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Alfred Galik (ed.)

FISH'N BONES

PROCEEDINGS OF THE XXI FISH REMAINS WORKING GROUP INTERNATIONAL CONFERENCE, VIENNA 2022

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ÖSTERREICHISCHEN ARCHÄOLOGISCHEN INSTITUTES

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Content

Introduction

Alfred Galik

The first Fish Remains Working Group (FRWG) of the International Council of Archaeozoology (ICAZ) was a meeting organised by Knud Rosenlund, Inge Bødker Enghoff and Jane Richter, and it took place in Copenhagen, Denmark, in 1980. The FRWG meetings continued biennially in various locations. The meeting for 2021 in Vienna, Austria, had to be postponed until 2022 due to the COVID-19 pandemic and the accompanying restrictions on travel. However, a short online pre-meeting was organised in 2021. Finally, the twenty-first meeting of the ICAZ FRWG took place in Vienna after the long and threatening pandemic that caused misery, lockdowns and personal isolation. It was an excellent opportunity to personally meet and share scientific research, done mainly in home office and via digital exchange and collaborations, only. The tradition[1] of making the results of these meetings accessible as a scientific publication is to be continued, and the collection of Archaeological and Anthropological Sciences represents the 13th contribution.

The 21st meeting of the FRWG took place in the Natural History Museum in Vienna, Austria, from 22nd to 27th August 2022, organised by Alfred Galik with the help of a very competent planning committee. Five days of communications featured 40 oral presentations, 11 posters and 51 communications, contributed by 54 participants representing 23 countries (fig. 1). The contributions cover the fields of archaeology, anthropology, history and ichthyology, and other disciplines contribute their unique results.

Fig. 1 Participants at the entrance of the lecture hall in the Natural History Museum, Vienna (© A. Galik)

The poster presentation took place on 23rd August in the Aula of the University building at Franz-Klein-Gasse 1, A-1190 Vienna, where the Austrian Archaeological Institute was housed at this time, followed by a half-day excursion to the so-called »Donauinsel«, providing information about this artificial island in the Danube, constructed as a highly effective flood protection, and visiting the station and breeding tanks for sturgeons of the LIFE-Sterlet Project located there. The social programme continued with the conference dinner in the upper dome hall of the Natural History Museum in Vien-

[1] Robson – Ritchie 2022 – collected, edited and summarised presentations of the last ICAZ FRWG meeting that took place in Portland, USA and were published in Archaeological and Anthropological Sciences in 2022.

Fig. 2 Field excursion to the museum Schloss Orth on the Danube, FRWG members enjoying a model of a large Beluga sturgeon (*Huso huso*) in the castle's yard (© A. Galik)

na. Saturday 27th August was reserved for the field trip around Vienna. It started by visiting the Schloss Orth Nationalpark-Zentrum Donau Auen, with a guided tour through the »Donauräume« exhibition and the »Schlossinsel« outdoor area (fig. 2). Next was a short bus ride to Orth on the Danube, followed by a short trip along the Danube with explanations about the river, the national park and the national park management. After a short break, a trip to Carnuntum, an important Roman city on the border of the Roman Empire from the 1st to the 4th century AD, commenced. It started with a visit to the Museum Carnuntinum in Bad Deutsch-Altenburg, followed by the »Roman town quarter« of Carnuntum in Petronell.

Various presentations of high and excellent quality were put on at the meeting. The proceedings are, of course, especially focused on ichthyoarchaeological-related contexts which aim to lay the groundwork for the future progress of various ichthyoarchaeological studies. The excellent and international contributions draw together current scientific standards of ichthyoarchaeological subjects. Methodological approaches are addressed by contributions about size estimations of archaeological fish, in the case of northern pike applying very precise statistical analyses for the evaluation of the estimates calculated from cranial bones. Another equally important methodological issue concerns the sampling of sediments, the use of different sieve mesh widths and the result on the identification of fish bones and species. The main topic of the proceedings is fishing and fish consumption, and they cover wide areas in these fields chronologically as well as socio-historically. New prehistoric data is made available from late Neolithic pile-dwellings in Austria and Slovenia. The Austrian site explains exploitation patterns of fish, molluscs and amphibians, while the Slovenian site provides new data, which are complementary to the already explored fish remains recovered from coprolites. Despite the precarious circumstances in the Ukraine, a Scythian settlement close to the banks of the river Dnieper was presented, where fishing and fish consumption appeared to be of importance. Production of fish sauce comprising various fishes and a vast number of crustacean remains is reported from a Roman site in France. Methodological issues such as sieving and fish size, potential fishing grounds and seasonality are addressed. The part concerning medieval through to modern contexts covers larger-scale comparative contributions, such as exploitation patterns differentiated by ecological areas, as well as sequential medieval developments at the western Mediterranean Fos-sur-Mer site in France. Similarly, the comparison of two Polish towns sheds light on ecological, economic, geographical and social differences in the Middle Ages and early modern times. Last but not least, the fishing and consumption behaviour at monasteries in medieval France and modern Slovakia was revealed, where fish remains came from kitchen and eremite houses. While the medieval diet in the French monastery consisted of marine and freshwater fish, in Slovakia mainly freshwater fish were consumed, and both sites yielded sturgeon remains. After a successful meeting, these proceedings intend to bring the conference to an equally successful conclusion.

Acknowledgements

The organising team is very grateful for the organisational help and financial support of our partners and the partner institutes at the University of Vienna, the VIAS (Vienna Institute for Archaeological Science) and the Institute for Palaeontology, the Institute of Hydrobiology and Aquatic Ecosystem Management at the BOKU (University of Natural Resources and Life Sciences) and the Austrian Archaeological Institute at the Austrian Academy of Sciences. We are indebted to the Natural History Museum in Vienna for hosting the meeting and the provision of the lecture hall for the presentations in this unique historic ambience.

Bibliography

Robson – Ritchie 2022 H. K. Robson – K. Ritchie, Fishing over the millennia. Zooarchaeological perspectives, Archaeological and Anthropological Sciences 14, 3, 2022, 44.

Acquisition and Management of Aquatic Resources in Fos-sur-Mer, Provence, France (11th–14th Cent. AD)

Archaeoichthyological Results[1]

Tatiana André

Abstract

Few studies have focused on marine resources in the medieval and modern western Mediterranean from an archaeoichthyological perspeactive. This paper presents preliminary results from one of the five sites that are part of a larger PhD project on the consumption and acquisition of aquatic resources in Provence (6th–17th cent. AD). This study also integrates some of the results obtained within the framework of the inter-team AMORCE project Icht'isomed[2], financed by the Institute of Mediterranean Archaeology ARKAIA.

Introduction

Located on the shores of the Gulf of Fos, sheltered from the prevailing winds and integrated into a complex hydrographic network, the Habitat Mistral site at Fos-sur-Mer (13) was the subject of excavations programmed between 1999 and 2001 and directed by J.-P. Lagrue (fig. 1)[2]. Located on a Burdigalian rocky outcrop of calcareous-sandy molasse nature[3] culminating at 32 m, the site overlooks two vast plains. The first, deltaic, extends from south-west to south-east. It is dotted with ponds, some of which serve as salt pans, and brackish marshy areas. Its coastline is continuously moving due to the important sedimentary contribution of the Rhône (fig. 2)[4]. To the north-east lies the La Crau plain, a palaeodelta of the Durance, which is suitable for agriculture and the breeding of bulls, horses and sheep. The first excavation campaign in 1999 revealed the presence of two structures described as habitats. For this article, only the Habitat Mistral II will be mentioned[5].

1 PI: Tatiana André, Aix Marseille Univ, CNRS, LA3M, Aix-en-Provence, France.

2 Lagrue – Del Corso 1999; Jean Phillipe Lagrue, Archaeologist/Conservation Officer, Archaeological Service of the SAN Ouest-Provence.

3 This type of substrate allows for excellent preservation of biological remains, especially bone and cartilage tissue.

4 Pichard et al. 2017; Vella et al. 2005.

5 Lagrue 2002.

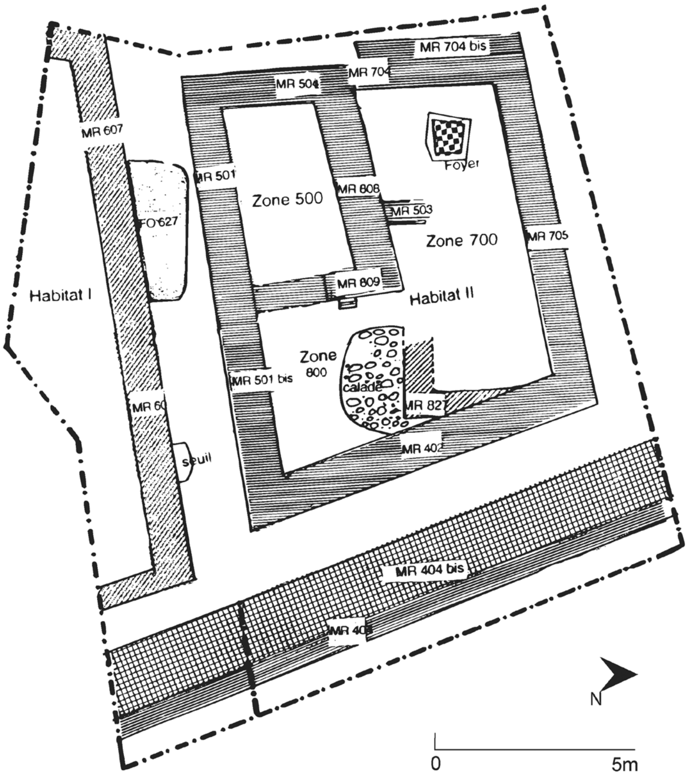

Fig. 1 General plan of the Habitat Mistral excavation site (T. André from the plan by Lagrue – Del Corso 1999)

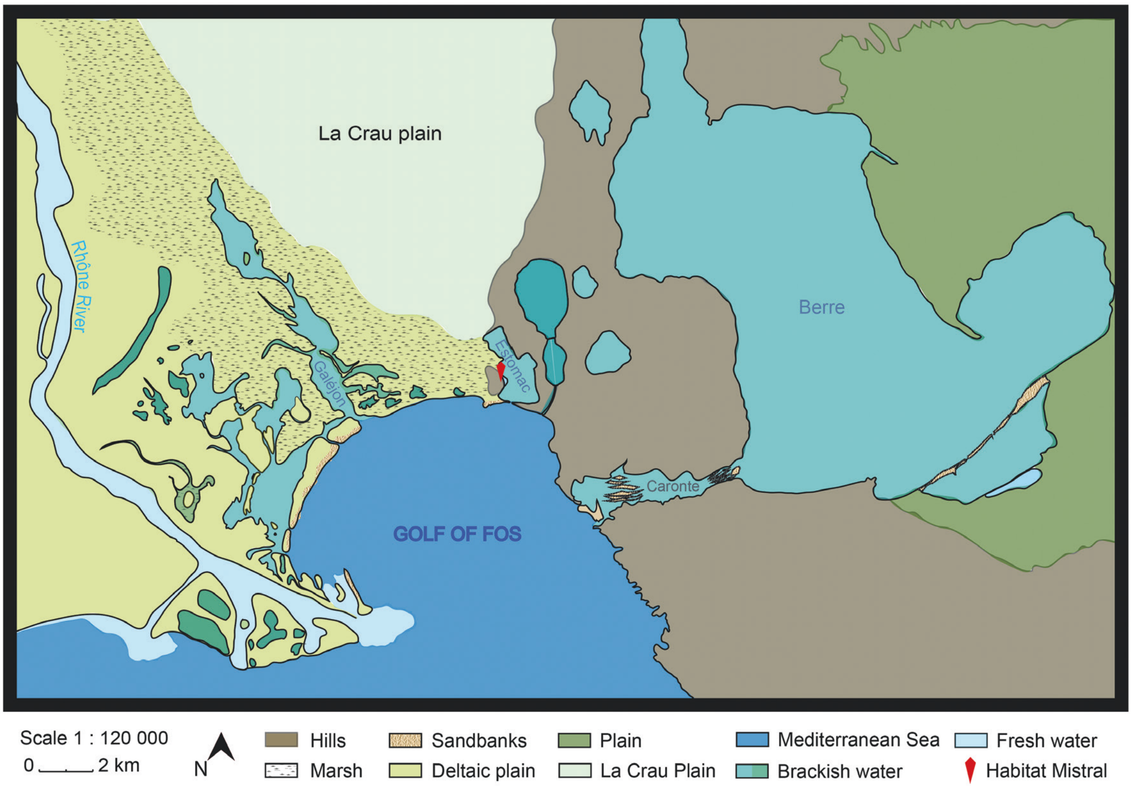

Fig. 2 Map of the Fos-sur-Mer area showing the various possible fishing grounds (T. André from the map of the Etat-Major [AD 1820–1866] <https://www.geoportail.gouv.fr/carte> [03.03.2023])

The Habitat Mistral II

This habitat, benefiting from a privileged environment, is part of the *borgada*[6] overhung by the *castrum*[7] de l'Hauture. Mentioned as early as AD 923, this *castrum*, governed by one of the greatest families of Provence, in coseigniorage[8], protects the *borgada* by its enclosure[9], within which the Mistral II habitat follows the same axis and against whose wall it rests. Located in the foothills of the eastern slope of the Hauture rock, the settlement is close to a vast silage area (7th–10th cent. AD) and a necropolis contemporary with the site (11th–14th cent. AD). Composed of three distinct spaces (zones 800, 700 and 500), Habitat II is articulated around zone 800, a central space of 22.5 m² (fig. 3). The purpose of these three units, and likewise the purpose of the building, is difficult to discern, given the poor conservation of the structures and the weakness of the material evidence. Zone 500, empty of hearths and ceramic and metallic material apart from a tubular fishing sinker, leads us to consider it as a storage or passage area. On the other hand, zone 800 contains numerous scattered hearths, consequent scatterings of bones and shells, and a high proportion of ceramic material, hooks and tubular fishing weights. These concentrations suggest the importance of this space in the building layout. By contrast, as for zone 500, zone 700, further back, seems to be a storage

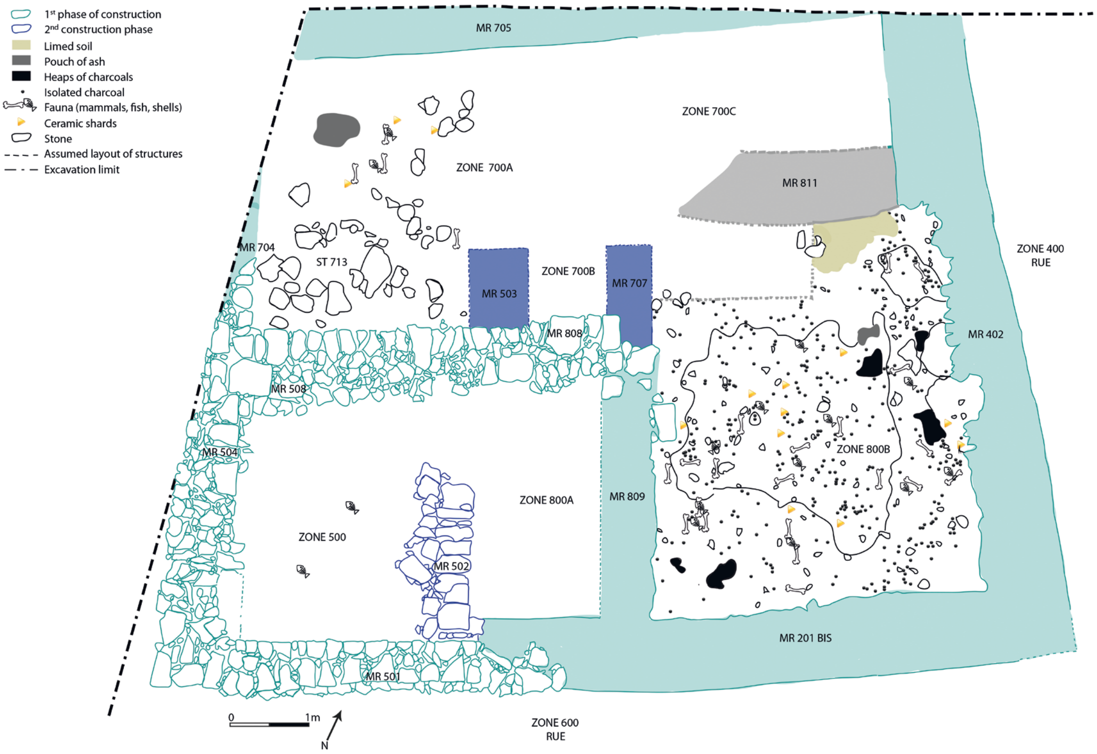

Fig. 3 General plan of the Mistral II Habitat (T. André from a plan by Lagrue – Del Corso 1999)

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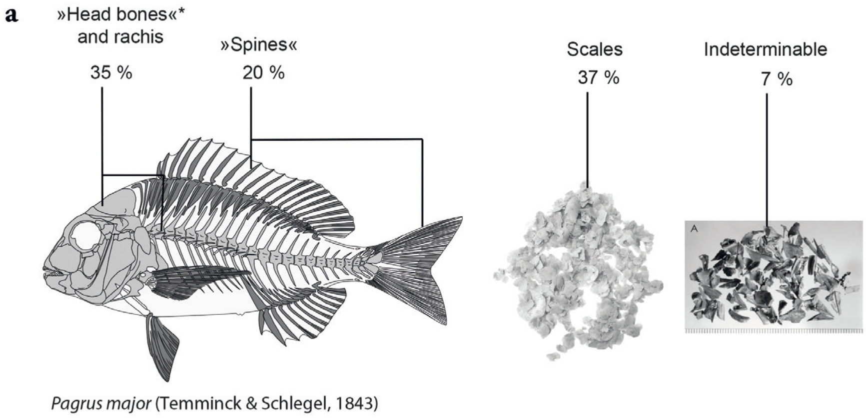
6 A small village with scattered houses occupying a fairly large area.

7 Refers to a medieval structure where the enclosed and fortified space is shared. It can be a place of aristocratic or peasant habitation, a town or a castle, more or less high up.

8 The *castrum* of Fos-sur-Mer was owned by the Fos family, one of the four great seigniorial families of Provence between the 10th and the 13th cent. AD, by the Archbishop of Arles and by the Porcelets family, who, from the 13th cent. AD onwards, recovered the power attributed to the Fos family through political games and financial transactions, to become the main managing family.

9 The first mention of the enclosure around the *borgada* was made in AD 1224 during a visit to the fortifications of the Provence coast, ADBR B 7 f° 84 v°, 1323.



NR = 17 805
NISP = 3 671 (21 %)
*Head bones: neurocranium, splanchnocranium and apendicular skeleton

NR = number of remains collected
NRDa = number of anatomically determined remains
NRDar = number of anatomically determined remains reduced (without scales and spines)
NISP = number of identified specimen
IND = indeterminate

b

	NR	NRDa	Scales	Spines	NRDar	NISP	IND
500	578	529	100	136	293	166	49
700	10790	10148	4325	2085	3738	2077	643
800	6437	5838	2181	1411	2246	1428	600
Total	**17805**	**16515**	**6606**	**3632**	**6277**	**3671**	**1292**

Fig. 4 General distribution of the ichthyological remains at the site from the 11th to the 14th century. a: Distribution of the ichthyological remains, all zones combined according to the total number of remains (left picture: T. André from M. Coutureau, 2019/Archeo-Zoo.org [Licence CC BY NC SA 4.0, INRAP] from Kishimoto et al. 2006; middle picture: photo: T. André [AMU-CNRS]; right picture: photo: M. Sternberg – S. Durand [CNRS]); b: Distribution of the ichthyological remains by zones (T. André)

area for fishing tools (see below, Fishing in the Fos Area) with the tenuous presence of fire-places. However, in contrast to the scattered distribution of the archaeological structures and furniture, aquatic remains[10] are found in all of these areas, although distributed in a different way. The dating of the different levels of occupation is still in progress, but the site evolved between the 11th century AD and the end of the 14th century AD.

Material and method

The archaeoichthyo remains from the Habitat Mistral II were obtained by hand collecting and systematically and exhaustively sieving all the strata on the site with a 1.5 mm mesh. Of the 105 stratigraphic units making up the site, 87 were taken into account for this study. The good level of preservation of the fish bones is consistent across the site, with very few remains in fragmentary form.

Identification of the bone elements was carried out with the help of the comparative anatomy collections of Myriam Sternberg[11], on deposit at the Camille Julian Centre (CCJ AMU

[10] The term »aquatic« includes Actinopterygians, Chondrichthyans and Chondrosteans, as well as the marine mammals and cephalopod molluscs that were grouped together in the medieval period under the term »fish«, Jacquemard et al. 2013.

[11] Archaeoichthyologist, CR CNRS-CCJ UMR 7299.

CNRS UMR 7299), and a personal collection established for the needs of the study[12], as well as reference works[13]. The numerous chondrichthyan pieces were identified with the valuable help of Wim Wouters[14]. Mass and size estimation was carried out where possible according to published references (see below, Osteometry). Seasonality analysis was not applied here due to the poor legibility of the last growth ring of the vertebrae of a large majority of samples. The study of the bones from the three mentioned zones (500. 700. 800) revealed the presence of 17,805 remains distributed over the entire skeleton (fig. 4 a. b). A large proportion of these bones are very well preserved. Apart from the scales and the ›spine‹[15], the anatomical distribution is mainly concentrated on the splanchnocranium and the rachis.

Results

Five distinct groups can be seen in the collection: the majority comprises teleosts, chondrichthyans, some chondrosteans, cephalopod molluscs and the very isolated marine mammals (fig. 5). It was decided to classify the teleosts by dominant, abundant, occasional and rare taxa in view of the large number of different species present. The dominant taxa are those which are most recurrent and most represented by zone and in the site as a whole. The term abundant corresponds to taxa represented by 100–299 remains. Occasional taxa are those with between 20 and 99 remains, while rare taxa have fewer than 20 remains per zone (fig. 5). A total of 92 taxa were identified, including 51 genera, 52 species and 41 family groups.

Teleosts

Salt and brackish water hosts

Of the very large number of teleostian remains, more than three-quarters come from species that lived in more or less salty environments. At first glance, two fishes dominate the whole sample: the European eel (*Anguilla anguilla*) is best represented[16], together with the European seabass (*Dicentrarchus labrax*). Apart from their easy fishing in the favourable environments of the Fos territory, the importance of eels remains also reveals their use as currency in the payment of taxes and fees. For example, in AD 1114, Pons de Fos gave 50 eels to the Hospitallers of Arles as annual dues[17].

Reduced to family groups, there are really five taxa that appear most frequently at the site. The eel is relegated to second place in the face of the abundance of the *Sparidae* ssp., a family in which the salema (*Sarpa salpa*) clearly stands out from the rest of the family group, followed by the sea bream (*Sparus aurata*) and the genus Diplodus (*Diplodus* ssp., *D. sargus sargus, D. vulgaris*). The *Mugilidae* ssp. and *Scorpaneidae* spp. are added in almost equal proportions (fig. 5). This order, which combines the data from the three zones, varies slightly when the zones are viewed separately. Nevertheless, these five groups remain dominant in relation to the rest of the collection.

In lesser quantities, two other taxa are found in abundance in the various zones of the site. These are the *Pleuronectidae* ssp., for which the complex diagnosis only allowed the

[12] This personal collection is on deposit at the Laboratoire d'Archéologie Médiévale et Moderne en Méditerranée (LA3M AMU CNRS UMR 7298).

[13] Cannon 1987; Courtemanche – Legendre 1985; Rosello Izquierdo 1986.

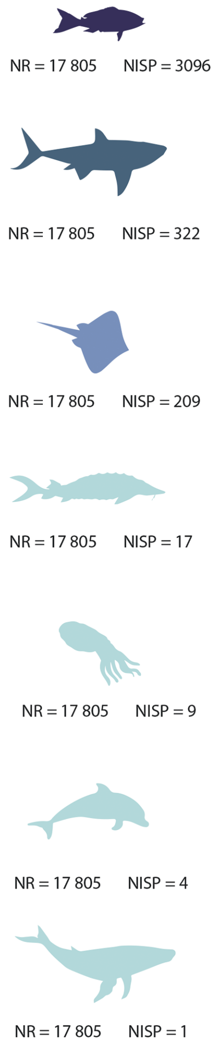
[14] We would like to warmly thank Wim Wouters for his expertise, his precious advice and all the help he provided during our stay at the Royal Belgian Museum of Natural Sciences in Brussels.

[15] The bones grouped under the term »spine« in this study are axonosts, spines, lepidotrichia and ribs.

[16] Given the large number of these remains (large number of vertebrae), the number of these preserved remains (NISP) is likely to be higher than in other teleost species. This issue has been discussed in Sternberg 1995, 91.

[17] TC No. 169, 1114.

				Zone 500	Zone 700	Zone 800	Total	Total Family
Teleosts		*Anguillidae*	*Anguilla Anguilla* (Linné, 1758)	18	243	202	**463**	
		Belonidae	*Belone belone* (Linné, 1760)	1	20	12	**33**	
		Carangidae	*Trachurus trachurus* (Linné, 1758)		2	1	**3**	
		Congridae	*Conger conger* (Linné, 1758)		9	10	**19**	
		Engraulidae	*Engraulis encrasicolus* (Linné, 1758)		4		**4**	
		Gadidae	*Gadidae ssp* (Rafinesque, 1810)			1	**1**	
			Merlangius merlangus (Linné, 1758)			1	**1**	
		Labridae	*Labridae spp* (Cuvier, 1816)	3	62	46	**111**	**131**
			Coris julis (Linné, 1758)		1		**1**	
			Symphodus tinca (Linné, 1758)	2	17		**19**	
		Lophiidae	*Lophiidae ssp* (Rafinesque, 1810)			1	**1**	
			Lophius budegassa (Spinola, 1807)		2	1	**3**	
			Lophius piscatorius (Linné, 1758)		1	9	**10**	
		Merlucciidae	*Merluccius merluccius* (Linné, 1758)		3	3	**6**	
		Moronidae	*Dicentrarchus labrax* (Linné, 1758)	24	250	129	**403**	
		Mugilidae	*Mugilidae ssp* (Jarocki, 1822)	16	247	95	**358**	
		Mullidae	*Mullus surmuletus* (Linné, 1758)		2	1	**3**	
		Muraenidae	*Muraena helena* (Linné, 1758)		1		**1**	
		Phycidae	*Phycis ssp* (Walbaum, 1792)	4	1	25	**30**	**57**
			Phycis phycis (Linné, 1766)	2	15	10	**27**	
		Pleuronectidae	*Pleuronectidae ssp* (Rafinesque, 1815)	11	202	80	**293**	**297**
			Pleuronectes platessa (Linné, 1758)		1	3	**4**	
		Pleuronectiforma	*Pleuronectiforma ssp*		10	1	**11**	
		Sciaenidae	*Argyrosomus regius* (Asso, 1801)		1	2	**3**	
		Scombridae	*Scomber scombrus* (Linné, 1758)		6	8	**14**	
			Thunnus thynnus (Linné, 1758)		1		**1**	
		Scophthalmidae	*Scophthalmidae ssp* (Chabanaud, 1933)	1	4	39	**44**	**66**
			Scophthalmus maximus (Linné, 1758)		8	3	**11**	
			Scophthalmus rhombus (Linné, 1758)		8		**8**	
		Scorpaenidae	*Scorpaenidae ssp* (Risso, 1827)	1	48	2	**51**	**352**
			Scorpaena ssp (Linné, 1758)	11	44	16	**71**	
			Scorpaena scrofa (Linné, 1758)	6	49	111	**166**	
			Scorpaena porcus (Linné, 1758)		63	1	**64**	
		Serranidae	*Serranidae ssp* (Swainson, 1839)			4	**4**	
			Epinephelus ssp (Bloch, 1793)		4	7	**11**	
			Serranus ssp (Cuvier, 1816)		4		**4**	
		Soleidae	*Soleidae ssp* (Bonaparte, 1833)		4	1	**5**	**79**
			Solea solea (Linné, 1758)		56	18	**74**	
		Sparidae	*Sparidae ssp* (Rafinesque, 1818)	7	113	62	**182**	**522**
			Dentex dentex (Linné, 1758)		8	2	**10**	
			Diplodus ssp (Rafinesque, 1810)	1	13	12	**26**	
			Diplodus sargus sargus (Linné, 1758)	2	30	14	**46**	
			Diplodus vulgaris (Geoffroy Saint-Hilaire, 1817)	1	26	1	**28**	
			Lithognathus mormyrus (Linné, 1758)		1		**1**	
			Oblada melanura (Linné, 1758)		1		**1**	
			Pagellus acarne (Risso, 1827)		3	1	**4**	
			Pagellus erythrinus (Linné, 1758)		42	6	**48**	
			Pagrus pagrus (Linné, 1758)		7		**7**	
			Sarpa salpa (Linné, 1758)	12	57	32	**101**	
			Sparus aurata (Linné, 1758)	3	41	26	**70**	
			Spondyliosoma cantharus (Linné, 1758)		1	5	**6**	
		Trachinidae	*Trachinus draco* (Linné, 1758)		1		**1**	
		Triglidae	*Triglidae ssp* (Rafinesque, 1815)		6	5	**11**	
			Chelidonichthys ssp (Kaup, 1873)			2	**2**	
		Uranoscopidae	*Uranoscopus scaber* (Linné, 1758)		4		**4**	
		Zeidae	*Zeus faber* (Linné, 1758)		2	1	**3**	
		Cyprinidae	*Cyprinidae ssp* (Rafinesque, 1815)	2	32	140	**174**	**209**
			Abramis brama (Linné, 1758)			5	**5**	
			Cyprinus carpio (Linné, 1758)		1	22	**23**	
			Rutilus rutilus (Linné, 1758)			1	**1**	
		Salmonidae	*Salmonidae ssp* (Jarocki ou Schinz, 1822)		2	3	**5**	
		Siluridaeycipitidae	*Siluris glanis* (Linné, 1758)			1	**1**	
		Total		**128**	**1784**	**1184**	**3096**	
Chondrosteans		*Acipenceridae*	*Acipenceridae ssp* (Bonaparte, 1831)		2	2	**4**	
			Acipenser sturio (Linné, 1758)		12	1	**13**	
		Total			**14**	**3**	**17**	
Chondrichthyans	*Batoidae*				31	17	**48**	
		Dyasistidae	*Dasyatidae ssp* (Jordan & Gilbert, 1879)		6	1	**7**	
		Myliobatidae	*Myliobatidae ssp* (Bonaparte, 1835)	20	1	2	**23**	
		Rajidae	*Rajidae ssp* (De Blainville, 1816)		1	5	**6**	
			Dipturus batis (Linné, 1758)		8		**8**	
			Raja ssp (Linné, 1758)			4	**4**	
			Raja clavata (Linné, 1758)	4	34	75	**113**	
		Total		**24**	**81**	**104**	**209**	
	Selachiforma			5	56	54	**115**	
		Carcharhiniforme			5	8	**13**	
		Carcharhinidae	*Carcharhinidae ssp* (Jordan & Evermann, 1896)		1	2	**3**	
			Carcharhinus ssp (Blainville, 1816)	3	39	15	**54**	
			Prionace glauca (Linné, 1758)			4	**4**	
		Laminiforme				1	**1**	
		Scyliorhinidae	*Scyliorhinus ssp* (Blainville, 1816)	1		1	**1**	
			Scyliorhinus canicula (Linné, 1758)		1		**1**	
			Scyliorhinus stellaris (Linné, 1758)		23		**23**	
		Sphyrnidae	*Sphyrna ssp* (Rafinesque, 1810)			5	**5**	
			Sphyrna lewini (Griffith & Smith, 1834)			1	**1**	
		Squalidae	*Squalidae ssp* (De Blainville, 1816)			1	**1**	
		Squatinidae	*Squatina ssp* (Duméril, 1805)	3	22	10	**32**	
			Squatina squatina (Linné, 1758)		3	10	**13**	
		Triakidae	*Triakidae ssp* (Gris, 1851)		4	6	**10**	
			Galeorhinus galeus (Linné, 1758)		25	4	**29**	
			Mustelus ssp (Linck, 1790)		14	4	**18**	
			Mustelus mustelus (Linné, 1758)	1		3	**3**	
		Total		**13**	**193**	**129**	**322**	
Mammalia	*Cetacea*			1			**1**	
		Delphinidae	*Delphinidae ssp* (Gris, 1821)		2	2	**4**	
				1	**2**	**2**	**5**	
Cephalopoda		*Sepiidae*	*Sepia ssp* (Linné, 1758)		3	6	**9**	



NR = 300 to 600 (blue)

NR = 100 to 299 (green)

NR = 20 to 99 (yellow)

NR = 1 to 19 (white)

Fig. 5 Taxonomic distribution by area according to the total number of remains for the period 11th–14th century AD. Blue: dominant taxa; green: abundant taxa; yellow: occasional taxa; white: rare taxa (T. André) identification of a single species, *Pleuronectes platessa*, and this in small quantities, as well as the *Labridae* ssp., for which it was possible to identify the East Atlantic peacock wrasse (*Symphodus tinca*) and a remnant of the Mediterranean rainbow wrasse (*Coris julis*).

Caught more occasionally, other flatfish such as common sole (*Solea solea*) and *Scophthalmidae* (*S. maximus* and *S. rhombus*) also seem to be appreciated. Sole is also mentioned, albeit in the 19th century[18], as being a catch of choice in the Galéjon pond, where it was caught along with the top-quality sea basses and eels. To a lesser extent, forkbeard (*Phycis* ssp., *Phycis phycis*) and garfish (*Belone belone*) were also caught by fishermen. As deep-sea inhabitants, forkbeard seem to have been caught off the coast of the Gulf of Fos, where the maximum depth of 18 m differs from their natural environment[19].

The other taxa are very discrete, but highly diversified. Unlike the anchovy (*Engraulis encrasicolus*[20]), the other rare species are not used to lagoon environments, despite a few rare incursions, notably for the red mullet[21]. The rest of the ichthyic spectrum seems to come from fishing in the gulf, or even in the open sea for a certain number of them (fig. 5).

The Rhône, a freshwater breeding ground

The only freshwater point[22] providing a supply of fish, the Rhône – in particular its delta and its mouth – seems to have been exploited to provide the Habitat Mistral II with freshwater species. Representing only 6 % of the fish spectrum, these are dominated by the Cyprinidae family. Although it is difficult to identify the species by the vertebrae, some remains of the splanchnocranium have made it possible to detect the presence of common carp (*Cyprinus carpio*[23]), common bream (*Abramis brama*) and roach (*Rutilus rutilus*).

A few sturgeon fragments[24] testify to their presence at the site, mainly in zone 700 (fig. 5). For the most part, these are dorsal and ventral scutes that are more or less well preserved. A palatopterygoid and a pectoral fin spine also allowed us to detect the presence of *Acipenser sturio*. It is attested in the Rhône and its estuary until AD 1970 and is mentioned in the expenses of the nephew of the seneschal[25] of Arles, as well as in the description recorded by P. Quiqueran de Beaujeau later on, for the preparation of caviar in this same town[26].

The tenuous presence of Salmonidae raises the following questions: is it a question of a sporadic supply from outside the territory of Fos or evidence of the presence in medieval times of established populations of salmon or sea trout in the Mediterranean which have now disappeared?

A few remnants of catfish (*Siluris glanis*) complete the spectrum of freshwater fishes.

18 Quiqueran de Beaujeu 1614.

19 Forkbeard (*Phycis* ssp.) generally evolve at depths between 20 m and 450 m, Louisy 2022.

20 Kara – Quignard 2018, 66.

21 Kara – Quignard 2018, 17–59.

22 Apart from the Rhone, the territory of Fos-sur-Mer has no rivers running through it, thus limiting the supply of freshwater species. Only a freshwater resurgence at the foot of the *castrum* in the Etang de l'Estomac allowed the population to obtain water during its occupation.

23 Although it temporarily frequents lagoons as a migratory potamolagoon species (Kara – Quignard 2018, 117–126), a decision was made to link the carp to its general biological niche.

24 Although an anadromous species, a decision has been made for this article to include it in the freshwater species because of the high probability that it may have been caught in the fresh waters of the delta towards Arles rather than in the brackish waters of the river mouth. Moreover, as defined by Clavel et al. 2008, for the Middle Ages it is not linked to the regulations related to tidal species (sea fish), but to those specific to freshwater fish.

25 »Here is the expense of the nephew of my lord the seneschal: ›Item plus, a soupar lodich jort una pessa de sturjon […]‹«; A.C. Arles CC 183 f° 42, 1455.

26 »The other fish roe jam called cavial came from the Greeks and is made in Arles in this way […]«, Quiqueran de Beaujeu 1614.

Sharks and rays

On the whole, the very good preservation of chondrichthyan remains has made it possible to detect a large number of taxa despite the multitude of cutting marks (cf. below, Anthropogenic Traces). The selachiformes comprise the largest number of remains (NR = 335) and include six families in which the requiem sharks (*Carcharhinidae* ssp.), angel sharks (*Squatinidae* ssp.), hound sharks (*Triakidae* ssp.) and cat sharks (*Scyliorhinidae* ssp.) constitute the majority (fig. 5). Requiem sharks, particularly the genus *Carcharhinus* ssp. seem to be highly valued, but the lack of detail in the ancient sources does not allow us to deduce whether they were the result of a targeted or incidental fishery. Several hypotheses could also explain their important presence. It may be directly linked to their evolution in specific shallow water habitats – closed bays and estuaries, coastal areas and the open sea (continental shelf) – that the Gulf of Fos encompasses. It may also be a mass effect, as the *Carcharhinidae* ssp. are the dominant group in the Mediterranean in terms of both diversity and abundance[27]. In the case of angel sharks and the nursehound (*Scyliorhinus stellaris*), reuse of their skin may have been a reason for fishing for them. This very rough skin could be used as sandpaper for carpentry, but also in the form of shagreen[28] to make marquetry and cabinet-making objects, etc. Used to estuarine and coastal areas, the Gulf of Fos certainly provided a favourable environment for their evolution, making them both abundant and easy to catch. As for *Galeorhinus galeus* and *Mustelus* ssp., apart from the targeted fishing for consumption of their flesh and the obtaining of oil from their liver, like the other sharks, their habit of gathering in greater or lesser numbers may also explain their abundance at the site.

Other open-water sharks such as hammerheads (*Sphyrna* ssp.) and blue sharks (*Prionace glauca*) appear to be the result of incidental fishing or perhaps recovery from strandings. It should be remembered that their near absence from the faunal spectrum may also be the result of taphonomic bias, complete reuse of their skeletons or simply processing in other areas of the town.

In the Batoidae, the majority of the bony remains are represented by the family *Rajidae* ssp., mainly by skin denticles of *Raja clavata* (fig. 5). The *Dyasistidae* ssp. could only be detected by their sting. In addition to their taste properties, these two families could also be treated in the same way as *Scyliorhinus stellaris*. As for the *Myliobatidae* ssp., they are only attested by their teeth.

Marine mammals and cephalopods

Marine mammals complete the exploitation of the site's aquatic resources (fig. 5). Thus, in zone 500 a vertebra of a large cetacean with traces of burning and notches caused by a blunt object was found. In zones 800 and 700 two vertebrae of small cetaceans had their spinous processes cut out. Those from zone 800 seem to correspond to juvenile individuals because of the epiphysis in progress between the body and the vertebral head. Conversely, the total epiphysis of the vertebrae in zone 700 suggests the presence of mature individuals. These remains also raise the question of the presence of groups or isolated individuals of large and small cetaceans in the Fos maritime area during the medieval period. They may have come from fishing in the Gulf of Fos or from timely collection on one of its beaches – as is the case on the Basque coast and in the north of France[29] – where the presence of isolated indi-

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[27] Although generally solitary, basking sharks can form small and large groups; Ebert – Dando 2022.

[28] Made fashionable by Marie Antoinette in the 18th cent. AD thanks to the (re)discovery by the artisan Jean-Claude Galluchat, it is likely that medieval French society was already employing this tanning process, as was the case as early as the 8th cent. AD in Japan in the field of armaments to cover shields, sword guards or certain samurai armours for practical (very solid and allows for a good grip) and ostentatious purposes.

[29] Lestocquoy 1948.

viduals and groups[30] is currently attested. Their presence, together with the traces of burning and cutting, suggests consumption of the flesh and fat, use of the fat for lighting and so much more for the skeleton. The plan is to carry out ZooMs analyses (zooarchaeology by mass spectrometry) to determine at least the family and to couple these results with isotopic analyses in order to verify whether these specimens consume the fish in our study and whether they evolved in the same environment.

A very small proportion of cuttlefish bones completes the spectrum of species fished at the site. Apart from the consumption of the flesh, their presence may mean that their ink was used and their bones reused for various anthropogenic activities. The latter might be components of hygiene products[31] and/or medicines[32], or may have allowed the practising of artisanal activities such as the manufacture of moulds for costume elements or jewellery[33].

Osteometry

The size and mass estimates based on the work of E. Thieren et al.[34] for *Anguilla anquilla* and J. Desse and N. Desse-Berset for *Sparus aurata*[35] suggested the size profile for this taxon. The results by zone were obtained from calculation of the MNI (minimal number of individuals). For eels, this was calculated on the basis of recorded dentalia. It shows a great deal of variability. Sizes ranged from 31 cm to approximately 94 cm, with an average of about 50 cm in all three areas (fig. 6 a). As an example, vertebral reconstructions have been illustrated to support the dental results (fig. 6 a).

The results of these estimates, supported by standardised systematic measurements and various observations, tend to suggest several hypotheses: eels were not subject to fishing pressure and developed in an environment that was very favourable to their growth; fishing targeted large individuals in particular, but nevertheless did not reject the others; or the bias towards using a mesh size greater than 1 mm may have induced this over-representation of large individuals[36].

For sea bream, the MNI was calculated from the right premaxillae (fig. 6 b). Due to the lower quantity and level of conservation, the estimate could only be based on a small number of individuals. The specimens are on average small, with values ranging from 16.87 cm for 125.94 g for the smallest specimen to 30.8 cm for 801.3 g for the largest. However, in area 700 two specimens stand out from the rest by being much larger than the remainder of the sample. The smaller of the two sea bream measured 33.6 cm with a mass of 1.03 kg while the larger measured 46 cm with a mass of 2.6 kg.

In contrast to eels, it seems that the choice was for medium-sized individuals, as is common in our current markets. This choice could be explained by the possible food preferences of consumers. Indeed, at a later date[37], H.-L. Duhamel Du Monceau recounted that those from Provence, in particular those from Martigues, were highly valued and that medium-sized ones

30 A group of Delphinidae has been established in the gulf for many years. During the last 20 years, a few isolated large cetaceans, including a sperm whale, have made occasional incursions into the gulf.

31 It is used in toothpaste; Philippe 2014.

32 For example, it is used as an ophthalmic treatment; Dumas 2014.

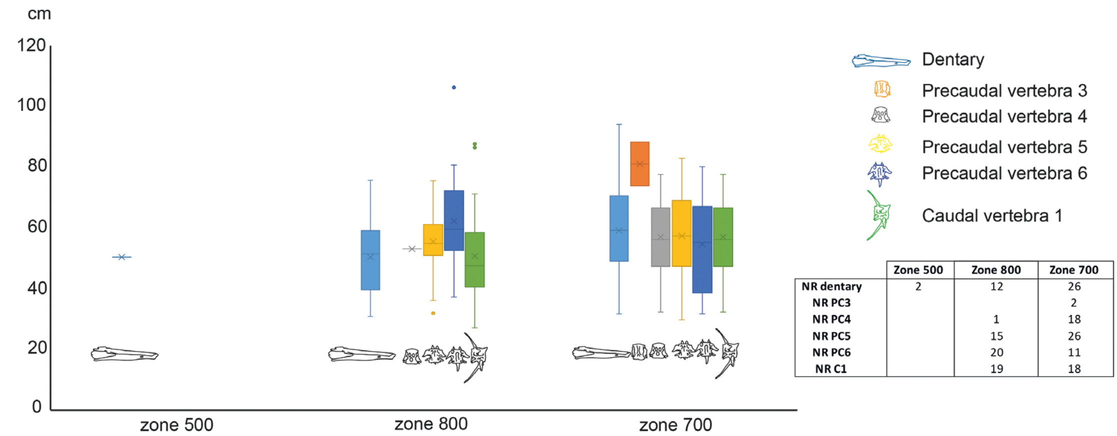
33 Carré et al. 2018, the use of the cuttlebone mould in goldsmithing according to medieval techniques. TV8 Mont-Blanc, Artisanat: la fonte à l'os de seiche <https://www.youtube.com/watch?v=so3dZY3Y2XE> (03.03.2023).

34 Thieren et al. 2012.

35 Desse – Desse-Berset 1996.

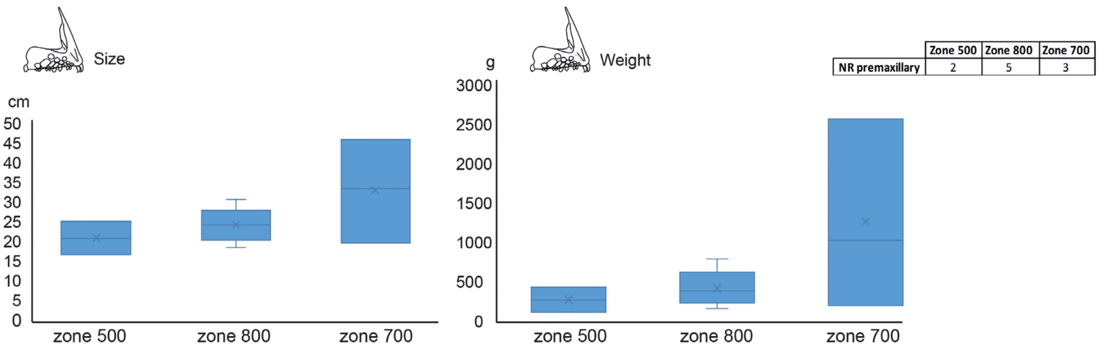
36 E.g. at the Place de l'Olivier site in Marignane (13), more than 90 % of the eel remains come from the rejects of 1 mm mesh sieves; André 2022.

37 In his treatise on fishing H.-L. Duhamel Du Monceau describes the preferences of his 18th-cent. contemporaries as well as the different fishing techniques and an atlas of common fish.



	Zone 500	Zone 800	Zone 700
NR dentary	2	12	26
NR PC3			2
NR PC4		1	18
NR PC5		15	26
NR PC6		20	11
NR C1		19	18

a



	Zone 500	Zone 800	Zone 700
NR premaxillary	2	5	3

b

Fig. 6 Restitution of sizes and masses from osteometric measurements; a: size of Anguilla anguilla from the dental remains (Thieren et al. 2012); b: size and mass of *Sparus aurata* from the premaxilla (Desse – Desse-Berset 1996)

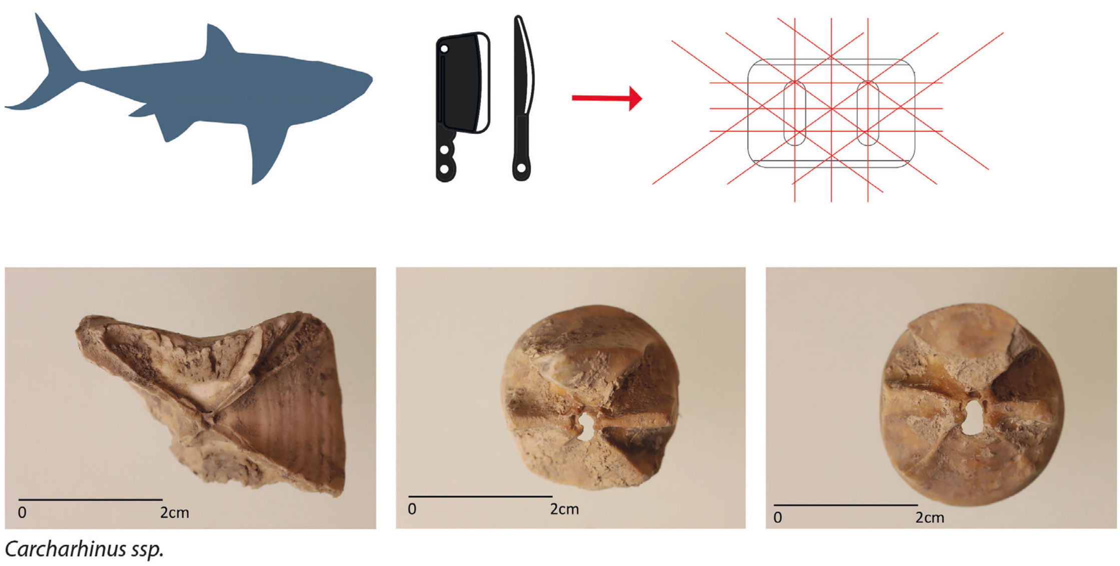


Fig. 7 Cutting angles on shark vertebrae (T. André, pictures: P. François [LA3M, CNRS-AMU UMR 7298])

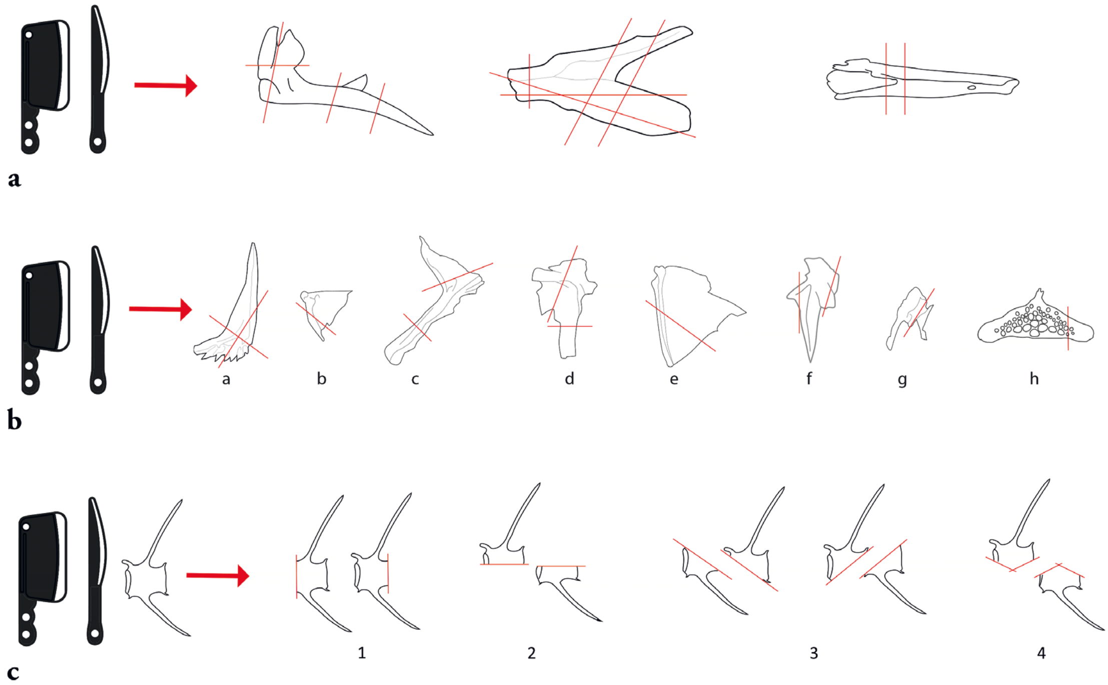


Fig. 8 Traces of cutting on teleosts. a: Schematisation of cutting angles on premaxillary and dentary bones (M. Coutureau – B. Clavel [collab.], 2005/ArcheoZoo.org [Licence CC BY NC SA 4.0], Cuvier – Valenciennes 1828 and Thieren et al. 2012); b: Schematisation of cutting angles on other bones (M. Coutureau – B. Clavel [collab.], 2005/ArcheoZoo.org [Licence CC BY NC SA 4.0], Cuvier – Valenciennes 1828 and T. André); c: Schematisation of cutting angles on vertebrae (T. André)

were preferred without hesitation[38]. This preference for finer and more delicate flesh may have been of the same ilk in the medieval period. However, this could also reflect a specific nursery type of fishing area, of which the Fos area has a large number, such as the Galéjon and Estomac ponds or the Caronte pond in Martigues.

Anthropogenic traces

The cut marks are mainly visible on shark vertebrae (mainly on *Carcharhinus* ssp.). These cuts do not seem to have any particular angle (fig. 7) and the logic or standardisation of the cutting is not clear to us.

For the teleosts, the splanchnocranial bones and vertebrae show this type of trace. The bones of the head that are most often cut are the dental and premaxillary bones (fig. 8 a). Other bones are also cut, such as the preoperculars, cleithra, squares, pharyngeals, hyomandibulars, post-temporals, articulars and operculars (fig. 8 b).

In the three zones of the site, the taxa that were most frequently cut were eels (*Anguilla anguilla*), European seabass (*Dicentrarchus labrax*), scorpion fishes (*Scorpaena* spp.) and Sparidae (*D. vulgaris, Dentex dentex, Sparus aurata, D. s. sargus, Pagellus erythinus, Sarpa salpa*). We have more occasional traces on Labridae (*Shymphodus tinca*), *Gadidae* ssp., *Conger conger* and *Belone belone*. The high frequency of cuts on the mandibular arch bones may suggest manipulation to remove the hook. In the case of eels, the cutting of the posterior

[38] The taste »is very good in sandy or stony bottoms, and in certain ponds where they fatten up; besides, the small sea breams are not much appreciated; those which are very fat have a somewhat tough flesh; thus those of medium size are, without doubt, the best […]«; Duhamel Du Monceau – De La Marre 1769.

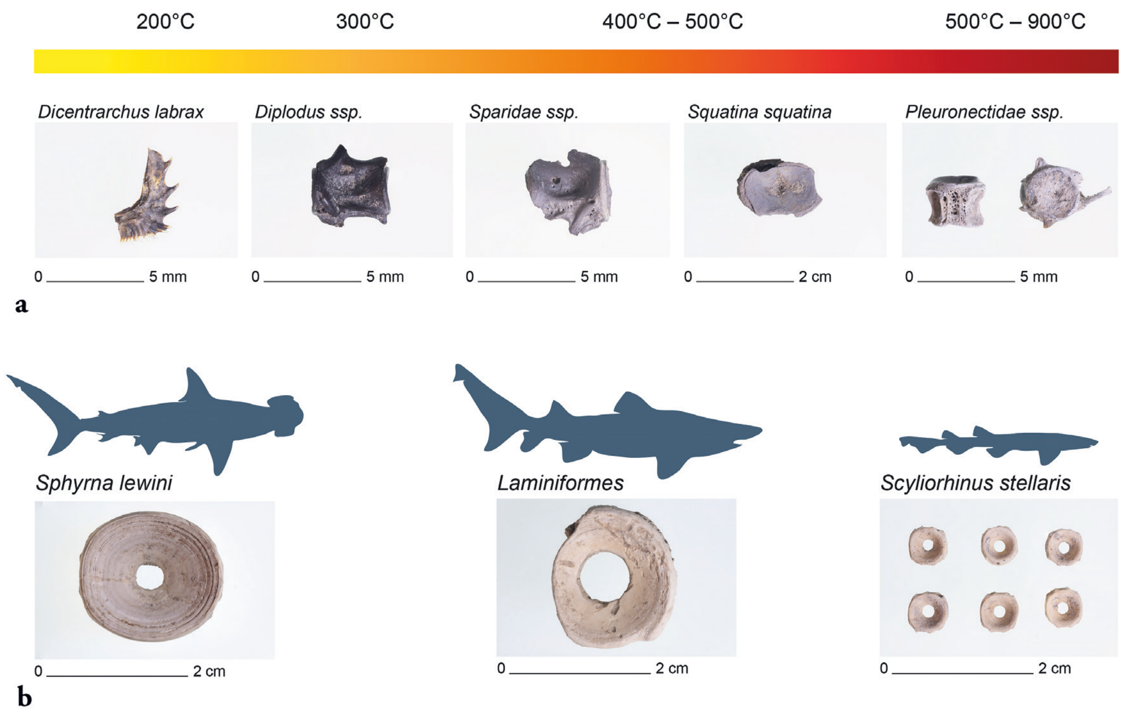


Fig. 9 Other observable marks; a: burn marks; b: anthropogenic marks (T. André, pictures: P. François [LA3M, CNRS-AMU UMR 7298])

part of the tooth could reflect, in addition to the previous hypothesis, the implementation of a technique used to lift the nets[39].

On the vertebrae, the position of the cuts is more systematic, whether dealing with eel, European seabass, scorpion fishes, *Sparidae* ssp. or *Mugilidae* ssp. Cutting appears to follow four patterns (fig. 8 c): longitudinal cutting of the *facies articularis anterior* or *posterior*; horizontal cutting of the vertebral body; single oblique cutting and double oblique cutting.

On the other hand, some taxa show little or no trace of cutting on their neurocranium, splanchnocranium or vertebra. These taxa are: angler fish (*Lophius spp.*), *Pleuronectidae* ssp., *Scophthalmidae* ssp., tuna (*Thunnus thynuus*) and *Cyprinidae* ssp.

In all three areas, as in the case of the cut marks, charred bone parts are visible. These are present on some or all of the bone, but mostly on the mandibular arch. The taxa that are largely affected are mainly the same as for the different cutting patterns. Several degrees of heating are visible, mainly on the vertebrae (fig. 9 a). At this stage of the study, it is not possible to define whether these burn marks are the result of culinary preparation or some other type of treatment. Precision of the destination and function of the discovered areas and structures of the site could provide an answer to this question in the near future.

Apart from the cuts and the effects of fire, a few other traces are also anthropogenic (fig. 9 b). They are only visible on vertebrae of selachiformes (*Lamniforma, Sphyrna* ssp. *and Scyliorhinus stellaris*). Their natural foramen in the vertebral centrum has been enlarged, transforming the bone into an object whose function is unknown.

[39] This technique is widely used in Japan for the preparation of eels. Delicious Tokyo, Japanese street food – Grilled Eel Barbecue Tokyo <https://www.youtube.com/watch?v=a5Y9v4ZQybg> (03.03.2023).

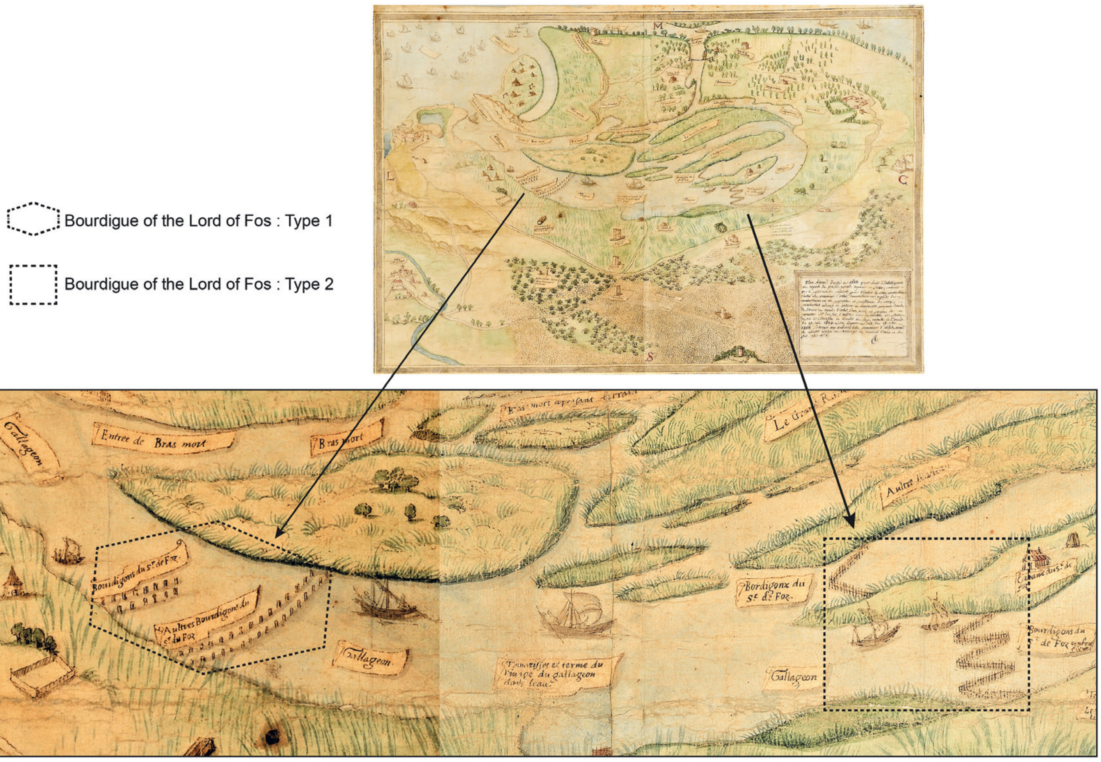


Fig. 10 Fos-sur-Mer, old Galegeon lagoon, figurative plan of the lands of Fos, 1584, Arles Municipal Library DD118 (T. André, photo: H. Lhote)

Fishing in the Fos area

In terms of acquisition practices, the study of archaeological objects related to fishing techniques, found *in situ*, may suggest the joint practice of net fishing and line fishing. The presence of tubular weights and several hooks in the three areas of the site encourage this hypothesis, which is confirmed by several medieval texts[40]. This type of practice seems to have been used in conjunction with bourdigues. Generally used in lagoons and shallow areas, these fixed traps made of reeds and wooden piles are still widely used in the Mediterranean[41] and allow the capture of a large number of varied coastal species, notably *Sparidae* ssp., *Mugilidae* ssp. and European eels (*Anguilla anguilla*). Mentioned as early as 1078[42], these highly productive fishing tools were the subject of covetousness and conflicts[43], some of which were waged at

40 It is mentioned in a notice dated 4th April 1217 that a trial took place between the inhabitants of Fos and Istres concerning the use of certain nets for fishing in the pond of Martigues; BA ms 861, 1413, 4th February. Item, it is mentioned in an extract of the agreements between the community of Fos and the coseigneurs in 1413 drawn up by the notary Isnard Fabri that »in the past, it was customary in the said *castrum* of Fos, for a long time and even more so, that the same men were obliged to ask for a licence to fish in the Etang de l'Estomac […] with nets and other implements […]«.

41 These are still actively used by professional fishermen in the Caronte canal, particularly for fishing sea bream (*Saprus aurata*) and mullets (*Mugilidae* ssp.), from which they obtain the eggs that will become poutargue.

42 Extract from the ›Authentic‹ register of the Chapter of Arles mentioning the restitution of the fishing of the ponds and the tithe of the bourdigues usurped by Pons de Fos and his followers from the church of Arles by the count of Toulouse, the archbishop of Arles and the lord of Baux; ACA GG f° 88 v° n° CII and f° 121, 1078.

43 At the end of the 13th cent. AD, a two-speed economy was established, with the bourdigues playing a dominant role in the local economy. As generators of super-profits, they dominated the market thanks to their profitability and their constant supply, unlike the small nomadic fishermen who moved from hut to hut according to the seasons and whose hazardous fishing was prey to increasing piracy, numerous local wars and leonine contracts imposed by the fishmongers, Rosello Izquierdo 1986.

the highest level of the state[44]. The importance of fishing and the use of bourdigues during the Middle Ages and the modern period is shown by their representation on a plan listing the lands belonging to the Lord of Fos in AD 1586 (fig. 10).

The wide range of species identified by our archaeoichthyological study tends to confirm the use of these different fishing tools, whether in the Galéjon or Estomac ponds and the Gulf of Fos on the Fos-sur-Mer side or in the Caronte and Berre ponds on the Martigues side.

With a view to specifying capture sites, isotopic analyses of bone collagen were carried out (analysis of carbon and nitrogen isotopic signatures) as part of the AMORCE project[45]. These analyses concern a sample of 78 remains belonging to six taxa and are elaborated in the work of L. Mion. However, we can note several interesting pieces of information: the eels are divided into two groups. The first, with low carbon values, spent the last stages of their lives in freshwater habitats. The second group, with high nitrogen and carbon values, spent their last years of life in marine environments or in lagoons. These distributions therefore suggest either two different fishing areas or two seasons. European seabass (*Dicentrarchus labrax*) and *Sparidae* ssp. have homogeneous values for each taxon with values specific to each. Bass have values consistent with their carnivorous diet. The Sparidae, omnivorous and with high carbon values, evolved in a lagoon or salt marsh type environment. The Mugilidae cover all the variability of the other taxa: several ethologies are therefore present, which is an additional argument for proposing the exploitation of different species and several fishing zones. Interestingly, the distribution of Mugilidae follows the different areas of the building: are they linked to specific fishing areas? To different uses? Do they come from different fishermen?

Finally, some specimens of Sparidae and European seabass (*Dicentrarchus labrax*) have values distinct from those of the others, which also raises the following questions: Does this indicate a fishing area beyond the range of the other individuals that were nevertheless present and fished locally; a different season of capture; modifications of the environment due to climatic and environmental changes[46]? Were these individuals that were caught during phases of occupation different from the general chronology of the site?

Undertaking more of this type of analysis and acquiring more in-depth results will eventually shed light on these issues.

Conclusion

The analysis of aquatic remains from the Habitat Mistral II shows opportunistic fishing throughout the entire fossa. Using nets, lines and bourdigues, the fishermen targeted European eel, European seabass, Mugilidae and Sparidae in particular, without, however, excluding other species evolving in the same environment. The presence of numerous chondrichthyan remains and rare open-water species suggests the exploitation of the margins of the territory. The richness of the faunal spectrum, the large number of scales, the multiple traces of debitage associated with other archaeobiological refuse and archaeological witnesses tend to characterise the site as a place of transformation and resale rather than a site of consumption throughout the duration of its occupation.

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44 Details of the trial between the archbishop of Arles and the king concerning the bourdigues of Saint-Geniès (Martigues); ACMA DD 28, 1331.

45 Mion et al. 2022. The project »Understanding fishing practices and the consumption of marine resources in the Mediterranean: contributions of isotopic analyses of archaeological-ichthyological remains« (ICHT'ISOMED²) has been funded by the Mediterranean Institute of Archaeology ARKAIA within the framework of the Start-up 2020 call for projects (end of activities: December 2021). It is co-funded by the Lampea and LA3M laboratories, the Doctoral School 355 Spaces Cultures Societies and the Autonomous University of Madrid <https://www.univ-amu.fr/en/public/icthisomed2> (03.03.2023).

46 This refers to changes in the deltaic plain that have led to changes in the environment. For example, a strong flood has modified the salinity and the substrate of the fishing area.

The in-depth study of ancient sources coupled with biochemical analyses will hopefully allow us to specify the precise exploitation of the different environments, the types of treatment inflicted on the fish, their trade on a regional or even national scale and to better understand the purpose of this building.

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Historical Sources

ACA GG f° 88 v° n° CII and f° 121, 1078	Municipal Archives of Arles
A.C. Arles CC 183 f° 42, 1455	Municipal Archives of Arles
ACMA DD 28, 1331	Municipal Archives of Martigues
ADBR B 7 f° 84 v°, 1323	Bouches-du-Rhône Departmental Archives
BA ms 861, 1413, 4 February	Arles Library
TC No. 169, 1114	Cartulary of Trinquetaille

Bibliography

André 2022 — T. André, Annexe 9. Étude archéoichtyologique du site de la place de l'Olivier à Marignane (13), in: M. Couval – C. Meunier – C. Vaschalde (eds.), Aux origines de Marignane: place de l'Olivier, îlot I1, école des arts, Marignane (13). Rapport final d'opération. Service Régional d'Archéologie de Provence-Alpes-Côte d'Azur, Mosaïques archéologie 2 (Cournonterral 2022) 643–653.

Cannon 1987 — D.-Y. Cannon, Marine fish osteology. A manual for archaeologists (Burnaby, BC 1987).

Carré et al. 2018 — F. Carré – A. Rast-Eicher – B. Bell – J. Boisson, L'étude des matériaux organiques dans les tombes du haut Moyen Âge. Un apport à la connaissance des pratiques funéraires et des vêtements?, in: L. Liogier – N. Bolo (eds.), Journées archéologiques de Haute-Normandie. Alizay, 20–22 June 2014, Journées archéologiques de Normandie (Mont-Saint-Aignan 2018) 195–214.

Clavel – Vorenger 2008 — B. Clavel – J. Vorenger, Quelques données sur la pêche et la consommation du poisson en milieu castral dans le comté d'Amiens (Somme, France) du X^{e} au XIV^{e} siècle, in: P. Béarez – S. Grouard – B. Clavel (eds.), XIVth ICAZ Fish Remains Working Group meeting. Archéologie du poisson. 30 ans d'archéo-ichthyologie au CNRS. Hommage aux travaux de Jean Desse et Nathalie Desse-Berset. XXVIII^{e} rencontres internationales d'archéologie et d'histoire d'Antibes (Antibes 2008) 61–66.

Courtemanche – Legendre 1985 — M. Courtemanche – V. Legendre, Fish Bones. Codified Nomenclature, French and English Names. Technical Report 06–38 (Montreal 1985).

Cuvier – Valenciennes 1828 — G. Cuvier – A. Valenciennes, Histoire naturelle des poissons (Paris 1828).

Desse – Desse-Berset 1996 — J. Desse – N. Desse-Berset, Osteometry and archaeology of the gilthead sea bream (*Sparus aurata*, Linnaeus 1758), Fiches d'ostéologie animale pour l'archéologie Series A – Fish 9, 1996, 3–31.

Duhamel Du Monceau – De La Marre 1769	H.-L Duhamel Du Monceau – L.-H. De La Marre, Traité général des pesches et histoire des poissons qu'elles fournissent, tant pour la subsistance des hommes, que pour plusieurs autres usages qui ont rapport aux arts et au commerce 2, Section IV, Chapter II, 1769, 11–12.
Dumas 2014	G. Dumas, Les substances marines dans le Livre des simples médecines, in: C. Connochie-Bourgne (ed.), Mondes marins du Moyen Âge, Senefiance (Aix-en-Provence 2014) 131–143.
Ebert – Dando 2022	D. A. Ebert – M. Dando, Requins, Raies et Chimères d'Europe et de Méditerranée (Paris 2022).
Jacquemard et al. 2013	C. Jacquemard – B. Gauvin – M.-A. Lucas-Avenel – C. Février – F. Lecocq, Hortus sanitatis 4. Fish, Fontes & Paginae. Centre de recherches archéologiques et historiques anciennes et médiévales (Caen 2013).
Kara – Quignard 2018	M.-H. Kara – J.-P. Quignard, Les poissons des lagunes et des estuaires de Méditerranée 1. Diversité, bio-écologie et exploitation (London 2018).
Kishimoto et al. 2006	H. Kishimoto – N. Suzuki – I. Akagawa, Gyoruigaku Zikken Tekisuto (Tokyo 2006).
Lagrue – Del Corso 1999	J.-P. Lagrue – M. Del Corso, Fos-sur-Mer, rue Frédéric Mistral. Document final de synthèse. Service Régional d'Archéologie de Provence-Alpes-Côte d'Azur (Aix-en-Provence 1999).
Lagrue 2002	J.-P. Lagrue, L'habitat médiéval de la rue Frédéric Mistral à Fos-sur-Mer, Etudes Vauclusiennes 67, 2002, 29–37.
Lestocquoy 1948	J. Lestocquoy, Baleine et ravitaillement au Moyen Age, Revue du Nord 30, 1948, 39–43.
Louisy 2022	P. Louisy, Guide d'identification des poissons marins. Europe et Méditerranée [4](Paris 2022).
Mion et al. 2022	L. Mion – T. André – A. Mailloux – M. Sternberg – A. Morales Muniz – E. Rosello Izquierdo – L. Llorente Rodríguez – E. Herrscher, Contribution to Mediterranean medieval dietary studies. Stable carbon and nitrogen isotope data of marine and catadromous fish from Provence (9th–14th CE), Data in Brief 41, 2022, 108016.
Philippe 2014	J. Philippe, La chirurgie dentaire de Guy de Chauliac, Actes Société française d'histoire de l'art dentaire 19, 2014, 22–25.
Pichard et al. 2017	G. Pichard – G. Arnaud-Fassetta – V. Moron – E. Roucaute, Hydroclimatology of the Lower Rhône Valley. Historical flood reconstruction (AD 1300–2000) based on documentary and instrumental sources, Hydrological Sciences Journal 62, 11, 2017, 1772–1795.
Quiqueran de Beaujeu 1614	P. Quiqueran de Beaujeu, La Provence louée. Divisée en trois livres, traduitz du latin par M. F. de Claret (Lyon 1614).
Rosello Izquierdo 1986	E. Rosello Izquierdo, Contribuciòn al Atlas Osteològico de los Teleòsteos Ibéricos 1. Dentario y Articular (PhD thesis Universidad Autònoma de Madrid 1986).
Sternberg 1995	M. Sternberg, La pêche à Lattes dans l'Antiquité à travers l'analyse de l'ichtyofaune, Lattara 8, 1995, 91.
Thieren et al. 2012	E. Thieren – W. Wouters – W. Van Neer – A. Ervynck, Body length estimation of the European eel *Anguilla anguilla* on the basis of isolated skeletal elements, Cybium. International Journal of Ichthyology 36, 4, 2012, 551–562.
Vella et al. 2005	C. Vella – T.-J. Fleury – G. Raccasi – M. Provansal – F. Sabatier – M. Bourcier, Evolution of the Rhône delta plain in the Holocene, Marine Geology 222/223, 2005, 235–265.

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What's Going on in the Head of a Fish?

Skeletal Measurements of Pike (*Esox lucius* L. 1758)

László Bartosiewicz

Abstract

Body length estimations of pike have had a long tradition in archaeoichthyology. However, relationships between measurements need to be further understood. A dozen commonly preserved bone lengths and transversal dimensions were studied in the skeletons of extant pike in Sweden. While traditionally used lengths (e.g. dentale inner length, cleithrum chord length) understandably offer the best estimates of total length, thanks to the growth characteristics of fish, all studied measurements were highly correlated with each other. Univariate parameters of the measurements can also be used in calculating standard scores (z) or variability size indices (VSI) for direct comparisons between fragmented archaeological finds.

Introduction

People have been fascinated by the pike since time immemorial. It has always been a valuable source of food laden with symbolic meaning. As is often the case with animals, the perception of this fish is dualistic in nature[1]. In medieval Europe the pike was described as a ferocious, insatiable and mysterious creature, which would attack people and animals[2]. On the other hand, white pike meat was considered to be healthy, and the liver was regarded a royal delicacy[3]. During the 15th century, a separate pond was built for highly valued pike in the Eger diocese, Hungary[4]. The prestigious pike stands out as the most frequently mentioned species in early modern age cuisine, making up over 12 % of all fish recipes in two Hungarian cookbooks, written by István Galgóczi[5] and János Keszei[6]. The latter work, dedicated to the wife of Michael Apafi I, elected prince of Transylvania, relied extensively on an earlier royal source, written by the court chef of the Mainz Elector[7]. When King Sigismund of Hungary donated the coat of arms to court master chef Ferenc Eresztvényi in 1414, of all the animals around the kitchen, pike was the symbol of choice[8].

Pike played a prominent role in pre-Christian Karelian and Finnish oral tradition, compiled into the romanticised national epic Kalevala in the mid-19th century. Its main protagonist, Väinämöinen, the god of songs and poetry, slayed the mighty pike of Northland. Then he made a magical *kantele*, a plucked string instrument, »from the jaw-bones of the monster«[9]. It speaks for the awe felt toward pike that this motif was selected to characterise Väinämöinen as late as the end of the 19th century (fig. 1). Even today, pike seems to be the only freshwa-

1 Bartosiewicz 1998.
2 De Laak – van Emmerik 2006, 39.
3 Csánki 1897, 37.
4 Kerezsy 1910.
5 1622 in Herman 1887, tab. 1: 168 fish recipes.
6 1690 in Lakó 1983: 331 fish recipes.
7 Rumpolt 1581.
8 Fejérpataky 1901, 36.
9 Lönnrot 1888, 601.

Fig. 1 A: Coat of arms donated to Ferenc Eresztvényi in 1414 (Fejérpataky 1901, 37); B: The 1888 romantic statue of Väinämöinen by Robert Stigell in Helsinki (photo: Wikimedia, Deed – Attribution-ShareAlike 3.0 Unported – Creative Commons)

ter fish whose head is regularly mounted as a trophy of ›water wolf‹, with mouth invariably agape to show off the row of fearsome teeth.

Pike bones tend to be well preserved in archaeological deposits. Larger specimens at least can even be retrieved by hand collection. Importantly, the identification of most skeletal elements from pike is unambiguous, in contrast to, for example, cyprinids, whose remains may represent a dozen osteologically very similar species. As will be demonstrated, a better understanding of size and body proportions can contribute to the archaeological interpretation of pike remains.

Research questions

As stated in the title of the paper, the research hypothesis is that better understanding the relationships between bone measurements in the head region of pike help in appraising how various measurements can be used in reconstructing the total length (henceforth TL) of pike from archaeozoological finds, thereby furthering their economic and cultural interpretation.

How does the quality of reference materials influence the reconstruction of pike size? In the first step, missing values will be estimated using previous results[10]. Following the appraisal of the way this procedure impacts the dataset, the multivariate structure of measurements and their influence on grouping individuals can be explored. Finally, the practical application of results will be illustrated.

[10] Bartosiewicz 1990.

This paper is the critical re-evaluation of data used in a previous study, presented at the fifth meeting of the Fish Remains Working Group of ICAZ on the island of Stora Kornö, Sweden, hosted by L. Jonsson in 1989. As the publication of formal conference proceedings did not follow, I submitted the paper to a local fisheries journal in Hungary[11]. The current study also offers an opportunity to reflect on 30 years of developments in research that have improved our theoretical and methodological insights.

Theoretical background and research history

Size is the result of growth. However, an important distinction needs to be made between absolute and relative growth. In contemporary fisheries research growth rates measured over time, such as weight gain, are instrumental in monitoring pike ontogeny in different habitats[12]. Precise ageing and measuring complex environmental parameters, however, are largely impossible in archaeological contexts.

On the other hand, relative growth rates are not measured in time but within the body itself, comparing its various measurements to one another. The resulting trends are thus less directly influenced by the environment and emphasise body proportions. Based on this principle, pike length estimations have had a century-long tradition in archaeozoology. E. L. Niezabitowski[13] noted that some pike teeth in his assemblage were as long as 14 mm, while an 8 mm-long tooth belonged to a 48 cm-long extant pike skeleton he used as a reference. Thus, he concluded that specimens from the second interglacial period reached 1 m. Using this simple proportional method seemed sufficient for fish, a class of animals that maintains a relatively even growth rate throughout life[14], resulting in the more or less linear growth of various body dimensions relative to one another. This is in contrast to homoiotherm animals, whose growth rates vary throughout their life, resulting in different body proportions along with decelerating size increases[15]. For example, the sequence of long bone epiphyseal fusion in mammals determines different body shapes at different stages of development. However, among fish, the main body proportions do not seem to change significantly beyond the larval stage. Figure 2 visually summarises this general ontogenetic feature in pike, synthesising results from B. N. Kazansky and A. Koblitskaya[16].

Meanwhile, reconstructing standard lengths for 2000-year-old pike remains in Russia, G. V. Nikolsky[17] noted that different measurements taken on the same cleithrum yielded different body length estimates, a subtle sign that not all measurements of pike grow at exactly the same rate. For example, the mouth of juveniles is relatively large[18].

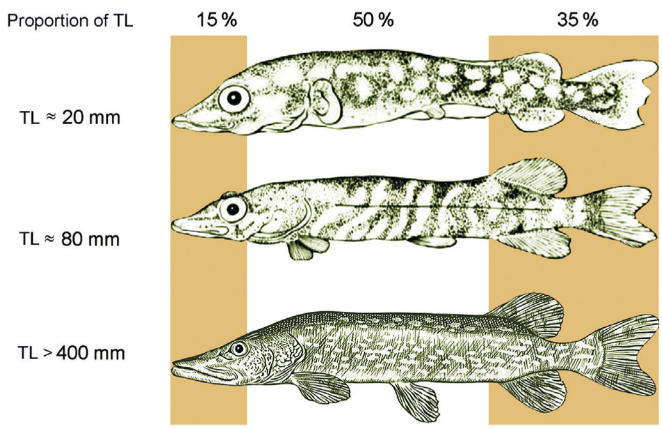

Fig. 2 Longitudinal body proportions within the TL of pike between ca. 10 days of age and full maturity (L. Bartosiewicz)

[11] Bartosiewicz 1990.
[12] Harka 1983, 112, tab. 4.
[13] Niezabitowski 1929, 64.
[14] Hecht 1916, fig. 11.
[15] Robbins et al. 1928.
[16] Kazansky 1956; Koblitskaya 1981.
[17] Nikolsky 1935, 92.
[18] Berinkey 1966, 36.

This would be a classic case of allometric growth: due to differences in their growth rates, some body parts grow ›apart‹ from each other, influencing shape: proportions change with overall size[19].

Absolute and relative growth are intimately related. J. M. Casselman monitored the concurrent linear growth of calcified structures in 315 extant pike over a broad age and size range (TL = 112–914 mm), and he recorded positive allometry in bone growth relative to TL during phases of rapid absolute growth and negative allometry during slow growth, demonstrating that slow-growing pike have relatively smaller cleithra[20]. In spite of their theoretical significance, such valuable observations in fisheries science are beyond the resolution of osteological studies in archaeology due to the paucity of data, including the frequently elusive absolute age. Ageable incremental structures (scales, otoliths, vertebrae) cannot be directly linked to the rest of the measurable bones, with the exception of the chance recovery of entire skeletons.

Material and methods

Thanks to the singular (or at most paired) presence of easily identifiable head elements, their use in size reconstruction is relatively straightforward and was increasingly studied by the end of the 1970s in archaeology[21], including the analysis of pike remains[22]. In spite of the large numbers of vertebrae recovered, their applicability in estimating size has been less advanced as there are 61–64 of them in pike[23]. Therefore, at the time of my data collection, vertebral measurements seemed of peripheral interest, although in a recent study of 27 complete extant individuals, I. Jelu et al. have elegantly demonstrated their applicability in reconstructing the body length and weight of pike in archaeological assemblages using the proportional method[24].

Material

I measured the 24 pike skeletons used in this analysis during a 1983 research trip in Sweden. Two-thirds (16) of these individuals were kept in the Museum of Natural History in Gothenburg (NHMG), while four could be studied in each of the Osteoarchaeological Research Laboratory of Stockholm University (OFL) and the Zoological Museum in Uppsala (UZM). Consistent documentation on the sex and geographical origins of these fish was missing; even the TL was recorded in only eight cases[25].

Due to this absence of fundamental information, the importance of sexual dimorphism in size estimation needs to be considered. Students' t-tests comparing the growth at absolute age intervals of 188 male and 159 female pike in England[26] showed no significant difference in the first two years; males become sexually mature by the second year, and females by the third[27]. In the study by P. R. Bregazzi and C. R. Kennedy[28], females of the same age became slightly larger among adults. According to a recent study, slow-growing, long-lived pike populations show greater female-biased sexual dimorphism in size, a trend corroborated by energy-dense offshore prey and cooler water temperatures at increasingly northern latitudes[29].

19 Huxley – Teissier 1936.
20 Casselman 1990, 679.
21 Casteel 1976.
22 E.g. Lepiksaar – Heinrich 1977; Torke 1981.
23 Kiss 2000.
24 Jelu et al. 2021.
25 Bartosiewicz 1990, 29, fig. 3.
26 Bregazzi – Kennedy 1980, 95.
27 Berinkey 1966.
28 Bregazzi – Kennedy 1980.
29 Kennedy – Rennie 2023, 3.

Although this phenomenon may have affected individuals from Sweden, being a function of absolute age, sexual dimorphism is unlikely to bias the proportion of bones within the skeleton. Independently of sex, cleithra from slow-growing pike were significantly smaller in comparison to those from fast-growing pike for a given body size in a sample of 133 extant pikes from Canada[30].

Differing aquatic habitats also influence body proportions through selection for optimal shape. In relation to sustained burst swimming in rapid rivers, pikes become selected for significantly more elongated heads, dorso-ventrally deeper bodies and longer dorsal fin insertions[31]. Pike in the brackish water of Bothnian Bay migrate upstream in coastal rivers to spawn[32], while those inhabiting the Great Hungarian Plain during prehistory lived in unregulated slow-flowing rivers and their stagnant oxbows[33]. Theoretically, a difference may be present in overall body proportions of the reference assemblage from Sweden and archaeological pike remains from Hungary. In practice, however, it would not be detectable in the small, non-random samples available for study.

In short, although both the sex and geographical origins/habitat characteristics of pike demonstrably influence body size, such differences are manifested in terms of absolute growth and thus cannot be investigated through the relationships between the bone measurements available for study.

Methods

Previous estimations of total length in pike

By the late 1980s the use of fish bone measurements in estimating fish size reached its peak in archaeology[34]. Of the measurements discussed in the previous study[35], dentale inner length (dn.i.l.) stands out in terms of practical importance. As a rule of thumb, multiplying this measurement by ten gives a fair estimate of TL[36]. This empirical observation was supported by two different sets of calculations. When plotting decimal logarithms of TL against those of dn.i.l. in 109 individuals, D. C. Brinkhuizen[37] obtained a relative growth rate corresponding to an allometric coefficient of 1.006 (the allometric coefficient 1 corresponds to isometry, indicative of linear growth). The same value was 0.948 on the basis of a small sample of 13 mostly large pike in my previous study[38].

Measurements selected for analysis

The thirteen measurements were taken according to the protocol published by A. Morales and K. Rosenlund[39]. They represent the ›head‹ region (neurocranium, suspensorium, gill cover and zonoskeleton) as listed in table 1 and shown in figure 3. Based on the clarity of definition according to A. Morales and K. Rosenlund[40], seven of them are of ›great value‹ thanks to their unequivocal measuring points. Six measurements are of ›medium value‹ due to their less precise measurability. In view of the practical applicability of results for archaeological

30 Casselman 1990, 679 f.
31 Senay et al. 2017.
32 Raat 1988.
33 Bartosiewicz 2012, 213.
34 Prummel – Brinkhuizen 1990.
35 Bartosiewicz 1990, 30.
36 J. Lepiksaar, personal communication.
37 Brinkhuizen 1989, 92.
38 Bartosiewicz 1990, 30.
39 Morales – Rosenlund 1979.
40 Morales – Rosenlund 1979, 7.

Table 1 The list of measurements taken after Morales – Rosenlund 1979. Abbreviations: C-C: cranio-caudal, M-L: medio-lateral, D-V: dorso-ventral

No.	Element	Measurement	Abbreviation	Dimension
1	Neurocranium	basal length (oral end of vomer to aboral end of proatlas)	ncr.ba.l.	C-C
2	Vomer	greatest breadth	vo.gr.b.	M-L
3	Proatlas	greatest breadth	proa.gr.b.	M-L
4	Proatlas	greatest height	proa.gr.h.	D-V
5	Dentale	anterior height	dn.a.h.	D-V
6	Dentale	inside length, from the oral end to the median incision	dn.i.l.	C-C
7	Maxillare	greatest length	mx.gr.l.	C-C
8	Articulare	greatest breadth of the articular surface	art.gr.b.	M-L
9	Quadratum	greatest breadth of the articular surface	qu.gr.b.	M-L
10	Operculum	greatest breadth of the articular surface	op.gr.b.a.s.	M-L
11	Operculum	greatest height of the articular surface	op.gr.h.a.s.	D-V
12	Preoperculum	chord length	pop.c.l.	D-V
13	Cleithrum	chord length	cl.c.l.	D-V

finds, I strove to include mostly compact, not easily damaged skeletal parts that have better-preserved, intact measurements.

The orientation of bones within the skeleton may influence their applicability in size estimation. Measurements within the same geometrical dimension are highly correlated, that is, represent potentially redundant information. In table 1, cranio-caudal, medio-lateral and dorso-ventral directions were distinguished.

Regardless of the methods of comparison, size reconstructions in archaeozoology directly depend on the composition of reference collections. This potential source of bias tends to be overlooked in analyses. In our case, the size distribution of the 24 extant pikes available for study was far from random. Almost half of the skeletons originated from individuals whose TL probably exceeded 1 m, while no individuals significantly shorter than 0.5 m were represented among them. This composition seems to indicate that capital size pike had a greater chance of ending up in museum collections.

Missing values

One important feature of the skeletons housed in museum collections not addressed in the previous study is that all of them were incomplete to some extent, that is, neither of the 24 skeletons had all 13 measurements available for study. As shown in table 2, altogether 84 (26.9 %) of the possible 312 measurements (13 variables by 24 cases) were missing. This shortage did not bias the pairwise allometric equations calculated between dn.i.l. and the other measurements[41] but would preclude the synthetic evaluation of relationships between skeletal dimensions.

Missing values in the dataset could be estimated using the allometric equations developed in the previous study[42]. The reliability of those equations was supported by high positive correlations between the decimal logarithms of dn.i.l. (used as a proxy for TL) and the rest of the measurements. Almost all correlations were highly significant ($p \leq 0.001$); only the poorly represented neurocranium base length (ncr.ba.l.) showed a slightly lesser, but still very convincing level of statistical probability ($p \leq 0.010$).

41 Bartosiewicz 1990, 30–32.
42 Bartosiewicz 1990, 32 tab. 5.

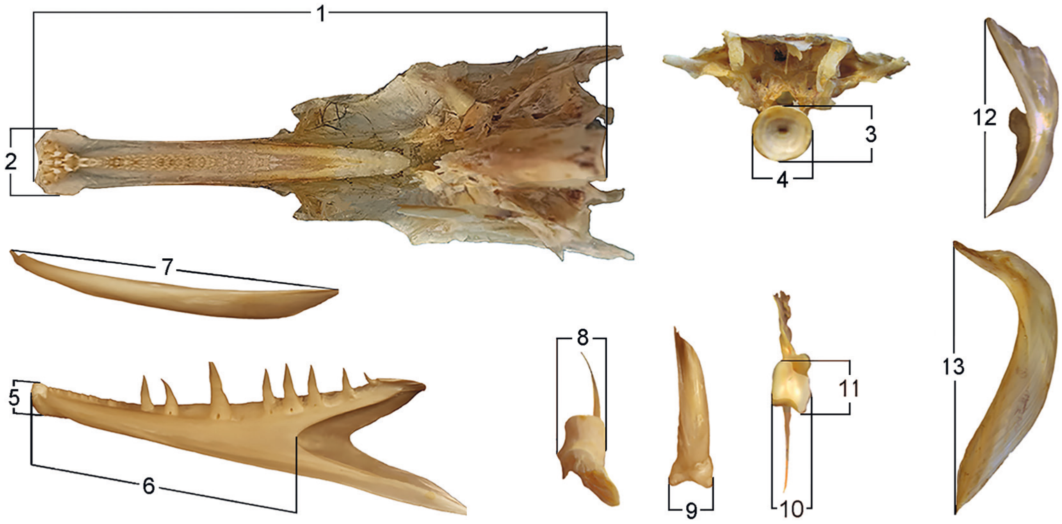

Fig. 3 Bone measurements used in the study. Numbers correspond to the descriptions listed in table 1 (L. Bartosiewicz)

Results obtained after the calculation of missing values were compared to statistical parameters of a ›core group‹ of 11 individuals (from the 24) represented by at least seven measurements. They formed a smaller but compact dataset in which all measurements were available for all individuals. Thus, the influence of missing value estimations could be appraised by comparing the statistical parameters of measurements prior to and after estimations.

Multivariate relationships between measurements

In the next step, the grouping of the 13 measurements was analysed using a principal component analysis (PCA) to explore their relationships and help map the 24 individuals by the patterns of measurements thus established. Given the large size differences between the 13 measurements, decimal logarithms were used in this calculation to buffer the overwhelming dominance of large values (usually lengths) compared to transversal dimensions (medio-lateral breadths and dorso-ventral depths). All calculations were performed using the PAST 2.04 software[43].

Archaeological specimens in relation to the reference collection

Mean values and standard deviations of all 13 measurements can be used in a range of size index scaling techniques based on size ranges in reference ›populations‹[44] rather than a single reference specimen. The advantage of these methods is that they utilise sometimes very different measurements through conversion to a uniform mean value (standardised as 0) and the pertinent standard deviation (±1). Standard scores (z-values) are calculated by dividing the difference between the individual archaeological measurement and the relevant reference mean value by the standard deviation of the same bone measurement. This will place each bone measurement against the backdrop of the known parameters of the reference collection. A potential bias of this method is that unless skeletons are discovered *in situ*, different skeletal elements originating from the same individual are difficult to recognise as such in commingled food refuse. This means that in a mathematical sense, the resulting scores are not guaranteed to be independent from one another.

[43] Hammer 2020.
[44] Meadow 1999.

Table 2 Raw data used in the analysis. For the abbreviation of museums, consult the text. Italics mark estimates for missing values

No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Abbreviation	ncr.ba.l.	vo.gr.b.	proa.gr.b.	proa.gr.h.	dn.a.h.	dn.i.l.	mx.gr.l.	art.gr.b.	qu.gr.b.	op.gr.b.a.s.	op.gr.h.a.s.	pop.c.l.	cl.c.l.
OFL	*106.1*	*11.6*	*7.1*	*6.9*	*4.2*	39.9	44.7	3.6	*4.0*	3.2	4.1	34.2	*41.5*
OFL	*108.6*	10.9	6.0	5.5	4.1	41.2	43.9	4.2	4.6	2.7	4.8	33.9	53.2
NHMG	112.2	10.8	7.9	10.2	4.8	42.2	35.4	4.2	4.6	*3.3*	*4.7*	*36.3*	58.1
NHMG	*115.7*	*13.1*	*8.1*	*7.7*	5.3	44.9	50.1	4.9	4.1	3.9	4.9	39.1	65.2
NHMG	115.7	19.4	8.9	7.6	5.4	51.1	59.9	5.3	5.4	*4.2*	*5.6*	40.1	66.9
NHMG	*131.5*	15.9	*9.9*	*9.0*	5.8	53.2	60.4	*5.6*	6.8	5.3	6.9	46.2	*57.8*
OFL	*144.3*	15.9	*11.3*	*10.1*	7.2	59.9	70.2	7.1	7.2	5.1	6.7	49.1	79.1
NHMG	*154.4*	18.3	13.3	11.2	5.7	65.2	*72.5*	5.7	8.2	5.5	7.2	58.9	98.6
OFL	*167.1*	20.6	*13.8*	*12.0*	9.1	71.9	76.1	8.6	8.1	5.3	7.1	*59.8*	93.9
NHMG	*178.4*	*23.0*	*15.1*	*13.0*	10.3	77.8	*88.0*	9.3	*9.6*	*6.7*	*8.6*	*64.5*	*88.0*
NHMG	*182.2*	22.1	14.6	12.2	7.9	79.8	91.7	9.1	8.9	6.1	9.3	68.1	106.3
NHMG	203.2	23.2	18.7	15.3	9.9	80.4	89.3	9.3	*10.0*	6.9	8.1	71.2	109.0
NHMG	*203.3*	*27.0*	*17.9*	*15.1*	9.9	90.9	*104.1*	9.9	*11.6*	*7.9*	*10.0*	*74.8*	104.1
NHMG	*210.8*	*28.2*	*18.7*	*15.7*	11.8	94.8	108.9	10.3	11.4	8.4	9.2	75.9	125.3
NHMG	212.5	35.1	19.5	15.8	12.6	97.1	107.2	12.2	13.4	10.2	12.0	81.9	125.2
UZM	209.5	29.6	18.1	13.2	11.2	98.1	113.6	11.9	13.2	7.1	10.4	76.1	134.2
NHMG	*217.4*	*29.2*	*19.4*	*16.3*	13.1	98.3	112.1	11.4	12.9	9.1	10.8	82.9	134.0
NHMG	*226.8*	26.1	*20.5*	*17.1*	15.0	103.2	112.9	13.2	13.8	*9.0*	*11.3*	*84.6*	131.8
UZM	238.4	36.1	23.2	18.8	10.2	103.4	122.2	12.6	13.4	8.9	11.2	81.9	*119.4*
UZM	228.0	31.6	18.4	14.8	13.2	105.2	108.2	12.5	13.2	8.6	10.8	78.8	130.4
NHMG	*238.2*	30.8	*21.7*	*18.1*	13.1	109.2	*126.5*	12.8	13.7	*9.6*	*12.0*	89.9	143.2
UZM	*251.5*	*34.6*	*23.2*	*19.2*	12.2	116.2	*135.1*	13.2	*15.3*	*10.3*	*12.8*	*94.8*	*135.1*
NHMG	243.6	35.2	22.9	20.6	15.9	116.4	151.2	14.8	15.1	10.7	10.9	99.3	152.4
NHMG	*254.8*	31.9	23.2	21.1	14.1	117.8	139.4	15.8	16.3	10.5	15.9	96.9	155.9

Table 3 Univariate statistical parameters of all measurements. Abbreviations: sd: standard deviation, cv: coefficient of variation. *TL estimates (Buitenhuis 1989) are included for general information

No.	Measurement	n	Mean	sd	Min.	Max.	Median	Skewness	Kurtosis	cv %
1	ncr.ba.l.	24	185.6	50.4	106.1	254.6	203.3	–0.355	–1.330	27.2
2	vo.gr.b.	24	24.2	8.3	10.8	36.1	24.7	–0.213	–1.219	34.3
3	proa.gr.b.	24	15.9	5.7	6.0	23.2	18.0	–0.347	–1.219	35.7
4	proa.gr.h.	24	13.6	4.5	5.5	21.1	14.0	–0.105	–0.917	32.7
5	dn.a.h.	24	9.7	3.7	4.1	15.9	10.1	–0.089	–1.257	37.8
6	dn.i.l.	24	81.6	26.3	39.9	117.8	85.7	–0.297	–1.315	32.2
7	mx.gr.l.	24	92.7	32.7	35.4	151.2	97.9	–0.138	–0.957	35.3
8	art.gr.b.	24	9.5	3.7	3.6	15.8	9.6	–0.145	–1.192	38.6
9	qu.gr.b.	24	10.2	3.9	4.0	16.3	10.7	–0.238	–1.291	38.5
10	op.gr.b.a.s.	24	7.0	2.5	2.7	10.7	7.0	–0.161	–1.251	36.1
11	op.gr.h.a.s.	24	9.0	3.0	4.1	15.9	9.3	0.149	–0.400	33.6
12	pop.c.l.	24	67.5	21.0	33.9	99.3	73.0	–0.298	–1.149	31.1
13	cl.c.l.	24	104.5	34.0	41.5	155.9	107.7	–0.340	–1.101	32.5
	TL*	24	88.4	26.5	46.5	124.9	92.5	–0.296	–1.315	29.9

Results

Missing values

Table 3 summarises the univariate statistical parameters for each measurement following the estimation of missing values using the allometric equations[45]. In table 3 the resulting mean values are indicative of relatively large individuals within the dataset. Differences between the mean and median values signal an asymmetry in the distribution, directly expressed by skewness. Compared to the normal distribution, a negative skew means that more values are concentrated on the right side of the bell-shaped Gaussian curve, while the left tail is distinctly elongated. Consistently negative kurtosis values indicate that the distribution has, in general, lighter tails than the normal distribution and that values do not particularly peak at the mean value, i.e. there are not many ›average‹ individuals. Nevertheless, the coefficients of variation (cv, %) are consistent with the degree of natural variability among the 24 pike in this non-random sample.

A comparison to the core group of 11 individuals in table 4 helps critical understanding of these results. The estimated missing values somewhat reduced the mean value, that is, improved the contribution of smaller pike: the substitution of missing values reduced the asymmetry of size distribution. With two exceptions, the coefficients of variation for the seven measurements slightly decreased, showing a weak homogenising effect of data estimation. All this means that thanks to the estimation of the 82 missing values, the 24 individuals represent a group of fish whose average size became somewhat smaller but more balanced in terms of the distribution of individual bone measurements.

The statistical parameters obtained for the reference collection will be a useful tool in reconstructing TL. In general, however, mean values for fish sizes cannot be exactly determined as fish maintain a relatively even growth rate throughout their lives[46].

45 Bartosiewicz 1990, 32 tab. 5.

46 Reitz et al. 1987, 306.

Table 4 Selected univariate statistical parameters of the core group of individuals represented by seven measurements

No.	Measurement	n	Mean	Min.	Max.	Skewness	cv %
2	vo.gr.b.	11	26.7	10.9	36.1	–0.564	31.3
3	proa.gr.b.	11	17.0	6.0	23.2	–0.775	33.8
4	proa.gr.h.	11	14.2	5.5	21.1	–0.280	35.0
5	dn.a.h.	11	10.0	4.1	15.9	–0.156	38.5
6	dn.i.l.	11	86.9	41.2	117.8	–0.603	29.6
8	art.gr.b.	11	10.3	4.2	15.8	–0.338	37.9
12	pop.c.l.	11	71.6	33.9	99.3	–0.639	28.9

Grouping of measurements and individuals

Principal component analysis (PCA) was used to identify components that account for possibly the most variance in the set of 24 extant pikes. While in principle 13 measurements could result in 13 components, only a single principal component emerged (PC1). The eigenvalue, measuring the variance encompassed by this component, represented an overwhelming 96.5 % of the total variance. Even the next principal component (PC2) was dwarfed by PC1, accounting for a mere 0.9 % of total variance. This result is unsurprising given the very high correlations between the measurements. All it shows is that the bigger the pike, the larger its bones, a conclusion evident even without complex calculations. PC1 thus corresponds to size.

However, relationships between each measurement and PC1 are more elucidating. They are characterised by the loadings of each measurement by which they are connected to the principal components within the +1 to –1 range. According to table 5, PC1 is unipolar, i.e. has only positive loadings. Thanks to the logarithmic transformation, shorter and longer measurements are equally associated with it. Only the greatest breadths of articulars (art.gr.b.) and quadrata (qu.gr.b.) attained loadings slightly exceeding 0.3, but even they do not stand out in particular.

Table 5 Principal component loadings of each measurement (PC3–PC13 represent only 2.619 % of total variance). Italics mark outstanding values mentioned in the text

No.	Measurement	PC1	PC2
1	ncr.ba.l.	0.214	0.076
2	vo.gr.b.	0.273	*0.458*
3	proa.gr.b.	0.299	0.232
4	proa.gr.h.	0.253	*0.692*
5	dn.a.h.	0.299	0.215
6	dn.i.l.	0.261	–0.078
7	mx.gr.l.	0.286	–0.356
8	art.gr.b.	*0.318*	–0.088
9	qu.gr.b.	*0.322*	–0.114
10	op.gr.b.a.s.	0.293	0.033
11	op.gr.h.a.s.	0.256	–0.208
12	pop.c.l.	0.250	0.071
13	cl.c.l.	0.262	0.048
	eigenvalue	0.364	0.003
	eigenvalue %	96.462	0.919

Even if PC2 is very weak (accounting for less than 1 % of total variance), it is bipolar and shows a greater spread of loadings. The extremes are represented by the greatest breadth of vomer (vo.gr.b., smallest loading) and the greatest height of the proatlas (proa.gr.h.; highest loading). These are measurements at either end of the neurocranium base length and perpendicular to one another.

Figure 4 A illustrates the low, positive but concentrated position of all measurements along PC1, while a more diverse vertical distribution is shown along PC2. This may suggest some polarisation between dorso-ventral dimensions and measurements in the cranio-caudal and medio-lateral dimensions. However, the visual pattern remains unconvincing, as the explanatory value of PC2 is very small (eigenvalue < 1).

Plotting the individual scores of each pike in the plane defined by PC1 and PC2 (fig. 4 B) offers an opportunity to visually summarise the differences between fish in the core group and those potentially affected by the estimation of

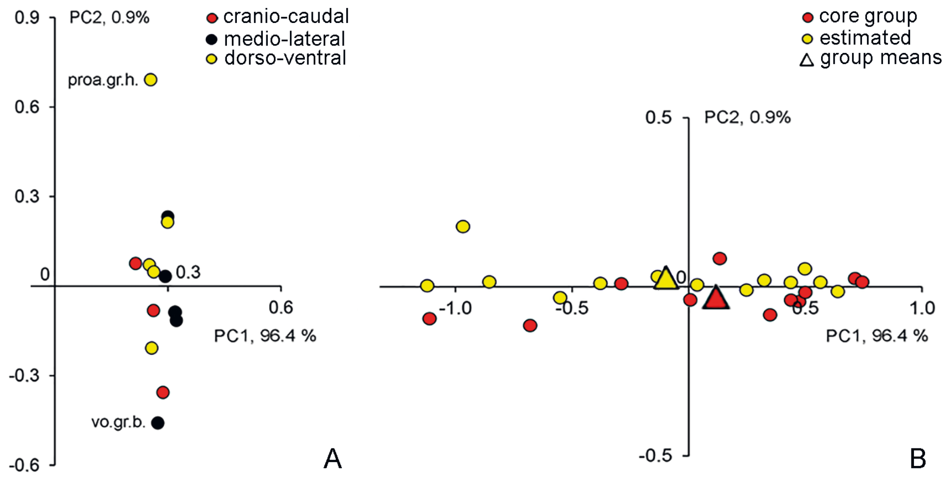

Fig. 4 A: The distribution of various types of measurements in the plane defined by the first two principal components (PC). B: The distribution of core individuals and those with estimated measurements in the plane defined by the first two principal components (PC) (L. Bartosiewicz)

more missing values. There is a strong overlap between the two groups, with slightly more small pike falling in the latter (negative scores on PC1, size). The mean scores of both groups fall close to the origin of the plot as well as one another.

Figure 5 is a practical comparison between measurements in terms of their potential in characterising size (loadings on PC1) and availability in the 24 studied skeletons (% of presence). The group of measurements occurring more frequently than 60 % of the cases and best associated with ›size‹ (PC1 > 0.275) includes the length of the maxilla and the breadths of the articular surface measured on the articular (art.g.b.), quadratum (qu.gr.b.) and operculum (op.gr.b.a.s.). Of the dorso-ventral dimensions, dentale anterior height (dn.a.h.) falls within this category. The eminence of this measurement is consonant with the observation that this measurement was of great use in estimating the TL of Ertebølle-period pike from Denmark[47]. Thanks to their especially close correlation to overall size, skeletal elements in the jaw region (dentale, articular, quadratum) can be profitably used in calculating TL.

In general, among the 13 measurements selected for study, bone breadths representing the medio-lateral dimension seem to be both well preserved and characteristic of the size of pike. I. Jelu et al.[48] noted that the allometric growth of the length of the first five vertebral centra in 27 extant individuals reflected an increase in TL quite closely (around b = 0.935). Smaller coefficients of allometric growth obtained for the transversal dimensions of the same five vertebrae (around b = 0.850) did not differ between medio-lateral breadth and dorso-ventral height.

Discussion

Improved familiarity with the way the 13 measurements are related to the length of individuals facilitates their use in defining the position of the archaeological specimens in relation to the size distribution of the 24 reference individuals. However, these predominantly large extant pikes do not serve for direct comparison. They rather provide a background, against which archaeological pike bones become comparable to one another.

This type of application is illustrated here by calculating standard scores (z-values) that allow diverse osteometric data measured on fragmented archaeological bone finds to be pooled.

47 Enghoff 1994, 86.
48 Jelu et al. 2021, 6 tab. 2.

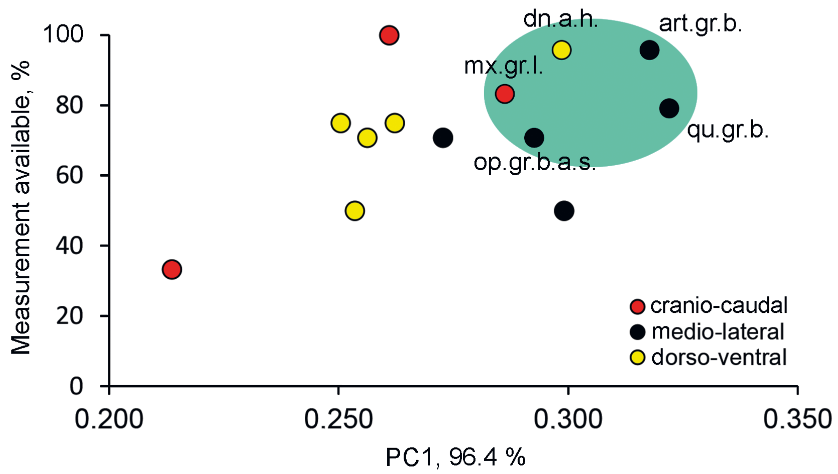

Fig. 5 Comparing measurements in terms of their relation to overall size (PC1) and availability in the dataset (%). Shading indicates measurements of most practical use (L. Bartosiewicz)

Several other scaling techniques reviewed by R. H. Meadow[49] rely on the use of mean values and standard deviations following the same principle. The advantage of these methods is that they offer a possibility for pooling measurements taken on various fragments.

Archaeological applications

Pike remains from three archaeological sites in Hungary will be used to illustrate this use of the results presented in this paper. These are the Early Neolithic settlements of Ecsegfalva 23B (5800/5750–5650 calBC)[50] and Ibrány-Nagyerdő (5620–5480 calBC)[51], while for the purpose of comparison, a third site, Esztergom-Várhegy-Kőbánya, represented a high-status late medieval settlement (1295–1395 calAD and 1405–1430 calAD, respectively)[52].

Water-sieving was carried out using a 2.5 mm mesh size at the two Early Neolithic sites, while the medieval material was dry screened with mesh sizes of 2 mm and 5 mm.

Table 6 shows the number of measurements taken on excavated pike bones at the two Neolithic and the medieval settlement. Three of these measurements, dentale anterior height[53] (dn.a.h.) and the breadths of articular (art.gr.b.) and quadratum (qu.gr.b.) have been proven well preserved and closely related to PC1 in figure 5.

The diversity of measurements available for study is comparable in spite of the radically different assemblage sizes. The presence of lengths in the small medieval set is conspicuous: percentages of the number of measurements relative to fish NISP in the three assemblages, however, point to the effects of poor preservation at Ecsegfalva and the good condition of the medieval fish bones. Ibrány falls between the two extremes, although – as a function of time – both fragmentation and surface erosion tend to be worse in prehistoric assemblages.

When plotted against the mean values and intervals of standard deviations of the reference collection of 24 large pikes from Sweden (fig. 6), the three archaeological assemblages display very different size distributions; the graph also contains a mm scale of estimated TLs to facilitate practical interpretation. Thanks to it having the largest number of cases, the

49 Meadow 1999.
50 Bartosiewicz 2007.
51 Kovács et al. 2010.
52 Bartosiewicz – Gál 2021.
53 Also recommended by Enghoff 1994, 86.

Table 6 The anatomical distribution of measurements taken on excavated pike bones

Measurement	Ecsegfalva	Ibrány	Esztergom	Total	Dimension
	Early Neolithic		Late Medieval		
Fish NISP	**18,186**	**16,704**	**1059**	35,949	
2 vo.gr.b.	18	32	2	52	M-L
3 proa.gr.b.	1	11		12	M-L
5 dn.a.h.	16	58		74	D-V
6 dn.i.l.	1	6	3	10	C-C
8 art.gr.b.	5	16	1	22	M-L
9 qu.gr.b.	15	31		46	M-L
12 pop.c.l.			2	2	D-V
13 cl.c.l.			4	4	D-V
Total	56	154	12	222	
% of fish NISP	0.308	0.922	1.133	0.618	

assemblage from Ibrány best approaches the bell-shape of the Gaussian curve, but it peaks at around –1 standard deviation of the 24 pikes in the museum collection. This corresponds to animals of approximately 550–650 mm TL, none reaching the 884 mm mean length of the reference individuals. The Ibrány sample also has a slight negative skew due to the presence of smaller individuals.

The set of Early Neolithic pike measurements from Ecsegfalva is only one-third of those taken in the Ibrány material. With the exception of a single ca. 750 mm-long individual (within the –1 standard deviation interval of the extant sample), it rather shows an even spread of much smaller pike, mostly overlapping with the smallest, 250–500 mm-long specimens from Ibrány.

Finally, the distribution of measurements of late medieval pike from Esztergom (fig. 6 B) looks rather hectic, in part due to the small number of individuals. The bones originate from even shorter, ca. 250–450 mm-long fish (within the –2.5 and –1.5 standard deviation interval of the 24 extant pikes). There was only a single exception: a large 14th-century pike that reached the almost 900 mm mean TL of the reference material.

Interpretations

In order to understand the patterns seen in figure 6, both pike and human behaviour need to be reviewed. In Hungary, pike spawning takes place from February to March[54], but it may be delayed until May/June in the northern part of the distribution area. Along with variations in the local climate, it coincides with spring high water (melt water) on flooded reed beds and grasslands, lakeshores or flood plains in water of 25–60 cm depth[55].

Young pikes need vegetation for protection, adults to be able to ambush their prey[56]. Pike of a TL of up to 60 cm thus prefer the vegetated edge of shallow waters. Only large individuals venture into deeper waters void of vegetation[57]. In the archaeological materials under discussion here, these may potentially be the few individuals caught in the main current of rivers.

54 Pike-Tay et al. 2004, 236 tab. 3.
55 Raat 1988; de Laak – van Emmerik 2006, 20.
56 Leijzer – Beekman 2003, 37.
57 De Laak – van Emmerik 2006, 17.

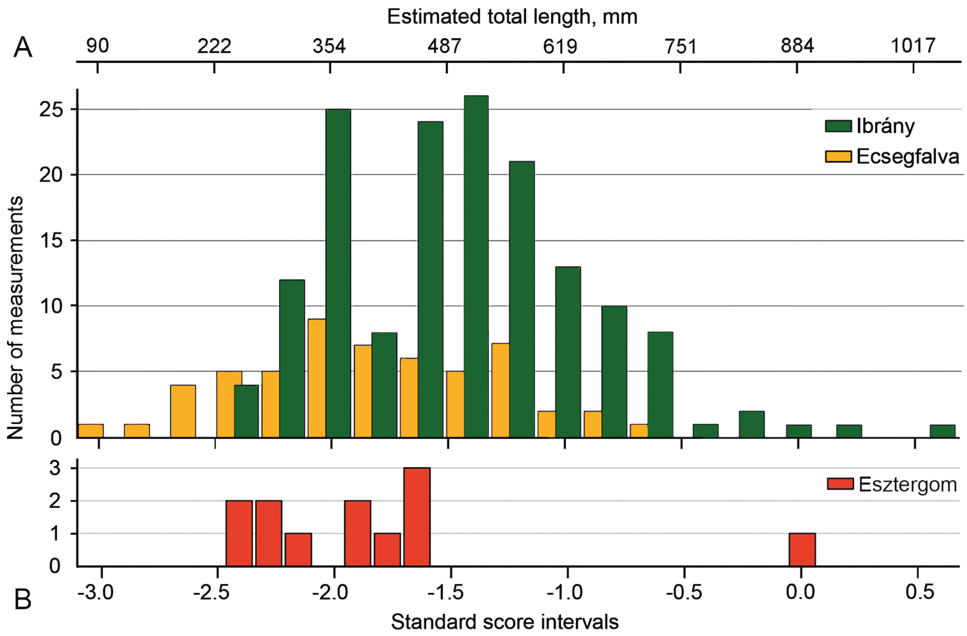

Fig. 6 A: The size distribution of Early Neolithic pike at Ecsegfalva and Ibrány based on the standard scores calculated from the 24 extant reference specimens; B: The size distribution of medieval pike from the Esztergom archbishopric (L. Bartosiewicz)

Early Neolithic fishing techniques

Prior to 19th-century river regulations, present-day eastern Hungary was prone to regular flooding. After floods, small fish – such as young pike – trapped in residual pools were easy to gather. They could even be picked up by hand. Fish seems to have been an opportunistic complement to the diet of the first sheep-herding communities in the Carpathian Basin, such as the putative inhabitants of Ecsegfalva.

However, the two Early Neolithic sites in the Great Hungarian Plain apparently represent different scenarios. At Ibrány the presence of large pike determining the size distribution in figure 6 A may be indicative of active fishing, as concluded by N. Noe-Nygaard[58] based on the presence of large pike among the Mesolithic fish remains from Præstelyngen, Denmark. A striking visual similarity to the difference between the pike sizes from Ecsegfalva and Ibrány is also visible in the size distributions of contemporary catches of pike using seine nets versus angling in the Weerribben National Park, the Netherlands[59]. In spite of the overlap between their standard deviations, the mean TL estimate for pike from Ecsegfalva was ca. 80 mm shorter ($P < 0.005$) than the mean value obtained for the Ibrány data[60]. According to P. R. Bregazzi and C. R. Kennedy[61], the average pike fork length (94 % of TL)[62] of pike caught using seine nets (540.1 mm, n = 66) was 115 mm shorter than those landed by anglers (654.4 mm, n = 56). The size diversity of net catch also varied within broader limits (cv = 34.0 % versus cv = 14.2 %). This difference parallels the phenomenon observed in the Ecsegfalva (cv = 35.0 %) and Ibrány (cv = 27.5 %) assemblages[63].

58 Noe-Nygaard 1983, 130.
59 Leijzer – Beekman 2003.
60 Kovács et al. 2010, 248 tab. 7.
61 Bregazzi – Kennedy 1980, 92 tab. 1.
62 Mann 1976, 186.
63 Kovács et al. 2010, 248 tab. 7.

Alternatives in medieval pike provisioning

According to figure 6 B, with one exception, the few measurable bones from the 14th–15th-century Esztergom archbishopric represent only 250–400 mm-long individuals, barely larger than one-summer-old pike[64]. This was the diametric opposite of our expectations, given the distinguished social status of the site. At 11th–15th-century settlements in England, pike appears to be the most abundant in the food refuse from castles at the peak of social hierarchy. The largest individuals also tend to occur at these sites[65]. It appears that large pike formed part of high-status diets. A closer parallel to the Esztergom finds is the dry-screened assemblage of fish remains from the 17th–18th-century monastery in Zobor, Slovakia[66]. That material yielded the bones of 900–1100 mm-long pikes, comparable to our reference collection.

Interpretations of the Esztergom fish remains benefit from the availability of the contemporaneous documentary record kept by Ippolito d'Este, archbishop of Esztergom[67]. Sporadic references to fish size in the castle's kitchen accounts (*Pro Coquina castri*, 1489) suggest that usually highly valued pikes were sold at conspicuously low prices to the archbishop's kitchen. While six carps cost 70 denarii, a dozen (twice as many [!]) pikes were bought for only 29 *denarii*[68]. In light of the archaeozoological finds, one of the possible explanations is the small size of the pike. A later, 1498 purchase of »five plates of pike«[69] may also be indicative of small individuals.

The broader economic context is also worth considering. The kitchen refuse from Esztergom shows a significant ($P \leq 0.001$) diachronic increase in cyprinid bones[70], in particular those of carp. By the High Middle Ages, large-scale fish farming developed in central Europe, including both Austria and Hungary[71]. By around the 14th century, pond fishing focused on carp, with pike as the occasional ›side-crop‹. Releasing small pikes into finishing ponds for carp was a known technique to cull the offspring of sexually precocious carp before their fry began competing for food with their parents[72]. Small pike as a by-catch would fit within this technological framework. Young pikes would prey upon anything smaller than themselves. Thus, beyond a certain size they would have jeopardized the profitability of carp stocks.

The consumption of small pike in Esztergom is consonant with the scarcity of bones from other high-status fish such as great sturgeon and from large terrestrial game (only two postcranial bones each of red deer and roe deer were found)[73]. Zooarchaeological finds thus refute ruling topoi that the consumption of expensive fish, venison and a variety of wild fowl played a key role in asserting social status among high clergy. The contradiction is so great that the possible plebeian origins of the Esztergom food refuse need to be considered. The de facto small size of pike finds from Esztergom might be related to fishing regulations such as those in Bavaria and Austria, which prescribed this size range as the smallest legal length for pike to be caught in around AD 1500[74]. Small ›pickerels‹ were certainly an item sold at fish markets to commoners in medieval England[75].

64 Berinkey 1966.
65 Macarinelli 2021, 133 figs. 7. 8. 17.
66 Bielichová et al. 2019.
67 Byatt 1993, 363.
68 Gál – Bartosiewicz 2021, 131 f.
69 Kuffart 2018, 175.
70 Gál – Bartosiewicz 2021, 4 fig. 2.
71 Galik et al. 2015, 347.
72 Hoffmann 1996, 664 f.
73 Gál – Bartosiewicz 2021, 2.
74 Hoffmann 2000.
75 Dyer 1994.

Conclusions

Given its significance and near ubiquitous presence since the earliest archaeological periods in Europe, an in-depth understanding of pike size is of evident interest. This review of estimating TL in pike using head elements from archaeological sites allows the following conclusions to be drawn:

Information on the sex and geographical origins of the reference individuals was missing. A review of contemporary fisheries science has shown that size potentially influenced by these two factors is a function of absolute growth, that is, of calendar age. Direct ageing of the skeletal elements selected for study is impossible. Size itself could be used as a proxy to age, but this would lead to circular reasoning. It is relative, rather than absolute growth that can be studied in our case. Body proportions in pike seem to be less affected by sex and environment than size. Accepting that the precision of our calculations will be finite, questions of sexual dimorphism and environmental influences were not addressed in this study.

The 24 reference skeletons available for study did not represent a random sample. Most of them originated from large individuals, a bias attributable to traditions in museum acquisition. Thanks to the linear nature of relative growth in pike, this bias did not distort the integrated evaluation of the 13 measurements in the head region. PCA has confirmed that all measurements are extremely highly correlated with overall size (PC1). This phenomenon is not severely influenced by the fact that one-quarter of the measurements had to be estimated using previously calculated correlations[76].

While the longest length measurements (e.g. neurocranium base length, cleithrum chord length, dentale inner length) understandably offer the best estimates for TL on a mathematical basis, they tend to be poorly preserved in archaeological assemblages. Thanks to the growth characteristics of pike, bone breadths representing the medio-lateral dimension, less prone to fragmentation, are just as characteristic of pike size; the dimensionality of measurements plays but a small role in size reconstruction.

A brief summary of case studies showed the relevance of integrating detailed biometric information on the size distribution of pike with data on fishing techniques and documentary sources in different chronological and cultural settings.

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Bibliography

Bartosiewicz 1990 — L. Bartosiewicz, Osteometrical studies on the skeleton of pike (*Esox lucius* L. 1758), Aquacultura Hungarica 6, 1990, 25–34.

Bartosiewicz 1998 — L. Bartosiewicz, Attitudes to pets in the ethnolinguistic record, in: P. Anreiter – L. Bartosiewicz – E. Jerem – W. Meid (eds.), Man and the Animal World. Studies in memoriam Sándor Bökönyi (Budapest 1998) 65–78.

[76] Bartosiewicz 1990.

Bartosiewicz 2007	L. Bartosiewicz, Fish remains, in: A. Whittle (ed.), The Early Neolithic on the Great Hungarian Plain. Investigations of the Körös culture site of Ecsegfalva 23, County Békés I, Varia Archaeologica Hungarica 21 (Budapest 2007) 377–394.
Bartosiewicz 2012	L. Bartosiewicz, Fish remains from Körös culture sites in Hungary, in: A. Anders – Zs. Siklósi (eds.), The First Neolithic Sites in Central/South-East European Transect III. The Körös Culture in Eastern Hungary, BARIntSer S2334 (Oxford 2012) 213–218.
Bartosiewicz – Gál 2021	L. Bartosiewicz – E. Gál, The archbishop’s dinner? Late medieval fish from Esztergom-Várhegy-Kőbánya, Hungary, Archaeological and Anthropological Sciences 13/132, 2021, 1–14; DOI:10.1007/s12520-021-01361-w
Berinkey 1966	L. Berinkey, Halak – Pisces, Magyarország állatvilága 20 (Budapest 1966).
Bielichová et al. 2019	Z. Bielichová – M. Samuel – K. Hensel, Ryby a pôst v Zoborskom kláštore pri Nitrevo svetle archeozoologických dokladov (Fish and fasting in the Zobor Monastery in Nitra in the light of archaeozoological evidence), Študijné Zvesti Archeologického Ústavu SAV 65, 2019, 133–177.
Bregazzi – Kennedy 1980	P. R. Bregazzi – C. R. Kennedy, The biology of pike, *Esox lucius* L., in a southern eutrophic lake, Journal of Fish Biology 17, 1980, 91–112; DOI:10.1111/j.1095-8649.1980.tb02745.x
Brinkhuizen 1989	D. C. Brinkhuizen, Ichthyo-archeologisch onderzoek. Methoden en toepassing aan de hand van Romeins vismateriaal uit Velsen (Nederland) (Ichthyo-archaeological research. Methods and application based on Roman fish material from Velsen [the Netherlands]) (PhD thesis Rijksuniversiteit Groningen 1989).
Byatt 1993	L. Byatt, Ippolito d’Este, Dizionario biografico degli italiani 43, 1993, 361–367.
Casselman 1990	J. M. Casselman, Growth and relative size of calcified structures of fish. Transactions of American Fisheries Society 119, 1990, 673–688; DOI:10.1577/1548-8659(1990)119<0673:GARSOC>2.3.CO;2
Casteel 1976	R. W. Casteel, Fish remains in archaeology and paleo-environmental studies (London 1976).
Csánki 1897	D. Csánki, Magyarország történeti földrajza a Hunyadiak korában III (The historical geography of Hungary in the age of the Hunyadis III) (Budapest 1897).
De Laak – van Emmerik 2006	G. A. J. de Laak – W. A. M. van Emmerik, Kennisdocument snoek, *Esox lucius* (Linnaeus, 1758) (Information document pike, *Esox lucius* [Linnaeus, 1758]), Kennisdocument 13 (Bilthoven 2006).
Dyer 1994	C. Dyer, Everyday life in Medieval England (London 1994).
Enghoff 1994	I. B. Enghoff, Fishing in Denmark during the Ertebølle period, International Journal of Osteoarchaeology 4, 1994, 65–96.
Fejérpataky 1901	L. Fejérpataky, Magyar czímeres emlékek I (Monumenta Hungariæ Heraldica I) (Budapest 1901).
Galik et al. 2015	A. Galik – G. Haidvogl – L. Bartosiewicz – G. Guti – M. Jungwirth, Fish remains as a source to reconstruct long-term changes of fish communities in the Austrian and Hungarian Danube, Aquatic Science 77, 2015, 337–354.
Gál – Bartosiewicz 2021	E. Gál – L. Bartosiewicz, Animal Remains from the Late Medieval Kitchen of the Esztergom Archdiocese, Hungary. The benefits of screening, Starinar 71, 2021, 231–251.
Hammer 2020	Ø. Hammer, Paleontological Statistics (PAST) Version 4.02 (Oslo 2020).
Harka 1983	Á. Harka, Growth of pike (*Esox lucius* L.) in the section of the Tisza river at Tiszafüred, Tiscia 18, 1983, 103–112.
Hecht 1916	S. Hecht, Form and growth in fishes, Journal of Morphology 27, 1916, 379–400.
Herman 1887	O. Herman, A magyar halászat könyve (The book of Hungarian Fisheries) (Budapest 1887).
Hoffmann 1996	R. C. Hoffmann, Economic Development and Aquatic Ecosystems in Medieval Europe, The American Historical Review 101, 3, 1996, 631–669; DOI:10.2307/2169418
Hoffmann 2000	R. C. Hoffmann, Medieval fishing, in: P. Squatriti (ed.), Working with water in medieval Europe. Technology and resource use (Leiden 2000) 331–393.

Huxley – Teissier 1936 J. S. Huxley – G. Teissier, Terminology of relative growth, Nature 137, 1936, 780–781.

Jelu et al. 2021 I. Jelu – W. Wouters – W. Van Neer, The use of vertebral measurements for body length and weight reconstruction of pike *(Esox lucius)* from archaeological sites, Archaeological and Anthropological Sciences 13, 72, 2021, 1–9; DOI:10.1007/s12520-021-01325-0

Kazansky 1956 B. N. Kazansky, Овогенез и адаптации связанные с размножением у рыб (Oogenesis and adaptations associated with reproduction in fish) (Leningrad 1956).

Kennedy – Rennie 2023 P. J. Kennedy – M. D. Rennie, Variation in female-biased sexual size dimorphism of Northern Pike *(Esox lucius)* associated with environment and life history, bioRxiv, 2023, 1–27; DOI:10.1101/2023.03.06.531313

Kerezsy 1910 J. Kerezsy, Bakócz Tamás egri püspök udvartartása és egyházmegyéje (The court and diocese of Tamás Bakócz, bishop of Eger), Művelődestörténeti Értekezések 39 (Budapest 1910).

Kiss 2000 I. Kiss, Biológiai alapismeretek (Basics of Biology), in: L. Horváth (ed.), Halbiológia és haltenyésztés (Budapest 2000) 17–68.

Koblitskaya 1981 A. Koblitskaya, Определитель молоди пресноводных рыб (Identification key to juvenile freshwater fish) (Moscow 1981).

Kovács et al. 2010 Zs. E. Kovács – E. Gál – L. Bartosiewicz, Early Neolithic animal bones from Ibrány-Nagyerdő, Hungary, in: J. K. Kozłowski – P. Raczky (eds.), Neolithization of the Carpathian Basin. Northernmost distribution of the Starčevo/Körös culture (Krakow 2010) 238–254.

Kuffart 2018 H. Kuffart, Modenában őrzött esztergomi számadáskönyvek és az esztergomi érsekség udvartartása (Esztergom account books kept in Modena and the court maintenance of the Esztergom archdiocese) (PhD thesis Pázmány Péter Catholic University Budapest 2018).

Lakó 1983 E. Lakó, Bornemisza Anna szakácskönyve 1680-ból (The cookbook of Anna Bornemisza from 1680) (Bucharest 1983).

Leijzer – Beekman 2003 T. B. Leijzer – J. Beekman, Visstandbeheerplan Nationaal Park de Weerribben 2003–2008 (Fish stock management plan National Park de Weerribben 2003–2008) (Nieuwegein 2003).

Lönnrot 1888 E. Lönnrot, The Kalevala. The Epic Poem of Finland. Into English by John Martin Crawford (New York 1888) <https://www.gutenberg.org/files/5186/5186-h/5186-h.htm#pref01>.

Lepiksaar – Heinrich 1977 J. Lepiksaar – D. Heinrich, Untersuchungen an Fischresten aus der frühmittelalterlichen Siedlung Haithabu (Neumünster 1977).

Maccarinelli 2021 A. Maccarinelli, Was pike on the menu? Exploring the role of freshwater fish in medieval England, Archaeological and Anthropological Sciences 13, 133, 2021, 132–150; DOI:10.1007/s12520-021-01373-6

Mann 1976 R. H. K. Mann, Observations on the age, growth, reproduction and food of the pike *Esox lucius* (L.) in two rivers in southern England, Journal of Fish Biology 8, 1976, 179–197; DOI:10.1111/j.1095-8649.1976.tb03930.x

Meadow 1999 R. H. Meadow, The use of size index scaling techniques for research on archaeozoological collections from the Middle East, in: C. Becker – H. Manhart – J. Peters – J. Schibler (eds.), Historia animalum ex ossibus (Rahden/Westfalen 1999) 285–300.

Morales – Rosenlund 1979 A. Morales – K. Rosenlund, Fish Bone Measurements. An attempt to standardize the measuring of fish bones from archaeological sites (Copenhagen 1979).

Niezabitowski 1929 E. L. Niezabitowski, Fauna pokładów drugiego okresu międzylodowcowego w Szelągu (Die Fauna der Schichten des zweiten Interglazial in Szeląg [Schilling]), Sprawozdanie Komisji Fizjograficznej Polskiej Akademii Umiejętności 63, 1929, 51–70.

Nikolsky 1935 G. V. Nikolsky, Материалы по ихтиофауне городищ бассейнов Ветлуги и Вятки (Materialien zur Kenntnis der Ichthyofauna der Burgen an der Wetluga und Wiatka), Зоологический журнал 14, 1, 1935, 79–96.

Noe-Nygaard 1983	N. Noe-Nygaard, The importance of aquatic resources to mesolithic man at inland sites in Denmark, in: C. Grigson – J. Clutton-Brock (eds.), Animals and Archaeology 2. Shell middens, fishes and birds, BARIntSer 183 (Oxford 1983) 125–142.
Pike-Tay et al. 2004	A. Pike-Tay – L. Bartosiewicz – E. Gál – A. Whittle, Body-part representation and seasonality. Sheep/goat, bird and fish remains from early Neolithic Ecsegfalva 23, SE Hungary, Journal of Taphonomy 2, 4, 2004, 221–246.
Prummel – Brinkhuizen 1990	W. Prummel – D. C. Brinkhuizen, Inventory of fish bone measurements for estimating fish size. Ichthyo-osteo-archaeology News. Newsletter for the ICAZ fish remains working group 6, 1990, 8–26.
Raat 1988	A. J. P. Raat, Synopsis of biological data on the northern pike, *Esox lucius* (Linnaeus 1758) (Rome 1988).
Reitz et al. 1987	E. J. Reitz – I. R. Quitmyer – H. S. Hale – S. J. Scudder – E. S. Wing, Application of Allometry to Zooarchaeology, American Antiquity 52, 2, 1987, 304–317.
Robbins et al. 1928	W. J. Robbins – S. Brody – A. G. Hogan – G. M. Jackson – C. W. Greene, Growth (London 1928).
Rumpolt 1581	M. Rumpolt, Ein new Kochbuch (Frankfurt 1581).
Senay et al. 2017	C. Senay – S. Harvey-Lavoie – C. J. Macnaughton – G. Bourque – D. Boisclair, Morphological differentiation in northern pike *(Esox lucius)*. The influence of environmental conditions and sex on body shape, Canadian Journal of Zoology, March, 2017; DOI:10.1139/cjz-2016-0159.
Torke 1981	W. Torke, Fischreste als Quellen der Ökologie und Ökonomie in der Steinzeit Südwest-Deutschlands, Urgeschichtliche Materialhefte 4 (Rahden/Westfalen 1981).

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The Monk's Last Supper

Faunal Remains from the Zobor Monastery in Nitra (Slovakia)

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Abstract

The archaeological excavation of the deserted Camaldolese monastery of St. Joseph on Zobor Hill in Nitra yielded rich faunal material. Most of this originated from a small cellar or cesspit in one of the explored monks' houses. The bone assemblage, partly dated by luxurious tableware to the final decades of the monastery's existence (1760–1782), is dominated by aquatic and semi-aquatic wild species. These include fish, crayfish, otters, beavers and the European pond turtle. Domestic animals – cattle, sheep, pigs and chicken – occurred in small numbers. The archaeological context and recorded butchery marks showed that all were part of the local diet. Among fish, the most frequent were pike and carp. Remains of catfish, stellate sturgeon, Russian sturgeon, sterlet, tench, dace and bleak were also present. Osteometric analysis revealed that large-sized individuals prevailed, meeting kitchen requirements and documenting the wealth of resources (fishponds [?]). The representation of fish skeletal elements and modifications suggests that complete (fresh [?]) fish were supplied to the monastery. Selected portions (various fish dishes) were served to the monks. Spatial analysis of finds revealed long-term fasting and strict adherence to dietary prescriptions in cell 9. On the other hand, it also suggested a possible breach in cell 3, perhaps due to relaxation of discipline, health problems, or the monk's advanced age. In this cell, meat of forbidden four-legged animals (veal and lamb) may have been consumed. However, contamination of bone material from different occupational layers may also have played its role.

Introduction

The Camaldoli, also known as »White Benedictines«, are among the strictest men's orders of the Roman Catholic Church. The order prioritises worship and prayer over economic and outreach activities. It was founded by St. Romuald († 1027). Inspired by the hermits' way of life in the desert, St. Romuald and a few companions retreated to the Etrurian hills near Arezzo in Tuscany. There, they were given a territory called Campo di Maldolo and built a monastery. The order adopted the name of this territory, and its existence was officially confirmed in 1072. In the following centuries, many monasteries abandoned this extremely strict form of monasticism. Only a small number remained faithful to the original idea. In the 16th century, the order divided into two branches: a new, reformist one centred on Monte Corona near Perugia, and a congregation of Camaldolese monks with a more relaxed way of life. The reformist branch of Monte Corona produced the founders of all the Camaldolese monasteries in the Habsburg monarchy, including Hungary and its former part, present-day Slovakia.

Over the centuries, eremitism developed in various forms[1]. Hermits lived either in solitude or in groups, sometimes in complete isolation and sometimes in association with a monastery or church. Their residences ranged from remote locations to urban centres. Some hermits

1 Pomfyová 2015, 299–303.

acted as itinerant ascetics and missionaries, serving the faithful as preachers or nurses. Others remained within the hermitage, dedicating themselves exclusively to contemplation and renunciation in closed cells, a practice known as reclusion. Regular fasting and strict dietary rules characterised their daily routines. Limited archival sources document the ascetic lifestyle at Zobor Monastery. For instance, in 1726, the General Chapter granted Friar Kajetán renewed permission for reclusion lasting more than fourteen years[2]. This privilege was extended to several monks, although maintaining discipline proved challenging. Friar Henry's reclusion, for example, was revoked after one year due to noncompliance with rules regarding contact with other friars[3]. Historical documents indicate that the Camaldolese of Zobor combined hermitic practices with coenobitic life. Notably, their religious interactions with the outside world were frequent[4]. They also collaborated with other hermitages in Hungary, such as the Lechnica hermitage (now the Red Monastery in Slovakia), on projects like translating the Bible into Slovak, and often served as referees in reports on candidates for the bishop's seat in Nitra[5]. Bishops of Nitra conferred sacred consecrations on members of the order, but also engaged in disputes with the monastery, for example, over forest usage[6]. Some Zobor monks travelled frequently, including to Vienna, which provoked criticism from the General Curia of the order in Monte Corona, particularly when monks stayed overnight in secular houses[7]. Additional criticisms included the purchase of expensive cloth for monks, visits by women to the monastery, and unmediated celebrations that featured extended debates and elaborate Lenten meals. These accounts present a complex, at times contradictory, image of the ascetic lifestyle within the hermitage.

Evidence of economic interactions between the Camaldolese monastery and the secular world is either limited[8] or originates from more recent periods[9]. To date, most information regarding the internal life and hermits of the monastery has been provided by M. Lacko, who examined the »Acts of the General Chapters« in Frascati near Rome[10]. Given the scarcity of literary sources, archaeological findings have become increasingly valuable. To document the site's complete history, the Institute of Archaeology of the Slovak Academy of Sciences in Nitra has conducted both rescue and systematic excavation campaigns[11]. Over recent decades, these efforts have yielded substantial archaeological material, including exceptional collections of artefacts and ecofacts that illustrate the luxurious lifestyle of certain monks and their interactions with the external world[12].

This article presents findings from the analysis of faunal remains recovered during a single excavation season. The assessment of well-dated material, most of which was found in its primary context as consumption waste, provides initial insights into the dietary habits of the local monastic community. It also sheds light on activities related to food production and acquisition, food storage, meal preparation, the variety of animals consumed, fasting practices and waste management. Furthermore, these results enhance understanding of the monks' relationship with animals and their environment. Literary and iconographic sources, which suggest that the local economy may have included livestock rearing (such as horse and pig

[2] Lacko 1965, 108 f.
[3] Lacko 1965, 109.
[4] Lacko 1965; Vozár 1997.
[5] Judák 1997, 79 f.
[6] Judák 1997; Vozár 1997, 87.
[7] Lacko 1965, 107 f.
[8] The account and inventory books related to economic matters, such as the food supply to the Camaldolese monastery on Zobor Hill, were likely destroyed during the monastery's closure. The remaining documents archived in Budapest (<https:// maps.hungaricana.hu/hu/MOLTerkeptar/4345/> [25.04.2023]) do not address topics related to food or daily life. P. Prohászka, personal communication.
[9] Lombardini 1895; Kompánek 1895, 111–114; Cserenyei 1911; Branecký 1945.
[10] Lacko 1965; Lacko 1967
[11] For a summary of the archaeological research at the site, see Samuel 2010.
[12] Samuel 2009; Samuel – Čurný 2010.

stables) and aquaculture (potentially fishponds), have been compared with newly acquired faunal data, including evidence of sturgeon consumption.

The site background

The Camaldolese monastery of St. Joseph was established in a small valley on the western slope of the Zobor hill (586.9 masl) above the town of Nitra in southwestern Slovakia (fig. 1). This legendary forested area, with its abundant spring and small cave[13], had previously been home to the Benedictine monastery of St. Hippolytus from the early Middle Ages (9th/11th cent.) until the end of the 15th century, serving as one of the Kingdom of Hungary's most important religious, public and cultural centres. Following the Benedictine monastery's abandonment in the 15th century, pilgrimages continued to a chapel later built on the site[14].

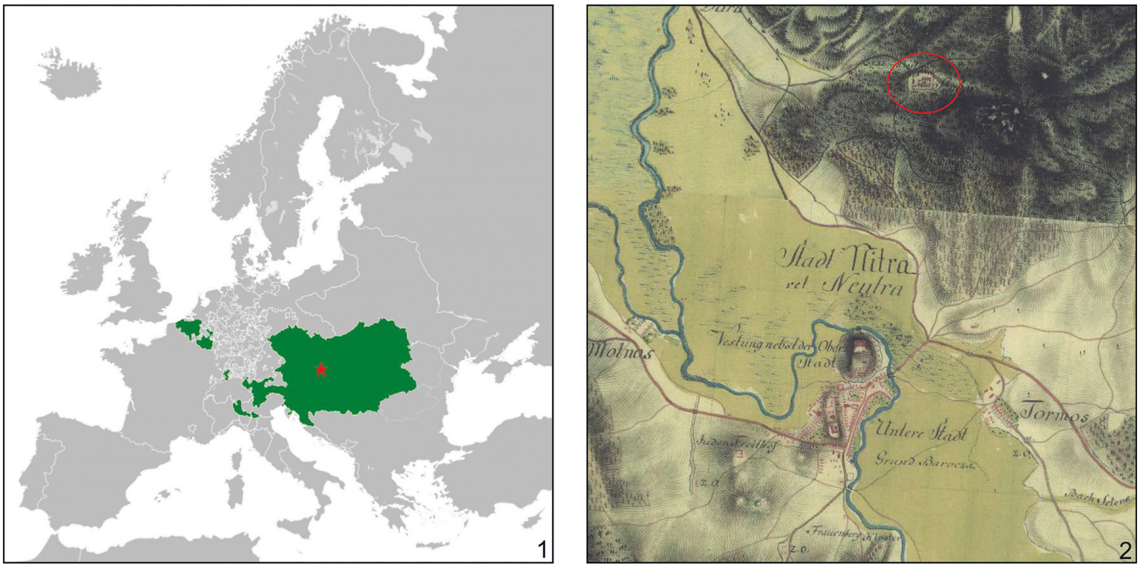

Fig. 1 Geographical location of the site on the map; 1: Europe with the extent of the Habsburg Monarchy in 1789; 2: The town of Nitra in 1782–1784 (source: <https://commons.wikimedia.org/wiki/File:Habsburg_Monarchy_1789.svg>)

In the 17th century, Baron Blažej Jaklin of Lefantovce, bishop of Nitra, and his cousin Baron Mikuláš Jaklin, captain of Nitra Castle, sought to revive monastic life there. On 28th June 1691, they drew up a document in Nitra expressing their intention and financial commitment to construct and maintain a monastery for twelve Camaldolese monks. This communication, meant for King Leopold I, led to his letter dated 5th September 1691, granting authorisation to use pensions from Pilis Abbey (now in Hungary) so that »they may serve for the benefit of the order, and the 12 monks may live decently on them«[15]. After project approval by the General Chapter of the Camaldolese Order in Monte Corona, Italy, in 1692, Cardinal Leopold Kolonič (Kollonitsch) officially established the ›hermitage‹ of St. Joseph on Zobor hill by decree on 14th March 1693[16].

The first inhabitants were Italian monks from Monte Corona, who gradually welcomed Hungarians, Germans, Silesians, Moravians and Slovaks. Most Slovak monks came from the Nitra region and eventually made up almost half of the hermits at the theological school at

13 According to legend, the cave was inhabited by the monk St. Svorad sometime during the 11th cent.
14 Kompánek 1895, 111.
15 Cserenyei 1911.
16 Lacko 1967, 152.

Fig. 2 Oil painting from the second half of the 18th century depicting the area of the Camaldolese Monastery of St. Joseph; Nitra Gallery, an unknown Central European artist; inv. 0-81 (photo: M. Samuel)

Zobor[17]. The second hermitage was founded in 1711 at the monastery in what is now the village of Červený Kláštor, then in the area of Lechnica in northern Slovakia. Together with hermitages in the Habsburg monarchy – present-day Kahlenberg and Landsee in Austria, and Majk in Hungary – Zobor and Lechnica formed an administrative unit called the Hermitage of the Germano-Hungarian Nation *(Eremi Nationis Germano-Hungaricae)*, which belonged to the Congregation of the Camaldolese Hermits of Monte Corona. In 1709, the General Chapter of the Camaldolese order promoted the Zobor monastery to the rank of priory and established a second novitiate there for all of Hungary. The Camaldolese monasteries became important cultural centres where significant scientific activities developed. The Camaldolese community attempted to establish Western Slovak as a national written language (Camaldolese Slovak) and to produce the first translation of the Bible into Slovak (the Camaldolese Bible)[18]. Notable community members included the Polish naturalist František Ignác Jäschke, known as Cyprian (1724–1775) – author of the oldest surviving five-language herbarium in Slovakia – and the Slovak linguist and translator Štefan Romuald Hadbavný (1714–1780); both spent part of their lives at the Zobor monastery.

The appearance of the monastery is known from several iconographic sources (fig. 2) and archaeological research. These show that the Zobor monastery was a large complex built on several artificially created terraces[19]. Its inner area, defined by a brick enclosure and buildings, measured almost 2.3 ha. The complex had a symmetrical central area, with the monastery church – a three-aisled basilica with a tower in the middle of the south aisle – at its core. On either side of the church were two double lines of monastic dwellings (cells). A third line of cells stood east of the church on the highest terrace. On the west side, the two inner lines of cells connected to the side wings of the main convent building, which had two floors and three wings arranged in a U-shaped plan. To the north of this building was a smaller, two-storey outbuilding with two wings; additional outbuildings were located against the enclosure walls. From 1704, the monastery included a sophisticated technical structure: a stone aqueduct that brought water from the Svorad Spring. This aqueduct distributed water through several branches to rooms, laundries, fountains, and reservoirs. Surplus water went to a pair of ponds below the monastery[20].

The preserved monastery plan (fig. 3) details the layout of catering-related buildings (refectory, kitchens and cook's room) and food storage (lard, oil, fruit, wine). Production areas, such as the bakery, gardens, greenhouses and pigsties, are also shown. Each monk's cell and garden followed a standardised design with four rooms: a chapel or prayer room *(oratorium)*, a main living room with a bed and library *(cubiculum)*, a workshop or workroom *(laboratorium)* and

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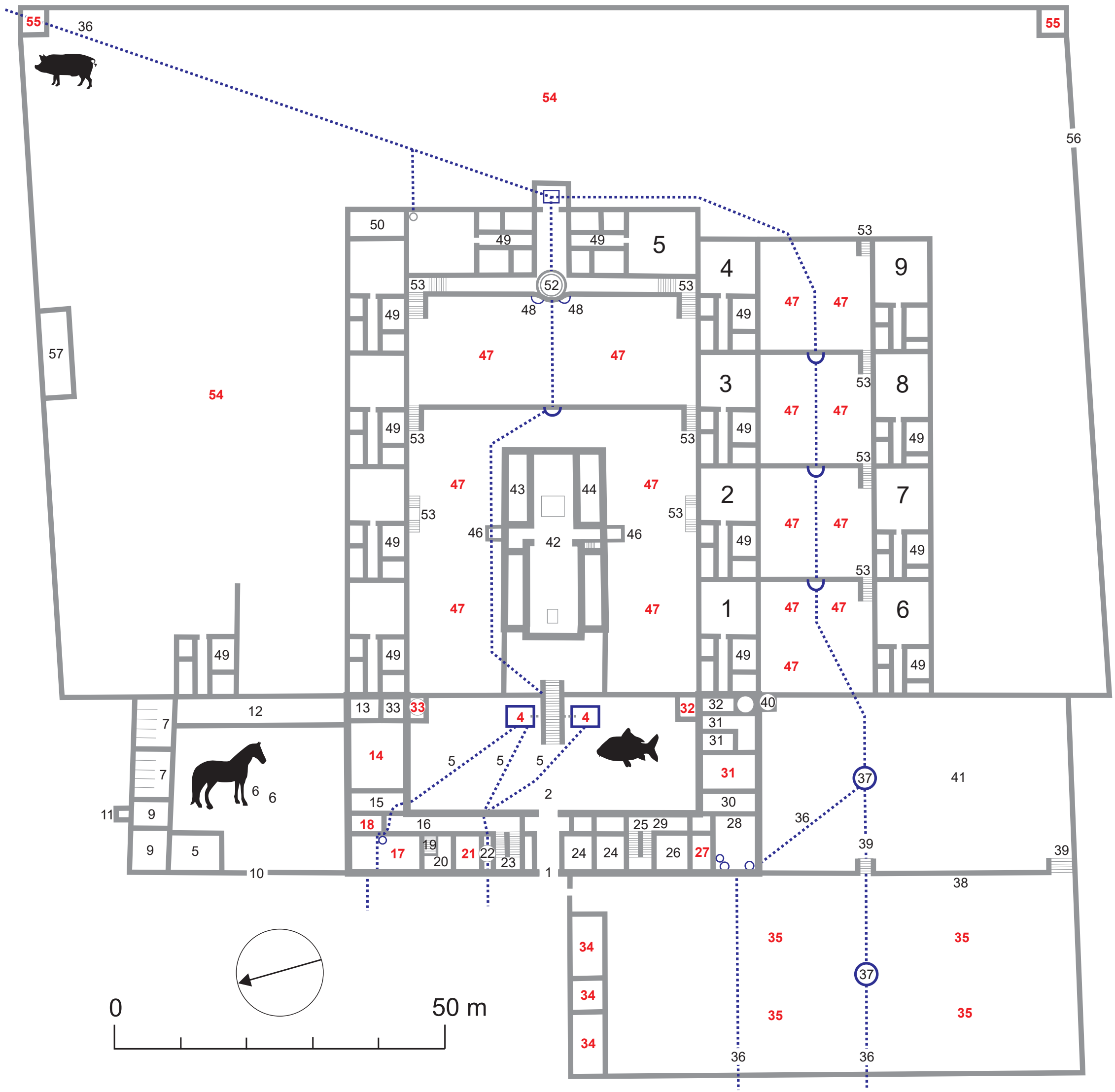
17 Lacko 1965.

18 See Encyclopaedia Beliana (<https://beliana.sav.sk/heslo/kamalduli> [05.05.2023]).

19 The project was designed by Italian architect Domenico Martinelli, based in Vienna. Lorenz 1991, 199.

20 In the work of Š. Cserényei, it is noted that both ponds, which have been abandoned for 30 years, are clogged with fallen leaves. Cserenyei 1911.



1. Entrance
2. Yard
3. Stairs to the church
4. **Fish tank**
5. Water supply
6. **Farmyard**
7. **Stable**
8. Blacksmith workshop
9. Room with a hallway
10. Gate to the farmyard
11. Toilet
12. Shed for wagons
13. Stairs to the cellar
14. **Refectory**
15. Hallway to the kitchen/refectory
16. Hallway
17. **Kitchen**
18. **Storage of oil and grease**
19. Stairs to the cellar
20. Cook's room
21. **Black kitchen**
22. Toilet and spout
23. Stairs to the first floor
24. Room by the entrance
25. Stairs to the first floor
26. Room with vaulted ceiling
27. **Black kitchen**
28. Laundry
29. Hallway
30. Hallway to the garden and bakery
31. **Bakery** with room
32. Entrance to the **wine cellar**
33. Entrance to the **fruit cellar**
34. **Greenhouses**
35. **Kitchen garden**
36. Water pipelines
37. Fountains
38. Wall
39. Stairs and terrace wall
40. Garden toilet
41. Rental garden
42. Church
43. Chapter hall
44. Sacristy
45. Stairs to the tower
46. Wooden hallway
47. **Fruit garden**
48. Water tank
49. **Monk cell**
50. Laundry
51. New cell
52. Garden gazebo
53. Stairs
54. **Fruit garden**
55. **Pigsty**
56. Entrance to the **big garden**
57. Ossuary

Fig. 3 Digitalised plan of the Camaldolese Monastery of St. Joseph showing the location of monks' cells 3 and 9 and the functions of interior and exterior areas. Bold: Space related to the production and consumption of food and the keeping of animals (according to the plan by C. Schlegel, digitalised by M. Samuel; the original deposited at the Magyar Országos Levéltár Budapest, sign. S12. Div. 9 No. 60, 1–2; translation of the text addendum: R. Ragač) a utility room with a sanitary corner that also served for wood storage *(camera pro conservandis lignis)*. These rooms opened onto a central corridor *(vestibulum)*. The entrance to each monk's garden *(introitus ad hortulum)* led directly to an area that was both decorative and functional. The convent's main building had three wings, stood two storeys high, and featured an entrance gate in the foreground with a façade marked by a bell tower and clock. Above the gate, an inscription read: *Absit ab hac porta sacra turbator eremi, Odit enim turbas turba sacrata Deo*[21]. The enclosed area, except for a small outbuilding, was surrounded by a wall and included orchards and gardens. A small cemetery lay before the monastery gate. A stone aqueduct brought water from the spring under Saint Svorad's cave, supplying the buildings and fountains and providing surplus water to the nearby ponds (?)[22].

In 1782, after nearly 90 years, Joseph II dissolved the convent. At that time, there were eight fathers, five clerics and five brothers living there[23]. Most of the property, including the church, was abandoned. Only parts of the outbuildings remained in use. Over the years, these served different purposes, such as textile manufacturing, an inn, climatic baths and a missionary residence – until the late 1950s. Then, work began to convert the site into a hospital for respiratory diseases. Today, only two wings of the main convent outbuilding, the ruins of the monastery church, and portions of the terraced garden walls remain.

Archaeological research and the discovery of faunal remains

Several rescue excavations have been carried out at the Zobor monastery site. In 1942, apart from relics of the medieval monastery, a pair of Baroque monks' houses were uncovered. However, the documentation and findings were burned during the Second World War bombing of Bratislava, and the available report does not mention findings documenting the processing or consumption of food[24]. Rescue campaigns conducted during the 1960s were similarly limited, as they also did not address this issue. Later on, research linked to the construction of the large therapeutic hospital for tuberculosis and respiratory diseases was restricted to monitoring engineering networks and documenting Baroque stone water pipelines[25]. It was not until after 2001 that a more systematic investigation became possible, when the Institute of Archaeology of the Slovak Academy of Sciences in Nitra began excavations. Sponsored in part by the City of Nitra, this research shifted its focus to documenting the remnants of the medieval monastery and exploring aspects of daily life in the Baroque monastery[26]. Regarding the Camaldolese monks' diet, the most important evidence emerged south of the Baroque church ruins, where three monks' dwellings (cells) were partially uncovered. In the utility room of one, a unique discovery provided rare evidence of daily life in the monastery.

The faunal remains analysed in this study comprise 5211 specimens with a total weight of 2.8 kg. The material includes vertebrate bones and teeth, the outer shell (exoskeleton) of crustaceans and eggshells. All are in excellent condition, with the bone surfaces intact and showing no hard coatings or erosion. Most modifications are of anthropogenic origin, as the remains accumulated at the site are known to be due to human activity. As a result, the degree of disturbance to bone integrity is low to medium, mainly caused by intervention during butchery or kitchen preparation and by the consumption of meat and bone by humans or animals. It is important to note that no complete animal skeletons or partially articulated elements were uncovered.

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21 Kompánek 1895, 112; Branecký 1945, 22.
22 Habovštiak 1971, 117 f.
23 Kompánek 1895, 114.
24 Kraskovská 1942/1943.
25 Habovštiak 1966; Habovštiak 1971.
26 Samuel 2011.

Table 1 Analysed samples with archaeological context

Sample	Trench	Sector	Depth (cm)	Dating	Context
1	2/03	A	150–160	Early Modern	A strip of black clay laying in front of the southern wall of cell 3
2	2/03	D	110–115	Early Modern	Rubble just above the floor in cell 3
3	2/03	C	145–155	Early Modern	Black clay under the older floor in cell 3
4	2/03	D	145–155	Early Modern	Dark clay under the older floor in cell 3
5	2/03	D	155–165	Early Modern	Light brown clay (silt)
6+8	5/03	–	80–85	Early Modern	Yellow-brown clay with stones, mortar and daub
7	6/03	–	up to 85	Early Modern (?)	Cleaning of the ground plan, mortar and clay layer over the medieval monastery wall
9	4/02/03	–	40–80	after 1782	Deepening of the western edge of the sounding (exterior of cell 9)
10	6/03	–	90–105	Middle Ages (?)	Dismantling the layer of white mortar with clay over the walls of the medieval monastery
11	5/03	–	105–150	Middle Ages	Dark feature infill (medieval pit), black-yellow clay
12	4/02/03	–	275–285	2nd half of the 18th cent.	Destruction in the »cellar« of the utility room in cell 9

Altogether twelve samples from the trenches S 2 and S 4–S 6, investigated in 2003 and covering the area of two monks' houses and their exteriors, were analysed (tab. 1; fig. 4). Among these, cell 3 was the best-preserved monk's house, with above-ground masonry walls preserved up to 1 m, and its western and northern perimeter walls – part of the Baroque terrace – preserved up to 2–3 m. The house measured 9 × 10 m and comprised four rooms divided by a corridor. The largest room, serving as the main living room, was accessible from the corridor through a doorway with sloping lintels situated on the left side of the entrance. In this room, the brick plinth of the heater, with a feeding hole located in the corridor, remains preserved. Adjacent to this main living room was a smaller room with an almost-square loft, probably used as a study, accessible through a doorway from the brick-paved corridor. To the right of the entrance was the chapel, distinguished by a square floor plan and a mortar floor. The remaining fourth room served as a utility or store room with a toilet.

In terms of sampling, samples 2–5 were collected during the surveying of the two southern rooms (main living room and study) and the adjacent section of the connecting corridor. These samples were found at varying depths in the layers just above the floors, within the floors themselves during their dismantling, or in layers beneath the floors. In contrast, sample 1 was collected outside the house, specifically from a layer of black clay running along the south elevation. This band of clay appeared as a shallow trough in profile, and field observations suggested that it was created during the construction of the dwelling, possibly to drain rainwater. Over the course of the monastery's existence, this trough was gradually filled in with washed clay containing food remains. Thus, all the above-mentioned contexts and corresponding samples relate to the construction of the monastery, its period of use, and the time immediately following its abandonment.

The vast majority of finds (82.5 %) came from the trench S 4/02/03, which covered the interiors and, to a lesser extent, the exteriors of cell 9[27]. The location of the monk's dwelling was indicated by a mound projecting over 1 m above the surrounding ground. Notably, a path running along the eastern façade of the house was uncovered in front of the entrance. This walkway was formed by various large flat rubble stones of local provenience. As excavation

[27] Bielichová et al. 2019, 142 fig. 6.

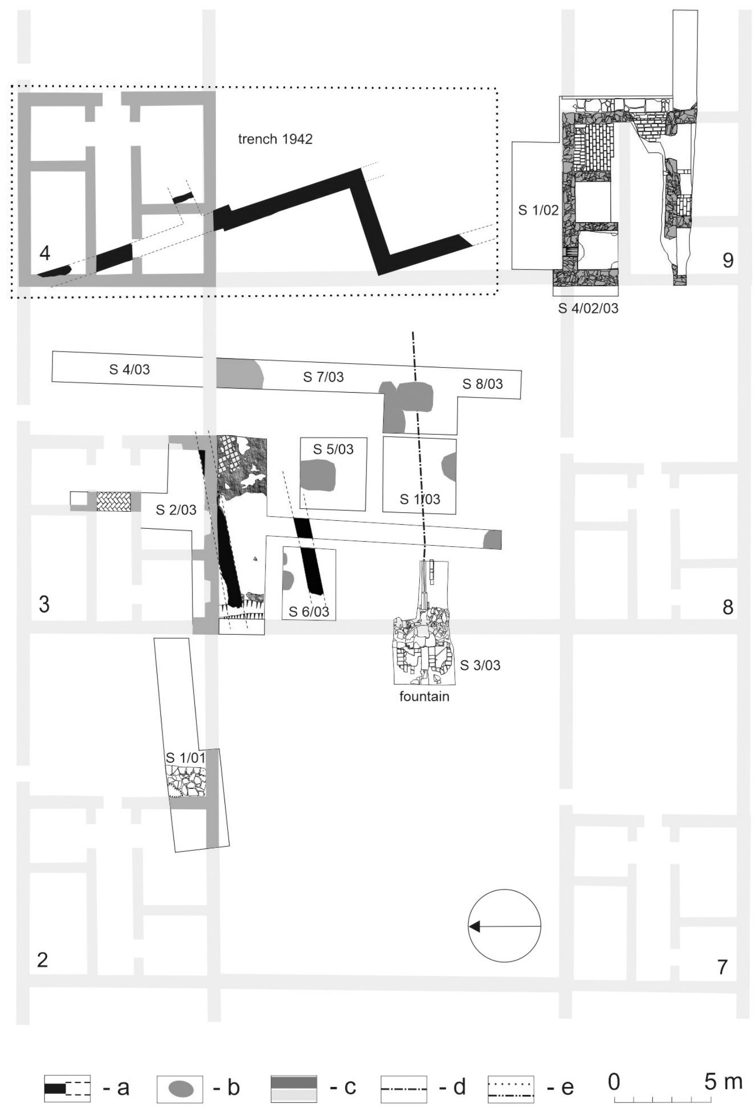

Fig. 4 Plan of the studied areas in 1942 and 2001–2003. a: Architectural relics of the medieval monastery and their assumed course; b: Medieval feature; c: Uncovered/assumed relics of the Camaldolese monastery; d: Baroque stone aqueduct with a fountain; e: Borders of the studied area (plan: M. Samuel)

progressed, the discovery of the doorway, a short section of the corridor with a brick floor, then the northern part of the main living room with the brick plinth of the heater, and the private chapel with a brick floor and the plinth of the altar attested to a similar outline for both houses. The walls of the house have been preserved up to a maximum height of 40 cm. Subsequently, the last room explored was the utility room, which was divided into two unequal parts. The larger part had a crumbled mortar floor, and the other part contained a sunken brick-built space 240 cm deep (from floor level in the passage) with clear traces of a vaulted wall. Along the northern wall, there was a vertical indentation in the masonry resembling a ventilation shaft; the bottom was formed by trampled clay (fig. 5). It is most probable that this space served as a small cellar or a toilet cesspit, which were usually located in this part of the house. The infill, up to a depth of 15–30 cm above the bottom, was made up of stones from the destroyed walls of the house and a mixture of lumps of mortar, sand and forest clay. In this part of the infill, archaeological finds were sporadic. Conversely, the remaining, lowermost part of this space was filled almost exclusively with fine-grained sediment, which

Fig. 5 The cellar or cesspit of the utility room in cell 9 with retrieved finds. 1: The northern view of the cellar/cesspit space; 2: Hypothetical appearance of the utility room in cell 3; 3: Collection of pottery; 4: Some of the recovered fish bones; 5: Collection of glass (photo: M. Samuel, sources: <https://zoborskyklastor.sk/exterier-pribytku-mnicha-audio-2/>)

was sieved and examined in detail. This process yielded the vast majority of the osteological material (sample 12), along with a unique set of ceramics and glass vessels. The majority of these items can be clearly associated with the dining and diet of the Camaldolese monk living in the cell. Based on an estimate of the pottery's lifespan, the dates on a pair of faience cups (1760 and 1765) and historical facts about the dissolution of the monastery (1782), it was possible to place the period of use of the discovered features in the last two to three decades of the Baroque monastery[28]. Supporting this dating, the accompanying archaeofaunal material is similarly dated (1760–1782).

The investigation of the dwelling was completed by extending the trench into a small area in front of its western wall, where several animal bones were found (sample 9). However, these bones are apparently no longer related to the existence of the Camaldolese monastery; instead, they represent the horizon of its abandonment or subsequent use for other purposes. In addition to sample 9, the archaeofaunal assemblage also included finds from trenches 5 and 6 (1.7 % of the total). These finds come from the spaces between the rows of dwellings where medieval contexts survive. Notably, while sample 11 represents the infill of a medieval building, samples 7 and 10 may instead relate to the period of the medieval monastery's demise and desertion at the end of the Middle Ages.

[28] Samuel – Čurný 2010, 269.

Archaeozoological research methods

Thanks to the presence of dedicated archaeology students at the site, great attention has been devoted to the recovery and collection of ecofacts. During the 2001–2003 excavation seasons, faunal remains were recovered through non-systematic, subjective sampling. The process began with hand-picking bones, teeth, eggshells and exoskeletal parts from the investigated sediments, down to the smallest fragment recognizable by eye. In addition to hand retrieval, most of the infill from the cellar or cesspit of the utility room in house no. 9 was dry-sieved through a mesh with a diameter of about 5 mm[29].

After recovery, animal remains were extracted either by hand or through sieving. Subsequently, an archaeologist consulted the osteologist about the material, after which it was transported to the archaeozoological laboratory at the Institute of Archaeology in Nitra. There, the material was cleaned and washed using sieves with a 1–2 mm mesh size. The cleaned remains were then sorted by anatomical and taxonomic affiliation – vertebrate bones and teeth, plus fragments of bird eggs, crayfish and mollusc shells.

In 2017, basic taxonomic and anatomic identification of fish (K. Hensel [†]) and other taxa (Z. Bielichová) was conducted. Fish remains were identified using the freshwater fish reference collection at the Department of Zoology, Faculty of Natural Sciences, and Comenius University in Bratislava. Throughout the process, finds were pre-sorted, analysed, and evaluated using comparative reference and archaeological specimens at the Institute of Archaeology of the Slovak Academy of Sciences in Nitra. Evaluation also considered age and sex determination, osteometric data[30] and recorded bone modifications[31]. Zoological and anatomical terminology adhered to standards for mammals[32] and fish[33]. Fish length and weight were calculated from published coefficients for pike[34] and other freshwater species[35]. Some questionable specimens (small rodents, turkey and sturgeons) were examined in laboratories in Prague and Kazan.

In 2022, sturgeon remains were analysed at the Biomonitoring Laboratory, Institute of Problems in Ecology and Mineral Wealth, Tatarstan Academy of Sciences in Kazan (I. Askeyev, D. Shaymuratova, S. Monakhov). Taxonomic and anatomical identification used a comparative bone collection of nine sturgeon species[36]. Regression equations to estimate length and weight were derived from laboratory databases of 20th–21st century sterlet specimens from the Volga River basin. Regression statistics ($y = ax^b$) related dorsal scute (2–5) measurements to total length (TL) for *Acipenser ruthenus*.

The type and accuracy of the regression model were then determined by the coefficient of determination (R^2)[37]. To ensure accurate length estimation, 95 % confidence limits were calculated, and the maximum relative errors (confidence limit/calculated length) were compared across measures. Next, regression significance was assessed ($P < 0.001$). The Akaike information criterion (AIC) was used to select the optimal regression model, where lower AIC values indicate a better fit[38]. Measurement (M1) of elements (dorsal scutes 2–5) for the sterlet is depicted in figure 6. The resulting regression equations based on sterlet (*Acipenser ruthenus*) in the biomonitoring laboratory are as follows: TL: 36.3–65.3 cm, dorsal scutes 2–5; non-linear: a: 13.789, b: 0.4988, R^2: 0.8342, n = 64, relative error (%): 1.019, AIC: 537.86.

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29 Due to time constraints at the close of the excavation season, approx. one-third of the infill remained unprocessed. As a result, this portion was dumped at the site rather than transferred to the laboratory. M. Čurný, personal communication.

30 von den Driesch 1976; Morales – Rosenlund 1979; Radu 2003.

31 Lyman 1994; Reitz – Wing 1999; Schmid 1972; Silver 1969; Uerpmann 1973; Wheeler – Jones 1989.

32 Gentry et al. 2004.

33 Lepiksaar 1983.

34 Bartosiewicz 1990.

35 Brikhuizen 1989; Libois – Hallet-Libois 1988; Radu 2003.

36 The anatomical names of sturgeon bone elements follow Hilton et al. 2011.

37 Zar 1999.

38 Hammer et al. 2001.

In parallel, the length-weight relationship (LWR) was determined using least squares with the equation $W = aL^b$, then transformed logarithmically to $LogW = Loga + bLogL$[39], in which W is the total body weight (g) and L is total length (mm); »a« and »b« are the intercept and slope, respectively[40]. Prior to regression, outliers were identified using log-log plots of length-weight pairs[41]. For LWR, descriptive statistics included sample sizes, standard length and weight ranges, means, 95 % confidence intervals (CIs), equation coefficients, and correlation coefficient (R^2). The LWR regressions were highly significant ($P < 0.001$). These regression equations were based on database measurements from recent (19th–21st cent.) sterlet specimens stored in the Kazan laboratory. The regression equations derived for sterlet (*Acipenser ruthenus*) are: TL: 237–880 mm; body weight: 72–4618 g; n = 496; Log a [95 % CIs]: –6.0691 [–6.3129, –5.8654], b [95 % CIs]: 3.2707 [3.1933, 3.3617], R^2: 0.957.

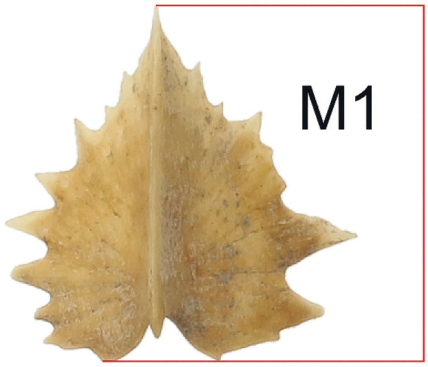

Fig. 6 The length of a dorsal scute (M1) used in the calculation of the total length (TL) in a sterlet (photo: Z. Bielichová)

Results and discussion

The analysed collection from the Zobor monastery comprises 5211 specimens of at least 22 animal species[42]. Wild taxa clearly predominated the assemblage, both by the number of identified specimens (94.2 %) and by the minimum number of individuals (69.9 %). By weight, the representation of wild taxa is lower (50.8 %), but it still accounts for the majority of identified finds (tab. 2). Except for the turkey, all species identified in Zobor Monastery are autochthonous to the studied region and are commonly represented in bone assemblages of that period. However, it is important to note that the share of particular taxonomic groups varied considerably, even within the studied Nitra microregion. This variability is due to taphonomic factors (e.g. sample origin, size, preservation, excavation procedures) as well as cultural reasons, such as the social and economic status of the sites[43]. When considering this variation, it is informative to compare ecclesiastical and secular settlements or seats. Previous research has shown that the proportion of bones of wild taxa in towns and castles does not exceed 3.5 % of NISP (number of identified specimens)[44]. Despite rich historical sources indicating the popularity of fish among urban and aristocratic society in the early modern period, there are as yet no plausible archaeoichtyological records available from Slovakia[45]. Furthermore, apart from mammals and fish, distinct differences in the representation of birds have been recorded among early modern sites in the Nitra region studied so far[46]. Specifically, when comparing the share of poultry in the monastery and the nearby castles and town, it is clear that at some aristocratic seats (e.g. Gýmeš Castle), poultry numbers among the important meat resources. In contrast, at the Zobor monastery, the overall representation of poultry is small

39 Froese 2006.
40 Froese et al. 2011.
41 Froese et al. 2011.
42 See also Bielichová et al. 2019, 146 f. tab. 2.
43 Bielichová et al. 2019, 145 fig. 8.
44 Miklíková – Fabiš 2004; Repka et al. 2017; Vozák – Bielich 2021. To provide a regional context, the comparative assemblages come from the town of Nitra and from the castles inhabited by the Hungarian noble families at Gýmeš and Oponice. These castles are situated on opposite outcrops of the Tríbeč Mountains, approx. 12 km from the monastery.
45 Cf. Miklíková 2007, 130; Hlavačková 2015; Vozák – Bielich 2021.
46 Bielichová et al. 2019, 147 fig. 8, 2.

Table 2 The basic taxonomic groups represented in the assemblage; quantified by number (n/NISP), weight (WISP) and minimum number of individuals (MNI)

Taxa	n	% n	% NISP	w	% w	% WISP	MNI
Fish	4834	92.8	91.5	1368.4	49.7	43.0	89
Undetermined mammal	143	2.7	–	323.4	11.7	–	–
Domestic mammal	108	2.1	4.5	990.7	36.0	53.7	33
Bird	49	0.9	1.1	40.2	1.5	1.5	12
Crayfish	43	0.8	1.8	3.8	0.1	0.2	1
Reptile	14	0.3	0.6	4.5	0.2	0.2	4
Wild mammal	12	0.2	0.5	22.7	0.8	1.2	4
Bird (eggshell)	5	0.1	–	0.1	0.0	–	–
Land snail (shell)	2	0.0	0.1	0.6	0.0	0.0	1
Undetermined bone	1	0.0	–	0.2	0.0	–	–
Wild	4908	94.2	–	1400.3	50.8	–	103
Domestic	133	2.6	–	1018.9	37.0	–	44
Domestic/wild	170	3.3	–	335.4	12.2	–	–
Identified	2431	46.7	–	1843.6	66.9	–	147
Unidentified	2780	53.3	–	911.0	33.1	–	–
Total	**5211**	**100**	**100**	**2754.6**	**100**	**100**	**147**

(1.1 % of total NISP), yet it ranks second among domestic species, and the occurrence of eggshells indicates an important complementary role in the monastic diet.

Regarding the spatial distribution of analysed food remains in the Zobor monastery, differences in the representation of taxonomic groups have been observed (tab. 3). Focusing first on the monks' dwellings, the remains of wild animals, especially fish, occur in contexts associated with both their interiors (cell 9: utility room, sample 12) and exteriors (cell 3: sediments along the outer southern façade of the building, sample 1). In contrast, some of the interior contexts in cell 3 (sediments under or above floor, samples 2–4), according to the excavator, represent »the period of the construction, the existence a short time after the suppression of the Camaldolese monastery«, and also demonstrate the representation of the farm mammals (fig. 7). Additionally, a few dog (sample 1) and horse specimens (sample 3) in front of the dwelling and below the floor indicate that samples covering the area of cell 3 may very well have included residual material from the previous medieval occupation at the site. However, this can only be proven by methods of absolute dating, and since the evaluation of the associated artefacts is not yet available, we shall leave open the possibility of the consumption of four-legged animals in cell 3. Turning to species diversity, in the interiors and exteriors of this cell, sheep and pig (samples 3–5), chicken (all except sample 3), goose (samples 4 and 5) and domestic turkey (sample 4) were present. Finally, the material from cell 9 shows a clear absence of domestic species, except for two chicken bones and bird egg shells, which correspond to the fasting nature of the monastic diet (fig. 7).

Terrestrial species

Domestic mammals in the assemblage include cattle (*Bos taurus*), pig (*Sus domesticus*), sheep (*Ovis aries*), horse (*Equus caballus*) and dog (*Canis familiaris*), while no goat bones were identified among the caprines. Among domestic birds, chicken (*Gallus domesticus*), goose (*Anser domesticus*) and turkey (*Meleagris domesticus*) were identified. The identification of turkey provides unique historical and archaeological evidence, with the complete left coracoid offering critical insight into the domestication and history of domestic birds. This specimen

Table 3 Representation of animal taxa in analysed samples; quantified by NISP

Taxa	Sample											
	1	2	3	4	5	6	7	8	9	10	11	12
Bos taurus	–	–	7	1	11	–	–	3	3	–	1	–
Ovis aries	–	–	1	1	6	–	–	1	–	–	–	–
Ovis/Capra	–	–	12	8	29	–	–	2	–	2	1	–
Sus domesticus	–	–	3	3	3	–	2	2	–	–	2	–
Sus cf. *domesticus*	–	–	1	–	–	–	–	–	–	–	–	–
Canis familiaris	2	–	–	–	–	–	–	–	–	–	–	–
Equus caballus	–	–	1	–	–	–	–	–	–	–	–	–
Lutra lutra	–	–	–	–	–	–	–	–	–	–	–	7
Castor fiber	–	–	–	2	–	–	–	–	–	–	–	–
cf. *Glis glis*	–	–	–	–	–	–	–	–	–	–	–	3
Gallus domesticus	1	7	–	4	2	2	–	1	–	–	–	2
Anser domesticus	–	–	–	2	3	–	–	1	–	–	–	–
Meleagris domesticus	–	–	–	1	–	–	–	–	–	–	–	–
Emys orbicularis	7	7	–	–	–	–	–	–	–	–	–	–
Acipenser ruthenus	–	–	–	–	–	–	–	–	–	–	–	4
Acipenser stellatus	–	–	–	–	–	–	–	–	–	–	–	19
Acipenser gueldenstaedtii	–	–	–	–	–	–	–	–	–	–	–	9
Acipenser sp.	–	–	–	–	–	–	–	–	–	–	–	1
Cyprinus carpio	130	10	–	–	–	–	–	–	–	–	–	487
Tinca tinca	–	–	–	–	–	–	–	–	–	–	–	5
Leuciscus idus	–	–	–	–	–	–	–	–	–	–	–	2
Alburnus alburnus	–	–	–	–	–	–	–	–	–	–	–	1
Esox lucius	75	2	–	–	–	–	–	–	–	–	–	816
Silurus glanis	12	3	–	–	–	–	–	–	–	–	–	70
cf. *Cyprinus/Silurus*	–	–	–	–	–	–	–	–	–	–	–	556
Cyprinidae	5	14	–	–	–	–	–	–	–	–	–	5
Astacus astacus	–	–	–	–	–	–	–	–	–	–	–	43
Cepaea cf. *vindobonensis*	–	–	–	–	–	–	–	–	–	–	–	2
Mammalia indeterminate	2	5	7	27	42	4	10	25	–	3	15	–
Rodentia indeterminate	–	–	–	–	–	–	–	–	–	–	–	3
Aves indeterminate (bone)	–	9	–	9	1	2	1	2	–	1	1	2
Aves indeterminate (eggshell)	–	–	–	–	–	–	–	–	–	–	–	5
Pisces indeterminate	44	301	–	–	–	2	–	–	–	–	–	2261
Unidentified bone	–	1	–	–	–	–	–	–	–	–	–	–

represents one of the earliest archaeozoological records of the species in Slovakia and Central Europe[47], and a cut mark shows it formed part of the local diet. Although the find’s chronological origin is disputed, it was discovered under the floor of cell 3, along with bones of other domestic animals (sample 4). Recent research on the timing of turkey domestication and arrival in Europe[48] indicates the find does not originate from the site’s medieval occupation. Instead, all that remains in this sample is now considered to be from the early modern period, possibly connected to the construction of a specific monk’s cell (?).

47 Bielichová et al. 2019, 152–154 fig. 11; Bielichová et al. 2025.
48 E.g. Crawford 1992; Thornton et al. 2012.

% of NISP	Cell 3 (Σ = 375)	Cell 9 (Σ = 2025)
Land snail	0	0.1
Crayfish	0	2.1
Fish	66.9	97
Pond turtle	3.7	0
Wild mammal	0.5	0.5
Poultry	5.3	0.1
Domestical mammal	23.5	0.1

Fig. 7 The spatial distribution of different taxonomic groups in two monks' cells (photos from the Camaldolese monastery in Majk, Hungary by Z. Bielichová)

Also of interest was the occurrence of two metacarpal bones of a dog and a horse in the assemblage (samples 1 and 3), since these animals are not typical meat sources. For both, the archaeological context correlates with the early modern period. However, the correlation with the monastery's phases of existence is complicated by the presence or absence of other faunal remains, such as fish. The dog was the only domestic mammal recorded in the sediments along the outer wall of cell 3, within sample 1, which was otherwise dominated by fish remains. The horse remains were found below the floor of the same cell (sample 3), so both a medieval (residual [?]) or an early modern dating is possible. Their non-alimentary use seems clear, as indicated by the elements preserved and the absence of anthropogenic marks.

Last but not least, the same applies to the only representative of the wild terrestrial species – the edible dormouse (*Glis glis*). According to the Bible[49], the meat of the mouse should not be consumed. However, the meat of squirrels or dormice was a natural part of human diets as late as early modern times[50]. At Zobor Monastery (sample 12), it is more than probable that the remains of subadult individuals found in the utility room of cell 9 resulted from natural death. They may have been attracted by the waste. It is possible they hibernated in the deserted building. The dormouse may also have been an unpleasant companion for a contemplating monk.

Among typical terrestrial meat suppliers, caprines are highlighted by their representation within the group of domestic animals (n = 63). This is also evident by the minimum number of individuals (MNI = 16). Poultry (MNI = 11), pig (MNI = 8) and cattle (MNI = 6) are also significant based on MNI. By weight (WISP), cattle predominate over caprines[51]. Most domestic animals are represented by skeletal elements that bear meat of good or moderate quality[52]. Elements viewed as carcass waste, such as bones of the face, tail and extremities, make up a low proportion: 15.4 % by NISP and 24.5 % by WISP. In poultry, the bones of chicken, goose and turkey are well-muscled. Dental and postcranial analysis in domestic mammals showed juvenile or subadult individuals dominated (86.9 % of those assessed)[53]. If

49 Leviticus, chap. 11.
50 Zíbrt 2012.
51 Bielichová et al. 2019, 149–152.
52 Bielichová et al. 2019, 152–154 tab. 4 and fig. 10. Classification of skeletal elements according to Uerpmann 1973.
53 Bielichová et al. 2019, tab. 5.

four-legged animals were consumed in the Camaldolese monastery, young caprines and cattle were preferred. Lamb (94.3 %) and veal (81 %) were most often chosen. Sheep/goats were slaughtered at 2 (MNI = 2), 6 (MNI = 10), 12 (MNI = 2), and at 12–24 months (MNI = 1). Only one older individual (3 years old) was recorded. For cattle, the animals died before 6 (MNI = 2) and at 24–30 (MNI = 1) or 42 months (MNI = 1). Pigs were slaughtered at young ages, between the first and third months (MNI = 1) and between the first year and a half (MNI = 1). Immature individuals also dominated among domestic poultry. The exception was chicken, which lacked less muscular elements (*carpometacarpus*) and included mature individuals. This may reflect general differences in exploitation patterns, such as keeping them for egg production, or differences in kitchen processing, such as soups versus meat dishes. Eggshells (n = 5) were identified in the cesspit of the utility room in cell 9 (sample 12). They have not yet been classified as to species. However, based on thickness and size, they have been preliminarily assigned to the domestic hen[54]. Consuming eggs was allowed under St. Benedict's dietary rules. Eggs formed an important part of monastic cuisine[55].

Except for the dog and horse remains, human-induced bone modifications have been observed in all of the identified domesticates[56]. Cutting, chopping and intentional breakage or splitting of bones occurred frequently in caprines (48.7 % of NISP) and cattle (28.2 %). They were less common in smaller animals. For example, such modifications affected pig (10.3 %), chicken (7.7 %), goose (2.6 %) and turkey (2.6 %). These marks were related to secondary butchery[57], including kitchen processing and meal preparation included separating limbs at the joints, defleshing and opening bones to extract marrow. No bones of domestic animals were burnt, except a single cattle phalanx. This phalanx was partially stained black and came from sample 11, dated to the medieval horizon of the site's occupation. Gnawing of bones by a carnivore rarely occurred (5.3 %). Thus, it can be assumed that predators or scavengers had limited access to food waste from the investigated cells[58]. Toothmarks were registered on cattle, caprines and chicken bones (samples 3, 4 and 5). These can be linked to the presence of a dog and a cat at the site at other times. This may have occurred during the construction of the Baroque monastery, when workers' meal waste accumulated. Extensive landscaping may have mixed this with older material.

In sample 12, a few fragments from the shell of a land snail have been recorded. The size, shape and remnants of dark bands on the preserved shell suggest it may be a species of the genus Cepaea. Most likely, it is the woodland slug *Cepaea vindobonensis*. This xerothermic species is a natural part of the malacofauna of Zobor and its foreland[59].

Aquatic and semi-aquatic species

The analysed assemblage contains more wild aquatic and semi-aquatic animals, both vertebrates and invertebrates (tab. 2). Bones of Eurasian beaver (*Castor fiber*) and otter (*Lutra lutra*) are relatively rare, making up only 0.4 % of the total identified bones (NISP)[60]. These species were present in local wildlife until the 19th century, when they disappeared[61]. However, bones from neither animal have been recovered from early modern sites in Nitra town or its castles to date. Beavers and otters might have been attracted to nearby monastery fishponds due to their ecological habits, but they were more likely brought to the monastery kitchen either

54 Bielichová et al. 2019, 151.
55 E.g. Moreno-García – Detry 2010.
56 Bielichová et al. 2019, tab. 6.
57 *sensu* Rixson 1988.
58 Bielichová et al. 2019, 152.
59 Ložek 1955, 337; Lučivjanská 1991.
60 Bielichová et al. 2019, tab. 2.
61 Valachovič 2008.

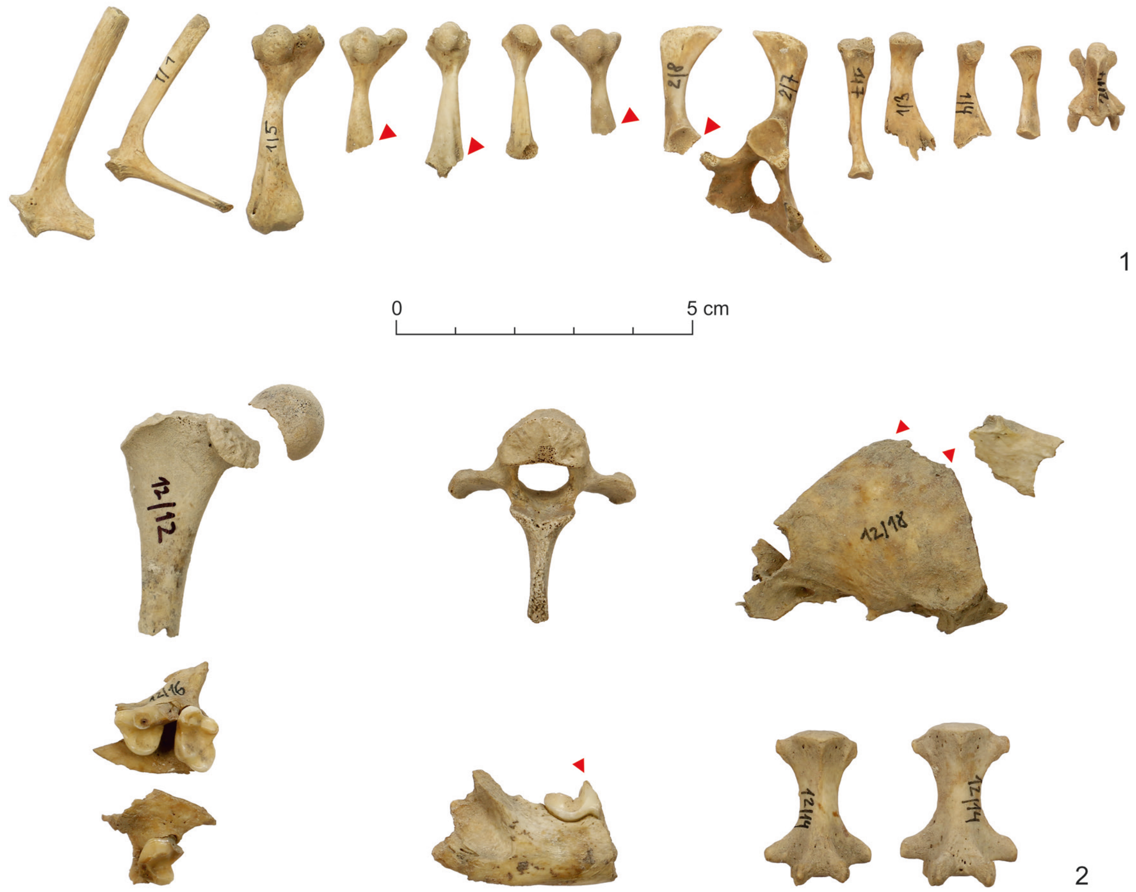

Fig. 8 Wild animals. 1: Skeletal elements of at least four individuals of the European pond turtle (*Emys orbicularis*); 2: Femur and vertebra of a sub-adult individual and fragments of the neurocranium, maxilla and mandibula, and two tail vertebrae of an adult individual of the Eurasian otter (*Lutra lutra*); cut mark indicated by an arrow (photos: Z. Bielichová)

dead or alive through regular purchases. Remains from both skull and limb bones suggest entire animals were processed. For the beaver, a pelvic bone fragment and a molar tooth were found in sample 4, showing that at least one adult was present (fig. 8). The ischium bone was cut through the hip joint and its lower end, likely during kitchen processing. The otter is represented by bones from at least two individuals: an immature animal (femur head and vertebra) and an adult (skull fragments with teeth and tail vertebrae) (fig. 8). The skull and jaw have several old fractures, possibly from cutting meat or accessing tissues such as the brain and tongue.

Another vertebrate animal with a preference for aquatic biotopes is a reptile, the European pond turtle (*Emys orbicularis*)[62], which is the sole turtle native to Slovakia. Their bones occurred in samples 1 and 2, which, along with fish and bird remains, represent the exterior and interior (floor) spaces of cell 3 (n = 14; 0.6 % NISP). These are exclusively elements of the animal's internal skeleton, the feature undoubtedly related to the previous kitchen processing, when the carapace and plastron were removed before cooking or serving the dish (fig. 8). Sample 1 (exterior of the cell) included the limb bones such as scapula, coracoid, humerus and tibia, most probably representing at least two individuals at different adult ages. Sample 2 consisted of the humerus, cervical vertebrae and pelvic bones from at least three individuals. Judging by the bone sizes, they were killed at various ages, possibly including subadults. The bones show no evidence of gnawing or burning. However, some have old fractures, suggesting they

[62] Čaputa et al. 1982; Fabiš – Miklíková 2002; Kánya 2015.

were probably deliberately broken. Key evidence of kitchen processing includes cut marks running across the diaphyses of two humeri below the proximal epiphyses. One bone was split into two pieces, with only the distal part preserved. The second, larger humerus shows transverse cut marks near the proximal epiphysis and longitudinal marks at the distal end. These likely indicate limbs were divided at the joint. Similar modifications were seen in the third humerus (fig. 8).

The crustacean remains registered in the assemblage (n = 45; 1.9 % NISP) are among the rarities in the archaeozoological records of Slovakia. The carapace fragments preserved came exclusively from sample 12 and constitute part of the food remains deposited in the cellar or cesspit, together with bones of vertebrate remains (fish and otter). They represent parts of the crayfish forelimb (claws), cephalothorax, and abdomen from at least one individual[63]. Based on the morphology of the fragmentary remains and the information on the crayfish species' ecology and history, it has been assumed that most probably, the shell belongs to the most widespread river crayfish (cf. *Astacus astacus*)[64]. It is one of the largest crayfish (TL up to 18 cm, male with massive claws) that naturally inhabit flowing waters and ponds with muddy bottoms. Historic and archaeological sources show that it was a seasonal food and was popular as a Lenten dish in monasteries and among the higher society in towns and castles[65].

The largest share of aquatic animals from the Zobor monastery is fish (n = 4834; 92.8 %). Most finds were recovered from the cesspit or cellar of the utility room in cell 9 (n = 4226; 81.2 %; tab. 3). Additional material comes from cell 3, from its exteriors (n = 266; 9.2 % NISP), or from sediments on its floor (n = 330; 1.2 % NISP). About half of the finds have been identified to the genus or species level (n = 2608; 67.6 % NISP). All identified species are freshwater fish native to the Middle Danube region: sterlet (*Acipenser ruthenus*), Russian sturgeon (*Acipenser gueldenstaedtii*), stellate sturgeon (*Acipenser stellatus*), common carp (*Cyprinus carpio*), common dace (*Leuciscus leuciscus*), common bleak (*Alburnus alburnus*), tench (*Tinca tinca*), Wels catfish (*Silurus glanis*) and northern pike (*Esox lucius*). For most species, remains of all parts of the body have been found (tab. 4). Comparing neurocranium, viscerocranium, shoulder girdle, vertebrae/ribs, fin rays and dermal scutes of Acipenseridae (fig. 9, 1), about half the specimens are vertebrae and ribs (55.5 % of NISP); most of the rest are branchiocranium elements (33.2 %). Bones of the neurocranium, fin rays, and shoulder girdle are rare (less than 5 % in each category). However, all these elements have been found for every identified fish species (fig. 9, 2). For the Sturgeon family, recovered elements include exoskeletal (dermal) bones, vertebrae, vertebral arches and ribs. The internal bones of the sturgeon neurocranium are cartilaginous, so they may be underrepresented. Still, both head and trunk parts are present in the sturgeon finds, suggesting that whole fish were supplied to the kitchen or different fish dishes were prepared throughout the year.

Pike

The pike is the dominant species in the material (n = 893; 36.9 % of NISP). However, it is the second most frequent (after carp) based on the minimum number of individuals (MNI = 32). Pike is a predatory, medium to large fish with a wide mouth. Its lower jaw has large, sharp, backward-curved teeth for gripping prey (fig. 11, 1). The intermaxilla and the rest of the oral cavity have many other sharp teeth. Pike has a European distribution. It occurs naturally in lakes and along the overgrown banks of the middle or lowland parts of rivers, including the Nitra River[66]. The body shape, size and colour depend on the environment. If conditions are favorable, it is shorter and stockier. When food is available, it grows quickly and reaches 20–40 cm by the end of the first season. The maximum size ranges from 100–150 cm and

[63] Bielichová et al. 2019, 168 f. fig. 18.
[64] Novikmec – Svitok 2015; Stloukal et al. 2013.
[65] Duchoňová – Lengyelová 2016; Patoka et al. 2016; Pucher 1991.
[66] Sedlár 1969.

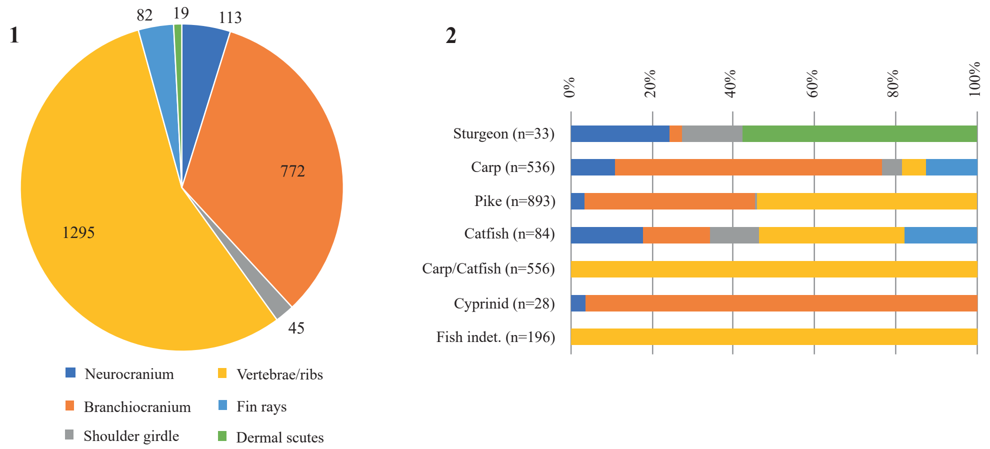

Fig. 9 The representation of fish body parts quantified by NISP. 1: In the whole assemblage (n = 2226); 2: Per particular species (compiled by Z. Bielichová)

12–35 kg[67]. In Slovak waters, the average pike weighs 3–5 kg, but there may be large variations even within one pond[68].

Most pikes in the assemblage measured 30–40 cm or 40–50 cm (84.4 %), matching the size they reach at age two or three (fig. 10, 1). These fish are slightly smaller than the current fishing size limits (60 cm)[69]. In their second to third year, pike typically weigh 100–1000 g[70], corresponding to the weights of the individuals found in the monastery material (tab. 5). Some large (caudal) vertebrae from sample 12 indicate single individuals of 90–110 cm in length and 7–11 kg in weight. Almost all skeletal elements are present in the material in similar amounts (tab. 4). This suggests most pikes were supplied to the kitchen as whole, unprocessed fish. Abdominal vertebrae outnumber caudal ones and may indicate a preference for meaty parts of the pike. Missing pike ribs may be due to identification challenges, possibly from a lack of comparative samples. Like many vertebrae, these ribs might be among the unidentified fish remains. The appendicular skeleton, including the cleithrum, postcleithrum and scapula, is also underrepresented. This may result from kitchen processing, which affects this region of the fish.

Cut marks and signs of chopping were recorded on various elements and parts of the skeleton (fig. 11). These marks were mostly observed on the skull and vertebrae in at least 34 specimens. The vertebrae being cut through are a clear indicator of the division of the fish carcass into smaller portions (fig. 11, 2). Other transversally and obliquely oriented cuts were recorded at the symphysis of several large dentalia. These were found on the medial plane of the mandible (fig. 11, 1). Some researchers interpret such modifications as an intervention intended to release a fisherman's hook that has been deeply swallowed and is therefore stuck[71]. Kitchen processing may also explain these modifications, such as the division of the head. Likewise, short, barely visible cut marks (two cases) recorded on the os supramaxillare and the radi branchiostegi could also be of culinary origin. Of interest were vertebrae (min. seven cases) that exhibit artificial deformities of the body, as reported in the literature. These deformities were previously associated with human or animal chewing (fig. 11, 3. 9)[72].

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67 Oliva et al. 1968, 77.
68 Sedlár 1954.
69 Following the current Slovak fishing rules and regulations <https://www.slov-lex.sk/static/pdf/2018/381/ZZ_2018_381_20190101.pdf> [14.04.2023].
70 Sedlár 1954, 111.
71 Wheeler – Jones 1989, 66.
72 Wheeler – Jones 1989, 75 fig. 5, 2.

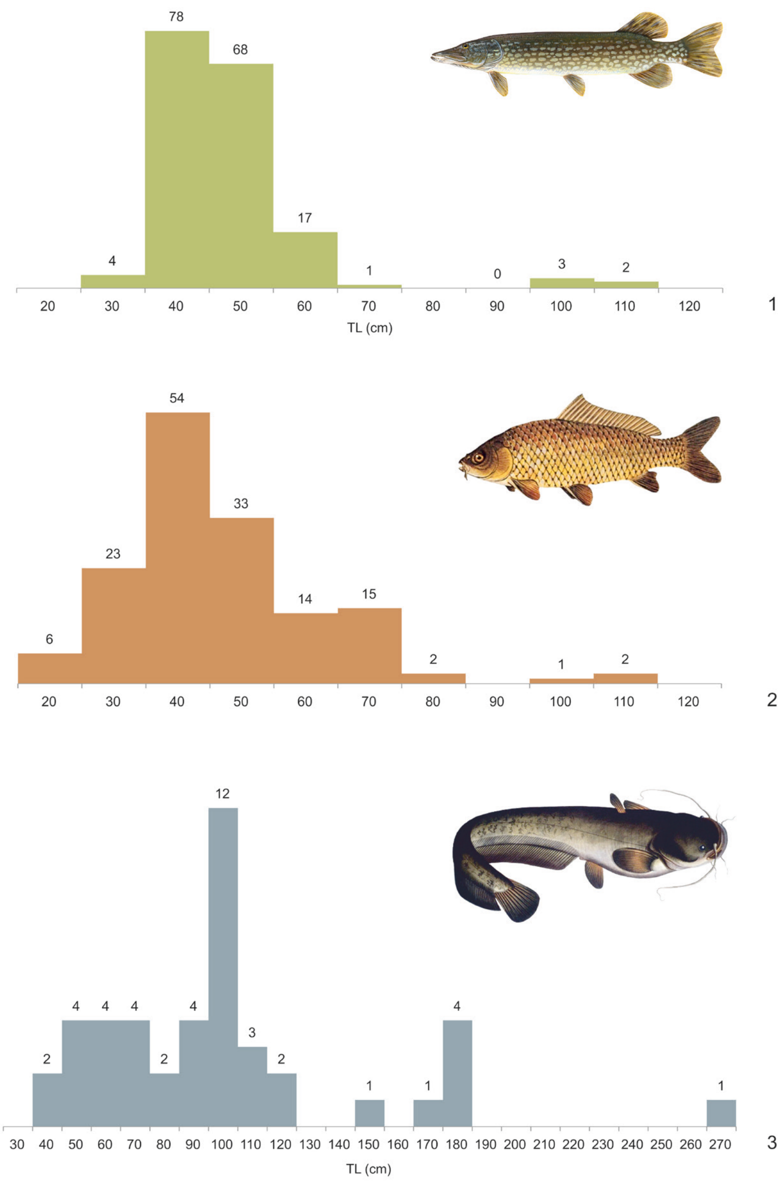

Fig. 10 The total length (including tail) of consumed fish. 1: *Esox lucius* (NISP = 173); 2: *Cyprinus carpio* (NISP = 150); 3: *Silurus glanis* (NISP = 44) (Bielichová et al. 2019, fig. 16)

Carp and other cyprinids

Cyprinid bones are among the second most abundant in the assemblage (n = 659; 27.2 % NISP). They were found in the samples with other species and sometimes, such as in sample 1, even outnumbered the pike. Within this group, the common carp dominated (n = 627; 25.9 % of NISP). Given the possibility of ponds below the monastery, we assume these bones are more likely to be from pond-reared, i.e. domesticated, individuals. Nevertheless, we must also consider the natural form of the Danube carp (*Cyprinus carpio*), known as the sazan, which is a critically endangered species and is practically extinct in Slovakia. Despite its rarity today, it was still recorded in the Nitra River in the last century[73], suggesting the fish might also have been supplied from local natural sources. The carp prefers warm waters, and its body growth depends on water temperature (it requires about 18–30 °C). For artificial farming, eutrophic

73 Sedlár 1959.

Table 4 Anatomic composition of fish remains; quantified by NISP

Anatomy	Skeletal element	Fish taxa													
		Sterlet	Stellate sturgeon	Russian sturgeon	Sturgeon indct.	Carp	Tench	Dace	Bleak	Pike	Catfish	Carp/Catfish?	Cyprinid	Fish indet.	NISP
NEUROCRANIUM	*praevomer*	–	–	–	–	–	–	–	–	–	5	–	–	–	5
	lacrimale	–	–	–	–	3	–	–	–	–	–	–	–	–	3
	suborbitale	–	–	–	–	16	–	–	–	–	–	–	–	–	16
	*postorbitale**	–	–	1	–	–	–	–	–	–	–	–	–	–	1
	frontale	–	–	–	–	8	–	–	–	23	–	–	–	–	31
	prooticum	–	–	–	–	2	–	–	–	–	–	–	–	–	2
	pteroticum	–	–	–	–	1	–	–	–	–	–	–	–	–	1
	exoccipitale	–	–	–	–	2	–	–	–	–	–	–	–	–	2
	supraoccipitale	–	–	–	–	3	–	–	–	–	–	–	–	–	3
	basioccipitale	–	–	–	–	12	–	–	–	–	9	–	1	–	22
	parasphenoideum	–	–	–	–	11	–	–	–	8	1	–	–	–	20
	*dermal skull bone (indeterminate)**	–	6	1	–	–	–	–	–	–	–	–	–	–	7
BRANCHIOCRANIUM	*dentale*	–	–	–	–	19	–	–	–	96	5	–	1	–	121
	retroarticulare	–	–	–	–	2	–	–	–	–	3	–	–	–	5
	anguloarticulare	–	–	–	–	–	–	–	–	46	–	–	–	–	46
	hyomandibulare	–	–	–	–	47	–	–	–	41	1	–	–	–	89
	palatinum	–	–	–	–	–	–	–	–	52	–	–	–	–	52
	ectopterygoideum	–	–	–	–	–	–	–	–	6	–	–	–	–	6
	metapterygoideum	–	–	–	–	7	–	–	–	–	1	–	–	–	8
	qadratum	–	–	–	–	20	–	–	–	11	1	–	2	–	34
	maxillare	–	–	–	–	6	–	–	–	–	–	–	–	–	6
	praemaxillare	–	–	–	–	4	–	–	–	–	–	–	–	–	4
	supramaxillare	–	–	–	–	–	–	–	–	2	–	–	–	–	2
	epihyale	–	–	–	–	–	–	–	–	18	–	–	3	–	21
	ceratohyale	–	–	–	–	–	–	–	–	25	2	–	1	–	28
	urohyale	–	–	–	–	8	–	–	–	–	–	–	6	–	14
	branchiostegale	–	–	–	–	9	–	–	–	60	–	–	–	–	69
	praeoperculare	–	–	–	–	37	–	–	–	12	–	–	–	–	49
	operculare	–	–	–	–	76	–	–	–	9	1	–	5	–	91
	interoperculare	–	–	–	–	10	–	–	–	–	–	–	–	–	10
	suboperculare	–	–	–	–	8	–	–	–	–	–	–	1	–	9
	*suboperculare**	–	1	–	–	–	–	–	–	–	–	–	–	–	1
	pharyngeum	–	–	–	–	75	5	2	1	–	–	–	–	–	83
	epibranchiale/pharyngobranchiale	–	–	–	–	12	–	–	–	–	–	–	–	–	12
	epibranchiale	–	–	–	–	12	–	–	–	–	–	–	–	–	12
APPENDICULAR SKELETON	*cleithrum*	–	4	–	1	17	–	–	–	2	8	–	–	–	32
	postcleithrum	–	–	–	–	8	–	–	–	–	–	–	–	–	8
	scapula	–	–	–	–	3	–	–	–	–	2	–	–	–	5

Table 4 cont.

COLLUMNA VERTEBRALIS	*vertebra cervicalis*	–	–	–	–	–	–	–	–	–	2	–	–	–	2
	vertebra thoracica (1)	–	–	–	–	–	–	–	–	–	1	–	–	–	1
	vertebrae thoraci-cae (1–5)	–	–	–	–	–	–	–	–	–	2	–	–	–	2
	vertebra abdomi-nalis	–	–	–	–	–	–	–	–	321	7	189	–	–	517
	vertebra abdomi-nalis (1)	–	–	–	–	–	–	–	–	–	2	–	–	–	2
	vertebrae abdomi-nales (2–5)	–	–	–	–	–	–	–	–	–	1	–	–	–	1
	vertebra abdomi-nalis (3)	–	–	–	–	9	–	–	–	–	–	–	–	–	9
	vertebrae abdomi-nales (7–8)	–	–	–	–	–	–	–	–	–	3	–	–	–	3
	vertebrae abdomi-nales (9–10)	–	–	–	–	–	–	–	–	–	5	–	–	–	5
	vertebrae abdomi-nales (12–13)	–	–	–	–	–	–	–	–	–	2	–	–	–	2
	vertebra abdomi-nalis (14 [?])	–	–	–	–	–	–	–	–	–	1	–	–	–	1
	vertebrae abdomi-nales (14–19)	–	–	–	–	–	–	–	–	–	3	–	–	–	3
	vertebrae abdomi-nales (16–18)	–	–	–	–	–	–	–	–	–	1	–	–	–	1
	vertebra caudalis/ abdominalis	–	–	–	–	–	–	–	–	56	–	127	–	–	183
	vertebra caudalis	–	–	–	–	–	–	–	–	71	–	137	–	–	208
	vertebra	–	–	–	–	–	–	–	–	34	–	103	–	44	181
	urostylus	–	–	–	–	5	–	–	–	–	–	–	–	–	5
	processus spinosus vert. III	–	–	–	–	7	–	–	–	–	–	–	–	–	7
	costa	–	–	–	–	–	–	–	–	–	–	–	–	152	152
PINNAE	*interspinale*	–	–	–	–	20	–	–	–	–	–	–	–	–	20
	interspinale/ inter-haemale	–	–	–	–	39	–	–	–	–	–	–	–	–	39
	lepidotrich D3	–	–	–	–	8	–	–	–	–	–	–	–	–	8
	lepidotrich P1	–	–	–	–	–	–	–	–	–	15	–	–	–	15
OTHER	dorsal scute	4	3	–	–	–	–	–	–	–	–	–	–	–	7
	lateral scute	–	–	1	–	–	–	–	–	–	–	–	–	–	1
	ventral scute	–	3	6	–	–	–	–	–	–	–	–	–	–	9
	scute	–	1	–	–	–	–	–	–	–	–	–	–	–	1
	caudal lateral scute	–	1	–	–	–	–	–	–	–	–	–	–	–	1
	tripus	–	–	–	–	10	–	–	–	–	–	–	–	–	10
Undetermi-ned		–	–	–	–	91	–	–	–	–	1	–	4	2412	2508
Total		**4**	**19**	**9**	**1**	**627**	**5**	**2**	**1**	**893**	**85**	**556**	**24**	**2608**	**4834**

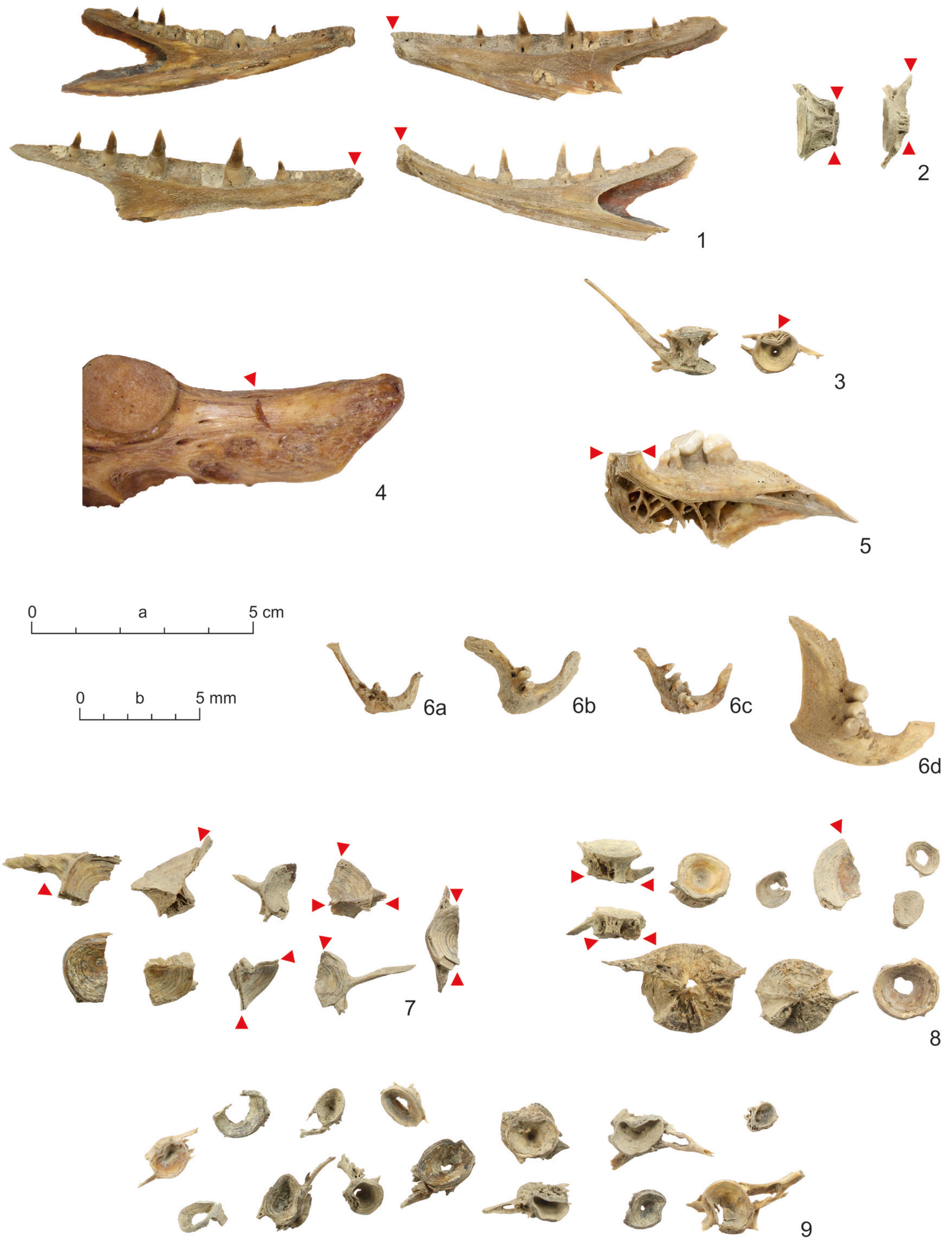

Fig. 11 *Esox lucius* and cyprinid fishes. 1: Large ossa dentalia of a pike; 2: Two pike vertebrae cut transversally to the axis of the fish body; 3: Deformed pike vertebrae; 4: Detail of the os hyomandibular of a carp with clearly visible cut mark; 5: Cross-section of a carp os pharyngeale; 6: Os pharyngeale with a row of teeth of *Alburnus alburnus* (a), *Tinca tinca* (a), *Leuciscus leuciscus* (c), *Cyprinus carpio* (d); 7: Catfish or carp vertebrae with cuts parallel to the body axis; 8: Catfish or carp vertebrae with cuts transversal to the body axis; 9: Catfish or carp vertebrae with deformed shape of the vertebral body and articular surfaces; selected cut marks indicated by red arrow (photos: Z. Bielichová)

shallow ponds that are well-heated and have a sufficient layer of fertile mud on the bottom provide optimum conditions. In such circumstances, individuals over 20 kg are no exception.

The current Slovak law does not allow the catching of carp below 40 cm in length[74]. In the context of this regulation, the measurable bones from the monastery indicated a preference for medium- to large-sized individuals, with body lengths ranging from 30–40 to 40–50 cm (fig. 10, 2). Notably, the first size category predominated (36 %). As with pike, this may indicate artificial selection of fish to maximise meat yield. Moreover, the average carp processed in the monastery kitchen was 42.4 cm long and weighed 1.7 kg (tab. 5). In the case of pond carps, this size can be reached between the second and third year, depending on food intake[75]. Additionally, remains of very large individuals with a body length of 90–110 cm and a maximum weight of approximately 19 kg were also recorded in the assemblage.

The representation of the skeletal elements indicated the presence of all body parts of a carp, with the exception of unidentified vertebrae and ribs (tab. 4). In contrast to pikes, carps show slightly more head bones compared to other parts of the body. While this result may be related to excavation and identification biases, it may also indicate some culinary practices (e.g. soups). Either way, as with the pike, it can be assumed that the carp entered the monastery kitchen as a whole fresh fish. Turning to the question of origin, the animals may have come from local artificial ponds, or alternatively, have been transported to the monastery from more distant natural sources. Supporting this, contemporary sources mention the possibility of storing live carps in damp moss in cellars[76]. Regarding specific practices at the Zobor monastery, they may have been stored in two fish tanks in the backyard of the main convent building.

We documented clear butchery on a few head and fin bones (seven cases). For example, a small, short knife incision has been identified on the hyomandibular, in the region of the arcus mandibularis (fig. 11, 4). Additionally, cuts through a terminal part of the os pharyngeum (area of the arcus branchialis) and the os parasphenoideum (neurocranium) were observed. Furthermore, the transversal division of the proximal part of the fin spine (interspinal), the septum of the praeopercular (opercular area) and old fractures of other head bones (e.g. the cleithrum, postcleithrum, operculum, praeoperculum) are not easy to interpret[77]. Given the archaeological context, it may be hypothesised that most of the modifications originated during the portioning of large carps and further kitchen preparation of meals. For instance, a cut running through the large pharyngeal bone (fig. 11, 5) perhaps documents the portioning of the fish head. In addition to these elements, we observed modifications of numerous undifferentiated vertebrae (cf. *Cyprinus/Silurus*). Specifically, clear transversal (min. 22 specimens) or longitudinal (min. 10) cuts through the vertebral body illustrate the division of the carp body into larger or smaller portions (fig. 11, 7. 8). In addition to cut marks, a considerable number of vertebrae (min. 80) exhibit body deformations, mainly of the articulation surface, compressions, fractures, or distinct flattening (fig. 11, 9), similar to those observed in pike. Notably, on several vertebrae, these modifications occur together with cut marks running transversely to the vertebral body axis. In addition, some of the deformed vertebrae (12 specimens) show differences in colouration, from butter yellow to grey-black, but it cannot be stated with certainty that this was due to burning, as information on the colouration of the surrounding sediment was unavailable. If burning was sufficient to produce a greyish to black colour, the meat would have been spoiled[78]. Nevertheless, the preparation of some portions over an open fire, or the burning of food remnants, cannot be ruled out. As noted above for pikes, some researchers interpret vertebral body deformations as consequences of consumption

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[74] Bielichová et al. 2019, tab. 2.
[75] Oliva et al. 1968, 154 f.
[76] Zeuner 1963, 481 f.
[77] Willis et al. 2008.
[78] Lyman 1994, 385 f.

(mastication) or passage through the digestive tract of mammals, including humans[79]. Even so, it remains questionable to what extent such interpretations can be applied to the larger vertebrae present in the samples.

Besides the common carp, other cyprinid species were sporadically present (n = 8; 0.3 % of NISP). Notably, the tench (*Tinca tinca*), the common dace (*Leuciscus leuciscus*) and the common bleak (*Alburnus alburnus*) were identified on the basis of the pharyngeal bone, whose teeth grow in three rows in carp, in two rows in the dace and bleak, and in a single row in tench. Among these, the most abundant was tench (n = 5; 0.2 % of NISP), a fish with a wide European distribution that prefers quiet river branches and pools in the inundation areas with muddy bottoms and permanent aquatic vegetation. It is also commonly found in the Nitra River catchment area[80]. Furthermore, it is the most common non-predatory fish (after carp) reared in the warm artificial ponds. Although tench is more tolerant with regard to some water parameters (acidity, clarity), it lacks the carp's ability to grow quickly, since it reaches a consumable size (250–300 g and 20–30 cm) only after the third year of life[81]. In terms of size, the tench is usually 30 cm long, very occasionally 70 cm, weighing 2 kg or more (up to 7.5 kg)[82]. The current law states the catch size to be 30 cm[83]. Analysis of the pharyngeal bones (fig. 11, 6b) from sample 12 indicated the size of four individuals between 20 and 28 cm in length and 578–820 g in weight (tab. 5). The tench has very tasty meat, and if smaller, it does not need to be cleaned of the small and thin scales that dissolve during cooking.

Turning to the other cyprinids, remaining two species represent the only economically unimportant fishes in the assemblage. Perhaps for that reason, they occur in negligible numbers (total n = 3; 0.1 % of NISP). The current representation of the common dace (*Leuciscus leuciscus*) varies from place to place and has not been registered during the biomonitoring of the fish populations in the river Nitra[84]. This small fish, which is accompanied by other species in aquaculture, grows to 20–25 cm and 200 g[85]. Two pharyngeal bones from sample 12 (fig. 11, 6c) indicate that the dace reached a sufficient size for the kitchen and consumption (19 and 21 cm in length). In addition to the dace, the common bleak (*Alburnus alburnus*) is a small cyprinid fish, widespread in all Slovak waters, whose body is only 15 and occasionally 17 cm long[86]. It is the most common prey of predatory species, especially pike, and is used as bait. In the case of a single pharyngeal bone identified in sample 12 (fig. 11, 6a), the fish size has not been accurately estimated, but, compared with other cyprinids, it appears to be the maximal dimension.

Catfish

The Wels catfish (*Silurus glanis*), the third most abundant species among the fish remains (n = 85; 3.5 % NISP), is a predatory, scaleless fish and the largest native to Slovak waters – previously, it was the beluga. It lives in bigger rivers and dammed lakes, typically in deep water near the bottom, where it feeds on smaller, economically insignificant fish, especially bleaks[87]. Catfish also breed in artificial ponds[88]. This species reaches maturity at 4–5 years and grows rapidly; at 20–30 years, individuals are about two meters long and weigh 40–60 kg.

79 Butler – Schroeder 1998; Jones 1984.
80 Sedlár 1969.
81 Sedlár 1954, 107 f.
82 Oliva et al. 1968, 106.
83 See n. 69.
84 Sedlár 1969.
85 Oliva et al. 1968, 88–90.
86 Oliva et al. 1968, 127–129.
87 Oliva et al. 1968, 167–170.
88 Sedlár 1954.

Table 5 Fish size descriptive statistic (total body length is given including the tail)

Fish taxa	Total body length (cm)				Total body weight (kg)			
	Esox	*Cyprinus*	*Tinca*	*Silurus*	*Esox*	*Cyprinus*	*Tinca*	*Silurus*
Mean	43.02	42.39	26.03	95.29	0.74	1.69	0.23	10.64
Standard error	0.91	1.31	3.06	6.87	0.10	0.21	0.07	3.05
Median	40.32	38.97	27.21	93.47	0.44	0.90	0.23	5.52
Mode	34.43	28.60	–	–	0.27	0.36	–	–
Standard Deviation	12.03	15.66	6.84	45.60	1.36	2.52	0.15	20.21
Sample Variance	144.73	245.38	46.85	2078.94	1.84	6.33	0.02	408.57
Range	82.28	92.72	16.33	225.89	10.73	19.20	0.35	123.02
Minimum	27.47	16.94	16.79	38.24	0.13	0.08	0.06	0.38
Maximum	109.75	109.66	33.12	264.14	10.86	19.28	0.41	123.40
Sum	7441.77	6061.77	130.14	4192.69	128.64	241.54	1.16	468.16
Count	173	143	5	44	173	143	5	44
Confidence level (95 %)	1.81	2.59	8.50	13.86	0.20	0.42	0.19	6.15

In the past, catfish of up to 100 kg were not rare, and one of the largest known, caught in the Oder River in 1761, reached 375 kg[89]. The current catch size in Slovakia is 70 cm.

The osteometric analysis of the monastery specimens (tab. 5) shows that large individuals with a total length of 80 cm or more (63.6 %) were supplied to the kitchen. Even older individuals, 140–180 cm in length, are regularly present in the assemblage (fig. 10, 3). Based on a partially preserved vomer (fig. 12, 1), it was possible to estimate that the capital catch had a body length of 264 cm and a weight of 123 kg. According to the literature sources, this individual belongs to one of the largest historically documented Wels catfish. It was probably caught in Slovak waters at approximately 33–35 years old[90]. The analysis also revealed that the average catfish supplied to the monastery kitchen weighed 10.6 kg (tab. 5). Catfish meat is very tasty and free of small bones when it comes from individuals weighing up to 5–6 kg[91]. Not surprisingly, the large proportion of bones (41 % of 44 evaluated cases) corresponds to this culinary observation.

In the assemblage, a balanced representation of head, trunk and fin skeletal elements was recorded (tab. 4). As in pike or carp, the presence of head bones and fins attests that catfish entered the kitchen as a whole, probably as fresh fish. Anthropogenic modifications were recorded on 22 different bone elements. The most common were transverse and longitudinal cuts through the vertebral body centrum and the first spine of the pectoral fin (fig. 12, 2). These cuts were probably related to the division of the trunk and to the separation of the pectoral fin and head from the trunk. Experimental work confirmed that both elements, along with the ribs, are among the most commonly affected during the processing of catfish meat in the kitchen[92]. Transversal cuts through the cleithrum were also relatively frequent (fig. 12, 3). The opercular, ceratohyal and quadratum were also affected (fig. 12, 4. 5). Their location is indicative of head dismemberment or the separation of the head from the trunk. An artificial, centrally located opening in a large cleithrum was recorded (fig. 12, 6. 7). The opening has irregular margins. Fracture lines extend radially from the centre. Some of the bone margin fragments were pushed inwards after the impact. The bone was punctured peri- or postmortally.

89 Mohr 1957.
90 Cf. Hensel 2004.
91 Sedlár 1954, 115.
92 Willis et al. 2008.

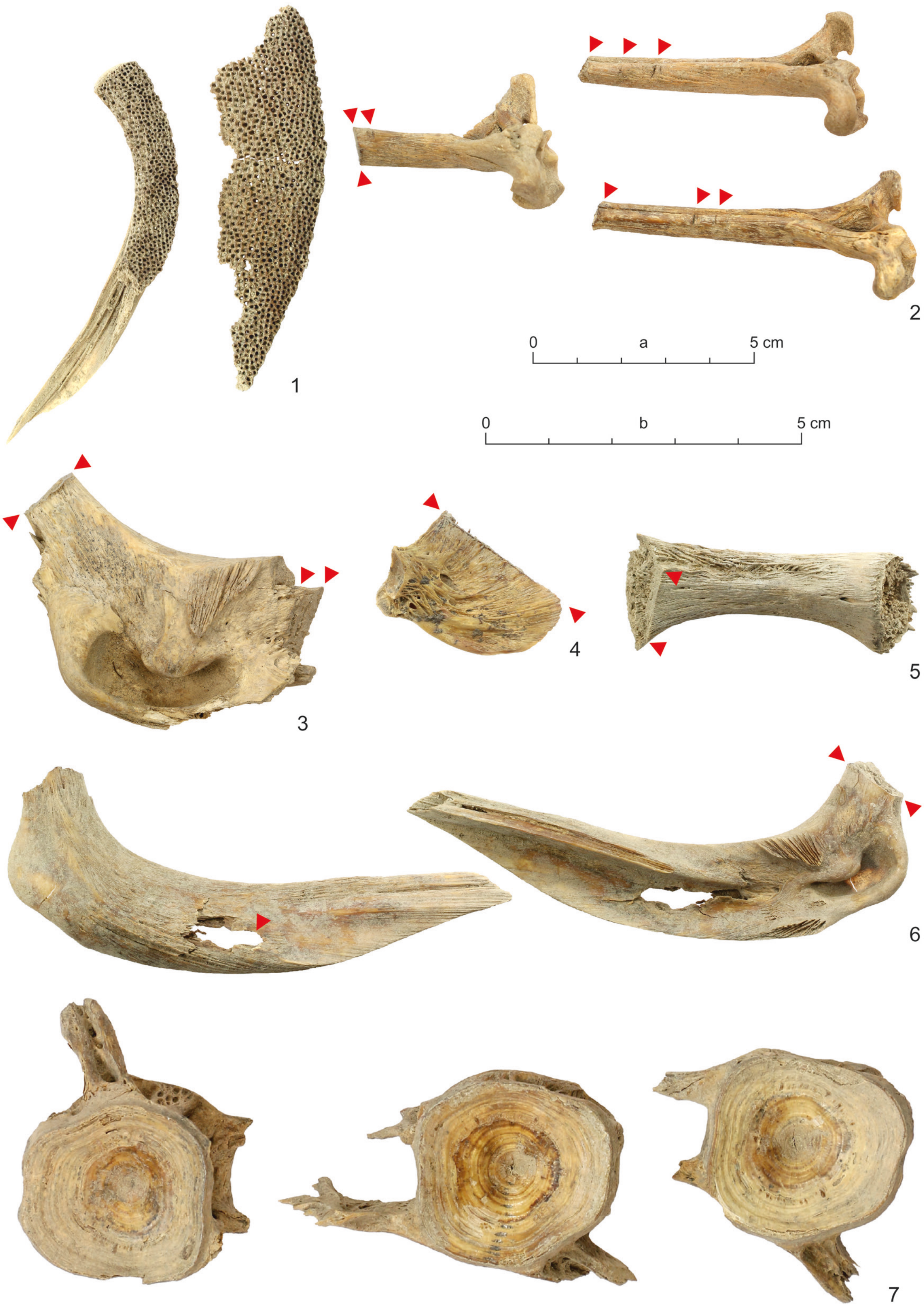

Fig. 12 Wels catfish (*Silurus glanis*). 1: Os dentale (left) and fragment of os vomere (right); 2: Pinnae pectorales with multiple cuts and cut-off tips; 3: Large os cleithrum with cuts on both ends; 4: Os operculum; 5: Os ceratohyale; 6: Os cleithrum with an artificial opening, ventral and dorsal view; 7: Three vertebrae abdominales (approx. 14th–19th) of an individual with approx. age 17–18 years and size of 175 cm/35 kg; human intervention indicated by a red arrow (photos: Z. Bielichová)

This could have occurred during fishing and catching the fish (using the fishing device)[93] or during the preparation of the meat. The numerous cut marks and/or deformations described above in unidentified vertebrae (fig. 12, 7) complete the range of anthropogenic modifications.

Sturgeon

Sturgeons are diadromous fishes that live near the river bottom and migrate upstream to spawn[94]. Today, only the sterlet (*Acipenser ruthenus*) and the potamodromous form of the Russian sturgeon (*A. gueldenstaedtii*) inhabit Slovak rivers. This limited presence is due to pollution and dam construction, which affect all migratory species and forms. Historical sources document that six sturgeon species were native to the Danube River basin. These include the fringebarbel sturgeon (*A. nudiventris*), the stellate sturgeon (*A. stellatus*) and the beluga or great sturgeon (*Huso huso*), which is Europe's largest freshwater fish[95]. Shifting to recent history, biomonitoring of the Nitra River in the 20th century confirmed the presence of both the sterlet and the Russian sturgeon in the 1960s[96]. Although these two species are similar in appearance, the Russian sturgeon grows larger. The average Russian sturgeon reaches a length of 80–160 cm and a weight of 4–30 kg, with a maximum length of 200–250 cm and a maximum weight of 100–130 kg. In contrast, the sterlet reaches about 40–60 cm in length and 0.5–1.5 kg in weight, with a maximum of 80–125 cm and 3–17 kg. The stellate sturgeon, while always rare in the Middle Danube region, ascended upstream to Bratislava and the Austrian part of the Danube during the spawning season[97]. Most Danube sturgeon species spawn from spring to early summer at temperatures between 6 and 25 °C, although some enter the river in spring, others in autumn or winter. Currently, the stellate sturgeon has been extirpated from the upper stretch of the Middle Danube. The last known specimen from the Slovakian section was caught at Komárno in 1926[98]. The stellate sturgeon can reach 220 cm and 68 kg[99].

The new analysis of the sturgeon remains shows that this species was the most frequent (NISP = 19). In comparison, the remaining remains have been identified as Russian sturgeon (NISP = 9) and sterlet (NISP = 4). Interestingly, nearly all body parts, including the head, abdominal and caudal regions, were recorded (fig. 13, 1–8). This wide variety perhaps suggests that at least some sturgeons arrived at the monastery in the same fresh form as carps or pikes. While the size of all other sturgeons remains unknown, the discovery of completely preserved dorsal scuta with a length of 14.5 mm allowed the size of one individual to be reconstructed. It confirmed that the sterlet was of ideal culinary size, measuring 523 mm (TL) and weighing 664 g (TW). Additionally, several elements of the sturgeon exoskeleton have been completely preserved, while the remaining ones represent fragments of different sizes. These latter fragments bear single or multiple cut marks running in various directions (fig. 13, 9). Most likely, they indicate the processing of fish in the monastery kitchen. However, the possibility of portioning large sturgeon carcasses at the place of capture or at the marketplace cannot be ruled out[100].

The exploitation of sturgeons has a long tradition in Europe[101]. For example, in the Baltic region, overfishing caused their rapid decline as early as the 11th–12th centuries[102]. In contrast, in

93 Mjartan 1984.
94 Oliva et al. 1968, 29–40.
95 Hensel – Holčík 1997; Holčík et al. 2006.
96 Sedlár 1969.
97 Hensel – Holčík 1997, 195 f.
98 Hensel – Holčík 1997, 196. According to Holčík, this individual measured 1282 mm in length and weighed 9.8 kg.
99 Oliva et al. 1968, 35.
100 E.g. Marsigli 1726.
101 Makowiecki 2003; Galik et al. 2015.
102 Makowiecki 2003, 196.

Fig. 13 Sturgeons. Stellate sturgeon (*Acipenser stellatus*). 1. 2: Ventral scute; 3: Caudal lateral scute; 4: Bone of dermocranium. Russian sturgeon (*Acipenser gueldenstaedtii*): 5: Ventral scute; 6: Postorbital; 7: Preanal fin scute. Sterlet (*Acipenser ruthenus*): 8: Three dorsal scutes; 9: Selection of sturgeon cranial elements with cut marks (indicated by red arrows) (photos: Z. Bielichová)

the Middle Danube region, a significant decline is recorded from the 16th century[103]. Sturgeons have been valued not only for their meat, but especially for the high-quality ›black‹ caviar they provide. While caviar yields were highest in giant sturgeon, smaller sturgeon were sought after for their more palatable meat[104]. Historical sources provide further context; for instance, they note: »the fish roe formed part of the food of the poorest inhabitants of the town, they were often even thrown away or used as fodder for pigs. Their advantage, however, was that they could be eaten even during fasting.«[105] As a consequence, sturgeon bones are often found at ecclesiastical sites[106]. Their presence in the Zobor monastery, in particular, can be considered a manifestation of the higher social status and the luxurious enrichment of the monks' diet. Additionally, the significantly lower representation of sturgeon bones in the assemblage may reflect both the higher price of the fish and various biological and taphonomic factors affecting the preservation of its partly cartilaginous skeleton in the archaeological context. Finally, as with carp or pike, the rearing of sturgeons in fishponds cannot be excluded.

Conclusions

The analysis of faunal remains from the Camaldolese monastery of St. Joseph sheds new light on the everyday life of the members of one of the strictest male orders of the Roman Catholic Church, which was settled below the Zobor hill in Nitra from 1693 to 1782. Specifically, the finds originating from the primary deposit in one of the monks' houses clearly attest to the long-term fasting and adherence to the strict dietary regulations of the monastic community. The vast majority of finds comprise the skeletal elements of aquatic and semi-aquatic animal species such as fish, otters, beavers, crayfish and turtles, i.e. animals whose meat was a typical Lenten food at the time. Thanks to the well-dated primary deposit of analysed remains, it can be assumed that the diet of the monks living in cell 9 shortly before the dissolution of the monastery (between 1760 and 1782) was clearly dominated by fish meat. In addition to fish, consumption of otter, crustaceans, eggs and perhaps occasionally chicken meat has been recorded.

By contrast, the findings from cell 3 present a different picture and can be interpreted in two ways. In addition to the Lenten culinary items such as fish, turtle and beaver, food that does not meet Saint Benedict's regulations, such as veal, lamb, pork and poultry, appeared in high numbers, similarly to the fish, with traces of kitchen processing. Thus, either their presence can be explained by a relaxation of monastic discipline or by the circumstances of their discovery at the site. In Zobor, the latter option seems more plausible, as the faunal remains from the area of cell 3 do not originate from the solitary enclosed deposit but from layers created during the construction of the Camaldolese monastery or after its demise. These layers may therefore relate to the presence of visitors or laypersons at the site, i.e. between the demise of the Benedictine monastery (end of the 15th cent.) and the beginning of Camaldolese activities (end of the 17th cent.).

To further clarify, it is evident that even during the several years of construction of the extensive Baroque monastery complex, substantial human food waste was generated, which may have entered the layers beneath the floors of cell 3. Similarly, after the dissolution of the monastery in 1782, when a textile manufacturing and later a cruise inn for Nitra's residents existed on the site, there was time for food waste or livestock bones to enter the deserted exteriors of the monks' houses. Therefore, in this context, the clear violation of strict dietary

[103] Hensel – Holčík 1997; Bartosiewicz – Bonsall 2008; Bartosiewicz et al. 2008.
[104] Bartosiewicz – Bonsall 2008.
[105] Tomčík 2008, 14 f.
[106] Kunst – Galik 2000; Bartosiewicz – Gál 2021.

rules, as reported in the written sources from the Camaldolese monastery in Lechnica[107], cannot be inferred from our analyses (e.g. the bone of a hen from cell 9).

The taxonomic analysis showed that only freshwater fish species were consumed in the monastery. With the exception of smaller cyprinids such as bleak and dace, all were economically valuable and had meat of excellent quality. The main fish supplied and consumed were pike, carp and catfish, with sturgeon being less common. Large fish individuals were provided to meet catering needs and ensure enough meat for all inhabitants. Anatomical analysis showed a balanced proportion of head and trunk bones, with few fins, indicating the fish entered the kitchen whole and likely alive. Temporary storage and preservation in courtyard tanks is evidenced by the surviving monastery plan.

No imported (marine) species or signs of fish preservation were identified. However, the reason for some modifications – especially vertebral deformities often attributed to chewing – remains unclear. Cut marks suggest fish were portioned in the kitchen and served cooked to hermitage cells as individual meals. The monastery may have acquired fish and other Lenten foods by purchase, donations, or its own breeding in ponds. Several contemporary sources note the existence of ponds near the complex[108]. According to an anonymous author[109], turtles and fish bred in these ponds were also traded and provided income for the monastery. However, we do not know to what extent they were exploited during the Camaldolese monastery's existence. The identified fish are often very large, suggesting purchasing rather than local production. Yet, some large fish may have been raised in well-managed ponds under favorable conditions. Only further archival research can provide more insight into this part of the monastery's economic history.

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Bibliography

Anonymous 1939	Anonymous, Z kroniky Zoborského kláštora, Hlasy z domova a misií 25, 7, b. m. v. 1939, 198–203.
Bartosiewicz 1990	L. Bartosiewicz, Osteometric studies on the skeleton of pike (*Esox lucius* L. 1758), Aquacultura Hungarica 6, 1990, 25–34.
Bartosiewicz – Bonsall 2008	L. Bartosiewicz – C. Bonsall, Complementary taphonomies. Medieval sturgeons from Hungary, in: P. Béarez – S. Grouard – B. Clavel (eds.), XIVth ICAZ Fish Remains Working Group meeting. Archéologie du poisson. 30 ans d'archéo-ichthyologie au CNRS. Hommage aux travaux de Jean Desse et Nathalie Desse-Berset. XXVIII^{e} rencontres internationales d'archéologie et d'histoire d'Antibes (Antibes 2008) 35–45.

107 Lacko 1965, 108. 194.
108 Habovštiak 1971, 117 f. fig. 14; Točka 2017, 111. According to A. Habovštiak, the monastery account books record two fishponds at Zobor. One was situated north of the Camaldolese complex. The second was in the forest west of the road leading from the town of Nitra to the monastery.
109 Anonymous 1939, 202.

Bartosiewicz et al. 2008 L. Bartosiewicz – C. Bonsall – V. Şişu, Sturgeon fishing in the Middle and Lower Danube region, in: C. Bonsall – V. Boronean – I. Radovanovi (eds.), The Iron Gates in Prehistory. New perspectives. BARIntSer 1893 (Oxford 2008) 39–54.

Bartosiewicz – Gál 2021 L. Bartosiewicz – E. Gál, The archbishop's dinner? Late medieval fish from Esztergom-Várhegy-Kőbánya, Hungary, Archaeological and Anthropological Sciences 13, 132, 2021, 1–14; DOI:10.1007/s12520-021-01361-w

Bielichová et al. 2019 Z. Bielichová – M. Samuel – K. Hensel, Ryby a pôst v Zoborskom kláštore pri Nitrevo svetle archeozoologických dokladov (Fish and fasting in the Zobor Monastery in Nitra in the light of archaeozoological evidence), Študijné Zvesti Archeologického Ústavu SAV 65, 2019, 133–177.

Bielichová et al. 2025 Z. Bielichová – D. Duchoňová – L. Bartosiewicz, Historical and archaeological records of turkey from Slovakia and Hungary, in: A. Manin – C. F. Speller – E. Corona-M. – E. K. Thornton (eds.), Exploring the history of turkey management and domestication. A transatlantic perspective, Natures en Sociétés 10 (Paris 2025) 251–259.

Branecký 1945 J. Branecký, Krátke dejiny zoborského kláštora a opátstva (Žilina 1945).

Brinkhuizen 1989 D. C. Brinkhuizen, Ichthyo-archeologisch onderzoek. Methoden en toepassing aan de hand van Romeins vismateriaal uit Velsen (PhD thesis Rijksuniversiteit Groningen 1989).

Butler – Schroeder 1998 V. L. Butler – R. A. Schroeder, Do digestive processes leave diagnostic traces on fish bones?, JASc 25, 1998, 957–971.

Crawford 1992 R. D. Crawford, Introduction to Europe and diffusion of domesticated turkeys from the America, Archivos de zootecnia 41 (extra), 1992, 307–314.

Cserenyei 1911 Š. Cserenyei, Príspevok k dejinám nitrianskych kamaldulov, Religio 1911, 423. 424. 439. 440.

Čaputa et al. 1982 A. Čaputa – J. Holčík – Z. Berger, Atlas chránených vodných živočíchov Slovenska (Bratislava 1982).

Duchoňová – Lengyelová 2016 D. Duchoňová – T. Lengyelová, Hradné kuchyne a šľachtické stravovanie v ranom novoveku. Radosti slávností, strasti každodennosti (Bratislava 2016).

Fabiš – Miklíková 2002 M. Fabiš – Z. Miklíková, Nálezy korytnačky močiarnej (*Emys orbicularis* L.) v archeofaunálnych zvyškoch z Nitry a okolia, Rosalia 16, 2002, 155–160.

Froese 2006 R. Froese, Cube law, condition factor and weight-length relationships. History, meta-analysis and recommendations, Journal of Applied Ichthyology 22, 4, 2006, 241–253; DOI:10.1111/j.1439-0426.2006.00805.x

Froese et al. 2011 R. Froese – A. C. Tsikliras – K. I. Stergiou, Editorial note on weight-length relations of fishes, Acta Ichthyologica et Piscatoria 41, 4, 2011, 261–263; DOI:10.3750/AIP2011.41.4.01

Galik et al. 2015 A. Galik – G. Haidvogl – L. Bartosiewicz – G. Guti – M. Jungwirth, Fish remains as a source to reconstruct long-term changes of fish communities in the Austrian and Hungarian Danube, Aquatic Science 77, 2015, 337–354.

Gentry et al. 2004 A. Gentry – J. Clutton-Brock – C. P. Groves, The naming of wild animal species and their domestic derivatives, JASc 31, 2004, 645–651.

Habovštiak 1966 A. Habovštiak, Záchranný výskum pri bývalom kláštore v Nitre na Zobore, Študijné zvesti AÚ SAV 14, 1966, 227–233.

Habovštiak 1971 A. Habovštiak, Stredoveké nálezy a pozostatky kamenného vodovodu pri bývalom Zoborskom kláštore, Zborník SNM 65, História 11, 1971, 97–119.

Hammer et al. 2001 O. Hammer – D. A. T. Harper – P. D. Ryan, PAST: Paleontological Statistics Software Package for Education and Data Analysis, Palaeontologia Electronica 4, 1, 2001, 1–9.

Hensel 2004 K. Hensel, Find of capital wels catfish *Silurus glanis* (Actinopterygii: Siluridae) in excavations of a Roman military fort in Southern Slovakia, Biologia 59 Suppl. 15, 2004, 191–203.

Hensel – Holčík 1997 K. Hensel – J. Holčík, Past and current status of sturgeons in the upper and middle Danube River, Environmental Biology of Fishes 48, 1997, 185–200.

Hilton et al. 2011 E. J. Hilton – L. Grande – W. E. Bemis, Skeletal anatomy of the shortnose sturgeon, *Acipenser brevirostrum* Lesueur, 1818, and the systematics of sturgeons (Acipenseriformes, Acipenseridae), Fieldiana Life and Earth Sciences 3, 2011, 1–168; DOI:10.3158/2158-5520-3.1.1

Hlavačková 2015 M. Hlavačková, Ryby a pôstna tradícia, in: D. Dvořáková (ed.), Človek a svet zvierat v stredoveku (Bratislava 2015) 447–460.

Holčík et al. 2006 J. Holčík – A. Klindová – J. Masár – J. Meszáros, Sturgeons in the Slovakian rivers of the Danube River basin. An overview of their current status and proposal for their conservation and restoration, Journal of Applied Ichtyology 22 Suppl. 1, 2006, 17–22.

Jones 1984 A. K. G. Jones, Some effects of the mammalian digestive system on fish bones, in: N. Desse-Berset (ed.), 2nd Fish Osteoarchaeology Meeting, CNRS. Centre de recherches archéologiques, Notes et Monographies Techniques 16 (Paris 1984) 6–65.

Judák 1997 V. Judák, Pôsobenie kamaldulov na území Slovenska, in: J. Doruľa (ed.), O prekladoch Biblie do slovenčiny a do iných slovanských jazykov (Bratislava 1997) 71–83.

Kánya 2015 M. Kánya, Korytnačka močiarna *Emys orbicularis* (Linaeus, 1768), in: M. Janák – J. Černecký – A. Saxa (eds.), Monitoring živočíchov európskeho významu v Slovenskej republike. Výsledky a hodnotenie za roky 2013–2015 (Banská Bystrica 2015) 202–203.

Kompánek 1895 J. Kompánek, Nitra. Nástin dejepisný, miestopisný a vzdelanostný, Tovaryšstvo 2, 1895, 54–114.

Kraskovská 1942/1943 Ľ. Kraskovská, Archeologický výskum na Zobore pri Nitre, Sborník SNM 36/37, 1942/1943, 217–227.

Kunst – Galik 2000 G. K. Kunst – A. Galik, Essen und Fasten in mittelalterlichen Klostern aus archäozoologischer Sicht, in: H. Adler (ed.), Fundort Kloster – Archäologie im Klösterreich, FÖ Materialhefte A 8 (Wien 2000) 246–258.

Lacko 1965 M. Lacko, Camaldolese Hermits in Slovakia (Zobor, Červený kláštor), Slovak Studies 5, 1965, 99–204.

Lacko 1967 M. Lacko, Kamalduli na Slovensku (Zobor, Červený kláštor), Most 14, 1967, 143–168.

Lepiksaar 1983 J. Lepiksaar, Osteologia I. Pisces (Göteborg 1983).

Libois – Hallet-Libois 1988 R. M. Libois – C. Hallet-Libois, Éléments pour l'identification des restes crâniens des poissons dulçaquicole de Belgique et du Nord de la France. 2 – Cypriniformes, in: J. Desse – N. Desse-Berset (eds.), Fishes d'ostéologie animale pour l'archéologie 4. Série A: Poissons (Paris 1988) 1–21.

Lombardini 1895 A. Lombardini, Zoborské opátstvo, Tovaryšstvo 2, 1895, 115–124.

Lorenz 1991 H. Lorenz, Domenico Martinelli und die österreichische Barockarchitektur (Vienna 1991).

Ložek 1955 V. Ložek, Měkkýši československého kvartéru (Prague 1955).

Lučivjanská 1991 V. Lučivjanská, Mäkkýše Zobora a jeho predpolia, Zobor 2, 1991, 17–38.

Lyman 1994 R. L. Lyman, Vertebrate taphonomy (Cambridge 1994).

Makowiecki 2003 D. Makowiecki, Historia ryb i rybołówstwa w holocenie na Niżu Polskim w świetle badań archeoichtiologicznych (Poznań 2003).

Marsigli 1726 A. F. C. Marsigli, Danubius Pannonicp-Mysticus, observationibus geographicis, astronomicis, hydrographicis, historicis, physicis perlustratus et in sex tomos digestus. Tomus quartus de Piscibus Danubii. Hagae Comitum (Amsterdam 1726).

Miklíková 2007 Z. Miklíková, Archeozoológia, in: G. Březinová – M. Samuel (eds.), Tak čo, našli ste niečo? Svedectvo archeológie o minulosti Mostnej ulice v Nitre (Nitra 2007) 127–130.

Miklíková – Fabiš 2004 Z. Miklíková – M. Fabiš, Zvyšky zvierat z mestskej tržnice v Nitre, in: V. Hašek – R. Nekuda – M. Ruttkay (eds.), Ve službách archeologie 5 (Brno 2004) 165–172.

Mjartan 1984 J. Mjartan, Ľudové rybárstvo na Slovensku, Klenotnica slovenskej ľudovej kultúry 14 (Bratislava 1984).

Mohr 1957	E. Mohr, Der Wels. Die Neue Brehm Bücherei, Heft 209 (Wittenberg Lutherstadt 1957).
Morales – Rosenlund 1979	A. Morales – K. Rosenlund, Fish Bone Measurements. An Attempt to Standardize the Measuring of Fish Bones from Archaeological Sites (Copenhagen 1979).
Moreno-García – Detry 2010	M. Moreno-García – C. Detry, The dietary role of hens, chickens and eggs among a 17th century monastic order. The Clarisse of Santa Clara-a-Velha, Coimbra (Portugal), in: W. Prummel – J. T. Zeiler – D. C. Brinkhuizen (eds.), Birds in Archaeology. Proceedings of the 6th meeting of the ICAZ Bird Working Group held in 23.–27. 8. 2008 in Groningen (Groningen 2010) 45–55.
Novikmec – Svitok 2015	M. Novikmec – M. Svitok, Rak riečny *Astacus astacus* (Linnaeus, 1758), in: M. Janák – J. Černecký – A. Saxa (eds.), Monitoring živočíchov európskeho významu v Slovenskej republike, Výsledky a hodnotenie za roky 2013–2015 (Banská Bystrica 2015) 116–117.
Oliva et al. 1968	O. Oliva – S. Hrabě – J. Lác, Stavovce Slovenska 1. Ryby, obojživelníky a plazy (Bratislava 1968).
Patoka et al. 2016	J. Patoka – B. Kocánová – L. Kalous, Crayfish in Czech cultural space. The longest documented relationship between humans and crayfish in Europe, Knowledge and Management of Aquatic Ecosystems 417, 2016, 5.
Pomfyová 2015	B. Pomfyová, Kláštory a kapituly, in: B. Pomfyová (ed.), Stredoveký kostol. Historické a funkčné premeny architektúry 1. Zväzok (Bratislava 2015) 249–324.
Pucher 1991	E. Pucher, Der frühneuzeitliche Knochenabfall eines Wirtshauses neben der Salzburger Rezidenz, in: W. K. Kovacsovics (ed.), Aus dem Wirtshaus zum Schinagl. Funde aus dem Toskanatrakt der Salzburger Residenz, JSM 35/36–1989/1990 (Salzburg 1991) 71–135.
Radu 2003	V. Radu, Exploitation des ressources aquatiques dans les cultures néolithiques et chalcolithiques de la Roumanie Méridionale (PhD thesis Université d'Aix-Marseille I, Aix-Marseille 2003).
Reitz – Wing 1999	E. J. Reitz – E. S. Wing, Zooarchaeology. Cambridge Manuals in Archaeology (Cambridge 1999).
Repka et al. 2017	D. Repka – P. Sater – K. Šimunková, Archeologické nálezy z Oponického hradu, Študijné zvesti AÚ SAV 62, 2017, 181–206.
Rixson 1988	D. Rixson, Butchery evidence on animal bones, Circaea 6, 1988, 49–62.
Samuel 2009	M. Samuel, Nálezy skla z archeologického výskumu Zoborského kláštora, Študijné zvesti AÚ SAV 46, 2009, 45–50.
Samuel 2010	M. Samuel, Najnovšie výsledky archeologických výskumov Zoborského kláštora v Nitre, Monumentorum Tutela 22, 2010, 276–287.
Samuel 2011	M. Samuel, Výskumy v areáli Zoborského kláštora v Nitre, AVANS 2008, 2011, 236–238.
Samuel – Čurný 2010	M. Samuel – M. Čurný, Pottery from the cellar of a monastic dwelling at the Camaldolese monastery in Nitra-Zobor, in: J. Žegklitz (ed.), Studies in Post-medieval Archaeology 4. Written and iconographic sources in post-medieval archaeology (Prague 2010) 429–452.
Sedlár 1954	J. Sedlár, Rybárstvo (Bratislava 1954).
Sedlár 1959	J. Sedlár, Ryby povodia rieky Nitry, Poľovníctvo a rybárstvo 2, 1959, 14–15.
Sedlár 1969	J. Sedlár, Súčasný stav zarybnenia povodia rieky Nitry, Biologické práce 15, 1969, 5–78.
Schmid 1972	E. Schmid, Atlas of animal bones (Amsterdam 1972).
Silver 1969	I. A. Silver, The ageing of domestic animals, in: D. R. Brothwell – E. S. Higgs (eds.), Science in archaeology a survey of progress and research 2 (New York 1969) 250–268.
Stloukal et al. 2013	E. Stloukal – B. Vitázková – M. Janák, Metodika monitoringu výskytu a stavu populácií raka riečneho (*Astacus astacus*) na Slovensku, Folia faunistica Slovaca 18, 2013, 233–250.

Thornton et al. 2012	E. K. Thornton – K. F. Emery – D. W. Steadman – C. Speller – R. Matheny, Earliest Mexican Turkeys (*Meleagris gallopavo*) in the Maya Region. Implications for Pre-Hispanic Animal Trade and the Timing of Turkey Domestication, PLoS ONE 7(8): e42630; DOI:10.1371/journal.pone.0042630
Točka 2017	I. Točka (ed.), Spomienky Zoborčanov (Nitra 2017).
Tomčík 2008	V. Tomčík, S vareškou dvoma tisícročiami. Kapitoly z dejín bratislavskej kuchyne a receptami našich predkov (Bratislava 2008).
Uerpmann 1973	H.-P. Uerpmann, Animal bone finds and economic archaeology. A critical study of »osteo-archaeological« method, WorldA 4, 1973, 307–322.
Valachovič 2008	D. Valachovič, Program záchrany bobra vodného (*Castor fiber*, Linné 1758) (Banská Bystrica 2008) <http://www.sopsr.sk/cinnost/programy/PZ_Castor_fiber.pdf> (02.03.2023).
Von den Driesch 1976	A. von den Driesch, A guide to the measurement of animal bones from archaeological sites, Peabody Museum Bulletins 1 (Harvard 1976).
Vozák – Bielich 2021	Z. Vozák – M. Bielich, Nálezy zvieracích kostí na hradoch. Základná porovnávacia štúdia hradu Gýmeš a Lietava, in: M. Bača (ed.), Pod stromom života, K životnému jubileu doc. Michala Slivku (Bratislava 2021) 105–117.
Vozár 1997	J. Vozár, Archívy kamaldulských kláštorov zo Slovenska v Budapešti, in: J. Doruľa (ed.), O prekladoch Biblie do slovenčiny a do iných slovanských jazykov (Bratislava 1997) 84–93.
Wheeler – Jones 1989	A. Wheeler – A. K. G. Jones, Fishes (Cambridge 1989).
Willis et al. 2008	L. M. Willis – M. I. Eren – T. C. Rick, Does butchering fish leave cut marks?, JASc 35, 2008, 1438–1444.
Zar 1999	J. H. Zar, Biostatistical Analysis [4](Englewood Cliffs, NJ 1999).
Zeuner 1963	F. E. Zeuner, A History of Domesticated Animals (New York 1963).
Zíbrt 2012	Č. Zíbrt, Česká kuchyně za dob nedostatku (Prague 2012).

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Fish Consumption at Vendôme Abbey (Loir-et-Cher, France)

Data from the 12^{th}–13^{th}-Century Kitchen

Aurélia Borvon

Abstract

Archaeological excavations carried out in the kitchen of the Trinité de Vendôme Abbey (Loir-et-Cher, France) uncovered large quantities of vertebrate remains and, among them, numerous fish bones. Most remains stem from contexts dated to the 12^{th}–13^{th} centuries. They were recovered by sieving sediment with a 2 mm square mesh. The fish bones were so abundant that it was decided that only a subsample of ca. 15,000 bones and ca. 27,000 scales would be studied. A total of 3155 bones were identified. Thirteen taxa are present in the assemblage, the foremost of which is the herring with a little less than 1800 bones. Numerous remains from freshwater and migratory species are also present, as cyprinids, bullhead, eel and sturgeon constitute the next four species by number of identified specimens. Salmonids, pike, perch, loach, stickleback and shad are also represented but by fewer bones. Marine species other than herring are very rare; common mackerel and conger eel are nonetheless identified. When permitted by the number of bones, the analysis of body part representation indicates that the remains correlate to food preparation rather than plate waste. The large number of scales also points in this direction. This study documents the consumption of fish in the monastery, which is dominated by herring in number of bones, though probably not in terms of flesh weight, and is characterised by a relatively high taxonomic diversity for an inland site. The demonstrated presence of sturgeon, probably related to the status of the consumers, should also be noted.

Introduction

The remains analysed come from archaeological excavations carried out in the Rochambeau district of Vendôme (Loir-et-Cher; fig. 1), in the southern wing of the Benedictine Abbey of the Trinity of Vendôme (operation manager: Philippe Blanchard, Inrap), founded in the 11^{th} century by Geoffroy Martel, count of Anjou. Rescue excavations, because of the development of a building, were undertaken in 2019. They took place under the current »Regence« building. The »Regence« was constructed in 1732 on the site of a conventual building in the south wing of the cloister (fig. 1). The excavations allowed discovery of a building of unknown function prior to the circular kitchen, which was built in the 12^{th} century. Fish remains come from various levels relating to monastic kitchens, described as cendro-charcoal deposits, or (residues of) occupation layers, for example. The faunal assemblages studied come from period 3, the most abundant in remains, which corresponds to the 12^{th} and 13^{th} centuries; the archaeologists cannot be more precise for the dating. The fish remains can be considered to be related to a generally similar chronological horizon. If archaeozoological data are beginning to be available for this period in France, few relate to strictly similar sites and/or contexts, which should thus be a monastic kitchen – Benedictine, if possible –, contemporaneous, and at a similar distance from the sea. The scarcity of data reinforces the interest of this study. Let us also recall here that medieval dietary prescriptions prohibiting the consumption of meat were not inconsiderable (weekly fasts, Lent, etc.) and that the consumption of fish is accentuated among Benedictine monks because the rule of St. Benedict orders them not to consume the meat of quadrupeds, making an exception only for the weak and the sick.

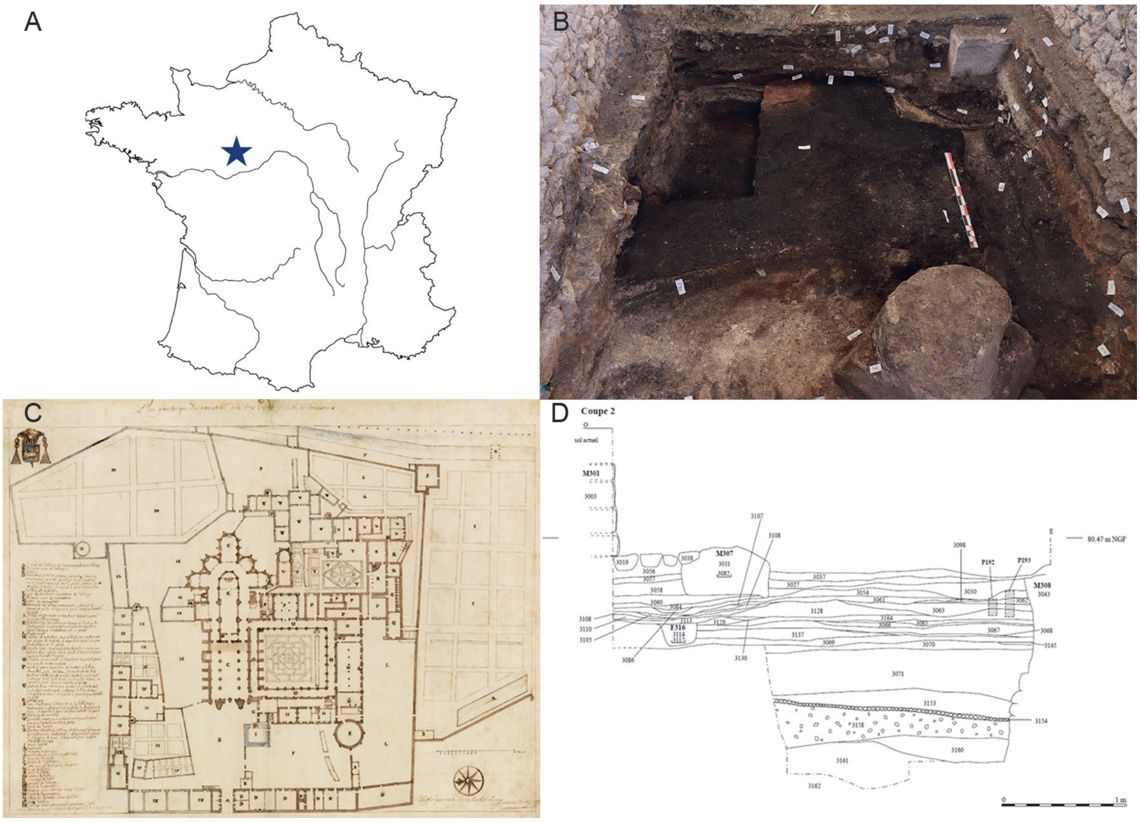

Fig. 1 A: Location of Vendôme Abbey; B: General view of excavations; C: Geometric plan of the monastery of the Most Holy Trinity of Vendôme, 1677, AN CP N/II Loir-et-Cher, piece 4 (Yvernault 2021); D: Stratigraphical section (photo and CAD: Blanchard 2021)

Methods

The remains were collected by hand and through sediment sampling, which was carried out in order to collect the smallest faunal elements. The total volume of sediment collected was approx. 450 l, of which a third was sieved and sorted, i.e. approx. 117 l were examined for the present study. Due to the quantity of possible material and the time available for the study, only certain levels were analysed in detail[1], with the volume of each sample varying between 4 l and 87 l. The sediments were sieved with water on a 2 mm mesh. S. Braguier (archaeozoologist, Inrap, France) sorted out the remains from the sieve residues and also studied the macrofauna remains[2]. Apart from the fish remains which are the subject of this article, the sieve rejects yielded quite a few bone remains of birds, especially chickens, but also woodcock and sometimes small passeriforms. Rare amphibian remains were also seen, in addition to bone fragments of generally unidentifiable mammals. Large quantities of chickens' eggshells were also found[3]. A few fragments of molluscs, both marine and terrestrial, were also observed; we will return to the presence of marine species in the discussion.

The determination of species or taxa was carried out with the help of general manuals[4], but above all thanks to the reference collection of the Comparative Anatomy Department of

1 Although not all of the material was studied, it was reviewed in its entirety (including the sieve rejects from the flotation). The species and their proportions appear to be similar in all respects to what has been seen elsewhere for the sample from period 3, as well as for those from the other periods, which are much less abundant in terms of remains. Period 2 in particular yielded only one sturgeon remain.

2 Braguier 2021.

3 Borvon 2021.

4 Lepiksaar 1994; Le Gall 1984; Libois – Hallet-Libois 1988; Cannon 1987; Radu 2005.

Oniris VetAgroBio (Nantes Veterinary School, France). Data recording was carried out per stratigraphic unit (SU) and per sediment sample. For each taxon, two classical quantification parameters were used: the number of identified specimens (NISP) and the minimum number of individuals (MNI). In the case of scales, their total is sometimes estimated. This estimation[5] is done in the following way: number of counted remains (a few hundred) × total mass)/mass of counted remains. This approximation of the total number of fragments is indicated in the tables by underlined values. The MNI corresponds to the highest minimum number of anatomical elements. Additional individuals can be counted when different sizes are recorded. In this study total fish lengths (TL) were largely estimated by direct comparison with reference specimens of known TL due to the low number of feasible elements and/or lack of suitable regression equations in the literature. For the most common species, an indication of the fish weight is provided. Any traces of any kind (tools, crushing, burning) were also recorded.

Results

General presentation of the corpus

Almost 12,000 fish bone remains were analysed. They are presented[6] in table 1. About 27 % of them were identified. This rate of identification is typical for this zoological group when sieving is carried out. In addition to the bones, a very large number of scales were also found, almost 30,000 in total. Apart from the highly transformed sturgeon scales, which were counted directly for this species, these scales are not identified further. They are mainly of the cycloid type, but some are also ctenoid, such as those of the perch.

Among the indeterminate parts, just over half are like ›needle-shaped bone‹, i.e. inter- and intramuscular elements shaped like a needle: the ribs and the skeleton of the median fins[7]. The neural and hemal spines of the vertebrae are also included in this category. These bones are fairly easily identified anatomically but not always attributable to a taxon. Tool marks were found on two of these unidentified bones.

Among the more than 3000 remains identified, 13 taxa were recognised (tab. 1). Their classification is based on their living environment, freshwater or marine, and the migrations carried out between the two: catadromous when it lives in freshwater and reproduces in the sea, such as the eel, and anadromous when it lives in the marine environment and reproduces in fresh water, such as the sturgeon or the shad. A taxon has an indeterminate status because the diagnosis has stopped at the genus level (see below for details of identification) and because it includes several species with different biological cycles, salmon being an anadromous migrator, trout being able to be freshwater (rivers and lakes) or anadromous.

Species present

Just over 500 pieces are attributed to the freshwater fish family of cyprinids. They correspond to 16.5 % of the remains identified (tab. 1). The bones fall into all the major anatomical groups of a skeleton (fig. 2, tab. 2), and no clear differences in their representation were observed between the different samples. Among the cephalic skeletal parts, the pharyngeal bones and teeth (fig. 3), which are particularly resistant, are the most numerous, with 88 remains. While the identification of the remains up to the level of the family does not really pose a problem, distinguishing between the numerous species that compose it is more complex[8], the diagnosis

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5 Variation of the total within ±10 %; Borvon 2012.

6 Details by SU and by sample are available in the report Borvon 2021.

7 Radial, lepidotrich, acanthotrich, pterygiophores.

8 Le Gall 1984; Libois – Hallet-Libois 1988.

Table 1 Taxonomic composition in number of identified specimens (NISP) of the 12th–13th-century kitchen level of the Trinité de Vendôme Abbey

			manual	sieved 2 mm	Total	%
freshwater species	Cyprinids	*Cyprinidae*	30	489	**519**	*16.5*
	Pike	*Esox lucius*	18	23	**41**	*1.3*
	Perch	*Perca fluviatilis*	2	15	**17**	*0.5*
	Bullhead	*Cottus perifretum*		126	**126**	*4.0*
	Loach	*Barbatula barbatula*		68	**68**	*2.2*
	Ninespine stickleback	*Pungitius pungitius*		68	**68**	*2.2*
migratory species	Eel	*Anguilla anguilla*	21	297	**318**	*10.1*
	Sturgeon	*Acipenser sturio*	95	69	**164**	*5.2*
	Alis shad	*Alosa alosa*		1	**1**	*0.03*
marine species	Herring	*Cuplea harengus*	11	1764	**1775**	*56.3*
	Common mackerel	*Scomber scombrus*		7	**7**	*0.2*
	Conger eel	*Conger conger*	1		**1**	*0.03*
other	Salmon/trout	*Salmo* sp.	1	49	**50**	*1.6*
Total NISP			**179**	**2976**	**3155**	*100*
	»needle-shape bone«		147	5813	**5960**	
	vertebra			48	**48**	
	other undetermined		60	5704	**5764**	
undetermined			207	11,565	**11,772**	
Total fish			**386**	**14,541**	**14,927**	
scales			50	27,612	**27,662**	

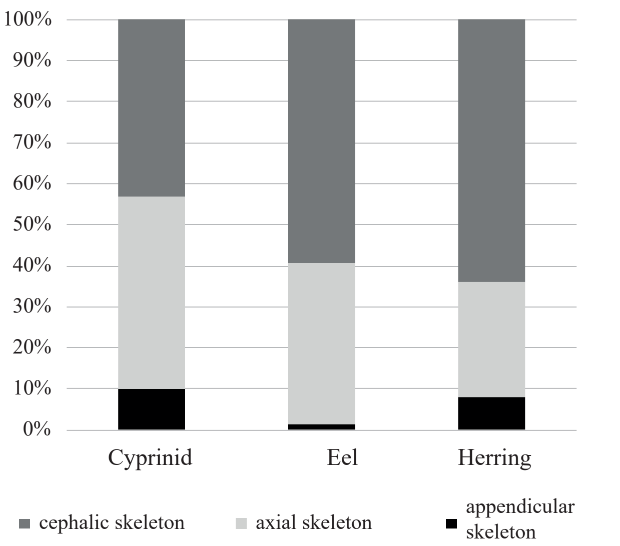

Fig. 2 Relative portion of large anatomical groups for the three main taxa as NISP (number of identified specimens) (A. Borvon)

being complicated by their strong morpho-anatomical resemblance and by the possible interfertility for most sympatric species within the same genus, but also between different genera[9]. These pharyngeal bones and teeth are among the pieces usually used for specific diagnosis (number of dental rows, number and shape of teeth)[10]. Here, however, they almost all have two rows of teeth (fig. 3), and apart from the gudgeon *Gobio gobio*, which is set apart by the shape of the pharyngeal bone, the various species of this group (chub *Squalius cephalus*, common dace *Leuciscus leuciscus*, etc.) are indistinguishable. These pharyngeal bones with two rows of teeth make it possible to count 45 individuals distributed as follows by size class:

9 Persat 2011.
10 Le Gall 1984; Libois – Hallet-Libois, 1988.

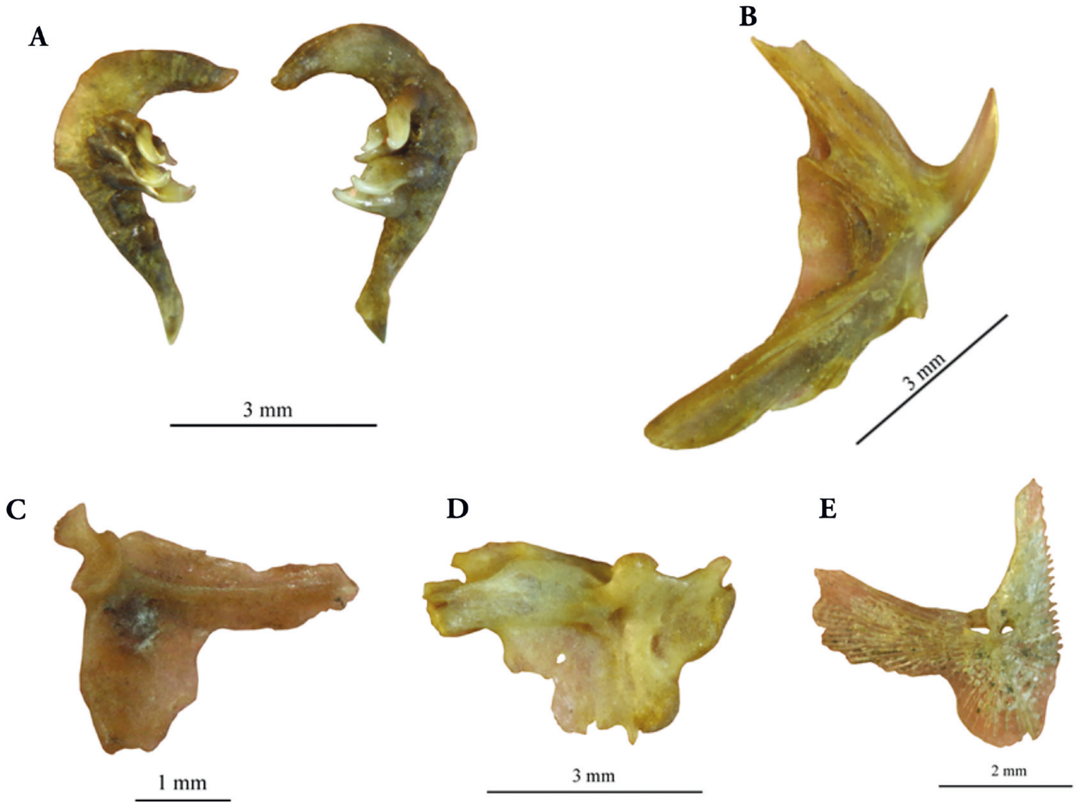

Fig. 3 A: Pharyngeal bones and teeth of cyprinids with two rows of teeth, unidentified species (SU 3068, sample 123); B: Preopercular of bullhead (SU 3068, sample 123); C. D: Hyomandibular and opercular of loach (SU 3064, samples 165 and 164); E: Basipterygium of ninespine stickleback (SU 3132, sample 147) (photos: A. Borvon, CAD: C. Picard, Oniris VetAgroBio)

- 10 cm long and less: 35 fish, of which only one is identified as a gudgeon;
- between 10 and 20 cm: 8 individuals;
- between 30 and 35 cm: 2 cyprinids.

A pharyngeal bone with a single row of teeth makes it possible to identify a tench *Tinca tinca* of about 30 cm TL. None of the pharyngeal bones have three rows of teeth, so no carp or barbel was detected.

The dentaries, which can also be used to establish specific identity[11], provide some details about the species present. Two chubs of 35–40 cm and 40–45 cm TL were detected, as well as a common dace of 15 cm TL and a common rudd *Scardinius erythrophthalmus* of between 15 and 20 cm. The white bream *Blicca bjoerkna* is suspected for two individuals of 15–20 cm and about 30 cm. The morphology of a basioccipital[12] is similar to a roach *Rutilus rutilus* of about 20 cm. Two large individuals, not specifically identified, were also detected. They measure between 45 and 50 cm TL.

Some vertebrae are deformed because they were crushed. Some pieces are charred (black coloration). Some also appear to have been heated, although the coloration of the bones does not really confirm this.

The pike was recognised in 41 pieces corresponding to various parts of the skeleton. As it can become large, its bones were regularly collected manually without sieving (tab. 1). At least eight individuals of different sizes were encountered. These range in size from 30 cm

[11] Libois – Hallet-Libois 1988.
[12] Le Gall 1984.

Table 2 Skeletal parts for the three main taxa in NISP

		Cyprinids	Eel	Herring
cepahlic skeleton	vomer	1	7	
	frontal	1	10	37
	parietal		7	6
	parasphenoid	4	5	37
	preotic		6	
	prootic			87
	and related			61
	epiotic			5
	basioccipital	16	5	37
	supraoccipital		1	
	premaxilla	1	3	
	supramaxilla			44
	maxilla	3	16	166
	palatine	14		
	entopterygoid	1		
	ectopterygoid	19		
	metapterygoid	3		
	quadrate	5	12	68
	articular (+ angular)	11	15	88
	dentary	9	19	107
	hyomandibular	13	16	79
	epihyal		16	50
	ceratohyal	3	20	77
	urohyal	2	4	44
	preopercular	14		34
	opercular	10	12	65
	interopercular	3	15	6
	subopercular	3		37
	pharyngeal bone + teeth	88		
axial skeleton	first vertebra	4	4	35
	second vertebra	6		41
	Weberian apparatus vertebra	8		
	Weberian apparatus bones	11		
	precaudal vertebra	92	66	297
	caudal vertebra	115	38	120
	urophor complex	9	17	2
appendicular skeleton	scapula	5		25
	coracoid	4		31
	mesocoracoid	2		
	cleithrum	13	3	24
	supracleithrum	2		27
	posttemporal	1		26
	basipterygium	23		10

to 1 m TL, falling in all 10 cm intervals. One tooth was crushed; another had probably been near a heat source.

The perch bones are few in number, 17 in total, relating to various skeletal parts. They allow the detection of four individuals whose lengths are estimated at 10 cm, 15 cm, 20 cm and 35 cm TL.

The bullhead, a freshwater species of about 10 cm TL (max. 15 cm)[13] was recognised on 126 remains (tab. 1). Essentially collected by sieving because of its size, the bones are distributed over the whole of the skeleton, although some of the most resilient are more numerous, such as the preopercular (21 remains; fig. 3). The latter allowed us to identify a dozen individuals. Two vertebrae were deformed, probably due to crushing.

Also small in size, with a length of about 10 cm too[14], the loach is fairly well represented, with 68 remains (tab. 1), which correspond to about ten individuals. Various parts of the skeleton were recognised, but the most resistant parts, such as the cleithrum or the hyomandibular (fig. 3) are slightly more numerous. Two species of loaches can theoretically be found near Vendôme[15], but only a few anatomical parts – the opercular (fig. 3), the dental, the maxilla and the pharyngeal bone – allow a specific identification[16]. In each case, they were found to be exactly like those of the most common species, the stone loach *Barbatula barbatula*. However, the occasional presence of the spined loach *Cobitis taenia* cannot be completely excluded. In view of the size of these fish, all their remains were collected in fine mesh.

The ninespine stickleback was recognised in nearly 70 remains (tab. 1). The extremely resilient basipterygiums (fig. 3) are the most numerous, amounting to 42 of the 68 bony pieces. Characteristic of the gastrosteidae family[17], they make it possible to distinguish osteologically the two species of the group, the three-spined stickleback *Gasterosteus gymnurus* and the ninespine stickleback *Pungitius laevis*. Only the latter has been identified here. They also allow us to count slightly more than twenty individuals, all of which were very small, since the species does not exceed 4–9 cm[18]. Here one reached 6 cm, all the others were less than 5 cm.

With nearly 320 remains, i.e. 10 % of the identified remains, the eel is rather well represented (tab. 1). Cephalic skeletal elements are particularly numerous (29 identifiable elements in one head) and amount to 59 % of the remains (fig. 2, tab. 2), while vertebrae only account for 39 %, although their number in this species is particularly high, ranging between 110 and 120[19]. The girdle elements are almost completely absent. While it is true that they are only represented by the cleithrum in this species (for identifiable elements), there are only three here, although it is an easy piece to identify. The 16 individuals recorded range in size from 30 cm to 1 m TL. Four measured between 30 cm and 45 cm, while all the others were 50 cm or more. Two of the vertebrae are charred (black); other pieces probably had to be heated.

Only one piece, a post-temporal, is related to the shad. The size of the individual approaches 65 cm TL. It is compatible with the allis shad *Alosa alosa* and rules out the possibility of being in the presence of the twait shad *Alosa fallax fallax*, which in theory does not exceed 42 cm[20], remembering however that there are also hybrids between the two species.

Numerous bones are attributed to the sturgeon, 164 in total, which makes it a rather frequent species with 5 % of the NISP (tab. 1). These are mainly dermal plates (fig. 4), which are modified scales. The specific diagnosis of the two possible species, the European sturgeon *Acipenser sturio* and the Atlantic sturgeon *Acipenser oxyrinchus*, was carried out by consulting the collections of the Museum of Natural Sciences in Brussels. The trabecular appearance of several large scutes suggests the almost exclusive presence of the former[21]. It is difficult to determine the size of the individuals from the bone plates, since it is not easy to assign a rank to those on the body of the animal. The presence of a first pectoral fin ray (fig. 4)

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[13] Persat 2011.
[14] Perrin 2011.
[15] Perrin 2011.
[16] Libois – Hallet-Libois 1988.
[17] Libois et al.1987.
[18] Lafaille – Feunteun 2011.
[19] Feunteun et al. 2011.
[20] Baglinière – Sabatié 2011.
[21] Desse-Berset 2011; Thieren et al. 2015.

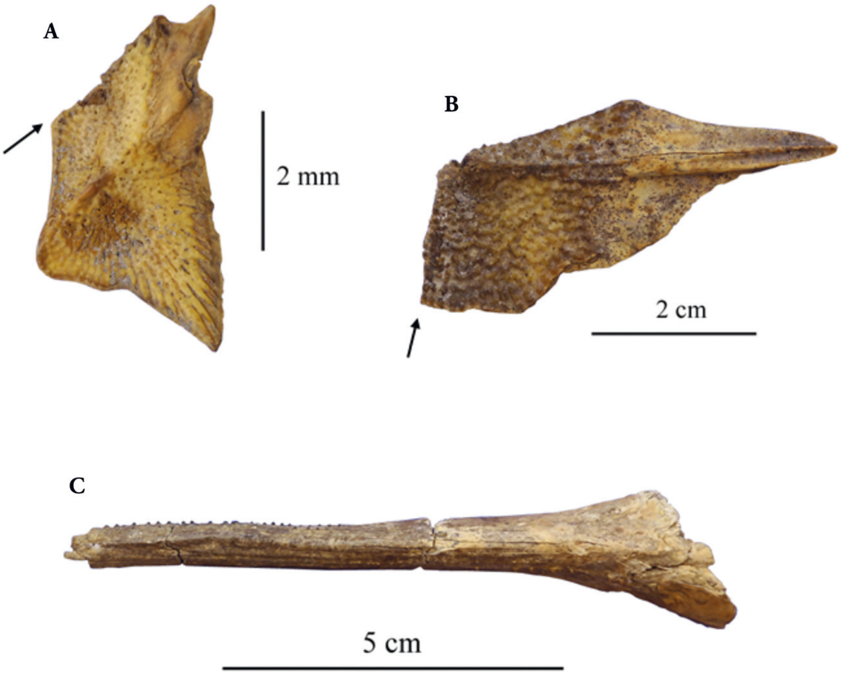

Fig. 4 A: Lateral; B: Ventral dermal scutes of sturgeon, with cut marks (SU 3064); C: First pectoral fin ray (SU 3065) (photos: A. Borvon, CAD: C. Picard, Oniris VetAgroBio)

indicates that one sturgeon measured about 1 m[22]. However, it should be noted that several individuals appear to be present, often of good size (1 m and more). Two plates were cut (fig. 4), probably with a view to making slices that would be easier to handle and/or cook.

Extremely well represented, with almost 1800 pieces, herring is the most frequent species with 56 % of the NISP (tab. 1). Almost all of its remains were collected by sieving the sediments. All the major anatomical groups are present, but the elements of the cephalic skeleton are slightly more numerous with 64 % of the remains (fig. 2). The maxillae are rather numerous (tab. 2), as they are among the most resistant parts of the clupeid skeleton, allowing 55 individuals to be counted. The articulars, also very resilient, also make it possible to detect many fish (42 individuals). The frequent unpaired bones (urohyal, basioccipital, first and second vertebrae; tab. 2) indicate a similar order of magnitude in terms of the number of individuals present. The vast majority of the fish are between 25 and 30 cm TL, with only a few being slightly smaller or larger. A little more than twenty vertebrae appear crushed. One vertebra is calcined and other three remains are burnt, too, and at least ten others are probably heated.

Seven remains are attributed to mackerel (tab. 1). The distinction between the two possible species, the common mackerel *Scomber scombrus* and the Spanish mackerel *S. colias*, did not pose any particular problem with the bones present. The quadrates (fig. 5) come from two individuals between 35 and 40 cm TL. One precaudal vertebra (fig. 5) belongs to a conger eel whose length is about 2 m.

Fifty remains are attributed to salmonids (tab. 1), mainly vertebrae (fig. 5). The four individuals detected measure approx. 10 cm, 35 cm, 45 cm and 70 cm TL. While it is tempting to attribute the smaller specimens to the trout *Salmo trutta* and the larger ones to the salmon *S. salar*, it should be kept in mind that trout can also reach large sizes, up to 1.10 m for the

22 Desse-Berset 1994a.

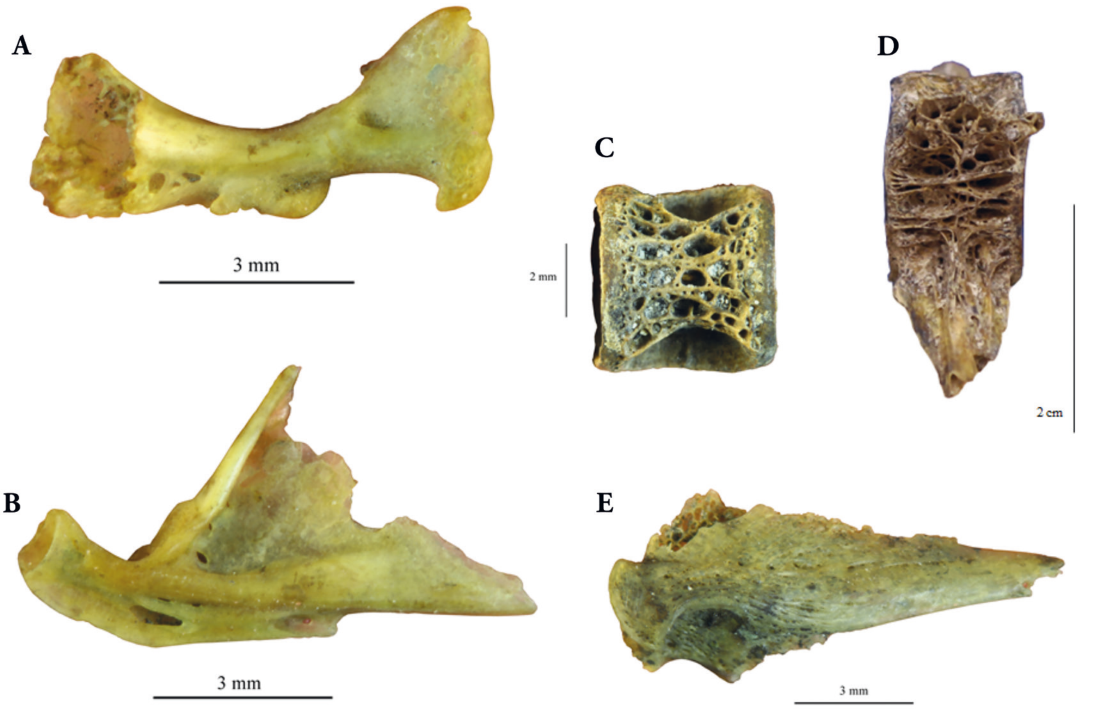

Fig. 5 A: Maxillary (broken on its left side); B: Articular of herring (SU 3064, sample 165); C: Precaudal vertebrae of Salmonid (SU 3064, sample 165); D: Precaudal vertebrae of conger eel (SU 3054); E: Quadrate of common mackerel (SU 3132, sample147 (photos: A. Borvon, CAD: C. Picard, Oniris VetAgroBio)

lacustrine form[23]. Distinguishing the two species is indeed difficult due to their great osteo-morphological similarity, especially in the vertebrae[24]. The rare pieces that sometimes allow a diagnosis[25] are also absent or too fragmentary to be used. For small individuals, however, the probability of being in the presence of trout is very high, since, theoretically, salmon of this size are at sea. The salmon is in fact an anadromous migrant, with freshwater juveniles that leave for the sea when they reach a size of 4–20 cm, and adults that come to fresh water to reproduce when they measure more than 45 cm[26]. So, the 10 cm salmonid could also be a salmon smolt migrating to the sea. Furthermore, the morphology of the vertebrae corresponding to the 70 cm individual seems to be closer to salmon than to trout, with all the reservations expressed so far, however.

Discussion

Food refuse

The fish bones found in the kitchens of the Trinité de Vendôme Abbey most likely come from species that were eaten, even if their consumption is less easy to demonstrate than that of mammals or birds, particularly because of the (near) absence of tool marks (which is quite usual at archaeological sites). A few were nevertheless found here, notably on the sturgeon bone plates. However, the remains were collected in a place described as a kitchen and among

23 Ombredane et al. 2011.
24 Desse-Berset 1994b; Guillaud et al. 2016; Borvon et al. 2018.
25 Spillmann 1989; Rosello Izquierdo – Brinkhuizen 1994.
26 Porcher – Baglinière 2011.

waste identified as being of food origin[27]. Furthermore, the presence of marine species, especially herring here but also mackerel and conger eel, that are not from local waters and are necessarily imported excludes an origin other than anthropic. In the case of the small fish, it should be considered that some of them may correspond to the stomach contents of larger fish, gutted and then discarded in this sector of the kitchens. There is, however, no evidence to support this hypothesis, particularly because of the absence of surface alterations resulting from passage through a digestive tract.

Consumption of fish

From a qualitative point of view, the consumption of fish appears to be diversified, since it is based on 13 taxa, not counting the various cyprinids (at least four distinct species), although they are diversely represented. From a quantitative point of view, herring remains are the most frequent, both in terms of the number of remains and the number of individuals. Their contribution to the diet, however, approximated by the restitution of the length of the individuals and consequently their mass, places them behind the meat contribution provided by the large species such as the sturgeon. Indeed, even if their size remains difficult to evaluate precisely, it should be noted that a sturgeon of 1 m TL already weighs around 20 kg[28], whereas even with 55 individuals, the herring would only total between 8 and 12 kg of flesh[29]. They are also very likely to be outweighed by large pike, which easily reach several kilos[30] or by the single conger eel, weighing around 20 kg, since it is almost 2 m long[31]. In the latter case, at least, it must have arrived whole at the site, since it is of more distant origin, and potentially prepared for transport. The eel would also be of some importance in this meaty diet of aquatic origin, as well as the cyprinid. Well represented in NISP with the second place, but often of small size, cyprinids, probably not differentiated by medieval consumers, appear as an important group in many medieval assemblages. The contribution of other taxa, particularly those that are well represented but small in size, such as the bullhead, loach and stickleback, remains more anecdotal.

What type(s) of waste?

Discovered in what is described as a kitchen, the question arises as to the nature of the food waste present, and in particular whether it is preparation waste, as one would expect in this type of place. The proportion of bones ›shaped like a needle‹ among the undetermined fish remains (50 %) is equally suggestive of the presence of plate waste and preparation waste. The same is true of the representation of the skeletal parts for the cyprinids; the presence in relatively equal proportions of the large anatomical groups (fig. 2) does not allow us to distinguish between the two hypotheses: they may have been prepared in a way that separates the flesh from the bones, as in a soup that was then filtered, for example, or served whole, and therefore correspond to dish waste. It should also be noted that the kitchen is of course used to prepare meals, but that the dishes must be washed somewhere and that this operation can produce plate waste ›in return‹, which would be the case for certain levels of the kitchens of the Royal Abbey of Fontevraud in France (ongoing study).

In the case of small individuals – juvenile cyprinids and small species such as the bullhead, loach and stickleback –, if consumption in their entirety, i.e. without separation of different

[27] Braguier 2021.
[28] Quéro – Vayne 2005.
[29] Around 150 g at 25 cm and 210 g at 30 cm; Quéro – Vayne 2005.
[30] Carpentier et al. 2011.
[31] Dorel 1986.

parts of the animal, seems probable for fish of 10 cm or less, it nevertheless also remains difficult to pronounce, always considering the hypothesis that they would be included in soups that were filtered for example.

The very large number of scales (almost 30,000), although generally not attributed to a taxon, strongly suggests the presence of preparation waste resulting from scaling phases. However, it is not necessarily at odds with the presence of plate waste if the fish were prepared and then consumed whole, given the very large number of scales in cyprinids in particular. The skeletal representation for eels (fig. 2) would also be more consistent with the presence of preparation waste. Indeed, the vertebrae, while certainly present, are not that abundant either, especially in relation to the number within an animal and compared to the frequency of the head parts. This imbalance in favour of the cephalic elements suggests that these fish, or at least some of them, were beheaded.

The case of large fish is probably still a little different. They may have been divided into more manageable portions (steaks) in the kitchen before being served. This is particularly the case for sturgeon, which was sliced in some cases. However, the possibility that they were touched by the wire of a tool because they were presented whole when served at the table cannot be ruled out.

For marine fish, this determination is also difficult, especially as they were generally prepared (dried, smoked, salted) before being transported. This is the case for conger eel, mentioned above, but especially for herring here. The anatomical distribution does not really allow us to specify in what form they were processed or consumed[32]. On the other hand, the relatively consistent presence of all the elements of the cephalic skeleton could point to fish whose heads were regularly separated from the rest of the animal (preparation waste, therefore), with a view to being eaten at the table. It should also be noted that other fish are also very suitable for preservation in dried, smoked or salted form, especially eels[33]. This possibility could explain the lack of elements from the belts of this species, since they were potentially removed at the same time as the animal was eviscerated and then prepared for longer preservation.

Furthermore, the few traces of burning found appear random and do not seem to testify to any cooking method. It is just possible that some of the bones were found in the vicinity of a heat source, probably located nearby, since several levels of the kitchen layers correspond to ash deposits[34].

In the end, it seems difficult to give a clear and definitive ruling on the nature of the waste present, although the possibility of preparation waste seems to be a little better supported, at least in some cases. On the other hand, coupled with the investigations carried out on the macrofaunal remains[35], some additional details can be provided. Indeed, in these 12th–13th-century levels, the waste that could have resulted from the preparation of large animal carcasses is not very numerous, probably because it was quickly removed from the kitchens. By contrast, parts of small species, particularly leporids and chickens, are much more frequent. Probably trapped in the operating levels of the kitchen due to their size, they often evoke preparation waste, especially in the case of the chicken, with the strong presence of the most distal elements of the pelvic limb, associated with the phalanges regularly seen in the sieving refuses. The crushing marks found on certain pieces, particularly the vertebrae, also point in the direction of bone remains trapped in the operating levels, as these marks are most certainly linked to the trampling caused by the use of these kitchens.

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32 Clavel 2001.

33 Clavel 2001; Cloquier 2006.

34 Blanchard 2021.

35 Braguier 2021.

Elements for comparison and supply network

The species encountered at Vendôme Abbey are those classically identified at contemporary religious sites distant from the sea, especially the strong predominance of herring, eel and cyprinids[36]. A point-by-point comparison with a particular site remains complicated for several reasons: kitchen contexts are not frequent in the literature; the chronology is not necessarily exactly the same; and the distance from the sea has a strong influence on the presence of marine fish in relation to the chronology[37]. Also, although freshwater taxa (or taxa caught in freshwater like eel) generally dominate the corpus, here it is herring that comes first, although its flesh, as we have seen, is perhaps not the most consumed. The significant diversity of species eaten, associated with the strong representation of a species considered prestigious, the sturgeon, and the large sizes of several species, lends credence to the hypothesis of the presence of a socially favoured human group[38]. Pike were also fish of high social status in 12th-century northern France, even presented as prestigious gifts among noble and chivalric elites[39]. The presence of these large quantities of herring could also support this hypothesis[40]. Indeed, the large quantities in 12th-century levels, and therefore at least for the beginning of the sequence here, are probably linked to the social status of the occupants, which perhaps enabled them to have dependencies on the coast and/or to free themselves from certain constraints (notably financial) relating to supplies. The presence of so many herrings appears to be quite early, since this species is relatively infrequent at inland sites, until its consumption increased steadily from the 13th century onwards[41]. However, this could also partly be a source effect, since it has been fairly systematically encountered at sites dating even earlier, albeit less markedly than at Vendôme, from the time when sediments started being taken and sieved[42].

Freshwater fish are very well represented, probably reflecting a supply of fresh fish of local origin, given the geographical location of the site. Rights relating to fishing are mentioned in the archives: donations granting rights to river fishing, to fisheries or to river management are indeed quite numerous, since 16 acts have been listed[43]. As early as the 11th century, the cartulary of the Trinité de Vendôme indicates that the monks directly owned several fisheries or had rights over some of them such as fish royalties[44]. As suggested by archives, the biotopes frequented by freshwater species refer to a variety of aquatic environments, but the proximity of the Loir River and its tributaries probably made it possible to obtain most of the species found in the kitchens without too much difficulty.

On the other hand, the marine species, which are necessarily imported, show different supply networks. While the herring supply network is more well-known and generally comes from the North Sea, questions remains for conger eel and mackerel. The presence of the latter appears quite remarkable here, since it was detected in chronological levels where marine fish (apart from herring) are rather rare as soon as the distance to the sea becomes significant. However, it is quite possible that they were caught in the herring beds, i.e. at the same time as the herring, and that they were then prepared in the same way as the herring, unless there are two totally different supply networks (because of a slightly different fishing seasonality [?]). The case of the conger eel is rather enigmatic for this period and so far from the sea, but perhaps because of a lack of documentation. This species could nevertheless be

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36 Clavel 2001; Borvon 2012; Borvon 2019; Hoffman 2023; Harland et al. 2016; Reynolds 2016; Hardy et al. 2003; Locker 1988; Locker 2018; Van Neer – Ervynck 2003; Van Neer – Ervynck 2004.

37 Clavel 2001.

38 Clavel 2001; Borvon 2012; Borvon 2019.

39 Le Goff 1988; Holden 2002–2006.

40 Borvon 2012.

41 Van Neer – Ervynck 2003; Clavel 2001; Borvon 2012; Borvon 2019.

42 Borvon 2019.

43 Yvernault 2021.

44 Yvernault 2021.

salted or, as its flesh is dry and not oily, dried and preserved for a long time. Conger was a favourite fish of the writer Bernard Silvestris in around 1150, and a fishery of dried or salted conger at Mont Saint-Michel is known in around 1175[45], as is one on the Channel Islands[46]. The monks of Westminster also ate it at that time[47]. Late medieval sources also mention an important trade in the south of France, in Iberia and in Italy[48]. The very rare fragments of mussel shells recovered also bear witness to the import of marine products. These mussels were most certainly brought in brine in a ›shelled‹ form, otherwise the shells would be more complete and/or more frequent, which seems to be a regular occurrence for the period.

Regarding herring, the Abbey of Vendôme is far enough south for such a quantity of herring in the 12th century, which would be less unusual for commercial distribution as known in the 13th century[49]. But monasteries to the south and inland received large annual gifts of herring from more northerly coastal patrons. For example, Cluny's sources show no record of herring in the 11th century, but sometime before 1150, the Count of Boulogne granted the abbey 20,000 herrings per year from his own fishing rights[50]. The Cistercians sent servants with carts to fetch herring from the fishing ports on the Normandy and Picardy coasts[51]. The Trinité de Vendôme nevertheless had priories in Saintonge (on the Atlantic coast), and especially that of Audrieu in Normandy, potentially favourable to the fishing of this species. This seems also to be supported by a textual source from 1383 that designates the prior of Audrieu as a supplier of 4000 herrings per year to the Abbey of the Trinity[52]. The supply of herrings, as well as other marine species, to Vendôme Abbey could therefore be linked to the network of priories, and specifically to that of Normandy. This type of royalty seems to have been frequent, since in 1215 we find one for the priory of Saint Pierre-Saint Paul d'Abbeville with a royalty of a thousand herrings or even an annuity of 10,000 pieces to the abbey of Saint-Josse[53].

Conclusion

The corpus studied, dating from the 12th and 13th centuries, is quite large, since nearly 15,000 bone remains were studied, of which more than 3000 were identified. These make it possible to ascertain a significant diversity, with 13 distinct taxa (excluding the various cyprinids). Many of the species are freshwater, or fished in freshwater contexts, such as eels. All of them could have come from the aquatic environments provided by the nearby Loir River. The marine species are mainly represented by the herring, which is attested here in large quantities. The importance of herring appears rather early compared to contemporary sites and perhaps testifies to financial comfort of consumers, essential to obtain this type of food from a distant source at that time, since these herrings were essentially imported from the North Sea, unless presence of these remains is in fact an effect linked to the fairly recent practice of sieving. The presence of mackerel and conger eel, on the other hand, raises questions about the abbey's relationship with the sea, with some priories located on the coast. The import of marine shellfish, most certainly in shelled form, should also be noted. A species considered to be prestigious was also found in fairly large quantities, namely the sturgeon. The bones of all fish are more likely to be preparation waste than plate waste in view of the analysis of

45 Hocquet 1987; Barré 1997.
46 Moss 2004.
47 Jones 1976.
48 E.g. Morales Muñiz et al. 2009; Hamilton 1975; Sanchez Quinones 2014; Serrano Larrayoz 2002; Weiss 2002.
49 Hoffmann 2023.
50 Receuil des chartes de l'abbaye de Cluny.
51 Canivez 1933, 41.
52 A fee in kind mentioned by Yvernault 2021, 134.
53 Jaminon 2006, 142.

the skeletal parts in particular. The study of macroremains would also point in this direction, particularly in the case of the chicken, which is also very well represented by its eggshells (several thousand fragments). These, as well as the bones of all the small animals mentioned, were most certainly trapped in the operating levels of the kitchen due to their size, while the larger waste was expelled to the outside.

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Bibliography

Baglinière – Sabatié 2011 J.-L. Baglinière – M.-R. Sabatié, La grande alose, l'alose feinte et l'alose feinte du Rhône, in: P. Keith et al. 2011, 267–272.

Barré 1997 E. Barré, Le droit maritime médiéval en Normandie, Annales de Normandie 47, 5, 1997, 511–536.

Blanchard 2021 P. Blanchard (ed.), Fouille et étude du bâti sur la cuisine et le réfectoire de l'abbaye de la Trinité de Vendôme, Centre-Val de Loire, Loir-et-Cher. Vendôme 2, quartier Rochambeau. Rapport de fouille, Inrap Centre-Île-de-France (Tours 2021).

Braguier 2021 S. Braguier, Etude archéozoologique, macrofaune, in: Blanchard 2021, 341–361.

Borvon 2012 A. Borvon, Acquisition des ressources animales, alimentation carnée et distinction sociale en Anjou de la fin du X^{e} au début du XII^{e} siècle. Étude archéozoologique du site de Montsoreau (Maine-et-Loire) (PhD thesis Université Paris 1 Panthéon-Sorbonne, Paris 2012) <https://hal.archives-ouvertes.fr/tel-00669956)>.

Borvon 2019 A. Borvon, New Data about the Consumption of Fish from the Alsace Region, France, International Journal of Osteoarchaeology 29, 2019, 407–419; DOI:10.1002/oa.2769

Borvon 2021 A. Borvon, Etude archéozoologique, macrofaune, in: Blanchard 2021, 363–386.

Borvon et al. 2018 A. Borvon – A. Bridault – R. Biton – R. Rabinovich – M. Prevost – H. Khalaily – F. Valla, Finding of trout (*Salmo* cf. *trutta*) in the Northern Jordan Valley (Israel) at the end of the Pleistocene. Preliminary results, JASc Reports 18, 2018, 59–64.

Canivez 1933 J.-M. Canivez (ed.), Statuta capitulorum generalium ordinis Cisterciensis 1. Ab anno 1116 ad annum 1220 (Louvain 1933).

Cannon 1987 D. Y. Cannon, Marine Fish Osteology. A Manual for Archaeologists (Burnaby 1987).

Carpentier et al. 2011 A. Carpentier – J. Cucherousset – E. Feunteun, Le brochet, in: Keith et al. 2011, 382–385.

Clavel 2001 B. Clavel, L'animal dans l'alimentation médiévale et moderne en France du Nord (XII^{e}–XVII^{e} siècles), Revue archéologique de Picardie, numéro spécial 19 (Picardie 2001).

Cloquier 2006 C. Cloquier, Approvisionnements en poissons dulçaquicoles et ichtyophagie dans les établissements monastiques picards du XII^{e} au XVIII^{e} siècle, in: B. Clavel (ed.), Production alimentaire et lieux de consommation dans les établissements religieux au Moyen Âge et à l'époque Moderne. Actes du colloque de Lille, 16–19 octobre 2003, Histoire Médiévale 19 (Caen 2006) 155–179.

Desse-Berset 1994a N. Desse-Berset, Sturgeons of the Rhône during Protohistory in Arles (6th–2nd century BC), in: W. Van Neer (ed.), Fish Exploitation in the Past. Proceedings of the 7th meeting of the ICAZ Fish Remains Working Group, Tervuren, Annales du Musée Royal de l'Afrique Centrale 274, Sciences Zoologiques (Tervuren 1994) 81–90.

Desse-Berset 1994b N. Desse-Berset, Les Poissons, GalliaPrehist 36, 1994, 219–224.

Desse-Berset 2011 N. Desse-Berset, Discrimination of Acipenser sturio, Acipenser oxyrinchus and Acipenser naccarii by Morphology of Bones and Osteometry, in: P. Williot – E. Rochard – N. Desse-Berset – F. Kirschbaum – J. Gessner (eds.), Biology and Conservation of the European Sturgeon Acipenser sturio L. 1758 (Berlin 2011) 23–48.

Dorel 1986 D. Dorel, Relations taille-poids pour l'Atlantique Nord-Est (Nantes 1986).

Feunteun et al. 2011 E. Feunteun – P. Elie – P. Lambert – C. Rigaud, L'anguille européenne, in: Keith et al. 2011, 260–263.

Guillaud et al. 2016 E. Guillaud – R. Cornette – P. Béarez, Is vertebral form a valid species-specific indicator for salmonids? The discrimination rate of trout and Atlantic salmon from archaeological to modern times, JASc 65, 2016, 84–92.

Hamilton 1975 E. J. Hamilton, Money, Prices and Wages in Valencia, Arago, and Navarre, 1351–1500, Harvard Economic Studies 51 (Philadelphia 1975).

Hardy et al. 2003 A. Hardy – A. Dodd – G. D. Keevil, Ælfric's Abbey. Excavations at Eynsham Abbey, Oxfordshire, 1989–1992 (Oxford 2003).

Harland et al. 2016 J. F. Harland – A. G. K. Jones – D. C. Orton – J. H. Barrett, Fishing and Fish Trade in Medieval York: The zooarchaeological evidence, in: J. H. Barrett – D. C. Orton (eds.), Cod and Herring (Oxford 2016) 172–204.

Hocquet 1987 J.-C. Hocquet, Les pêcheries médiévales, in: M. Mollat (ed.), Histoire des pêches maritimes en France (Toulouse 1987) 113–114.

Hoffman 2023 R. C. Hoffman, The Catch. An Environmental History of Medieval European Fisheries (Cambridge 2023).

Holden 2002–2006 A. J. Holden (ed.), History of William Marshal, with English translation by S. Gregory, and historical notes by D. Crouch 1–3 (London 2002–2006).

Jaminon 2006 R. Jaminon, Les ressources alimentaires des établissements religieux du Ponthieu et du Vimeu au Moyen Âge à travers l'étude des droits de pêche et de chasse, in: B. Clavel (ed.), Production alimentaire et lieux de consommation dans les établissements religieux au Moyen Âge et à l'époque Moderne. Actes du colloque de Lille, 16–19 octobre 2003, Histoire Médiévale 19 (Caen 2006) 141–154.

Jones 1976 A. K. G. Jones, The Fish Remains, in: G. Black, Excavations in the sub-vault of the Misericodes of Westminster Abbey, TransactLond 27, 1976, 170–176.

Keith et al. 2011 P. Keith – P. Persat – E. Feunteun – J. Allardi (eds.), Les poissons d'eau douce de France (Paris 2011).

Lafaille – Feunteun 2011 P. Lafaille – E. Feunteun, L'épinochette, in: Keith et al. 2011, 439–440.

Le Gall 1984 O. Le Gall, L'Ichtyofaune d'eau douce dans les sites préhistoriques. Ostéologie, Paléoécologie, Paléoethnologie. Cahiers du Quaternaire 8 (Paris 1984).

Le Goff 1988 J. Le Goff, Vestimentary and alimentary codes in Erec et Enide, in: J. Le Goff (ed.), The Medieval Imagination (Chicago 1988) 132–150.

Lepiksaar 1994 J. Lepiksaar, Introduction to osteology of fishes for paleozoologists (Göteborg 1994).

Libois et al. 1987 R.-M. Libois – C. Hallet-Libois – R. Rosoux, Éléments pour l'identification des restes crâniens des poissons dulçaquicoles de Belgique et du nord de la France. 1. Anguilliformes, Gastérostéiformes, Cyprinodontiformes et Perciformes. Fiches d'ostéologie animale pour l'archéologie, série A: poissons, 3 (Antibes 1987).

Libois – Hallet-Libois 1988 R.-M. Libois – C. Hallet-Libois, Éléments pour l'identification des restes crâniens des poissons dulçaquicoles de Belgique et du nord de la France. 2. Cypriniformes. Fiches d'ostéologie animale pour l'archéologie, série A, poissons, 4 (Antibes 1988).

Locker 1988 A. Locker, Fish Bones, in: R. Daniels, The Anglo-Saxon Monastery at Church Close, Hartlepool, Cleveland, The Archaeological Journal 145, 1988, 201.

Locker 2018 A. Locker, Freshwater fish in England. A social and cultural history of coarse fish from prehistory to the present day (Oxford 2018).

Morales Muñiz et al. 2009 D. C. Morales Muñiz – E. Roselló Izquierdo – A. Morales Muñiz, Pesquerías medievales hispanas: Las evidencias arqueofaunísticas, in: La Pesca en la Edad Media, Monografías de la Sociedad Española de Estudios Medievales 1 (Madrid 2009) 145–165.

Moss 2004 V. Moss (ed.), Pipe Rolls of the Exchequer of Normandy for the reign of Henry II, 1180 and 1184 (London 2004).

Ombredane et al. 2011 D. Ombredane – J.-L. Baglinière – P. Berrebi, La truite commune, in: Keith 2011, 398–403.

Perrin 2011 J.-F. Perrin, La Loche épineuse, la Loche d'étang, la loche franche, in: Keith 2011, 366–374.

Persat 2011 H. Persat, Ordre des Cypriniformes, famille des Cyprinidae, in: Keith 2011, 273–274.

Porcher – Baglinière 2011 J -P. Porcher – J. L. Baglinière, Le saumon atlantique, in: Keith 2011, 394–396.

Quéro – Vayne 2005 J. C. Quéro – J. J. Vayne, Les poissons de mer des pêches françaises (Paris 2005).

Radu 2005 V. Radu, Atlas for the identification of bony fish bones from archaeological sites. Studii de Preistorie Suppl. 1 (Bucharest 2005).

Reynolds 2016 R. Reynolds, The Social Complexities of Early Marine Fish Consumption. New Evidence from Southeast England, in: J. H. Barrett – D. C. Orton (eds.), Cod and Herring (Oxford 2016) 215–220.

Rosello Izquierdo – Brinkhuizen 1994 E. Rosello Izquierdo – D. C. Brinkhuizen, Laminak II/Spain. Alternative taxonomies as approaches to the interpretation of a fish fauna, Offa 51, 1994, 401–409.

Sánchez Quiñones 2014 J. Sánchez Quiñones, Pesca y Comercio e el Reino de Castilla Durante la Edad Media: los valles del Guadiana, Júcar y Tajo (siglos XII y XVI), Serie Histórica 6 (Madrid 2014).

Serrano Larráyoz 2002 F. Serrano Larráyoz, Fernando, La mesa del rey. Cocina y régimen alimentario e la corte de Carlos III el noble de Navarra (1411–1425) (Pamplona 2002).

Spillmann 1989 C.-J. Spillmann, Poissons d'eau douce. Fédération Française des Sociétés de Sciences Naturelles, Faune de France 65 (Paris 1989).

Thieren et al. 2015 E. Thieren – W. Wouters – W. Van Neer, Guide for the identification of archaeological sea sturgeon (Acipenser sturio and A. oxyrinchus) remains, Cybium. International Journal of Ichthyology 39, 2015, 175–192.

Van Neer – Ervynck 2003 W. Van Neer – A. Ervynck, Remains of traded fish in archaeological sites: indicators of status, or bulk food?, in: S. Jones O'Day – W. Van Neer – A. Ervynck (eds.), Behavior Behind Bones. The zooarchaeology of ritual, religion, status and identity. Proceedings of the 9th Conference of the International Council of Archaeozoology, Durham, August 2002 (Oxford 2003) 202–214.

Van Neer – Ervynck 2004 W. Van Neer – A. Ervynck, Apport de l'archéozoologie à la connaissance de l'exploitation de l'eau douce au Moyen Age et à l'Epoque Moderne en Belgique, in: P. Benoit – F. Loridant – O. Mattéoni (eds.), Pêche et pisciculture en eau douce: la rivière et l'étang au Moyen Age. Actes des 1ères Rencontres Internationales de Liessies, avril 1998 (Lille 2004) 31–44.

Weiss 2002 S. Weiss, Die Versorgung des päpstlichen Hofes in Avignon mit Lebensmitteln (1316–1378). Studien zur Sozial- und Wirtschaftsgeschichte eines mittelalterlichen Hofes (Berlin 2002).

Yvernault 2021 F. Yvernault, Etude d'archives, in: Blanchard 2021, 467–489.

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Late Neolithic Fish Remains from the Stare gmajne Pile-Dwelling Site at the Ljubljansko barje in Slovenia

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Abstract

The Late Neolithic pile-dwelling site Stare gmajne at Ljubljansko barje in Slovenia brought ichthyoarchaeological material to light, uncovered in recent excavations in 2021. On the one hand, the study of remains derived from coprolites can fortunately be continued in the near future, and on the other hand, the intense cooperation between archaeobotany, palynology, palaeoparasitology and ichthyoarchaeology enhances the picture of fish exploitation at the pile-dwelling site. Abundant fish remains were recovered due to fine wet-sieving of sediment samples and as a result of sorting and counting waterlogged remains in a wet condition. Not only the coprolites, most likely produced by canids and humans, but additionally sampled sediments from the archaeological contexts revealed various small fish remains, too. These contexts of the continued excavations at the settlement provide further important information on fishing and fish consumption in the Late Neolithic. The human protein supply provided by fish is mainly composed of cyprinids, river perch and northern pike.

Introduction

Archaeological excavations were carried out in the two trenches 4 and 5 at the Stare gmajne site at Ljubljansko barje in Slovenia in the summer of 2021 (fig. 1). The excavations localised a dark-brown layer, accumulated due to human activity in the Late Neolithic (ca. 3521–3366 calBC)[1] and composed of very fine sediments. The layer lies approximately 60 cm beneath the topsoil, extends vertically over about 60 cm and comprised most of the recovered archaeological material. Underlying this cultural sedimentological unit, a grey clay layer contained ceramic and organic findings, too. Underneath, lake marl or so-called polžarica continues, into which wooden piles were driven vertically, serving as sub-constructions for the pile-dwelling.

Sediment samples were collected in both trenches, though only trench 4 evidenced the specific dark cultural layer. One focus was on archaeobotanical assessment of sampled material in areas of moss concentrations and around fragmented vessels. Other sediment samples were taken around a wooden ring; a bow and two dog/human coprolites were also collected during excavation. The wet-sieving of the systematically sampled sediments yielded six additional coprolites and another two wooden rings, most of them coming from trench 4 within an area of 2 m² (quadrants A4 and B4; fig. 2).

Sediment sample remains offer the potential to compare fish remains that accumulated within the pile-dwelling settlement due to human activity with the remains from the coprolites, which certainly passed through someone's digestive system. Potential differences or similarities in fish and skeletal element composition may help in explaining whether the coprolites are of human or canine origin. Dogs were probably fed on discarded carcasses and/or cast-off fish of small sizes. Sampled fish remains also enable reconstruction of the main fishing methods

[1] Leghissa et al. 2022.

Fig. 1 Excavation in trench 4 at the Stare gmajne site in 2021 (photo: D. Valoh, Institute of Archaeology, ZRC SAZU)

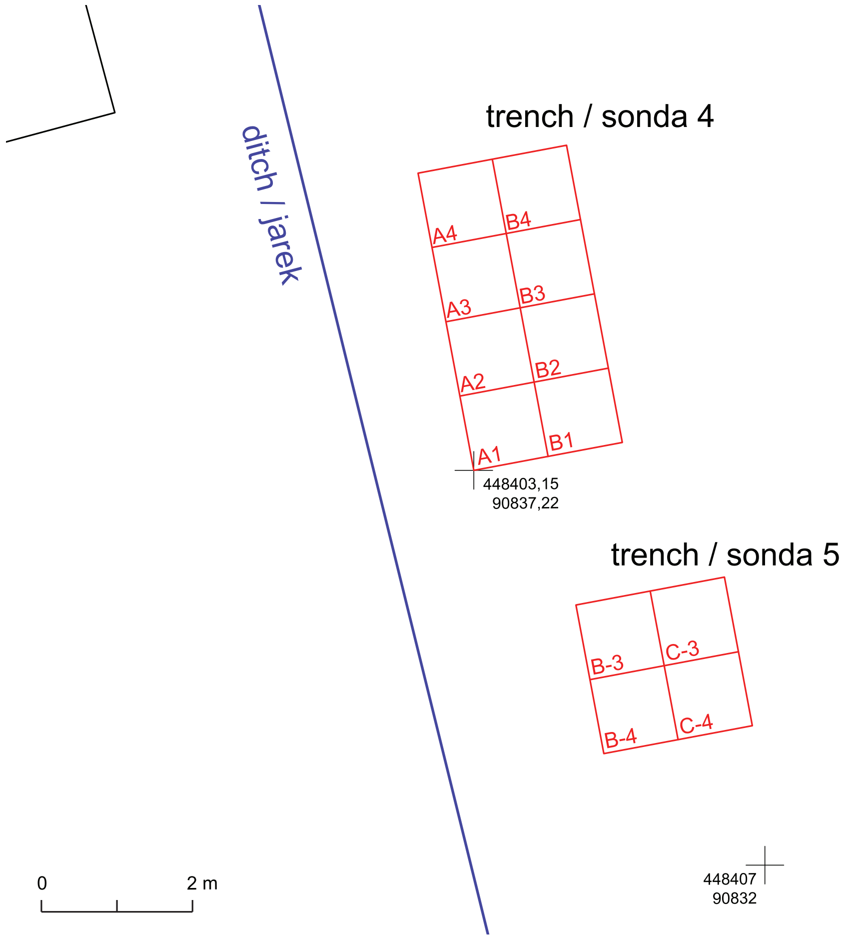

Fig. 2 Excavated trenches at Stare gmajne in 2021 (© Institute of Archaeology, ZRC SAZU)

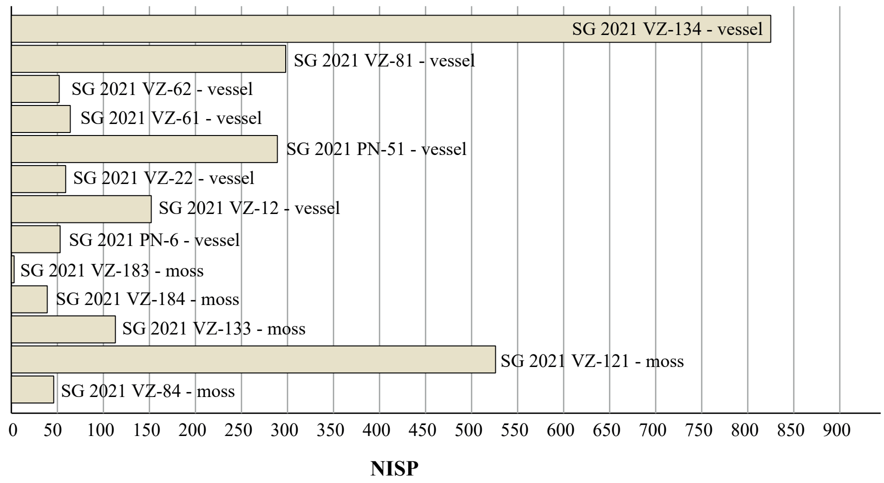

Fig. 3 Quantification of fish remains in moss and vessel sediment samples (© OeAW-OeAI/A. Galik)

and of what the catches looked like through the quantification of large and small individuals. Another intention of this scientific undertaking is the collection of sufficient data in order to set it into the larger picture of Neolithic pile-dwellings in Alpine regions, a research focus of our department at the Austrian Archaeological Institute.

Fish remains, including scales, bones and isolated teeth, appeared in all archaeobotanical assessment/evaluation samples[2] and were carefully picked out during the archaeobotanical examinations. In addition to macroanalyses, the two coprolites from the excavations in 2021 were also subsampled for microanalyses such as palaeoparasitological, palynological and biochemical investigations[3]. Six more coprolites were subsequently discovered during wet-sieving of the systematically taken sediment samples in 2021 and 2022, and the macro-remains, including fish, will certainly be collected to some extent and prepared for further, and again fish-related, investigations. An Olympus SZX10 microscope was used for identification and measurement of the small remains.

Results

All the fish remains were erratically distributed within moss, vessel sediment samples and regular patterns are not observable (fig. 3). Some of the vessel and some of the moss samples contained frequent but also infrequent remains of fishes. Sample SG 2021 VZ-134[4] from a vessel sample showed the highest frequency of fish remains, while sample SG 2021 VZ-183 contained only three fish scales and was collected beneath the 182-C2 coprolite 2. Unidentifiable fish remains consist mainly of fish scale fragments, fin rays and uniserial bone elements. In most of the samples, more trunk than cranial elements are available. Only two pelvises appeared, and few elements of the shoulder girdle can be proven in most samples.

All sediment samples contained fish scales. The scales stem from river perch, northern pike and cyprinids. Scales of larger northern pike as well as larger cyprinids are usually heavily fragmented, while the harder ctenoid scales of river perch are preserved in better condition. Complete scales and fragments at least including the centre and outermost margin were documented and photographed and will be analysed according to age and the seasonality of catches in the near future.

2 Tolar – Matika 2024.
3 Tolar et al. 2023; Tolar et al. 2024a; Tolar et al. 2024b.
4 Tolar et al. 2023; Tolar et al. 2024a; Tolar et al. 2024b.

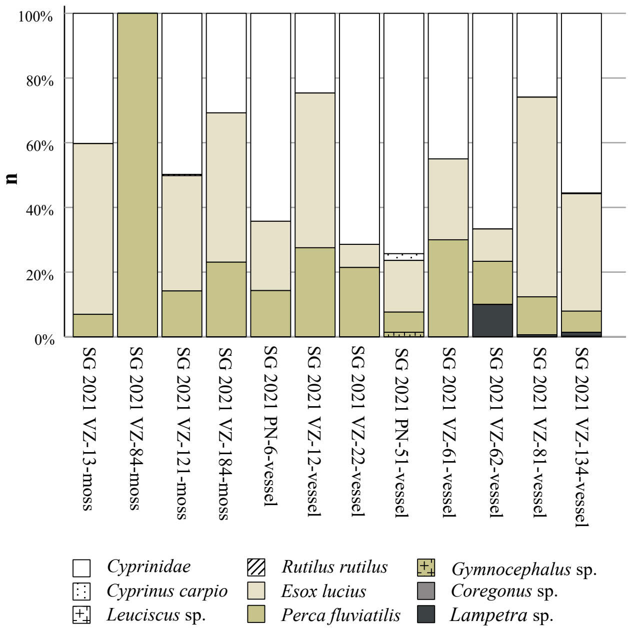

Fig. 4 Distribution of fish species in the sediment samples (© OeAW-OeAI/A. Galik)

Though the frequencies of fish vary significantly amongst the moss and vessel samples from 2021, the samples certainly contain fish refuse of domestic origin. In all samples the frequencies reflect a high percentage of not identifiable and highly fragmented fish remains. The most abundant species are cyprinids, river perch (*Perca fluviatilis*) and northern pike (*Esox Lucius*; fig. 4). Besides river perches, a few remains of ruffe (*Gymnocephalus* sp.) appeared amongst the percid remains as well. The cyprinids comprised only very few identifiable cranial remains, common carp (*Cyprinus carpio*) proven with isolated pharyngeal teeth and probably with a dentary and two small ceratohyals. Common roach (*Rutilus rutilus*) is present with pharyngeal bone fragments, while the major part represents cyprinid vertebrae. Lampreys (*Petromyzontidae*) are proven due to the special preservation conditions in waterlogged sediments and by the presence of three isolated oral disk teeth. A single vertebra, most probably of a whitefish (*Coregonus* sp.), astonishingly appeared in the material, too.

Within the group of cyprinids mainly trunk and fewer cranial elements are countable, if the isolated teeth of pharyngeal bones are listed individually (tabs. 1. 2). Solely trunk remains occurred in samples SG 2021 VZ-133 (moss sample) and SG 2021 VZ-12 (vessel sample). Slightly more cranial elements than uniserial bones are documented in SG 2021 VZ-61 (vessel sample) and SG 2021 PN-51 (vessel sample). Elements of the shoulder girdle are less abundant, and basipterygia are generally rare in cyprinids. The representation of northern pike is also clearly biased by the presence of isolated teeth, but in general more trunk bones are available than cranial elements. Only a few trunk- and no cranial elements appear in two samples (SG 2021 VZ-184 [moss sample], SG 2021 VZ-22 [vessel sample]), while another two samples contained only a few cranial elements but no trunk bones (SG 2021 PN-51, SG 2021 PN-6; both vessel samples). A similar skeletal element pattern seems true for river perch: trunk remains dominate, or cranial bones are completely missing. Only sample SG 2021 VZ-62 (vessel sample) yielded a sole cranial element.

Fish bones allow the size to be reconstructed, and though maybe roughly estimated, fish size allows interpretation of fishing behaviour and strategies[5]. In this case, as vertebrae are most abundant, size reconstructions are attempted using these bones, being aware of the potential size differences of vertebrae in the full length of the rachis[6]. Therefore, the greatest height and the greatest breadth of the cranial vertebra surface was chosen, and the measurements are depicted in bivariate plots. One group of cyprinids lies in the size range clearly less than 1 mm up to 1.4 mm, and another group widely accumulates between 1.4 and 2.4 mm (fig. 5). Vertebrae of larger sizes appear to be sparsely distributed, though a few quite large individuals up to 5 mm in height and breadth are proven, too.

Pike vertebrae also indicate quite small individuals with a size distribution less than 3 mm in vertebral dimensions (fig. 6). A cluster might be seen between 3 and 4.4 mm and ranging

[5] Wheeler – Jones 1989; Brinkhuizen 1989; Radu 2003.

[6] Desse et al. 1989; Jelu et al. 2021.

Table 1 Distribution of fish and anatomical elements from the sediment samples

	Pisces	Cyprinidae	Coregonus sp.	Cyprinus carpio	Lampetra sp.	Esox Lucius	Gymnocephalus sp.	Perca fluviatilis	Total
Indeterminate	240								240
Cran. frgm.						2			2
Parasphenoid		2				1			3
Supraoccipitale	1								1
Basioccipitale						3			3
Frontale								1	1
Praemaxilla		1							1
Dens		86		4	10	40			140
Dentale		1				10		4	15
Articulare	1	3				2			6
Praeoperculum		1						4	5
Operculum		4							4
Palatinum						4			4
Ectopterygoid						1			1
Quadratum		1							1
Hyomandibulare	1							2	3
Ceratohyale		5							5
Urohyale		1							1
Os pharyng.		16							16
Posttemporale								1	1
Scapula		1							1
Cleithrum	1	3				2		2	8
Radiale	1								1
Basipterygium		1							1
Epipleurale Costa	2								2
Pleurale Costa	15								15
Vertebra	226	184	1			56	2	66	535
V.process.	1	1							2
Fin ray	168								168
Pterygiophore	18								18
Scale	144	192				231		18	585
Total	**819**	**503**	**1**	**4**	**10**	**352**	**2**	**98**	**1789**

from 4.4–5.2 mm; larger specimens are up to 6.8 mm and a single remain is around 10 mm in size, coming from sample SG 2021 VZ-81, from the fill of a vessel.

The sizes of river perch vertebrae also suggest quite a wide distribution. Besides very small specimens ranging from less than 1 mm, there is a cluster between 1.6–3.2 mm in size. Larger individuals are 3.2–4 mm in size, and only two specimens exceed this, at about 5 mm in size (fig. 7).

Table 2 Distribution of fish and anatomical elements from the moss samples

	Pisces	Cyprinidae	Rutilus rutilus	Esox Lucius	Perca fluviatilis	Total
Indeterminate	104					104
Cran. frgm.				1		1
Mesethmoid		1			1	2
Pteroticum		2				2
Frontale	1					1
Dens		21		13		34
Dentale		1				1
Articulare				2		2
Praeoperculum	1	1				2
Interoperculum		1				1
Palatinum					3	3
Quadratum		1				1
Epihyale	1					1
Os pharyng.		4	1			5
Scapula		2				2
Cleithrum	1	2			2	5
Radiale	1					1
Basipterygium	1					1
Costa	1	1				2
Pleurale Costa	24					24
Apophysis Costae	3					3
Vertebra	41	45		11	18	115
Fin ray	87					87
Pterygiophore	4					4
Scale	241	89		106	24	460
Total	**511**	**171**	**1**	**133**	**48**	**864**

Discussion

The main aim in this scientific project is to use the biogene contents derived from coprolites as archives for multi-proxy analysis[7]. Coprolite samples from Stare gmajne contained various materials for palynological, palaeoparasitological, archaeobotanical and archaeozoological investigations, as well as potential markers for biochemical analyses, which are in progress[8]. Three types of archaeobotanical remains were analysed from assessment samples: moss and seeds/fruits, waterlogged wood and charcoal[9]. Plant taxa such as water plants, weeds and ruderals can be used to reconstruct the economy and environment in and around the Late Neolithic pile-dwelling. Complementarily, coprolite samples contained pollen, mainly consisting of water-dependent flora. A high percentage of oak, hazel shrub and alder and a low abun-

7 Tolar et al. 2021; Tolar – Galik 2019
8 Tolar et al. 2021.
9 Tolar – Matika 2024.

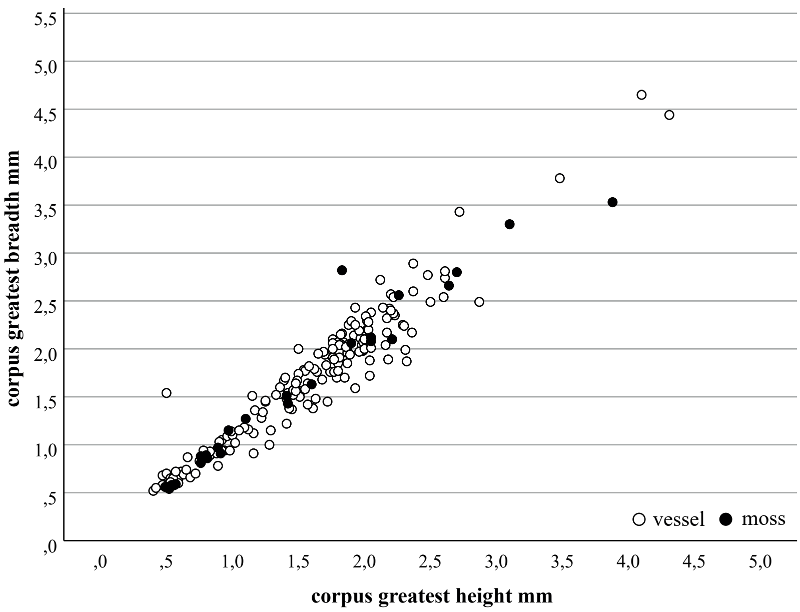

Fig. 5 Size distribution of cyprinid vertebrae (© OeAW-OeAI/ A. Galik)

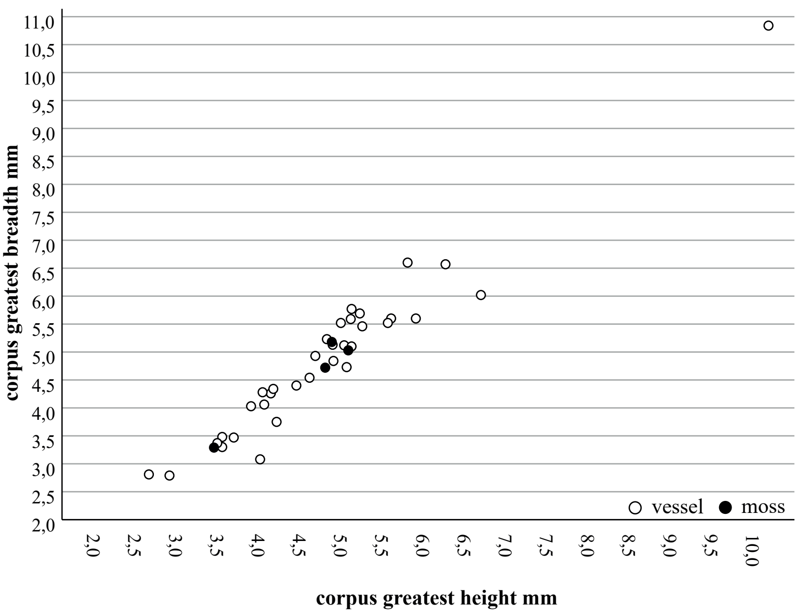

Fig. 6 Size distribution of northern pike (*Esox lucius*) vertebrae (© OeAW-OeAI/ A. Galik)

dance of beech and fir trees support reconstruction of marshy areas as well as open waters and anthropogenically opened landscapes[10].

The new archaeoichthyological results complement and enhance data on the catching and exploitation of fishes as a nutritive basis for the Slovenian Eneolithic pile-dwellers based on examinations on undigested fish remains from the sediment samples. So, these remains add new data to the already existing data from another Late Neolithic pile-dwelling site in Slovenia, i.e. Hočevarica[11].

Including scales and considering the low frequency of fish remains recovered from coprolites, the distribution of fish species appears, maybe not astonishingly, quite similar compared to the sediment samples (fig. 8). However, cyprinids are most important, though the frequency is a bit higher in coprolites, followed by pike and perch. A similar distribution is found as in

[10] Andrič et al. 2008; Tolar et al. 2011; Tolar et al. 2023.
[11] Govedič 2004, 133 f.

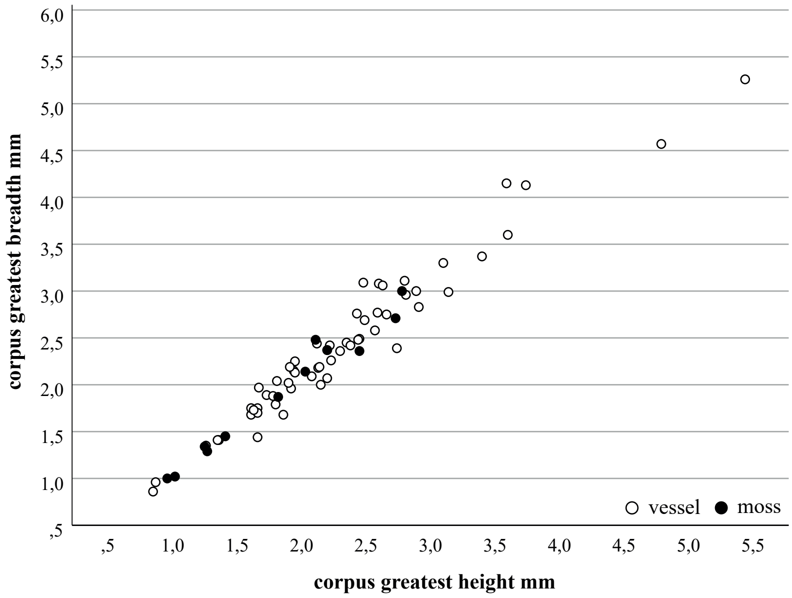

Fig. 7 Size distribution of river perch (*Perca fluviatilis*) vertebrae (© OeAW-OeAI/ A. Galik)

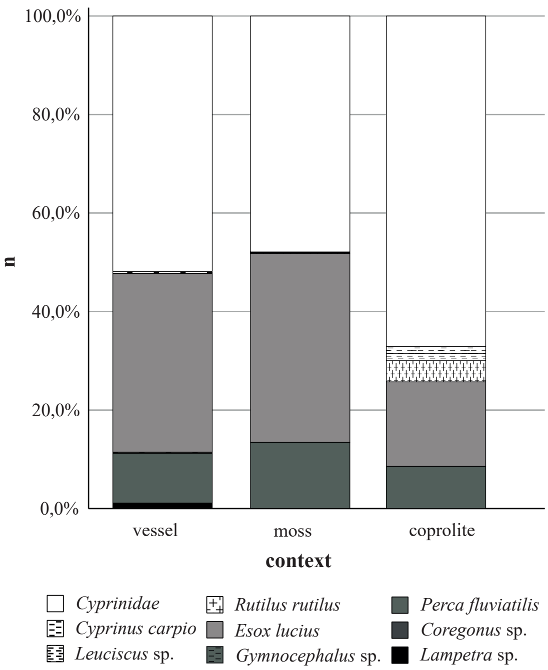

Fig. 8 Comparison of the fish composition in sediment samples and coprolites from Stare gmajne (© OeAW-OeAI/A. Galik; Tolar et al. 2021)

Hočevarica, although sheatfish[12] is missing in Stare gmajne samples to date. Common carp and roach are found in both coprolites and sediment samples, whilst *Leuciscus* sp. was only found in a coprolite[13]. Common carp was evidenced by very characteristic isolated pharyngeal teeth. However, some small cranial elements may indicate catches of very young common carp that were caught in areas where juvenile fish schooled.

The present and ancient distribution of common carp has been thoroughly discussed by Govedič, and the finds belong to the oldest evidence of autochthonous common carp in Slovenia[14] to be recovered at such a distance from the Danube Basin[15]. New data on fish exploitation is provided by the presence of ruffe, which probably represents the common ruffe but could also be Balon's ruffe[16], and tiny lamprey teeth, both native in the local water systems. European whitefish, on the other hand, seems to be an intrusive species that drifts in from Austrian waters and nowadays does not reproduce in Slovenia[17], a phenomenon that is probably also applicable to Late Neolithic times. The fishes

12 Govedič 2004, 140.
13 Tolar et al. 2021.
14 Govedič 2004, 138.
15 Govedič 2004, 140.
16 Povž et al. 1997.
17 Povž – Sumer 2005; Povž et al. 2018.

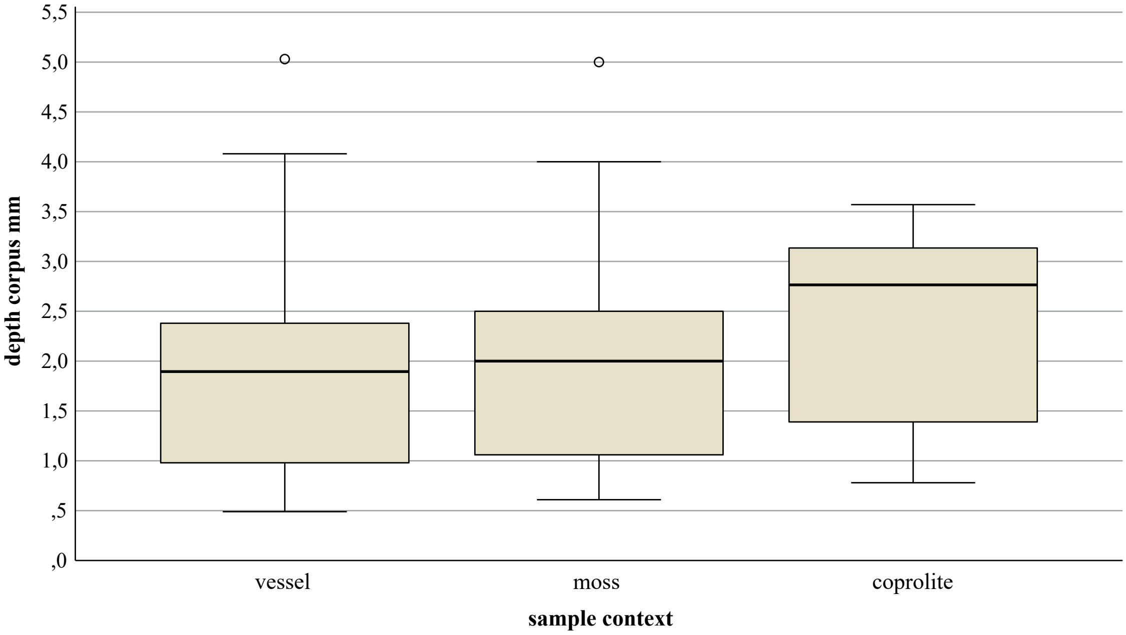

Fig. 9 Comparison of cyprinid size composition in sediment samples and coprolites from Stare gmajne (© OeAW-OeAI/A. Galik; Tolar et al. 2021)

proven at Stare gmajne largely resemble references on fish fauna for the Ljubljansko barje as already described by Govedič[18].

The size distribution of fish offers insights into the fishing strategies and consumption patterns of the dwellers and potentially their dogs. The caught cyprinids start from yearlings of less than 10 cm in length up to older fish of larger size. The bulk of cyprinid remains indicates small fish such as yearlings and two-summer fish. Pike remains reveal a similar pattern, starting with fish of around 20 cm up to 40 cm, as well as a large specimen of about 70 cm in length[19]. A small group of river perch yearlings represents rather small fish, too, followed by fish up to two and three years of age and a few relatively large individuals.

The majority of the fish were caught early as quite young and rather small individuals, though some appear to be a bit older. Catches of large fish are evident but seem to represent acknowledged exceptions and occasional catches. This holds especially true for large raptor fish such as pike, which are less abundant than smaller specimens, and catching them nutritive basis. They could have been caught near the lake banks in shallow waters with nets or fish traps, for example[20]. Only in cyprinids is a comparable number of vertebral measurements available from coprolites, but a similar distribution in sizes of the fish caught seems to be present in the coprolites, too (fig. 9).

Originally, not only owing to their shape and size, the coprolites from Stare gmajne (2007 excavation) were interpreted as being of canine origin because of the high frequency of fish bones and the presence of specific archaeobotanical remains and the eggs of parasites such as tapeworm and whipworm[21]. The parasites use fish as intermediate host and only infect the host through consumption of raw or not well-cooked fish, affecting both humans and dogs.

Certainly, larger fish were dismembered, while smaller fish were used whole. So, small fish constitute the bulk of catches and we interpret them as being for human subsistence. Some of these could have been fed to or were discarded and eaten by dogs. Whether small fish had

18 Govedič 2004, 140.
19 Jelu et al. 2021.
20 Govedič, 2004, 146.
21 Tolar et al. 2021; 2023.

been fileted remains uncertain, but larger carcasses certainly were discarded and scavenged by dogs. And dogs certainly played a role in organic refuse management within the settlement. It was established that the coprolites from Stare gmajne were excreted in spring[22], fitting with yearlings or two-summer cyprinids.

The fish remains under examination here indicate intense fishing, certainly with a focus on small and very small fish. Determining the age and season might provide a better insight into the fishing behaviour and consumption pattern of the Late Neolithic people at Stare gmajne. The distribution of skeletal elements may indicate the usage and consumption of complete fish, despite these specific preservation patterns. Teeth, vertebrae and other robust cranial elements probably outsurvived the less solid bones. According to Govedič[23], the Late Neolithic fishes from the Ljubljansko barje prefer lower regions of rivers and stagnant waters, and remains of rheophile fishes such as trout, grayling, huchen, nase or Danubian roach have not yet been proven[24].

Conclusions

In general, our focus is on the settling and supply of prehistoric pile-dwelling sites. However, studies of coprolites preserved in special preservation conditions provide insight into a microcosmos within the aforementioned large-scale research questions. The recently taken sediment samples from Stare gmajne now complement the research results already obtained. Men and dogs lived as companions in close areas within the pile settlement and evidently consumed mainly small fish. This leads to another aspect of the prehistoric pile-dwelling investigations concerning fishing and consumption. Recent excavations apply modern methods including sediment sampling, wet- and fine-sieving of samples and picking out, in this case not only coprolites, but also the smallest bio-archaeological finds, even from inside coprolites, information that is sometimes missing in old excavations, where the washing of sediments through fine sieves took place irregularly or not at all. The inevitable result is missing information on the small remains that were not discovered while hand-picking finds in excavations. These new results allow us to complete information on fishing and fish consumption in these very special forms of prehistoric settlements and societies.

Acknowledgements

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22 Tolar et al. 2021.
23 Govedič 2004.
24 Govedič 2004, 136.

Bibliography

Andrič et al. 2008 — M. Andrič – B. Kroflič – M. J. Toman – N. Ogrinc – T. Dolenec – M. Dobnikar – B. Čermelj, Late quaternary vegetation and hydrological change at Ljubljansko barje (Slovenia), Palaeogeography, Palaeoclimatology, Palaeoecology 270, 1, 2008, 150–165.

Brinkhuizen 1989 — D. C. Brinkhuizen, Ichthyo-archeologisch onderzoek. Methoden en toepassing aan de hand van Romeins vismateriaal uit Velsen (PhD thesis Rijksuniversiteit Groningen 1989).

Desse et al. 1989 — J. Desse – N. Desse-Berset – M. Rocheteau, Les profiles rachidiens globaux. Reconstitution de la taille des poissons et appreciation du nombre minimal d'individus a partir des pieces rachidiennes, Revue de Paleobiologie 8, 1, 1989, 89–94.

Govedič 2004 — M. Govedič, Fishes from the archeological site at Hočevarica, in: A. Velušček (ed.), Hočevarica. An Eneolithic Pile Dwelling in Ljubljansko Barje, Opera Instituti Archaeologici Sloveniae 8, 2004, 133–151.

Jelu et al. 2021 — I. Jelu – W. Wouters – W. Van Neer, The use of vertebral measurements for body length and weight reconstruction of pike (*Esox lucius*) from archaeological sites, Archaeological and Anthropological Sciences 13, 5, 72, 2021; DOI:10.1007/s12520-021-01325-0

Leghissa et al. 2022 — E. A. Leghissa – A. Velušček – T. Tolar, Arheološke raziskave na najdišču Stare gmajne – prazgodovinsko kolišče. Prvo strokovno poročilo o raziskavi, 2022, 21-0293 (unpublished archaeological report, kept in ZVKDS OE Ljubljana and ZRC SAZU Institute of Archaeology).

Povž – Sumer 2005 — M. Povž – S. K. Sumer, A brief review of non-native freshwater fishes in Slovenia, Journal of Applied Ichthyology 21, 2005, 316–318.

Povž et al. 1997 — M. Povž – M. Mrakovčić – M. Kerovec, The first find of Balon's ruffe (*Gymnocephalus baloni*) in the river Drava in Slovenia and in Croatia, Folia Zoologica 46, 2, 1997, 189–190.

Povž et al. 2018 — M. Povž – G. Jakšić – M. Piria, The updated list of the non-native freshwater fishes in Slovenia with note of their potential impact in inland waters, Pakistan Journal of Zoology Suppl. 13, 2018, 1–7.

Radu 2003 — V. Radu, Exploitation des ressources aquatiques dans les cultures néolithiques et chalcolithiques de la Roumanie Méridionale (PhD thesis Université d'Aix-Marseille I, Aix-Marseille 2003).

Tolar – Galik 2019 — T. Tolar – A. Galik, A Study of Dog Coprolite from Late Neolithic Pile-Dwelling Site in Slovenia, Archaeological Discovery 7, 2019, 20–29.

Tolar – Matika 2024 — T. Tolar – D. Matika, Archaeobotanical study of judgement samples from Stare gmajne, an Eneolithic pile-dwelling site. Mosses, vessel contents and the analysis of the wooden artefacts, Arheološki vestnik 75, 2024, 411–440.

Tolar et al. 2011 — T. Tolar – S. Jacomet – A. Velušček – K. Čufar, Plant economy at a late Neolithic lake dwelling site in Slovenia at the time of the Alpine Iceman, Vegetation History and Archaeobotany 20, 3, 2011, 207–222.

Tolar et al. 2021 — T. Tolar – A. Galik – M. Le Bailly – B. Dufour – N. Caf – B. Toškan – E. Bužan – L. Zver – F. Janžekovič – A. Velušček, Multi-proxy analysis of waterlogged preserved Late Neolithic canine excrements, Vegetation History and Archaeobotany 30, 1, 2021, 107–118.

Tolar et al. 2023 — T. Tolar – N. Caf – A. Galik – M. Le Bailly, The dog or its master? An interdisciplinary study on coprolites from the pile-dwelling site Stare gmajne, in: V. Koprivnik – D. Salecl (eds.), Srečanja tisočletij / The Convergence of Millennia: Museoeurope. The Collected Volume of Symposium 19.–21.10.2023 (Maribor 2023) 78–91.

Tolar et al. 2024a — T. Tolar – T. Podobnik – A. Galik – N. Caf – M. Le Bailly – E. Rosenberg – E. Buzan – L. Zver, Le chien ou son maître? Recherche interdisciplinaire sur les coprolithes de l'habitat palafittique néolithique de Stare Gmajne en Slovénie, in: Fumier, Bouses et Guano: Ordures ou Or Brun? 44[e] Rencontres Internationales d'Archéologie et d'Histoire de Nice Côte d'Azur. Nice 15–17 octobre 2024, CEPAM, Cultures et environnements, préhistoire, Antiquité, Moyen-âge (Nice 2024) 40.

Tolar et al. 2024b	T. Tolar – A. Galik– M. Le Bailly, The dog or its master? Further interdisciplinary research on coprolites from Site Stare Gmajne Eneollithic pile dwelling site in Slovenia. V: Persisting with change, in: 30th EAA Annual Meeting, Rome, Italy, 28th–31st August 2024 (Abstract Book) 1319.
Wheeler – Jones 1989	A. Wheeler – A. K. G. Jones, Fishes (Cambridge 1989).

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Fishing and Fish Preparation in Puck and Gdańsk in Late Medieval and Early Modern Times

Urszula Iwaszczuk – Anna Gręzak

Abstract

In this paper, we followed the connections between two late medieval and early modern port towns, Puck and Gdańsk, based on the fish remains, and analysed the environmental and economic factors that could have been responsible for the differences between the materials from the locations as well as the diachronic changes. We also discussed the possible fisheries and the distribution of fish. The materials were analysed in phase 1 (the 2nd quarter of the 14th to the 1st half of the 15th cent. AD) and phase 2 (the 2nd half of the 15th to the 1st half of the 16th cent. AD). Despite the apparent focus on catching and consuming marine fish in late medieval and early modern Puck and Gdańsk, fish composition in these towns differed. In our opinion, these differences were due to the status of the inhabitants and the availability of fisheries and opportunities to obtain fish in other ways. Our research showed that during phase 2, garfish became a rarer guest in the waters of Puck Bay; in contrast, flounder became more accessible. We also noticed a slight shift towards smaller individuals in the case of cod caught by Puck fishermen. The fish consumed in Puck mainly came from the local Baltic Sea and Puck Bay fisheries; only a small addition of large cod could have been imported, probably from the north. In Gdańsk, on the other hand, the deep-sea fisheries were exploited, and the sources of fish supply were more diverse. Among others, cod could have been imported to a greater extent. We also observed an increased interest in freshwater fish in phase 2 in Gdańsk, which shows that the Gdańsk Bay fisheries were also used.

Introduction

There is a significant inconsistency in the analysis of the archaeozoological materials from the Polish territory, particularly concerning archaeoichthyological materials. Some regions are well researched, while others are almost *terra incognita* in this respect. Pomerania is one of the unevenly recognised regions. On the one hand, the early medieval assemblages have been quite frequently excavated and analysed; on the other hand, the late medieval materials were discovered almost exclusively during financially oriented surveys and are mostly hand-collected. This is especially visible in the case of Gdańsk Pomerania. All this makes the analysis difficult, because the researcher has to compare like with unlike, i.e. large assemblages of several hundred fragments with small collections of materials of only a few or a few dozen fragments, or random discoveries with the remains coming from the regular excavations. Fortunately, we dealt with the problem, as we decided to analyse the assemblages from the late medieval/early modern town and castle in Puck, dating to the second quarter of the 14th to the first half of the 16th century AD, against the broader background and to compare this assemblage with the contemporary materials from the region's central town at the time, i.e. the town of Gdańsk (fig. 1). We must stress that these are the only archaeoichthyological materials from the area that have been published so far.

The two towns, Puck and Gdańsk, differed in many respects, but there were many economic and political links between them. These differences are obvious, as during the period

Fig. 1 Location of the sites included in the research (© U. Iwaszczuk; based on map tiles by CartoDB, under CC BY 3.0. Data by OpenStreetMap, under ODbL)

under discussion, Puck was a small town with a number of inhabitants not exceeding 520[1], while in the case of Gdańsk, the estimation indicates 40,000–50,000 inhabitants at the end of the 16th century[2]. As to the links, Puck was undoubtedly in a zone that fell under the economic, social and cultural influence of Gdańsk, and according to M. Starski[3], these links were more vital than in the case of other small towns located further inland. Gdańsk was one of the entities united in the Hanseatic League at that time; Puck was not. However, it was included in the Hanseatic network to some extent, and merchants from Puck were involved in trading in Gdańsk market. From the archaeological point of view, these connections may be followed based on some types of luxury goods; it seems that their import had been minor but noticeable since the town's inception[4]. What is more, similar sources of supply in luxury goods probably existed in the case of both the town and the castle in Puck because of the similarity of the range of these goods at both locations[5].

In our paper, we will concentrate, however, on a specific type of goods that could have been imported or that could have been of a local origin: fish. Our goal is to interpret the archaeoichthyological assemblages from Puck, including those from the town and the castle, and the materials obtained during the excavations in Gdańsk. We would like to follow the

1 Kardasz 2017, 80.
2 Bogucka 1982, 547.
3 Starski 2017a, 507 f.
4 Starski 2017a, 501–503.
5 Starski 2017a, 502.

connections between these locations based on the fish remains and analyse the factors that could have been responsible for both the differences and the diachronic changes. We would also like to discuss the possible fisheries and the distribution of fish.

History of Puck

The town of Puck, located in Gdańsk Pomerania at the mouth of the Płutnica River where it flows into Puck Bay, was granted a location privilege by the Grand Master of the Teutonic Order on 16th November 1348[6]. However, the settlement of this area in the Middle Ages dates back at least to the end of the 9th and the first half of the 10th century AD, when a port was in use here, the remains of which have been discovered under the waters of the bay north-west of Puck[7]. So far, the background of the port is not known, and information about the existence of the village of Puck, considered to be the predecessor of the urban centre, relates only to the late 12th century AD. Its role in the region is evidenced by the functioning of a market here and, from the beginning of the 13th century, one of the first parishes in Pomerania. The growing importance of the centre was manifested by the establishment of the Puck Castellany, which was to take place at the end of the 13th century, after the end of the civil war in Gdańsk Pomerania in AD 1269–1271. After the Teutonic Order occupied Pomerania, Puck was incorporated into the Gdańsk komturship established in AD 1311, and 37 years later it received the status of a town. In the incorporation document, the inhabitants of the town and the village in front of it were granted Chełmno law *(Jus Culmense vetus)*. One hundred habitations (town parcels) were to be created within the town's boundaries, the inhabitants of which were granted the right to fish with one net in both the Great and the Little Sea (»in der grosin Se und in dem cleynem«), i.e. in the Baltic Sea and in Puck Bay. From 1368, a Teutonic official in Puck was mentioned in the historical sources – rybicki pucki (»magister piscature in Puczk«), who supervised fishing in the Gdańsk komturship[8].

At the beginning of 1440, the Prussian Union was founded – a kind of confederation of towns and knights of the Teutonic state area, in reaction to the fiscal oppression and judicial abuses by Teutonic officials, of which Puck was a representative, and Gdańsk played a leading role. As a result of the conflict, the Prussian Union denounced obedience to the Teutonic Order and yielded to the authority of the Polish king Casimir Jagiellon. This led to Poland declaring war on the order and the incorporation of Prussia into Poland in March 1454. The conflict (the Thirteen Years' War) ended with the Second Peace of Toruń (1466), under which the former Teutonic possessions passed to the state[9]. In Royal Prussia, starosties were established, leased or pledged to the nobility in return for loans taken out during the war effort. The Starosty of Puck was still pledged to the Danzigers during the war and remained in their hands intermittently until 1545. This was the period of Puck's dependence on Gdańsk. The Gdańsk Burgher Council exercised administrative and military authority here. In 1457 the Burgher Council, being in financial trouble, borrowed 15,000 Prussian grzywnas from the Swedish king Charles VIII Knutsson Bonde, who was taking refuge in Gdańsk during the conflict with Denmark, as a pledge for the Łebsko and Puck district. Charles VIII Knutsson Bonde lived in Puck Castle for three years, then it passed into Teutonic possession for a while, only to return to Gdańsk in 1464. In 1468, the Gdańsk army returned the Starosty of Puck to Casimir Jagiellon, who gave it to a Pomeranian voivode. He and his successors held the office of voivode until 1491, when the monarch pawned the starosty to the Danzigers for 5000 Hungarian zlotys, and it remained in their hands for more than 50 years. In 1546, King Sigismund the Old took the Starosty of Puck away from the Danzigers and leased it to the

[6] Burski 1998, 74.
[7] Pomian et al. 2016.
[8] Burski 1998, 69.
[9] Burski 1998, 84–90.

castellan Chełmno Stanislaw Kostka. After his death, it was taken over by his son Jan Kostka, castellan of Gdańsk. Then for several decades, until the Swedish Deluge, rule in the starosty was handed to the Wejher family, a Pomeranian family in the service of the Polish king[10].

The area intended for the later castle foundation was not included in the foundation document and is clearly separated from the town on the town plans produced in 1634 and 1810. This means that, in practice, it was not under the town's jurisdiction and was outside its administrative boundaries. The remains of the castle, which does not exist today, are located in the north-western corner of the town, on the shore of Puck Bay. Such a location was characteristic of Teutonic Order foundations. In the case of Puck, the choice of site was also favoured by the natural elevation of the terrain, about 4 m high, cutting off the castle space from the marshy coastal areas. From the west, the Płutnica River surrounded the area and therefore served as the castle moat. According to the results of archaeological excavations and information from historical sources, the castle foundation dates back to the last years of the 14th century AD or the first years of the 15th century. During the Teutonic Knights' times, the castle served as the seat of the rybicki office, and after 1468 it became the seat of the officials of the starosty[11].

According to F. Schultz, fishermen lived in suburbs and along the coast and were divided into two groups: one working for the castle and the other for the town[12]. A. Groth[13] estimated the number of fishermen connected with Puck to be 10 % of the town's inhabitants, while the historical sources named 21 families associated with this craft. Additionally, fishermen from Gdańsk also had the right to fish off the coast of Puck[14].

Material and methods

Material

The archaeoichthyological research included material from sites located in two port towns, Puck and Gdańsk, dated to two phases from the turn of late medieval to early modern times. Phase 1 covered the period from the second quarter of the 14th to the first half of the 15th century AD and phase 2 from the second half of the 15th to the first half of the 16th century AD. In most cases, the remains were collected by hand during investment surveys within the administrative boundaries of the present towns, so the randomness of the finds was high and the areas (sites) surveyed differed in the size and amount of material collected, as well as the conditions under which the excavations were carried out. For example, some of the excavations were set up in areas with high groundwater, which, on the one hand, made exploration difficult and, on the other, affected the state of preservation of the remains. Some of the material was obtained from between the collapses of architectural structures or latrines. Due to the overall small number of remains that could be included in the present study, remains from different types of contexts were not distinguished.

Puck

The starting point for the research was the hitherto unpublished material from the town of Puck (879 fragments in total) analysed by the authors of this paper. Fish bones, like other animal remains, were relatively well preserved, which contributed to the high percentage of identified remains: for phase 1 it was 76.5 %; and for phase 2, 65.7 % (it should be taken into

10 Groth 1998, 91–93.
11 Kruppé – Milewska 2014, 31–58.
12 Schultz 2011, 200.
13 Groth 1998, 80.
14 Odyniec 1961, 168.

account that the percentage of identified remains was also influenced by the specific nature of archaeoichthyological material, i.e. the limited possibility concerning the identification of ribs and some other anatomical elements).

The remains excavated at the castle (backfill layers from the moat) in 1991 and identified by P. Koperski[15] were also taken into account. Fish remains were sieved using water flotation. In addition, a small number of bone fragments from more recent excavations were also studied by the authors of this article and counted together with the rest of the material from the castle. The number of unidentified bone fragments was provided only for the newly studied material; such data were not given for the material analysed by Koperski. It enabled us to analyse at least some fish sizes from this site, as the previous analysis did not contain such data. In total, this constituted more abundant material (1136 fragments), but some relevant information was missing. In addition to estimation of fish sizes, it also lacked information about the presence of marks on the bones. Unfortunately, we did not have access to this material; we could only use a catalogue of fish remains from the site.

Gdańsk

Materials from Gdańsk were excavated during numerous investment surveys carried out in different parts of the town. Only the fish bones from the Powroźnicza/Długi Targ region were analysed by the authors of this publication, and some of the results have recently been published[16]. This material was not very abundant and contained 91 identified fish remains. For the sake of a broader context, material from the sites Mariacka/Św. Ducha (market/butchery place), Olejarna 2, Młyńska, Zielona Brama, Plac Heweliusza, Kładki 24, Wyspa Spichrzów and Na Piaskach analysed by D. Makowiecki and co-authors were therefore included in this study[17]. Data for some of these sites have been presented in several publications, including the most recent one, which discusses more abundant material from Olejarna 2 than that analysed in the previous papers[18]. The analysis was likely extended to include material from more recent studies that were not covered in the previously mentioned papers. The study included the dating of the distinguished phases for Olejarna 2 and the anatomical composition of cod bones for the sites from the Gdańsk area, lacking in earlier publications. At the same time, it should be noted that the data provided was partial and included only quantitative data for the remains of cod and fish from the Clupeidae and Pleuronectidae families. However, despite these issues, this study was used by us as the most detailed one.

Methods

Identification

The remains from Puck (town) and Gdańsk (Powroźnicza/Długi Targ) were identified anatomically and by species, and where species identification was not possible, the fragments were identified by genus or family. The comparative collection held at the Institute of Mediterranean and Oriental Cultures of the Polish Academy of Sciences was used for identification purposes. Presentation of fish species was based on the taxonomic classification of modern fish[19]. Latin species names were given after <https://fishbase.mnhn.fr/>; anatomical terminology was taken from the classic work by W. K. Gregory[20].

15 Gręzak 1993.
16 Gręzak 2022.
17 Makowiecka – Makowiecki 2018; Makowiecki 1998a; Makowiecki 1998b; Makowiecki 2000; Makowiecki 2001; Makowiecki et al. 2016.
18 Makowiecki et al. 2016.
19 Van Der Laan et al. 2014.
20 Gregory 1959.

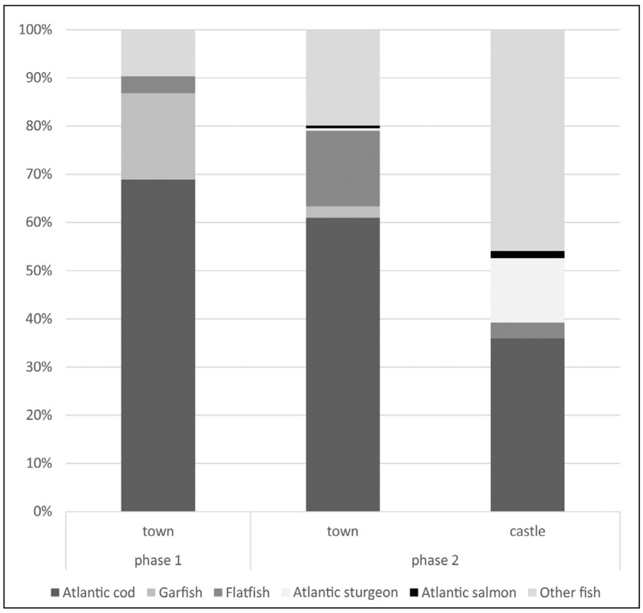

Fig. 2 Taxonomic composition of fish remains from Puck (© U. Iwaszczuk)

Size estimation

A series of measurements were taken to determine the size of the fish[21]. SL (standard length) was estimated based on a series of linear regression equations performed for the bones of the analysed species. In addition, for some bones for which measurements could not be taken due to their incomplete preservation, SL was estimated by comparing the analysed fragments to analogous bones from skeletons of known SL from a reference collection. Fish lengths (SL) were analysed in 5 cm intervals (cyprinid fish, flounder and perch) and 10 cm intervals (cod, garfish, pike, pikeperch, catfish and salmon).

Analysis

Archaeoichthyological materials were compared within phases. Materials from Puck and Gdańsk were discussed separately due to the specificity of both centres (small town vs large town) and their economic history, including the possibility of long-distance trade by merchants from Gdańsk, as this town was part of the Hanseatic Union. Due to the small sample sizes, statistical analyses were not carried out, and the focus was on descriptive research.

Results

Phase 1 (2nd quarter of the 14th–1st half of the 15th cent. AD)

Puck

The small sample size (only 298 fragments) is striking compared to the later material. Three-quarters of the remains could be identified at least to family level and, in most cases, to species level (tab. 1). The material dated to this phase came exclusively from the location town. Marine fish remains predominated, with the majority being cod bones (68.9 %) (fig. 2). There was also a relatively high proportion of garfish bones (18 %), although this may be partially due to the fact that a grouping of bones of this species, probably from only four individuals (minimum number of individuals [MNI] = 4), was found in one of the parcels in the market area. The share of bones of fish from the Pleuronectidae family was insignificant (3.4 %), with bones of only two species identified: turbot and flounder. Other species from the Cyprinidae and Percidae families were poorly represented, and pike remains were similarly scarce (9.6 %). Only cod bones were abundant enough to analyse anatomical composition (tab. 2). The juxtaposition of cranial elements, with the addition of bones from the pectoral girdle, such as the cleithrum, posttemporal or supracleithrum, with elements from the vertebral column and ribs showed a clear dominance of the former (97.5 %) (fig. 3). In the case of the remaining species, only fish from the Percidae and Cyprinidae families provided a few postcranial elements, mainly vertebrae (tab. 2). The measurements allowed the size of fish to be estimated, but due to the poor representation of other species in the phase 1 material,

21 Morales – Rosenlund 1979.

Table 1 Taxonomic identification of fish remains from Puck (the town and the castle)

	Phase 1		Phase 2					
	town		town		castle		TOTAL	
	n.	%	n.	%	n.	%	n.	%
Atlantic sturgeon (*Acipenser oxyrinchus*)			2	0.5	149	13.4	151	10.1
European eel (*Anguilla anguilla*)			1	0.3			1	0.1
Common carp (*Cyprinus carpio*)			1	0.3			1	0.1
Dace (*Leuciscus* sp.)					1	0.1	1	0.1
Freshwater bream (*Abramis brama*)	2	0.9	1	0.3	17	1.5	18	1.2
Roach (*Rutilus rutilus*)	2	0.9	3	0.8	1	0.1	4	0.3
Cyprinidae indeterminate	4	1.8	14	3.7	15	1.3	29	1.9
Wels catfish (*Silurus glanis*)					4	0.4	4	0.3
Northern pike (*Esox lucius*)	2	0.9	29	7.6	59	5.3	88	5.9
Atlantic salmon (*Salmo salar*)/Sea trout (*Salmo trutta*)			2	0.5	17	1.5	19	1.3
Atlantic cod (*Gadus morhua*)	157	68.9	233	61.0	402	36.0	635	42.4
Garfish (*Belone belone*)	41	18.0	9	2.4			9	0.6
European perch (*Perca fluviatilis*)	12	5.3	27	7.1	415	37.2	442	29.5
Turbot (*Scophthalmus maximus*)	1	0.4	1	0.3			1	0.1
Brill (*Scophthalmus rhombus*)			1	0.3			1	0.1
European flounder (*Platichthys flesus*)	6	2.6	41	10.7	2	0.2	43	2.9
European plaice (*Pleuronectes platessa*)			3	0.8			3	0.2
Pleuronectidae indeterminate	1	0.4	14	3.7	34	3.0	48	3.2
TOTAL determinate	228	76.5	382	65.7	1116	98.2	1498	
Pisces indeterminate	70	23.5	199	34.3	20	1.8	219	
TOTAL	**298**		**581**		**1136**		**1717**	

only the SL for cod can be discussed more extensively. The size range for fish of this species was between 30–40 and 80–90 cm, although most individuals did not exceed 70–80 cm; high extremes were rare (fig. 4). For the other species, few measurements were taken that could be converted to SL. Four uniform measurements in the 50–60 cm range were obtained for garfish. The only estimated length for the pike was in the 40–50 cm range. Also, very few measurements of cyprinid bones allowed SL estimation. In the case of roach, two measurements indicated individuals of 15–20 and 25–30 cm in length; in the case of bream, there were also two measurements of the bones of individuals of 35–40 and 45–50 cm in length. Fish bones, unlike mammal bones, rarely bear butchering and processing marks, and the material from Puck was also not exceptional in this respect – the number of bones bearing such marks was extremely low. However, it is interesting to note that marks associated with fish processing were recorded exclusively on a few cod bones; the bones of other species did not bear any marks, including traces of burning. What is important is the location of these marks, which may indicate the fish processing techniques[22]. In the case of cod, these were mainly located on the cranial elements: supraoccipital (fig. 5 c) and two each of ceratohyal and premaxilla. These bones bore cut marks, and cutting was also observed on the cleithrum (fig. 5 a).

Gdańsk

Fish remains from the following sites within the town dating to phase 1 were included in the study: Powroźnicza/Długi Targ, Mariacka/Św. Ducha (market/butchery place), Olejarna 2, Młyńska, Zielona Brama (tab. 3). In the case of Gdańsk, as with the previously discussed

22 Wheeler – Jones 1989, 65–69.

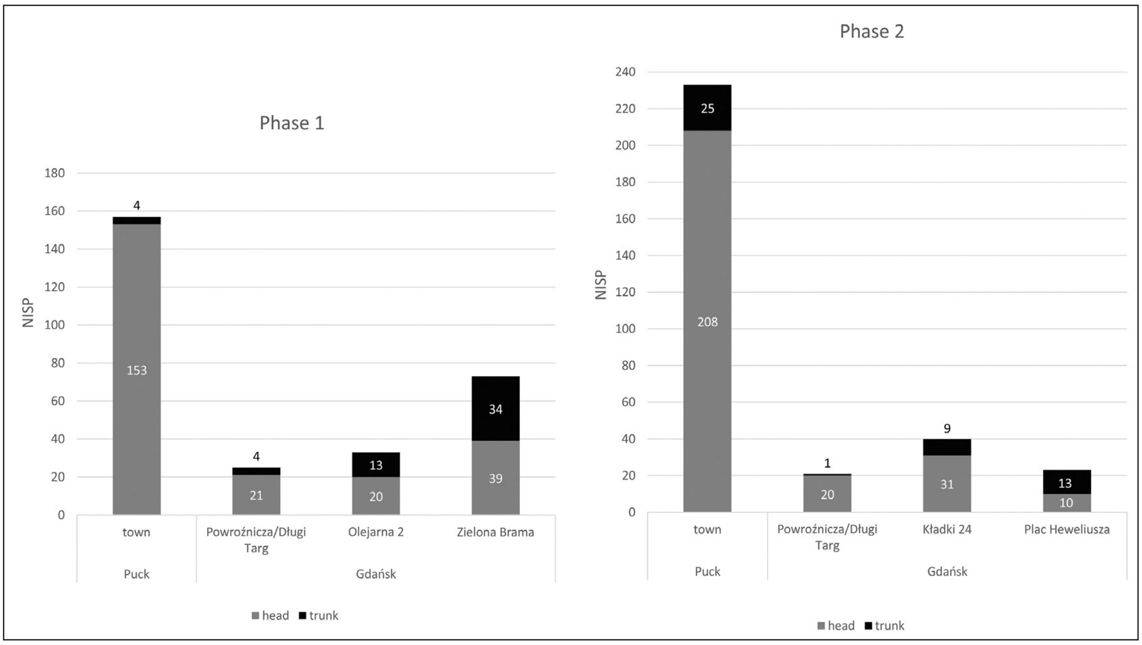

Fig. 3 Proportions of cranial and postcranial elements of cod in the materials from the towns of Puck and Gdańsk (© U. Iwaszczuk)

materials from Puck, a high proportion of cod remains was confirmed. However, the materials from the different sites within the town showed considerable variation with an overall low proportion of fish bones (the only exception being Zielona Brama, where relatively numerous fish bones were found). Amongst others, of the fish remains found within Olejarna 2, over 50 % were sturgeon bones, while cod bones only accounted for less than 17 %. However, this was the only site within Gdańsk with such a low proportion of cod bones. In this group of assemblages, other fish families were poorly represented, including an exceptionally low proportion of cyprinids. It is interesting to note the appearance of herring and other clupeoid bones in the material from Zielona Brama. It should be emphasised that fish bones from this family did not appear in the material from Puck discussed above. Perhaps of significance in this case was the fact that Zielona Brama was located in an undeveloped area at the time, close to the Motława River, and therefore the search for small bones did not entail such difficulties as in the case of frequently redeveloped urban parcels with elaborate architecture. The predominance of cod cranial over postcranial elements was also noticeable in Gdańsk, although the proportion of the postcranial skeleton was relatively high compared to both the Puck material from the same phase and the phase 2 material from both towns (fig. 3). Estimation of fish length was possible only for Powroźnicza/Długi Targ, for which a few measurements were acquired. The size of cod was very homogeneous in this phase. The fish were between 50–60 and 80–90 cm, although only one fish corresponds to the smallest estimated size (fig. 4). It was only possible to estimate the size of one pike (50–60 cm), one bream (40–45 cm), one pikeperch (70–80 cm), two catfish (both of size 90–100 cm) and one flounder (25–30 cm). Additionally, four scutes and three clavicles of large and very large sturgeon were found, but it was impossible to calculate the exact size of the individuals from which they originated. Therefore, the estimation was based solely on an assessment of the relative size and massiveness of the scute fragments and was not supported by an estimation of fish size based on a linear regression equation. Also, bones with marks associated with fish processing were not abundant in this material. A cod maxilla was found with the edge cut off on the anterior side, as well as two scutes from large sturgeon specimens, one of which had been chopped lengthwise and crosswise, while the other bore the mark of a slight cut from the underside of the scute near its edge.

Table 2 Skeletal elements distribution of fish from the town of Puck, phase 1

	Abramis brama	*Rutilus rutilus*	Cyprinidae indeterminate	*Esox lucius*	*Gadus morhua*	*Belone belone*	*Perca fluviatilis*	*Scophthalmus maximus*	*Platichthys flesus*	Pleuronectidae indeterminate
Neurocranium										
lacrimale					4					
vomer					1					
frontale					12	2				
basioccipitale					3					
parasphenoideum					8		1			
pterotic					2					
opisthoticum									1	
supraoccipitale					2					
Oromandibular region										
articulare					14	1				
dentale				1	25	18				
ectopterygoideum					1					
maxillare					5					
palatinum					1					
praemaxillare					9	9				
quadratum					1	1				
Hyoid region										
ceratohyale					17					
epihyale					4					
hyomandibulare					4					
hypohyale					2					
interoperculare							1		2	
operculare	2	1			15	7	2			
preoperculare			1		3	1	3			
suboperculare					3					
Branchial region										
pharyngeum inferior		1								
Pectoral girdle										
cleithrum				1	13	2	2	1		
posttemporale					2					
supracleithrale					1					
Pelvic girdle										
os anale									3	1
Vertebral column										
vertebra praecaudalis					1		2			
vertebra caudalis			1		1		1			
costa			2		2					
Other										
scale			x				x			
unidentified element					1					

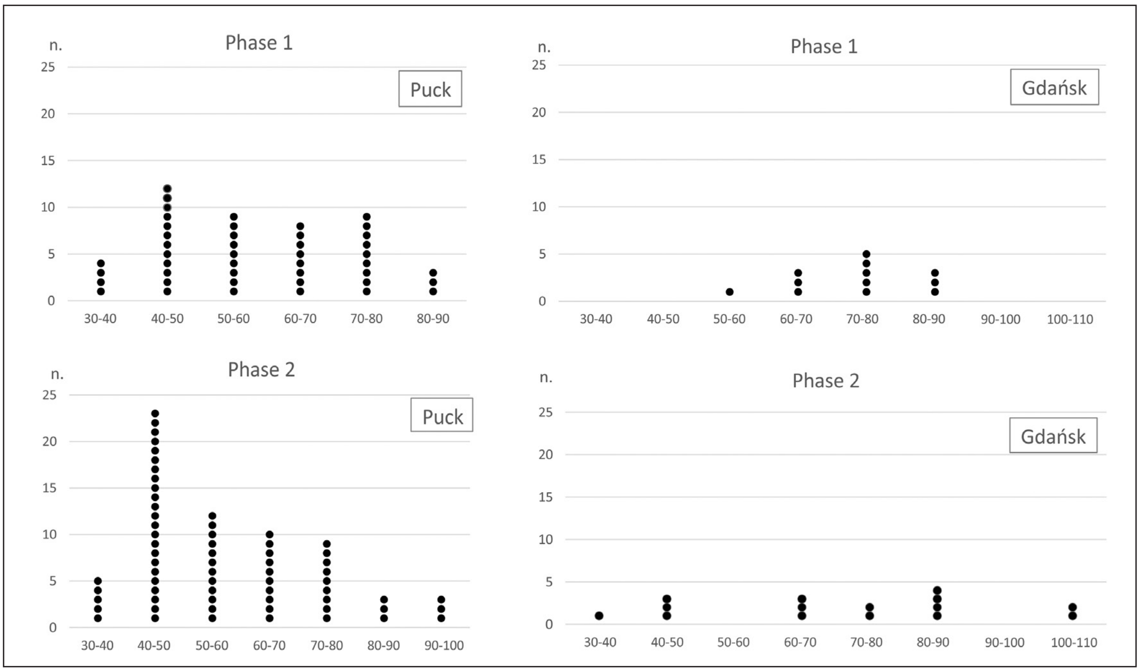

Fig. 4 The size (SL, in cm) of the fish from late medieval/early modern Puck and Gdańsk (© U. Iwaszczuk)

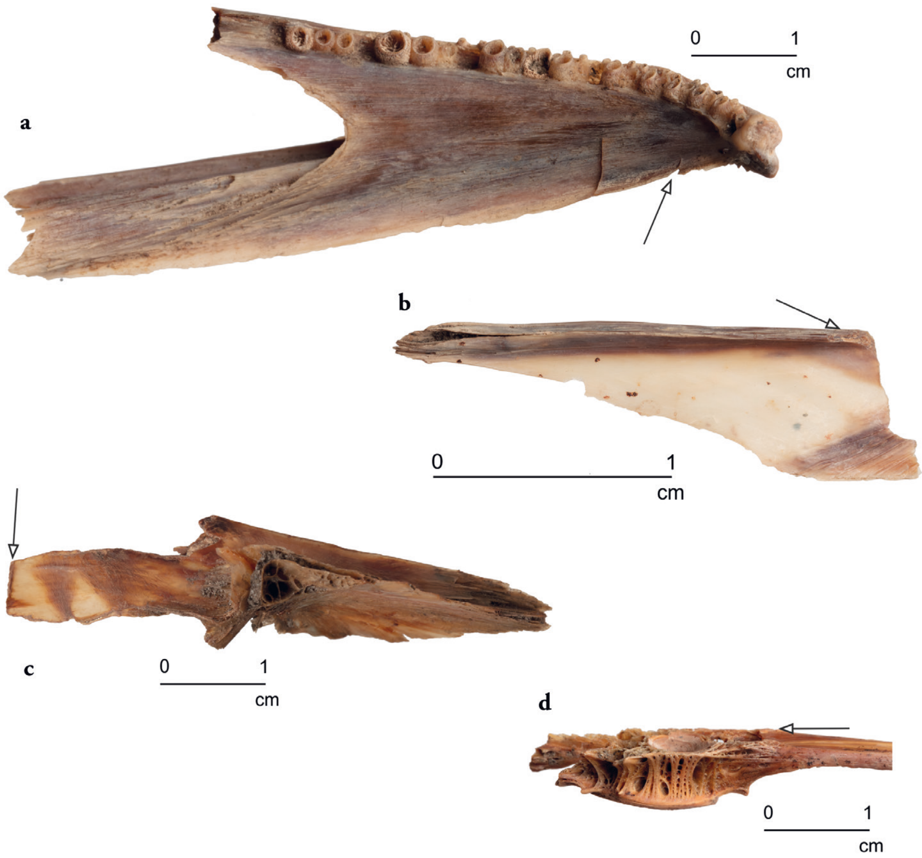

Fig. 5 Marks on a: Dentary; b: Cleithrum; c: Supraoccipital of cod; d: Vertebra of flounder (© M. Bogacki)

Phase 2 (2nd half of 15th–1st half of 16th cent. AD)

Puck

Much more abundant finds (1717 fragments) came from phase 2, including a smaller number of materials from the town (581 fragments) and materials amounting to almost twice that quantity from the castle (1136 fragments). The greater abundance of the phase 2 materials may be due to the mode of formation of urban stratification, including numerous building alterations and changes in land use over the centuries destroying previous constructions, as well as the peculiarities of urban fieldwork and the resulting difficulties concerning the exploration of small elements. As in phase 1, the urban material was characterised by the dominance of marine fish (tab. 1). Cod remains predominated (fig. 2), although there were slightly fewer than in phase 1 (61 %); in addition, there were generally fewer bones from garfish (2.4 %). By contrast, flatfish bones were abundant (15.7 %); it was possible to identify more species of these fish than in phase 1, including turbot, brill, European flounder and European plaice. Additionally, a few bones of anadromous fish, like sturgeon and salmon or trout, appeared in the material (1 % in total). Fish bones of other species (cyprinids, percids and pike) were proportionally more abundant than in phase 1 (phase 1 – 9.6 %, phase 2 – 19.9 %). The anatomical composition showed some difference in the proportions of cranial and postcranial elements of cod relative to phase 1. Although vertebrae and ribs were significantly more abundant here (10.7 % in phase 2 compared to 2.5 % in phase 1), the head elements still constituted the majority (89.5 %) (fig. 3). The presence of a few vertebrae was also recorded for other fish, although cranial elements predominated in this group of fish as well. Vertebrae were identified for cyprinids and flatfish, and one perch vertebra was also observed (tab. 4). SL estimated for cod had a slightly wider size range than in phase 1. The range was between 30–40 and 90–100 cm, but smaller fish in the 40–80 cm range predominated, with a high proportion of 40–50 cm-long fish (fig. 4). For the remaining fish, few data were obtained to estimate SL. The length of one garfish was in the 60–70 cm range. For flounder, the sizes of six individuals were estimated, including four with a length of 20–25 cm and two with a length of 25–30 cm. Also, for pike, the lengths of six individuals were estimated, one very small (20–30 cm), one only slightly larger (30–40 cm), three falling within the 40–50 cm range and one 50–60 cm. The only bream for which it was possible to estimate length was of medium size (40–50 cm). Two perch bones were from small fish of 15–20 and 20–25 cm in length. Marks of fish processing were noted on a small number of cod bones, including five dentaries bearing cut marks on the anterior side (fig. 5 b), one of which was incised in several places. A ceratohyal was also incised, and a further three bones were chopped (frontal, articular and maxilla). Unlike phase 1, these were not the only bones bearing marks of processing. Indeed, in the phase 2 assemblage, the first caudal vertebra of a flounder (fig. 5 d) was also found chopped across the vertebral column, indicating that the fish had been portioned.

The remains recovered from the castle area were different. Freshwater fish bones predominated (45.9 %), with perch in particular (37.2 %) (tab. 1). Cod remains were also relatively abundant, although the proportion of cod remains was just over half that for the town in phase 2 (36 % vs. 61 %). Also significant was the relatively high proportion of anadromous fish (14.9 %), among which a large group of sturgeon bones stood out (13.4 %). By contrast, there were very few flatfish remains (3.2 %), of which only flounder bones were identified to species level. The differences between the town and castle assemblages included not only the species composition but also the proportion of elements from the cranial and postcranial parts. However, although there were twice as many cod postcranial elements as in the town material (10.7 % in the town compared to 20.1 % in the castle), still the majority were head elements (79.9 %) (fig. 3). The small-scale material analysed by the authors of this article indicate mostly medium-sized fish. In the case of cod, all three estimated sizes were in the 40–50 cm range. The only bream was in the 30–35 cm length range, while the perch was in

Table 3 Taxonomic composition of fish remains from the towns of Puck and Gdańsk, phase 1

	Puck	Gdańsk					
	town	Powroźnicza/Długi Targ	Mariacka/Św. Ducha (market/ butchery place)	Olejarna 2	Młyńska	Zielona Brama	TOTAL
	2^{nd} quarter of the 14^{th}–1^{st} half of the 15^{th} cent.	2^{nd} quarter of the 14^{th}–1^{st} half of the 15^{th} cent.	2^{nd}–3^{rd} quarter of the 14^{th} cent.	AD 1250/1350–1500	AD 1250/1350–1500	14^{th}–15^{th} cent.	
	current research	Gręzak 2022	Makowiecki – Makowiecka 2018	Makowiecki 2000	Makowiecki 2000	Makowiecki et al. 2016	
Sturgeon (*Acipenser* sp.)		8	6	55	3	no data	72
Atlantic herring (*Clupea harengus*)						55	55
Shad (*Alosa* sp.)						3	3
Freshwater bream (*Abramis brama*)	2	2		4		no data	6
Roach (*Rutilus rutilus*)	2			1		no data	1
Cyprinidae indeterminate	4		1	16		no data	17
Wels catfish (*Silurus glanis*)		2	2	1		no data	5
Northern pike (*Esox lucius*)	2	2		4		no data	6
Atlantic cod (*Gadus morhua*)	157	25	49	18		73	165
Garfish (*Belone belone*)	41					no data	
European perch (*Perca fluviatilis*)	12					no data	
Pike-perch (*Sander lucioperca*)		2		7		no data	9
Turbot (*Scophthalmus maximus*)	1					no data	
European flounder (*Platichthys flesus*)	6	1				no data	1
Pleuronectidae indeterminate	1			1		27	28
TOTAL	**228**	**42**	**58**	**107**	**3**	**(677) NSP**	368

the 20–25 cm range. The pike was slightly larger (60–70 cm), while the length of the two salmon individuals was in the 120–130 cm range, so they should be considered large fish.

Gdańsk

Not all of the sites from the town area included in phase 1 continued into phase 2. Therefore, the study has also considered other assemblages from Gdańsk. Materials from Powroźnicza/Długi Targ, Plac Heweliusza, Kładki 24, Wyspa Spichrzów and Na Piaskach dating to phase 2 were analysed (tab. 5). These materials provided mainly the remains of large fish, such as cod, sturgeon, pike and pikeperch (tab. 5). Other families, including cyprinid fish, were very poorly represented. Most assemblages, except for that from Plac Heweliusza, were characterised by a predominance of cranial elements (fig. 3). For the assemblages published by D. Makowiecki et al., there is, unfortunately, no analysis of fish size. Thus, relatively few measurements were obtained, exclusively for one site within Gdańsk (Powroźnicza/Długi Targ). In contrast to Puck, there was a predominance of cod of large size in the 60–90 cm range, although the remains of individuals over 1 m in length were also found, as well as those of small fish of 30–50 cm, and the dimensions were arranged in three separate clusters (fig. 4). The remaining species provided very few dimensions. For pike, as many as three measurements were obtained. These lengths ranged between 40–50 cm (one individual) and 70–80 cm (two individuals), so these were larger specimens than those recorded in the town in Puck, although similar to those collected from Puck Castle. Pikeperch lengths (five estimations) were also between 40 and 70 cm. The length of the bream was 35–40 cm, so the fish was similar to those recorded in Puck. In the case of the sturgeon, the scute of the large individual was excavated, but this estimation, like other estimations of sturgeon size, is based solely on an assessment of the relative size and massiveness of the scute. Marks produced during fish processing were recorded on some cod and sturgeon bones excavated in the Powroźnicza/Długi Targ area. In the case of cod, marks were located in the mandibular region (six dentaries with cutting close to the symphysis), the otic region (one epiotic of a large individual chopped lengthwise and crosswise) and the pectoral girdle (four cleithra cut across, including one cut from the lateral side, and a supracleithrum cut across the articulation surface). On the other hand, no marks were recorded on vertebrae. The only bone element of a sturgeon that bore marks of cutting was the lateral scute of a large individual.

Discussion

Due to the coastal location of both towns, it seems natural that marine fish made up a sizeable majority of the post-consumption refuse. On the other hand, it is interesting to observe the diachronic changes, the differences between the towns, and in the case of Puck, also between the town and castle. However, the interpretation of these differences is not apparent. There are possible explanations due to environmental as well as economic factors. The former include, amongst others, the different preferred habitats of certain species as well as different fisheries being accessible to the fishermen from Puck and Gdańsk. The latter might have resulted from different levels of development of the two towns or the different statuses of the inhabitants of the town and the castle. We will discuss separately the environmental and economic factors that could have affected the accumulation of fish remains within different locations in Puck and Gdańsk.

Table 4 Skeletal elements distribution of fish from the town of Puck, phase 2

	Acipenser oxyrinchus	***Anguilla anguilla***	***Cyprinus carpio***	***Abramis brama***	***Rutilus rutilus***	**Cyprinidae indeterminate**	***Esox lucius***	***Salmo salar/ Salmo trutta***	***Gadus morhua***	***Belone belone***	***Perca fluviatilis***	***Scophthalmus maximus***	***Scophthalmus rhombus***	***Platichthys flesus***	***Pleuronectes platessa***	**Pleuronectidae indeterminate**
Neurocranium																
nasale									1							
vomer									1							
frontale							1		5		1					
parasphenoideum								2	6		1					
opisthoticum									1							
supraoccipitale									3							
neurocranium									4							
Oromandibular region																
angulare									1							
articulare							1		18							
dentale		1					11		43	4	1					
ectopterygoideum							3		1							
maxillare							1		24							
metapterygoideum									3							
palatinum							1									
praemaxillare									10	3						
quadratum							1		1							
Hyoid region																
ceratohyale							1		15		1					
epihyale									3							

hyomandibulare				1					2				1			
interoperculare									1		2					
operculare							1		6	2	7					1
preoperculare						3			16		9					1
suboperculare									3							
urohyale							1									
Branchial region																
branchial element						2	1									
pharyngeum inferior					3											
Pectoral girdle																
cleithrum							5		29		4	1				
coracoideum									1							
postcleithrale									1							
posttemporale							1		2							
supracleithrale			1						6							
Pelvic girdle																
basipterygium									1							
os anale														36	2	10
Vertebral column																
vertebra praecaudalis						1			11					2		
vertebra caudalis						2			3		1			3	1	2
processus									3							
costa						6			8							
Other																
scale/scute	1															
unidentified element	1															

Table 5 Taxonomic composition of fish remains from the towns of Puck and Gdańsk, phase 2

	Puck	**Gdańsk**					
	town 2nd half of the 15th –1st half of the 16th cent.	Powroźnicza/Długi Targ 2nd half of the 15th –1st half of the 16th cent.	Plac Heweliusza 15th–17th cent.	Kładki 24 15th–17th/18th cent.	Wyspa Spichrzów 2nd half of the 14th –18th/19th cent.	Na Piaskach AD 1250/1350–1700/1800	TOTAL
	current research	Grężak 2022	Makowiecki 1998a	Makowiecki 1998a	Makowiecki 1998a	Makowiecki 2000	
Sturgeon (*Acipenser* sp.)	2	4	2	26	40	17	89
European eel (*Anguilla anguilla*)	1						
Common carp (*Cyprinus carpio*)	1						
Asp (*Leuciscus aspius*)					3		3
Freshwater bream (*Abramis brama*)	1	1			13		14
Roach (*Rutilus rutilus*)	3						
Cyprinidae indeterminate	14		10	10	3		23
Wels catfish (*Silurus glanis*)			1	5	6	1	13
Northern pike (*Esox lucius*)	29	10	17	27	42		96
Atlantic salmon (*Salmo salar*)/Sea trout (*Salmo trutta*)	2						
Salmonidae indeterminate				1			1
Atlantic cod (*Gadus morhua*)	233	21	23	36	123	1	204
Garfish (*Belone belone*)	9		1				
European perch (*Perca fluviatilis*)	27						
Pike-perch (*Sander lucioperca*)		11		2	22		35
Percidae		1					1
Turbot (*Scophthalmus maximus*)	1						
Brill (*Scophthalmus rhombus*)	1						
European flounder (*Platichthys flesus*)	41	1					1
European plaice (*Pleuronectes platessa*)	3						
Pleuronectidae indeterminate	14			9	13		22
TOTAL	**382**	**49**	**54**	**116**	**265**	**19**	502

Environmental factors and the sources of supply in fish

The Great and Little Seas

The Baltic Sea is a large brackish water ecosystem in which the salinity varies between 2 and 30 ‰ (in the central part of the Baltic Sea it is 6–8 ‰)[23]. An influx of saline water from the North Sea is irregular. At the same time, freshwater continuously flows into the Baltic Sea through the estuaries of large rivers, which causes the fluctuation in the salinity level. The depth of the sea varies: in the area of interest there are both shallow waters and shoals, as is the case for Puck Bay, especially its inner part, as well as deep waters, including the Gdańsk Deep (118 m depth). Puck Bay constitutes the western part of Gdańsk Bay. It is a relatively small body of water with a maximum depth of 9.4 m, although the average depth is much lower – about 3 m. Recent research concerning the fluctuation of the water level in Puck Bay showed that the sea level about 2000 years ago was approx. 1.1–1.3 m lower than today, and it rose about 0.4 m between AD 1100 and AD 1400, with hydrodynamic activity also increasing noticeably at that time[24]. Given the environmental variability, which includes, in addition to those mentioned above, different seabed substrates and differences in the oxygenation of waters at different depths[25], it can be expected that the availability of marine resources would vary by fishing region. Therefore, let us look at the possible fish supply sources for the inhabitants of the analysed locations.

Cod, the predominant fish in the materials from Puck and Gdańsk, might be the most problematic fish in this respect. Currently, most cod in the Baltic Sea are caught at depths of 50–60 m, although demersal juveniles can also be found at depths of less than 5 m in coastal waters[26]. In light of this, it seems probable that the fish registered in Puck came from the marine fisheries and could not have been caught in Puck Bay. The fishermen from Puck had access to the Baltic Sea fisheries, the so-called Great Sea[27], so it is possible that the fish could have come from this area. The most favourable conditions for the spawning of fish are found in the region of the Gdańsk Deep[28]. However, considering the sizes of cod registered in Puck (a standard length of up to 1 m), it seems highly improbable that all the fish were local. The most common size in Puck (40–50 cm) could have come from the Great Sea fisheries, but the fish of the largest size were probably imported, as bigger fish over 50–60 cm are currently almost non-existent in the Baltic Sea[29], although some researchers believe that specimens from late medieval sites with a length (TL [total length]) of around 70–100 cm could conceivably represent either targeted catches of the largest cod from the Baltic or imports from the North Sea/North Atlantic, where cod grow to a greater size[30].

Gdańsk displayed a slightly different pattern. The size range of cod was slightly broader in comparison to the range observed in Puck: the biggest specimens exceeded 1 m and there was also an evident tendency towards bigger fish of sizes between 60 and 90 cm. This may indicate the more regular trade of imported fish in Gdańsk compared to Puck. However, the direction of such an import remains uncertain, as fish of this size are now rare in the North Sea, too[31]. Isotopic analyses by D. Makowiecki et al. indicate that at least some fish remains coming from individuals in the 50–100 cm size range obtained from the archaeological sites in the region under discussion came from Arctic Norway and the southern North Sea or the

23 Håkanson 1991.
24 Uścinowicz et al. 2011, 99.
25 Heessen et al. 2015, 29 f.
26 Heessen et al. 2015, 190.
27 Burski 1998, 69.
28 Makowiecki 1998a, 122.
29 Heessen et al. 2015, 190.
30 Makowiecki et al. 2016, 127.
31 Heessen et al. 2015, 190.

English Channel[32]. The other evidence of traded fish might come from the anatomical composition of the cod remains. In both phases in Puck, the analysed materials showed a very high proportion of cranial elements, counted together with bones from the pectoral girdle. In the case of phase 1, the proportion of head and pectoral girdle elements was 97.5 %; in phase 2 it was slightly less, 89.3 %. This pattern is very similar to the one registered in another late medieval site in Mała Nieszawka discussed by D. Makowiecki et al.[33]. It indicates that complete fresh or preserved fish were delivered to the site, while dried cod (stockfish) imported from northern fisheries were de-headed, and the dried carcass contained some vertebrae and often the cleithrum. This may indicate the sourcing of whole locally caught cod and imported stockfish.

The marks on the cod bones from Puck are also very consistent with those registered in Mała Nieszawka[34]. Most of them are situated on the caudal part of the head (epiotic, supraoccipital) or on the bones from the pectoral girdle (cleithrum, supracleithrum), except for one type of mark left on the anterior part of the dentary in proximity to the symphysis. D. Makowiecki and co-authors interpret the first type of mark as left during the decapitation of the fish[35]. They conclude that the pattern from Mała Nieszawska, similar to that registered in Uppsala, is of local origin within the Baltic Sea basin. The problem is that this type of mark was registered in Puck on the larger cleithrum, most probably from the individual over 50–60 cm in length, which may indicate that this individual also came from fishing in the Baltic Sea. Notably, marks on cleithra might also be interpreted as those left during the filleting of fish[36]. The other type of mark is equally interesting. According to A. Wheeler and A. K. G. Jones[37], the marks in the anterior part of the dentary are associated with removing the gills or taking out deeply embedded hooks. Considering the latter possibility, we might suggest that nets with hooks were used for catching cod. Hooks are known from the excavations in Puck[38], although the authors of the report associate them with the fishing of eel. Nowadays, cod can be caught mostly with equipment used in demersal fisheries[39], which means that it is not specific to fishing for this particular species. The remains of the equipment in Puck might have been the sinkers[40], although this kind of fishing accessory is a common element of almost all types of fishing nets.

The bycatch during demersal fishing can be plaice, which stays close to the bottom[41]. Plaice from the Baltic Sea prefers slightly deeper waters, to depths of more than 15 m[42], while turbot and brill, both adult and juveniles, migrate in the spring from their winter deep-water habitats to the shallow coastal waters[43] and can be caught in both these environments. Therefore, the presence of their remains is not conclusive for establishing the possible fisheries.

It seems to be confirmed that sturgeon (*Acipenser oxyrhinchus*), now extinct in the region[44], spawned in the southern tributaries of the Baltic Sea, including the Vistula but also smaller rivers[45]. The fish could have entered the rivers, travelling even about 1000 km along them. This behaviour was undoubtedly known to the inhabitants of Puck, as one of the historical sources mentioned that royal commissioners ordered works to clean the Reda riverbed so

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32 Makowiecki et al. 2016, 128.
33 Makowiecki et al. 2016, 127.
34 Makowiecki et al. 2016, 127.
35 Makowiecki et al. 2016, 127.
36 Wheeler – Jones 1989, 66–69.
37 Wheeler – Jones 1989, 66–69.
38 Kruppé – Milewska 2014, 95; Miścicki 2017, 206.
39 Heessen et al. 2015, 193.
40 Kruppé – Milewska 2014, 94.
41 Heessen et al. 2015, 470.
42 Heessen et al. 2015, 468.
43 Heessen et al. 2015, 436.
44 Nikulina – Schmölcke 2016.
45 Gessner et al. 2007.

salmon could migrate to spawn. According to the historical sources, sturgeon were caught at weirs in the vicinity of Puck[46].

Salmon, the other large marine fish species, live in the Baltic in relatively shallow waters at a depth of about 5–10 m[47]. Large salmon > 90 cm are scarce in the Baltic, and that size is not currently reported from the other regions where these fish were found, including the North Sea basin. Larger individuals of this migratory fish dominate the catches in waters > 50 m in depth. Baltic salmon stay in the Baltic, only migrate to spawn up rivers and return to the sea. After 1–3 years (max. 5–6), smolts move to the Baltic Sea and stay there for a period of 1–4 years[48]. Use of seines was reported for offshore salmon fishing[49]. This kind of net has been used since the 16th century AD on and, from that time, fees on the use of as many as 34 nets of this type are known in the district of Puck. The ethnographic sources indicate that this kind of large seine net, called a laskorn, was used in the coastal fishing of salmon in the region of the Hel Peninsula[50]. Fishing was also done at weirs[51], and fees were charged here as well, known from 17th-century AD historical sources[52]. Possible evidence of seine use can be seen in both sinkers and wooden floats found in Puck[53]. All this suggests that two individual specimens of large salmon found at the castle in Puck came from the local fisheries, located, however, not in Puck Bay but in the Great Sea. As the fishermen were obliged to work for castle officials, the fish were intended for the castle, as were other luxurious fish. Interestingly, remains of this fish were not found in assemblages from Gdańsk.

The case of the garfish is also very interesting. The fish migrate from the North Sea to spawn in the Baltic Sea in May–June and remain there until October[54]. They reside in shallow coastal waters (about 1–2 m deep). Currently, they are primarily caught in the waters of Puck Bay, where the fish are endangered due to pollution[55]. It seems that also in the 15th and 16th centuries AD, Puck (Puck Bay) was an essential producer of this fish, while in the catches of the fishermen from Gdańsk, it was almost absent.

Flounder is common in brackish waters, estuaries and up the river stream. Juveniles are an especially frequent addition to estuarine resources. It is characteristic for this species that catch rates drop rapidly the farther from the shore the catch takes place. However, in the case of the Baltic Sea, they can also be caught in deep waters, even up to 200 m, but in lower numbers. Fish of size < 25 cm, being the most common catch in the Baltic Sea, are still juvenile and stay in the shallow waters of the coastal area or the freshwater reservoirs; larger fish, up to a maximum of 60 cm, can be caught only in the deeper waters > 20 m[56]. In this regard, it seems significant that the sizes of flounder discovered in Puck and Gdańsk had similar patterns. In Puck, the fish did not exceed the standard length of 25–30 cm, and four out of six individuals were below that size; in Gdańsk, the size of the only flounder was established at 25–30 cm. It shows that the inshore fisheries were used in both cases. There was a small type of seine called a ceza used till the 19th century AD in Puck Bay, also mentioned in the 16th-century historical sources as associated with flounder fishing[57].

All freshwater fish registered in late medieval/early modern Puck and Gdańsk, namely cyprinids, pike, catfish, perch and pikeperch, tolerate a large spectrum of environmental con-

46 Odyniec 1961, 164.
47 Heessen et al. 2015, 162.
48 Heessen et al. 2015, 162 f.
49 Odyniec 1961, 165.
50 Znamierowska-Prüfferowa 1988, 59.
51 Cios 2007, 176.
52 Odyniec 1961, 90.
53 Starski 2017b, 167; Miścicki 2017, 206.
54 Heessen et al. 2015, 254.
55 Grabowska – Grabowski 2015, 168.
56 Heessen et al. 2015, 465 f.
57 Znamierowska-Prüfferowa 1988, 60; Odyniec 1961, 165.

ditions, including brackish water[58]. Interestingly, the remains of freshwater fish constituted a significant addition to the catches from phase 2, both in Puck and in Gdańsk. Fish from both discussed archaeological sites could probably have been caught inshore. This kind of coastal fishing is also known in other localities, such as, among others, Kołobrzeg[59]. It must have been relatively common, as even until 1960, pike fishing under the ice was reported[60]. We observed an interesting difference between Puck and Gdańsk. In the former, the Percidae family was represented only by perch with small fish of 15–20 and 20–25 cm, in the latter only by pikeperch in a size of 40–70 cm. These fish were caught for the local market, as specific species appeared only in one of these locations and were absent in the others. Apparently, the deeper waters of Gdańsk Bay were more conducive to the larger pikeperch, while the shallower Puck Bay provided a better ecosystem for perch. Perch choose relatively shallow reservoirs with dense vegetation[61]. On the other hand, pikeperch are more sensitive to oxygen deficits and therefore prefer deeper waters. Unlike perch, they also choose areas less covered with vegetation[62].

Diachronic changes

Our research indicates that during phase 2, garfish became a rarer guest in the waters of Puck Bay; by contrast, flounder became more accessible, resulting in weaker catches of the former and larger catches of the latter. Freshwater fish were also caught more frequently. The changes are less evident in phase 2 in Gdańsk, although increased interest in freshwater fish can be seen there. It should be noted here that flounder and freshwater fish have a wider tolerance of environmental conditions than garfish. We also observed a slight shift towards smaller individuals in the case of cod caught by Puck fishermen, which may have been due to a change in fisheries and a decrease in the size of Baltic cod resulting from increasingly unfavourable environmental conditions. In addition, changes were also related to the appearance of other flatfish species available in deeper waters and thus in Baltic fisheries, such as turbot and brill and larger adult flounder over 20 cm, which could represent the bycatch in cod fisheries. In our opinion, these changes may be related to gradual environmental changes occurring within Puck Bay itself at the time or to changes of a broader scope.

Slight changes occurring within Puck Bay were recorded by S. Uścinowicz et al.[63]. They found a slow rise in the water level in the bay from AD 1100 onwards, with results indicating that between AD 1100 and AD 1400, the water level rose by about 0.4 m (about 1.5 mm/year). Hydrodynamic activity also increased; the frequent occurrence of storms during AD 1300–1500 is also confirmed by historical sources[64]. These authors associate the anomalies with the Little Ice Age. According to them, the beginnings of the Little Ice Age are linked to the minimal solar activity that correlates with the changes observed by them in $\delta^{18}O$ values in AD 1200–1300. Their research shows that the main phase of the Little Ice Age was evident in AD 1650–1850[65]. According to the research of K. Kabel et al.[66], the Little Ice Age was a slightly shorter process, starting about 100 years later. K. Kabel and co-authors indicate the correlation between the temperature and the low total organic carbon content observed in samples of the mid-14th- to mid-19th-century AD sediments[67]. Is it possible that such slowly progressing changes could cause a visible effect on the archaeological materials covering the

58 Grabowska – Grabowski 2015.
59 Makowiecki 1998a, 124.
60 Znamierowska-Prüfferowa 1988, 62.
61 Grabowska – Grabowski 2015, 190.
62 Grabowska – Grabowski 2015, 193.
63 Uścinowicz et al. 2011; Uścinowicz et al. 2020.
64 Uścinowicz et al. 2011, 101.
65 Uścinowicz et al. 2011, 93.
66 Kabel et al. 2012.
67 Kabel et al. 2012, 872.

200-year history of Puck and Gdańsk, the beginning of which almost coincides with that of the Little Ice Age?

Interestingly, the environmental changes do not seem to have affected the sturgeon population to any great extent; it continued to be successful in phase 2, and the proportion of its remains did not show a decreasing trend in the Gdańsk material, while its remains, absent from the phase 1 material at Puck, were found in small numbers in layers dated to phase 2. Nor does the size of the sturgeon caught in Gdańsk appear to have changed, with remains from almost exclusively large and very large individuals in both phases. These results differ from D. Makowiecki's observations, who suggested that this fish was being overfished as early as between the 10th and 14th centuries AD[68].

Economic aspects of supply in fish

Despite the apparent focus on catching and consuming marine fish in late medieval and early modern Puck and Gdańsk, the materials from the locations within these towns differed. In our opinion, these differences were due to the status of the inhabitants of these localities and the availability of fisheries and opportunities to obtain fish.

In the case of Puck, the different nature of the materials from the castle and those from the town is apparent. Among other things, the disproportion between the consumption of cod by the inhabitants of both locations is evident. While in the town the remains of this fish constituted almost two-thirds of the bone material recovered, in the castle, it was only one-third. Therefore, it seems that the town inhabitants' consumption needs were primarily satisfied by cod, sourced mainly from local Baltic fisheries, and garfish caught in Puck Bay. On the other hand, the officials living in the castle, in addition to cod, consumed relatively large quantities of luxury fish such as sturgeon, salmon, catfish and possibly larger specimens of pike, all also sourced from Baltic fisheries or Puck Bay, as well as smaller freshwater fish also available today in Puck Bay.

It is likely that cod, along with herring, were the main fish consumed in the 14th–15th centuries AD during the numerous fast days of the year[69]. At this point, we must digress, as the almost complete absence of herring in the materials from Puck and Gdańsk is puzzling. We know of only one site from Gdańsk (Zielona Brama) where the presence of fish remains of the Clupeidae family was recorded. As mentioned above, this may be due to excavation techniques or the different location of Zielona Brama from the other sites within Gdańsk, which may have affected the state of preservation of the remains, although perhaps herring consumption, contrary to historical sources, may not have been so massive in both port towns over the period in question. The property inventories from AD 1565 named only four herring nets in the entire Starosty of Puck[70]. However, it is known from property inventories dating to the second decade of the 15th century AD that several herring barrels were stored in the rybicki's cellar at the castle in Puck[71]. On the other hand, the excavation material we examined from both sites is in line with the wording of the historical sources analysed by M. Dembińska[72], which indicate the mass consumption of cod, especially stockfish. The widespread availability of this fish is clear from the prices mentioned in 14th–15th-century AD sources, where the cost of buying cod and herring was similar[73]. What is interesting in this context is the consumption of unpreserved fish by the inhabitants of Puck, which is indicated by the presence of almost exclusively head remains in the material. The nearly complete

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68 Makowiecki 1998a, 122 f.; Makowiecki 2003, 49; Makowiecki 2008, 762.

69 Dembińska 1999, 98–103.

70 Cios 2007, 129.

71 Kruppé – Milewska 2014, 102.

72 Dembińska 1999.

73 Dembińska 1999, 99–103.

absence of cod postcranial elements in the Puck materials suggests that they represented the remains of meal preparation rather than the meals themselves. The latter remains must have been deposited elsewhere than the materials we examined.

Flounder was in demand mainly among the town's inhabitants, especially in phase 2; it was not consumed in higher quantities at the castle. The vertebra found indicates removal of the anterior part of the fish's carcass, i.e. primarily the head, which may relate to the method of preparing this fish. In the 1920s–1930s and the post-war era, dried flounder was a traditional food for fishermen. The flounder was beheaded and dried in the summer in the sun on special scaffolding or under the roofs of fishermen's houses[74].

The study showed a high level of interest in freshwater fish at the castle, with little consumption of these fish within the town. Interestingly, most of the remains in this group were perch bones, indicating a consumption preference of the castle residents, as these fish did not occur in a significant proportion in the town. Only a small proportion of other fish, including pike and fish from the Cyprinidae family, were observed. It is certain that the main fish consumed were wild-caught fish. Only one supracleithrum found in the urban material was of carp, and no bones of what were clearly farmed fish were found in the castle. It is possible that some of the other freshwater fish may have come from breeding and ended up in the castle along with other goods for the officials, although references to this in the sources are ambiguous[75]. Ponds were also dug near the mills and stocked with fish. It is known that some lakes belonging to the starosty were exploited, such as Góra, Wielkie Okuniewo, Małe Okuniewo and Wyspowo. However, we have no clear evidence of starosty officials benefiting from these waters, although based on the AD 1664 property inventories, W. Odyniec[76] assumed that freshwater fish mainly went to the starosty's table. Thus, in principle, the greater interest in freshwater fish at the castle than in the town may also have been due to how the peasants were taxed.

The appearance of luxurious fish in the material from the castle in Puck may result from the intensification of trade and broader cultural contacts with the central town of the region, i.e. Gdańsk, and the assimilation of the local lifestyle by the wealthy townsmen and castle officials. Gdańsk's participation in the Hanseatic Union and the resulting extensive contacts are not without significance, although it seems that the availability of these fish in Puck Bay and the Baltic fisheries was also important. Unfortunately, the earliest reliable record of the distribution of this type of fish dates from AD 1555[77] and is therefore relatively late. The document mentioned the distribution of the catches between the Burgher Council and the official residing in the castle. When the luxurious fish (Germ. »Herrenfisch«) were caught by the fishermen within the council's jurisdiction, they belonged to the council; when the castle's fishermen caught them, they belonged to the castle. The restrictions concerning certain luxurious fish species are also known from later sources. According to the later records (mid-17th and late 18th cent. AD), all sturgeon had to be given to the castle and the fish was paid at 1 grosz a foot, not counting the head and tail[78]. It seems that, at the very least, sturgeon, which was particularly sought-after, and salmon should be considered luxurious fish[79]. However, other 17th- to 18th-century AD Polish sources indicate that any large fish were to be given to the castle for an appropriate fee[80]. Thus, in the case of the castle, luxury fish included, in our opinion, catfish and pike larger in length than the fish from the town materials. The presence of these fish, especially the high share of sturgeon remains, distinguish the material

74 Kuklik 2022, 166–168.
75 Odyniec 1961, 24.
76 Odyniec 1961, 164.
77 Schultz 2011, 200.
78 Cios 2007, 110.
79 Odyniec 1961, 164.
80 Cios 2007, 105.

from the castle from that of the town, indicating the evidently higher social position of the castle's inhabitants.

We do not have clear confirmation of a fish trade on a grander scale in Puck. It seems it was mainly local fishing in Puck Bay (Little Sea) and exploitation of available fisheries in the Great Sea. The inhabitants of the town of Puck consumed almost no luxurious fish, in contrast to the inhabitants of Gdańsk. In fact, the proportion of large fish in the excavation material was mainly observed in Gdańsk. This was partly due to the sheer availability of larger species in the deeper waters of the Gulf of Gdańsk, among other things, which is confirmed by the presence of pikeperch bones in the material from Gdańsk, and the exploitation of the Baltic fisheries, probably on a larger scale than in the case of Puck. However, some fish in Gdańsk, such as cod, may have come from long-distance trade associated with Gdańsk's participation in the Hanseatic League. On the other hand, historical sources mention the obligatory distribution of the sturgeon catches east of Gdańsk in the 16^{th}–17^{th} century AD. The large fish were intended for Gdańsk, while smaller ones, below 5 feet (142 cm), could be sold in the local markets[81]. It is possible that this rule also applied in other localities that were economically linked to Gdańsk. We cannot confirm this directly; however, almost all the remains of the sturgeon discovered in Puck, both town and castle, came from small or medium-sized animals, while most of the bone fragments from Gdańsk Powroźnicza/Długi Targ belonged to large and very large individuals. Therefore, the small share of sturgeon remains in Puck, especially from the town, might have also resulted from transferring large fish caught in the Puck area to Gdańsk under the law. On the other hand, we have to take into consideration that different fish can penetrate large rivers, like the Vistula River, and the other much smaller streams, like the Reda or Płutnica rivers, and therefore, the difference in size might have been a result of environmental conditions and not deliberate legal interference in Baltic fisheries.

Conclusions

The research on archaeoichthyological material from excavations in Puck and Gdańsk revealed differences between these assemblages. It seems that an important role was played by the catch limit and obligations towards Gdańsk that resulted, among other things, in fish of smaller size being consumed by the inhabitants of Puck in comparison with those consumed in Gdańsk. Another factor that significantly impacted fish consumption in Puck was the different status of the town's inhabitants and those of the castle, with other fish intended for the officials residing in the castle compared to the town's inhabitants. The fish consumed in Puck mainly came from the local Baltic Sea and Puck Bay fisheries; only a small addition of large cod might have been imported, probably from the north. We were able to track the diachronic changes in the catches concerning replacing one species (garfish) with another (freshwater fish and flatfish). These changes could have been due to the changing environmental conditions associated with climate change, although the grounds for such reasoning are inconclusive. Gdańsk was in a better position, being a large town and the central one in the region. Thanks to that, it was able to acquire fish from various sources, including commercially. The Danzigers also had increased opportunities to source fish due to legal arrangements, giving them an advantage in the region. Gdańsk, a much bigger town included in the interregional exchange, offered a wider range of fish and fish products compared to the minor centre that was late medieval and early modern Puck.

81 Ropolewski 1963, 57.

Bibliography

Bogucka 1982 — M. Bogucka, Przemiany form życia w Gdańsku w dobie ery nowożytnej, Kwartalnik Historyczny 89, 4, 1982, 547–566.

Burski 1998 — K. Burski, Puck w czasach krzyżackich (1308–1466), in: A. Groth (ed.), Historia Pucka (Gdańsk 1998) 68–90.

Cios 2007 — S. Cios, Ryby w życiu Polaków od X do XIX wieku (Olsztyn 2007).

Dembińska 1999 — M. Dembińska, Food and drink in Medieval Poland. Rediscovering a Cuisine of the Past (Philadelphia, PA 1999).

Gessner et al. 2007 — J. Gessner – G. M. Arndt – A. N. Ludwig – F. Kirschbaum, Remediation of Atlantic sturgeon Acipenser oxyrinchus in the Baltic Sea. Background, Status, and Perspectives, American Fisheries Symposium 56, 2007, 301–317.

Grabowska – Grabowski 2015 — J. Grabowska – M. Grabowski, Ilustrowana encyklopedia ryb Polski. Atlas (Kluki 2015).

Gregory 1959 — W. K. Gregory, Fish skulls. A study of the evolution of natural mechanisms (Laurel, FL 1959).

Gręzak 1993 — A. Gręzak, Konsumpcja mięsa na zamku w Pucku w okresie od schyłku XV do końca XVIII wieku na podstawie szczątków zwierzęcych (MA thesis Uniwersytet Warszawski, Warsaw 1993).

Gręzak 2022 — A. Gręzak, Uwagi na temat diety mieszkańców działek przy Długim Targu i ul. Powroźniczej w późnym średniowieczu i czasach nowożytnych, in: K. Blusiewicz – M. Starski (eds.), Między Długim Targiem a Powroźniczą. Parcele mieszczańskie na Głównym Mieście w Gdańsku w świetle badań archeologicznych (Warsaw 2022).

Groth 1998 — A. Groth, Królewskie starostwo, in: A. Groth (ed.), Historia Pucka (Gdańsk 1998) 91–95.

Håkanson 1991 — L. Håkanson, Charakterystyka fizycznogeograficzna zlewiska Morza Bałtyckiego, Środowisko Morza Bałtyckiego 1 (Uppsala 1991).

Heessen et al. 2015 — H. J. L. Heessen – N. Daan – J. R. Ellis, Fish atlas of the Celtic Sea, North Sea, and Baltic Sea (Wageningen 2015).

Kabel et al. 2012 — K. Kabel – M. Moros – C. Porsche – T. Neumann – F. Adolphi – T. J. Andersen – M. Siegel – T. Leipe – E. Jansen – J. S. S. Damsté, Impact of climate change on the Baltic Sea ecosystem over the past 1,000 years, Nature Climate Change 2, 2012, 871–874.

Kardasz 2017 — C. Kardasz, Przestrzeń, społeczeństwo i gospodarka późnośredniowiecznego Pucka w świetle źródeł pisanych, in: Starski 2017c, 71–90.

Kruppé – Milewska 2014 — J. Kruppé – M. Milewska, Dzieje zamku w Pucku (Warsaw 2014).

Kuklik 2022 — M. Kuklik, Tradycyjne pożywienie rybaków z kaszubskiego wybrzeża, Zapiski Puckie 21, 2022, 165–177.

Makowiecka – Makowiecki 2018 — M. Makowiecka – D. Makowiecki, Zwierzęce szczątki kostne z jatek rzeźniczych w Gdańsku, in: A. Pudło – W. Ossowski – E. Trawicka (eds.), Jatki mięsne w Gdańsku od XIV do XX w. (Gdańsk 2018) 589–648.

Makowiecki 1998a — D. Makowiecki, Niektóre aspekty średniowiecznego rybołówstwa na Niżu Polskim, in: H. Kočka-Krenz – W. Łosiński (eds.), Kraje słowiańskie w wiekach średnich. Profanum i sacrum (Poznań 1998) 322–331.

Makowiecki 1998b — D. Makowiecki, About the history of fishing and its development in prehistoric and medieval times in Poland, Beiträge zum Oder-Projekt 5, 1998, 113–127.

Makowiecki 2000 — D. Makowiecki, Catalogue of Subfossil Fish Remains from Poland, Archaeofauna 9, 2000, 133–149.

Makowiecki 2001 — D. Makowiecki, Some remarks on medieval fishing in Poland, in: H. Buitenhuis – W. Prummel (eds.), Animals and Man in the Past. Essays in honour of Dr. A. T. Clason emeritus professor of archaeozoology Rijksuniversiteit Groningen, the Netherlands (Groningen 2001) 236–241.

Makowiecki 2003 — D. Makowiecki, Historia ryb i rybołówstwa w holocenie na Niżu Polskim w świetle badań archeoichtiologicznych (Warsaw 2003).

Makowiecki 2008 — D. Makowiecki, Exploitation of early medieval aquatic environments in Poland and other Baltic Sea countries. An archaeozoological consideration, L'acqua nei secoli altomedievali 2, 2008, 753–777.

Makowiecki et al. 2016 — D. Makowiecki – D. C. Orton – J. H. Barrett, Cod and Herring in Medieval Poland, in: J. H. Barrett – D. C. Orton (eds.), Cod and Herring. The archaeology and history of medieval sea fishing (Oxford 2016) 117–132.

Miścicki 2017 — M. Miścicki, Wyroby i produkcja przedmiotów metalowych w późnośredniowiecznym Pucku, in: Starski 2017c, 193–238.

Morales – Rosenlund 1979 — A. Morales – K. Rosenlund, Fish bone measurements. An attempt to standardize the measuring of fish bones from archaeological sites (Copenhagen 1979).

Odyniec 1961 — W. Odyniec, Starostwo Puckie 1546–1678 (Gdańsk 1961).

Pomian et al. 2016 — I. Pomian – B. Śliwiński – S. Uścinowicz – T. Ważny, The remains of the medieval harbour in Puck (northern Poland). A few words about the results of previous research, Archaeologia Baltica 23, 2016, 235–243.

Nikulina – Schmölcke 2016 — E. A. Nikulina – U. Schmölcke, Reconstruction of the historical distribution of sturgeons (Acipenseridae) in the eastern North Atlantic based on ancient DNA and bone morphology of archaeological remains. Implications for conservation and restoration programmes, Diversity and Distributions 22, 10, 2016, 1036–1044.

Ropelewski 1963 — A. Ropelewski, 1000 lat naszego rybołówstwa (Gdynia 1963).

Schultz 2011 — F. Schultz, Dzieje powiatu wejherowskiego i puckiego (Gdańsk 2011).

Starski 2017a — M. Starski, Kultura materialna miasta lokacyjnego w Pucku w późnym średniowieczu. Wnioski końcowe, in: Starski 2017c, 481–513.

Starski 2017b — M. Starski, Wyroby drewniane oraz wytwórczość bednarska i tokarska w późnośredniowiecznym Pucku, in: Starski 2017c, 125–176.

Starski 2017c — M. Starski (ed.), Puck. Kultura materialna małego miasta w późnym średniowieczu (Warsaw 2017).

Uścinowicz et al. 2011 — S. Uścinowicz – G. Miotk-Szpiganowicz – M. Gałka – J. Pawlyta – N. Piotrkowska – I. Pomian – M. Witak, The rise, development and destruction of the medieval port of Puck in the light of research into palaeoclimate and sea level change, APol 49, 2011, 87–104.

Uścinowicz et al. 2020 — S. Uścinowicz – M. Witak – G. Miotk-Szpiganowicz – D. Burska – W. Cieślikiewicz – W. Jegliński – L. Jurys – P. Sydor – J. Pawlyta – N. Piotrowska, Climate and sea level variability on a centennial time scale over the last 1500 years as inferred from the Coastal Peatland of Puck Lagoon (southern Baltic Sea), The Holocene 30, 12, 2020, 1801–1816.

Van Der Laan et al. 2014 — R. Van Der Laan – W. N. Eschmeyer – R. Fricke, Family-Group Names of Recent Fishes, Zootaxa 3882, 2, 2014, 1–230.

Wheeler – Jones 1989 — A. Wheeler – A. K. G. Jones, Fishes (Cambridge 1989).

Znamierowska-Prüfferowa 1988 — M. Znamierowska-Prüfferowa, Tradycyjne rybołówstwo ludowe w Polsce na tle zbiorów i badań terenowych Muzeum Etnograficznego w Toruniu (Toruń 1988).

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Fishes, Amphibians and Molluscs Excavated Under Water from the Mooswinkel Neolithic Pile-Dwelling Site in Lake Mondsee, Austria

Dafni Nikolaidou – Alfred Galik

Abstract

Mooswinkel is a Neolithic underwater pile-dwelling site located in the Mondsee lake in Upper Austria and dates to the 4th millennium BC. Recent excavations were carried out in an interdisciplinary research initiative called »Zeitensprung« (Leap in Time). At least three in situ cultural layers separated by erosional horizons were recovered presenting outstandingly preserved material from waterlogged sediments. Therefore, the Mooswinkel site offers valuable ichthyoarchaeological material and data for a better understanding of fish exploitation in the 4th millennium BC. The fish remains, which were carefully selected from floated and wet-sieved sediment samples, are important sources of information on fishing and the fish consumption of the Neolithic settlers in Austria. Certainly, the fish species reflect a repertoire of fishing techniques such as near-shore fishing and net fishing in more open waters. In addition to the typical freshwater fishes (cyprinids, northern pike, river perch, brook trout and coregonids) large quantities of mainly frog bones and mollusc shells were collected. More than fish, these remains raise the question of whether frogs and molluscs accumulated naturally or reflect part of the inhabitants' diet.

Introduction and materials

Exploration of pile-dwellings has a long tradition in Austria and its discoveries started in the mid-18th century, when researchers localised the first pile-dwellings at very low water levels. In the 19th century, archaeological material was recovered and collected. More recently, research on underwater pile-dwellings[1] with a focus on fish remains was poorly conducted in Austria. Therefore, sufficient data on fish consumption and fishing remained unavailable. Occasionally, mainly hand-picked Neolithic fish remains drew scientific interest[2], while fish remains from sieved, floated and screened sediment samples were rare[3].

However, new projects on prehistoric pile-dwellings in Austria conducted scientific underwater excavations. The project »Zeitensprung«[4] is part of a large research initiative (UNESCO World Heritage Prehistoric Pile Dwellings around the Alps), and one of its aims is to excavate, explore and protect archaeological domestic structures underwater. Gathered data will provide new knowledge, enabling interpretation of wider prehistoric developmental and environmental settlement aspects in the Neolithic[5]. The current project is being conducted in cooperation with J. Leskovar from the Upper Austrian State Museum. The underwater excavations were organised and carried out by the »Kuratorium Pfahlbauten«[6]. The team of the Kuratorium Pfahlbauten discovered the Mooswinkel pile-dwelling in 2017, an area that was unknown

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1 Offenberger 1981; Ruttkay et al. 2004.
2 Pucher – Engl 1997, 75; Schmitzberger 1999, 34; Schmitzberger 2005, 84.
3 Galik 2008, 310.
4 <https://www.pfahlbauten.at/zeitensprung> (24.03.2023).
5 Galik – Nikolaidou 2021.
6 <https://www.pfahlbauten.at> (24.03.2023).

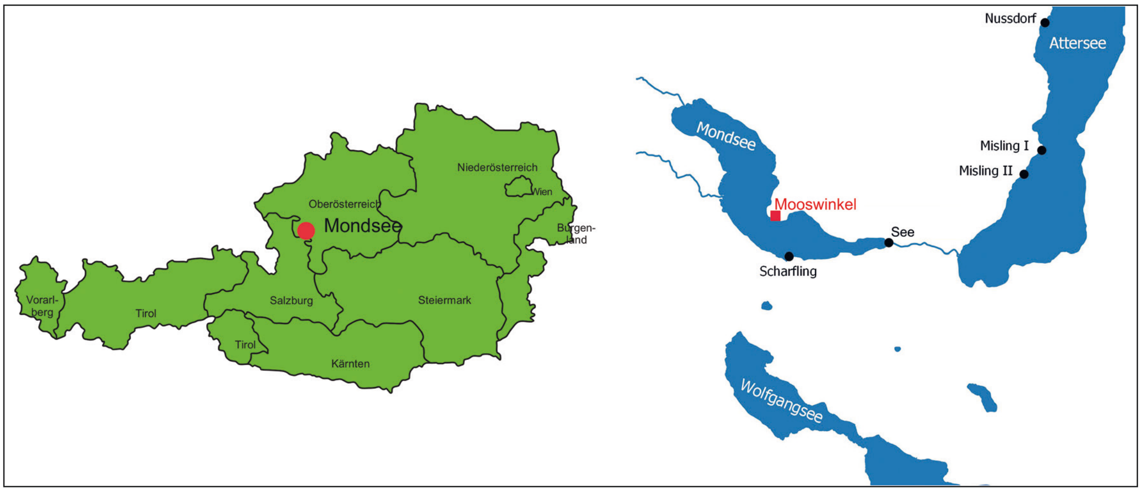

Fig. 1 Geographical position of the Mooswinkel pile-dwelling site on Lake Mondsee (© OeAW-OeAI/A. Galik and Kuratorium Pfahlbauten)

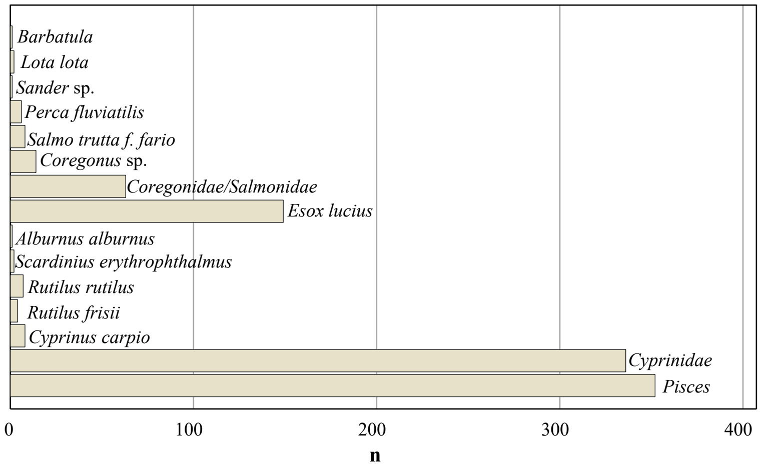

Fig. 2 Distribution of fish species from Mooswinkel (© OeAW-OeAI/A. Galik)

and therefore had remained intact. The organic material that is the focus of this study came from the underwater excavation campaign at Mooswinkel in 2018. A trench of 3 m² provided cultural depositions of more than a metre in depth containing at least three sequences. The radiometric dating points to a time frame of ca. 3770–3400 calBC[7]. The excavations brought diverse organic finds to light, both botanical and animal remains. Besides the fish remains, a preliminary rough inspection of the carefully salvaged finds indicated a high frequency of frog bones and mollusc shells. Therefore, we focused our scientific interest on fish, amphibian and mollusc remains, preserved in a high quality in the form of fish scales, bones and shells. So, seizing the opportunity, here we present additional and new data on prehistoric fish and amphibian exploitation from the Mooswinkel Neolithic pile-dwelling in Austria (fig. 1).

Besides important plant-based food, the prehistoric inhabitants exploited animal protein from domestic animals, and hunting certainly played a role in their diet, too. This specific site also yielded animal dung that allowed interesting conclusions on prehistoric keeping and foddering strategies for ruminant species[8].

If someone lives on a body of water, then, as long as they have the technical possibilities and skills, they will use these environments as much as possible for nourishment. The »Zeitensprung« project opens up the opportunity to investigate such questions. On the one

7 <https://www.pfahlbauten.at/zeitensprung> (24.03.2023).

8 Jakobitsch et al. 2023.

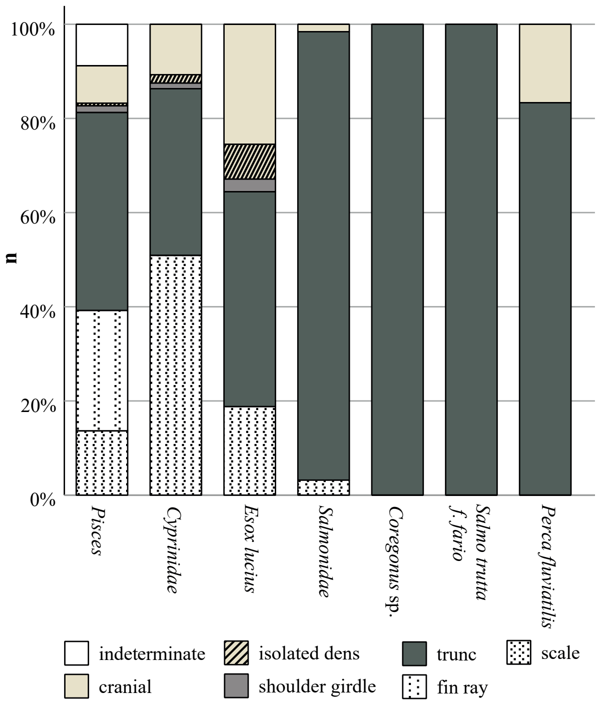

Fig. 3 Distribution of fish species and body parts (© OeAW-OeAI/A. Galik)

hand, we gain knowledge about the prehistoric fish stocks of Lake Mondsee, and on the other hand, we are able to reconstruct how people fished and what kind of fish played a role in the diet of these people.

The carefully selected materials, shells, bones and scales were stored in small, stable containers. The mainly very well-preserved but partly charred material was then analysed at the Austrian Archaeological Institute using our extensive reference collections. Due to the small size of most of the material, a microscope, namely an Olympus SZX10, was used for the identification and taking measurements of the remains.

Results

The identification of fish remains revealed various species, but the majority of the fish remains, such as frequent scale fragments, fin rays and other not identifiable fish bone fragments, remained indeterminable (fig. 2). The presence of coregonids makes a differentiation of fish scale fragments into cyprinids and coregonids complicated. However, fish scales indicate certain cyprinids, northern pike (*Esox lucius*) and coregonids. Quite a few rather small but very ›cycloidic‹ scales may represent brook trout (*Salmo trutta f. fario*), while river perch (*Perca fluviatilis*) is so far not represented by scales.

Cyprinids are most abundant, followed by pike with a frequency of around half the cyprinid abundancy. Some species among the cyprinids are identifiable, such as wild carp (*Cyprinus carpio*), common roach (*Rutilus rutilus*), the so-called Perlfisch (*Rutilus meidingeri*), common rudd (Scardinius erythrophthalmus) and bleak (Alburnus alburnus), followed by brook trout and coregonids. In many cases these remains, which are mainly vertebrae, are not clearly identifiable. A few remains testify to occasional catches of burbot (*Lota lota*), loaches (*Barbatula barbatula* cf.), river perch and pikeperch (*Sander lucioperca*; fig. 2).

Generally, uniserial elements such as vertebrae outweigh bilateral cranial fish remains (fig. 3). However, in this case, it has to be stated that only a few isolated pharyngeal teeth of cyprinids and isolated teeth of northern pike were detected (tab. 1). Two other isolated small teeth, which are of very circular shape at the base and slightly curved towards the tip, might represent European catfish (*Silurus glanis*); if so, they are the only evidence of these fish here. Clearly more vertebrae are available than cranial elements in cyprinids, while in northern pike a higher frequency of cranial elements is visible. River perch shows only one cranial element and five uniserial elements (fig. 3) and pikeperch is proven by the presence of a cleithrum. Some species, such as burbot, brook trout and coregonids, are predominantly or solely proven by the presence of vertebrae. In combination with the severe fragmentation of the vertebrae, an identification between the latter two is complicated and often impossible. The good criteria for identification, besides the shape of the corpus vertebrae, the position and orientation of the prae- and postzygapophyses as well as the position of the neural- and haemal arches, are very often missing. The indeterminate vertebrae are grouped as *Salmonidae*/

Table 1 Fish remains from Mooswinkel

	Pisces	Cyprinidae	Alburnus alburnus	Coregonus sp.	Cyprinus carpio	Rutilus frisii	Rutilus rutilus	Scardinius erythrophthalmus	Cobitidae	Esox lucius	Salmonidae	Salmo trutta f. fario	Lota lota	Perca fluviatilis	Sander sp.	Total
Indeterminate	214															214
cran. frgm.	4	1														5
Vomer		1														1
Parasphenoid		1								5						6
Basioccipitale	2	3					1			1	1					8
Pteroticum		1														1
Frontale	1									1						2
Praemaxilla	1															1
Maxilla		1								1				1		3
Entopterygoid										1						1
Dens	2	7				1				12						22
Dentale	1								1	11						13
Articulare		2								2						4
Praeoperculum		3								2						5
Operculum	9	1					1									11
Suboperculum		1														1
Palatinum										7						7
Quadratum					2					5						7
Hyomandibulare		2			1					2						5
Ceratohyale	1									2						3
Branchial Bogen	8									1						9

Urohyale	1															1
Os pharyng. inf.	2	33	1		2	3	5	2								48
Posttemporale		1														1
Scapula	1	2														3
Cleithrum	2	2								3					1	8
Radiale	2															2
Basipterygium										1						1
Pleurale Costa	36	15														50
Basapophyse	3															3
V.thor.	3	58		9						52	22	2		1		147
Tripus		2														2
V.praecaud.		3								1			1	2		7
V.caud.	8	33		3						11	18	6	1	2		82
V.penulitmat.	1			2							1					4
V.ultimat.		1									1					2
Vertebra	93									4	18					115
Vert.proc.	2	7														9
Flossenstrahl	110															110
3. fin ray					2											2
Pect. fin ray	2															2
Pterygiophore	28															28
Scale	1054	250			1					102	3					1410
Total	**1591**	**431**	**1**	**14**	**8**	**4**	**7**	**2**	**1**	**227**	**64**	**8**	**2**	**6**	**1**	**2367**

Fig. 4 Distribution of cyprinid vertebral measurements (© OeAW-OeAI/A. Galik)

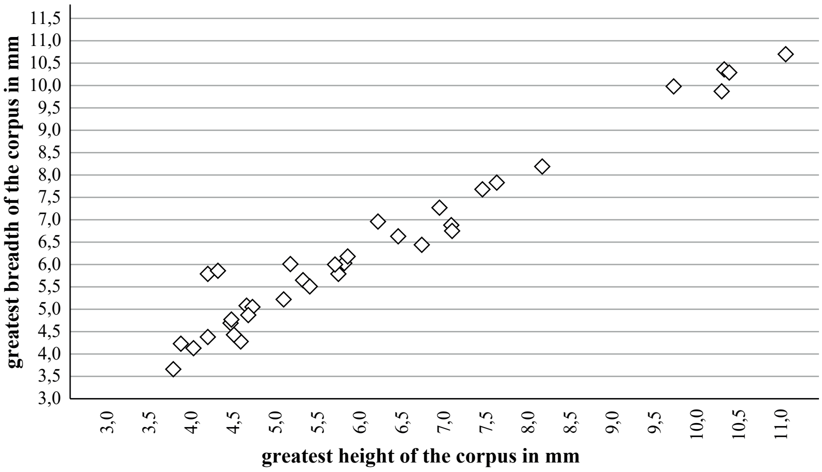

Fig. 5 Distribution of northern pike vertebral measurements (© OeAW-OeAI/A. Galik)

Coregonidae, but nevertheless the coregonids are certainly available in a higher frequency than brook trout (figs. 2. 3).

Traces of charring are visible on 3.5 % of the fish remains. Bones of all fish species and all anatomical elements from the skull through the vertebrae to fin rays are affected. About 80 % of the burnt material is calcinated by high fire temperatures.

Bivariate graphs in millimetre scales try to reconstruct the size distribution of caught fish[9] from their vertebral dimensions using the greatest height and breadth of anterior corpora. These measurements were chosen to minimise potential biases caused by size differences of vertebrae along the spine[10]. The size of cyprinid vertebrae forms a peak from less than 1 mm up to 2 mm indicating the exploitation of young and rather small fish. Larger vertebrae between 2.5 and 5.5 mm represent larger cyprinids up to 20 and 30 cm in length, and one specimen with a diameter of about 9 mm suggests a large cyprinid, but not a common carp; possibly it represents a large »Perlfisch« (fig. 4). Most of the northern pike vertebrae fall between 3 and 5 mm, indicating fish of a size up to 40 cm, followed by a group of fish up to 50 cm with vertebrae between 5 and 7 mm. Larger fish up to 60 cm in length with vertebral dimensions between 7 and 8 mm and northern pike with vertebral heights and breadths from 9–11 mm indicate even larger individuals, up to approx. 75 cm (fig. 5). However, such large fish appear infrequently compared to the smaller individuals.

9 Wheeler – Jones 1989; Brinkhuizen 1989; Radu 2003.

10 Desse et al. 1989; Jelu et al. 2021.

Table 2 Amphibian remains from Mooswinkel

	Anura	Bufo bufo	Bufo sp.	Rana sp.	Total
Cran. frgm.	15				15
Exoccipital			1	12	13
Frontoparietal				5	5
Maxilla				5	5
Parasphenoid			1	25	26
Prooticum				2	2
Pterygoid				20	20
Sphenethmoid				13	13
Squamosum				4	4
Goniale				58	58
Clavicula			1		1
Coracoid		1		139	140
Scapula				69	69
Humerus	3	3	6	291	303
Radioulnare	3		4	218	225
Metacarpus				13	13
Atlas				19	19
V.thor.				62	62
V.abdomin.				134	134
Sacrum				38	38
Urostyle	3			202	205
Vertebra				56	56
Episternum				3	3
Mesosternum				11	11
Ilium	6			476	482
Pubis				8	8
Femur				614	614
Tibiofibulare	4			622	626
Tarsalia	2			263	265
Metatarsus				37	37
Metapodium	9			246	255
Phalanx	1			1	2
P.prox.				1	1
P.dist				1	1
long bone	630			1	1
Indeterminate	3			10	13
Total	**46**	**4**	**13**	**3668**	**3731**

The amphibian remains consist almost exclusively of frog (*Rana* sp.*)* bones, besides a few toad bones (tab. 2). The bones reflect relatively few skull and trunk remains, such as vertebrae. Bones from the anterior extremity are better represented, while remains from the posterior extremity, on the other hand, appear in a way overrepresented (fig. 6). Some pathologies were observable, mainly on shafts of long bones. The pathologies concern traumatic events, such as bone fractures, which finally healed up. However, if one looks at the long bones of fore- and hind limbs, a conspicuously high fragmentation of the bone shafts becomes visible. They show almost exclusively old and spiral-type fracture edges and indicate a contemporaneous fragmentation of fresh bones prior to deposition. Many of the bones are of dark to black colour and have a very shiny surface, but are not charred. About 5 % of the frog bones are charred, and the majority of the burnt material is calcinated, indicating exposure to high fire temperatures. Amongst the thousands of frog remains, only one abdominal vertebra exhibits two cut marks, located between the corpus vertebrae and the processus transversus (fig. 7).

Many molluscs, gastropods and bivalves appeared in the sieve residues (fig. 8; tab. 3). Some of the shells can clearly be separated into recent intrusions, covering all varieties of the small gastropods and bivalves. A very high level of identified species was achieved, indicating a high proportion of completely preserved shells. The most frequent species can be found in all age classes from juvenile to adult. Some of the gastropods still have their operculum in position. The distribution of the recent molluscs is dominated by a few species such as European stream valvata (*Valvata piscinalis*) and mud bithynia (*Bithynia tentaculata*), followed by radix snails (*Radix ovata* and *R. auricularia*), planorbis (*Planorbis carinatus*) and a few remains of the fresh water limpet *(Ancylus fluviatilis*). Extant bivalves are represented by valves of *Pisidium* and an umbo fragment of an introduced alien species, the zebra mussel (*Dreissena polymorpha*). Some of the unio shells might come from

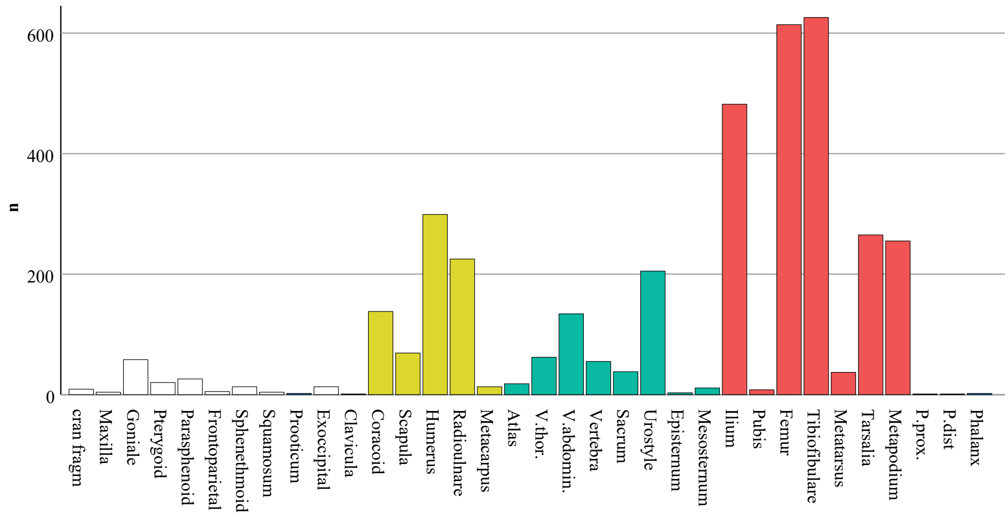

Fig. 6 Quantification of the element distribution of frog bones (© OeAW-OeAI/A. Galik)

Fig. 7 Two cut marks dorsal at the caudal basis on the Processus transversus on an abdominal frog vertebra (© OeAW-OeAI/A. Galik)

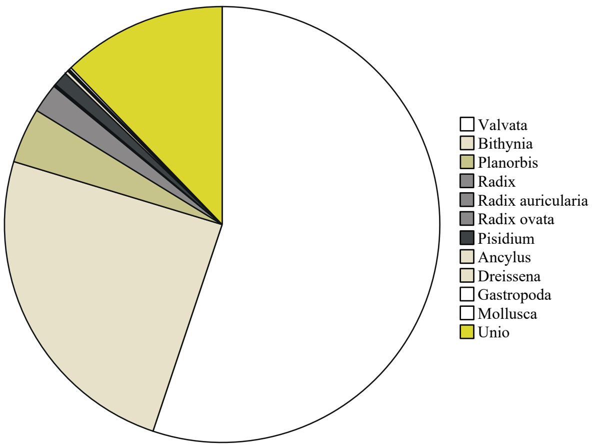

Fig. 8 Quantification of fresh water molluscs (© OeAW-OeAI/A. Galik)

bivalves introduced in modern times. In contrast to the modern molluscs, all unio shells are fragmented, which may be due to exposure of the larger size of valves. Nevertheless, three valve fragments are charred and certainly indicate exploitation of unio shells in the settlement.

Discussion

Underwater excavations are always subject to the risk of recently deceased organisms intermingling with and not being part of the archaeological assemblages. An assumption made at

Table 3 Molluscs from Mooswinkel quantified by total finds (n) and NISP (number of identified specimens – not refitted)

	Mollusca	Gastropoda	Ancylus fluviatilis	Planorbis carinata	Radix sp.	Radix auri-cularia	Radix ovata	Valvata piscinalis	Bithynia tentaculata	Dreissena polymorpha	Pisidium sp	Unio sp.	Total
n	2	1	3	49	26	1	1	659	293	1	13	778	1827
NISP	2	1	3	49	26	1	1	659	293	1	13	146	1195

the beginning of the study that contemporaneous archaeological mollusc fauna was recognisable and could perhaps allow ecological reconstructions to be effected, proved not to be true in the end. However, as is clearly evident from the age distribution, typical transparent preservation of shells and occasional specimens with the operculum still *in situ*, the majority of the molluscs are recent intrusions. The completeness of the small-sized shells also speaks for recent intrusions that were first protected by the muddy sea bottom and then carefully picked out by the archaeologist's hands.

On the one hand, in the case of frogs one might argue that species selection can come about naturally and accumulate during the spawning seasons of amphibians when they gather at the lake. On the other hand, this would be a promising opportunity to collect food in high frequencies. Charred remains can be used as an argument to demonstrate that at least bivalves, frogs and fishes represent archaeological material, which was burnt outside the body of water and reflects Neolithic human exploitation. Cut marks were found on a single abdominal frog vertebra (fig. 7) that was probably attached when the hind limb was removed, while cut marks are totally absent on fish remains. The overrepresentation of hind legs, as meat bearing parts, and the conspicuous high fragmentation of long bones may also relate to human exploitation of frogs.

Skeletal fish elements are *grosso modo* completely available and their distribution speaks for exploitation of complete fish, though some fish are missing their cranial elements. The possibility of natural intrusions of fish that died in the excavated area seems to be relatively low, while the preservation of recent fish remains usually differs clearly from the studied Neolithic material.

Cyprinids and northern pike were the most important Neolithic fishes, most probably followed by coregonids. Fishes proven in lower quantities are trout and river perch, followed by burbot and pike perch. Amongst the cyprinids, typical species such as common roach, common rudd and bleak appeared. Lake Mondsee is a protected area of European rank since 1992 and the so-called Perlfisch is as an endangered species of special interest[11] that can now be archaeologically proven, too. The other important finding is the evidence for the presence of wild carp. However, the catchment area of the Danube is not so far away, and wild carp can now be archaeologically and autochthonously proven for the Neolithic Mondsee[12]. Evidence of exploitation of a small-sized fish species may have succeeded with a loach bone.

Comparison of size distribution is only of quantitative relevance for cyprinids and northern pike. For the cyprinids, exploitation of predominantly young and rather small fish is indicated, starting with yearlings of less than 10 cm up to older fish of larger sizes such as 20 and 30 cm in total length. Northern pike catches accumulate in sizes from 40 up to 50 cm[13], while larger specimens up to 75 cm are rarely found, similar to the size distribution of cyprinids.

The majority of fish were probably caught quite early and young. Large fish are present, but they seem to represent occasional and exceptional catches. For such large fish, fishing

11 Siligato – Gumpinger 2005; Mayr – Wanzenböck 2006.
12 Spindler 1997, 15. 58; Galik et al. in this volume.
13 Jelu et al. 2021.

methods such as fish traps, solid nets, fish spears or line fishing might be discussed[14]. The most productive fishing periods usually fall in the spawning seasons, when the fish swim close to the shore in large numbers and are easier to catch.

Coregonids are ›typical‹ fish of pre-alpine lakes, such as the Mondsee and the nearby Attersee in Austria. The endemic coregonid is *C. atterensis*[15]. Coregonids were obviously part of the Neolithic human fishing activities in diverse water bodies[16]. They usually swim in groups and mainly stay in open and deeper water areas[17]. Since these fish mostly feed on zooplankton, they are difficult to hook. At the Swiss site Arbon-Bleiche, most coregonids were caught during the spawning season[18], while at the Wallhausen-Ziegelhütte site on Lake Konstanz, the fish might be caught year-round[19]. However, the coregonids from Mooswinkel speak for fishing with nets from boats in open bodies of water[20]. Nevertheless, we argue that smaller fish occurred in higher frequencies and therefore were better suited to providing a stable dietary basis. On top of this, they can be easily caught near the banks in shallow waters, with nets or fish traps, for example.

Conclusions

Underwater excavation in an Austrian pile-dwelling settlement applying modern excavation methods was a long desideratum, and luckily new investigations on fishing and fisheries can be presented. Not only important for knowledge on the Neolithic progression in Austria, the results are a significant piece of the mosaic enabling us to compare northern and the more southern Neolithic pile-dwellings settlements in order to work out the local specific characteristics and probably the more general developments in prehistoric fisheries. The specific distribution of species may mirror ecological differences in settlement habitats and specific fishing strategies targeting preferred species. However, in this regard the Mondsee site reveals an opportunistic way of fishing for small fish and some larger ones, but also a kind of special fishing for coregonids. A striking input comes from the frog remains, though in masses available around the lake, charred bones and a cut mark might prove their nutritive exploitation.

Acknowledgements

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Bibliography

Brinkhuizen 1989 — D. C. Brinkhuizen, Ichthyo-archeologisch onderzoek. Methoden en toepassing aan de hand van Romeins vismateriaal uit Velsen (PhD thesis Rijksuniversiteit Groningen 1989).

[14] Schibler et al. 1997, 119.
[15] Pamminger-Lahnsteiner et al. 2010, 301.
[16] Hüster Plogmann – Häberle 2017; Hüster Plogmann 2004; Marti-Grädel et al. 2004; Galik 2009.
[17] Kottelat – Freyhof 2007, 365.
[18] Hüster Plogmann 2004, 270.
[19] Galik 2009, 141. 143.
[20] For Einbaum see e. g. Leuzinger 2002, 103; Lübke 2009, 40.

Desse et al. 1989	J. Desse – N. Desse-Berset – M. Rocheteau, Les profiles rachidiens globaux. Reconstitution de la taille des poissons et appreciationdu nombre minimal d'individus a partir des pieces rachidiennes, Revue de Paleobiologie 8, 1, 1989, 89–94.
Galik 2008	A. Galik, Die Fischreste, in: P. Trebsche (ed.), Die Höhensiedlung »Burgwiese« in Ansfelden (Oberösterreich), LAF 38, 2 (Linz 2008) 307–315.
Galik 2009	A. Galik, Die Bedeutung des Fischfangs in der Horgener Seeufersiedlung Wallhausen-Ziegelhütte am Überlinger See, Hemmenhofener Skripte 8, 2009, 138–144.
Galik – Nikolaidou 2021	A. Galik – D. Nikolaidou, Fisch und Frosch am Seeufer aus Mooswinkel am Mondsee, Palafittes News 21, 2, 2021, 48–53.
Hüster Plogmann 2004	H. Hüster Plogmann, Fischfang und Kleintierbeute. Ergebnisse der Untersuchung aus den Schlämmproben, in: S. Jacomet – U. Leuzinger – J. Schibler, Die jungsteinzeitliche Seeufersiedlung Arbon, Bleiche 3. Umwelt und Wirtschaft, Archäologie im Thurgau 12 (Frauenfeld 2004) 253–276.
Hüster Plogmann – Häberle 2017	H. Hüster Plogmann – S. Häberle, Archäozoologische Schlämmreste aus den Schichten 13 und 14, in: N. Bleicher – C. Harb (eds.), Zürich-Parkhaus Opéra. Eine neolithische Feuchtbodenfundstelle 3. Naturwissenschaftliche Analysen und Synthese, Monographien der Kantonsarchäologie Zürich 50 (Zurich 2017) 127–144.
Kottelat – Freyhof 2007	M. Kottelat – J. Freyhof, Handbook of European Freshwater Fishes (Berlin 2007).
Jakobitsch et al. 2023	T. Jakobitsch – C. Dworsky – A. G. Heiss – M. Kühn – S. Rosner – J. Leskovar, How animal dung can help to reconstruct past forest use. A late Neolithic case study from the Mooswinkel pile dwelling (Austria), Archaeological and Anthropological Sciences 15, 3, 2023, 20.
Jelu et al. 2021	I. Jelu – W. Wouters – W. Van Neer, The use of vertebral measurements for body length and weight reconstruction of pike *(Esox lucius)* from archaeological sites, Archaeological and Anthropological Sciences 13, 5, 2021, 72.
Leuzinger 2002	U. Leuzinger, Holzartefakte, in: A. de Capitani – S. Deschler-Erb – U. Leuzinger (eds.), Die jungsteinzeitliche Seeufersiedlung Arbon, Bleiche 3. Funde, Archäologie im Thurgau 11 (Frauenfeld 2002) 115–134.
Lübke 2009	C. Lübke, Funde und Befunde aus den Untersuchungen der Jahre 1982 und 1998–2000 unter Steg 2, in: Arbeitsstelle Hemmenhofen des Landesamtes für Denkmalpflege (ed.), Tauchsondagen und Rettungsgrabungen unter Wasser in der jung- und endneolithischen Seeufersiedlung Wallhausen-Ziegelhütte, Kreis Konstanz, Hemmenhofener Skripte 8 (Stuttgart 2009) 9–82.
Marti-Grädel et al. 2004	E. Marti-Grädel – S. Deschler-Erb – H. Hüster Plogmann – J. Schibler, Early evidence of economic specialization or social differentiation. A case study from Neolithic lake shore settlement »Arbon-Bleiche 3« (Switzerland), in: S. Jones O'Day – W. Van Neer – A. Ervynck (eds.), Behaviour Behind Bones. The zooarchaeology of ritual, religion, status and identity (Oxford 2004) 164–176.
Mayr – Wanzenböck 2006	S. Mayr – J. Wanzenböck, Der Perlfisch (*Rutilus meidingeri* [Heckel, 1851]), ein Tiefwasserbewohner unserer Seen. Mythos oder Wahrheit? Seine Habitatnutzung und Nahrungswahl im Mondsee, Österreichs Fischerei 59, 2006, 262–272.
Offenberger 1981	J. Offenberger, Die »Pfahlbauten« der Salzkammergutseen, in: Das Mondseeland. Geschichte und Kultur. Exhibition catalogue Mondsee (Linz 1981) 295–357.
Pamminger-Lahnsteiner et. al. 2010	B. Pamminger-Lahnsteiner – K. A. Winkler – J. Wanzenböck, Verschwinden unsere heimischen Reinanken im Mondsee durch den Besatz mit Maränen? Morphologische, genetische und experimentell-ökologische Untersuchungen, Österreichs Fischerei 63, 2010, 300–311.
Pucher – Engl 1997	E. Pucher – K. Engl, Studien zur Pfahlbauforschung in Österreich. Materialien I. Die Pfahlbaustation des Mondsees. Tierknochenfunde, MPK 33 (Vienna 1997).
Radu 2003	V. Radu, Exploitation des ressources aquatiques dans les cultures néolithiques et chalcolithiques de la Roumanie Méridionale (PhD thesis Université d'Aix-Marseille I, Aix-Marseille 2003).
Ruttkay et al. 2004	E. Ruttkay – O. Cichocki – E. Pernicka – E. Pucher, Prehistoric lacustrine villages on the Austrian lakes, in: F. Menotti (ed.), Living on the Lake in Prehistoric Europe. 150 years of lake-dwelling research (London 2004) 50–68.

Schibler et al. 1997	J. Schibler – S. Jacomet – H. Hüster Plogmann – C. Brombacher, Economic crash in the 37th and 36th centuries cal. BC in Neolithic lake shore sites in Switzerland. Anthropozoologica 25/26, 1997, 553–570.
Schmitzberger 1999	M. Schmitzberger, Die Tierknochen aus der mittelneolithischen Kreisgrabenanlage Ölkam/OÖ (diploma thesis University of Vienna 1999).
Schmitzberger 2005	M. Schmitzberger, Die Tiernkochen aus der mittelneolithischen Kreisgrabenanlage und Siedlung von Kamegg, Niederösterreich, ArchA 89, 2005, 83–96.
Siligato – Gumpinger 2005	S. Siligato – C. Gumpinger, Der Perlfisch. Eine weltweite zoologische Rarität im Mondsee-Attersee-Gebiet. ÖKO-L Zeitschrift für Ökologie, Natur- und Umweltschutz 27, 3, 2005, 3–9.
Spindler 1997	T. Spindler, Fischfauna in Österreich. Ökologie – Gefährdung – Bioindikation – Fischerei – Gesetzgebung, Umweltbundesamt Monographien 87 (Scheibbs 1997).
Wheeler – Jones 1989	A. Wheeler – A. K. G. Jones, Fishes (Cambridge 1989).

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The Place of Fish in Funerary Rituals According to Two Late Roman Necropoleis from Northern France

Nempont-Saint-Firmin and Amiens (3rd–4th Cent. AD)

Tarek Oueslati – Josabeth Millereux-Le Béchennec – Samuel Lelarge

Abstract

Two late Roman sites from the north of France provide numerous examples of tomb offerings consisting of fish. They allow us to establish the role of fish in the ceremonies of funerals, giving more weight to past discoveries of isolated cases in the area. The nature of the deposits, especially those in ceramic vessels, documents the composition of a platter for the funeral meal, with the sharing of fish and various other meats. This work also allows a comparison between the composition of the daily diet, as documented by food refuse, and the choices made for the offerings. Plaice and flounder dominate in both types of contexts, but some species, such as cod and eel, do not seem to be associated with funerary rituals. Finally, specimens could be deposited whole, but often chunks of fish were served, accompanied by pork or chicken and a vegetable component that is not preserved.

Introduction

The research on fish consumption in northern France during the Roman era presents a complex and diverse situation. While many isolated rural sites lack evidence of fish consumption, some coastal settlements show a surprising absence of fish despite their abundant cockle harvests, notwithstanding significant sampling and sieving efforts. Conversely, cities like Bavay, Amiens and Arras (fig. 1) exhibit clear evidence of frequent consumption of marine fish, as documented by various scholars[1]. This enjoyment of fish products in urban areas stimulated the import of *Salsamenta* and *garum*, as well as the development of local fermented fish sauce production on the Atlantic coast[2], the estuary of the Seine[3] and in Belgium[4]. Fish also played a significant role in sanctuaries, where ritual pits near temples revealed the presence of both marine and freshwater fish consumed during banquets[5].

Moreover, the recurrent discovery of fish remains in late Roman burials within the territory of the Ambiens sheds light on another facet of fish consumption. These findings indicate the inclusion of fish in the funerary process, revealing their ceremonial significance. In order to explore the role of fish among the animal offerings, this paper focuses on 3rd–4th-century AD tombs from the necropolis of Nempont-Saint-Firmin (NSF) and Amiens (fig. 1). This study first addresses the selection of taxa found in tombs and the characterisation of the deposits within the ceremonial context, and thereafter, it compares this choice of taxa with the fish taxa found in food refuse from everyday life.

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1 Oueslati 2013; Clavel – Lepetz 2014; Oueslati 2017.
2 Driard 2014; Ephrem 2014.
3 Oueslati 2017.
4 Van Neer et al. 2005; Van Neer et al. 2010.
5 Michel et al. 2014; Oueslati – Michel 2018; Fercoq du Leslay – Lepetz 2008.

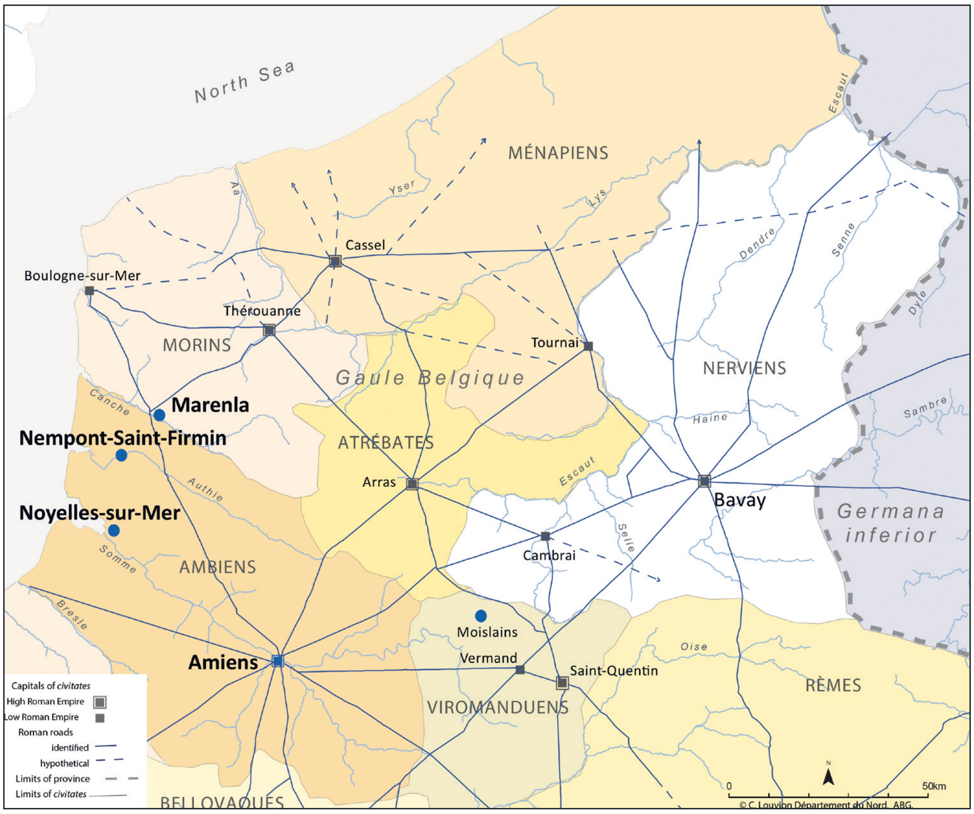

Fig. 1 Map of the territories of Belgic Gaul with the situation of the archaeological sites mentioned in this work (© C. Louvion, Department du Nord, ABG)

The Necropolis of Nempont-Saint-Firmin

The Late Roman settlement of Nempont-Saint-Firmin (NSF) is located on the river Authie in the vicinity of the estuary. It reveals the existence of a relatively rich and large-scale occupation known only through the great volume of domestic and artisanal waste it generated, as well as a necropolis that has only been partially excavated[6]. The buried population in the 90 tombs includes men, women and children of all ages, frequently accompanied by luxurious deposits. The presence of *militariae* and weapons in the tombs (approx. 50 % of male tombs) testifies to the military role of the establishment in the defensive organisation of the *litus saxonicum*, especially during the reign of the Emperor Valentinian. The first phase of the occupation of NSF is dated to AD 290/300–320, immediately preceding the installation of the first tombs of the necropolis dated from AD 325/330–345/350. The occupation continued until AD 410/420.

Meat consumption relied mainly on cattle and pig. Wild resources included red deer, which were exploited for meat and for the transformation of the antlers, as well as roe deer, hares, wild boars, badgers, wolves and Right or Bowhead whales[7]. The assemblage comprises both wild and domestic birds. Marine molluscs are dominated by cockles. Fish remains were collected from food refuse from both phases of occupation and from the tombs, where they were found among the grave goods. This provides the possibility to document the choice of fish in daily life and in funerary rituals.

6 Doyen et al. 2013.

7 Identified by ZooMS (zooarchaeology by mass spectrometry), BioArCh University of York.

Table 1 Nempont-Saint-Firmin, inventory of the offerings within the 14 tombs that provided fish remains with the indication of the sex (M = male, M [?] = probable male, F = female and imm = too young to be diagnosed) and age in years of the deceased, the chronology, fish taxa and other associated animal offerings in the same tomb

Grave number		**Sex**	**Age**	**Phase**	**Plaice**	**Flounder**	**Pleuronectidae**	**Herring**	**Mugilidae**	**Salmon**	**Sea trout**	**Fish unidentified**	**pig**	**Piglet**	**Cattle**	**Chicken**	**Duck**	**Goose**	**Cockles**
2028	25	M (?)	40–60	1	–	–	**1**	–	–	**1**	–	–	–	**1**	–	**1**	**1**	–	–
2031	27	M (?)	20–40	1	–	–	**1**	–	–	–	–	–	–	**1**	–	–	–	–	–
2036	30	–	–	1	–	**1**	–	–	–	–	–	–	–	–	–	**1**	–	–	–
2047	40	M (?)	40–60	1	–	**1**	**1**	–	–	–	–	–	–	**1**	–	**1**	–	–	–
2033	28	–	40–60	2	–	**2**	–	**1**	–	–	–	–	–	–	–	**1**	–	–	–
2003	3	F	40–60	2	–	–	–	–	–	–	–	**1**	–	–	–	–	–	–	–
2038	32	F	–	2	–	–	**6**	–	–	–	–	–	**1**	**1**	–	**2**	–	–	–
2044	37	imm	5–9	3	**1**	–	–	**1**	–	–	**1**	**1**	–	–	–	**1**	–	–	–
2051	44	M (?)	40–60	3	**1**	–	**1**	–	–	–	–	–	–	–	–	**1**	–	–	**34**
2053	46	imm	5–9	3	–	–	**1**	–	**1**	**1**	–	–	**1**	**1**	–	**1**	–	–	–
1151	5	M (?)	–	4	–	–	**1**	–	–	–	–	–	–	–	–	–	–	–	–
2029	26	M (?)	–	4	**1**	–	–	–	–	–	–	–	–	–	**1**	–	–	–	–
2054	47	M (?)	40–60	4	–	–	**1**	–	–	–	–	–	–	**1**	–	**1**	–	–	–
2068	60	M (?)	–	5	**2**	**1**	–	**1**	–	–	–	–	–	–	–	**2**	–	–	–

Fish in tombs

The excavation of 83 inhumations revealed the deposit of animal offerings in 45 cases. Fish remains were found in 14 tombs, thus in 31.1 % of tombs with animal remains (tab. 1). Taxonomically we identified plaice (5), flounder (5), plaice or flounder (13), salmon (1)[8], sea trout (1) and herring (3). It appears that plaice and flounder are the dominant species and that over half of the tombs contained more than one individual. Herring was present in three tombs, associated with two flounders in one instance, a plaice and a sea trout in another instance and finally, with three pleuronectids in the last instance.

If, in some cases, the fish were deposited complete, in other cases, only portions were found. This is the case for the flounder from tomb 2036/30, where the cranial half of the fish was present. In 2029/26, a plaice found on a plate lacks the last five caudal vertebrae. Tomb 2053/46 comprises a steak of salmon constituted of one and a half caudal vertebrae, with transverse chop marks defining this portion. This context also includes three portions of a grey mullet with two precaudals, caudals ranked 2–8, and caudals ranked 12–13, and finally, seven caudal vertebrae of a pleuronectid. In the case of 2047/40, a portion from a large flounder was found along with a basipterygium from a smaller pleuronectid, which may have been included in a dish where several fish were prepared for consumption during the funerary banquet.

8 The identification of salmonids from the vertebrae is based on the genetic analysis carried out as part of a collaboration with Dongya Yang (Ancient DNA Laboratory Simon Fraser University). Ancient DNA analysis was conducted on two archaeological salmonid remains. Mitochondrial DNA (mtDNA) sequences were obtained for both samples. Based on the obtained 16S and COI sequences, one bone was identified as *Salmo salar* and the other as *Salmo trutta trutta*.

Fig. 2 Nempont-Saint-Firmin, tomb 2038/32. Ceramic bowl Chenet 320 bearing animal offerings occupying half of the vessel. From right to left, a combination of the posterior area of a flatfish, two ribs from an adult pig and a shoulder from a piglet. Note that part of the bowl is empty and might have contained organic material that disappeared (photo: © Archéopole)

Fig. 3 Nempont-Saint-Firmin, tomb 2033/28. Plate with the combination of two flounders and a chicken, clearly placed on one side of the dish and suggesting that another component, which has not been preserved, was placed on the other part (photo: © Archéopole)

Similarly, portions of cattle, pig or duck were also documented, whereas most chickens and some new-born piglets were complete, except in cases of the former in which the head and wing phalanges were removed.

The deposits of portions of fish on plates containing various combinations suggests the sharing of food between the living and the deceased during the ceremony. From our observations, we reproduce a scenario with the preparation of various dishes served to the deceased in the same manner as to the people participating in the funeral. The photographs of ceramic and metal vessels taken during the excavations allow visualisation of the *in situ* organisation of the deposits. In the case of 2038/32, we can see, in a ceramic bowl, the caudal part of a flatfish comprising the last ten vertebrae, a left shoulder of a piglet and two ribs from an adult pig (fig. 2). This documents how various meats were consumed at banquets, with, in this case, the mixing of fish with pork and, in other instances, the combining of fish and chicken (fig. 3).

Furthermore, it should be specified that traces of cooking on an open hearth could be observed in the case of burial 2033/28. It affected the two specimens of flounder in the form of very limited charring of certain protruding parts. These two individuals were deposited with a chicken, and the empty part of the plate is probably the negative linked to the decomposition of other organic foods such as cereals (fig. 3).

Fish in daily life

The hand-collected fish from the excavations include 57 remains first attributed to cod, then to plaice and flounder. Sieving allows for a more precise image of the exploited fish remains, with 273 identified remains from eleven species (tab. 2). The estimation of the total length of cod is based on 13 observations. A minimum of 65 cm, a maximum of 141 cm and a

Table 2 Nempont-Saint-Firmin, fish remains from hand-collected (HC) and sieved material according to the chronology of accumulations of consumption waste

NISP	End of 3rd – beginning of 4th cent.		End of 4th–5th cent.		End of 3rd – beginning of 5th cent.	
	sieving	HC	sieving	HC	sieving	HC
Plaice	8	1	–	–	8	1
Flounder	2	–	2	1	4	1
Plaice/flounder	5	–	–	–	5	0
Pleuronectid	181	7	19	2	200	9
Sole	2	–	1	–	3	0
Scophtalmid	1	–	–	–	1	0
Herring	19	–	2	–	21	0
Cod	2	10	–	–	2	10
Whiting	4	–	–	–	4	0
Gadid	5	6	–	–	5	6
Conger eel	4	–	–	–	4	0
Eel	14	–	–	–	14	0
Salmonid	–	–	1	–	1	0
Triglid	1	–	–	–	1	0
Unidentified fish	603	27	174	3	777	30
Total	**851**	**51**	**199**	**6**	**1050**	**57**

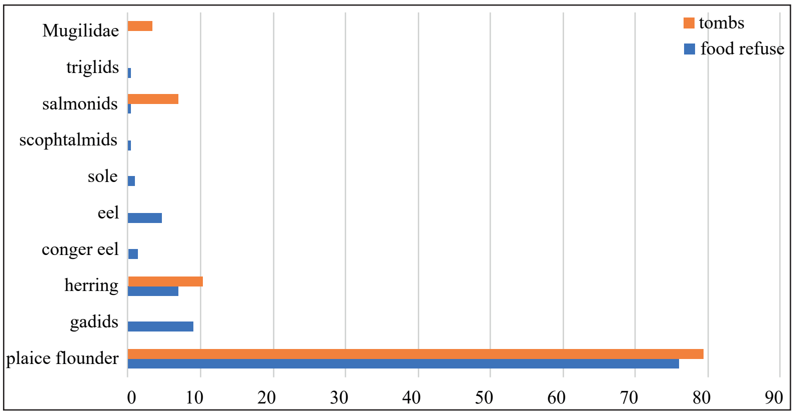

Fig. 4 Nempont-Saint-Firmin, frequencies of fish taxa according to provenance (% NISP) (© T. Oueslati)

median of 119 cm were recorded. The medians of the sizes of the other species are 26 cm for herring (12 individuals), 28.5 cm for plaice and flounder (87 individuals), 37.5 cm for eel and 120 cm for conger eel.

The comparison between funeral offerings and daily consumption waste reveals the predominance of plaice and flounder in both (fig. 4). Herring is abundant in both but slightly more frequent in tombs. Salmonids and mugilids are better represented in tombs, whereas other species such as gadids, eel, conger eel, triglids, sole and scophtalmids are only present in consumption refuse. The lack of gadids and eel in tombs, two species which are regularly consumed, attracts our attention. This may suggest that some choices were made, but it is also likely linked to the availability of fish at the time of the ceremony, which is linked to the seasonal availability of some resources such as salmon or herring and also to the uncertainties linked to fish landings.

The Necropolis of Amiens

Fish in tombs

The rescue excavation of La Citadelle uncovered part of an extended area of burials located to the north of the Roman city of Amiens, Samarobriva. This is only part of the necropolis identified since the 17th century, whose northern, southern and eastern limits are still not known[9]. A large part of this funerary space unfolds on each side of the supposed axis of the Via Agrippa but also in connection with a number of other roads exiting the city.

This excavation investigated the largest surface of this necropolis explored to date, with 166 tombs, giving us the opportunity to deepen our knowledge of the funerary rites of this city between the end of the 3rd century and the end of the 4th century AD.

Three lead sarcophagi are present, and 80 % of the tombs show clear traces of nailed mounts. This mode of assembly concerns both possible coffins and probable formwork. During the ceremony, deposits of offerings were placed either in the coffin or, more frequently, outside of it, or sometimes in the backfill of the pit.

In all, we listed 508 objects. The 166 tombs account for almost two-thirds of these finds, and this despite some very poorly preserved tombs. Overall, we note the multiplicity and diversity of the metal, pottery and glass vessels accompanying the deceased, with a total of 90 complete ceramics and 115 complete glass vessels. Nevertheless, one must consider that we discovered only a part of the possible categories of objects potentially found in Roman tombs[10], with a characteristic lack of weapons. This marks an important difference in comparison with NSF.

Animal bones were identified only in 28 of the 166 excavated tombs (16.9 %). Of these, seven contained fish, so about a quarter of these contexts. Plaice and flounder are the most represented species with four plaice, two flounder and one plaice or flounder. The other species are thicklip grey mullet (*Chelon labrosus*) and roach (*Rutilus rutilus*) (tab. 3). Most fish were deposited complete, with only a few missing elements that may be linked to excavation in the field or to cooking and serving. In fact, the removal of a cooked fish from the pan often leads to the loss of elements, particularly the lateral skull bones.

The estimations of the size of the fish reveal total lengths (TL) for plaice between 50 and 60 cm, whereas flounder is smaller, in the 36–38 cm range. Thicklip grey mullet is the biggest fish with an estimated TL of 61–62 cm, while the roach was only 19–20 cm TL (tab. 3).

Fish in daily consumption

The consumption of fish at Roman habitation sites of Amiens has been investigated via the excavation of La Citadelle and two other excavations of the Palais des Sports (PDS)[11] and Rue Gaultier Rumilly (RGR)[12]. Collecting procedures were limited to collection by hand for the first two sites, whereas the third site benefitted from sieving. Pleuronectidae appear to be the dominant species in food refuse, with frequencies ranging from 59.4 % to 82.5 % (tab. 4). Eel and herring are quite abundant in the sieved assemblage of RGR, but they are lacking in the tombs.

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9 Bayard 2007.
10 Feugère 1993.
11 Lepetz 2010.
12 Clavel – Lepetz 2014.

Table 3 Necropolis of Amiens, animal offerings in the tombs that provided fish remains

Context		Pig	Cattle	Chicken	Golden plover	Plaice	Flounder	Plaice/flounder	Grey mullet	Roach	Size estimation
2201	I008	–	1	1	–	1	1*	–	–	–	*TL 37–38cm
2459	I055	1	–	–	1	–	1*	–	–	–	*TL 36–37cm
2659	I074	1	–	1	–	1*	–	–	–	–	*TL 58–59cm
2471	I105	1	–	–	–	1*	–	–	–	–	*TL 48–49cm
2365	I106	–	–	–	–	–	–	–	–	1*	*TL 19–20cm
2968	I136	–	–	1	–	–	–	1*	–	–	*TL 35–36cm
3017	I156	1	1	1	–	1*	–	–	1**	–	*TL 51–52cm; **TL 61–62cm

Discussion

Throughout prehistory and history, fish have been found only in a few tombs, and their inclusion in rituals seems to be anecdotal in nature[13]. In Gallia Belgica, the participation of fish in the mortuary ritual developed after the Roman conquest and was particularly visible in the Late Roman occupation of the *civitates* of the *Ambiani* and *Morini*, as seen in NSF and Amiens, but also on the sites of Noyelles-sur-mer[14], Marenla[15] and Étaples[16]. Plaice and flounder appear as the main species in daily life and also as offerings in tombs. These pleuronectids must have been an abundant resource. In the future, the many unidentified pleuronectid remains from NSF would benefit from specific identification with ZooMS, as this technique has been proven efficient in the discrimination between the species of pleuronectids from the North Sea[17]. We identified other fish offerings as herring, salmonids and grey mullet. The comparison with food refuse reveals the consumption of other taxa that are not encountered in tombs. This is the case for cod at NSF and for herring and eel at Amiens. We can deduce the choices made during the preparations for the ceremony, but we must stress that the availability of resources at the time of the burial must have played a major role in the selection of taxa and specimens. Beyond the taxa, the preparation of fish completes our understanding of the ritual. In fact, for NSF, the frequent deposits of fish in ceramic vessels and their careful cleaning post-excavation ensures a limited loss of bones in the sediment in comparison with offerings deposited on the sediment outside of the coffin. At the same time, this protocol ensures understanding of the way the deposit was made at the time of the burial. We deduced from this that fish were cooked and often shared between the deceased and the living. Rather than entire fish, deposits comprised chunks of fish or even a steak in the case of salmon. We also observed the combination of fish with pork or chicken in the same dish. This defines the type of food prepared for feasting and the way a meal was served to the deceased. An unknown persists with regard to the place were feasting took place. The possibility that this meal took place in the necropolis is documented with the consumption of fish among many other animals excavated in pits surrounding tombs and cemetery enclosure ditches at Aventicum, thus documenting that these stages of the mortuary ritual took place during the burial[18].

13 Mittermeier 1986; Klaus 2000; Dierkens et al. 2008.
14 Piton – Marchand 1978.
15 Piton 2006.
16 Souquet 1865.
17 Dierickx et al. 2022.
18 Castella 1999.

Table 4 Fish consumption refuse from the excavations of Amiens and Arras; Amiens CIT: Amiens Citadelle sectors 1–2, 3 and 6 hand-collected; Amiens PDS: Palais des Sports hand-collected (Lepetz 2010); Amiens RGR: Rue Gaultier Rumilly sieving (Clavel – Lepetz 2014); Arras: Baudimont sieving (Jacques et al. 2008)

	Amiens CIT		**Amiens PDS**	**Amiens RGR**	**Arras**
	1st–2nd cent.	3rd–4th cent.	1st–2nd cent.	1st–2nd cent.	4th cent.
Herring	–	–	–	13	35
Horse mackerel	2	–	–	2	–
Crangids	1	–	–	–	–
Cod	4	–	–	–	–
Triglids	–	–	3	7	17
Black sea bream	1	–	–	1	–
Sparids	–	–	–	3	1
Grey mullet	–	–	–	–	2
Atlantic mackerel	–	–	–	1	16
Scophtalmids	–	–	10	–	–
Plaice	14	–	17	240	3
Flounder	–	–	2	–	–
Plaice or flounder	33	4	–	40	85
Sole	–	–	–	2	–
Atlantic sturgeon	1	–	–	–	–
Allis shad	–	–	–	–	3
Eel	–	–	–	41	67
Cyprinids	–	–	–	2	11
Pike	1	–	–	1	5
Unidentified fish	15	–	–	1567	1606
Total	**72**	**4**	**31**	**1920**	**1851**

Other regional Roman sites have provided deposits of fish in tombs. This is the case in Marck, near Calais, where chicken and fish were deposited on the pyre and burnt with the deceased[19]. In this case, the growth rings on the burnt vertebrae of pleuronectids revealed different stages of growth, suggesting that these flatfishes were probably caught in different seasons and therefore at least some were salted and dried. Further inland, the tomb of Cantin contained remains of barbel and perch on plates among other offerings[20]. Still north of the Seine River, the deposit in a tomb in Moislains (1st cent. AD) consisted of a plate containing a chunk of Spanish mackerel comprising ten vertebrae, indicating the offering of a preserved fish from the Mediterranean[21]. Another case is documented in the East of France at the site of Strasbourg, Route des Romains (1st–2nd cent. AD), where 17 out of 19 cremations contained animal bones, four of which contained burnt fish remains, mainly cyprinids and including probably preserved marine fish (scombrids and herring)[22]. It is worth mentioning that the deposit of fish in tombs is also encountered in southern France, such as in Nîmes in the 1st century BC, thus suggesting that this practice could have originated from Mediterranean influences through the Roman conquest[23].

From our work, the deposition of offerings appears linked to the sharing of food between the living and the deceased. It is worth mentioning the depositing in the same dishes of

[19] Oueslati 2011.
[20] Loridant et al. 2011.
[21] Clavel – Lepetz 2014.
[22] Borvon 2020.
[23] Feugère et al. 1995.

various types of poultry, pork and fish, along with some vegetal components that appear as the empty part of the dish. This sharing of sacrificed animals is characteristic of the Roman funerary ritual, with the aim, according to the Roman beliefs, of purifying the family stained by death, as described in the funeral process[24].

After the Roman period, the deposition of fish in early medieval tombs still represents 1.44 % of animal offerings in Merovingian tombs[25], but the significance of this gesture might have evolved then, especially with the advent of Christianity.

Conclusions

The two late Roman necropoleis from northern France provide a better understanding of the role of fish in mortuary rituals. The species selected for offerings follow the same rules as in consumption waste, with a leading role given to plaice and flounder. Some examples cited above indicate the possible use of preserved fish and the spatial extension of these practices across Gaul and even after the collapse of the empire.

Fish may be deposited whole, in pieces or as steaks in the case of large fish. Burning marks indicate, in some cases, how the fish was cooked. Moreover, when dishes were used, it was possible to observe the combination of fish, poultry, adult and juvenile pork, reflecting the sharing of food presented in the funerary banquet. This information on the blending of different meats within the same dish is unique, illustrating what a platter would have looked like on the table of these Romans feasting at funerals. The presented sites are the best examples available to date of the inclusion of fish in tomb offerings. We have established a correlation between the deposit of offerings of fish in tombs and the rise of fish consumption since the Roman conquest, a trait not systematically encountered at all regional sites, thus contributing to the characterisation of the socio-economic status of consumers.

The defensive organisation of the *litus saxonicum* may explain the specificities of some Late Roman sites such as Nempont-Saint-Firmin, Boulogne, or Étaples which were home to important stationed garrisons in this territory. Nevertheless, this explanation is not sufficient, as the necropolis of Amiens did not yield any weapons despite the presence of fish, thus suggesting that the enjoyment of fish was widespread in urban populations.

Bibliography

Bayard 2007 — D. Bayard, Amiens 1983–2003. Un bilan vingt ans après Amiens romain, in: R. Hanoune (ed.), Les villes romaines du Nord de la Gaule. Vingt ans de recherches nouvelles. Actes du XXV^e colloque international de HALMA-IPEL UMR CNRS 8164 (Lille 2007) 11–42.

Borvon 2020 — A. Borvon, Bilan ichthyologique, in: P. Flotte – G. Alberti (eds.), Strasbourg, Bas-Rhin 8–20 route des Romains 1. La nécropole de Strasbourg-Koenigshoffen du 1^er siècle apr. J.-C. au début du 2^e siècle, Rapports de fouille d'Archéologie Alsace 6108 (Strasbourg 2020) 335.

Castella et al. 1999 — D. Castella – C. Martin Pruvot – H. Amrein – A. Duvauchelle – F. E. Koenig, La Nécropole gallo-romaine d'Avenches »En Chaplix«. Fouilles 1987–1992, 2, Cahiers d'Archéologie romande 78 (Lausanne 1999).

[24] Lepetz – Van Andringa 2004.
[25] Dierkens et al. 2008.

Clavel – Lepetz 2014 B. Clavel – S. Lepetz, La consommation des poissons en France du nord à la période romaine. Marqueur socio-culturel et artefacts taphonomiques, in: X. Deru – R. González Villaescusa (eds.), Consommer dans les campagnes de la Gaule romaine. Actes du colloque X[e] congrès de l'Association AGER, Revue du Nord 21 (Lille 2014) 93–108.

Dierickx et al. 2022 K. Dierickx – S. Presslee – R. Hagan – T. Oueslati – J. Harland – J. Hendy – D. Orton – M. Alexander – V. L. Harvey, Peptide mass fingerprinting of preserved collagen in archaeological fish bones for the identification of flatfish in European waters, Royal Society Open Science 9, 7, 2022; DOI:10.1098/rsos.220149

Dierkens et al. 2008 A. Dierkens – C. Le Bec – P. Périn, Sacrifice animal et offrandes alimentaires en Gaule mérovingienne, in: S. Lepetz – W. Van Andringa (eds.), Archéologie du sacrifice animal en Gaule romaine Rituels et pratiques alimentaires (Montagnac 2008) 279–299.

Doyen et al. 2013 J.-M. Doyen – S. Lelarge – M. Demarest – G. Florent – T. Oueslati – J. Minne – R. Delmaire, La circulation monétaire sous les Valentiniens et les Théodosiens (364 – vers 420 apr. J.-C.) dans le nord-ouest de la Gaule. L'apport des fouilles de la rue du Warnier à Nempont-Saint-Firmin (Pas-de-Calais, France), Journal of Archaeological Numismatics 3, 2013, 89–262.

Driard 2014 C. Driard, Les sauces de poisson dans l'ouest de la province romaine de Lyonnaise. Réflexions sur l'élaboration et la nature des produits, in: E. Botte – V. Leitch (eds.), Production et commerce des salsamenta durant l'antiquité fish and ships (Aix-en-Provence 2014) 47–60.

Ephrem 2014 B. Ephrem, Piscatores Oceanici et Garumnae. Pour une approche par l'archéo-ichtyologie de la pêche en Aquitaine romaine, Acquitania Suppl. 31, 2014, 250.

Fercoq du Leslay – Lepetz 2008 G. Fercoq du Leslay – S. Lepetz, Manger dans les sanctuaires. Salaisons et viandes fraîches à Ribemont-sur-Ancre, in: S. Lepetz – W. Van Andringa (eds.), Archéologie du sacrifice animal en Gaule romaine. Rituels et pratiques alimentaires (Montagnac 2008) 203–2007.

Feugère 1993 M. Feugère, L'évolution du mobilier non céramique dans les sépultures antiques de Gaule méridionale (II[e] siècle av. J.-C. – début du V[e] siècle ap. J.-C.), in: M. Struck (ed.), Römerzeitliche Gräber als Quellen zu Religion, Bevölkerungsstruktur und Sozialgeschichte, Archäologische Schriften des Instituts für Vor- und Frühgeschichte der Johannes Gutenberg-Universität Mainz (Mainz 1993) 119–165.

Feugère et al. 1995 M. Feugère – A. Gardeisen – Y. Manniez – M. Monteil – L. Vidal – F. Brien-Poitevin – B. T. Mai – M. Lejeune – M. Sternberg, Un espace funéraire du deuxième quart du I[er] s. avant J.-C. Nîmes, Gard, Gallia 52, 1995, 165–204.

Jacques et al. 2008 A. Jacques – S. Lepetz – W. Van Andringa – V. Matterne – M. Tuffreau-Libre, Vestiges de repas et identification d'un siège de collège à Arras Nemetacum, in: S. Lepetz – W. Van Andringa (eds.), Archéologie du sacrifice animal en Gaule romaine. Rituels et pratiques alimentaires (Montagnac 2008) 237–252.

Lepetz 2010 S. Lepetz, Pratiques alimentaires dans un quartier d'Amiens au I[er] siècle – les restes osseux animaux du »Palais des Sports«, Revue Archéologique de Picardie. Numéro spécial 27, 2010, 409–422.

Lepetz – Van Andringa 2004 S. Lepetz – W. Van Andringa, Caractériser les rituels alimentaires dans les nécropoles gallo-romaines. L'apport conjoint des os et des textes, in: L. Baray (ed.), Archéologie des pratiques funéraires. Approches critiques. Actes de la table ronde de Bibracte, 7–9 juin 2001, Bibracte 9 (Glux-en-Glenne 2004) 161–169.

Loridant et al. 2011 F. Loridant – P. Herbin – T. Oueslati – I. Raineau, Découvertes archéologiques à Cantin (Nord). Parcellaire et caveaux gallo-romains, occupation carolingienne, Revue du Nord 393, 2011, 233–260.

Michel et al. 2014 M. Michel – Y.-M. Adrian – J.-M. Doyen – A. Hanotte – T. Oueslati – N. Roudié, Pratiques religieuses dans un sanctuaire véliocasse. Les Mureaux à Authevernes (Eure), Gallia 71, 2014, 189–259.

Mittermeier 1986 I. Mittermeier, Speisebeigaben in Gräbern der Merowingerzeit (PhD thesis Julius-Maximilians-Universitat Würzburg 1986).

Oueslati 2011 — T. Oueslati, Rapport d'étude de la faune issue de la fouille du site, in: R. Blondeau (ed.), Marck. Pas-de-Calais (62). »ZAC des Pins dite Transmarck« juillet – septembre 2009. Rapport final d'opération d'archéologie preventive 2011, 1 (Linselles 2011) 261–275.

Oueslati 2013 — T. Oueslati, Analyse ichtyoarchéologique de la place du poisson de mer dans les pratiques alimentaires romaines du Nord de la France, in: M.-Y. Daire – C. Dupont – A. Baudry – C. Billard – J.-M. Large – L. Lespez – E. Normand – C. Scarre, Anciens peuplements littoraux et relations Homme/Milieu sur les côtes de l'Europe atlantique, BARIntSer 2570 (Oxford 2013) 535–544.

Oueslati 2017 — T. Oueslati, Aller à la pêche au gros et produire du garum à l'époque romaine dans le Nord de la Gaule, in: R. González Villaescusa – K. Schörle – F. Gayet – F. Rechin (eds.), L'exploitation des ressources maritimes de l'Antiquité. Activités productives et organisation des territoires. XXXVII^e^ Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. XII^e^ Colloque de l'Association AGER (Antibes 2017) 41–56.

Oueslati – Michel 2018 — T. Oueslati – M. Michel, Du mutisme de l'os à la restitution des rituels à caractères gaulois et romains dans le sanctuaire territorial de Authevernes »Les Mureaux« (Eure), Revue archéologique de Picardie. Numéro spécial 32, 2018, 147–159.

Piton 2006 — D. Piton, Une nécropole du Bas-Empire à Marenla (Le But de Marles), in: D. Piton (ed.), Sept nécropoles du Bas-Empire dans le Pas-de-Calais, Nord-Ouest Archéologie 14 (Berck-sur-Mer 2006) 7–58.

Piton – Marchand 1978 — D. Piton – H. Marchand, Une nécropole du IV^e^ siècle à Noyelles-sur-Mer, Cahiers archéologiques de Picardie 5, 1978, 199–229.

Souquet 1865 — G. Souquet, Rapport des fouilles faites au château d'Etaples en 1864, Bull Commission antiquités département du Pas-de-Calais 2, 1865, 270–274.

Van Neer et al. 2005 — W. Van Neer – W. Wouters – A. Ervynck – J. Maes, New evidence from a Roman context in Belgium for fish sauce locally produced in northern Gaul, Archaeofauna 14, 2005, 171–182.

Van Neer et al. 2010 — W. Van Neer – A. Ervynck – P. Monsieur, Fish bones and amphorae: evidence for the production and consumption of salted fish products outside the Mediterranean region, JRA 23, 2010, 161–195.

Klaus 2000 — K. Klaus, Die Tierbeigaben aus vier frühmittelalterlichen Gräberfeldern in Unterfranken, Germania 78, 2000, 125–138.

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Shrimp and Fish

The Unique Mixture of a Locally Produced Fish Sauce in Roman Harfleur (Normandy, France)

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Abstract

Several fish assemblages were discovered during excavations on the site Les Coteaux du Calvaire in the city of Harfleur, located in Normandy, France. Two pits contained very small remains of fish bones and/or Crustacea, which are characteristic by-products of the production of garum. The species composition of this material is tremendously rich, with approx. 2000 shrimps present in the assemblage, along with 2790 individuals of herring, at least 276 gobies and 125 sand lances, if we consider only the 1 mm fraction. The other 22 fish species can be interpreted as the bycatch of the fishing activity in the estuary. This is the first assemblage of locally produced Roman fish sauce where Crustacea are present in such huge numbers. Several indications suggest that this fish sauce was prepared in late spring or early summer. This assemblage underlines again the role of estuarine waters as a nursery place for many species that are now becoming rare or are even close to extinction. From a methodological point of view, we tested different sampling approaches for the fractions of the 1 mm and 0.5 mm sieve and verified the effects on the final results. These protocols will be briefly illustrated and discussed.

Introduction

Indications for local fishing and fish consumption seem to be almost absent for the Roman period in the region of Gaul. Most often, the fish remains found represent preserved fish imported from the Mediterranean region. The numerous finds of chub mackerel (*Scomber japonicus*) bones, a species that lives in the Mediterranean, illustrate the trade of this preserved fish all over western Europe. An extensive list of this import of *salsamenta* is provided by Van Neer et al.[1]. Although written sources and several amphorae with their *tituli picti* attest the commerce of Mediterranean fish sauces into Gaul, bone evidence from Mediterranean fish species remains absent. Several contexts with concentrations of small bone finds, dated from the second half of the 2nd century onwards, indicate that these fish sauces were prepared from local fish catches[2]. Since the appearance of that publication, some new assemblages have been studied, which will be incorporated into this article.

The site Les Coteaux du Calvaire, situated in the city of Harfleur was excavated from October 2011 till July 2012[3]. Harfleur, called Caracotinum in Roman times, is situated on the right bank of the Seine estuary, close to the sea (fig. 1).

The excavated materials cover a time span starting at the beginning of the 1st century and continuing into the 3rd century AD. Although hand-collected fish bones were rather limited in number (NISP [number of individual specimens] = 86), they belong to two important groups: small flatfishes, mostly pleuronectids, and many representatives of the cod family or

1 Van Neer et al. 2010, tab. 1.
2 Van Neer et al. 2010, tab. 3.
3 Boisson 2015.

Fig. 1 a: Harfleur situated on the coast of France (T. Oueslati); b: A detailed view of the natural course of the Seine estuary in 1750 with the location of Harfleur (source: Carte de la Basse-Seine, entre Rouen et Le Havre, Bibliothèque nationale de France, adapted by W. Wouters)

Gadidae[4]. A particular aspect in this latter group is the presence of very large cods (*Gadus morhua*). A sieved assemblage from well 1525 provided a larger assemblage (NISP = 623) comprising very small fish with 76.9 % pleuronectids and 13 % clupeids and some minor taxa including sand eel, eel, gobies and whiting. The remains of the small pleuronectids (total lengths [TL] < 20 cm), herring and eel exhibit modifications associated with consumption including crushing and burning. They were associated with mineralised seeds, which suggests possible accumulations of consumption waste. Two neighbouring pits (3116 and 3117) had a deviate content, their bottom fills were composed exclusively of very tiny fish bones without other artefacts. These contexts were dated to around AD 70/75–125. Only pit 3116 was sampled for sieving, revealing thousands of tiny remains that were partially studied, with a predominance of clupeids that showed no bone modifications, and the comparison with similar deposits led to the interpretation of *garum* production waste[5].

The assemblage from pit 3116 is the focus of this in-depth work. The size of the bones turned the research into a challenging work. A specific approach to study this material was developed during the process and will be critically analysed further on. The remains of the fish sauces found here provide information about fishing methods and seasonality. Unfortunately, the material from pit 3117 was not sampled, so any comparison between both assemblages is ruled out.

[4] Boisson 2015; Oueslati 2017.

[5] Oueslati 2017.

Material and methods

Crustacea

A subsample of 3 % (3.3 g out of 105.4 g) was searched for elements that could be identified to the smallest taxon. The identification key constructed by Borvon and Gruet[6] was used to identify the remains of the crustaceans. A minimum number of individuals (MNI) was estimated based on the most abundant element in the sample, and size reconstructions were based on regressions detailed in the same publication.

Fish

Identification of the fish bones was conducted using the reference collections of the Royal Belgian Institute of Natural Sciences in Brussels, Belgium. An identification guide[7] was consulted to distinguish the dermal denticles of the rays. Bones from plaice and flounder were identified using Wouters et al.[8] MNI was counted on the basis of the most abundant element, although sometimes corrections were made using size estimations. The body length for most of the fishes was reconstructed by direct comparison of reference material of known length. In the case of *Clupea harengus* (herring)/*Sprattus sprattus* (sprat), existing regressions were used[9]. In the case of eel, size calculations were based on Thieren et al.[10].

The material was sieved on three different meshes: 2 mm, 1 mm and 0.5 mm. The fish bones from the 2 mm sample contained only a few bones, which were all identified to the smallest taxon. A total amount of 177.8 g was collected from the 1 mm mesh (fig. 2).

In the initial stage of the identification process, two subsamples of 17.8 g (10 %) were taken. It became almost immediately clear that picking out all identifiable elements would be inefficient and time-consuming. The good preservation of many head bones combined with all the vertebrae would result in an enormous NISP. Moreover, this kind of closed context can better be understood in terms of MNI for each species[11]. The focus was placed on clearly recognisable elements for each taxon that were well represented in the assemblage. After analysis of the first 10 %, the selection of specific elements was slightly reduced for the second 10 %. In the subsequent samples, this process was further refined. This approach accelerated the identification process enormously. The first 10 % sample was completed in about three days, whereas the final remaining 50 % of the 1 mm sample took approximately a full day. Additionally, the 0.5 mm sample was quickly scanned for additional specimens and or species.

After some intensive scanning, it became clear that the prooticum was the most abundant element present in the case of small clupeids. This characteristic round-shaped head bone was only counted in every subsample, without retrieving them. This approach reduced work by several hours. In a second step, the other bones were picked out for species identification of the fishes present. Size reconstructions for sprat (*Sprattus sprattus*)/herring (*Clupea harengus*) were undertaken on the basis of the basioccipital using regressions[12]. This element could only be measured using a binocular microscope with a grid (Graticules Ltd, Tonbridge, UK). All the basioccipitals present in the first 50 % of the assemblage were measured.

Vertebrae for the families of the Syngnathidae (pipefishes and seahorses), Gobiidae (gobies) and Ammodytidae (sand lances) were abundant. In a first approach, only the first three precau-

6 Borvon – Gruet 2024.
7 Gravendeel et al. 2002.
8 Wouters et al. 2007.
9 Described by Van Neer et al. 2005.
10 Thieren et al. 2012.
11 Wheeler – Jones 1989.
12 Van Neer et al. 2005.

Fig. 2 Overview of some animal remains from the 1 mm sieve from the Harfleur, pit 3116 (T. Oueslati)

Fig. 3 Easily identifiable elements of the sand shrimp (*Crangon crangon*), from left to right a mandible, scaphocerite and telson from Harfleur, pit 3116 (A. Borvon)

Fig. 4 Size reconstruction, based on the scaphocerite of 41 elements (A. Borvon – Y. Gruet)

dal vertebrae were picked out because of their characteristic appearance. However, the second and third vertebrae are prone to fragmentation of the processus dorsalis, making distinction more difficult. After the two first samples of 10 %, it became apparent that the first caudal vertebra was the easiest to recognise and most abundant in the assemblage. For all other fish taxa, all the recognisable bones were sorted out. In the case of eel *(Anguilla anguilla)*, head bones were very rare, so all precaudal vertebrae were sampled for size reconstructions. For this last group of fish, the MNI was identified based on the laterality of elements combined with differences in size reconstructions.

Results

Crustacea

Although the material from the crustacea is highly fragmented, some key elements remained identifiable to species. The subsample of 3 % contained several elements identified as sand shrimp (*Crangon crangon*). Scaphocerites were the most numerous with 108 finds, followed by 32 mandibles, 9 dactyli of perepod I and 2 telsa. Some of these elements are illustrated in figure 3.

The estimation of the MNI is based on the scaphocerite, with 63 right elements counted against 47 left ones in the subsample. The total amount of sand shrimps present in the assemblage was estimated as approximately 2000 specimens. The scaphocerite was also used to reconstruct the total size length, based on 41 measurable elements: 21 right and 20 left ones. The result is presented in figure 4.

Only a few elements indicate the presence of Palaemonidae. One telson and a few broken rostra were identified as delta prawn (*Palaemon longirostris*). One small part of a crab was found, but this could not be identified to species.

Fishes

Species composition and MNI

The MNI for each species combining the 2 and 1 mm sample is provided in table 1 along with the proportional frequency for each taxon. This rich assemblage contains 25 different taxa[13].

Cartilaginous fishes are present in very low numbers. One vertebra was identified as starry smooth-hound (*Mustelus asterias*). The vertebra is from a small individual between 25 and 35 cm TL. Vertebrae of the angel shark (*Squatina squatina*) were recovered in both meshes. The animal was of small size, rather arbitrarily estimated between 20–40 cm TL. Several vertebrae, some thorns and prickles of a ray were recognised. The dermal prickles were compared with the key constructed by Gravendeel et al.[14]. At first sight, they did not match any species, until we realised that the heavier thorns belonged to young specimens. Juvenile rays have less strongly developed thorns than adults[15], which made identification with the identification key impossible. By comparison with some small specimens in the reference collection, these thorns were identified as a young specimen of a thornback ray (*Raja clavata*) of less than 40 cm SL (standard length) which corresponds to a specimen of around 3 years of age[16].

A few remains belong to shads (*Alosa* sp.). Most of the remains are caudal vertebrae, and two articulars were from fish of 12–15 cm SL. Differentiation between allis shad (*Alosa*

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13 An overview of all the NISP per species over the different subsamples is detailed in tab. 2 (Appendix).
14 Gravendeel et al. 2002.
15 Serre-Pereira et al. 2005.
16 Serre-Pereira et al. 2005.

Table 1 MNI and relative frequency for the assemblage based on the 2 and 1 mm together

	MNI (2 + 1 mm)	**Proportional frequency**
Species		
Mustelus mustelus (smooth-hound)	1	0.0
Squatina squatina (monkfish)	1	0.0
Raja clavata (thornback ray)	1	0.0
Alosa sp. (shad)	3	0.1
Sardina pilchardus (sardine)	1	0.0
Clupeidae (herring/sprat)	2790	83.4
Merlangius merlangus (whiting)	7	0.2
Belone belone (garfish)	3	0.1
Syngnathus sp. (pipefish)	39	1.2
Triglidae (searobins)	4	0.1
Myoxocephalus scorpius (shorthorn sculpin)	4	0.1
Agonus cataphractus (hooknose)	7	0.2
Sparidae (porgies)	1	0.0
Mullus sp. (red mullets)	2	0.1
Mugilidae (grey mullets)	1	0.0
Ammodytes tobianus (small sandeel)	125	3.7
Gobiidae (gobies)	276	8.2
Zoarces viviparus (viviparous blenny)	1	0.0
Gasterosteus aculeatus (three spined stickleback)	2	0.1
Callionymus lyra (dragonet)	1	0.0
Pleuronectes platessa (plaice)	39	1.2
Platichthys flesus (flounder)	23	0.7
Solea solea (sole)	4	0.1
Anguilla anguilla (eel)	8	0.2
Scardinius erythrophthalmus (rudd)	2	0.1
Total	**3346**	**100**

alosa) or twaite shad (*Alosa fallax*) seems not to be possible with these elements. A single caudal vertebra was attributed to a sardine (*Sardina pilchardus*) of 6–7 cm SL.

Remains of small clupeids dominate the assemblage. The round and rather robust prooticum was used to estimate the MNI. 104 prootics were counted in the 2 mm fraction, and a total of 5475 in the 1 mm fraction. Because this is a paired bone, at least 2790 Clupeidae must have been present in this preparation. We checked an estimated total of 600 dentaries present in the assemblage during the sorting process. All of these belong to herring, while remains of sprat were not detected. Size was estimated using the regression formula for the width of the basioccipitals[17]. Only 50 % of the 1 mm fraction was searched for this bone; size estimations were calculated on a total of 184 basioccipitals. This element, certainly for the small specimens, was not always perfectly preserved. We estimate a possible measurement error of 0.3–0.5 mm. Results are given in figure 5.

There is a high peak around size 3.0–4.5 cm SL, with the highest score (24.2 %) for size class 3.5–4 cm SL. The smallest herring has an estimated length of 2.5 cm SL and the biggest 9.4 cm SL. A second, smaller peak is seen in the size class 6.5–7 cm SL with 9.1 % of the herrings.

17 Van Neer et al. 2005.

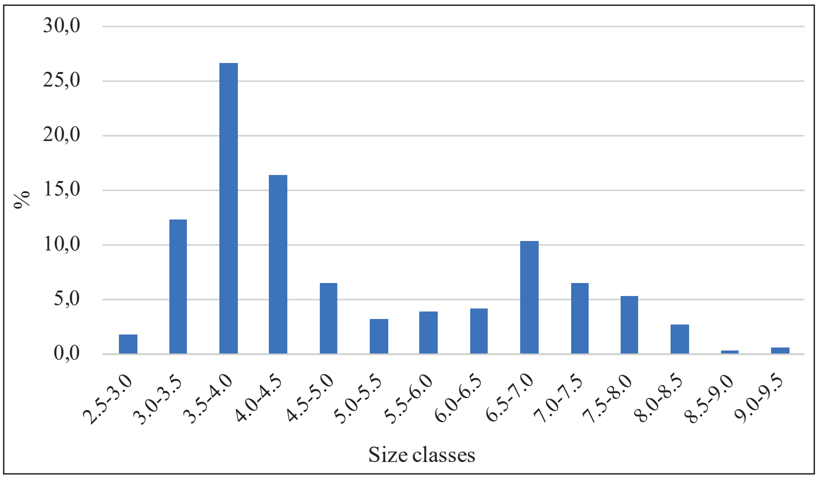

Fig. 5 Relative frequencies of size classes (SL cm) of the small clupeids based on the width of the basioc cipitals from Harfleur, pit 3116 (W. Wouters)

Remains of whiting (*Merlangius merlangus*) were dominated by vertebrae. At least four specimens could be distinguished, with sizes between 6 and 14 cm SL using dentaries and premaxillae.

Garfish (*Belone belone*) was only represented by vertebrae belonging to at least two specimens of 20–25 cm and 35–40 cm SL, respectively. A total of 48 first precaudal vertebrae of pipefishes (*Syngnathus* sp.) were counted, which measured between 10 and 15 cm SL. Species identifications were tried based on the preopercular, but the distinction between greater pipefish (*Syngnathus acus*) and Nillson's pipefish (*Syngnathus rostellatus*) seems doubtful when relying on this element. Two caudal vertebrae were identified as red mullet (*Mullus* sp.). They represent two specimens of 8–10 and 10–12 cm SL, respectively. Bones with the typical texture of the neurocranium of searobins (Triglidae) were rare. The size for these specimens mainly varied between 5 and 12 cm SL, and a slightly larger fish of 14–16 cm SL was also present. Sand lances (Ammodytidae) were well represented in the assemblage, with 96 specimens estimated to be between 6 and 12 cm SL. The finer dorsal neural arch on the first vertebra permits a certain identification as small sand eel (*Ammodytes tobianus*). Gobies (Gobiidae) were abundant in the material with a count of 280 first precaudal vertebrae. These specimens measured between 2 and 8 cm SL. Any species identification was impossible, even using some complete dentary, hyomandibular or other head elements. The eelpout (*Zoarces viviparus*) is represented by two caudal vertebrae that differed a bit in size. However, they could belong to one and the same specimen between 10 and 14 cm SL, so the MNI of 1 was retained. The shorthorn sculpin (*Myoxocephalus scorpius*) was recognised from two preoperculars and a precaudal vertebra. At least two specimens were distinguished of 6–8 and 8–10 cm SL. Hooknose (*Agonus cataphractus*) is rather easy to identify due to the typical pattern of the scales and head bones. Scales were abundant but could not be used to estimate size or MNI. Two larger left preoperculars were found from specimens of 9–11 cm SL. Five right frontals were of specimens between 3 and 6 cm SL, so the MNI is 7. Two pelvic bones of the three-spined stickleback (*Gasterosteus aculeatus*) were found. They belong to two different fish of around 3–5 cm SL. The dragonet (*Callionymus lyra*) is represented by a single precaudal vertebra of a fish of 5–6 cm SL.

Plaice (*Pleuronectes platessa*) was identified using the prefrontal and frontal bone and the dentary, but the anal bone (specifically, the first anal pterygiophore) was the most abundant. A total of 39 juvenile specimens were present, with reconstructed lengths of 5–12 cm SL. Flounder (*Platichthys flesus*) was also best represented by the os anale, with 23 individuals of the same size. The sole (*Solea solea*) is identified by one articular and some caudal vertebrae. At least three specimens are present, with two specimens between 6 and 10 cm SL and one of 14–16 cm SL.

Three basioccipitals of eel (*Anguilla Anguilla*) were found, and additional size classes were found by measuring the precaudals present in the material. The eight eels measured between 14 and 30 cm SL, with each specimen representing a 2 cm size interval to exclude overlap. Two pharyngeal bones of small cyprinids were found in the 1 mm fraction. The two pharyngeal plates differ in size, which means that two individuals are present; their size was estimated at around 3 cm SL for the smallest one and 4 cm SL for the second specimen. The shape of the bones is rather similar to that of bleak (*Alburnus alburnus*), but the three small teeth in the second row and the large alveoli in the lateral side are the criteria used to identify these bones as rudd (*Scardinius erythrophthalmus*).

Discussion

Species composition

Sand shrimps are known to live in soft bottoms consisting of sandy or muddy substrates[18], which are typical for estuarine environments and beaches.

The fish assemblage consists of a mix of pure marine species, some migratory with anadromous and catadromous patterns, and only one freshwater species. However, almost all fish are juvenile and typically found in an estuarine environment, which serves as a spawning area and later on as a nursery ground. It is well documented that the tides maintain a rich nutritional level in the estuary, while the vegetation serves as cover for the small fish against larger preying ones[19]. This applies to sharks and rays as well. Poll[20] mentions only the smooth-hound (*Mustelus mustelus*) as present in Belgian waters. However, recent research suggests that this is a misidentification[21]. The differentiation based on the absence or presence of white spots is not maintained, and all catches must be labelled as starry smooth-hound. This shark is regularly seen in estuaries[22] and lives close to the shore[23]. They move inshore in spring and return in winter to deeper and warmer waters in the Irish Sea. The angel shark lives close to the shore on sandy bottoms[24], while the thornback ray lives close to the beach in summer and retreats into deeper water in winter[25]. According to Gilson[26], juveniles were often found in the nets of shrimp fishers. Heessen[27] states that this species can also be found in shallow estuarine middens.

Juveniles of herring are abundant throughout the year and can be easily caught in shrimp nets on beaches or in the estuary[28]. These juveniles can stay in the coastal marine environment but often enter the estuary, which is the principal nursery ground[29]. Juveniles from shad, whiting, garfish, searobins and flatfishes are typical for the estuarine environment[30]. Immature eels (*Anguilla anguilla*) are often found close to the beaches, with the eel bones found likely belonging to resident males who stay close to the estuary, while females tend

18 Campos – van der Veer 2008.
19 Titmus et al. 1978.
20 Poll 1947.
21 Farrell et al. 2009.
22 Heessen et al. 2015.
23 Poll 1947.
24 Poll 1947; Roux 1984.
25 Poll 1947.
26 Gilson 1921.
27 Heessen 2015.
28 Poll 1947; Heessen et al. 2015.
29 Titmus et al. 1978.
30 Poll 1947; Heessen et al. 2015.

to live farther inland. Sizes around 25 cm TL are typical for the North Sea ecoregion[31]. The other marine species represent a mix of juveniles and adults that are known to live on the sandy bottoms of estuarine waters and shallow coastal waters. Their presence in estuarine middens is well documented in studies inventorying the fish component of the estuaries, such as those conducted for the river Severn in Great Britain[32], the Seine in France[33], the Scheldt Basin between Belgium and the Netherlands[34] or the Elbe in Germany[35], among many others.

Rudd prefer shallow waters but tolerate higher salt concentrations and can even be found in the brackish water of the Baltic[36]. Considering this information, we can conclude that these fish were captured rather close to the coast where the salinity is too high for most freshwater fish[37]. The species composition combined with size ranges indicates that these fish were caught near the transition of the estuary and the sea, in other words, in the vicinity of the site of Harfleur. The presence of a few species of elasmobranch fish supports this statement. Sharks and rays are vulnerable to lower salt concentrations[38]. The high dominance of herring indicates that this schooling fish was the real target of the catch, and all other fishes must be seen as bycatch.

Seasonality

The presence of numerous sand shrimp is an indication that this catch was captured sometime between May and September. This species moves from deeper waters in winter to the warmer, shallower regions in the estuary in summer[39]. Although this species spawns year-round, the size classes present also support this thesis. The very small numbers of the delta prawn, on the other hand, are also typical of this period. This species moves deeper inland in summer to escape the higher salinity of the outer estuary[40]. Newborn specimens of the angel shark are about 30 cm long at birth, around July[41], which corresponds with the remains found here. The presence of the juvenile smooth-hound and the thornback ray are also typical for summer. Juveniles of *Alosa* sp. occupy inshore areas from mid-May to mid-September[42].

The size of the herring indicates that we are dealing with the larval stage of this species. The whitebait fishery in the estuary of the Thames yielded high catches dominated by young herring in the months of June and July[43]. A similar tendency was found for the Elbe by Thiel[44]. Maes et al.[45] showed that high numbers of larvae of both sprat and herring reached the Zeeschelde from May onwards, and Breine et al.[46] illustrated that juvenile herring from the Scheldt estuary measured 4–5 cm TL in April while growing to around 7 cm TL in July. A similar pattern is attested by Titmus et al.[47]. Juvenile plaice are only found in waters between 0 and 10 m deep, close to the coast. The growth pattern of rudd is similar to that of roach. A length of 3–4 cm is attained at the end of the first year, as rudd spawns in the months

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31 Heessen et al. 2015.
32 Claridge et al. 1986.
33 Mouny et al. 1998.
34 Maes et al. 1998.
35 Thiel 2011.
36 Duncker 1960.
37 Maes et al. 1998.
38 Whitfield 1999.
39 Campos – van der Veer 2008.
40 Cartaxana 2014.
41 Poll 1947; Roux 1984.
42 Heessen et al. 2015.
43 Wheeler – Jones 1989.
44 Thiel 2011.
45 Maes et al. 2000.
46 Breine et al. 2020.
47 Titmus et al. 1978.

April to July, depending on the water temperature[48]. All indications point to the harvest of this shrimp and fish assemblage in early summer, more precisely around May/June.

A supporting argument for placing the preparation of this fish sauce in early summer is the prevailing temperature. It is evident that temperatures between late autumn and early spring are too low to process these fish sauces without heating[49]. The temperatures in northern Gaul during the high summer were high enough for the processing of fish sauces made of small fish. Higher temperatures will support the dissolution and hydrolysation of the flesh of fish into the final product of *garum*. Experiments by Driard[50] proved that fish sauces could be produced in normal summer conditions on the coast of Gallia Lugdunensis, which is approximately 200 km farther south. In the event that weather conditions were unfavourable, extra heat would be added. The building in Harfleur where the fish sauce remains were found contained two low temperature ovens that could have been used to accelerate the fermentation[51]. It is thought that this installation was in use during periods when outside temperatures were too low for a natural fermentation to occur. The oven could raise the temperature of the brine by a few degrees, so the small fish could disintegrate faster. Heat also increased the nutritional level of protein in the fish sauce[52].

Fishing method

Sand shrimps are bottom dwellers and do not move in the water column. Fish, by contrast, move on a daily basis. It is well known that herring moves in a vertical way from the bottom during the day to feed on the surface at night[53]. Gobies move in the opposite direction[54]. Given the size of the sand shrimp and fish in this assemblage, it is clear that a net with a fine mesh was used to collect the catch. However, the exact construction of the net is difficult to determine. Perhaps it was a type of seine net[55], which could collect both bottom-dwelling and more pelagic fish in the same movement. However, different techniques were used in the whitebait fishery in the Thames over the last 200 years[56], sometimes directed at catching pelagic fish, and at other times bottom-dwellers.

An update of local marine fish sauce assemblages in Gaul

Van Neer[57] provides an overview of four sites from Belgium and seven sites from Great Britain were the marine fish remains attest to the local production of Roman fish sauce. Ten assemblages are dominated by clupeids. The site of Arlon in the French part of Belgium is the only outlier, where the remains of flatfish (MNI = 24) are almost equal to the clupeids (21) in terms of MNI[58].

Since this publication, several other assemblages have been discovered and studied. Excavations in Asse-Nerviersstraat[59] contained traces of fish sauces from six different contexts, broadly dated to the Roman period. The marine assemblage came from small-sized clupeids,

48 Kottelat – Freyhof 2007.
49 Grainger 2021.
50 Driard 2014.
51 Oueslati 2017.
52 Grainger 2021.
53 Poll 1947.
54 Maes et al. 1998.
55 As illustrated in Delaval – Sternberg 2007.
56 Wheeler 1979.
57 Van Neer et al. 2010.
58 Details can be consulted in Van Neer et al. 2010, 176 tab. 3.
59 Udrescu – Van Neer 2012.

gobies, pipefishes and unidentified flatfish. Ervynck et al.[60] mentioned a sample of a concentration of small fish bones found in a water well in Oudenburg. It is interpreted as remains of a fish sauce made from several species, including herrings and other clupeids, sand smelts (*Atherina presbyter*), bass (*Dicentrachus labrax*), pipefishes, sand eels, gobies, flatfishes, smelt (*Osmerus eperlanus*) and three-spined sticklebacks. From all the sites mentioned above, only the Arlon assemblage[61] also contained numerous fragments of shrimps and crabs together with some herbs[62].

A particular assemblage, with abundant remains of crustacea, came from the port of the Roman city of Ratiatum[63]. This port is situated in the inner estuary of the river Loire, approx. 250 km south of Harfleur, which explains the difference in the species spectrum here. Most of the remains belong to delta prawn (96 %), and only 4 % were identified as sand shrimp. This reversed result is probably connected with the place of fishing in the inner versus the outer estuary. These finds were associated with fish remains of small marine species, mainly anchovies (*Engraulis encrasicolus*), Gobiidae and Syngnathidae. There is an important spawning area in the region for anchovies[64].

All these sites seem to be oriented towards small-scale production of *garum*. In the absence of large production structures such as vats or larger assemblages of *garum* filtration residue, there are no indications for large-scale production of *garum*.

In contrast to the previous sites, Driard[65] describes the remains of a *garum* factory in Etel, La Falaise (Brittany, France), where four storage vats for mass production of the sauce were discovered. The fish remains in two of them were identified as sardine. Since then, several new sites for massive production have been found in the Bay of Douarnenez[66]. The targeted species was also sardine, a schooling species with a large spawning area near the North of Bretagne[67]. Remains of crustaceans are absent in these contexts, given the pelagic nature of the main target, the sardine. The rocky bottoms in this region obstruct the use of nets for the catch of demersal. Remains of amphorae are not mentioned for these sites, which suggests that the sauce was transported in materials that did not survive. Casks made of wood were suggested by Van Neer[68], a material that does not preserve well in dry middens and which was probably used in the whole region.

Conclusion

The animal remains studied in this article provide new insight into the local production of *garum* in Gaul. The fish sauce residue from Harfleur is now the oldest find of such a production in Gaul, made somewhere between the end of the 1st century to halfway into the 2nd century AD at the latest. The species composition indicates that this catch was made somewhere in May or June, a period when the weather was more favourable for decomposing the fish into *garum*.

Regional habitat differences had a huge impact on the species composition used for the production of fish sauce. In some regions only pelagic species were targeted, while sandy bottoms allowed all fishes in the water column to be caught. In the latter, shrimp remains are not rare, although the abundance in this assemblage is spectacular. In the Loire Basin fishing

60 Ervynck et al. 2017.
61 Van Neer et al. 2010.
62 Derreumaux et al. 2011.
63 Borvon 2017; Borvon – Gruet 2018; Borvon 2020.
64 Quéro 1997.
65 Driard 2008.
66 Driard 2014.
67 Quéro 1997.
68 Van Neer et al. 2010.

was concentrated on anchovies. The industrial production region of the Bay of Douarnenez took advantage of the spawning area of the sardine nearby.

Thus far, the evidenced small-scale production of *garum* in northern Gaul was mainly based on fishes like sprat and herring, which are typically species that spawn further to the north. The bycatch of these targeted species was processed without any prior sorting of the catch.

The mix of a high proportion of delta prawn combined with the fish bones is attested for the Loire, while sand shrimps and fish are now proven for the Seine estuary. Catching methods were specific for each region. In estuaries, some kind of seine nets must have been used, while the rocky bottom of the Bay of Douarnenez prevented the catching of the bottom feeders.

The site of Harfleur is remarkable in comparison with other regional coastal sites due to the mastering of fishing techniques allowing very large fish to be caught and the presence of consumers enjoying the consumption of cod but also of smaller fish, eaten fresh in some instances and transformed into *garum* in others. Harfleur can be considered an urban settlement with a population that fully embraced the innovations in the diet brought in under the influence of Romanisation.

Appendix

A critical analysis of the effects of subsampling in a closed context

A question often raised in our midden concerns how much material must be identified to reach sound conclusions. It is clear that the study of all material has advantages but the time invested is not necessarily reflected in better interpretations. Subsampling will affect species composition, that is clear. The 2 mm fraction was small and contained already 15 taxa. If we compare the 5 different samples for the 1 mm fraction seen as singular entities (tab. 2), the number of taxa present varies lightly between 11 (sample C) versus 14 and 15 for sample A and B. These are all samples containing 10 %. The bigger sample D (20 %) shows 18 taxa just as the last, big sample (the remaining 50 %). For a total of 24 taxa, present in the 1 mm material, seven taxa were only found in a single sample: sardine, shorthorn sculpin, porgies, mullets, grey mullets, viviparous blenny and dragonet. We may indeed conclude that subsampling has an effect on the number of taxa present in a heterogenous closed context.

However, the number of taxa in itself is not the most important question here. All studies mentioned above about the recent fish fauna in the inner estuaries list far more than the 25 taxa present in this study. If we look at the relative frequency of the species, subsampling will not change the general interpretation (tab. 3). Dependent on the size of the different subsamples we took of 10 % (sample A, B and C), 20 % (D + E) or 50 % (F), the MNI of herring varies between 2480 and 3180, which is quite a big difference. However, if we look to the proportions of herring within each sample, these vary between 80.2 % (B) and 86.9 % in sample A. The numbers of small sand eel vary between 2.2 and 4.9 % and those for the gobies between 4.6 and 11.1 %. The proportional score for these three species is best represented by subsample D + E compared to the global study of this material (see also tab. 1). The score of herring shifts only 1 %, small sand eel 0.6 % and gobies 1.9 %. Which means that the general interpretation would always be maintained. Of course, such reasoning can only be applied to a closed context like this residue of a fish sauce and not to open contexts like latrines or fish remains recovered over a huge surface.

Effects of the 0,5 mm content: to study or to ignore?

A quick scan was made of the material left on the 0.5 mesh. Therefore 3.5 g (or 5 %) of a total of 69 g was searched for additional specimens. Only one extra prooticum of herring

Table 2 MNI for all species in each subsample, estimated as separate samples

NISP	2 mm	1 mm				
Species	100 %	A 10 %	B 10 %	C 10 %	D + E 20 %	F 50 %
Mustelus asterias (smooth-hound)	1					
Squatina squatina (monkfish)	1	1		1		
Raja clavata (thornback ray)		1	1		1	1
Batoidea (rays)	1					
Alosa sp. (shad)	2		2		2	2
Sardina pilchardus (sardine)						1
Clupeidae (herring/sprat)	52	318	312	248	572	1288
Merlangius merlangus (whiting)	1	2	2	2	4	2
Belone belone (garfish)	2	1	1		2	2
Sygnathus sp. (pipefish)		4	6	4	8	15
Triglidae (searobins)	2	1	1		2	1
Myoxocephalus scorpius (shorthorn sculpin)	2		1			
Agonus cataphractus (hooknose)	2	1	1	1	2	3
Sparidae (porgies)						1
Mullus sp. (red mullets)	2			1		
Mugilidae (grey mullets)						1
Ammodytes tobianus (small sand eel)		8	9	10	21	77
Gobiidae (gobies)		17	43	25	43	136
Zoarces viviparus (viviparous blenny)					1	
Gasterosteus aculeatus (three spined stickleback)					1	1
Callionymus lyra (dragonet)					1	
Pleuronectes platessa (plaice)	6	5	3	4	4	27
Platichthys flesus (flounder)	4	3	3	1	6	12
Solea solea (sole)	1		2		2	2
Anguilla anguilla (eel)	3	3	2	3	5	7
Scardinius erythrophthalmus (rudd)		1			1	
Number of taxa	15	14	15	11	18	18

Table 3 MNI and relative frequency for the three main species in the 1 mm material for each subsample

	A	B	C	D + E	F
	absolute MNI reconstructed to 100 %				
Clupeidae (herring/sprat)	3180	3120	2480	2860	2576
Ammodytes tobianus (small sand eel)	80	90	100	105	154
Gobiidae (gobies)	170	430	250	215	272
	proportional percentage				
Clupeidae (herring/sprat)	86.9	80.2	82.7	84.4	81.6
Ammodytes tobianus (small sand eel)	2.2	2.3	3.3	3.1	4.9
Gobiidae (gobies)	4.6	11.1	8.3	6.3	8.6

was found which indicates that the estimated MNI for this species is not affected. Another 12 basioccipitales of herring were found and measured when possible. All extra size reconstructions indicated fishes between 3 and 5 cm SL which reinforce the previous results (see fig. 5). The most abundant size classes between 3 and 4,5 cm SL will just dominate more explicitly if more material from the smallest mesh would have been measured. Only two other species were identified. Another 10 first precaudals of sand lances were found as well as 9 of gobies. If we correct the MNI for these fishes, we should add another 200 small sand eels and 180 gobies to our list. The relative frequency for herring would in that case decrease from 83 to 75 % while the sand lances rise from 3.7 to 8 % and the gobies from 8 to 12 % respectively. If all material would have been studied, these three fishes still dominate the assemblage with 95.9 % which is approximately the score for the 2 + 1 mm (95 %). Again, the shift would only be minimal if we studied the 0.5 mm in a higher proportion while the amount of work would raise in time. In conclusion, the 0.5 mm fraction is not really affecting the results of the research[69].

Bibliography

Boisson 2015 — J. Boisson, Harfleur Seine-Maritime, »Les coteaux du Calvaire«. Rapport d'opération d'archéologie préventive, 2. Descriptions des découvertes (hors nécropole mérovingienne) (Linselles 2015).

Borvon 2017 — A. Borvon, Les poissons du port romain de Ratiatum (Rezé, Loire-Atlantique): espèces consommées, sauces et techniques de pêche, in: R. González Villaescusa – K. Schörle – F. Gayet – F. Rechin (eds.), L'exploitation des ressources maritimes de l'Antiquité. Activités productives et organisation des territoires. XXXVII[e] Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. XII[e] Colloque de l'Association AGER (Antibes 2017) 23–40.

Borvon 2020 — A. Borvon, Étude archéozoologique du quartier portuaire romain de Saint-Lupien à Rezé/Ratiatum (Loire-Atlantique). Les vestiges fauniques en pied de berge, Gallia 77, 1, 2020, 163–182.

Borvon – Gruet 2018 — A. Borvon – Y. Gruet, Découverte exceptionnelle de restes de Crevettes (Crustacés Décapodes) dans les niveaux du port romain de Ratiatum (Rezé, Loire-Atlantique), ArcheoSciences 42, 1, 2018, 7–15.

Borvon – Gruet 2024 — A. Borvon – Y. Gruet, Crevettes marines et dulcicoles: critères d'identification des restes archéologiques. Application au quartier portuaire romain de Saint-Lupien à Rezé/Ratiatum (Loire-Atlantique, France), Archaeofauna 33, 1, 2024, 101–122.

Breine et al. 2020 — J. Breine – L. Galle – I. Lambeens – Y. Maes – T. Terrie – G. Van Thuyne, Monitoring van de visgemeenschap in het Zeeschelde-estuarium. Ankerkuilcampagnes 2019, Rapporten van het Instituut voor Natuur- en Bosonderzoek 4 (Brussels 2020); DOI:10.21436/inbor.17680566

Campos – van der Veer 2008 — J. Campos – H. W. van der Veer, Autecology of *Crangon Crangon* (L.) with an emphasis on latitudinal Trends, Oceanography and Marine Biology 46, 2008, 65–104.

Cartaxana 2014 — M. A. S. D. Cartaxana, Biology and ecology of the white prawn *Palaemon longirostris*, H. Milne Edwards, 1837 (Crustacea, Decapoda, Palaemonidae) in the Mira River, Portugal (PhD thesis Universidade de Lisboa, Lisbon 2014).

Claridge et al. 1986 — P. N. Claridge – I. C. Potter – M. W. Hardisty, Seasonal changes in movements, abundance, size composition and diversity of the fish fauna of the Severn estuary, Journal of the Marine Biological Association of the United Kingdom 66, 1986, 229–258.

Delaval – Sternberg 2007 — E. Delaval – M, Sternberg (eds.), Garum et Pissalat. De la pêche à la table, mémoires d'une tradition. Exhibition catalogue Antibes (Antibes 2007).

Derreumaux et al. 2011 — M. Derreumaux – F. Pigière – W. Wouters – W. Van Neer, Arlon/Arlon. Une sauce de poissons gauloise dans le vicus d'Arlon, approche archéozoologique et carpologique, Chronique de l'Archéologie wallonne 18, 2011, 186–188.

69 However, it can never be excluded that results would change the interpretation. This is illustrated by Veeckman et al. 2000, wahere the 0.5 mm fraction contained thousands of bones from smelt (*Osmerus eperlanus*) whereas this species was almost absent in the 1 or 2 mm mesh.

Driard 2008 — C. Driard, Un établissement romain spécialisé dans les productions de salaisons et sauces de poisson à Étel (Morbihan, France), in: P. Béarez – S. Grouard – B. Clavel (eds.), XIVth ICAZ Fish Remains Working Group meeting. Archéologie du poisson. 30 ans d'archéo-ichthyologie au CNRS. Hommage aux travaux de Jean Desse et Nathalie Desse-Berset. XXVIIIe rencontres internationales d'archéologie et d'histoire d'Antibes (Antibes 2008) 237–244.

Driard 2014 — C. Driard, Les sauces de poisson dans l'ouest de la province de Lyonnaise: réflexions sur l'élaboration et la nature des produits, in: E. Botte – V. Leitch (eds.), Production and commerce of salsamenta during Antiquity, Bibliothèque d'Archéologie Méditerranéenne et Africaine 17, 2014, 47–60.

Duncker 1960 — G. Duncker, Die Fische der Nordmark (Hamburg 1960).

Ervynck et al. 2017 — A. Ervynck – B. De Cupere – M. Fret – A. Lentacker – L. Massagé – M. Udrescu – S. Vanhoutte – W. Wouters – W. Van Neer, Het *castellum* aan het eind van de wereld. Vlees en vis voor de soldaten te Oudenburg, Signa 6, 2017, 41–45.

Farrell et al. 2009 — E. D. Farrell – M. W. Clarke – S. Mariani, A simple genetic identification method for Northeast Atlantic smoothhound sharks (*Mustelus* spp.), ICES Journal of Marine Science 66, 2009, 561–565.

Gilson 1921 — G. Gilson, Les poisons d'Ostende (Brussels 1921).

Grainger 2021 — S. Grainger, The story of garum fermented fish sauce and salted fish in the ancient world (London 2021).

Gravendeel et al. 2002 — R. Gravendeel – W. Van Neer – D. Brinkhuizen, An identification key for dermal denticles of Rajidae from the North Sea, International Journal of Osteoarchaeology 12, 6, 2002, 420–441.

Heessen et al. 2015 — H. J. L. Heessen – N. Daan – J. R. Ellis, Fish atlas of the Celtic Sea, North Sea, and Baltic Sea (Wageningen 2015).

Kottelat – Freyhof 2007 — M. Kottelat – J. Freyhof, Handbook of European Freshwater Fishes (Berlin 2007).

Maes et al. 1998 — J. Maes – P. A. Van Damme – A. Taillieu – F. Ollevier, Fish communities along an oxygen-poor salinity gradient (Zeeschelde Estuary, Belgium), Journal of Fish Biology 52, 1998, 534–546.

Maes et al. 2000 — J. Maes, The structure of the fish community of the Zeeschelde estuary (PhD thesis Katholieke Universiteit Leuven 2000).

Mouny et al. 1998 — P. Mouny – J. C. Dauvin – C. Bessineton – B. Elkail – S. Simon, Biological components from the Seine estuary. First results, Hydrobiologia 373/374, 1998, 333–347.

Poll 1947 — M. Poll, Poissons marins (Brussels 1947).

Quéro 1997 — J.-C. Quéro, Les poissons de mer des pêches françaises (Lausanne 1997).

Oueslati 2017 — T. Oueslati, Aller à la pêche au gros et produire du garum à l'époque romaine dans le Nord de la Gaule, in: R. González Villaescusa – K. Schörle – F. Gayet – F. Rechin (eds.), L'exploitation des ressources maritimes de l'Antiquité. Activités productives et organisation des territoires. XXXVIIe Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. XIIe Colloque de l'Association AGER (Antibes 2017) 41–56.

Roux 1984 — C. Roux, Squatinidae, in: P. J. P. Whitehead – M.-L. Bauchot – J.-C. Hureau – J. Nielsen – E. Tortonese (eds.), Fishes of the North-Eastern Atlantic and the Mediterranean 1 (Paris 1984) 148–152.

Serra-Pereira et al. 2005 — B. Serra-Pereira – P. Figueiredo – P. Bordalo-Machado – I. Farias – T. Moura – L. S. Gordo, Age and growth of *Raja clavata* Linnaeus, 1758. Evaluation of ageing precision using different types of caudal denticles, International Council for the Exploration of the Sea Conference and Meeting 17 (Copenhagen 2005).

Thiel 2011 — R. Thiel, Die Fischfauna europäischer Ästuare. Eine Strukturanalyse mit Schwerpunkt Tideelbe (Hamburg 2011).

Thieren et al. 2012 — E. Thieren – W. Wouters – W. Van Neer – A. Ervynck, Body length estimation of the European eel Anguilla anguilla on the basis of isolated skeletal elements, Cybium. International Journal of Ichthyology 36, 4, 2012, 551–562.

Titmus et al. 1978 G. Titmus – P. N. Claridge – I. C. Potter, Growth and abundance of O-group herrings, *Clupea harengus* L., in the Severn Estuary, Zoological Journal of the Linnean Society 64, 3, 1978, 251–260.

Udrescu – Van Neer 2012 M. Udrescu – W. Van Neer, Asse-Nerviërsstraat 2009–2010. Archeozoölogisch onderzoek (Brussels 2012).

Van Neer et al. 2005 W. Van Neer – W. Wouters – A. Ervynck – J. Maes, New evidence from a Roman context in Belgium for fish sauce locally produced in northern Gaul, Archaeofauna 14, 2005, 171–182.

Van Neer et al. 2010 W. Van Neer – A. Ervynck – P. Monsieur, Fish bones and amphorae. Evidence for the production and consumption of salted fish products outside the Mediterranean region, JRA 23, 2010, 161–195.

Veeckman et al. 2000 J. Veeckman – W. Van Hoof – B. Cooremans – A. Ervynck – W. Van Neer, De inhoud van de afvalput van de Groote Schalien Loove. Speuren naar de 17de-eeuwse bewoners. Brabom – Berichten en Rapporten over het Antwerps Bodemonderzoek en Monumentenzorg 4, 2000, 115–190.

Wheeler 1979 A. Wheeler, The Tidal Thames. The History of a River and its Fishes (London 1979).

Wheeler – Jones 1989 A. Wheeler – A. K. G. Jones, Fishes (Cambridge 1989).

Whitfield 1999 A. K. Whitfield, Ichthyofaunal assemblages in estuaries. A South African case study, Reviews in Fish Biology and Fisheries 9, 1999, 151–186.

Wouters et al. 2007 W. Wouters – L. Muylaert – W. Van Neer, The distinction of isolated bones from plaice (*Pleuronectes platess-a*), flounder (*Platichthys flesus*) and dab (*Limanda limanda*). A description of the diagnostic characters, Archaeofauna 16, 2007, 33–95.

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Archaeoichthyological Materials from the Scythian-Era Site of »Konsulivs'ke Settlement« (1st Cent. BC – 2nd Cent. AD, Kherson Region, Ukraine)

Yevheniia Yanish

Abstract

In the course of the work, a site from the Scythian era, the Konsulivs'ke settlement, was investigated. An archaeozoological collection with a total number of 2149 remains of animal origin has been studied. Fish made up 7.7 % of all remains, and seven species of fish were found at the settlement: catfish, pike, vyrezub, roach, bream, carp and pikeperch. Animal husbandry was well developed in the Konsulivs'ke settlement, while there was most likely no poultry farming. Hunting and fishing were also an important source of food for the settlement.

Introduction

The practice of fishing among the Scythians is a question that interests many researchers. The number of fish bones that are usually found at monuments from the Scythian period is very small. Sometimes this is due to the fact that the bones were poorly preserved in the ground, and sometimes to an insufficiently good selection of material even at the stage of excavation.

Osteological material was obtained as a result of excavations of the Konsulivs'ke settlement (1st cent. BC – 2nd cent. AD), located within the territory of the modern Kherson region (fig. 1). The figure 1 shows the most famous archaeological sites (mounds and settlements of the Scythian era), located near the Konsulivs'ke settlement.

It is located on a high, steep slope of the plateau on the right bank of the Kakhovsky Reservoir. The plateau on which the settlement is located gradually descends to the water (slope angle 7°) and ends with a steep slope (slope angle 26°), the last 10 m of which is a vertical cliff[1]. On the other side of the Dnieper is the Kamens'ke settlement, which in the 4th–3rd centuries BC was the capital of the Scythians. The site is single-layer, bounded on both sides by beams perpendicular to the water. Similar topographical conditions were observed for the Annovs'ke settlement[2]. The obtained material is typical for the Late Scythian settlements of the Lower Dnieper region. A large number of Scythian mounds are also located in the Middle Dnieper. Some researchers associate these territories with the chronicled Γέρρος described by Herodotus, where the royal Scythians lived[3].

Now this territory is located near the zone of active hostilities, and any work on the monument is impossible. Given the massive mining of territories, the resumption of archaeological work in this area will not be possible for some time to come.

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1 Nikonenko 2015.

2 Gavrilyuk – Abikulova 1991.

3 Mishchenko 1888.

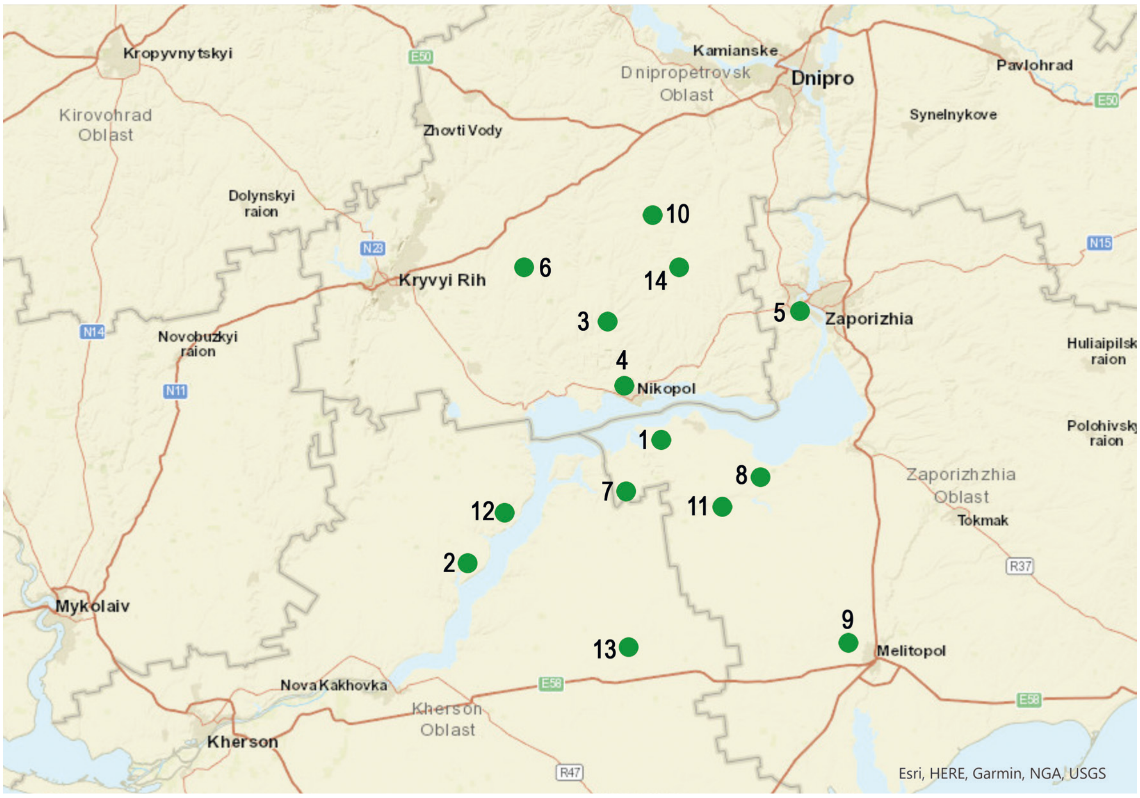

Fig. 1 The most famous burial mounds and settlements of the Scythian time, including the Konsulsvs'ke settlement. 1: Kamjanske settlement; 2: Konsulivs'ke settlement; 3: Chortomlyk; 4: Nikopol; 5: Zaporizhzha; 6: Tovsta Mogyla; 7: Soloha; 8: Hajmanova Mohyla; 9: Melitopol barrow; 10: Oleksandropil'skyj barrow; 11: Velyka Tsymbalka; 12: Kozel; 13: Oguz; 14: Nechayeva barrow (source: ESRI, HERE, Garmin, NGA, USGS)

Materials and methods

In 2016, during archaeological excavations, 924 remains of animal origin from this site were found and studied. In 2018, 1023 remains from the same site were examined. The remains of fish were identified by comparing bone fragments with specimens of modern and sub-fossil species from the collection of the National Museum of Natural History of the National Academy of Sciences of Ukraine. The size of the fish was calculated according to the method described by V. Lebedev[4], then the length and weight were reconstructed. Determination of age was carried out on the basis of scales and vertebrae.

Results

During the work, it was found that mammals took first place in terms of the number of remains at 91.2 %; fish accounted for 7.7 %; birds, 0.5 %; and molluscs, 0.6 % (fig. 2). In earlier works we came to the conclusion that there were nine main commercial species in the northern Black Sea region: sturgeon (*Acipenser guldenstadti*, Brandt – Ratzeburg 1833), stellate sturgeon (*Acipenser stellatus*, Pallas 1771), sterlet (*Acipenser ruthenus*, Linnaeus 1758), beluga (*Huso huso*, Linnaeus 1758), catfish (*Silurus glanis*, Linnaeus 1758), carp (*Cyprinus carpio*, Linnaeus 1758), bream (*Abramis brama*, Linnaeus 1758), pikeperch (*Sander lucioperca*, Linnaeus 1758) and vyrezub (*Rutilus frisii*, Nordmann 1840)[5]. According to our preliminary

4 Lebedev 1960.
5 Bylkova – Yanish 2010.

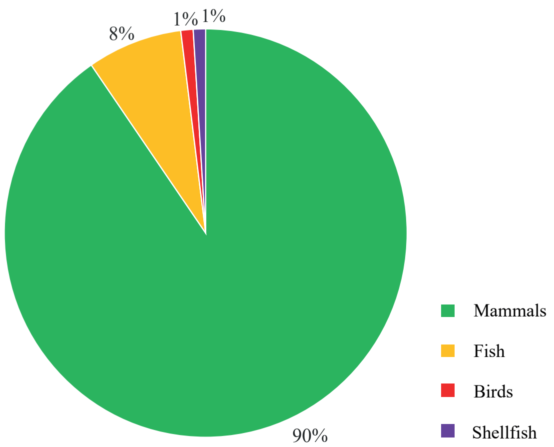

Fig. 2 The ratio of fish, birds, mollusks and mammals in archaeozoological materials from the Konsulivs'ke settlement (Y. Yanish)

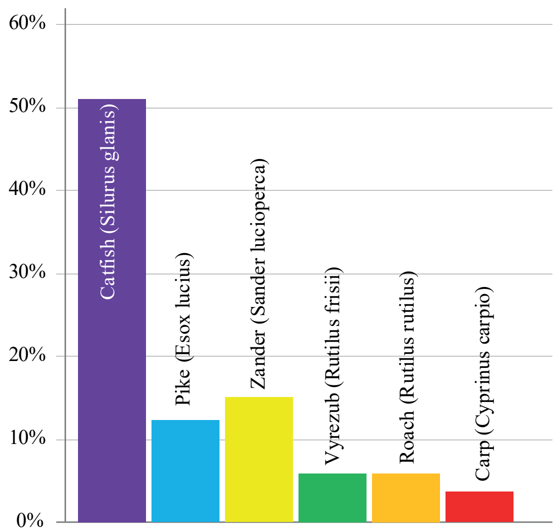

Fig. 3 Species composition of fish from the archaeozoological collection from the Konsulivs'ke settlement (Y. Yanish)

data, in ancient times, sturgeon and catfish were of the greatest importance for the local population in the northern Black Sea region.

At the same time, all the species found by us at the Konsulivs'ke settlement also fall into the list of commercial species published by us earlier, except for Acipenseridae. We did not find them at this site, but these species were well known to the Scythians. In total, seven species of fish were found at the Konsulivs'ke settlement: catfish, pike (*Esox lucius*, Linnaeus 1758), vyrezub, roach (*Rutilus rutilus*), bream, carp and zander.

In first place in terms of the absolute number of remains in the material (fig. 3), catfish accounts for 51.0 % of all detectable fish remains (n = 41); zander is in second place at 15.0 % (n = 12) and pike is in third place with 12.3 % (n = 10). The sample is not sufficient to determine a reliable ratio of species, but it does allow the main commercial species to be identified and reflects the main trends.

It is also important to take into account the number of bones of the cranial and post-cranial skeletal elements when analysing the materials, since separation of the head from the body usually increases the shelf life of fresh fish without special preservation methods (salting or drying). If the fish were cut and gutted in advance, for example for sale, then the cranial bones (head bones) would either not get into the material, or they would be found in insignificant quantities[6]. The presence of both cranial and post-cranial skeletons of fish bones in the material from the site indirectly indicates that the fish were caught near the settlement and were not transported over long distances.

Also, when it was possible, we determined the age of individuals and reconstructed the length, weight and age. Naturally, fishing for the largest in size and most widespread species was the most economically profitable for the inhabitants of ancient settlements. Table 1 shows ageing data for 2016; for the material from 2018 it was not possible to determine the age of the fish. The maximum number of individuals falls on 6- and 12-year-old fish (but the sample is insufficient for final conclusions). Most of the catfish were large in size, and the material does not contain vertebrae from catfish younger than 12 years old.

The age of the fish, the size of the scales and, accordingly, the size that the fish could have reached by this age suggest that (by analogy with other archaeological evidence and ethnographic data) it is most likely that these fish were caught using hook gear or nets with a mesh of medium and large size.

6 Bylkova – Yanish 2010.

Table 1 Age ratio of fish from the Konsulivs'ke settlement, 2016

Species	Age, years											
	5 +	6 +	7 +	9 +	10 +	11 +	12 +	13 +	15 +	20 +	30 +	Total
Catfish							1		2	2	1	**6**
Carp					1							1
Pike				1								1
Indefinable												
Vertebrae	1	3	1			1	2	1				9
Total	1	3	1	1	1	1	3	1	2	2	1	17

Images of fish from earlier sites of the Scythian steppe, including sturgeons, are well known, although we did not find remains of this particular fish at this site. By way of an example, images from Nadezhda Gavrilyuk's monograph on earlier Scythian sites are provided[7]. However, we assume that all these species, as well as fishing gear, were well known at a later time and could be actively used at the Konsulivs'ke settlement. Acipenseridae fish, like sturgeon and sterlet, lived in the Dnieper and reached Kyiv and beyond in the middle of the 20th century. The main reason for the sharp decline in their population was the construction of hydroelectric power plants along the river.

Bronze hooks, and later iron hooks, were used for catching fish over a long chronological period. For catching small fish, special traps were probably used, which are usually not preserved or have not been found in the excavated archaeological areas. Large fish (by analogy with other sites and ethnographic data) were probably caught with hook gear and nets, while spears and harpoons could be used to a lesser extent.

Based on the characteristics of faunal complexes and the species composition of fish from this site, we can assume that during the period under study, the water of the river where these species were caught contained a sufficient amount of oxygen for the habitation of an oxyphilic species such as zander, while having good transparency. In addition, the presence of carp in the material indicates the presence of areas with a slow current and a hard, slightly silty bottom. We can also say that the carp was caught in the warm season, since in winter this fish is covered with a thick layer of mucus, stops feeding and digs into the silt, making it impossible to catch during this period.

The vyrezub is a semi-anadromous fish and feeds in desalinated areas of the sea or in the brackish mouths of large rivers (in the historical past, including the Dnieper; at present, as a result of the construction of a cascade of hydroelectric power stations, the vyrezub is not found in the Dnieper). It enters rivers for spawning and wintering. The species entered the Dnieper from March to early June and in autumn – from the second half of August/early September to the end of December. In the river, it stays in deep sections of the channel with a fast current, clear water and dense soil[8]. Thus, vyrezub specimens were probably caught during the spawning run and most likely, like the pikeperch, in the main channel of the Dnieper. Vyrezub could have been caught in one of the lakes or oxbow lakes, if there were any near the settlement.

Conclusions

Animal husbandry was well developed in the Konsulivs'ke settlement, while most likely there was no poultry farming. A large percentage of wild species along with the presence of bird and fish bones confirms the importance of hunting and fishing as an important source of food in

7 Gavrilyuk 2013.
8 Movchan 2011.

the settlement. Fish made up 7.7 % of all remains. In the first place in terms of the absolute number of remains among fish, catfish accounts for 48.5 % of all detectable remains of fish; pikeperch is in second place at 18.2 %, and pike is in third place with 12.0 %. The material is dominated by adult individuals of medium and large sizes for all species. During the study period, the water of the river where these species were caught contained a sufficiently large amount of oxygen to serve as the habitat for such oxyphilic species as pikeperch and carp, while it had good transparency.

Bibliography

Bylkova – Yanish	V. Bylkova – Y. Yanish, Борисфен найбільш корисний людям. Іхтіологічні дані з Білозерського поселення, Археологія 3, 2010, 75–81.
Gavrilyuk – Abikulova 1991	H. A. Gavrilyuk – M. I. Abikulova, Позднескифские памятники Нижнего Поднепровья (новые материалы) (Kiev 1991) 1–2.
Gavrilyuk 2013	H. A. Gavrilyuk, Экономика Степной Скифии. VI–II вв. до н. э. (Kyiv 2013).
Lebedev 1960	B. D. Lebedev, Пресноводная четвертичная ихтиофауна европейской части СССР (Moscow 1960).
Mishchenko 1888	M. Mishchenko, Herodotus. История в 9 кн (1888).
Movchan 2011	Y. V. Movchan, Риби України (Kyiv 2011).
Nikonenko 2015	D. D. Nikonenko, Пізньоскіфське Консуловське городище, Археологія 2015, 1, 91–99.

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Conclusions of the XXI Fish Remains Working Group

Alfred Galik

The twenty-first meeting of the FRWG in Vienna was of specific significance and took place in Vienna after the long and threatening pandemic that caused all the lockdowns and personal isolation. The meeting offered an excellent opportunity to meet personally and share scientific research, previously mainly done in home office and via digital exchange and collaborations. Various presentations of excellent quality at a high scientific level were presented at the meeting in Vienna. The proceedings are, of course, especially focused on ichthyoarchaeological-related contexts, which aim to lay the groundwork for the future progress of various ichthyoarchaeological studies. The excellent and international contributions bring together current scientific standards of ichthyoarchaeological subjects.

The overarching hypothesis behind most archaeoichthyological research is finding explanations for the exploitation of fish as part of human behaviour and human interaction with aquatic environments. The reconstruction of the catching and consumption of fish as an additional protein source, as well as reconstructing historic aquatic environments, is of major ichthyoarchaeological interest, i.e. what kind of fish were caught, where they were caught and the size of these fish, which supplied the demand of consumers. Therefore, contributions in this book successfully address and bring together various ichthyoarchaelogical methodological approaches, such as the possibility of fish genus/species identification or shape and size reconstructions of fish. Qualitative aspects of excavation methods are addressed, too, because they influence and bias analytical and scientific results. Bearing taphonomical influences on archaeoichthyological material in mind, and in collaboration with the historical sciences where possible, attempts are made to understand the methods of transport, preservation and catching, as well as developing methods that are easily usable for future investigations. Another important research topic is the incorporation of social aspects of consumers documented in archaeological contexts such as prehistoric settlements, Roman to medieval and modern urban and rural sites. Therefore, this book spans a wide range from technical methodological contributions to prehistoric to historically relevant ichthyological but also environmental-historical and socio-historical presentations of very important sites with archaeoichthyological relevance.

The major topic of the proceedings is fishing and fish consumption, of course, and it covers wide areas in these fields chronologically as well as environmentally and socio-historically. New prehistoric data is made available from late Neolithic pile-dwellings in more alpine regions in Austria and Slovenia, as well as results on fish exploitation in the Great Hungarian Plain from the Neolithic to modern times. The contribution on the late Neolithic underwater excavated pile-dwelling site Mooswinkel in Lake Mondsee, Austria, provided by Nikolaidou, illustrates local exploitation patterns for fish, molluscs and amphibians. The Mooswinkel site provides beneficial ichthyoarchaeological data for a better understanding of Neolithic fish exploitation in an alpine lake in Austria. The fishes reflect a range of various fishing techniques, such as near-shore fishing and net fishing in more open waters. The freshwater fishes are cyprinids, northern pike, river perch, brook trout and coregonids, which are accompanied by large quantities of mainly frog bones and mollusc shells.

Alfred Galik et al.'s contribution about the late Neolithic pile-dwelling site Stare gmajne at the Ljubljansko barje in Slovenia presents new data which appear to complement the already explored fish remains recovered from coprolites from this settlement. The intense cooperation between archaeobotany, palynology, palaeoparasitology and ichthyoarchaeology completes understanding of fish exploitation at the site. Fish remains are derived from wet-sieved sediment samples. Not only the coprolites, but also the sampled sediments from archaeological contexts revealed various small fish remains, too. The results provide further information on fishing and fish consumption provided by small fish, mainly composed of cyprinids, river perch and northern pike.

Despite the precarious circumstances in the Ukraine, a chronological presentation of a Scythian settlement close to a riverbank where fishing was of importance is contributed by Yevheniia Yanish. The archaeoichthyological results from Konsulivs'ke settlement in the Kherson region lasted from the 1st century BC to the 2nd century AD in the Kherson region. Animal husbandry appeared to be significant, but hunting and fishing were also an important source of food. The presence of several typical freshwater fishes prove fishing and maybe seasonal activities.

Wim Wouters and co-authors presented an essay on the local production of fish sauces from the Roman site Les Coteaux du Calvaire in Harfleur, Normandy, in France. The paper contributes to knowledge on the production of fish sauces, adding new elements to the other already documented components. The animal composition in samples coming from pits is extremely rich, with a massive frequency of crustaceans, along with mostly herring, gobies and sand lances. Therefore, methodological subjects such as sieving, fish size, potential fishing grounds and seasonality are addressed, too. However, this is the first record of locally produced fish sauce with so many crustaceans. Indications suggest production of the fish sauce in late spring or early summer, and the assemblage supports the role of estuarine waters as nursery places for various species. Furthermore, from a methodological point of view, the authors tested sampling methods for the fractions of the 1 mm and 0.5 mm sieve and discussed these protocols.

Despite the fact that most of the contributions deal with typical archaeological patterns such as catches and the consumption of fish, Tarek Oueslati's contribution extends the discussion of profane fish exploitation to the use of fish in late Roman funerary rituals as grave goods for the deceased at two late Roman necropoleis, Nempont-Saint-Firmin and Amiens in northern France. Numerous tombs revealed offerings of fish, which constituted part of a funerary meal along with meat-bearing parts of other animals. Plaice and flounder were used both for offerings and as food in daily life. Other species such as cod and eel were consumed too, but they are not associated with funerary rituals. Oueslati and co-authors argue that specimens can be deposited whole, but often pieces of fish are offered alongside pork or chicken and unpreserved vegetable components.

The next chapter, provided by Tatiana André, concerns contexts dating from medieval up to early modern times and covers large-scale comparative research on the exploitation and management of aquatic resources in Fos-sur-Mer, Provence, France, relying not only on archaeoichthyological results. The Fos-sur-Mer site is located on the shores of the Gulf of Fos, which is integrated into a complex hydrographic system of the Mistral. The importance of this specific but far-reaching research is that only a few studies have focused on marine resources in the medieval and modern western Mediterranean from archaeoichthyological perspectives. The contribution presents results on the consumption and procurement of marine and freshwater fish from aquatic resources, and it additionally integrates some of the results achieved in the framework of the inter-team AMORCE project »ICHT'ISOMED«.

The comparison of two late medieval and early modern Polish harbour cities presented by Urszula Iwaszczuk and Anna Gręzak sheds light on ecological, economic, geographical and social differences in the Middle Ages. The cities Puck and Gdańsk traded and were connected, but environmental and economic factors as well as diachronic changes probably caused differences in fish exploitation. The composition of fish may have differed due to the social status of the inhabitants, as well as the availability of and opportunities to acquire fish in alternative ways. In Puck local Baltic Sea and bay fisheries were important, and only some large cod may have been imported, probably from the north. In Gdańsk the deeper waters were fished, resulting in a more diverse fish composition. In contrast to Puck, in Gdańsk cod and other species may have been imported more frequently. The fish composition in Gdańsk reflects an increasing proportion of freshwater species in the later phase.

Pike remains from medieval and modern times make contemporary exploitation patterns comparable to Neolithic fishing. Last but not least, essential fishing and fish consumption behaviour, as well as the consumption of other fauna, is documented from monasteries in France and Slovakia. Aurélia Borvon presents a contribution on fish consumption at the medieval Trinité de Vendôme Abbey (Loir-et-Cher, France). What is particularly advantageous in this case is that it was possible to carry out excavations in kitchen areas, and fish bones were most abundant in sieves with a 2 mm mesh width. The most frequent species was herring, alongside other marine fishes such as common mackerel and conger eel. Freshwater and migratory fish such as cyprinids, bullhead, eel and sturgeon were also evidenced in higher frequencies, while other species, for example salmonids, northern pike, river perch, loaches, sticklebacks or shad are present in lower frequencies. The representation of body parts is linked to kitchen waste rather than food refuse. In this monastery the consumption pattern was dominated by herring bones, though it is characterised by a high taxonomic diversity for an inland site. The presence of sturgeon is probably related to the status of the consumers in the abbey.

The other monastery contribution is presented by Zora Bielichová and co-authors and concerns the Camaldolese monastery of St. Joseph on the Zobor hill in Nitra, Slovakia. The paper contributes information on the nutrition and behaviour of the monks and enhances actual knowledge with new results excavated in a well-known modern-era convent. The majority of material originates from a small cellar or cesspit situated in one of the eremite houses and partly represents the local monk's diet. The assemblage is dominated by aquatic and semi-aquatic wild animals including fish, crayfish, otter, beaver and the European pond turtle. Remains of the four major domesticates appeared only in low frequencies. The most frequent remains stem from northern pike and common carp, supplemented by various other fishes such as catfish, tench, dace and bleak. The often large-sized fish are interpreted as required for preparation in the kitchen and probably document resources such as fishponds and aquaculture. However, similarly to the Trinité de Vendôme Abbey, the presence of starry sturgeon, Russian sturgeon and sterlet may also reflect the social status of these inland consumers.

Book contributions address methodological approaches such as the size estimation of archaeological fish, in the case of Lázló Bartosiwcz's northern pike paper, applying precise statistical analyses for the evaluation of estimates calculated from cranial bones in addition to a short historical outline of the history of pike. In general, size estimations are important tools for reconstructing ecological and habitat conditions, targeted fishes and also fishing techniques, as well as for furthering the economic and cultural interpretation of archaeoichthyological material in various book contributions. Neolithic Hungarian sites, in comparison to Hungarian medieval and modern era sites, revealed catches of smaller specimens and a lack of large northern pikes. Juvenile fish remain in shallow waters covered by vegetation, while the larger northern pike prefers deeper waters. Despite the assumption that the presence of large northern pike speaks for social high-status diets, pike were still small in contexts relating to the medieval archbishop of Esztergom, a situation comparable to the modern-era monastery in Zobor, Slovakia, which also yielded only a few remains of large northern pike. According to Bartosiewcz, medieval pond fishing focused on carp »with pike as the occasional side-crop«, because such juvenile pike prey upon anything up to their own range.

Another important methodological issue in this book concerns the sampling of sediments, the use of different sieve mesh widths and the result on the identification of fish bones and species. Precise and accurate excavation methods are recognised as necessary and therefore are applied at most of the settlements presented, sometimes in combination with archaeobotanical research. Besides prehistoric contexts, these methods are applied at rural and urban excavations or excavations in cloisters and monasteries. Evidence of large fish in any case indicates that fish of certain sizes were caught and exploited, but where there is no evidence from the screening of sediment samples, the absence of small fish does not necessarily mean that small fish were not exploited. The latter is an excavation method essential to prove the presence of fish and crustaceans which were used to produce fish sauces, for example. However, northern pike are found in sizes up to 40 and 50 cm, while larger fish appear infrequently compared to the smaller individuals at the two Neolithic sites in Austria and Slovenia. At both sites numerous cyprinid vertebrae reflect exploitation of very young and rather small individuals, less than 10 cm in size. Altogether, similarities in prehistoric northern pike fishing on the Great Hungarian Plain and at two pile-dwelling sites can be seen, namely fishing with nets/seines, fish traps for smaller fish and active fishing for larger specimens. Since sampling of sediments in archaeological excavations has established itself as a commonly used method, maybe a paradigm shift is underway, away from the idea that fishing mainly targeted large fish for food supply towards explicit fishing of small fish, which could be caught in large quantities.

The overarching hypothesis behind most archaeoichthyological research is finding explanations for the exploitation of fish as part of human behaviour and human interaction with aquatic environments. The reconstruction of the catching and consumption of fish as an additional protein source as well as reconstructing historic aquatic environments, is of major interest. The proceedings are especially focused on ichthyoarchaeological-related contexts, and the international contributions bring together current scientific standards and present new prehistoric data.

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