



Coprolites as paleoarchives for the study of hunter-fisher-gatherer groups (Dnieper-Dvina region, 4-3rd mill BC)

Ekaterina Dolbunova¹ · Yolaine Maigrot² · Alexander Kulkov³ · Igor Askeyev⁴ · Arthur Askeyev⁴ · Matthieu Le Bailly⁵ · Celine Maicher⁵ · Andrey Mazurkevich¹

Received: 27 December 2025 / Accepted: 21 April 2026

© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2026

Abstract

The article represents the results of study of an exceptional collection of coprolites recovered at the Serteya II and Duborkay V wetland settlements (Dnieper-Dvina region, NW Russia), assigned to ca. 4200–2200 cal BC. The research summarizes results of paleoparasitological analysis, micro computed tomography, macroremains, faunal analysis and spatial investigation. This whole set is regarded diachronically to address seasonality of sites occupation by local hunter-fisher-gatherers groups, their dietary patterns, and a range of zoonotic parasite infections for specific time periods and within a wider cultural and chronological frame. Given scarcity of human remains in this region, coprolites serve as a proxy for understanding human diet and pathogens in a diachronic way. It can also be testified by the results of isotopic analysis and faunal remains that show an important role played by fish procurement in the life of ancient people that inhabited this area during the 4th–3rd mill BC. The change in the occurrence of the parasites might have been an indication of cultural changes recorded for the time period from the 4th mill BC till the 1st mill BC connected with changes in food range or cooking techniques.

Keywords Coprolites · Micro computed tomography · Parasitology · Hunter-fisher groups · Neolithic · Macroremains

Introduction

Coprolites serve to be one of the best paleoarchives, providing data about paleodiet, ancient zoonotic infections, environment, and seasons of occupations within short time periods (Reinhard and Bryant 1992; Shillito et al. 2020; Witt et al. 2021; Romaniuk et al. 2020; Kubiak-Martens and van der Linden 2021; Blong and Shillito 2021). However, only single studies are known for the coprolites originating from hunter-fisher-gatherer groups in Eastern Europe, and

they are rarely encountered at these sites (Engovatova and Khrustalev 1996; Savinetsky and Khrustalev 2013; Maicher et al. 2021). The exceptional case is Dnieper-Dvina region where numerous coprolites were uncovered at the Serteya II wetland site, and few – at the Duborkay V site. Based on the context of recovery and direct AMS dates, the major set of coprolites is assigned to ca. 4200–2200 cal BC. Here we have examined 30 coprolites from the Serteya II site, yielded to paleoparasitological analysis (Maicher et al. 2021; Maigrot et al. 2025), and another set of 20 coprolites (including two samples from Dubokray V site) selected to perform analysis of structure through Micro computed tomography and macroremains analysis. This whole set is regarded diachronically to address seasonality of sites occupation by local hunter-fisher-gatherer groups, their dietary patterns, and a range of zoonotic parasite infections for specific time periods and within a wider cultural and chronological frame. The spatial analysis of coprolites was performed for their chronological attribution and spatial patterns investigations, correlated with coprophilous fungal spores' indicators within the timeline established for the Serteya II site.

✉ Ekaterina Dolbunova
katjer@mail.ru

¹ The State Hermitage Museum, St. Petersburg, Russia

² CNRS, Trajectoires (UMR 8215), Paris, France

³ The Saint-Petersburg State University, St. Petersburg, Russia

⁴ The Institute of Problems in Ecology and Mineral Wealth, Tatarstan Academy of Sciences, Kazan, Russia

⁵ University Marie et Louis Pasteur, CNRS, Chrono-environnement (UMR 6249), Besancon 25000, France

Materials and methods

The Serteya II site

The Serteya II site is located in Dnieper-Dvina basin (North-Western Russia), in the present day Serteyka River valley, on the southern border of the Great Serteysky paleobasin (Fig. 1). The site was discovered in 1972, underwater area (Serteya Isub) was investigated during 1972–1974, 1980–1989, 1993–2024 (ca. 132 m²), wetland area adjacent to it (Serteya II-1) in 2015, 2017 (64 m²) and western shore zone (Serteya II-2) – during 2015–2024 (352 m²). It is a multilayer complex which was occupied or shortly visited from the 8th mill BC till the 1st mill BC. Wetland conditions allowed for exceptional preservation of organic artefacts, ecofacts and contexts (Mazurkevich and Dolbunova 2011). Several major occupation phases were noted in the western area (Mazurkevich et al. 2017), i.e. single finds of arrowheads dated to Mesolithic period, ceramics and rare

flint materials attributed to the 6th–5th mill BC representing short episodes of occupation of shore zone, followed by chronological hiatus. Further ca. 4200–3800 calBC (Middle Neolithic) new groups arrived from steppe-forest/steppe areas of Eastern Europe who left wooden fishing constructions ca. 3766–3641, 3633–3372 calBC. During a short episode ca. 3093–2898 calBC dwelling area was established with particular items, e.g. long wooden dart with snake heads, wooden sledge, and a wooden carved item in the human hand's form. Shortly after this (ca. 2861–2489 calBC) two skeletons were buried here. During 2470–2270 calBC pile-dwelling constructions with raised floors were erected (Serteya Isub and II-1 areas). We might suppose that during this period a small society lived there and successively constructed pile dwellings and/or reconstructed them at the same place (Pranckenaite et al. 2021). During several millennia the subsistence strategy of groups populated this place was based on hunting, fishing and gathering, embedded into seasonal cycles of resources exploitation.

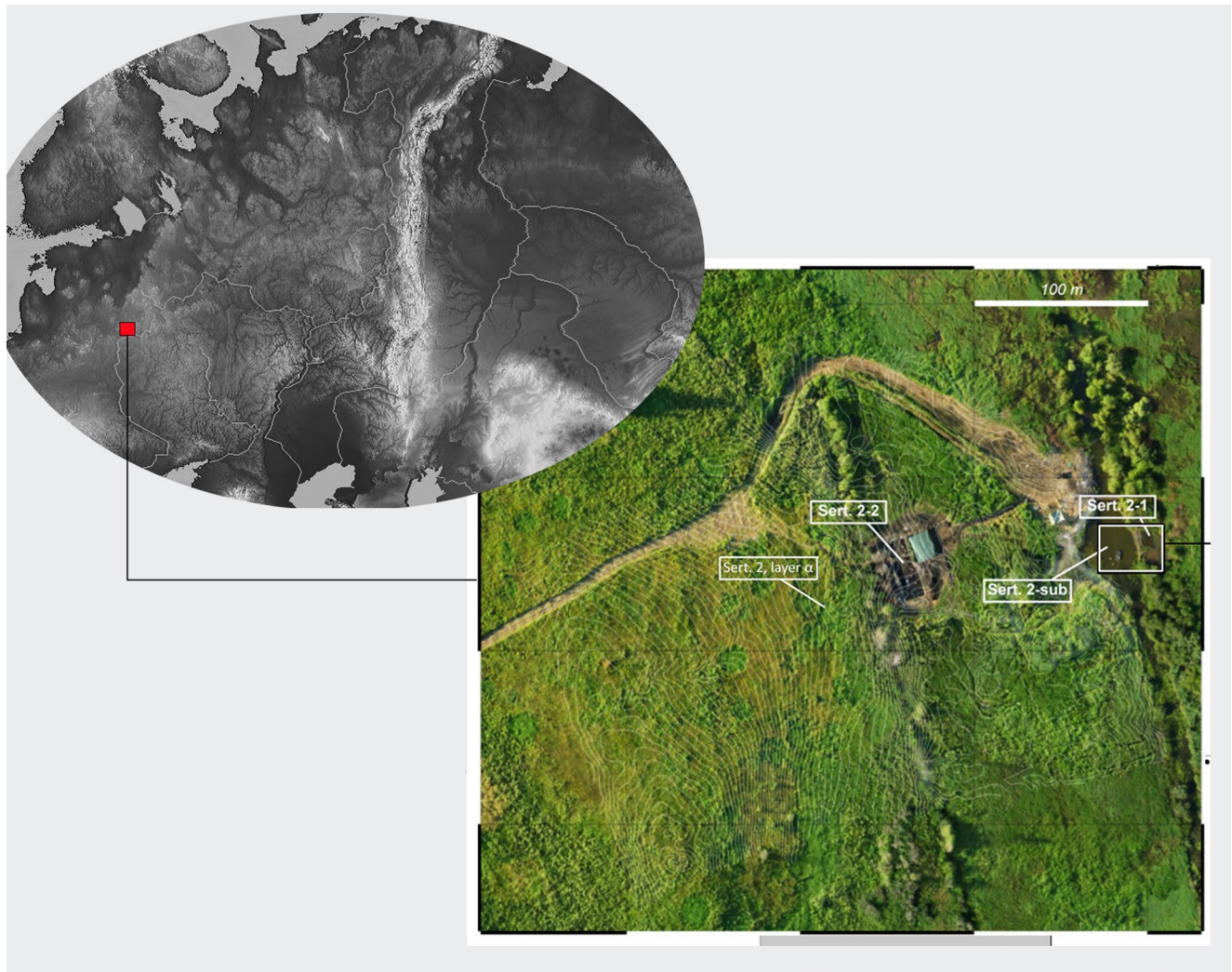


Fig. 1 Serteya site location, with indication of the excavated areas

After ca. 2100 calBC this place was abandoned, seasonal water fluctuations are noted which could have been connected with global climatic events (Pióciennik et al. 2022). Ca. 1985–1510 and 931–801 calBC this place was shortly visited by different groups of Textile culture of the Bronze Age.

Recording and 3D reconstruction

All of the artefacts and ecofacts, e.g. major number of coprolites, were recorded in a three-dimensional coordinate system. They were incorporated in a 3D model of the site created in ArchiCad and QGIS with all the constructions and objects. The entire layer was washed through a 0.5 cm sieve, the coprolites uncovered were labeled according to lithological layers and squares, and attributed to the distinguished chronological horizons (Mazurkevich et al. 2020a, b). During underwater excavations of the pile-dwelling 1 (Serteya IISub), between the 1970–1990s, water ejector was not used which could explain a much smaller number of coprolites found here.

Micro-CT analysis

Micro computed tomography (micro-CT) was performed to access the internal structure of the coprolites, identify the inclusions and forms of the voids (Romaniuk et al. 2020). Coprolites contain partially digested macro-food remains which can be distinguished on a micro-CT scan due to their contrast in terms of X-ray attenuation values and/or patterns with the faecal mass (Kubiak-Martens and van der Linden 2021). The images were implemented on micro-Computed Tomography scan model Neoscan N80. The following settings were used - source Voltage=79 kV, source Current=73 mA, camera exposure=322 ms, 1,0 mm Al filter, rotation step=0,2 deg, helical scanning trajectory, image pixel size=10 µm. “Neoscan” application software was used for reconstruction of scan results. Post-reconstruction processing was made by applying Bruker software CTAn (binarisation, separation and so on), CTVox (3D rendering and imaging) and DataViewer (2D imaging). A 3D rendering was made through scanning and reconstruction based on two-dimensional images.

Macroremains analysis

The identification of species, anatomical, morphological and age/sex diagnostics of the osteological material were performed with the aid of the reference collection of modern and sub-fossil vertebrates of the Laboratory of Biomonitoring,

The Institute of Problems in Ecology and Mineral Wealth, Tatarstan Academy of Sciences, Kazan. The estimation of fish body length for the species of the families for Esocidae, Cyprinidae and Percidae – the Standard length (SL). The size reconstructions were based on regression equations on the basis of the osteological reference collection and the database of bone measurements and dimensions of modern fish species (see Askeyev et al. (2023)). The determination of the age of fish was carried out according to standard methods (Chugunova 1959; Lebedev 1960; Pravdin 1966; Panfili et al. 2002; Askeyev et al. 2023), and is based on the tendency of bones to form layers into alternating rings, belts, planes and sclerites (Askeyev et al. 2023). The reconstruction of the season of death was based on the sclerochronological method, on the study of the cyclical growth increments on fish bones, indicating the period of the year when the specimen was caught (Chugunova 1959; Van Neer et al. 1999; Guillaud et al. 2021; Askeyev et al. 2022, 2023). Bone integrity and deformation were determined according to the methods described for fish bones extracted from feces (Wheeler and Jones 1989, 69–75) and for overall bone health (as a percentage of the anatomical size and shape of the bone) (Reitz and Wing 2008).

Results

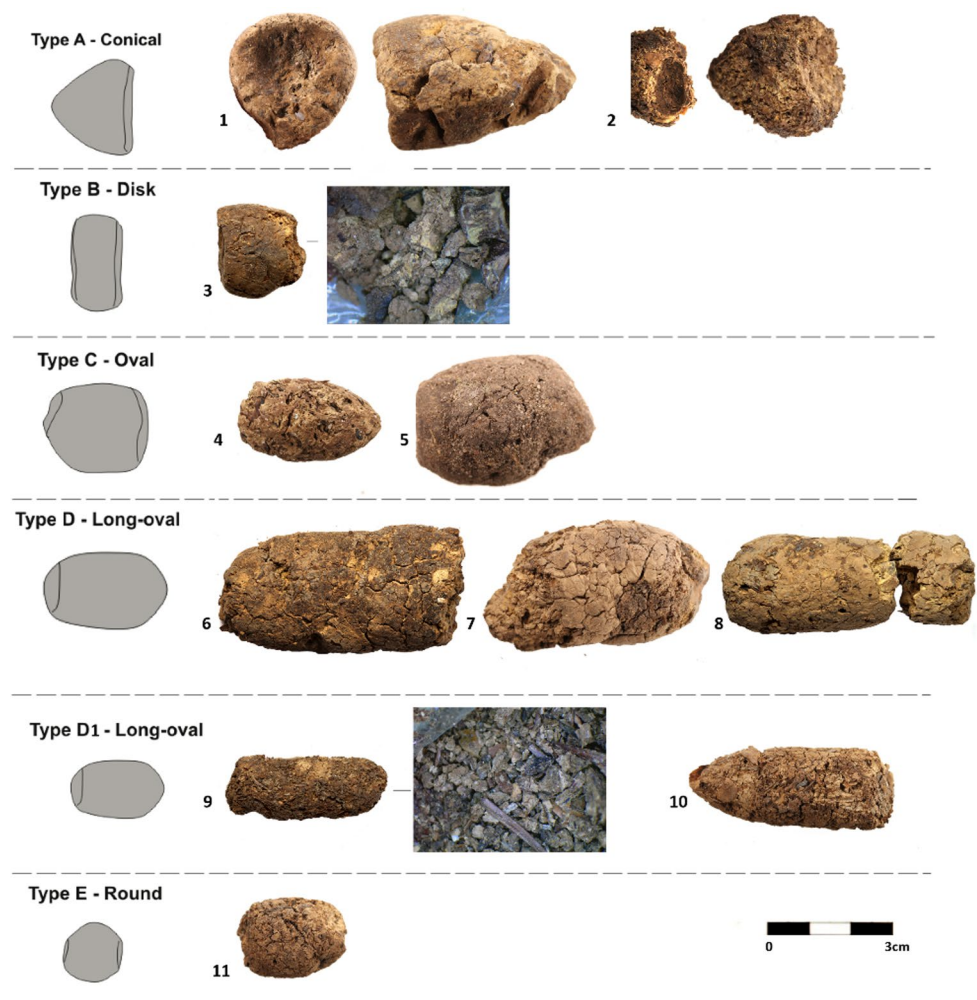
Description of the coprolites

Waterlogged conditions led to conservation of an outstanding number of coprolites: 1220 pieces, e.g. 443 in different layers of the Serteya II-2 sector and 777 in the pile-dwelling site (Serteya IISub and II-1). The whole set of coprolites found at Serteya II site belong mainly to types C, D and D1 (Fig. 2) (according to general classification of coprolites in Diedrich 2012; Cambroner and Garcia 2024; Yang et al. 2021). Here we have examined coprolites from the Serteya II, e.g. 30 coprolites were yielded before to paleoparasitological analysis (Maicher et al. 2021; Maigrot et al. 2025), from which 20 were dated and investigated through palynological and plant macroremains study (Maigrot et al. 2025), a new set of 20 coprolites (including two samples from Dubokray V site) was selected to perform analysis of structure through Micro computed tomography and macroremains analysis.

Distribution patterns and chronology

Direct dating of coprolites is a rather challenging issue due to amount of fish remains which could have led to reservoir effect influenced the final date. Cross—dating

Fig. 2 Different morphological categories of coprolites (types of forms – after Diedrich 2012): 1 – #IIsb-22-c.3, 2 – #6482, 3 – #658, 4 – #9628, 5 – #13,136, 6 – #1095, 7 – #2057, 8 – #1569, 9 – IIsb-16, 10 – # IIsb-13-c.1(b), 11 – #IIsb-13-c.1(a)



of terrestrial materials and study into reservoir effect (Kulkova et al. 2015) at the Serteya II site allowed suggesting a correction value, which was further verified through 3D spatial analysis and correlation with dwelling zones. Spatial distribution of coprolites showed several clusters localized within pile-dwelling site - in construction 3, few coprolites were concentrated in the eastern part nearby construction 1 (Fig. 3). Mainly discrete coprolites were recorded in the western shore zone, with two clusters envisaged (Fig. 4). Coprolites were attributed to several episodes – single coprolites from the western shore zone (Serteya II-2) can be assigned to ca. 4500–4300, 4200–3800 calBC (Middle Neolithic, early phase), 3766–3641, 3633–3372 calBC (Middle Neolithic, fishing constructions phase) (29 p.) and 3093–2898 calBC (Middle Neolithic, late phase, dwelling area (357 p.). Major part of coprolites is assigned to ca. 2470–2270 calBC (pile-dwelling settlement episode: 777 p. (Serteya IIsb and II-1) and 50 p. (Serteya II-2, brown gyttja layer). Single coprolites can be attributed to Textile culture phase (early stage, 3 p.; late stage, 4 p.).

Micro-CT analysis

The 3D volume rendering allowed for better reconstruction of the surface and content of the coprolites (Figs. 5 and 6, Fig. S.1-3).

Inclusions recorded in coprolites consisted of trabecular and cortical bones and teeth. Mammalian and avian bones are highly fragmented and range within 2–5 mm. Fish bones are easily recognized, since are better preserved and could be up to 10 mm. They constitute the most numerous category. Bones originate mainly from smaller fish species which could be due to the degree of preservation - greater loss in ingested fish of around 40 cm long was noted (Kubiak-Martens and van der Linden 2021). Analysis of porosity allowed different types of the voids to be detected - longitudinal voids could mark plant remains, roundish voids reveal the outline of the seeds. Cylindrical, discoidal, spherical, or ellipsoidal forms could have been left by stems or seeds. Possibly, rate of bone fragmentation and structure of the coprolites reconstructed through digital model could point also to

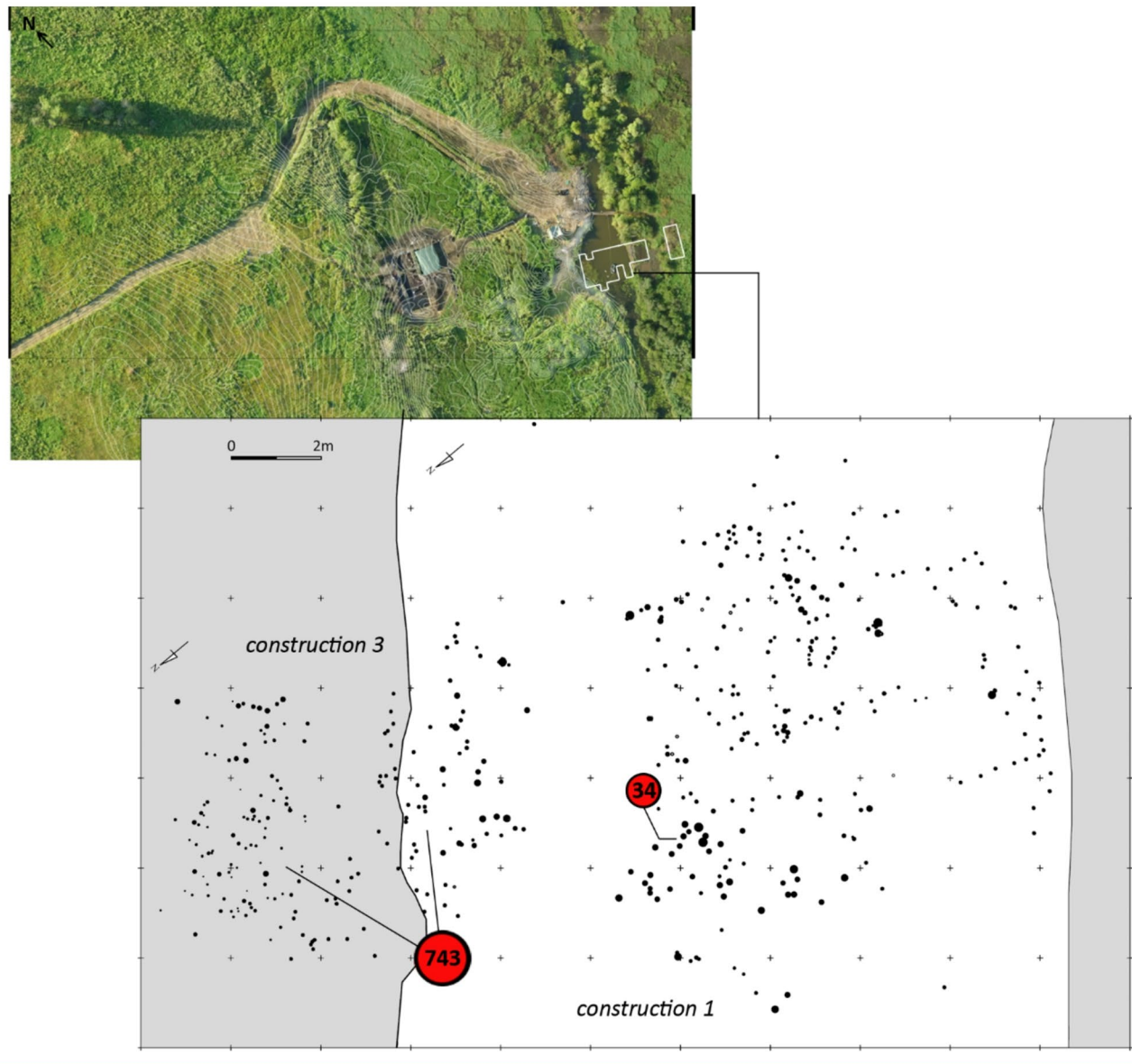


Fig. 3 Pile-dwelling area (Serteya IISub and II-1) with indication of the number of coprolites found in each dwelling

different producers. Micro-CT images allowed revealing several groups of coprolites based on the difference in shape, internal structure (porosity, cracks, fragmentation), and set of macroremains:

Group 1: irregular surface with lots of cracks, many angular voids and moderately large fish bones.

Group 2: irregular surface with oval voids (most probably originating from *Nymphaea alba* based on reference materials) and fish bones.

Group 3: irregular surface with compact fecal material and highly fragmented trabecular/cortical bones possibly of mammal origin.

Group 4: irregular surface with lots of cracks, many longitudinal voids and fragmented mammal/avian bones.

Macroremains analysis

After dissolution of fecal matrix a range of macroremains was identified – remains of mammal bones, hair and teeth; fish bones and scales, avian bones and plant material (Tables 1 and 2). The bones were examined for skeletal element representation.

All coprolites contain fish remains, with a predominance of European perch (*Perca fluviatilis*), Northern pike (*Esox lucius*) and roach (*Rutilus rutilus*). The reconstructed size of the fishes is mainly within the range of 5.5–20 cm, with single specimens measuring 34 and 48 cm. Similar contents were recorded for former set of samples from the Serteya II site (Maigrot et al. 2025).

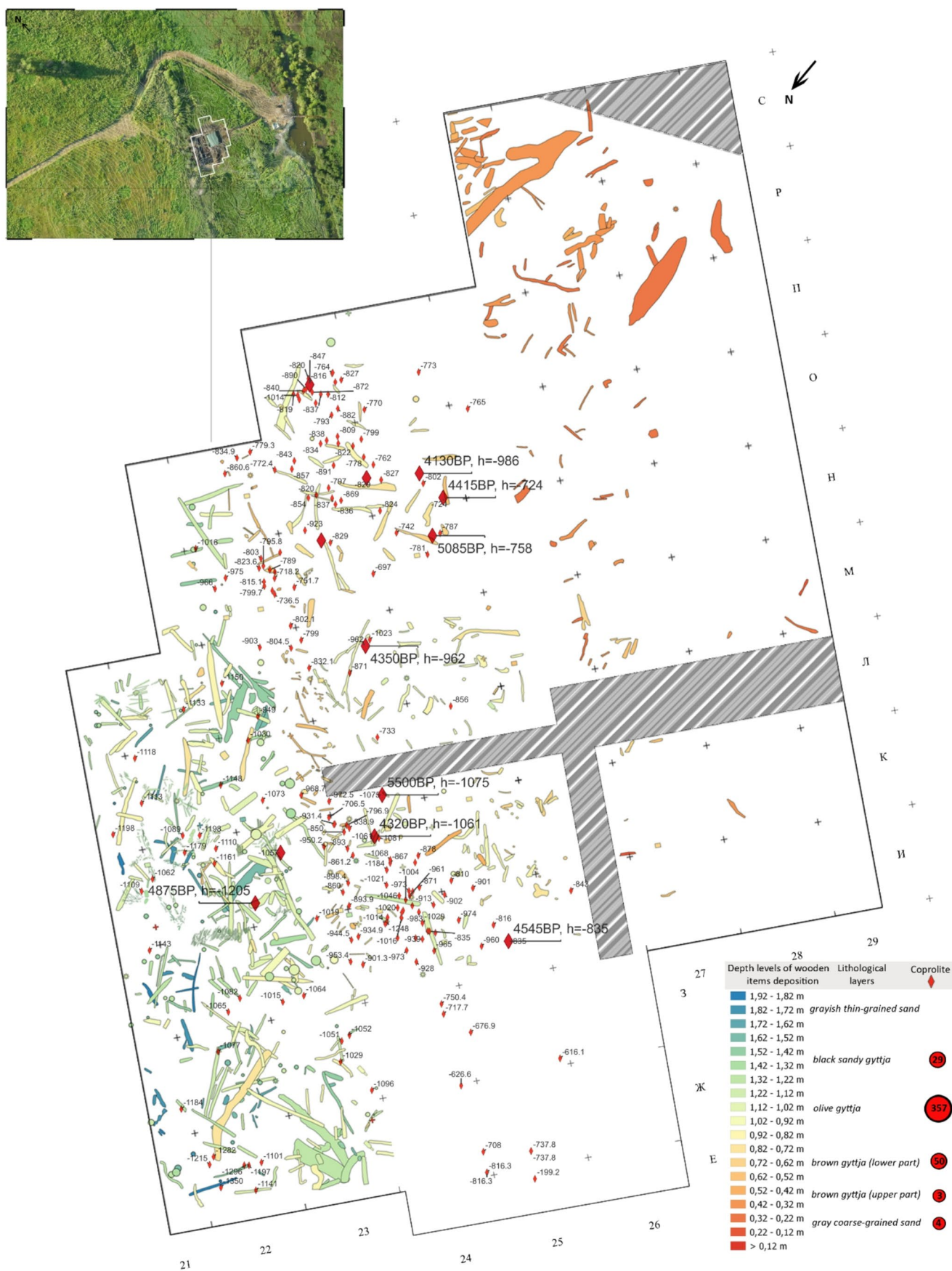


Fig. 4 Spatial distribution of wooden items and coprolites within the western shore zone (Serteya II-2) with indication of dated coprolites and number of coprolites within the archaeological layers (produced by and V.Filippova)

Mammal bone remains are highly fragmented and are found primarily in coprolites originating from a residential area dating back to the 4th millennium BC. The presence of a *Micromys minutus* bone in one of the coprolites could have come from occasional dog catches. Two coprolites from the pile dwelling contained fragmented bird bones, which significant amount was recorded in the area of the pile-dwelling settlement (Mazurkevich et al. 2023).

The majority of the bones examined are fairly well preserved with the presence of small structural details, up to 80% of the bones do not have strong deformation (see Wheeler and Jones 1989, 69–75).

Plant remains are highly fragmented, dismembered and deformed and cannot be securely identified in major cases. In four coprolites dated to the 4th mill BC, the remains of plant stem epidermis-like tissues were discovered (see also Maigrot et al. 2025), and in two, the remains of charcoal were found. Three coprolites from the pile dwelling contained seeds of *Nymphaea alba*. Based on micro-CT digital reconstructions more samples can be suggested with seeds of *Nymphaea alba*.

Paleoparasitological analysis through diachronic perspective

Paleoparasitological analysis allowed the identification of several taxa – *Diphyllbothrium*, *Spirometra*, *Fasciola*, *Diocotophyma renale*, *Alaria alata*, *Dicrocoelium* sp. (Fig. 7; Table 3) (Maicher et al. 2021; Maigrot et al. 2025). Though a small number of samples and taphonomic conditions which could lead to non-uniform distribution of parasites types major outlines could be suggested for different periods, which should be verified during future researches.

Diphyllbothrium (fish tapeworm) is the most numerous within horizons where the remains of dwelling structures were noted, both for the 4th and 3rd mill BC. Fish tapeworm can only be contracted when the intermediate forms of zoonotic parasites are consumed in raw, dried, smoked, pickled or uncooked meats. When the parasite infects humans, it can be responsible for abdominal pains, diarrhea, and anemia (Ash and Orihel 2007; Soulsby 1982; Taylor et al. 2007). It is noted particularly well for the pile-dwelling chronological episode, as well as one case of *Dicrocoelium* sp., which indicates the consumption of offal from infected mammal.

Consuming water plants encrusted by the intermediate form of *Fasciola hepatica* (liver fluke) can also lead to infection, which was noted almost exclusively for the coprolites assigned to the 4th mill BC dwelling horizons.

For coprolites assigned to later periods - Textile culture no *Diphyllbothrium* sp. were noted, neither larger quantities of other parasites which could point both to the lack of data as well as changes in food supply or cooking techniques that could have led to ceasing of the former range of zoonotic diseases.

Discussion

Coprolites found at the Serteya II site can be ascribed to dogs or humans based on the morphology, spatial analysis and stable isotopic values for humans, dogs and wild boars originating from the Serteya II site (Dolbunova et al. 2024), and a major set is more likely to be classified as dogs. However coprolites produced by humans and dogs are very complicated to be distinguished from each other (Kubiak-Martens and van der Linden 2021). The range of parasites identified does not allow narrowing determination of their producer, as humans share the highest percentage of their parasites with carnivores, followed by ruminants and pigs (Ledger and Mitchell 2019). Though analysis of the shape and structure of the coprolites, the content of digested materials, types of porosity narrow down the determination of the producer, its identification is not always possible. Coprophagia could lead also to an enrichment of features of different producers, which can challenge the identification (Brönnimann et al. 2017; Tolar et al. 2021; Linseele et al. 2013).

The analysis of cyclical growth increments on fish bones found in the coprolites indicate late spring to early autumn (May – September) as the period when the specimen was caught. The same pattern was suggested through pollen analysis of coprolites originating from the Serteya II site (Maigrot et al. 2025). Based on faunal remains all-year round occupation was suggested for the site with the prevalence of fishing activity during late spring-summer period (Mazurkevich et al. 2020a, b). Coprolites were most probably left during a high seasonal fishing activity occurred within particular periods, and might have not been linked to any storage activity and consumption during other periods.

The majority of coprolites at the Serteya II site was found within the remains of the pile-dwelling structure №3 (Fig. 3) (ca. 2470–2270 calBC) which could point to permanent defecation at one place. This pattern is rather common for coprolites distribution which are often recorded in direct

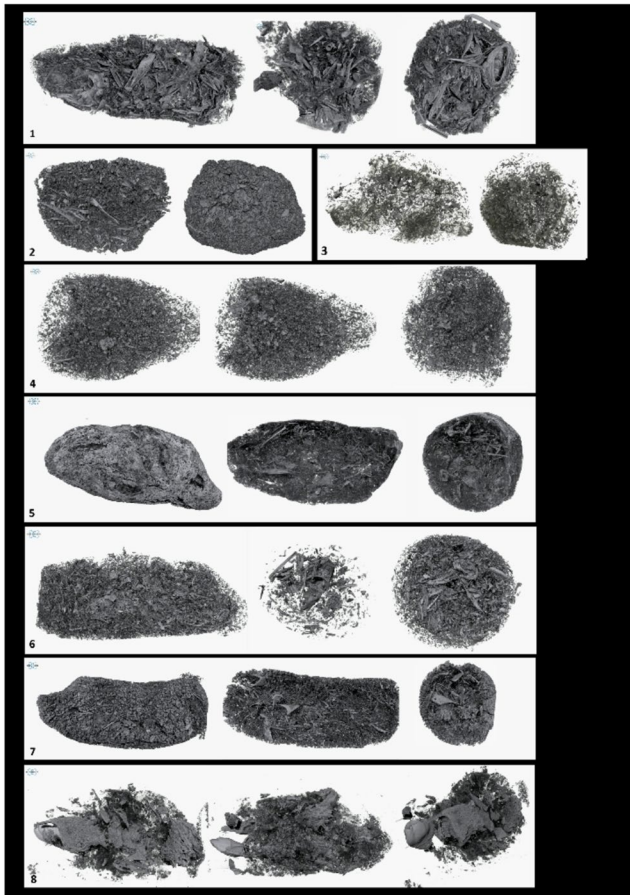


Fig. 5 Digital models made with micro-CT images, showing various types and material fabrics, porosities and degradation: 1 - #IIsb-13-c.1(a), 2 - # IIsb-13-c.1(b), 3 - #2057, 4 - # IIsb-22-c.3, 5 - #2065, 6 - #1984, 7 - #2214, 8 - #6500

proximity to habitation areas (Dommelier et al. 1998). In the western zone distribution of the major part of the coprolites ascribed to the 3093–2898 calBC (Middle Neolithic, late phase) seem to concentrate along the construction uncovered (Fig. 4). Other episodes can be also suggested for the coprolites - ca. 4500–4300, 4200–3800 calBC (Middle Neolithic, early phase), 3766–3641, 3633–3372 calBC (Middle Neolithic, fishing constructions phase) and Textile culture phase. Markers of coprophilous fungal spores recorded within the whole stratigraphical column from the 5500 calBC (for Serteya IIsb) and 4318 calBC (for Serteya II-2) (Kittel et al. 2021; Wieckowska-Lüth et al. 2021) could be the marker of both herbivore and dogs coprolites. Coprophilous fungal spores (*Coniochaeta* sp., *Sporormiella*, *Podospora*, and *Trichodelischia*) usually associated with herbivores were identified, except for *Sporormiella* which can also inhabit dog droppings (Lee et al. 2022; Ledger 2018).

Probably, changes in the food ranges or food cooking techniques could have led to changes in the set of

Fig. 6 Micro-CT scans of coprolites, showing various types and material fabrics, porosities and degradation: 1 – group 1 (#1704), 2 – group 2 (#1931), 3 – group 3 (#IIsb-22-c.3), 4 – group 4 (#6500)

parasites recorded so far for the later periods of the Serteya II assemblage (Textile pottery culture phase). Adopting new food habits also led to transitions in various parasitic infections in humans (Kubiak-Martens and van der Linden 2021). Ranges of zoonotic parasite infections can be quite different for hunter-fisher-gatherers and farming societies. Particular species of parasites which are not usually met at hunter-gatherer groups are associated with farmers groups, when animal domestication and the consumption of the meat of infected animals increased the presence of zoonotic parasites. Effect of lifestyle, dietary habits, and hygiene of the population could influence infection risk (Barbera et al. 2022). A trend towards parasites spread by faecal contamination and poor sanitation, and little evidence for those parasites spread by the eating of undercooked wild animals can be noted for later periods (Mitchell 2015).

The distribution of parasites also depends on the local environment, which should meet all the requirements for its life cycle (Mitchell 2015) and the presence of intermediate, additional and final hosts, ensuring the circulation of the invasion in biocenoses (Serduykov 1979). The dominance of parasites *Diphyllbothrium* sp. spread by eating raw fish and other freshwater foods can be noted for the Serteya II site, the Mesolithic sites in Moscow region (Savinetsky and Khrustalev 2013) and a range of north Alpine wetland sites (Mitchell 2024; Dommelier et al. 1998; Dommelier- Espejo and Pétrequin 2016; Maicher and Le Bailly 2024) with particular differences for some regions where fishing appeared to be a sporadic activity (Maicher et al. 2017). Similar content of fish bones, mainly small fishes, and range of parasites (*Fasciolidae*, *Diphyllbothriidae* and *Diocetophymas* sp.) were identified in the materials of Swifterbandt culture (Kubiak-Martens and van der Linden 2021). *Diphyllbothrium* sp. have remained one of the most widely spread parasites through human history (Mitchell 2015; Slepchenko et al. 2022). Investigations of modern hunter-fisher groups in Western Siberia where fish, and particularly raw fish consumption, is one of the main components of the population's diet, allowed revealing different patterns. In the areas where the custom of eating pike raw is most widespread, the highest rate of diphyllbothriasis is observed. The percentage of infected pike is significant (up to 60–90%), while that of perch and other species (ruff) is much lower (around 5–9% and up to 20%). The rate of indigenous population (Nenets, Khanty, Mansi, Komi) infected could vary between 32.1% and 73% (Serduykov 1979).

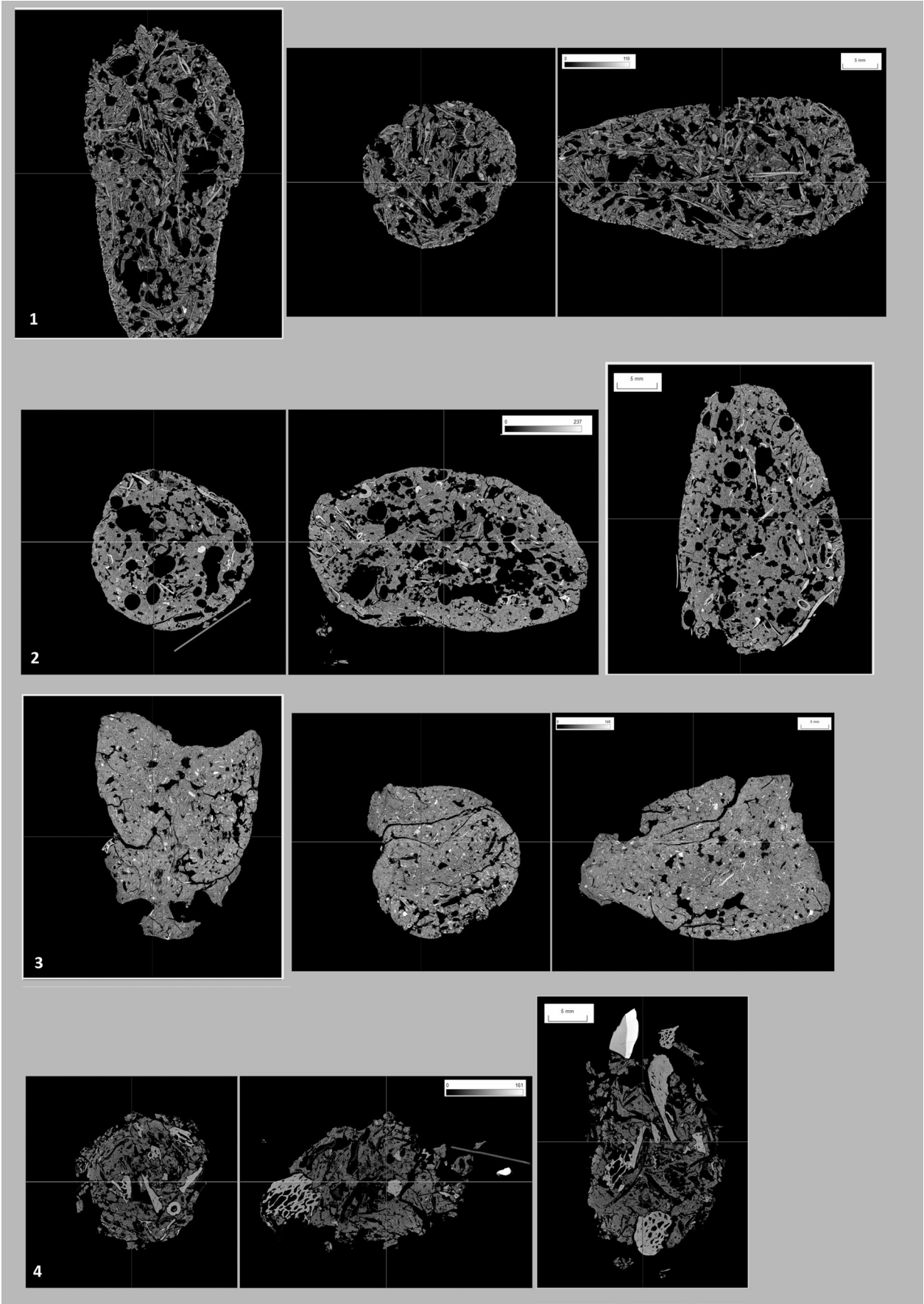


Table 1 Fish bones and scales identified in coprolites

# Species	NISP / MNI	Types of bones	Rate of preservation	SL	Age	Season of capture
#IIsb-13-c.1(a) <i>Esox lucius</i> <i>Perca fluviatilis</i>	Serteya IIsb 5/1 8/1 + 2 scales	Praecaual vertebra – 2; Fragments of neurocranium bones – 3 Posttemporal – 1; Opercular – 1; Preopercular – 1; Fin ray(lepidotrich) – 2; Axonost – 2; Branchiostegal – 1; Scale-2;	1–60% 10–30%	48 cm 11 cm	4 2	autumn autumn
#IIsb-13-c.1(b) <i>Perca fluviatilis</i> #IIsb-22-c.3 <i>Rutilus rutilus</i>	Serteya IIsb 6/1 + 2 scales Serteya IIsb 2/2	Praecaual vertebra – 1; Rib-1; Branchiostegal-1; Quadrate – 1; Cleithrum – 1; Dentary – 1; Scale-2; Praecaual vertebra – 2;	30–80% 70–80%	16.5 cm 19.3 cm; 23.8 cm	4 7	autumn late spring
#2065 <i>Rutilus rutilus</i> # 1984 <i>Esox lucius</i> <i>Rutilus rutilus</i>	Serteya II-1 11/2 Serteya II-1 1/1 8/2	Caudal vertebra – 2; Suborbital Serie bone – 2; Fin ray(lepidotrich) – 3; Rib – 1; Metapterygoid – 1; Articular – 1; Preopercular – 1 Tooth from the palatine bone Caudal vertebra – 1; Praecaual vertebra – 3; Dentary – 2; Opercular – 1; Hypural – 1	70–80% 30–70%	8.9 cm; 15.5 cm 13 cm; 25 cm	2; 5 4; 10	summer - autumn late summer - autumn
<i>Perca fluviatilis</i> # 2214 <i>Rutilus rutilus</i>	2/1 + 1 scale Serteya II-1 2/2	Praecaual vertebra – 1; Opercular – 1; Scale-1 Pharyngeal bone – 2	20–30% 40–60%	5.5 cm; 6.8 cm		
<i>Perca fluviatilis</i> <i>Blicca bjoerkna</i> <i>Leuciscus idus</i> #2057 <i>Rutilus rutilus</i> # 1931 <i>Esox lucius</i>	8/2 + 3 scales 1/1 1/1 Serteya II-1 8/2 and 5 scales Serteya II-1 4/1	Praecaual vertebra – 1; Caudal vertebra – 1; Cleithrum – 1; Axonost – 1; Fin ray(lepidotrich) – 1; Interopercular – 2; Subopercular – 1; Scale – 3 Urohyal Pharyngeal bone Caudal vertebra – 2; Fin ray(lepidotrich) – 4; Branchiostegal – 1; Frontal – 1; Scale – 5 Two teeth from the Dentary and Palatine; Dentary – 1; Opercular – 1	10–80% 50% 40% 5–60% 5–15%	10 cm; 12.5 cm 11 cm 10 cm 5.3 cm; 15 cm	2 3 1; 4 3	summer late spring late summer - autumn
# 1704 <i>Perca fluviatilis</i> # 13,374 <i>Perca fluviatilis</i> # 13,176	Serteya II-1 7/1 + 4 scales Serteya II-2 17/1 + 4 scales Serteya II-2	Praecaual vertebra – 2; Quadrate – 1; Frontal – 1; Dentary – 1; Cleithrum – 1; Hyomandibular – 1; Posttemporal – 1; Scale-4; Praecaual vertebra – 5; Caudal vertebra – 3; Maxilla – 1; Quadrate – 1; Preopercular – 1; Opercular – 1; Cleithrum – 1; Fragments of neurocranium bones – 4; Scale – 4;	10–80% 10–80%	10.6 cm 9.5 cm	2 2	late summer - autumn summer - autumn

Table 1 (continued)

# Species	NISP / MINI	Types of bones	Rate of preservation	SL	Age	Season of capture
Unidentifiable fish bones	3	Bone fragments	0.1%			
# 9336	Serteya II-2					
<i>Esox lucius</i>	13/3	Tooth - 4; Praecaual vertebra - 3 (of 7 fragments); Ceratohyal - 1; Fragments of neurocranium bones - 5;	1-80%	34 cm	2	summer
<i>Rutilus rutilus</i>	2/1 and 1 scale	Rib - 2; Scale - 1	30-50%			
# 7020	Serteya II-2					
<i>Esox lucius</i>	2/1	Tooth - 4; Dentary - 1 (of 8 fragments); Palatine - 1 (of 3 fragments)	1-5%	34 cm	2	summer
# DubV-1985(a)	Dubokray V					
<i>Perca fluviatilis</i>	15/1	Praecaual vertebra - 3; Caudal vertebra - 2; Rib - 3; Fin ray(lepidotrich) - 2; Fragments of neurocranium bones - 3	5-90%	7 cm	1	late spring - early summer
<i>Rutilus rutilus</i>	5/1	Praecaual vertebra - 1; Caudal vertebra - 1; Fragments of neurocranium bones - 2	25-60%	12 cm	3+	late spring
# DubV-1985(b)	Dubokray V					
<i>Perca fluviatilis</i>	3/1 + 2 scales	Praecaual vertebra - 1; Caudal vertebra - 1; Epihyal - 1; Scale - 2;	30-90%	10.8 cm	2	summer
<i>Scardinus erythrophthalmus</i>	13/1	Praecaual vertebra - 3; Caudal vertebra - 3; Pharyngeal bone - 2; Preopercular - 1; Suborbital Serie bone - 3; Maxilla - 1	30-70%	12 cm	4	summer
# 9628	Serteya II-2					
<i>Esox lucius</i>	1/1	Tooth - 1;				
<i>Tinca tinca</i>	1/1	pharyngeal tooth with a fragment of the axis of the pharyngeal bone	10%	25 cm		
# 10,883	Serteya II-2					
<i>Esox lucius</i>	3/2	Tooth - 1; Praecaual vertebra - 1; Palatine - 1	20-70%	9 cm	0	summer
<i>Perca fluviatilis</i>	12/1 + 1 scale	Praecaual vertebra - 1; Rib - 4; Dentary - 1; Fin ray(lepidotrich) - 6; Scale - 1;	10-70%	9.4 cm	2	summer
Cyprinidae	4	Bone fragments	1%			
# 6482	Serteya II-2					
<i>Esox lucius</i>	2/1	Praecaual vertebra - 1; Frontal - 1	10-20%			
<i>Rutilus rutilus</i>	26/1	Caudal vertebra - 3; Praecaual vertebra - 3; Dentary - 1; Opercular - 1; Pharyngeal bone - 1; Hyomandibular - 1; Maxilla - 1; Coracoid - 1; Rib - 3; Hypural - 5; Fragments of neurocranium bones - 3; Articular - 1; Epihyal - 1; Ceratohyal - 2	20-80%	8.5 cm	2	spring
<i>Perca fluviatilis</i>	10/2 + 2 scales	Praecaual vertebra - 2; Dentary - 2; Cleithrum - 1; Fin ray(lepidotrich) - 3; Fragments of neurocranium bones - 2; Scale - 2	30-80%	7.5 cm; 6.1 cm	2; 1	spring
Cyprinidae	3	Bone fragments	1-5%			
# 6500	Serteya II-2					
Cyprinidae	4	Scale - 4	5-10%			
# 6915	Serteya II-2					
<i>Perca fluviatilis</i>	16/1	Praecaual vertebrae - 3; Caudal vertebra - 2; Hypural - 1; Rib - 2; Supracleithrum - 1; Subopercular - 1; Opercular - 1; Ceratohyal - 1; Branchiostegal - 1; Ceratobranchial - 3	5-80%	10.9 cm	2	late spring - early summer

Table 2 Mammalian, avian bones and plant remains identified in coprolites

N°	sector	chronological attribution based on 3D modelling	Mammalia	Micromys minutus	Aves	Nymphaea alba	Plant remains	Char-coal
IIsb-13-c.1(a)	Serteya IIsb	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.1 (ca.2470–2270))			2 (6 fr) sternum, coracoid	6 (seeds)		
IIsb-13-c.1(b)	Serteya IIsb	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.1 (ca.2470–2270))						
IIsb-22-c.3	Serteya IIsb	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))	1 fr.					
2065	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))				9 (3 - seeds)		
1984	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))						
2214	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))			3 (6 fr), radius, ulna tibiotarsus			
2057	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))						
1931	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))		tibia-1 (Ad)		7 (seeds)		
1704	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))						
13,374	Serteya II-2	Middle Neolithic (late phase, dwelling zone) (3093–2898 calBC)					2	1
13,176	Serteya II-2	Middle Neolithic (late phase, dwelling zone) (3093–2898 calBC)	3 fr.					
9336	Serteya II-2	Middle Neolithic (phase with fishing constructions) (3766–3641, 3633–3372 calBC)						
7020	Serteya II-2	Middle Neolithic (phase with fishing constructions) (3766–3641, 3633–3372 calBC)	7 fr.					
9628	Serteya II-2	Middle Neolithic (early phase) (4200–3800 calBC)					5	
10,883	Serteya II-2	Middle Neolithic (early phase) (4200–3800 calBC)						2
6482	Serteya II-2	Middle Neolithic (early phase) (4200–3800 calBC)					2	
6500	Serteya II-2	Middle Neolithic (early phase) (4200–3800 calBC)					5	
6915	Serteya II-2	Middle Neolithic (early phase) (4200–3800 calBC)	8 fr.					

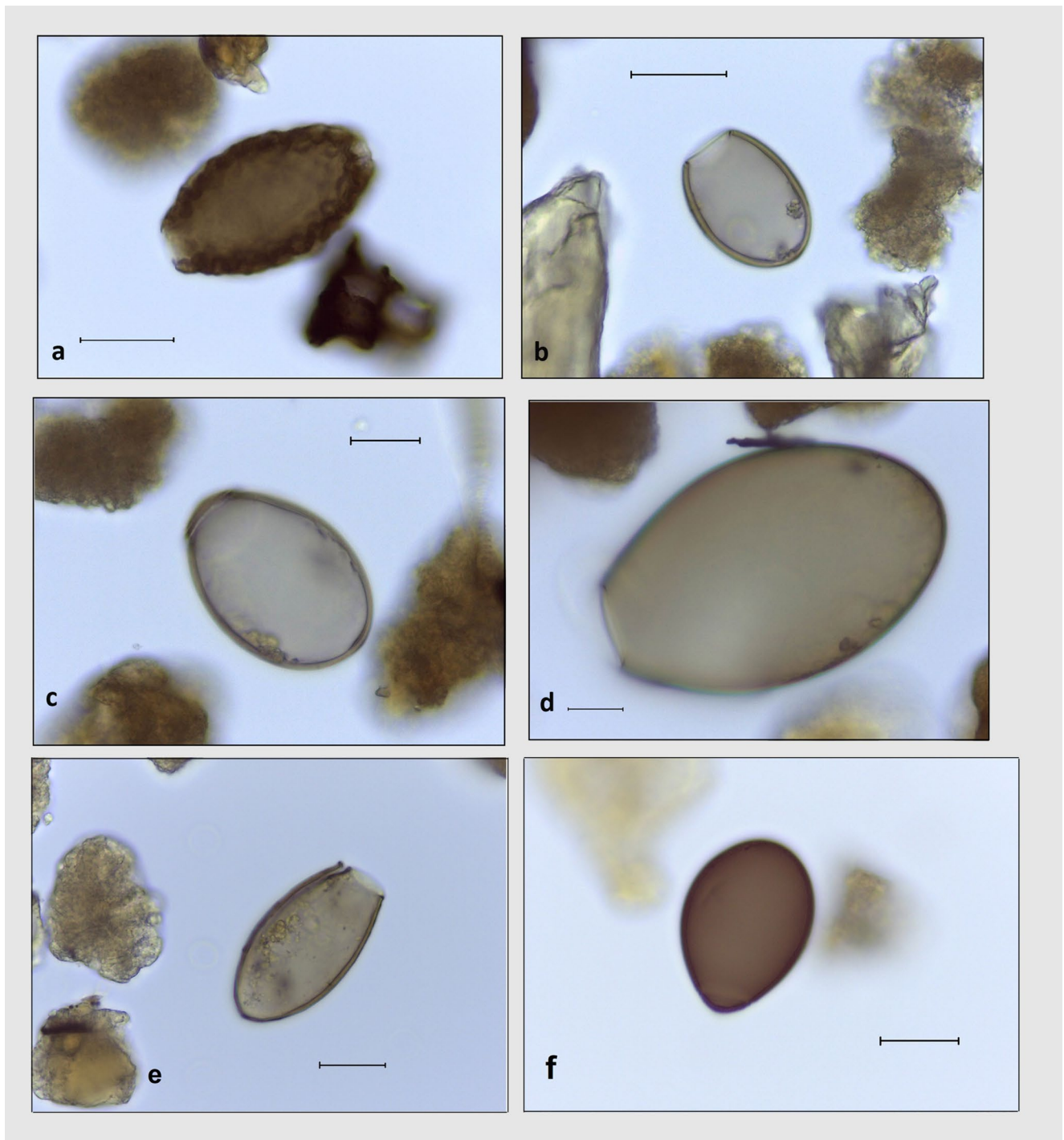


Fig. 7 Photos of parasite eggs retrieved at the Serteya II site: **a:** *Dioctophyma renale*; **b:** *Dicrocoelium*; **c:** *Diphylobothrium*; **d:** *Fasciola*; **e :** *Echinostoma*; **f:** *Spirometra*. Scale bar: 20 μ m (Photo: Celine Maicher)

Table 3 Parasitological data through diachronic view (after Maicher et al. 2021; after Maigrot et al. 2025)

N°	sector	chronological attribution based on 3D modelling and dates correction	calibration interval acc. to AMS date	Diphyllbothrium	Spirometra	Fasciola	Dioctophyma renale	Alaria alata	Dicrocoelium sp.
1493	Serteya II-1	Textile culture (late phase, 931–801 calBC)	931–801 calBC	1					
687	Serteya II-1	Textile culture (early phase) (1985–1871 calBC)	1985–1871 calBC						
1515	Serteya II-1	Textile culture (early phase) (1827–1670 calBC)	1827–1670 calBC		1				
658	Serteya II-1	Textile culture (early phase) (1687–1510 calBC)	1687–1510 calBC	-	-				
SI114 -TII	Serteya IISub	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.1 (ca.2470–2270))	-	16,113					2
SI114 - P2	Serteya IISub	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.1 (ca.2470–2270))	-					1	
SI114 - YII1	Serteya IISub	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.1 (ca.2470–2270))	-	15					
SI114 - YII2	Serteya IISub	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.1 (ca.2470–2270))	-	10			1	2	
SI114 - YII3	Serteya IISub	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.1 (ca.2470–2270))	-	4			1	1	
SI115 - Y18	Serteya IISub	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.1 (ca.2470–2270))	-	193					
SI115 276	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))	-				1		
SI115 1367	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))	-	-	-		-	-	-
SI115 1459	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))	-	4956			1	25	
SI115 1495	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))	-					19	
1569	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))	2896–2673 calBC	1					
1300	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))	2881–2623 calBC		103				
1095	Serteya II-1	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.3 (ca.2470–2270))	3025–2888 calBC	1					
IISub-16	Serteya IISub	Late Neolithic (Zhizhitsa culture, pile-dwelling, c.1 (ca.2470–2270))	2871–2574 calBC	-	-		-	-	-
7302	Serteya II-2	Late Neolithic (Zhizhitsa culture, pile-dwelling episode (ca.2470–2270))	2872–2580 calBC	2					
6898	Serteya II-2	Middle Neolithic (late phase, dwelling zone) (3093–2898 calBC)	3326–2916 calBC	331					
3633	Serteya II-2	Middle Neolithic (late phase, dwelling zone) (3093–2898 calBC)	3370–3101 calBC	4					
4465	Serteya II-2	Middle Neolithic (late phase, dwelling zone) (3093–2898 calBC)	3021–2886 calBC	6					
2451	Serteya II-2	Middle Neolithic (late phase, dwelling zone) (3093–2898 calBC)	3031–2896 calBC		3483				
7034	Serteya II-2	fishing constructions (3766–3641, 3633–3372 calBC)	3530–3368 calBC	2240					
8393	Serteya II-2	fishing constructions (3766–3641, 3633–3372 calBC)	3715–3626 calBC	-					
6916	Serteya II-2	Middle Neolithic (phase with fishing constructions) (3766–3641, 3633–3372 calBC)	3778–3636 calBC		1				
7025	Serteya II-2	Middle Neolithic (early phase) (4200–3800 calBC)	3960–3777 calBC	2					

Table 3 (continued)

N°	sector	chronological attribution based on 3D modelling and dates correction	calibration interval acc. to AMS date	<i>Diphyllbothrium</i>	<i>Spirometra</i>	<i>Fasciola</i>	<i>Dioctophyma alata renale</i>	<i>Alaria alata</i>	<i>Dicrocoelium</i> sp.
6769	Serteya II-2	Middle Neolithic (early phase) (4200–3800 calBC)	3962–3797 calBC	1541					
8234	Serteya II-2	Middle Neolithic (early phase) (4500–4300 calBC)	4447–4325 calBC		2				
4468	Serteya II-2	Middle Neolithic (early phase) (4500–4300 calBC)	4450–4313 calBC	1	1				

Conclusion

Given scarcity of human remains in this region coprolites serve as a proxy for understanding human diet and pathogens in a diachronic way. Coprolites provide information on dietary patterns at a very high temporal resolution and can be used to determine specific periods of seasonal site occupancy (Shillito et al. 2020) or food procurement strategies seasonality as was shown at Serteya II case. Specific dietary components and parasites in coprolites could point to one event, seasonal variation in availability of some foods may also explain the restricted set identified (Witt et al. 2021). Stable isotope $^{13}\text{C}/^{15}\text{N}$ analysis for the Serteya II site could illuminate larger-scale trends and point to aquatic resources as an important part of the diet and seasonal economic resource procurement system during the 4th -3rd millBC (Dolbunova et al. 2024; Mazurkevich et al. 2020a, b).

Coprolites are often recorded in direct proximity to habitation areas, which was traced also at the Serteya II site for the 3rd mill BC, that could have led to reinforcement of parasitic cycles and made some of them endemic. A shared diet and environment between companion animals and humans increase the likelihood of infection by similar parasites and pathogens (Witt et al. 2021), that can be also supposed for the Serteya II case where dogs were suggested to be producers for major part of coprolites with the dominance of *Diphyllbothrium* sp. *Diphyllbothrium* sp. is one of the principal parasitic infections of Neolithic times in both societies practiced productive economy and foraging one. The change in the occurrence of the parasites might have been an indication of cultural changes (Le Bailly et al. 2005). This could explain different parasites in coprolites at the Serteya II site dated to the 4th mill BC - the 1st mill BC connected with changes in food range or cooking techniques. Eliminating the effect of fish consumption could have been through cultural taboo of processing particular fish species, e.g. pike, recorded in modern groups of hunter-fisher-gatherers of Western Siberia (Serduykov 1979), or through medical treatment, e.g. with *Chenopodium* (Dommelier-Espejo and Pétrequin 2016), which has been recorded in a number of pollen diagrams and carpological analysis of Eastern European hunter-fisher-gatherer sites (Berihuete 2018; Kittel et al. 2020; Wieckowska-Lüth et al. 2021).

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s12520-026-02489-3>.

Acknowledgements Archaeological research of coprolites, including macroremains analysis was supported by Russian Science Foundation (project 22-18-00086-P). Radiocarbon dates and parasitological analysis were supported by CNRS (IRP NORth) and MEAE (Mission 2NOR). Micro-CT images were made within research project 125021702335-5 (Saint-Petersburg State University).

Author contributions E.D., Y.M., A.M. led the excavations and analyzed the whole context and materials, represented in the manuscript. A.K. made micro-ct analysis, A.A. and I.A. made macroremains and faunal analysis, M.le B. and C.M. completed parasitological analysis. All authors were involved in reviewing the manuscript and its conceptualization.

Funding Archaeological research of coprolites, including macroremains analysis was supported by Russian Science Foundation (project 22-18-00086-P). Radiocarbon dates and parasitological analysis were supported by CNRS (IRP NORTH) and MEAE (Mission 2NOR). Micro-CT images were made within research project 125021702335-5 (Saint-Petersburg State University).

Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

References

- Ash LR, Orihel TC (2007) Ash & Orihel's atlas of human parasitology. ASCP, Chicago
- Askeyev IV, Tarasov AY, Askeyev AO, Askeyev OV, Shaymuratova DN, Monakhov SP (2023) Highly productive fishing in Lake Onega? New data on the subsistence basis of the Late Stone age populations in Russian Karelia. *J Archaeol Sci Rep* 47(2023):103771. <https://doi.org/10.1016/j.jasrep.2022.103771>
- Askeyev IV, Tarasov AY, Shaymuratova DN, Askeyev AO, Monakhov SP, Askeyev OV (2022) Seasonality estimation of archaeological sites basing of fish bone remains in the case of Eneolithic workshop site Fofanovo XIII in Lake Onega. *Povolzhskaya arheologiya* 41(3):158–169 (in Russian). <https://doi.org/10.24852/pa.2022.3.41.158.169>
- Barbera AR, Camacho M, Reinhard K (2022) Parasitology and paleopathology. the routledge handbook of paleopathology. Routledge
- Berihuete M (2018) First results of the archaeobotanical study of the Test pit 2 Profile column. In: Lozovskaya O, Lozovsky V (eds.) Site Zamostje 2 and landscape evolution in the Volga-Oka region during the Holocene. St. Petersburg, IIMK RAN, pp 41–48
- Blong JC, Shillito LM (2021) Coprolite research: archaeological and paleoenvironmental potentials. *Archaeol Anthropol Sci* 13:15
- Brönnimann D, Pümpin C, Ismail-Meyer K, Rentzel P, Egüez N (2017) Excrements of omnivores and carnivores. In: Nicosia C, Stoops G (eds) Archaeological soil and sediment micromorphology. Wiley, Hoboken, pp 67–82
- Cambronero I, García N (2024) Does size matter? Morphological and content analysis of the coprolites from a Quaternary deposit in the Iberian Peninsula. *Quaternary Environ Hum* 2:100009
- Chugunova NI (1959) Guide to the Study of Age and Growth of Fish. Publishing House of the USSR Academy of Sciences, Moscow. (in Russian)
- Diedrich CG (2012) Typology of ice age spotted hyena *Crocuta crocuta spelaea* (Goldfuss, 1823) coprolite aggregate pellets from the European Late Pleistocene and their significance at dens and scavenging sites. In: Hunt AP, Milán J, Lucas SG, Spielmann JA (eds) Vertebrate Coprolites. New Mexico Museum of Natural History and Science, Albuquerque, pp 369–377
- Dolbunova EV, Dobrovolskaya MV, Mazurkevich AN, Danilevskaya VI, Korobushkin DI, Sablin MV, Iltsevich KY (2024) Izotopnyj sostav azota i ugljeroda kollagena kostej i zubov Suscorfa pamjatnikov neolita 6–3 tys. do n.e. (Dnepro-Dvinskoe mezhdurech'e i Nizhnee Podon'e): rekonstrukcija pishhevyyh racionov i jekosistem. In: Dobrovolskaya MV (ed.) Byulleten' vserossiyskogo seminaru stabil'nyye izotopy v arkheologicheskikh issledovaniyakh: metodicheskiye problemy i istoricheskaya problematika. Materialy VI zasedaniya (Bulletin of the All-Russian Seminar Stable Isotopes in Archaeological Research: Methodological Problems and Historical Issues. Proceedings of the VI Session). Moscow, IAN Publ (in Russian)
- Dommelier-Espejo S, Pétrequin P (2016) Analyses paléoparasitologiques à Clairvaux et à Châlain. In: Pétrequin P, Pétrequin AM (eds) Clairvaux et le 'Néolithique Moyen Bourguignon'. Les Cahiers de La MSHE Ledoux. Presses Universitaires de Franche-Comté, Besançon, pp 1175–1192
- Dommelier S, Bentrud S, Paicheler JC, Pétrequin P, Bouchet F (1998) Parasitoses liées à l'alimentation chez les populations néolithiques du lac de Châlain (Jura, France). *Anthropozoologica* 27:41–49
- Engovatova AV, Khrustalev A (1996) Coprolites from stone age sites of Podmoskovye. *Tver Sb* 2:148–154
- Guillaud É, Béarez P, Daujeard C, Defleur AR, Desclaux E, Roselló-Izquierdo E, Morales-Muñiz A, Moncel MH (2021) Neanderthal foraging in freshwater ecosystems: A reappraisal of the Middle Palaeolithic archaeological fish record from continental Western Europe. *Q Sci Rev* 252:106731. <https://doi.org/10.1016/j.quascirev.2020.106731>
- Kittel P, Mazurkevich A, Wieckowska-Lüth M, Pawłowski D, Dolbunova E, Plóciennik M, Gauthier E, Krąpiec M, Maigrot Y, Danger M, Mroczkowska A, Okupny D, Szymańska J, Thiebaut E, Słowiński M (2021) On the border between land and water: the environmental conditions of the Neolithic occupation from 4.3 until 1.6 ka BC at Serteya, Western Russia. *Geoarchaeology – Int J* 36:173–202
- Kubiak-Martens L, van der Linden M (eds) (2021) Neolithic human diet – Based on studies of coprolites from the Swifterbant Culture Sites, the Netherlands. Amersfoort: Cultural Heritage Agency of the Netherlands, Nederlandse Archeologische Rapporten 77
- Kulkova M, Mazurkevich A, Dolbunova E, Regert M, Mazuy A, Nestorova E, Sinai M (2015) Late Neolithic subsistence strategy and reservoir effects in 14 C dating of artifacts at the pile-dwelling site Serteya II (NW Russia). *Radiocarbon* 57(4):611623. https://doi.org/10.2458/azu_rc.57.18427
- Le Bailly M, Leuzinger U, Schlichtherle H, Bouchet F (2005) Diphyllorhynchus: Neolithic Parasite? *J Parasitol* 91(4):957–959
- Lebedev VD (1960) Freshwater Quaternary Ichthyofauna of the European Part of the USSR. Moscow State University Publishing, Moscow, Russia. (in Russian)
- Ledger ML, Mitchell PD (2019) Tracing zoonotic parasite infections throughout human evolution. *Int J Osteoarchaeology*. <https://doi.org/10.1002/oa.2786>
- Ledger PM (2018) Are circumpolar hunter-gatherers visible in the paleoenvironmental record? Pollen-analytical evidence from Nunalleq, southwestern Alaska. *Holocene* 28(3):415–426
- Lee CM, van Geel B, Gosling WD (2022) On the Use of Spores of Coprophilous Fungi Preserved in Sediments to Indicate Past Herbivore Presence. *Quaternary* 5:30
- Linseele V, Riemer H, Baeten J, De Vos D, Marinova E, Ottoni C (2013) Species identification of archaeological dung remains: A critical review of potential methods. *J Environ Archaeol* 18(1):5–17
- Maicher C, Hoffmann A, Cote NML, Perez AP, Seguí MS, Le Bailly M (2017) Paleoparasitological investigations on the neolithic lakeside settlement of La Draga (lake Banyoles, Spain). *Holocene* 27:1659–1668
- Maicher C, Le Bailly M (2024) The impact of climate change upon intestinal parasites in central Europe during the 4th millennium

- BCE. *Quat Sci Rev* 338:1–11. <https://doi.org/10.1016/j.quascirev.2024.108795>
- Maicher C, Maigrot Y, Mazurkevich A, Dolbunova E, Le Bailly M (2021) First contribution of paleoparasitology to the study of coprolites from the Neolithic site Serteya II (NW Russia). *J Archaeol Science: Rep* 38:1–6. <https://doi.org/10.1016/j.jasrep.2021.103093>
- Maigrot Y, Mazurkevich A, Dolbunova E, Gauthier E, Le Bailly M, Maicher C, Salavert A, Valayer A, Kulkov A (2025) Résultats d'une analyse multiproxy de coprolithes issus du sites de Serteya II, Ve-IIIe mill. Av. n. è., oblast de Smolensk, Fédération de Russie. In: Delhon C, Gourichon L, Martin L (eds) *Fumiers, bouses et guano: ordures ou or bun ? Statut, usage et gestion des déjections animales depuis la Préhistoire : potentiel archéologique et paléoenvironnemental*, 44e rencontres internationales d'archéologie et d'histoire Nice Côte d'Azur. éditions APDCA, Nice, pp 79–90
- Mazurkevich A, Dolbunova E (2011) Underwater Investigations in Northwest Russia: lacustrine archaeology of Neolithic pile dwellings. In: Benjamin J, Bonsall C, Pickard C, Fischer A (eds.) *Submerged Prehistory*. Oxbow Books, pp 158–172
- Mazurkevich A, Kittel P, Maigrot Y, Dolbunova E, Mroczkowska A, Wieckowska-Lüth M, Piech W (2020a) Natural and anthropogenic impact on deposits' formation in the wetland shore area: case study from the Serteya site, Western Russia. *Acta Geogr Lodziana* 110:81–102
- Mazurkevich AN, Dolbunova EV, Zaitseva GI, Kulkova MA (2017) Chronological timeframes of cultural changes in the Dnepr-Dvina region (7th to 3rd millennium BC). *Doc Praehistorica XLIV*:162–175
- Mazurkevich AN, Sablin MV, Dolbunova EV, Kittel P, Maigrot Y, Kazakov E (2020b) Landscape, seasonality and natural resources use in the 3rd millennium BC by pile-dwelling communities (NW Russia). In: Hafner A, Dolbunova E, Mazurkevich A, Prankenaite E, Hinz M (eds) *Settling Waterscapes in Europe. The Archaeology of Neolithic and Bronze Age Pile-Dwellings*. Open Series in Prehistoric Archaeology 1. Propylaeum, Bern and Heidelberg, pp 17–35. DOI: <https://doi.org/10.11588/propylaeum.714>
- Mazurkevich A, Panteleev A, Maigrot Y, Płóciennik M, Kittel P, Sablin M, Dolbunova E (2023) Human and birds: Avifauna at hunter-gatherer sites of the 6th to 3rd millennia BC (Western Dvina Lakeland). *Doc Praehistorica* 50:238–253
- Mitchell PD (2015) Human parasites in medieval Europe: lifestyle, sanitation and medical treatment. *Adv Parasitol* 90:389–420
- Mitchell PD (2024) Ancient parasite analysis: exploring infectious diseases in past societies. *J Archaeol Sci* 170:106067. <https://doi.org/10.1016/j.jas.2024.106067>
- Panfili J, Pontual H, Troade H, Wright PJ (eds) (2002) *Manual of fish sclerochronology*. Ifremer-IRD coedition, Brest
- Płóciennik M, Mroczkowska A, Pawłowski D, Wieckowska-Lüth M, Kurawska A, Rzdokiewicz M, Okupny D, Szymańska J, Mazurkevich A, Dolbunova E, Luoto TP, Kotrys B, Nazarova L, Syrykh L, Krapiec M, Kittel P (2022) Summer temperature drives the lake ecosystem during the Late Weichselian and Holocene in Eastern Europe: A case study from East European Plain. *CATENA* 214:106206. <https://doi.org/10.1016/j.catena.2022.106206>
- Prankenaite E, Dolbunova E, Mazurkevich A (2021) Pile dwellings in the Circum-Baltic area. *Doc Praehistorica XLVIII*:102–116
- Pravdin IF (1966) *Guide to the study of fish*. Moscow, Pischevaya Promyshlennost (in Russian)
- Reinhard KJ, Bryant VM (1992) Coprolite Analysis: A Biological Perspective on Archaeology. *Archaeol Method Theory* 4:245–288
- Reitz EJ, Wing ES (2008) *Zooarchaeology*. New York: Cambridge University Press, Second edition
- Romaniuk AA, Panciroli E, Buckley M, Pal Chowdhury M, Willars C, Herman JS, Troalen LG, Shepherd AN, Clarke DV, Sheridan A, van Dongen BE, Butler IB, Bendrey R (2020) Combined visual and biochemical analyses confirm depositor and diet for Neolithic coprolites from Skara Brae. *Archaeol Anthropol Sci* 12:274
- Savinetsky AB, Khrustalev AV (2013) Research Article Paleoparasitological investigations in Mongolia, Middle Asia and Russia. *Int J Paleopathol* 3:176–181
- Serduykov AM (1979) *Difillobotriidy Zapadnoj Sibiri*. (In Russian)
- Shillito L-M, Blong JC, Green EJ, van Asperen EN (2020) The what, how and why of archaeological coprolite analysis. *Earth Sci Rev* 207:103196
- Slepchenko SM, Lobanova TV, Vizgalov GP, Alyamkin GV, Ivanov SN (2022) New contribution of archaeoparasitology in the Far North of Eastern Siberia: First data about the parasitological spectrum of Stadukhinsky Fort in the 17th-18th centuries. *J Archaeol Science: Rep* 41:103304. <https://doi.org/10.1016/j.jasrep.2021.103304>
- Soulsby EJJ (1982) *Helminths, arthropods and protozoa of domesticated animals*. 1982, 7th ed. Baillière Tindall, London
- Taylor M, Coop R, Wall R (2007) *Veterinary parasitology*. Blackwell Pub., Oxford; Ames, Iowa
- Tolar T, Galik A, Le Bailly M, Dufour B, Caf N, Toškan B, Bužan E, Zver L, Janžekovič F, Velušček A (2021) Multi-proxy analysis of waterlogged preserved Late Neolithic canine excrements. *Veget Hist Archaeobot* 30:107–118
- Van Neer W, Lõugas L, Rijnsdorp AD (1999) Reconstructing Age Distribution, Season of Capture and Growth Rate of Fish from Archaeological Sites Based on Otoliths and Vertebrae. *Int J Osteoarchaeology* 9:116–130
- Wheeler A, Jones AKG (1989) *Fishes*, xiv, 21 pp. Cambridge University Press
- Wieckowska-Lüth M, Gauthier E, Thiebaut E, Słowiński M, Krapiec M, Dolbunova E, Mazurkevich A, Maigrot Y, Danger M, Kittel P (2021) The palaeoenvironment and settlement history of a lake-shore setting: An interdisciplinary study from the multi-layered archaeological site of Serteya II, Western Russia. *J Archaeol Science: Rep* 40(B):103219
- Witt KE, Yarlagadda K, Allen JM, Bader AC, Simon ML, Kuehn SR, Swanson KS, Tzu-Wen L, Cross, Hedman KM, Ambrose SH, Malhi RS (2021) Integrative analysis of DNA, macroscopic remains and stable isotopes of dog coprolites to reconstruct community diet. *Sci Rep* 11:3113
- Yang Liu Z, Xing Z, Xingbo X Hai (2021) The technological advance and application of coprolite analysis. *Front Ecol Evol* 9 : 1-10

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.