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Changes in the exploitation and consumption of seafood vs freshwater resources in medieval and early modern Estonia

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ABSTRACT
This paper focuses on evaluating the changing role of seafood imports in comparison with freshwater resources in medieval and early modern Estonia, based on zooarchaeological material and provenance analyses. A secondary aim was to find evidence of the early stages of practicing aquaculture in Estonia. The work presents the results of taxonomic and morphological analyses of the zooarchaeological material of aquatic animals, including marine and freshwater vertebrates (fish, marine mammals) and invertebrates (shellfish). These results were combined with additional evidence gained from previously published stable isotope data from the bone collagen of fish and marine mammals, allowing us to identify and investigate local and foreign resources among the medieval and early modern fish populations in Estonia. Our results show that herring and cod were the most exploited marine species during this period; however, freshwater species dominated at both coastal and inland sites. Compared to earlier periods, the remains of seals disappear almost completely from the zooarchaeological record, whereas those of oyster shells increase. Stable isotope analyses revealed the diverse habitats of consumed fish: from the Atlantic to the eastern Baltic, and from inland rivers to shallow coastal waters. Not much evidence was found of commonly farmed fish in the Estonian archaeological material.

KEYWORDS
provenance analysis, seafood, stable isotopes, Middle Ages, Early Modern Period.

Introduction

The Baltic Sea basin has undergone multiple changes during its long post-glacial history. Diverse fauna in this basin has offered resources both for humans and top predators of the sea throughout millennia. The food chains in the Baltic Sea, although usually shorter than in the oceans, have been recorded in the form of various compounds in the bone tissue of organisms who once lived in this sea.

Valuable material for the investigation of such food chains (and the trophic levels of organisms within the food chain) in the past comes from archaeological sites which yield human and faunal remains, either as bones or other residues. Preserved collagen is one of the valuable sources for studies on past diets. In addition, the analysis of animal remains by recording taxonomic and anatomical features, as well as traces of treatment on bones, offers valuable insight into the economic activity of past populations. By combining different methods and approaches, a more detailed interpretation of the archaeological record can be achieved, allowing us, for example, to study the origin and movement of animals and goods.

Within the last five years, our research has focused, inter alia, on the search for imported seafood among aquatic animal products, i.e., fish, shellfish and marine mammals, based on archaeological bone specimens (Lõugas et al. 2020; Orton et al. 2019; Pluskowski et al. 2019; Glykou et al. 2021; Lõugas & Bläuer 2021; Aguraiuja-Lätti et al. 2022; Lõugas et al. 2022; Lõugas & Bērziņš 2023; Religa-Sobczyk et al. 2023). One of the principal approaches to detecting imported aquatic animals or animal products in our archaeological material is through the presence of species which do not naturally populate the waters of Estonia. However, taxonomic identification alone is not enough to identify, for example, fish species which populate the Atlantic and have a subspecies in the Baltic Proper. Stable isotope analysis of bone collagen has provided a valuable tool for differentiating between Atlantic/North Sea and Baltic Sea marine fauna, as first demonstrated by Barrett et al. (2008; 2011). The development of medieval cod fishery in the Baltics has also been studied by Orton et al. (2011; 2019), whereas new isotopic data on medieval and early modern fish from the territory of Estonia have recently been published in Aguraiuja-Lätti et al. (2022) and Malve et al. (2023).

Biomolecular methods such as aDNA (DNA isolated from ancient bones) also aid in distinguishing between Atlantic and Baltic specimens. Recently, a groundbreaking analysis of ancient herring populations included, inter alia, the herring found in the sediment of a preserved wood barrel from the Kadriorg shipwreck in Estonia (Atmore et al. 2022). The study managed to cluster the genetic profiles of herring specimens (their origin) into different aquatic habitats in the Atlantic, the Baltic or in the Sounds. Because herring bones are very small, Atmore et al. (2023) also demonstrated that DNA sequence quality is not directly dependent on the weight of the fish bone.

The main aim of this study is to evaluate the changing role of seafood imports in comparison with freshwater resources based on zooarchaeological material and provenance analyses, and to find evidence of the early stages of practicing aquaculture in Estonia, i.e., fish farming in ponds. The work presents the results of taxonomic and morphological analyses of zooarchaeological material, including marine and freshwater vertebrate (fish, marine mammals) and invertebrate (shellfish) species. In addition, evidence was gained from previously published stable isotope data from the bone collagen of fish and marine mammals, which helped identify and investigate local and foreign seafood in the medieval and early modern eastern Baltic region.

Materials and methods

AQUATIC FAUNAL REMAINS FROM ARCHAEOLOGICAL SITES

The remains of the aquatic animals in this study (incl. oysters, fish, and marine mammals) come from different medieval and early modern contexts across Estonia (Fig. 1). Included are 47 sites from Tallinn, 19 sites from Tartu, 2 from Haapsalu, 7 sites from Pärnu, in addition to Põltsamaa (castle), Otepää (hillfort), Kastre (castle), Pöide (hillfort), Padise (monastery), Rebala (village), Viljandi (town) and Karksi (castle). All these sites differ somewhat in collection methods as well as species representation and archaeological context (Lõugas 2022; Lõugas & Russow 2022). Previously excavated sites are characterized by a lack of fine sieving, which has resulted in the perception that only "big fish" were captured. For more recent excavations, either dry- or wet-sieving was applied. Soil samples were typically collected in quantities of 10–15 liters and wet-sieved through a mesh (size 2 mm) to obtain bones of small fish (see e.g., Kadakas et al. 2010). Oyster shells and bones of marine mammals were collected manually only.

Unfortunately, there is not much information about medieval fish farming in ponds among the archaeological material. For this reason, special attention was paid to possible finds of the crucian carp (*Carassius carassius*), the common carp (*Cyprinus carpio*) and the common rudd (*Scardinius erythrophthalmus*), as commonly farmed fish, in Estonian zooarchaeological collections. They are, however, extremely rare.

From the zooarchaeological samples analyzed for this study, a sub-selection was made for stable isotope analysis, the results of which were recently published in

FIG. 1. Locations of the sites mentioned in the text.

Aguraiuja-Lätti et al. (2022). Samples for isotope analyses were chosen from both coastal and inland sites, considering taxonomic representation and the ecological requirements of different species. As the aim was to obtain as wide a spectrum of samples as possible, the spatio-temporal dimension was also considered during the selection. This dataset was compared with material from similar contexts in the Baltic Sea region (Kosiba et al. 2007; Grupe et al. 2009; Orton et al. 2011; 2019; Lahtinen & Salmi 2018; Malve et al. 2023). Details on the sample context, methodological and quality control information, and full results can be found in the respective publications.

ZOOARCHAEOLOGICAL METHODS

Zooarchaeological methods used in this study include the taxonomic and anatomical identifications of animal remains, as well as standard calculations of bone finds, i.e., the Number of Identified Specimens (NISP) and, for a few cases, the Minimum Number of Individuals (MNI). The identifications were done by using the reference collections at the Archaeological Research Collection of Tallinn University. In addition, measurements of fish bones (after Morales & Rosenlund 1979) and oyster shells (after Winder 2011; 2017; Thomas et al. 2020) were recorded as part of the analyses. Detailed data on identifications and measurements are available in the DataDOI repository (Lõugas 2022; Lõugas & Russow 2022).

It should be noted that the choice of identification method depends somewhat on the specific assemblage. Closely related species like the Atlantic and the Baltic cod and herring are initially identified by the size of their bones, as are whitefish. From the whitefish genus *Coregonus*, two species were identified in this study: *C. lavaretus* and *C. albula*; however, in some cases, reaching an exact identification was challenging. Although size is not the best characteristic for distinguishing between closely related (sub-)species, it provides a good basis for a more precise identification. For example, stable isotope analysis is a useful tool for distinguishing between the Atlantic and Baltic cods (see below), whereas for the identification of the small bones of the herring, aDNA analysis has shown great potential (Atmore et al. 2022a). In addition, most of the skeletal units of cyprinids found in archaeological contexts are similar and distinguishing between species by bone morphology is impossible.

STABLE ISOTOPE ANALYSES

Stable isotope analysis is a quantitative method for reconstructing the palaeodiet and -ecology of individuals based on the isotopic compositions of their tissue (usually bone collagen). Aquatic organisms from various habitats differ in their isotopic compositions in a more or less predictable manner. For example, marine fish and mammals typically have carbon isotopic ratios δ^{13}C of around –14‰ (Schoeninger & Moore 1992; Sealy 2001), whereas freshwater organisms can display a much wider range of values, usually below –22‰ (Guiry 2019). Brackish conditions such as those seen in estuaries (or in the low-salinity Baltic Sea) can produce δ^{13}C values that are in between the typical marine and freshwater ranges (Grupe et al. 2009). Nitrogen isotopic ratios $\delta^{15}N$, on the other hand, reflect the trophic level of the organism, meaning that there is an increase in $\delta^{15}N$ values of about 3–5‰ with each step of the food chain (Bocherens & Drucker 2003; Hedges & Reynard 2007). The $\delta^{15}N$ values thus reflect both the length of the local aquatic food chain but also the individual trophic position of the analyzed specimen.

Marine mammals

ZOOARCHAEOLOGICAL DATA

Among the thirty-four seal bones discovered in medieval and early modern contexts in Estonia (see Table 1), one is from the gray seal (*Halichoerus grypus*) and eight from the ringed seal (*Pusa hispida*). Surprisingly, bones belonging to the harp seal (*Pagophilus groenlandicus*) have also been found: one in Tallinn (Lai 23) in 2022 and one temporal bone in Rebala village (1990), east of Tallinn, northern Estonia. The latter find has recently been radiocarbon dated to 1215–1390 cal CE (Aguraiuja-Lätti et al. 2022). The remaining seal bones cannot be identified to species level.

TABLE 1. Sites, taxa and NISP (number of identified specimens) of marine mammals found in medieval (MA – Middle Ages) and early modern (EMP – Early Modern Period) contexts in Estonia. Exact dating remains unclear in some cases

Site	Taxon (NISP)	ID number in collection	Context
Tallinn, Tartu mnt 1	*Phocidae* (3)	AI 7032/AZ-38:053 AZ-51:467 AZ-51:361	15th–16th c.
Tallinn, Tatari 13	*Phocidae* (7) *Phocoena phocoena* (1)	AI 7863	13th–15th c.
Tallinn, Lai 23	*Phoca groenlandica* (1)	AI 8553/AZ-013	14th–15th c.
Tallinn, Jahu 6	*Pusa hispida* (1) *Halichoerus grypus* (1)	AI 7909/AZ-13 AZ-12	15th–16th c.
Tallinn, Roosikrantsi Street	*Phocidae* (2)	AI 8288/AZ-078 AZ-026	MA; prehistoric layers also present
Tallinn, Pärnu mnt 31	*Pusa hispida* (1)	AI 7575/AZ-868	MA; prehistoric layers also present
Tallinn, Town Hall Square	*Pusa hispida* (1)	AI 4061/AZ-06	MA
Tallinn, Pikksilma 2	*Phocidae* (1) *Odontoceti* (1)	AI-MM 15329/AZ-91:2 AI-MM 15329/AZ-89:1	14th c.
Pärnu, Malmö 15	*Pusa hispida* (3) *Phocidae* (2)	AI-PäMu A-2509/AZ-1016, 1976, 2001, 0313, 1717	MA 1st half, 2nd half; EMP 1st half
Rebala	*Phoca groenlandica* (1) *Pusa hispida* (1) *Phocidae* (6)	AI 5916/1990/AZ-3:2 AZ-3:3	13th–14th c.
Omedu	*Pusa hispida* (1)	AI 7517/AZ-77	N/A

Among other marine mammals, a lumbar vertebra of a harbor porpoise (*Phocoena phocoena*) was found in Tallinn (Lõugas & Bērziņš 2023) and one tooth belonging to a toothed whale (*Odontoceti*) was retrieved from the Kadriorg shipwreck (see e.g., Roio et al. 2016b).

STABLE ISOTOPES

Carbon and nitrogen isotopic evidence is available for four seal bones originating from historical period contexts (Aguraiuja-Lätti et al. 2022). These include a gray seal and a ringed seal from Jahu 6 in Tallinn, a harp seal from the settlement site of Rebala, and a seal (most likely a ringed seal) from the Late Iron Age Valjala hillfort in Saaremaa. Their results are comparable to those from other historical period sites around the Baltic Sea (Fig. 2), suggesting that they were local in origin. The Rebala harp seal with a medieval radiocarbon date has slightly higher δ^{13}C and δ^{15}N values, indicating an origin closer to the ocean. This is also supported by the similarity of its isotopic values with some seals sampled in Germany (Grupe et al. 2009).

As expected, the four Estonian seals have carbon isotope ratios similar to Baltic Sea marine fish (see discussion below) but display significantly higher δ^{15}N values (Mann-Whitney U test, $U = 3$, $p = 0.006$). This is consistent with their position in the food chain, being approximately one trophic level higher compared to their main prey item (average δ^{15}N of seals is 13.6‰ compared to 10.6‰ for Baltic Sea fish).

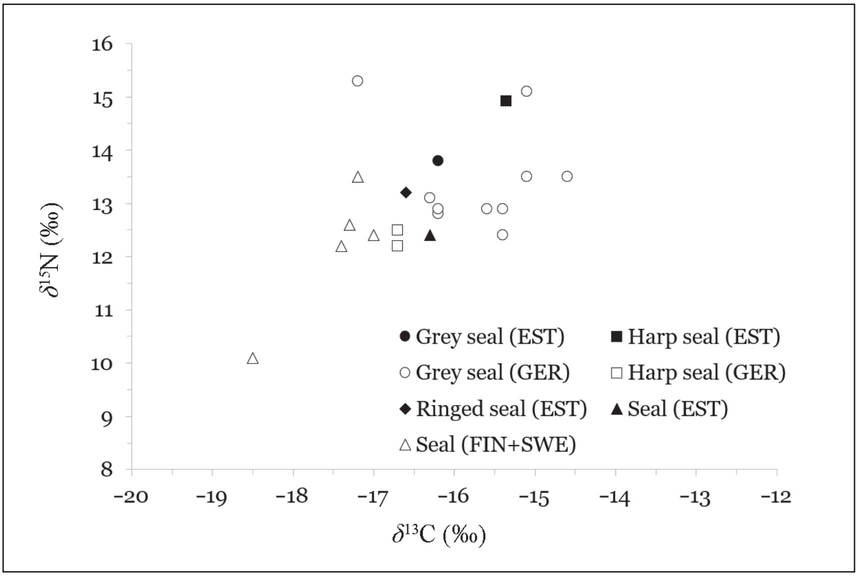

FIG. 2. Scatterplot of δ^{13}C and δ^{15}N measurements of seals from historical period sites around the Baltic Sea. Data from Estonia (EST; Aguraiuja-Lätti et al. 2022), Finland (FIN; Lahtinen & Salmi 2018), Sweden (SWE; Kosiba et al. 2007) and Germany (GER; Grupe et al. 2009).

Fish

ZOOARCHAEOLOGICAL DATA

Medieval and early modern collections of fish remains found in Estonian towns and villages are quite diverse (see e.g., Lõugas et al. 2012; 2016; 2019; Lõugas & Bläuer 2020; Rannamäe & Lõugas 2019; Pluskowski et al. 2019; Lõugas 2022). Still, higher diversity would be expected, especially from sites where we have only collected fish bones manually. The excavations where wet-sieving was performed, even if only partly, yielded much more remains and taxa, including e.g., small-sized fish such as the herring and the smelt. In this study, the identified fish taxa were divided into two groups: freshwater/brackish water fish and marine fish (Table 2). In the current dataset, a total of 16 231 fish bones identified to lower taxonomic levels are included; in addition, ca 5000 unidentified fish bones and a huge amount of scales were registered.

TABLE 2. Diversity of fish in the medieval and early modern archaeological assemblages found at Estonian archaeological sites, divided into two groups. Both groups include migratory fish, which were assigned to marine and freshwater categories according to the most probable catch area. Number of identified specimens (NISP) is presented

Freshwater/brackish water fish (NISP)	**Marine fish (NISP)**
Pike, *Esox lucius* (3528)	Sturgeon, *Acipenser* sp. (7)
Cyprinids, *Cyprinidae* (2736)	Herring, *Clupea harengus* (1822)***
Salmon/trout, *Salmo* sp. (13)*	Eel, *Anguilla anguilla* (41)
Whitefish, *Coregonidae* (173)**	Smelt, *Osmerus eperlanus* (41)
Perch, *Perca fluviatilis* (5255)	Garfish, *Belone belone* (3)
Pikeperch, *Sander lucioperca* (228)	Cod, *Gadus morhua* (1794)****
Ruffe, *Gymnocephalus cernuus* (10)	Turbot, *Scophthalmus maximus* (24)
Wels, *Silurus glanis* (4)	Flounder, *Platichthys flesus* (506)
Burbot, *Lota lota* (44)	Fourhorn sculpin, *Triglopsis quadricornis* (2)
Total (11 991)	**Total (4240)**

* most probably only includes trout (*Salmo trutta*); ** mainly includes Peipsi whitefish (*Coregonus lavaretus maraenoides*) and vendace (*Coregonus albula*), but also European whitefish (*Coregonus lavaretus*); *** mainly includes Baltic herring since no Atlantic herring has been identified; **** includes both Baltic and Atlantic cod.

According to the geographical location, sites were categorized into coastal and inland areas (see also Fig. 1). Fish bones were sorted into these two categories, revealing, as expected, that coastal sites yielded more bones of marine fish than inland sites. However, marine fish are also well represented (based on the NISP) at inland sites, demonstrating the extent of the fish trade between the coast and remote inland areas.

Despite there being numerous marine fish in Estonian ichthyo-archaeological material, freshwater fish strongly dominate in fish bone assemblages from both coastal and inland sites (Fig. 3). The pike, the perch and cyprinids, all of which still inhabit the fresh and brackish water bodies in and around Estonia, were widely used for food. Although the perch was seemingly the most favored, the pike and cyprinids were equally important. Cyprinids in this material include (starting from the most abundant) bones of the bream (*Abramis brama*), the roach (*Rutilus rutilus*), the ide (*Leuciscus idus*), the dace (*Leuciscus leuciscus*), the vimba bream (*Vimba vimba*), the tench (*Tinca tinca*), the blue bream (*Abramis ballerus*) and at least two bones of the crucian carp (*Carassius carassius*). Other brackish and freshwater species are represented by fewer bone finds, but considering the inconsistent excavation techniques used, their importance has likely been underestimated.

Unfortunately, a comparison between fish taxa found in rural and urban areas is not possible since our study material comes mainly from urban/suburban contexts and less from castles and monasteries. All of this reflects the consumption of aquatic food by urban people or inhabitants of castles and monasteries, but not by people

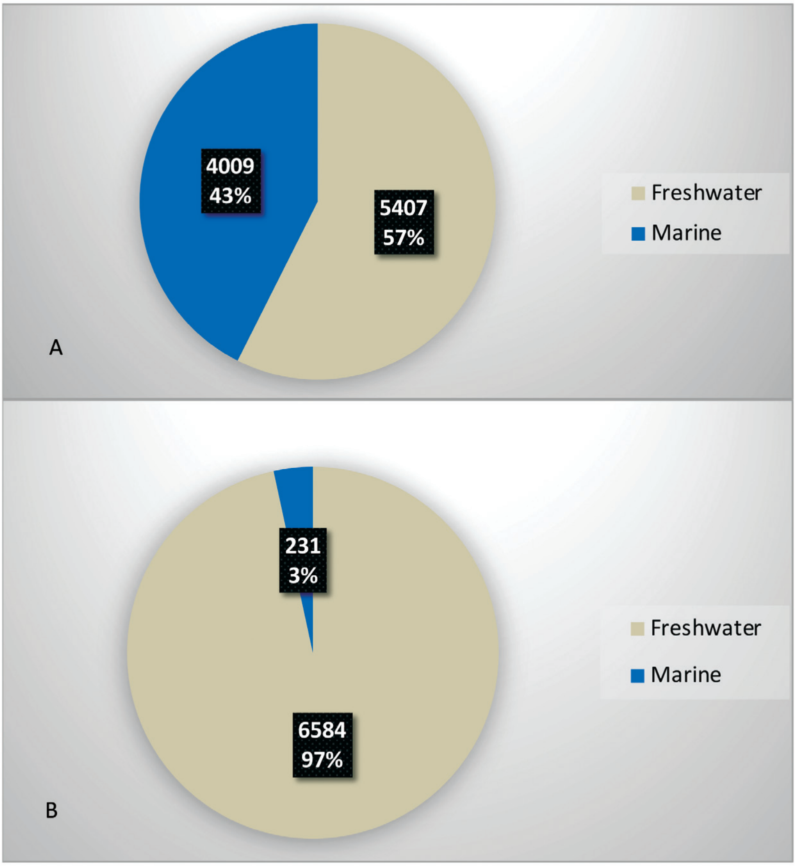

FIG. 3. Freshwater and marine (including migratory) fish from coastal and inland sites. A – coastal, B – inland.

living in villages and farms. The only medieval village in our material is Rebala, which did not yield fish bones (or they were not collected) but offered a few seal bones. This highlights the need for wet sieving soil from medieval rural settlements in the future. Otherwise, all small bone remains may remain unnoticed, as probably happened at Rebala.

STABLE ISOTOPES

Analyses of fish bones from historical period contexts in Estonia demonstrate a wide range of stable isotope values (even within one species), which can be interpreted as representing different habitats and/or catch areas (Fig. 4). Based on their $\delta^{13}C$ and $\delta^{15}N$ values, marine species fall into one of two groups: local (from the Baltic Sea) or imported (from the Atlantic/North Sea). The two groups are quite easily distinguishable, with the Atlantic cod having much higher $\delta^{13}C$ and $\delta^{15}N$ values, as was first demonstrated by Barrett et al. (2008). Some marine fish show an overlap with freshwater species – these may represent specimens who lived close to the shoreline or in highly brackish conditions such as those seen in the Gulf of Finland off the northern coast of Estonia, where the high influx of fresh water has influenced the isotopic values of marine organisms (see Grupe et al. 2009).

Based on their isotopic values, freshwater fish can also be grouped into two distinct niches, with one of them partly overlapping with the Baltic Sea marine fish (Fig. 4). These fish likely originate from brackish environments such as coastal and/or estuarine regions (Aguraiuja-Lätti et al. 2022). Their comparatively high $\delta^{13}C$ values may also be caused by low water turbidity, which characterizes stale

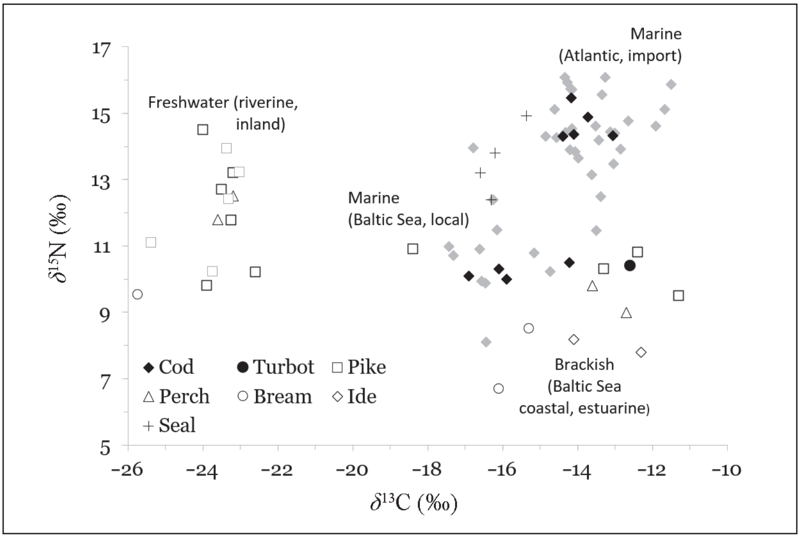

FIG. 4. Scatterplot of $\delta^{13}C$ and $\delta^{15}N$ measurements of fish and marine mammals from historical period sites in Estonia. Filled symbols represent marine species, empty symbols are for freshwater species. Black symbols represent data from Aguraiuja-Lätti et al. (2022), gray symbols are comparative data from Orton et al. (2011; 2019) for cod and from Malve et al. (2023) for pike.

and shallow coastal waters (Guiry 2019). These brackish-water fish also have δ^{15}N values (on average 9‰) that are very modest for aquatic organisms, suggestive of feeding on a low trophic level (e.g., seagrass).

The other group of freshwater fish has a more "typical" carbon isotopic signal (on average –24‰), associated with specimens living in fast flowing rivers (Guiry 2019). Based on isotopic evidence, the pike, the perch and the bream all inhabited both pure freshwater and brackish environments, as is the case in modern times (Ojaveer et al. 2003). One pike specimen is situated in between the two freshwater niches (Fig. 4) and may refer to an individual who was migrating between the two habitats (e.g., downstream from the inland to the coast) while its bone collagen isotopic composition was in the process of equilibrating with its new environment. Alternatively, this pike could also have been living in conditions similar to those of the Baltic cod.

Shellfish

ZOOARCHAEOLOGICAL DATA

Previously published material includes 1096 more or less complete oyster shells and ca 323 shell fragments (Lõugas et al. 2022; Lõugas & Russow 2022; Lõugas & Vedru 2022; Malve et al. 2022). In this study, 237 complete and 76 fragments of shells were registered at Estonia pst 7 and Toom-Kooli 15, Tallinn. The largest collections come from archaeological sites in Tallinn, Pärnu and Tartu, while other locations, such as Narva and Viljandi, yielded very few specimens. Oyster finds from other locations within Estonia indicate that they were transported to several destinations, not just the large centers.

Summarized results of the analysis of oyster shells found in archaeological deposits in Estonia are presented in Table 3. The locations of archaeological sites are grouped by towns, with a number indicating how many excavated sites were included in this study. The dates, according to the context, are divided into three time periods: from the 15th to the middle of the 16th century, representing the medieval Hanseatic period; the middle of the 16th to the 17th century (ca 1550–1700); and the 18th to the 19th century. No radiocarbon dating was performed on the shells (i.e., on the material from the mineral compound or preserved ligaments), and all dates are estimates based on information from the archaeological context, i.e., accompanying find types (mostly fragments of pottery and clay tobacco pipes). Furthermore, the numbers of more or less complete left and right shells and the numbers of shell fragments are shown. The larger number in the NISP 1 column (Table 3) also indicates the minimum number of individuals (MNI). The range of measurements gives some idea of shell sizes.

TABLE 3. Oyster shells and fragments from archaeological deposits in Estonia, sorted by context (after Lõugas et al. 2022). NISP 1 – number of identified (more or less complete) specimens (S – left shell / D – right shell), NISP 2 – number of identified (broken) specimens, Valve H – height in mm, Valve L – length in mm

Location	**Date by context**	**NISP 1 S/D**	**NISP 2**	**Valve H (mm) min–max**	**Valve L (mm) min–max**
Tallinn (47 sites)	15th–16th c.	3/2	30	46–111	64–103
	16th–17th c.	25/28	24	44–112	39–98
	18th–19th c.	236/98	76	35–107	31–101
	N/A (14th–19th c.)	24/36	63	41–108	33–95
Tartu (20 sites)	16th–17th c.	14/16	26	62–85	55–68
	18th–19th c.	79/88	15	47–121	44–100
Pärnu (8 sites)	15th–16th c.	0/1	4	78	80
	16th–17th c.	85/84	38	50–106	43–100
	18th–19th c.	209/304	93	41–117	34–109
Other (Narva, Viljandi)	17th–19th c.	ca 30		N/A	N/A

Discussion

CHANGES IN THE EXPLOITATION AND CONSUMPTION OF AQUATIC RESOURCES BASED ON FAUNAL REMAINS

From the beginning of the 13th century onwards, the lives and economic activity of the people living in the eastern Baltic region changed remarkably. This was mainly because of a change in political power, but also because a variety of foreign products started to appear in the local markets. This was preceded by other important changes. The zooarchaeological finds from the eastern Baltic region indicate the disappearance of marine species after the Late Neolithic when agricultural activities began to spread more widely here. Was it a substantial agricultural resource which diminished the need to catch marine fish far from the shallow littoral, or some other reason, but indeed, this food disappeared from people's table at that time. However, freshwater fish still remained an important subsistence source of protein as proved by fish bone finds from the Late Bronze Age Asva site and the Viking Age Tornimäe sites on Saaremaa Island, Estonia (Lõugas 2008; 2016; Lõugas & Bläuer 2021). The absence of marine fish from eastern Baltic sites even at the end of prehistory is unique compared to southern and western Baltic regions, where large-scale herring fishery and trade started to evolve already in the 9th century (e.g., Holm 2016; Atmore et al. 2022). The beginning of commercial fishing of cod in the North Sea is also dated to around 1000 AD (Barrett 2016).

New products arrived with new people at the beginning of the 13th century, but how long did it take for the local population to adapt to, for example, foreign food? Considering all the zooarchaeological evidence, we can pinpoint the first appearance of imported marine fish in the zooarchaeological material of rural and urban sites in Estonia. There are many papers which discuss the import of dried cod from the North Sea to Estonia, among others places (Lõugas 2001; Barrett et al. 2008; Orton et al. 2011; Lõugas 2016; Lõugas et al. 2016; Orton et al. 2019; Lõugas & Bläuer 2021), but only recently have we had an opportunity to date the early import and trade of this fish into central and eastern Estonia (Aguraiuja-Lätti et al. 2022; Lõugas et al. 2019). The results show that imported cod were present in Otepää in the 13th–14th centuries and the trade reached as far as Kastre Castle in eastern central Estonia. According to the bone evidence found at Estonian archaeological sites, the Atlantic cod is the only fish that has been imported to the region from outside the Baltic. Medieval herring, on the other hand, seems to be originating solely from within the Baltic and not from the North Sea, as supported by aDNA analyses of a herring found in a barrel in the Kadriorg shipwreck, which demonstrated a southwestern Baltic Sea origin for the herring (Atmore et al. 2022). These examples indicate that marine food was imported to Estonia from the 13th century onwards, whereas the appearance of bones belonging to local Baltic cod in the archaeological material was dated (by the find context) closer to the 15th century. Local herring fishing was also established from the 13th century onwards, but the early fishermen villages were founded by Swedish and Finnish settlers, not by local people (Lõugas & Bläuer 2021). It seems that the local population needed some time to adapt to seafood or respond to market needs before starting to fish herring, cod, and other marine fish, such as flounder.

Freshwater fish such as the pike, the perch, the bream, the ide and other cyprinids found at Estonian archaeological sites likely belong to local fish fauna but may also have formed a part of export and import, even if it only took place on a local scale. This short-distance trade is hard to establish based on taxonomic analyses of fish remains but can be studied further using stable isotope analyses (see discussion below and Aguraiuja-Lätti et al. 2022).

Not much information can be yielded from taxonomic analyses of fish remains on fish farming in ponds. Although we know there were such ponds close to castles and monasteries, the remains of fish species found in archaeological contexts in Estonia are those belonging to local fish inhabiting natural water bodies. For example, no bones of the common carp have been found so far. The only exception is Haapsalu Castle, where two bones of the crucian carp were found in a 17th century context – one of them is a caudal vertebra with slightly deformed spines, which may indicate that the fish was living in a restricted area, e.g., in a pond (Lõugas et al. 2020). More careful excavations are required at the locations of any potential fish ponds in the future.

Archaeological finds of sea mammals constitute quite a small part of medieval and early modern bone material in Estonia, despite the fact that the Estonian coast and islands offered good hunting grounds and the sea mammal populations were intensively utilized throughout prehistory (see e.g., Lõugas 1999; Storå & Lõugas 2005; Ukkonen et al. 2014; Glykou et al. 2021; Lõugas & Bērziņš 2023). Their rarity may be due to remote hunting and processing locations, which led to the absence of their bones from towns and villages. However, we have a few seal bones in our medieval and early modern collections (Table 1), and as late as 2022, the first evidence of a harbor porpoise in the form of a vertebral bone was found in a medieval/early modern context in Tallinn (Lõugas & Bērziņš 2023). Still, there is some doubt about its temporal origin since the dating was based on accompanying finds and context. In historical sources, seals and porpoises are also mentioned as provisions in Tallinn and other towns in Estonia (see e.g., Põltsam-Jürjo 2018). Whales are represented only by a single tooth from a non-local toothed whale (Roio et al. 2016b).

The presence of the gray seal and the ringed seal in the medieval and early modern material is not a surprise. On the contrary, we would expect much more of their faunal remains. As a rarity for this period, the proximal part of the humerus of a harp seal found in Tallinn is much more sensational. Radiocarbon dating is necessary to determine whether it is indeed a medieval find or a prehistoric find which has been mixed with the medieval ones. However, the 13th–14th century harp seal from Rebala village (Aguraiuja-Lätti et al. 2022) supports the argument that this species still appeared in the waters of northern Estonia during the Medieval Period. These could thus be the latest finds of the harp seal population that once inhabited the Baltic Sea (Glykou et al. 2021), although we cannot exclude long-distance migration (see e.g., Sergeant 1991) or trade from the Atlantic either.

One of the quite exceptional ringed seal finds (AI-7517/AZ-77) comes from lake sediments in central eastern Estonia. It was found close to the Omedu River estuary in Lake Peipsi together with animal bones and archaeological items in sediments, which were most likely redeposited by the river (Roio et al. 2016a). Even though redeposition has taken place, a seal found on the shore of an inland lake attracts attention. Without radiocarbon dating, it is impossible to tell the age of the bone; based on the accompanying finds, it may originate anywhere from the Stone Age up until the modern period. Theoretically, a ringed seal could have inhabited the lake at the end of Pleistocene, but a more likely explanation would be import by humans.

This is a common problem concerning all non-radiocarbon-dated finds of marine mammals. Another example is from Vabaduse Square, Tallinn, where all the sea mammals seemingly come from the Late Neolithic (Lõugas & Tomek 2013). Even though the layers were mixed with medieval and modern material, we cannot associate any seal and porpoise finds with these later times, unless shown by radiocarbon dating.

The only certain evidence of the import of sea mammals comes from the Kadriorg shipwreck, where a tooth of a toothed whale was found. It remains unclear whether it was imported as a raw material for carving or for something else, or whether whale flesh also played a role in the trade.

Another major article of import is oysters. The first oyster shells appear in the archaeological material in the 16th century and become very numerous during the 17th and 18th centuries (Lõugas et al. 2022; Lõugas & Vedru 2022). Unfortunately, only oysters that were imported with the shells leave a trace in the archaeological record. If oysters were already imported before the 16th century but were prepared (salted or boiled) for the journey without shells, then no evidence is preserved in the archaeological material. However, there are also no written records, e.g., in accounting books, indicating that oysters were imported into the eastern Baltic region any earlier than the 16th century (Lõugas et al. 2022).

EXPLOITATION OF AQUATIC RESOURCES AS EVIDENCED BY STABLE ISOTOPE ANALYSIS

When comparing aquatic resource exploitation at coastal and inland sites (Fig. 5), several trends can be noticed. For one, all sampled freshwater species from inland sites display a "pure" freshwater signal. These samples are from the sites of Tartu, Viljandi and Otepää, all situated in southern Estonia and near rivers and lakes. On the other hand, all freshwater species with δ^{13}C values of above –17‰, indicative of living in brackish conditions, are from coastal sites such as Tallinn and Haapsalu. There are four pike specimens recovered from coastal sites that have δ^{13}C values similar to those from inland sites: two from medieval Tallinn, one from the early modern Haapsalu Castle, and one from the Late Iron Age site of Kukruse in northeastern Estonia. While these could represent pikes that had migrated downstream from rivers into coastal waters before being caught, it can also be considered as potential evidence for fish trade from inland to coastal regions. For example, pikes from Tartu were often mentioned as being important menu items at feasts of the elite social class in medieval Tallinn, although it is not clear how they would have differed from the pike caught at other locations (Põltsam-Jürjo 2013). Although there is currently relatively little isotopic evidence available for freshwater species from Estonia, it could theoretically be possible to differentiate between distinct catch regions on a local scale by following a systematic and extensive sampling strategy.

It seems that, in general, people preferentially exploited the types of (freshwater) fish that were the most convenient to acquire, which for inland settlements were riverine fish and for coastal settlements brackish-water fish. This may explain why zooarchaeological analysis indicates that freshwater species were more numerous at coastal sites than marine species – not because coastal fishing was insignificant but because freshwater species living in coastal waters were possibly preferred over marine species. These results also suggest that instead of a decline in marine fishing in the periods preceding the Middle Ages, as demonstrated by the nature of the zooarchaeological assemblages, only open-sea fishing decreased while coastal exploitation may have continued at a similar level. This is supported by the fact that the isotopic values of freshwater species from the Late Iron Age site of Tornimägi on Saaremaa Island clearly indicate that these fish were living in coastal waters (Aguraiuja-Lätti et al. 2022).

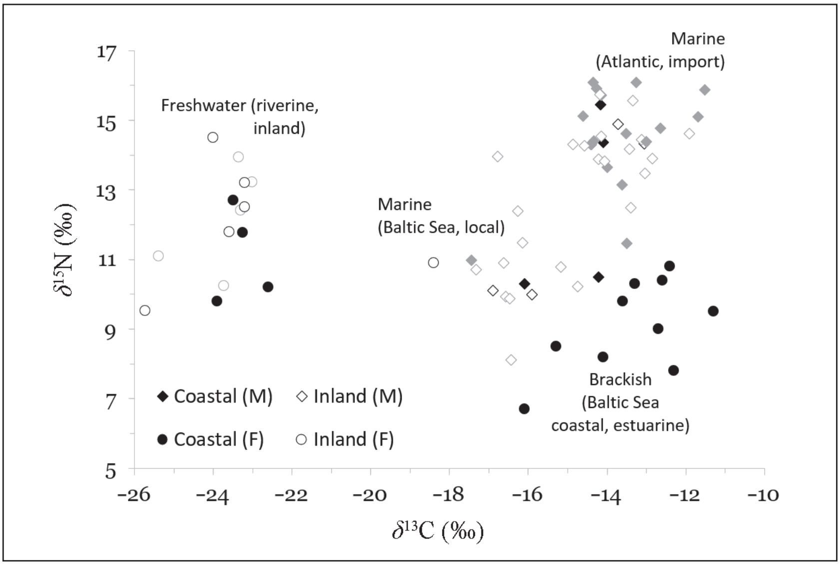

FIG. 5. Scatterplot of δ^{13}C and δ^{15}N measurements of marine (M) and freshwater (F) fish species from historical period sites in Estonia. Filled symbols represent coastal sites, empty symbols are inland sites. Black symbols represent data from Aguraiuja-Lätti et al. (2022), gray symbols are comparative data from Orton et al. (2011; 2019) for cod and from Malve et al. (2023) for pike.

With regard to the exploitation of marine species (specifically cod), Orton et al. (2011; 2019) have already suggested that cod import from the North Sea in the Early Medieval Period preceded the development of local cod fishery in the Late Medieval Period. This is also supported by the results of Aguraiuja-Lätti et al. (2022), where early medieval cod samples from Tallinn and Otepää show a clear North Sea isotopic signal, and samples from later medieval Tartu and early modern Haapsalu have isotopic values similar to Baltic Sea fauna.

The available isotopic record also demonstrates that cod from both the Atlantic and the Baltic Sea was similarly present inland and at coastal sites (Fig. 5). Although all the cod sampled from medieval Tallinn have isotope values consistent with the North Sea region (Orton et al. 2011; 2019; Aguraiuja-Lätti et al. 2022), this is likely due to the limited dataset. Smaller-sized cod bones, which are associated with the local Baltic subspecies, appear in the zooarchaeological assemblages of Tallinn in the 15th–16th centuries (Lõugas 2001; Orton et al. 2011), but no early modern fish bones were submitted for isotopic analysis. Assemblages from other towns, such as Pärnu, Tartu and Viljandi, include samples from both the Medieval and Early Modern Periods and suitably display a more equal distribution of Atlantic and Baltic Sea cod δ^{13}C and δ^{15}N values. Regrettably, we lack stable isotope evidence of fish from rural areas to determine how much of the marine imports reached these regions away from the main urban trading centers.

Conclusions

After the Neolithic, marine fish appeared anew into the archaeological material evidently no earlier than the 13th century AD, with their amount increasing until the 15th–16th centuries in most larger centers in Estonia. On the other hand, exploitation of freshwater fish was consistently intensive, both inland and in coastal areas. In the 17th–18th centuries, fish seemed to decrease among archaeological finds, whereas the import of oysters reached a peak. The remains of marine mammals, however, almost disappeared during the historical periods, possibly due to being processed further from the large centers. Although written records give some ideas about early aquaculture (fish ponds) in Estonia, zooarchaeological evidence is rather scant and does not show that any commonly farmed species were raised here.

The isotopic record indicates that local people exploited the types of aquatic resources that were the most accessible, meaning that freshwater species living in both inland bodies of water and in coastal brackish water were routinely caught. Atlantic cod was commonly imported into medieval towns but cod from the Baltic Sea became increasingly important from the Late Medieval Period onwards. It must be taken into consideration that the available isotopic dataset is very diverse with samples originating from different regions, periods and contexts, which may not accurately reflect the true extent of aquatic resource exploitation in medieval and early modern Estonia. In the future, large-scale isotopic studies focused on discrete contexts and species are necessary to explore the nuances of fishing and fish trade at Estonian sites more fully.

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Muutused meretoidu vs. *mageveeressursside kasutamises ja tarbimises kesk- ja varauusaja Eestis*

Lembi Lõugas ja Ülle Aguraiuja-Lätti

RESÜMEE

Meie uuringu eesmärk oli zooarheoloogilise materjali ja päritoluanalüüside abil hinnata meretoidu impordi ulatust kesk- ja varauusaegses Eestis võrrelduna mageveest saadud toiduga ning leida tõendeid vesiviljeluse (kalakasvatuse) algusaja määramiseks. Artiklis esitame zooarheoloogilise materjali taksonoomia ja morfoloogia andmeid, mis saadi mere- ja magevee selgroogsete (kalad, mereimetajad) ning selgrootute (austrid) kohta. Lisaks esitame hiljuti avaldatud tõendusmaterjali kalade ja mereimetajate luude kollageenist määratud stabiilsete isotoopide analüüsidest, mis annab mh infot kalade ja mereimetajate püügipiirkondade kohta. Zooarheoloogia ja stabiilsete isotoopide analüüsi meetodeid kõrvutades arutleme kohaliku ja võõrast päritolu meretoidu tarbimise ulatuse üle Eestis.

Zooarheoloogilised analüüsid näitavad, et merekalad ilmusid pärast neoliitikumi lõppu Eesti arheoloogilisse materjali uuesti alles 13. sajandil. Sellest ajast on teada heeringa (pigem räime) ja suurte (imporditud) turskade luid mitmest asustuskeskusest Läänemere ida-aladel. Merekalade jäänuste hulk ja mitmekesisus (sh Läänemere kohalik kala) jõudis kõrgpunkti 15.–16. sajandil. Samal ajal on mageveekalu ühtlaselt suurel määral kasutatud ja tarbitud nii rannikul kui ka sisemaal. 17.–18. sajandi materjalis näib kalaluude hulk vähenevat, kuid austrite import ja tarbimine oli sel perioodil intensiivseim. Vastupidiselt merekalade rohkusele keskaegses materjalis kaovad aga mereimetajate jäänused peaaegu sootuks. Võimalik põhjus on hülgejahi ja saagi töötlemiskohtade paiknemine keskustest väljaspool, otse rannikul või merejääl.

Kuigi kirjalikud allikad annavad aimu varajasest vesiviljelusest kalatiikides, siis zooarheoloogiline leiuaines tüüpiliste kalakasvatuse liikide (nt karpkala, koger ja roosärg) kohta tõendeid eriti juurde ei anna. Erandiks on ühe suurema kogre deformeerunud jätketega selgroolüli leid Haapsalu lossi 17. sajandi jäätmete seas. Selline jätkete deformatsioon võib tuleneda kala piiratud tingimustes (nt tiigis) elamisest.

Stabiilsete isotoopide analüüsi tulemused mereimetajate kohta näitavad, et hall- ja viigerhüljes olid kohalikku päritolu, kuid keskaegseks dateeritud ja ilmselt üks viimastest grööni hülge isendeist Läänemeres oli tõenäoliselt pärit mere lääneosast. Kalaluude isotoopanalüüsid näitavad, et tarbitud kalad pärinesid väga erinevatest keskkondadest: Läänemerest, Põhjamerest ja/või Atlandi ookeanist, rannikuvetest

ning sisemaa veekogudest. Ahvenat, haugi ja latikat püüti isotoopandmete põhjal nii riimveelisest rannikuveest kui ka jõgedest.

Analüüsi tulemused osutavad, et sisemaal tarbiti ülekaalukalt mageveekalu, mis olid püütud peamiselt jõgedest. Samas jõudis sisemaale ka kaugemalt toodud merekalu ning nende hulgas oli nii Läänemere liike kui ka Atlandi turska. Ka rannikul olid esindatud nii kohapeal püütud kui ka kaugemalt toodud merekalad ning oodatult oli mereliikide osakaal rannikul palju suurem kui sisemaal. Sarnaselt eelnevate selle valdkonna uuringutega selgus, et keskajal tarbiti valdavalt Põhjamerest ja/või Atlandilt imporditud turska, kohalik Läänemere tursapüük hakkas kujunema alles 15. sajandil.

Merekalade tähtsusest hoolimata olid ranniku leiukohtades ülekaalus mageveeliikide luud, mis isotoopanalüüside põhjal olid tõenäoliselt pärit valdavalt Läänemere rannikuvetest. Kuigi meresaaduste tarbimine enne keskaega oli zooarheoloogilisest materjalist lähtuvalt üsna olematu, siis näib, et rannikuvees elavate mageveeliikide püük oli püsivalt oluline kogu muinasajal kuni varauusajani välja. Zooarheoloogilistest ja isotoopanalüüsidest ei selgunud, et mageveekalu (nt töödeldud kujul) oleks ranniku ja sisemaa vahel transporditud, kuigi kirjalikud allikad annavad sellest aimu. Võimalik, et edaspidi laekuv leiuaines pakub selle valdkonna uurimistööde jaoks rohkem materjali.