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Original Paper

LIVING ON THE CLIMATE EDGE SUITABLE FOR EARLY FARMING: THE COMPLEX SUBSISTENCE STRATEGIES OF THE LATE NEOLITHIC PEOPLE AT THE ABORA SITE IN LATVIA

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The Late Neolithic Abora settlement site occupies a prominent place in Lake Lubāns micro-region archaeology. The Lake Lubāns wetland, including the Abora site, has been systematically researched by the archaeologist Ilze Biruta Loze in 1962–1990 and episodically in 1999–2012. Besides the settlement culture layers, the Abora site includes human burials as well, providing both osteological and archaeological material. Altogether, 61 burials have been excavated within the settlement territory. The Abora settlement is a tempting site for further investigations of complexities of the transition to farming in the Late Neolithic in Latvia. This paper represents an attempt to apply palaeodemographic methodology, ^{14}C dating, FRUITS analysis and estimates of the freshwater reservoir effect to preserved osteological and archaeological material of Abora site and discusses the results in context with the previous data and archaeological interpretations. The new radiocarbon dates of the human bones generally correspond with the previous absolute dating of the site, spanning from 3484–3102 calBC to 2137–1925 calBC. The adult and adolescent isotopic data (29 individuals) generally corresponds very well with the local Lake Lubāns wetland isotope ecology. However, it contradicts the previous interpretations that overemphasised the role of domesticated animals and cultivated crops in the Abora human subsistence strategies. The new data show that the majority of individuals had a freshwater diet and others — a mixed freshwater/terrestrial diet.

Keywords: *Abora settlement site, stable isotope analysis, palaeodemography, radiocarbon dating, freshwater reservoir effect.*

INTRODUCTION

Palaeodietary research in Latvian archaeology. One of the most researched topics in contemporary archaeology has been the transition from foraging to farming. Although more popularly known as the Neolithic Revolution, in Northern Europe this transition was in no way a rapid change. More likely, it was a slow and gradual process with several phases, possible setbacks and local variabilities. East Baltic archaeologists have been discussing this important transition and the way it took place since the last century. For example, earlier Latvian scientific publications argued that the Early Neolithic started with the introduction of pottery, the Middle Neolithic was the time when first evidence of farming can be found, and during the Late Neolithic farming started to slowly replace foraging and became the dominant subsistence strategy by the Broze Age (Loze, 1979). Estonian archaeologist Valter Lang proposed a more detailed four-phased transition model, specific for the East Baltic: 1) foraging societies start to focus more on a plant-based diet; 2) first introduction of cultivated crops and domesticated animals; 3) gradual transition to farming as the leading subsistence strategy; and 4) first intensification of farming (Lang, 1999). Baltic archaeologists of the 20th century generally emphasised hunting of wild animals as the most prominent subsistence strategy of Stone Age foragers, complemented by gathering plants and fishing. This interpretation was based both on zooarchaeological material and

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burial archaeology, with grave goods emphasising hunting, and therefore Lang's model with the first phase — transition to plant-based diets — was consistent with the scientific thought at the time.

Later palaeodietary research that was based on carbon and nitrogen stable isotope analysis, however, proved that the Mesolithic and Early Neolithic people of the Zvejnieki site in Latvia relied primarily on fishing as the protein source, with hunting as an occasional supplementary source (Eriksson 2003; 2006). More recently, a locally specific term — the Forest Neolithic — has been appropriated in the scientific literature to characterise the unique situation in the Baltics, where pottery and a semi-sedentary lifestyle became widespread, without the usually accompanying early farming and/or animal husbandry. In Latvian archaeology, stable isotope analysis and other more contemporary palaeodietary research methods have been more widely applied to the Mesolithic and Forest Neolithic periods, with occasional insights in the Late Neolithic Corded Ware Culture (CWC) people, who are considered to be at least to some extent associated with farming practices, such as animal husbandry (Eriksson, 2006).

Previously, research on transition to farming in Latvia was carried out by archaeologists Harri Moora (1952), Jānis Graudonis (2001), Andrejs Vasks (2015), Ilze Biruta Loze (2001), and others. I. B. Loze based her research strongly on the Lake Lubāns wetland material, which represents the most densely populated Stone Age micro-region in Latvia. Her research led to a conclusion that farming in this micro-region became more widespread during the Late Neolithic and became the leading subsistence strategy during or shortly after the transition to the Bronze Age (Loze, 1997). Another body of discussion is related to the question of how strongly the transition to farming was connected with migrations. The Corded Ware Culture (CWC) was suggested as the people that introduced crop cultivation and animal husbandry in Latvia. However, there is no strong evidence for this suggestion, as it is largely based on correlation between the CWC sites and potentially agricultural lands (Vasks, 2015, 66, 67). More interestingly, recent aDNA analysis of the Zvejnieki cemetery in Latvia called in question previous suggestions that the CWC people migrated to Latvia from the Central-European early farmers' societies. The new hypotheses states that they were migrants from the Eastern steppe regions instead (Mittnik *et al*., 2018).

Recent research of Bronze Age cemeteries in Latvia (1400–600 calBC) indicated that farming, as the leading subsistence strategy, could be dated with the Late Bronze Age, but not necessarily with the Early Bronze Age. This hypothesis was based on correlation between stable isotope analysis and radiocarbon dates, but the sample size was not large enough for a strong claim (Legzdiņa *et al*., 2020; Vasks *et al*., 2021).

Recently, more widespread application of stable isotope analysis in East Baltic archaeology sparked new discussions regarding the time and the complexity of the transition (Piličiauskas *et al*., 2016; 2017), and re-evaluation of older data and new radiocarbon dates strongly called in question previous claims of crop cultivation during the Late Neolithic in the East Baltic (Grikpėdis *et al*., 2017). The Late Neolithic Abora settlement human skeletal material previously has not been studied using the stable isotope analysis method. Therefore, with this paper, we join the discussion by providing new stable isotope and radiocarbon data from the Late Neolithic Abora site and by discussing them in context with previous data and archaeological interpretations.

To further investigate the complexities of the transition to farming, the Late Neolithic Abora site was chosen as a case study. Abora occupies a prominent place in Lake Lubāns micro-region archaeology. Although the settlement was occupied most densely during the Late Neoltihic, it has been argued that the inhabitation continued in the Early Bronze Age as well, thus chronologically covering the period most discussed regarding the transition to farming. Besides the settlement culture layers, the Abora site includes human burials as well, providing both osteological and archaeological material.

Archaeology and palaeogeography of the Abora site. Lubāns is the largest lake in Latvia, although it is rather shallow — the median depth of the modern lake is only 1.6 m. A unique micro-environment forms around the lake, which occupies an area of 480.2 km^2 — the Lake Lubāns wetland (Fig. 1). It was formed in a geological depression resulting from the activity of the last glacier. Since the end of the last glaciation, i.e. since the beginning of the Holocene ~9700 BC, the Lubāns palaeo-lake water levels



Fig. 1. Location of Abora settlement.

dropped and the climate became warmer. Therefore, since the beginning of the Mesolithic, the shores of Lake Lubāns and banks of the many rivers that had formed due to lake level lowering, became an attractive ecological niche for groups of foragers. Until now, a total of 27 Stone and Bronze Age settlements and a large number of stray finds have been recorded in the wetland. During the Neolithic, this micro-region was the most densely inhabited territory throughout the entire East Baltic. It is the largest known crossing point of the Stone Age trade routes in the East-Baltic inland territories. The formation of this centre was possible due to the advantageous location near a local water route — Aiviekste river — which connects the lake with the largest water route in East Baltic – Daugava river (Loze, 2015). Consequently, many important innovations reached this micro-region foremost: earliest pottery and evidence of domesticated animals and crops in Latvia, widely practiced amber craft (imported from seacoast), earliest evidence of bronze processing (Vasks, 2015).

The Lake Lubāns wetland, including the Abora site, has been systematically studied by the leading archaeologist Ilze Biruta Loze during 1962–1990, and episodically during 1999–2012 (Loze, 1979; 2000; 2015). Alongside research on archaeological topics such as lifestyle and demography of the inhabitants, their housing, migrations, etc., palaeogeographical research was carried out as well: geomorphology, palaeovegetation, modelling of lake forming stages and water level fluctuations since the early Holocene till nowadays (Eberhards, 2015; Grūbe, 2015; Kalniņa, 2015). Research on subsistence strategies and dietary practices was based on palynological and zooarchaeological analysis (Loze, 1979) and palaeobotanical analysis (Loze and Iakubovskaia, 1984).

The Abora site is located at the right bank of its namesake Abora stream that flows into Abaine river that, in turn, flows into the larger Aiviekste river, thus connecting the area with lake Lubāns. Therefore, the local environment was rich in easily accessible water bodies and water routes. The settlement was established on an elevated ground and the slope. The estimated area of the settlement is ~5000 m^2, of which 1311 m^2 have been unearthed during the many archaeological excavations supervised by Ilze Biruta Loze. The thickness of the culture layer reached 0.6 m on the higher ground and 1 m on the slope. Altogether, 3885 wooden, flint, stone, amber, bone and antler artefacts have been found in the site. The number of amber finds (1410) suggests that it was the largest amber workshop in the Lubāns wetland. Proportions of the 18 000 potsherds are as follows: 16 697 are local Late Neolithic types, and 1112 are Early Bronze Age richly ornamented Lubāns-type ware (Loze, 1979).

Altogether, 61 burials were unearthed within the settlement territory. The dead were buried on their backs or in crouched positions (Fig. 2a), in two cases in a seated position and in different cardinal directions. Single burials dominated, although a few were common graves with two or three burials (Fig. 2 b). Grave goods were found in 22 burials: pendants (animal teeth, bone lunulae, and trapezoids), amber ornaments, and bone and flint points. The cemetery was contemporaneous with the settlement; thus, it is not surprising that the burials were more or less disturbed. Additionally, single human bones were discovered not only in clear burial contexts, but across the cultural layer as well (Loze, 1979). Previous ^{14}C dates suggested the calendar range of the settlement to be 3350–2200 BC, i.e. the very end of the Middle Neolithic to the Late Neolithic. However, the Early Bronze Age pottery finds suggested continuous inhabitation for some time after the Late Neolithic (Loze, 2008).

Interdisciplinary research on the Abora material was carried out during and shortly after the first (and largest) excavation phase. Zooarchaeological, macrobotanical, and palynological analysis were incorporated with the archaeological research and published along with similar analysis of other lake Lubāns sites (Loze, 1979; Loze and Iakubovskaia, 1984). Although carried out almost half a century ago, this research, its gathered data, and drawn conclusions are still influential in Latvian archaeology.

MATERIAL AND METHODS

Anthropological material from Abora is stored at the Bioarchaeological Repository, University of Latvia, Institute of

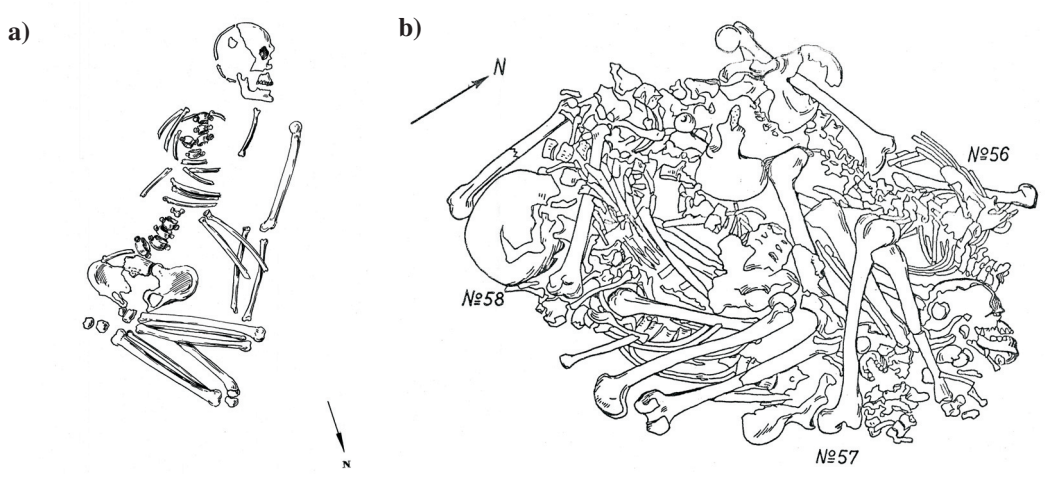


Fig. 2. **a)** Burial 6 (Loze, 1979, Fig. 40). **b)** Common grave 56–58 (Loze, 1979, Fig. 41).

Latvian History. From the 61 burials recorded during the Abora excavations, well preserved full or partial skeletal material was available from 32 burials. Most of them were single graves, but burials 3–4&6, 12–14, 56–58, 20/21 and 23/24 formed common graves. Archaeologically, all of the graves were dated to the Late Neolithic. Eight individuals were most likely buried in a crouched position, which is considered to be a signifying cultural tradition of the CWC people. However, none of these burials had any grave goods that could confirm this interpretation. Interestingly, three of the common grave groups — 3–4&6, 12–13 and 56–58 were formed by crouched burials.

Given that this is not a typical cemetery, but a burial ground that was used parallel with the settlement and over a time span of more than 1000 years, these burials most likely do not reflect the demographic structure of the society. However, sex and age determination was done when possible. In interest of keeping a consistent sampling strategy for stable isotope analysis, almost all were sampled from cranial elements, with an exception for burials 56 and 57, where no cranial material was available and femur was sampled instead. Twenty-four burials were sampled for carbon and nitrogen stable isotope analysis, and 14 of them were sampled for radiocarbon analysis as well. In two cases it was possible to identify terrestrial animal bones associated with burials; therefore, two burials were double-sampled in order to address the freshwater reservoir effect (FRE): burial 8 (human and auroch) and burial 39 (human and wild boar). Additionally, a modern fish (pike) bone, caught in Lake Lubāns in autumn 2019, was dated as well to determine the full FRE of the lake.

Besides the burials, there was additional anthropological material available from Abora that was collected as different single human bones from the culture layers. Samples for stable isotope analysis were taken from 11 humeri and one cranial bone.

Ageing and sexing of the burials was carried out following internationally approved methodology (Buikstra and Ubelaker 1994). Radiocarbon dating was done at the Oxford Radiocarbon Accelerator Unit, Oxford University (Bronk Ramsey *et al*., 2004; Brock *et al*., 2010).

Stable isotope analysis was carried out by the leading author over the last four years. Part of the samples were analysed at the Research Laboratory for Archaeology and the History of Art, Oxford University (RLAHA, OU), and the other part — at the Analytical Chemistry Department, Chemistry Faculty, University of Latvia (CF, UL). In both cases, given the old age of the bones and the uniqueness of the material, bone 'collagen' extraction was done with a relatively mild method, generally following laboratory protocol established by Longin (1971) with some modifications (Chisholm *et al*. 1983). Bone chunks were demineralised in 0.5M HCl solution over a course of days, depending on each individual sample. Repeated rinsing in a deionised H_2O followed. 'Collagen' gelatinisation was done in a pH = 3 solution at ~72 °C for approximately 48 hours. The gelatine was filtered with 60–90 μm Ezee filters and freeze-dried. The collagen samples were then analysed for $\delta^{13}C$ and $\delta^{15}N$ with SerCon Callisto CF-IRMS system at the RLAHA, OU and with Nu Instruments Nu Horizon IRMS and EuroVector Euro EA3024 at the CF, UL. Delta notation (δ) expresses ratios of $^{13}C/^{12}C$ and $^{15}N/^{14}N$ relative to the international standards V-BDP for carbon and AIR for nitrogen in parts per mill (‰). Standard deviations are < 0.2‰ for δ13C and < 0.3‰ for δ15N.

RESULTS

The results are displayed in Tables 1 and 2, and they include: anthropological evaluation, demographic analysis, radiocarbon dates and stable isotope analysis data, including the relevant 'collagen' purity parameters and indications of the laboratory in which they were prepared and analysed.

Anthropological analysis. The 61 burials recorded in excavations could be divided in three groups according to their depth from the surface: 0.50–0.60 m, 0.3–0.5 m and 0.2–0.3 m. It was possible to determine that 24 individuals were buried on their backs in a stretched-out position, but 8 were most likely buried in a crouched position. For the rest the burial position was not possible to determine. The cardinal positions were highly variable and did not form patterns. Both single and common burials were unearthed in different depths. Altogether, 35 single burials, 7 double burials and 4 common burials have been reported (Loze, 1979).

In some cases, it was possible to determine the sex and age of the individuals in group graves. Common burials 3–4&6 and 56–58 both had one adult female and two adult males. Common burial 12–14, on the other hand, had three children: two 3–4 years olds and one 8–9 years olds.

Due to the fragmentary nature of the material, altogether, sex and age determination was possible only for 32 of the 61 recorded burials, i.e. 52%. Additional anthropological data could be gathered from the single human bones found in the culture layer: cranial fragments, mandibles and long bones. Within the stray human bone collection, a minimum number of 40 individuals belonging to different age groups could be determined.

Combination of the burials and the stray human bones thus provides anthropological data of 72 individuals (Table 2). Twenty-four of them were subadults (33%), 20 were adult females, 26 — adult males, and two — undetermined adults. Children aged 0–14 were distributed evenly, but the nine subadults aged 15–19 was a notably large proportion. As there were slightly more adult males than females, the sex dimorphism coefficient was 1.2. Adult female age at death was notable: from the 11 with determined age at death, five were under 25 years old. In adult males this tendency was the opposite: eight of 12 with determined age at death were 30–50 years old. It is possible that these differences reflect reproductive processes and complications during the first pregnancies. However, it should be stressed that

Table 1. Stable isotope analysis data and radiocarbon dates of burials

Burial	Lab code	Sex	Age (years)	Bone	%C	%N	C/N	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Arch. dating/ depth m	^{14}C BP	^{14}C calBC (95.4%) / median
3	Abo3a	male	19–21	crania	42	15	3.2	–22.4	13.6	LN	–	–
4	Abo4a	female	25–28	crania	47	16	3.3	–22.7	9.7	LN	–	–
6	OxA-34419	male	30–40?	crania				–22.5	14.2	LN / 0,58	4553 ± 33	3484–3102 3218
8	OxA-38996	–	1 (± 2 months)				3.2	–24.6	17.8	LN / 0,35	4303 ± 20	3004–2885 2906
8	OxA-38997	animal	–	*Bos primigenius*			3,2	–23.1	5	LN	4119 ± 20	2862–2579 2694
9	Abo 9a	–	4 ± 1	crania	45	16	3.3	–20.5	14.9	LN / 0,5		
	OxA-38998			crania			3.2	–20.7	15.1		4457 ± 20	3331–3024 3223
12	OxA-39054	–	8–9				3.2	–21	14.7	LN / 0,4	4465 ± 21	3334–3027 3235
13	OxA-34420	–	4 ± 1	crania				–22.8	15.7	LN / 0,38	4384 ± 33	3096–2910 2991
17	OxA-38999	–	3 ± 1	crania			3.3	–23.3	11.6	LN / 0,2	3657 ± 26	2136–1947 2030
20/21	Abo 20-2a	male	adult	crania	39	14	3.4	–24.0	12.5	LN	–	–
22	Abo22a	male	adult	crania	39	14	3.3	–23.8	12.1	LN / 0,25	–	–
	OxA-39000						3.2	–24.8	12,1		3823 ± 20	2397–2151 252
23/24	OxA-34421	male	adult	crania				–24.1	12.1	LN / 0,25	3645 ± 34	2137–1925 2013
25	Abo 25a	?	adult	crania	43	16	3.2	–21.8	14.4	LN	–	–
30	Abo 30a	male	25–30?	crania	43	15	3.3	–24.5	12.8	LN	–	–
33	OxA-34422	female	30–40	crania				–22,5	10.9	LN / 0,3	3937 ± 31	2566–2300 2424
39	Abo39a	female	25–30	crania	39	13	3.4	–23.5	12.0	LN 0,35		
	OxA-39055						3.3	–25.2	9.4		4105 ± 21	2857–2574 2663
39	OxA-39056	animal		*Sus scrofa*			3.2	–21.3	6.1	LN	4063 ± 20	2837–2492 2590
40	Abo 40a	female	19–21	crania	44	15	3.4	–23.0	12.2	N 0,35	–	–
	OxA-39057						3.3	–22.4	12.5		4096 ± 21	2851–2573 2646
51	OxA-34423	–	7–8	crania				–23.7	11.7	LN / 0,2	3784 ± 32	2339–2050 2212
52	Abo52a	–	8–9	crania	45	16	3.3	–23.2	11.5	LN	–	–
54	Abo 54a	–	13–15	crania	45	16	3.3	–23.3	12.3	LN / 0,2	–	–
	OxA-39058						3.2	–23.6	11.3		4333 ± 20	3011–2898 2928
55	Abo 55a	female	20–25	crania	45	16	3.3	–22.7	9.9	LN	–	–
56	OxA-34424	male	35–40	femur				–22.9	11.2	LN / 0,5	4374 ± 33	3092–2907 2983
57	Abo57a	male	40–50	femur	42	15	3.3	–23.0	10.7	LN	–	–
S1	Abo 1h	–	adult	humerus	46	16	3.3	–24.2	12.5	LN	–	–
S2	Abo 2h	–	adult	humerus	44	16	3.2	–23.4	11.4	LN	–	–
S3	Abo 3h	–	adult	humerus	44	16	3.2	–22.2	11.5	LN	–	–
S5	Abo 5h	–	adult	humerus	43	16	3.2	–23.7	12.9	LN	–	–
S6	Abo 6h	–	adult	humerus	43	16	3.2	–21.8	10.5	LN	–	–
S7	Abo 7h	–	adult	humerus	43	16	3.2	–24.3	11.9	LN	–	–
S8	Abo 8h	–	adult	humerus	44	16	3.2	–22.4	10.4	LN	–	–
S9	Abo 9h	–	adult	humerus	43	16	3.1	–24.1	12.0	LN	–	–
S10	Abo 10h	–	adult	humerus	43	16	3.1	–22.8	9.9	LN	–	–
S11	Abo 11h	–	adult	humerus	44	16	3.1	–24.0	11.6	LN	–	–
S12	Abo 1c	–	adult	crania	40	14	3.2	–21.7	13.7	LN	–	–
L. Lubāns	modern	pike		*Esox lucius*						2019	284 ± 18	1521–1658 calAD 1562 calAD

Table 2. Sex and age of Abora I settlement burials (number of individuals)

Age group	Children (n)	Male	Female	Adults
0	3			
1–4	3			
5–9	7			
10–14	2			
15–19	9			
20–24		3	5	
25–29		1	4	
30–40		5	2	
40–50		3	0	
Adults		14	9	2
Total	24	26	20	2

due to the small sample size and the character of the site, all of the addressed demographic tendencies could very well be incidental.

Analysis of Abora human dental health was possible for 15 individuals. However, the teeth were preserved partially, and therefore statistical analysis of caries and other pathologies was impossible. Most of the analysed were young individuals from the age group 18–25 years. Most common extent of tooth wear was the second degree, in some cases the third degree (Fig. 3a). One case, burial 58, was an older man, 40–50 years old with maxilla teeth, all having the maximum 8th degree wear. This demonstrated intense abrasive stress for the teeth during his lifetime (Hillson, 2008) (Fig. 3b).

Bone 'collagen': radiocarbon dates and stable isotope analysis. Preservation of the bones turned out to be very good — it was possible to extract organic matter from almost all of the samples, except one, which is remarkable, given the old age of the bones. Only two samples failed 'collagen' quality tests: samples from burials 7 and 58 had C/N ratios out of range and were therefore excluded from further discussion. All of the samples selected for radiocarbon analysis could be successfully dated. Human individuals from burials 9, 39, 40, and 45 were double sampled, first for stable isotope analysis, and later for radiocarbon dating when additional funding became available. As the 'collagen' extracted for ^{14}C dating were analysed for stable isotopes as well, we now have two sets of isotopic data for each of those individuals. In case of burial 39, this sampling strategy turned out to be beneficial. It was one of the two burials that were selected for double-dating — a human bone and a wild boar bone from the burial context. Although both ^{14}C dates turned out to be very close, δ^{13}C and δ^{15}N values of the human 'collagen' were alarming: 25.2‰ and 9.4‰, respectively. Such a low δ^{13}C value by itself would not be suspicious as it falls within the local isotope ecology, but in combination with the low δ^{15}N it is hard to explain. Previous stable isotope analysis from the same individual, but from a different cranial fragment, produced values δ^{13}C = –23.5 and δ^{15}N = 12.0, which is an expected combination for a diet high in fish protein intake. In previous decades, it was a common praxis for anthropologists to use wax in skull reconstructions, and such was the case with the Abora collection as well. Although the sample was thoroughly cleaned before treatment, it is possible that some wax particles still contaminated the sample. We therefore include the data in this paper, but in further discussion we approach the ^{14}C date with caution and disregard the stable isotope data of this sample entirely.

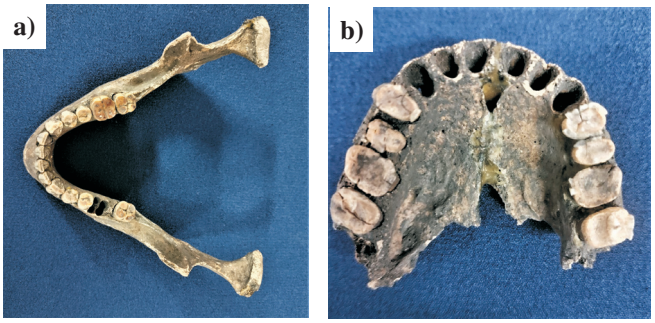


Fig. 3. **a)** Mandible of burial 3. Male 19–21years. **b)** Maxilla of burial 58. Male 40–50 years. Photo by G. Zariņa

The following discussion is therefore based on 14 human bone and 2 terrestrial animal bone ^{14}C dates, stable isotope data of 33 individuals, and anthropological data of 72 full or partial human skeletal material.

DISCUSSION

The data collected in this research allow us to address several different aspects of the Late Neolithic Abora people and their way of life: demographic tendencies, individual diets, as well as population subsistence strategies during the time span of site inhabitation, and additionally a preliminary discussion of the Lake Lubāns freshwater reservoir effect on the human bones 'collagen' radiocarbon dates, as well as the temporal distribution of burials within the settlement culture layer.

Demography. Previous research on the Late Neolitithic demography in Latvia is largely based on comprehensive analysis of the Zvejnieki Stone Age cemetery. With more than 300 burials, it is the largest Stone Age cemetery in Northern Europe. This research showed notable demographic changes from the Late Meosolithic till the Late Neolithic. During the Neolithic, there was a slight increase in male life expectancy. Female life expectancy, on the other hand, experienced a decrease due to increased number of deaths in the 15–25 age group. Most probably, this was connected with reproductive acceleration and complications during first pregnancy. Also, the age of the first pregnancy seemed to be lower as well — 16–20 years (Zariņa, 2009). It is theorised that the reproductive acceleration was possible with introduction of farming, as it provided such food groups as grains and milk, and could enable earlier weaning, which, consequently, enabled a shorter time gap between pregnancies. More frequent pregnancies caused stronger biological stress for the women's bodies, thus decreasing life expectancy even more.

Thus, the Zvejnieki demographic data correlates with other North-European Neolithic populations with acceleration of reproductive rates and decrease in female life expectancy. Although the Abora site is not a typical cemetery and its demographic data should be approached with caution, anthropological analysis of this Late Neolithic site demonstrated similar tendencies: large proportion of adult females died before reaching 25 years of age (5 out of 11), while most of the males died after 30 years old (8 out of 12).

Stable isotope analysis of the Zvejnieki material shows that during the Mesolithic, breastfeeding could be prolonged up to three years, but during the Late Neolithic, it shortened to 1.5–2 years, thus indicating that the first demographic transition in Latvia correlated with introduction of farming (Zariņa, 2019).

Four of the analysed Abora individuals were children younger than five years and could potentially reflect breastfeeding or weaning. Burial 8 was an approximately 1-year-old child, and the isotope data were $\delta^{13}C = -24.6‰$ and $\delta^{15}N = 17.8‰$ (OxA-38996). The $\delta^{13}C$ value is one of the lowest of the whole dataset, but it corresponds with six adults with $\delta^{13}C$ values –24‰ (burials 20/21, 23/24, 30, and single bone samples S1, S7, S9). Five of them have $\delta^{15}N$ values 12‰ and one was 11.9‰, putting them on the far end of the local freshwater diet. The 1-year-old child from burial 8 in this context is someone who is one full trophic level above the adults, i.e. an infant with an exclusively breastfeeding diet. Two children, both 4 ± 1 years old, have notably differing $\delta^{13}C$ values, but somewhat elevated $\delta^{15}N$ values: burial 9 — $\delta^{13}C = -20.7‰$, $\delta^{15}N = 15.1‰$ (OxA-38998); burial 13 — $\delta^{13}C = -22.8‰$, $\delta^{15}N = 15.7‰$ (OxA-34420). Although they have differing diets in means of the ecological sources, in both cases the elevated $\delta^{15}N$ values could be seen as indicating still some proportion of breastmilk in their diet, which is notable, given their age. The fourth case was a 3 ± 1 year old child from burial 17, with isotopic values $\delta^{13}C = -23.3‰$, $\delta^{15}N = 11.6‰$, placing it with the largest adult value cluster and indicating no signs of breastfeeding or weaning. Although there are very few data points, they show some possible contradictions with the Zvejnieki material discussed above, and only burial 9 corresponds with the Zvejnieki study conclusion of shortened breastfeeding during the Late Neolithic. Future research with application of tooth dentine micro-sample stable isotope analysis will draw a clearer picture regarding breastfeeding patterns in the Abora Late Neolithic society.

Palaeodietary implications. The adult and adolescent isotopic data (n = 29), on the other hand, provide a prominent dataset, based on which a deeper analysis of the Abora human diets can be carried out. Except a few outliers, the human diet data correspond very well with the local Lake Lubāns wetland isotope ecology (Fig. 4). The data show that the Abora human diets during the Late Neolithic were definitely not what would be expected from early farmers, i.e. less depleted $\delta^{13}C$ and lower $\delta^{15}N$ values. Whereas the majority of human isotope values, when viewed in context with the Stone Age animal data, group in a cluster with one

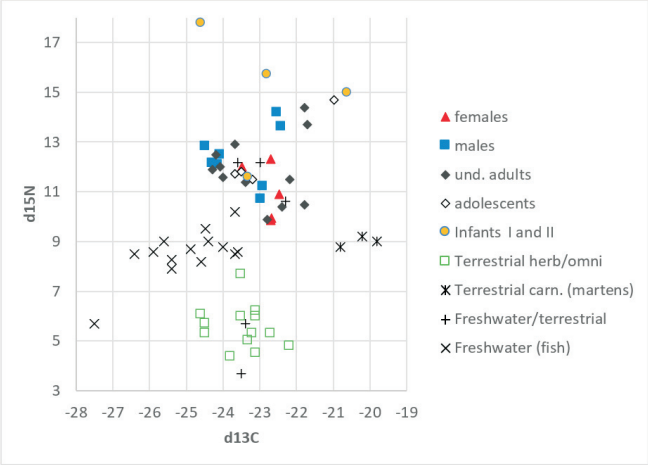


Fig. 4. Plot chart of $\delta^{13}C$ and $\delta^{15}N$ values (‰).

end reflecting a freshwater diet and the other end — a mixed freshwater/terrestrial diet. Most interestingly, there are three animals that fall together with the human cluster: two otters and a badger. Both otters and badgers are omnivores, with otters tending to include more aquatic resources in their diet, and badgers — more terrestrial. However, an important part of the badger diet is amphibians and bird eggs, which in the case of the Lake Lubāns wetland would be dominated by water-fowl eggs. In most important part of the otter diet is fish, but other variable food sources are included as well. The human data overlapping with these animals is a strong confirmation of the reliance on aquatic resources in the Abora human diets.

Bayesian statistical analysis of isotope data with FRUITS. FRUITS (Food Reconstruction Using Isotopic Transferred Signals) is a programme that allows the user to build their own statistical analysis model, by applying different determinants, such as uncertainties, dietary offsets, source fractions and priors (Fernandes *et al.*, 2014). With the programme becoming more widely used, there can be found a variety of determinants and their combinations that researchers have chosen to apply to their models. From very simple, to highly complicated FRUITS models, there are significantly different values of dietary offsets and fraction values used in literature, which, consequently, returns differing statistical approximations. The most detailed model takes into account collagen-to-flesh offsets for the source values, adding the highest trophic offsets, and applies $\delta^{13}C$ source fractions in protein vs. carbohydrates and lipids (commonly referred to as "energy") (Fernandes *et al.*, 2015), FRUITS produced highly counter-intuitive estimations of our data, attributing very low fish intake for the individuals with the most depleted $\delta^{13}C$ and elevated $\delta^{15}N$. Other models with different parameters (Meadows *et al.*, 2018), although less conspicuous, still produced estimations that in our opinion are questionable. Some of the Abora individual estimations mirrored those of Zvejnieki contradictions, for example, Zvejnieki burials 305 (–22.4; 14.4) vs. 197 (–24.1; 13.0), where with obviously notable differences in $\delta^{13}C$ values, while less significant differences in $\delta^{15}N$ values, the utilised FRUITS model estimated both their fish

caloric intake to be 35 ± 11% and 36 ± 11%, respectively, and consequently — the freshwater contribution to $\delta^{13}C$ to be 48 ± 13% and 49 ± 13%, respectively. The same — only 1% differences — have been estimated for the terrestrial animal and plant intake as well (Meadows *et al*., 2018).

Given the discordance in literature and the different FRUITS models utilised, we therefore decided to build a FRUITS model uniquely applicable to the Lubāns wetland stable isotope ecology, testing different models for the known diets of different animals. This was possible due to the large Stone Age animal bone collagen stable isotope dataset. There were three marten samples (fully terrestrial carnivore diet), two otter samples (freshwater carnivore/omnivore diet) and one badger sample (mixed freshwater/terrestrial omnivore diet). As the dietary habits of these animals are well known, we tested different FRUITS models to find the one most accurately reflecting their diets. As a result, the most accurate model that corresponds very well with the known diets of these animals, is as follows: very conservative dietary offsets ($\Delta^{13}C_{\text{consumer coll – source coll}} = 1 \pm 0.2‰$; $\Delta^{15}N_{\text{consumer coll – source coll}} = 3 \pm 0.3‰$) combined with source $\delta^{13}C$ fractions in 74 ± 4% protein and 26 ± 4% "energy"; however, source collagen-to-flesh offset is not considered. Protein content of the three food groups was specified as follows: terrestrial herbivores — 30 ± 2.5%, plants —10 ± 2.5% and fish —65 ± 5%. As the animals tested are carnivores or mostly carnivores, protein intake restriction was not applied. However, when estimating the human diet, protein intake restriction was added to the model to be within 5–45% of the whole diet (Fernandes *et al*., 2015).

We applied this FRUITS model to 29 of the 33 individuals, excluding the four children that had or could have had breastfeeding in their diet. FRUITS estimates are displayed in Table 3 and Figure 5.

For 17 individuals, FRUITS estimated a very high mean 50–60% fish intake in their diet, in combination with a low or very low terrestrial animal intake (mean 4–22%) and, across this group, a consistent plant intake (mean 28–37%). These individuals had the most elevated $\delta^{15}N$ values. However, as a group they have large variance in $\delta^{13}C$, which is partially reflected in both the differences in animal intake and probability margins. Estimates of four individuals had mean 40–50% fish intake, in combination with mean 20–34% animal and mean 25–31% plant intake. In comparison with the previous group, plant intake seems the most consistent, and the decrease in fish intake is compensated with increase in animal intake, while fish still being the dominant source. The proportion of terrestrial animals in the diet slightly exceeded that of the fish for three individuals with medium $\delta^{13}C$ values and lower $\delta^{15}N$; the estimated fish intake was mean 34–38%, combined with mean 39–48% animal intake and the very low mean 16–25% plant intake. Finally, five individuals were estimated to have comparatively low fish intake: mean 18–26%, in combination with the animal intake being the main source — mean

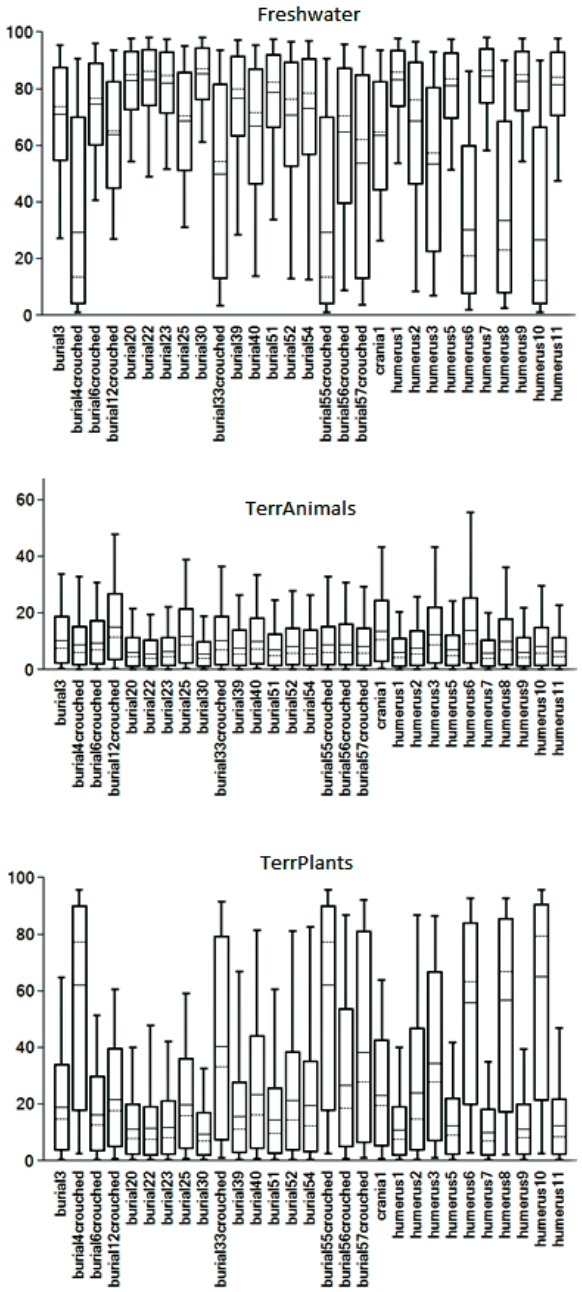


Fig. 5. FRUITS box plots

53–73%, and low plant intake — mean 9–22%. These individuals have the lowest $\delta^{15}N$ values (9.7–10.5‰) (Table 3).

In general, stable isotope data of the Abora humans show that most of the population relied heavily on freshwater with complementary terrestrial plant resources, while having a low contribution from terrestrial animal resources. Several individuals, however, had a different subsistence strategy that relied heavily on terrestrial animal sources, with complementing freshwater and plant sources. None of the individuals had isotope data that would indicate agriculture as a significant subsistence strategy. The few individuals with the highest terrestrial animal intake, however, could be interpreted as pastoralists, but due to the lack of the domesticated animal bone isotope data, for now it is impossi-

Table 3. FRUITS estimates. Mean ± standard deviation (median) values from posterior probability distributions for overall intake (caloric intake) and contributions to isotopic signals in human collagen

Burial	$\delta^{13}C$, ‰	$\delta^{15}N$, ‰	Animal intake, %	Plant intake, %	Freshwater fish intake, %	Fish contribution to $\delta^{13}C$	^{14}C BP	FRE	Corrected ^{14}C BP
Burial 3	–22.4	13.6	9 ± 9 [0]	35 ± 9 [15]	57 ± 7 [41]	71 ± 6 [56]			
Burial 4	–22.7	9.7	56 ± 19 [12]	22 ± 17 [1]	23 ± 10 [4]	31 ± 12 [7]			
Burial 6	–22.5	14.2	6 ± 7 [0]	35 ± 9 [17]	58 ± 7 [43]	73 ± 6 [59]	4553 ± 33	207	4346 ± 33
Burial 12	–21	14.7	4 ± 4 [0]	36 ± 11 [22]	60 ± 11 [16]	75 ± 11 [29]	4465 ± 21	214	4251 ± 21
Burial 20	–24.0	12.5	9 ± 8 [0]	36 ± 10 [18]	55 ± 8 [38]	69 ± 7 [54]			
Burial 22	–24.8	12.1	7 ± 7 [0]	37 ± 9 [20]	56 ± 7 [40]	70 ± 6 [55]	3823 ± 20	198	3630 ± 20
Burial 23	–24.1	12.1	11 ± 9 [0]	36 ± 10 [15]	53 ± 8 [36]	67 ± 7 [51]	3645 ± 34	190	3455 ± 34
Burial 25	–21.8	14.4	6 ± 6 [0]	35 ± 9 [19]	60 ± 8 [42]	74 ± 7 [60]			
Burial 30	–24.5	12.8	7 ± 6 [0]	36 ± 8 [20]	57 ± 7 [42]	71 ± 6 [58]			
Burial 33	–22.5	10.9	48 ± 19 [6]	18 ± 15 [1]	34 ± 11 [13]	44 ± 12 [19]	3937 ± 31	124	3813 ± 31
Burial 39	–23.5	12.0	16 ± 13 [1]	33 ± 12 [7]	1 ± 8 [33]	64 ± 8 [46]			
Burial 40	–22.4	12.5	22 ± 17 [1]	28 ± 13 [3]	51 ± 8 [33]	63 ± 9 [43]	4096 ± 21	179	3918 ± 21
Burial 51	–23.7	11.7	16 ± 13 [1]	34 ± 12 [8]	50 ± 9 [32]	63 ± 8 [44]	3784 ± 32	178	3606 ± 32
Burial 52	–23.2	11.5	26 ± 17 [1]	28 ± 15 [2]	46 ± 9 [27]	58 ± 10 [38]			
Burial 54	–23.6	11.3	20 ± 15 [1]	33 ± 14 [6]	47 ± 9 [28]	59 ± 9 [39]	4333 ± 20	168	4156 ± 20
Burial 55	–22.7	9.9	56 ± 19 [12]	22 ± 17 [1]	23 ± 10 [4]	31 ± 12 [7]			
Burial 56	–22.9	11.2	34 ± 18 [2]	25 ± 15 [1]	41 ± 10 [22]	52 ± 11 [31]	4374 ± 33	149	4225 ± 33
Burial 57	–23.0	10.7	39 ± 19 [4]	25 ± 16 [1]	37 ± 10 [17]	47 ± 12 [23]			
Crania 1	–21.7	13.7	9 ± 9 [0]	34 ± 10 [13]	58 ± 8 [40]	72 ± 8 [55]			
Humerus 1	–24.2	12.5	9 ± 8 [0]	36 ± 9 [17]	55 ± 7 [39]	69 ± 7 [54]			
Humerus 2	–23.4	11.4	23 ± 16 [1]	31 ± 15 [4]	46 ± 9 [27]	58 ± 10 [38]			
Humerus 3	–22.2	11.5	46 ± 20 [4]	16 ± 14 [4]	38 ± 11 [16]	48 ± 12 [22]			
Humerus 5	–23.7	12.9	9 ± 8 [0]	36 ± 9 [17]	55 ± 7 [39]	69 ± 7 [54]			
Humerus 6	–21.8	10.5	73 ± 14 [40]	9 ± 9 [0]	18 ± 10 [2]	24 ± 13 [2]			
Humerus 7	–24.3	11.9	10 ± 9 [0]	37 ± 11 [17]	53 ± 8 [35]	67 ± 8 [50]			
Humerus 8	–22.4	10.4	59 ± 18 [16]	15 ± 14 [0]	26 ± 11 [7]	33 ± 13 [9]			
Humerus 9	–24.1	12.0	11 ± 10 [0]	36 ± 11 [13]	53 ± 8 [35]	66 ± 8 [49]			
Humerus 10	–22.8	9.9	53 ± 19 [11]	22 ± 16 [1]	24 ± 10 [6]	32 ± 12 [9]			
Humerus 11	–24.0	11.6	14 ± 12 [0]	35 ± 12 [9]	51 ± 8 [33]	64 ± 8 [46]			

ble to distinguish their diet from that of hunters (Fig. 5). Additionally to locating and analysing the domesticated animal bones, it would be highly beneficial would analyse different plant remains, including cultivated crops if available. This could potentially draw a clearer picture, if there is a) isotopic distinction between wild and domesticated animals; and b) if cultivated crops could had been manured, thus differentiating their isotopic signal from wild plants and raising the plant proportion in diet models.

In conclusion, FRUITS is a highly useful tool to gain a different perspective on the raw data and the more widespread use of plot graphics. However, there are inevitable complications when building FRUITS models, for example, due to lack of a comprehensive baseline. In our case, the terrestrial plant baseline was extrapolated from the terrestrial animal baseline, as there was no isotope analysis data available from Stone Age plants, and that introduced one more ambiguity to the FRUITS models. Another discussion is warranted regarding the isotopic offsets and other parameters that were utilised in both our and other research papers. In our opinion, the estimates we report here should be viewed critically and a possibility of skewed outcomes needs to be taken into account. However, FRUITS estimates are beneficial for detecting individuals with the highest fish contribution to $\delta^{13}C$ values, which will be discussed further in context with ^{14}C dates and FRE.

Demographic tendencies in diets and dietary outliers. With the exception of infants and a few outliers, no demographic patterns emerged in the dietary variability. Male, female and adolescent groups overlapped across the freshwater-mixed diet axis (Fig. 6). Outliers can be defined in two ways. Firstly, a more traditional approach is to look at the individuals that fall out of the general cluster. That is the case with burials 3, 6, 12, 25 and sample c1. They are samples with $\delta^{13}C$ values ranging –22.5‰ – –21‰, while at the same time having $\delta^{15}N$ values above 13‰. In the plot graphic, these five individuals position closer to infant diets discussed above, thus indicating an elevated trophic level.

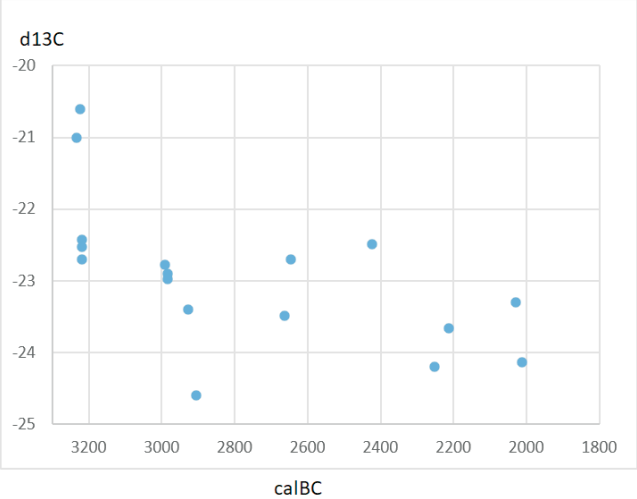


Fig. 6. $\delta^{13}C$ values (‰) plotted against the ^{14}C dates

For comparison, there are three marten samples that reflect a fully terrestrial carnivore diet, but the five outliers do not correspond with that cluster, meaning that the elevation of $\delta^{15}N$ values comes from different sources. In literature, it has been widely recognised that biochemical processes during fasting and starvation cause isotopic fractionation, as the body is in a sense "feeding" on itself, thus isotopically placing it on the next trophic level (Fuller *et al*., 2005). The five outliers can be strong candidates for such explanation. Another explanation could be a geographically highly mixed diet, for example, if the individuals were regularly travelling between the Lubāns wetland and the Baltic Sea coast. Close contacts between the two regions are evidenced by the large amount of amber finds, as well as some seal bone finds (Loze, 2008).

Incorporating isotopic and previous bioarchaeological data. For now, conclusions drawn from stable isotope data are in contradiction with the contemporary archaeology narrative that emphasises agriculture and animal husbandry as important subsistence strategies alongside the forager economy during the Late Neolithic in Abora and, by induction, in Latvia as well (Loze, 2000). Presence of farming and animal husbandry is indicated by archaeological evidence (grinding stones) and palynological and zooarchaeological data. However, from a very critical point of view, even those data do not show farming economy as a prominent element in the Abora people daily life. For example, animal bone assemblage zooarchaeological analysis showed that from the 799 terrestrial animals (minimal number of individuals), livestock included only 22 animals, i.e. 2.8% (15 cattle and 7 sheep/goat). Unfortunately, the current location of the Abora domesticated animal bones is unknown, as they are not part of the wild animal bone collection. Keeping in mind that the whole animal bone assemblage includes 2085 fish bones and a minimal number of individual avifauna (21), the livestock proportion is indeed marginal. It was reported that presence of *Cerelia* pollen was detected in palynological analysis, and there was indirect evidence of goosefoot seeds, a typical field weed. However, no grains have been found in the assemblage of edible seeds, which consists of variable edible wild plants (Loze and Iakubovskaia, 1984). In conclusion, the new isotope data are in contradiction with the archaeology narrative, but not necessarily with the previous bioarchaeological raw data. Additional considerations can be drawn from palaeogeographical reseach, showing that the territory was a marshy wetland already during the Stone Age, and therefore not well suited for agriculture. The relatively dry and warm sub-boreal climate during the Late Neolithic and Bronze Age gradually became more humid and cooler, leading to rise of water level in Lake Lubāns and decrease of the known settlement number from 22 in the Middle Neolithic (4100–2900 BC) to eight in the Late Neolithic and beginning of Bronze Age (Eberhards, 2015).–

C-14 dates and freshwater reservoir effect. The Abora site has been radiocarbon dated several times before; samples used were from the settlement culture layers — charcoal, peat and wood samples. Firstly, three samples were dated in 1970 at the Leningrad (St. Petersburg) Institute of Archaeology. In 1982, three more samples were dated at the Institute of Zoology and Botany of Estonian Academy of Sciences. In 2008, five more samples were dated at the Institute of Geology of Tallinn Technical University (Table 4).

The earliest dates show some human activity at the site as early or even earlier than ~3000 BC. However, archaeologist Ilze B. Loze approached these dates cautiously, and argued that CWC people arrived at the site possibly as early as 2940–2850 BC, but more confidently she dates it with 2820–2660 BC. The latest date indicates inhabitation as late as ~2300–2100 BC, however, the Early Bronze Age pottery indicates at least some human activity after that as well. Altogether, the previous ^{14}C date sequence shows human activity at the site spanning for at least ~1000 years (Loze and Eberhards, 2012). The new radiocarbon dates of the human bones generally correspond with the previous absolute dating of the site, spanning from 3484–3102 calBC (95.4%; OxA-34419) till 2137–1925 calBC (95.4%; OxA-34421).

Burials 6, 9, and 12 have been dated to ~3400–3000 calBC. $\delta^{13}C$ values of these individuals range from –22.5‰ to –20.7‰, indicating much smaller fish intake than the burial 8, and therefore FRE should as well be smaller than 184 ± 20 BP. Thus, the previous caution in dating human activity at the Abora site earlier than 2800 BC seems to be unfounded. Regarding the earliest dates of the individuals — burial 17 (–23.3; 11.6; 3657 ± 26 BP, 2136–1947 calBC), burial 23/24 (–24.1; 12.1; 2137–1925 calBC) — prior FRE corrections date to the very end of the Late Neolithic. Thus, the new radiocarbon dates from the burials confirm the previous Abora settlement dates, and strengthen the claim of regular human activity prior 3000 BC. The Early Bronze Age, however, is still unrepresented by radiocarbon dates and remains evidenced by the potsherds, indicating that with the transition to the Bronze Age, this Late Neolithic centre was abandoned.

Table 4. Previous ^{14}C dates

Lab code	Sample	Year	Laboratory	^{14}C BP	^{14}C calBC*	Reference
Tln–3109	wood	2008	Institute of Geology of Tallinn Technical University	4079 ± 110	2760 BC (56.1 0%) 2480 BC	Loze and Eberhards, 2012
Tln–3110	wood	2008	Institute of Geology of Tallinn Technical University	4261 ± 70	2940 BC (35.9 %) 2850 BC	Loze and Eberhards, 2012
Tln–3115	charcoal	2008	Institute of Geology of Tallinn Technical University	4053 ± 80	2700 BC (59.5%) 2470 BC	Loze and Eberhards, 2012
Tln–3116	charcoal	2008	Institute of Geology of Tallinn Technical University	4135 ± 80	2780 BC (47.3%) 2620 BC	Loze and Eberhards, 2012
Tln–3117	charcoal	2008	Institute of Geology of Tallinn Technical University	4045 ± 80	2680 BC (61.6 %) 2470BC	Loze and Eberhards, 2012
TA–2145	charcoal	1982	Institute of Zoology and Botany of Estonian Academy of Sciences	4250 ± 100	2820 BC (34.7%) 2660 BC	Loze and Eberhards, 2012
TA–2144	wood	1982	Institute of Zoology and Botany of Estonian Academy of Sciences	4490 ± 80	3350 BC (68.2 %) 3090 BC	Loze and Eberhards, 2012
TA–394	wood	1982	Institute of Zoology and Botany of Estonian Academy of Sciences	3770 ± 60	2290 BC (58.7%) 2130 BC	Loze and Eberhards, 2012
LE–749	peat		Leningrad (St. Petersburg) Institute of Archaeology	3869 ± 100	2470 BC (68.2%) 2200 BC	Doluchanov *et al*., 1970.
LE–304	wood	70.tie	Leningrad (St. Petersburg) Institute of Archaeology	3770 ± 60		Doluchanov 1973
LE–671	peat	70.tie	Leningrad (St. Petersburg) Institute of Archaeology	3870 ± 70	2470 BC (62%) 2280 BC	Doluchanov *et al.,* 1970.

As this is the first attempt to radiocarbon date human bones from the Abora site, a possible Freshwater Reservoir Effect (FRE) has to be considered. For this purpose, a modern pike bone, caught in Lake Lubāns in 2019, was submitted for dating. The sample showed that FRE of Lake Lubāns was 284 ± 18 ^{14}C yr (Table 1). For comparison, FRE of the Lake Burtnieks was established to be 750 ± 50 ^{14}C yr, and thus the Zvejnieki Stone Age human dates called for noticeable corrections (Meadows *et al*. 2018). As the FRE of Lake Lubāns is not as large, the new dates should not be strongly skewed even for individuals with the largest fish intake in their diet. This is well demonstrated by burial 8, which was double sampled: a human bone (approximately 1-year old child), sample OxA-38996, was dated to 4303 ± 20 BP, and an auroch bone from the burial context was dated to 4119 ± 20 BP; thus, the FRE in the human bone was 184 ± 20 BP. With δ^{13}C = –24.6‰ and δ^{15}N = 17.8‰, this infant was breastfed by a mother that was on the far end of the freshwater diet axis. Thus, even in other cases of freshwater diets, we should expect the FRE to be less than 200 radiocarbon years. The other double dated burial, No. 39, shows an even smaller FRE: 4105 ± 21 BP for the human bone (OxA-39055) and 4063 ± 20 BP for the wild boar bone (OxA-39056), i.e. only 42 radiocarbon years. However, the stable isotope analysis of the human bone indicates possible sample contamination with modern wax particles, and thus, unfortunately, the radiocarbon data gathered from burial 39 should be viewed with caution.

A common approach to calculating FRE of individual dates is to utilise the FRUITS programme, which among other estimates source contribution to different proxies, i.e. fish contribution to δ^{13}C. Our FRUITS model estimates very high fish intake in the whole diet, and therefore we are confident that the estimated fish contribution to δ^{13}C should be close to the maximum possible, and underestimation of the FRE impact on ^{14}C dates should be unlikely (Table 3). More likely, the FRUITS is overestimating fish contribution, as evidenced by the double dated burial 8, where the FRE offset was 184, although the human stable isotope data are –24.6; 17.8. However, if the maximum FRE estimation is applied for correcting ^{14}C dates, as it was possible for the adult individual data (n = 9), then the oldest burial 6 is at least 3080–2896 calBC (95.4%), and close to it is burial 12 — 2910–2782 calBC (95.4%). The oldest radiocarbon date, however, is that of burial 9 (3331–3024 calBC (95.4%)), but that is from an infant and has not been FRE corrected (Table 3).

Spatial organisation of the Abora cemetery. One of the supposedly common burials is represented by two dates — from the burial group 12–14, burial 12 was dated to be 4465 ± 21 BP (OxA-39054), and burial 13 to be 4384 ± 33 BP (OxA-34420), thus showing an offset between them of 81 ± 33 radiocarbon years. Notably, burial 13 is the earliest date and also has stable isotope data that indicates more fish intake in the diet as the other individual, thus most likely adding FRE and making the offset between them even larger. This example calls to question this burial group as a common grave particularly, and, by extension, questions other common burials as well. As explained above, the Abora site is unique with it being a mixed-type archaeological site, with the burials not forming an isolated cemetery, but rather being distributed among the settlement culture layers. From an archaeological point of view, it complicates drawing a clear picture of the site's organisation and, consequently, the supposed *in situ* status even of the seemingly undisturbed burial groups.

This interpretation of the site is further supported by the lack of correlation between the burial dates and their spatial organisation, meaning that there are obviously no older and younger parts of the cemetery, as the dates are spatially mixed. There is, however, correlation between the dates and depths of the burials, with the very earliest burials unearthed only ~0.2 m deep, while the oldest burials were revealed 0.3–0.5 m deep. However, burial 54 falls out of this pattern with date 3011–2898 calBC and buried only 0.2 m deep (Table 1).

Burials 6, 12, 13, 33, and 56 call for special attention, as they were recorded as crouched burials and have been linked to the CWC. With the exception of burial 33, the crouched burials form the group of the oldest burial dates of the Abora humans. Another commonality is that all of the crouched burials had lower freshwater fish and higher terrestrial plant intake in their diet (a mixed freshwater/terrestrial diet), thus indicating that this burial position could indeed be a culture signifier, not incidental. Four more individuals had similar diets: samples from humerus 3, 6, 8, 10.

Palaeodietary shifts in time. As most of the crouched burials have both different diet and the oldest dates, thus a noticeable temporal shift in the Abora human forms. This is best visible when $\delta^{13}C$ values are plotted against the ^{14}C dates (Fig. 6). A pattern emerges that during ~3200–3000 calBC the diets were more mixed freshwater/terrestrial, with $\delta^{13}C$ values above –23‰. Later, the Abora human subsistence relied more and more on the freshwater resources, and by ~2200–2000 calBC was below –23‰. This is a remarkable and unexpected trend, as by the end of the Late Neolithic the traditional archaeological explanation would predict exactly the opposite trend. Of course, these results and interpretations of this case study of Abora humans should not be ascribed to the palaeodietary tendencies in the whole Latvian region. However, the Abora data show an interesting local palaeodietary history where the Late Neolithic people, despite being familiar with farming and animal husbandry, became more and more reliant on fishing by the end of the Neolithic. By the beginning of the Bronze Age, the Lake Lubāns wetland got abandoned *en masse*, with just few inhabitation sites remaining, when compared to the once widely populated Stone Age region. Perhaps this case study shows a fraction of the processes that led to the populations moving away from the Lake wetland that could not fully sustain early farming.

CONCLUSIONS

Although in the literature usually referred to as the Abora settlement and cemetery, this is a complex inhabitation and human activity site, spanning at least 1000 years of use. As described before, the human burials do not form a typical cemetery, the burial positions cannot always be precisely prescribed, and cardinal positions are highly variable. The new radiocarbon dates confirm that the only correlation is with the depth of burials, but not with the spatial organisation of the site. Consequently, this affects demographic analysis, as it has to be based not only on full skeletons, but also on stray human bones most likely coming from burials destroyed already during the site's occupation. However, there can be conclusions drawn about the demographic tendencies. The anthropological data of 72 individuals show a large portion of subadults (33%), sex dimorphism coefficient 1.2 and higher female mortality at a young age than that of the males, possibly reflecting reproductive processes. Although the demographic data corresponds with other North-European Neolithic populations, some differences in breastfeeding patterns are indicated by the stable isotope analysis. Material from the Zvejnieki cemetery shows that the breastfeeding shortened from up to three years during the Mesolithic, to 1.5–2 years in the Neolithic. However, two Abora children 4 ± 1 years old had elevated $\delta^{15}N$ values, indicated ongoing weaning, while one 3 ± 1 years old had isotopic values similar to the adult population.

The adult and adolescent isotopic data (n = 29) generally corresponds very well with the local Lake Lubāns wetland isotope ecology. However, this contradicts the previous interpretations that overemphasise the role of domesticated animals and cultivated crops in the Abora human subsistence strategies. The data show that the diets were definitely not what would be expected from early farmers. The majority of humans, when viewed in context with the Stone Age animal data, group in a cluster with one end reflecting a freshwater diet and the other end — a mixed freshwater/terrestrial diet. This is confirmed by the three animals that fall together with the human cluster: two otters and a badger. A FRUITS model tested by correctly estimating known animal diets, confirmed this conclusion about the human diets as well. For the majority, FRUITS estimated mean 50–60% fish intake in combination with low or very low terrestrial animal intake (mean 4–22%) and, across the group, consistent plant intake (mean 28–37%). In general, stable isotope data of the Abora humans showed that most of the population relied heavily on freshwater with complementary terrestrial plant resources, while having a low contribution from terrestrial animal resources. Several individuals, however, had a different subsistence strategy, which that relied heavily on terrestrial animal sources, with complementing freshwater and plant sources. None of the individuals have isotope data that would indicate agriculture as a significant subsistence strategy. The few individuals with the highest terrestrial animal intake, however, could be interpreted as pastoralists, but due to the lack of the domesticated animal bone isotope data for now it is impossible to distinguish their diet from that of hunters. More interestingly, these same individuals are both the oldest of the dated and attributed to the CWC. Therefore, there is a dietary shift from a diet being more mixed freshwater/terrestrial in ~3200–3000 calBC to strongly freshwater based at the very end of the Late Neolithic.

The new radiocarbon dates of the human bones generally correspond with the previous absolute dating of the site, spanning from 3484–3102 calBC (95.4%; OxA-34419) till

2137–1925 calBC (95.4%; OxA-34421). If the maximum FRE estimation is applied for correcting ^{14}C dates, then the oldest burial 6 is at least 3080–2896 calBC (95.4%) old, and close to it is burial 12 — 2910–2782 calBC (95.4%). Thus, the previous caution in dating the earliest arrival of CWC people at the site can be lifted.

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DZĪVE TUVU AGRĪNAI LAUKSAIMNIECĪBAI PIEMĒROTU KLIMATISKO APSTĀKĻU ROBEŽAI: VĒLĀ NEOLĪTA IEDZĪVOTĀJU IZTIKAS STRATĒĢIJAS LATVIJĀ ABORAS APMETNĒ

Vēlā neolīta Aboras apmetnei ir ievērojama nozīme Lubāna ezera mikrorajona arheoloģijā. Lubāna ezera mitrāju, tajā skaitā Aboras apmetni, sistemātiski pētījusi arheoloģe Ilze Biruta Loze 1962.–1990. gadā un epizodiski 1999.–2012.gadā. Bez apmetņu kultūras slāņiem Aboras apmetnē atrasti arī cilvēku apbedījumi (kopā 61), kas sniedz gan osteoloģisku, gan arheoloģisko materiālu. Aboras apmetnes arheoloģiskais materiāls ir piemērots kompleksiem lauksaimniecības aizsākumu pētījumiem vēlajā neolītā Latvijā. Šajā rakstā Aboras apmetnes arheoloģiskais un osteoloģiskais materiāls analizēts, pielietojot paleodemogrāfiskos datus, radioaktīvā oglekļa datējumus, iespējamo saldūdens rezervuāra efekta ietekmi uz tiem un FRUITS metodiku (*Food Reconstruction Using Isotopic Transferred Signals* — Uztura rekonstrukcija izmantojot izotopiski nosakamos signālus), kā arī veikts rezultātu salīdzinājums ar iepriekšējiem datiem un arheoloģiskajām interpretācijām. Jaunie cilvēka kaulu radioaktīvā oglekļa datējumi atbilst iepriekšējiem Aboras apmetnes vietas datējumiem, kas svārstās no 3484–3102 calBC līdz 2137–1925 calBC. Pieaugušo un pusaudžu kaulu materiāla izotopu dati (29 indivīdi) kopumā labi atbilst Lubāna ezera mitrāja vietējai izotopu ekoloģijai. Tomēr iegūtie rezultāti ir pretrunā ar iepriekšējām interpretācijām, kas pārmērīgi uzsver pieradināto dzīvnieku un kultivēto kultūru lomu Aboras cilvēku iztikas stratēģijās. Jaunie dati liecina, ka lielākajai daļai cilvēku bija saldūdens diēta ar ievērojamu zivju īpatsvaru uzturā, bet citiem – jaukta saldūdens/sauszemes diēta.