Apollo and the goddess Artemis. This meant it was an important religious centre from Archaic times and home to one of the largest sanctuaries in Greece. Its management is particularly well known for the Hellenistic period during which the city of Delos was independent (314–167 BC) before becoming an Athenian colony (167–c. 90 BC). It was in this same period that the economic reach of the Aegean island achieved its greatest extent. The city-state developed through its thriving trading activities that attracted a cosmopolitan population (Bruneau et al., 1996; Bruneau and Ducat, 2005: 31–48).

It is worth asking where fishing fitted into this thriving Delian economy. The question has been addressed briefly in more general studies of Delos (Déonna, 1938, 1948; Vial, 1984: 338) or of fishing in Ancient Greece (Dumont, 1977, 1981; Corvisier, 2008; Brun, 2008; Mylona, 2008, 2016; Lytle, 2013). Those authors tackled the subject through the study of textual and epigraphic sources and through archaeological finds of fishing gear. Although these sources are valuable and especially abundant for Delos, they are only very rarely renewed and do not provide a picture of fishing in all its complexity. To date, no summary covering all the available sources has enabled us to investigate the economic and cultural significance of fishing and how fish fitted into human diet on Delos. This being the case, the need has arisen to take account of archaeo-ichthyological data so as to have a list of species that were commonly consumed. Although some fish remains had been unearthed by hand in the context of ritual banquets (Brun and Leguilloux, 2003; Leguilloux, 2003) and in a

cistern (Zapheiroupolou, 1991: 24), fine-mesh screening had never been undertaken. The results of our study provide the first spectrum of fish species eaten on Delos in ancient times.

2. Material and methods

2.1. Sampling and sieving

The fish bones presented here were collected over the course of five excavation campaigns as part of the DELAT project “*Aux origines de l’hygiène publique, les latrines de Délos*” directed by A. Bouet (2012–2016). This research programme was designed to make an exhaustive study of the island’s latrines. The study was backed up by considerations on waste management in ancient times. Remains of ichthyofauna were unearthed among the waste disposed of in latrines once abandoned. Samples were collected from seven abandonment or construction backfills of latrine conduits dating from Hellenistic times (second century BC). Samples were taken from various districts and from both private and public buildings (Fig. 2) so as to provide a representative sample on the scale of the city (Table 1).

Sediments were sampled and sieved in accordance with recognized protocols in archaeo-ichthyology (Wheeler and Jones, 1989: 50-51; Sternberg, 1995: 41-44; Zohar and Belmaker, 2005). Twenty-litre dispersed samples were collected, and some were doubled (40 litres) so as to have larger batches. The material was sieved on a two-mesh column (1 and 3 mm). The material collected after sorting was studied as part of the ALHYEN project “*Alimentation, hygiène et environnement en Grèce ancienne*” directed by A. Bouet (2016–2019).

2.2. Quantitative and qualitative analysis

The naming system used for the types of bones was that of Wheeler and Jones (1989: 122-124). The biological nomenclature is that of the fish database (Froese and Pauly, 2018). Fish bones were identified at the most precise taxonomic level: species, genus (sp.), family or class. The bones were compared using two reference collections of fish bones. The first is a personal collection housed in Bordeaux (France). The second is that of the CEPAM laboratory (Nice, France). On-line databases were also used (<http://fishbone.nottingham.ac.uk>).

Frontal x-rays of vertebrae were taken at the PACEA laboratory (Bordeaux) to confirm the identification of certain items. This technique reveals the internal matrix of the fish bones that can be seen in a single plane using x-rays. The images obtained from a reference chart were identified in several books one of which is about freshwater ray-finned fish (Desse and Desse, 1976).

The number of remains (NR) is the sum of two subsets: anatomically identified remains, that is remains that could be relocated in the skeleton (head bones, vertebral column, scales and median fins) and anatomically indeterminate remains, bone fragments or slivers whose skeletal position could not be located. NR refers therefore to the total number of remains of the study sample. NISP (i.e. the number of identified specimens), the number of identified bones for each taxon, was chosen as an estimator of abundance (Wheeler and Jones, 1989: 152 ; Morales, 2014: 3652).

3. Results

Fine screening reveals 5124 fish remains 667 of which can be taxonomically identified (NISP). The spectrum of species covers 60 taxa distributed among 25 families of fish (Table 2).

Remains attributed to the Sparidae, Labridae and Serranidae families are the most numerous in the sample. Fish from coastal waters (littoral zone) make up 87.3% of the NISP, pelagic fish 6.9% and freshwater fish 5.8%. The presence of marine fish is consistent with the species available in the natural environment of Delos and the Aegean Sea (Whitehead et al., 1986; Powell, 1996: 24-31; Papaconstantinou, 2014).

However, the discovery of freshwater fish remains is more surprising. The island of Delos has no drainage network and no natural freshwater ponds (Fouache and Desruelles, 2014: 209).

Three species have been identified (NISP = 39): the wels catfish (*Silurus glanis*), the pikeperch (*Sander lucioperca*) and the common roach (*Rutilus rutilus*). The identification was made using fishbone collections and confirmed by frontal x-rays (Fig. 3).

The remains of at least 11 individuals were found in the five samples from the Hellenistic period indicating that they were regularly consumed although the NISP is low. Fish might have been consumed either regularly but in small quantities or during a brief period of the year. The taxa are represented by bones of the head and vertebrae (Fig. 4), indicating that whole fish were consumed. No cut marks were observed.

Sizes were determined based on the equations from the osteometric work of Radu (2003) (Table 3). The pikeperch (*Sander lucioperca*) were 31 to 86 cm long TL-total length (4 individuals). The wels catfish (*Silurus glanis*) were in a similar length range of 35 to 85 cm TL (6 individuals). A single bone of the common roach (*Rutilus rutilus*) was used to estimate the length of one individual as 38 cm TL.

All three species are native to the drainage basins of northern Greece in the present day (Thraki, Makedonia and Thessaly) (Barbieri et al., 2015: 78, 62, 103). The catfish has reportedly been introduced further south in the Peloponnese (Economidis et al., 2000).

Of course, the variability of ecosystems over time and the introduction of certain species do not provide an accurate picture of the distribution of these species in ancient times (Van Neer et al., 2004; Mylona, 2016). This limitation can be weighted by the study of the distribution of freshwater fish remains in ancient Greece.

4. Discussion

4.1 Distribution area of freshwater fish in historical and archaeological sources

Freshwater fish were caught from prehistoric times at sites in northern Greece. Freshwater fish remains are found in archaeological assemblages of the Neolithic and the Bronze Age (Archontiko, Toumba, Dikili Tash, Dimitra, Dispilio, Kastanas, Kryoneri, Megalo Nisi Galanis, Nea Nikomedeia, Pefkakia, Paradeisos, Sitagroi, Pentapolis, Lithares, Zygouries, Sovjan). The commonest taxa are the northern pike (*Esox lucius*), the wels catfish (*Silurus glanis*) and species of the Cyprinidae family (Theodoropoulou, 2007a, 2007b, 2011).

In classical Thebes, the higher $\delta^{15}\text{N}$ values in human bones have been attributed to increased consumption of freshwater fish from that period onwards (Vika et al., 2009).

The capture of freshwater fish is also attested for the Hellenistic and Roman periods. Several stretches of fresh water were reputed to be rich in fish in ancient times (Lake Kalydon, Str., 10.2.21; Lake near Aigiae, Paus., 3.21.5; Pharae fountain,

Paus., 7.12.4; Lake Volve, Ath., 8.334e-334f). The catfish (*glanis*; Thompson 1947: 43-48) was to be found in the Strymon River according to Aelian (Ael., 12.14). A Hellenistic decree at Akraiphia in Boeotia contained lists of fish with their prices, at least six of which were freshwater fish (Lytle, 2010). This inscription clearly attests that these fish were part of the diet even if sea fish commanded higher prices (Collin-Bouffier, 2008: 103).

The discovery of freshwater fish bones (Cyprinidae, *Silurus* sp. and other river fishes) at Krania (Hellenistic period) and Mytilene (Roman period) (Mylona, 2008) are further evidence that they formed part of the inhabitants' diet.

The geographical distribution of these various historical and archaeological indications (Fig. 1) shows that the lakes and rivers of northern Greece and the Peloponnese were the main sources. This observation is consistent with the current distribution of freshwater fish in drainage basins in Greece (Barbieri et al., 2015: 17-20). This evidence supports the non-native character of the freshwater fish on Delos.

4.2. Acclimatization of freshwater fish in the Sacred Lake

In the case of long-distance trading of fish, the commonest hypothesis is that the products were processed. On the island of Delos, the amphictyonic acts (ID 104-13; ID 104-18; ID 104-20) mention a sacred house serving as a shop for the sale of salted fish (Hennig, 1983; Chankowski, 2008: 293; Lytle, 2013). Trade in processed foodstuffs is well attested in the Aegean in ancient times, but it involved mostly salt-water fish judging from archaeo-ichthyofaunal data (Theodoropoulou, 2014, 2018; Lytle, 2018). Evidence of fish processing can be inferred from anomalies in skeletal element presentation, cut marks and the presence of non-local species (Zohar and Artzy 2019: 900). The presence of catfish and roach head bones proves that these fish were whole. If the method of processing including the whole fish had been used, cut marks would be present, for example on the catfish cleithrum. However, in Delos, the bones of freshwater fish have no cut marks.

For freshwater species, fish were exported from the Nile ever since prehistoric times and the practice intensified from the Bronze Age onwards (Van Neer et al., 2004). For ancient times, the site of Sagalassos (Turkey) is an example of long-distance trade from Egypt. Mitochondrial DNA analyses have been used to define the North African catfish (*Clarias gariepinus*) and its source area in the lower Nile region. This information has been thought-provoking when it comes to the conditions for the supply and the necessary processing of fish to cope with the duration of transport (salting, smoking) (Arndt et al., 2003). In the Aegean area, the only mention of the presence of the Nile catfish is from temple C (375 BC–AD 160/170) of Kommos (Fig. 1; Reese et al., 2000: 431). Theodoropoulou (2018) claims this fish was probably processed, unless it had been transported alive.

Indeed, unlike marine fish, freshwater fish can survive transport in water because they withstand changes in their environment better (Berka, 1986; Huss, 1995). The existence of fish-well boats (*naves vivariae*) is well recorded in ancient literary (Ath. 5.208; Macrobius, Sat., 3.16.10; Plin., HN, 9.62-63) and archaeological sources (Boetto, 2010: 248-253), attesting to proficiency in the transport of live fish. This hypothesis is further supported for the island of Delos by epigraphic and archaeological sources mentioning fish breeding in the Sacred Lake.

The Sacred Lake (100 m x 70 m) was formed in a natural depression that captured run-off water (Fig. 2). Its elliptical wall was built in the Hellenistic period

and could contain at most 22,500 m³ of fresh water. Salinity has been measured at 7‰ (Desruelles, 2004: 381, 2007). Archaeological soundings (Brunet et al., 2001) supported by a geomorphological study (Desruelles, 2004: 368-377) put its depth at 1.50 m around the edges and 2.50 m in the centre. This hollow was periodically refilled by precipitation over six months of the year (Desruelles and Fouache, 2014: 206). In the dry season, the lake might be completely dry. This alternating pattern of filling up and drying out has been observed in the stratigraphy revealed by the soundings (Desruelles, 2004: 374). The lake was filled in definitively in 1925 for health reasons and its present-day appearance says little of its role when it was operational in the third and second centuries BC. Desruelles and Fouache (2014) report that the climate has changed little since Antiquity. A photograph (Fig. 5) from 1909 provides a partial view of the natural filling of this depression as it might have looked in ancient times.

Reference in the sanctuary's accounts (ID 353, A, l. 36, Homolle, 1890: 442-443; IG XI, 226, Molinier, 1914: 103) to fish breeding in the Sacred Lake in the third century BC suggests that freshwater fish might have been acclimatized in this pool. Mylona (2008: 80-81) suggests that the Sacred Lake would have been too small to sustain a fish population but the pond could have been a breeding area for Mugilidae larvae. Without archaeo-ichthyological data, this hypothesis was based solely on the physiological characteristics of these fish which can live in briny water. The surface of the sacred lake is 5500 m². Now, the minimum size for a pond is 300m² (Carballo et al., 2008: 16). It is possible, then, that this sacred area was used to the fish breeding during the Hellenistic period. The three species identified in the assemblages (roach, catfish and pikeperch) can also adapt to low salinity stagnant water (Keith et al., 2011: 460; Bruslé, Quignard, 2013: 40, 58, 238; Copp et al., 2009: 257). They may cohabit even though catfish and pikeperch are predatory species. The roach is omnivorous and phytophagous from adulthood (Keith et al., 2011: 353). The estimated lengths show that the specimens measured from 30 to 90 cm, which would certainly have limited any predation among them. For example, depending on the zones studied, the catfish and pikeperch consume prey that measure on average from 10 to 25% of their own size (Orlova and Popova, 1987; Turesson, 2002; Poulet, 2004: 122-123; Dörner et al., 2007; Alp, 2017). This implies species were selected depending on their biology and their body size. It is possible to acclimatize several species in the same pool. Polyculture has the advantage of using the various natural food resources in the basin. The combination of fish such as roach with predatory species is also a way to control the population (Carballo et al., 2008: 50-51).

Acclimatization of these fish required good knowledge of the species chosen. In Antiquity, engineers and agronomists were able to recreate the natural habitat of freshwater fish and the conditions for their survival (Kron 2008a, 2008b, 2014; Marzano, 2013: 199-210).

The elliptical wall was probably built around the lake to develop fish breeding in the existing pool. This construction belongs to the current category of rain-water ponds (Coche et al., 1995: 4). This extensive practice favoured a natural environment in which the fish would have been able to feed on what the lake had to offer. It remains difficult to determine precisely what human involvement there was in the development of species. Semi-intensive practices involving increased production through the introduction of additional foodstuff (Carballo et al., 2008: 9) cannot be ruled out entirely.

The growth of fish must also have been controlled by the managers to limit predation as the estimated body sizes suggest. Besides, fishing could have been one way of regulating large specimens by the use of selective instruments such as hooks.

The periods of drying-out of the lake observed in geomorphological studies imply suitable management. Rain recharges the groundwater table essentially from October to April. During the six warmest months of the year, evaporation intensified by strong winds and high temperatures offsets all of the water input. Precipitation is irregular from year to year. Depending on the amounts of rainfall, wet, moderately wet, or dry seasons may follow one another directly influencing whether the water table is maintained constant, recharged or dries up (Desruelles, 2004: 81, 269-299; Desruelles, 2007; Desruelles and Fouache, 2014). This year-to-year irregularity precludes identification of the periodicity of the different seasons. Acclimatized fish would have been able to grow from year to year in the lake if wet and moderately wet seasons alternated. However, in the event of a protracted dry season, it would have been necessary to catch the fish before the lake dried out completely. Specimens could have been reintroduced when rainfall refilled the lake. Adjoining holding tanks might have been used to keep the fish alive during spells when the lake was dry. No structure that might have served this purpose has been identified on the island. The lake could also have been dug out while dry so as to prevent the pool from silting up (Desruelles, 2004: 382).

Mylona (2008: 80-81) suggests that Mugilidae larvae could have been recovered from the coastal marsh at the mouth of the Inopos near the harbour. The marsh was seasonal (Hasenohr 1996: 905) and certainly small and shallow because, in the fourth and third centuries BC, the watercourse held the run-off from in Inopos water reservoir (Desruelles 2004: 905). The marsh was backfilled from the second century BC (Bruneau and Ducat 2005: 161). It is likely that live fish could have been brought in along the trade routes in containers loaded on merchant vessels. Live fish (larvae) can be transported for one or two days in small containers (Coche and Muir, 1998: 205). Their geographical origin can only be guessed at (northern Greece, the Peloponnese, Asia Minor?). Isotopic analyses might provide an answer to the question of provenance but there are difficulties in interpreting the results (Vika and Theodoropoulou, 2012).

5. Conclusion

Desse and Desse-Berset (2011: 268) wrote that “interpreting the faunal record is the surest way, for want of any textual data, of defining the territories exploited by humans”. It is essential to supplement this statement. Despite plentiful literary and epigraphic sources, as is the case for Delos, input from archaeo-ichthyology is still necessary. The complementary nature of the sources has made it possible to address the issues in all their complexity. It has been possible to go beyond simply mentioning there was fishing in the Sacred Lake by identifying the species caught.

The Sacred Lake was therefore an ecosystem that was created and managed by humans. It was a divine estate made available to individuals. The profits from fish breeding were paid directly into a sacred fund (Migeotte, 2014: 277, 605). It must therefore have been managed by the sanctuary. The selection of species (biological characters, sizes and predation), their transport to the island of Delos, their acclimatization in the lake and their seasonal management, were all stages attesting to a certain proficiency in breeding freshwater fish. The small proportion of freshwater fish in the diet is a first indicator of consumption over a short period of the year. The cost of the fishing activity in the lake had to be met by the fishermen. Thus, the scarcity of catches may have been a factor influencing price. While profit may

have been one of the driving forces for the site managers, it cannot be ruled out that fish breeding may have served cultural or ritual purposes (Linders, 1994).

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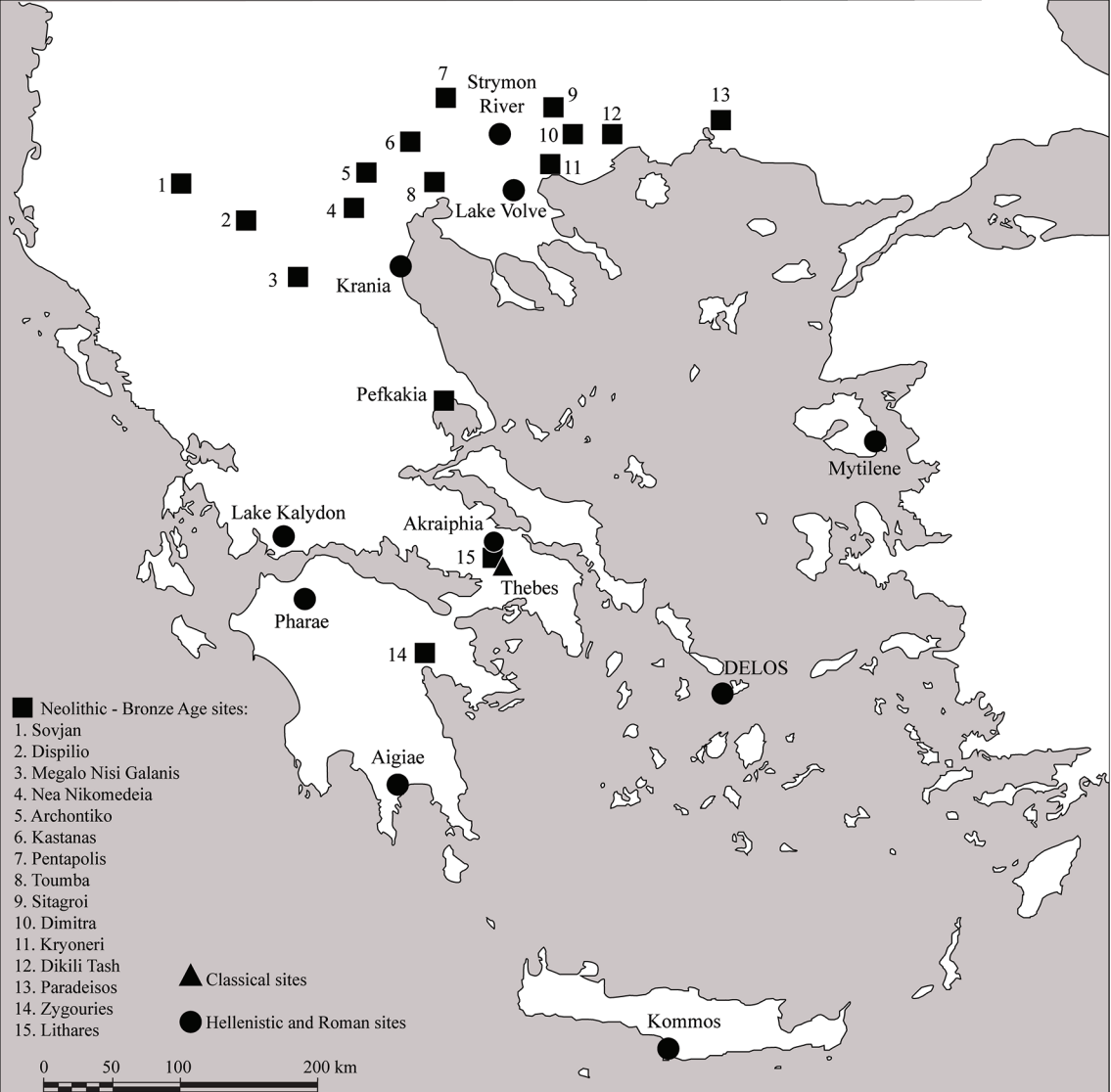
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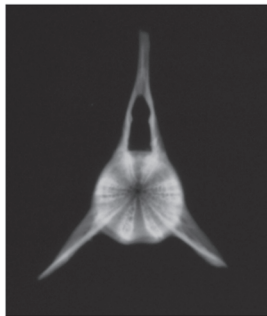
left lateral view



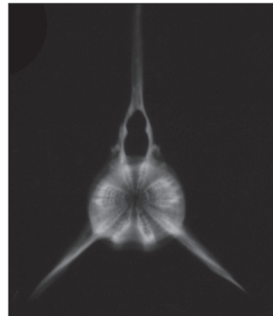
frontal view



Scale 1 : 1

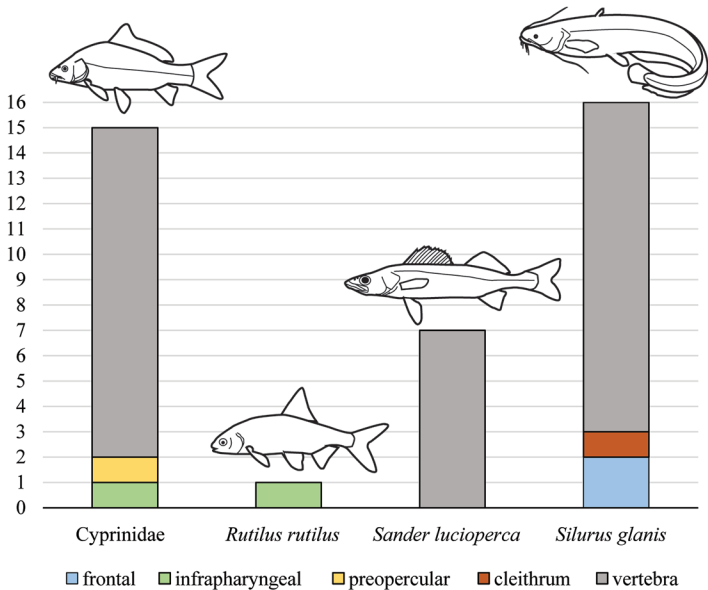


archaeological specimen



reference specimen

Frontal radiography (M. Bessou, PACEA, Bordeaux)





Samples	Area	House	Datation	Volume (litres)	NR	NISP	head bones	vertebral column	median fins	scales	indeterminate
A	Lac	Poseidoniastes de Bérytos	2 nd century BC	40	393	98	46	132	145	9	61
B	Rue de l'est	D'	2 nd century BC	40	1041	144	65	201	429	154	192
C	Rue de l'est	Kerdon II	2 nd century BC	40	1565	208	99	276	> 500	442	248
D	Théâtre	House VI pièce F	2 nd century BC	20	772	87	43	148	352	24	205
E	Masques	House B pièce K	2 nd century BC	20	1353	130	104	130	> 500	301	318
TOTAL				160	5124	667	357	887	1926	930	1024

Class	Family	Genus or Species	A	B	C	D	E	NISP
Chondrichthyes			1		3	1	3	8
	Rajidae		1					1
Actinopterygii	Anguillidae	<i>Anguilla anguilla</i>	3	1	4			8
	Muraenidae	<i>Muraena helena</i>	1				1	2
	Congridae	<i>Conger conger</i>	2		11	2	7	22
	Clupeidae			1			1	2
		<i>Sardina</i> sp.			1			1
	Cyprinidae		7	2	3	1	2	15
		<i>Rutilus rutilus</i>	1					1
	Siluridae	<i>Siluris glanis</i>	7		5	3	1	16
	Phycidae	<i>Phycis phycis</i>		1	1			2
	Scorpaenidae	<i>Scorpaena</i> sp.	8	7	11	3	3	32
	Triglidae						1	1
	Serranidae			9	27	2	2	40
		<i>Serranus</i> sp.		13	4	7	19	43
		<i>Serranus cabrilla</i>	3		1	1		5
		<i>Serranus scriba</i>	14	1		1	2	18
		<i>Epinephelus</i> sp.	1	5	4			10
	Percidae	<i>Sander lucioperca</i>	2		4		1	7
	Carangidae	<i>Trachurus</i> sp.				1		1
		<i>Trachurus trachurus</i>					3	3
		<i>Trachurus mediterraneus</i>					1	1
	Coryphaenidae	<i>Coryphaena hippurus</i>	1		1			2
	Sparidae		7	22	15	6	8	58
		<i>Pagrus</i> sp.	5	1	2			8
		<i>Diplodus</i> sp.	1	4		1	3	9
		<i>Diplodus annularis</i>	1					1
		<i>Diplodus sargus</i>					5	5
		<i>Diplodus vulgaris</i>		1	1		2	4
		<i>Lithognathus mormyrus</i>			1			1
		<i>Oblada melanura</i>			1			1
		<i>Boops boops</i>	5	24	13	7	34	83
		<i>Sarpa salpa</i>			1			1
		<i>SpondylIOSoma cantharus</i>		1	2		1	4
		<i>Sparus aurata</i>	1					1
		<i>Pagellus</i> sp.			8	1		9
		<i>Pagellus acarne</i>		1	1		4	6
		<i>Pagellus erythrinus</i>	2		1		1	4
		<i>Dentex</i> sp.					1	1
	Centracanthidae	<i>Spicara maena</i>				2		2
		<i>Spicara smaris</i>		1	1		2	4
	Mullidae	<i>Mullus</i> sp.		4	7			11
	Pomacentridae	<i>Chromis chromis</i>	1	3		17		21
	Mugilidae		3	2	7	1	1	14
	Belonidae	<i>Belone belone</i>	1	1	16	5	4	27
	Labridae		3	7	9	9	2	30
		<i>Labrus</i> sp.	5	3	15		1	24
		<i>Symphodus</i> sp.	3	8	8	1	8	28
		<i>Symphodus tinca</i>			1			1
		<i>Coris julis</i>		6	10	9	4	29
		<i>Thalassoma pavo</i>				1		1
	Scaridae	<i>Sparisoma cretense</i>	2	1	1			4
	Uranoscopidae	<i>Uranoscopus scaber</i>	1	10	1	2		14
	Gobiidae		1	1	1		1	4
		<i>Gobius</i> sp.	1			1		2
	Scombridae		2		5			7
		<i>Scomber scombrus</i>					1	1
		<i>Scomber japonicus</i>		3		2		5
	Scophthalmidae	<i>Scophthalmus</i> sp.	1					1
			98	144	208	87	130	667

	A	B	C	D	E
freshwater fish					
coastal waters fish					
pelagic fish					

Sample	Skeletal element	Taxa	Measurement	Equation	R	TL (cm)
A	vertebra 2	<i>Sander lucioperca</i>	M1=15	$y=52,732x+72,762$	0.992	86
A	caudal vertebra	<i>Sander lucioperca</i>	M1=4,4	$y=59,237x+51,186$	0.991	31
E	vertebra 4	<i>Sander lucioperca</i>	M1=13,7	$y=52,732x+72,762$	0.992	80
C	vertebra 5	<i>Sander lucioperca</i>	M1=9,2	$y=52,732x+72,762$	0.992	56
C	infrapharyngeal	<i>Rutilus rutilus</i>	M1=25,2	$y=14,11x+24,673$	0.989	38
C	vertebra 20	<i>Siluris glanis</i>	M1=12,2	$y=130,7+58,663x$	0.982	85
C	vertebra 30	<i>Siluris glanis</i>	M1=6,6	$y=68,303x+61,084$	0.99	52
E	cleithrum	<i>Siluris glanis</i>	M2=6,9	$y=45,479+60,382x$	0.997	46
A	vertebra 30	<i>Siluris glanis</i>	M1=6,4	$y=68,303x+61,084$	0.99	50
A	vertebra 30	<i>Siluris glanis</i>	M1=5,2	$y=68,303x+61,084$	0.99	42
D	vertebra 30	<i>Siluris glanis</i>	M1=4,2	$y=68,303x+61,084$	0.99	35