

Full length article



Spatial and temporal differences in Late Neolithic Serovo to Early Bronze Age Glazkovo forager diet in Lake Baikal's Little Sea Microregion, Siberia

Andrea L. Waters Rist^{a,*}, Angela R. Lieveise^b, Alexei G. Novikov^c, Olga I. Goriunova^c,
Artur A. Kharinskii^d, Hugh G. McKenzie^e

^a Department of Anthropology, University of Western Ontario, Canada

^b Department of Archaeology and Anthropology, University of Saskatchewan, Canada

^c Laboratory of Archaeology and Paleocology, Institute of Archaeology and Ethnography, Siberian Branch of Russian Academy of Science, Irkutsk State University, Russian Federation

^d Irkutsk National Research Technical University, Irkutsk, Russian Federation

^e Department of Anthropology, MacEwan University, Canada

ARTICLE INFO

Keywords:

Subsistence practices
Hunter-gatherers
Stable isotopes
Middle Holocene
Seal
Island

ABSTRACT

Research on Middle Holocene hunter-gatherers from the Cis-Baikal region of Eastern Siberia has yielded many insights into their dietary and mobility patterns. A large dataset of stable carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotope values, when paired with freshwater-reservoir corrected carbon-14 dates, allows us to conduct fine-scale investigations into dietary change. Our Small Cemeteries Project has increased the sample of Late Neolithic (LN) Serovo individuals, and Ol'khon Island burials, allowing for new investigations into changes between the Serovo and subsequent Early Bronze Age (EBA) Glazkovo mortuary traditions in the Little Sea Microregion. This is important because research exploring the extent and nature of cultural continuity and change between these mortuary traditions has received less attention than more pronounced earlier transitions. We use stable isotope data from 134 adolescents and adults to explore (1) temporal changes in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values across the Serovo and Glazkovo mortuary traditions, and (2) differences in stable isotope values between individuals buried on Ol'khon Island vs. the Mainland. During Serovo times, Islanders and Mainlanders were eating somewhat different diets, with the former consuming more seal and the latter more shallow-water fish. Glazkovo Islanders maintained a broadly similar diet to their Serovo Islander predecessors suggesting the continued existence of a specialized group of Island seal hunters. After ~ 4100 calBP, and the arrival of the Glazkovo mortuary tradition in the Little Sea Microregion, there is the appearance of a new group of Mainlanders consuming a diet with low $\delta^{15}\text{N}$ ($\leq 14.6\text{‰}$) and/or low $\delta^{13}\text{C}$ ($\leq -19.0\text{‰}$) values unlike anything seen previously. This diet included less lake fish and seal and more terrestrial herbivores. Previous research has shown that many Mainland Glazkovo individuals with this new diet were non-local. Our study finds that just over half of Glazkovo Mainlanders have a low $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ value and they are found in all cemeteries with multiple individuals. This suggests such individuals, many of which were non-local, were fully incorporated into local social groups. Further increasing the sample of LN and Island individuals is needed to better establish these findings; nonetheless, our research highlights the diversity in Middle Holocene adaptive strategies in the Little Sea Microregion.

1. Introduction

A few decades of stable isotope research on Middle Holocene hunter-gatherers in the Cis-Baikal region, Eastern Siberia, permits fine scale

investigations of dietary change across time and space (Katzenberg and Weber, 1999; Katzenberg et al., 2009, 2010, 2012; Weber and Bettinger, 2010; Weber et al., 2002, 2011, 2016, 2020). In this research, we focus on the Little Sea Microregion (Fig. 1) and the shift between the Serovo

* Corresponding author.

E-mail address: awaters8@uwo.ca (A.L. Waters Rist).

(ca. 5280–4586 calBP) and Glazkovo (ca. 4955–3565 calBP) mortuary traditions, which is typically used to mark the transition from the Late Neolithic (LN) to Early Bronze Age (EBA)¹ (Weber et al., 2020). There is close cultural affiliation between these two mortuary traditions, as evidenced by continuity in carbon-14 dates as well as similarities in mortuary practices and material culture, including burial form, grave architecture, spatial organization of cemeteries, and the use of fire in grave pits (Weber and Bettinger, 2010). Ancient DNA and dental non-metric data suggest the Serovo and Glazkovo were genetically

continuous populations (Mooder et al., 2010; Waters-Rist et al., 2015), although this continuity might be less pronounced than previously thought (Moussa et al., 2020). However, there are also changes between mortuary traditions, including the appearance of copper alloy and polished nephrite artifacts, larger Glazkovo cemeteries, new pottery styles, fewer graves with multiple burials, an increase in exotic and labour-intensive objects, different orientations of individuals in graves, and increased heterogeneity in grave good distribution between Glazkovo individuals (Weber, 1995; Weber et al., 2002; Weber and Bettinger,

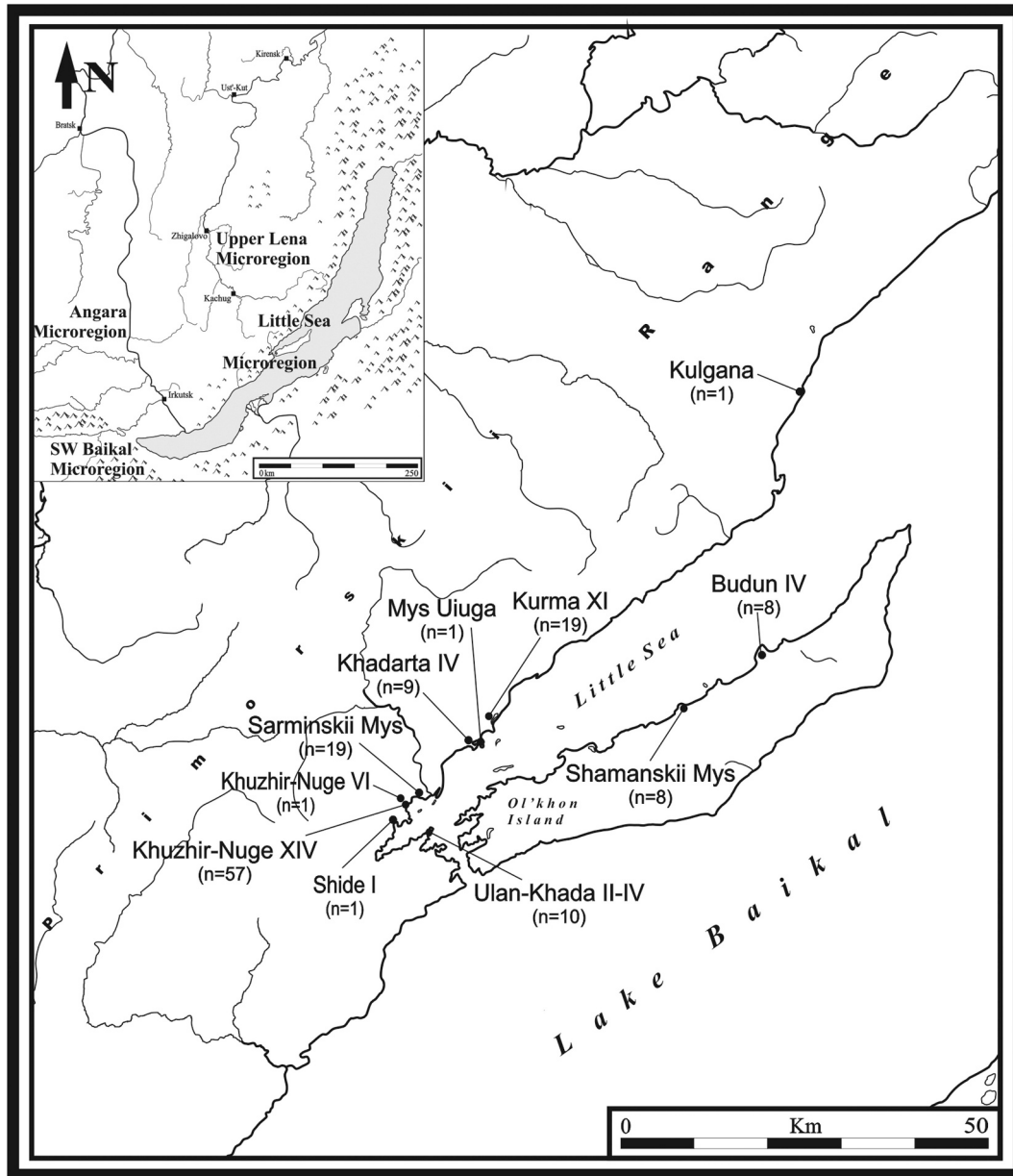


Fig. 1. Map of Late Neolithic and Early Bronze Age Cemeteries in the Little Sea Microregion, Lake Baikal, Siberia. n indicates the number of individuals with stable isotope data included in this paper. Map inset showing microregions from Weber et al. (2016).

¹ These start and end dates are modelled before present (BP) highest posterior distributions (HPD) specific to the LN Serovo and EBA Glazkovo in the Little Sea Microregion, using results from trapezium models (see Weber et al., 2020). Our analysis below plots individual unmodeled (but FRE-corrected) dates against one another.

2010).

Research exploring the extent and nature of cultural continuity and change between the Serovo and Glazkovo has received less attention than the more dramatic changes seen between earlier cultural transitions (e.g., the Early Neolithic vs. Middle/Late Neolithic) (McKenzie, 2010; Shepard, 2012; Weber et al., 2002). Shepard (2012); Shepard et al. (2016) has proposed that the change from Serovo to Glazkovo

mortuary protocols reflects a change in socio-political organization. Specifically, he suggests that the Serovo political economy emphasized corporate strategies involving local resources while the political economy of the Glazkovo shifted to include network-orientated exclusionary strategies that emphasized status distinctions between individuals. Weber, (2020) argues the change is due to the introduction of a new form of socioeconomic organization involving any of the following: new mechanisms of land tenure, new patterns of group formation, expanded exchange networks, and/or lower competition between gender and age groups. Whatever the case, there is clear evidence and agreement about the presence of non-local individuals in Little Sea EBA-Glazkovo cemeteries. Different scenarios to explain the influx of non-locals include a larger seasonal round, more long-distance ‘macro-regional’ interaction, and/or the prosperity of Little Sea Glazkovo society drawing in individuals from neighbouring groups (Haverkort et al., 2008; Shepard et al., 2016; Weber, 2020; Weber and Goriunova, 2013). Our analysis contributes to this discussion by adding a new isotope dataset of Late Neolithic Serovo individuals to the otherwise scant sample from this population, facilitating a more substantive comparison of the two periods especially in terms of subsistence practices.

All individuals included in this analysis have region-specific, freshwater reservoir effect (FRE) corrected, AMS (accelerator mass spectrometry) carbon-14 dates (Weber et al., 2016, 2020) that permit fine-scale temporal comparisons within and between mortuary traditions. Cemeteries in the Little Sea Microregion are concentrated along the shores of the mainland and on the northern shores of Ol’khon Island (Fig. 1). The Little Sea Microregion is dominated by a steppe landscape on the mainland with mountains along the western coast. Ol’khon Island has cliffs lining its southern shore and has areas of taiga, steppe, and desert (very low annual precipitation) ecozones, and its own small lakes. There are numerous shallow bays and lagoons along the southernmost reaches of the mainland shore but few shallow areas along the island shores.

Relatively shallow water exists in many areas of the Little Sea with a comparatively deep gulf (straight) of up to 250 m separating the mainland and island at the northeastern end. The lake provides an aquatic resource base of seal (the Baikal freshwater seal, *Phoca sibirica*) and many species of fish. The Sarma river also contains several species of fish, and the mountains and nearby forested areas were traditionally a source of ungulates such as red, roe, and musk deer (*Cervus elaphus*, *Capreolus capreolus*, *Moschus moschiferus*), and occasionally elk/moose (*Alces alces*; Losey et al., 2012; Weber and Bettinger, 2010). The type and quantity of aquatic and terrestrial resources varied among the four Microregions of the Cis-Baikal (the four Microregions are the Little Sea, Angara River Valley, Upper Lena River Valley, and Southwest Baikal; these are shown in the inset in Fig. 1). The Angara River Valley is argued to have had the most productive fisheries, while the Upper Lena Microregion likely had the lowest density of aquatic resources forcing people to rely more heavily on terrestrial game (Losey et al., 2012; Losey and Nomokonova, 2017; Weber and Bettinger, 2010; Weber et al., 2002, 2011). While less productive than the Angara River Valley, the Little Sea Microregion is thought to have been quite productive and, importantly, to have had aquatic resources reliably available throughout most of the year, although winter ice cover would have reduced the availability of fish (Losey et al., 2008, 2012). As evidenced by faunal analyses, hunter-gatherers in the Little Sea mostly exploited shallow-water cove and lagoon fish including perch (*Perca fluviatilis*; constituting over half the faunal remains at some Little Sea campsites), pike (*Esox lucius*), ide (*Leuciscus idus*), roach (*Rutilus rutilus lacustris*), dace (*Leuciscus leuciscus baicalensis*), lenok (*Branchimystax lenok*), and black grayling (*Thymallus baicalensis*), as well as some open-water fish like whitefish (*Coregonus* sp.) (Losey et al., 2012; Losey and Nomokonova, 2017; Weber et al., 2011). Importantly, the Little Sea fish have a broad range of $\delta^{13}\text{C}$ values ($\sim 10\text{‰}$) because of the different aquatic ecosystems within the micro-region (Weber et al., 2011).

Weber and colleagues (2011) analyses of human bone collagen stable

carbon ($\delta^{13}\text{C}$) and nitrogen isotope ($\delta^{15}\text{N}$) data for the Little Sea Serovo-Glazkovo distinguished two dietary clusters. One cluster had higher $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (-19.3 to -18.3‰ ; 13.2 to 17.4‰) and was called the “game-fish-seal” (GFS) diet. The other cluster had lower $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (-20.1 to -18.9‰ ; 10.3 to 12.8‰) and was called the “game-fish” (GF) diet. Weber et al. (2011) argued that the GF diet likely included more non-local resources, meaning game or fish outside the boundaries of the Little Sea. They also suggested that the Upper Lena River Valley was the most probable microregion of non-local game or fish, based on the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of individuals interred in that area and the low $\delta^{13}\text{C}$ values of the river fish (Weber et al., 2011). More recently, Weber, (2020) proposed these non-locals may have come from the forested region to the west of the Little Sea Microregion. Shepard (2012) worked with stable isotope data for the Little Sea Microregion from the University of Calgary dataset (see Katzenberg et al., 2009, 2012; Weber et al., 2002, 2011), which contained a small sample of LN Serovo individuals ($n = 6$; $n = 61$ for the EBA Glazkovo). He found the proportion of individuals with the GFS diet decreased from 100% to 66.7% from the LN to EBA, but as this difference was not statistically significant he concluded, “it appears that the relative size of groups employing the GF vs. GFS diets may have remained relatively similar in the Little Sea micro-region during the Late Neolithic and Early Bronze Age” (Shepard, 2012: 125). When Shepard combined the University of Calgary results with those from the Oxford Radiocarbon Accelerator Unit to achieve a slightly larger LN sample size (LN $n = 11$; EBA $n = 102$) the difference was still not significant but, as the p -value “approached significance,” he argued that Serovo individuals consumed more locally available resources such as seals (2012: 126).

Since the work of Weber et al. (2011) and Shepard (2012), more LN samples have been obtained and analyzed for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, some as a part of the Small Cemeteries Project led by H. McKenzie, A. Lieverse, and A. Novikov. With these additional data, we are in a better position to explore dietary variation between the Serovo and Glazkovo in the Little Sea Microregion. Moreover, additional stable isotope data are now available for individuals buried on Ol’khon Island, permitting the first systematic examination of dietary variation between the Island and Mainland burials. Katzenberg and Weber (1999) reported high $\delta^{15}\text{N}$ values for six individuals from the EBA Island cemetery of Shamanskii Mys (then called Khuzhir), and proposed that these individuals may have had better access to the Baikal seal. While sample sizes for the LN Serovo and Island are still small, especially compared to the EBA Glazkovo Mainland (Table 2), they have reached their largest size since the inception of the Baikal Archaeology Project in the mid 1990s. Because it is unlikely many more LN Serovo or Island cemeteries exist, with which we could markedly increase these sample sizes, we will work with the data at hand keeping in mind the limitations imposed by relatively small sample sizes.

We address the following research questions and explore how these fine-scale spatial and temporal dietary stable isotope data contribute to our understanding of the sociopolitical and economic organization of these ancient foragers. First, are there significant temporal changes in $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ values within or across the Serovo and Glazkovo mortuary traditions? Second, are there significant differences in $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ values between individuals buried on Ol’khon Island and the Mainland? This research will further our understanding of forager lifeways, highlighting the diversity of middle Holocene adaptive strategies in the Little Sea Microregion.

2. Materials

Data come from 13 cemeteries containing 134 individuals aged 13+ years (14 adolescents of 13–17 years; 118 adults of 18+ years; 2 adolescents-adults of 13+ years) (Fig. 1; Table 1). The 16 individuals radiocarbon dated as a part of the Small Cemeteries Project, published here for the first time, are indicated in Table 1 as ‘this study’. Because infant and child diets can differ from those of adults, such individuals

Table 1
Map of Late Neolithic and Early Bronze Age Cemeteries in the Little Sea Microregion, Lake Baikal, Siberia. n indicates the number of individuals with stable isotope data included in this paper. Map inset showing microregions from Weber *et al.* (2016).

| Cemetery | Master ID | Date BP | Date ± | Mean Cal Date BP | Mean Cal Date ± | Mortuary Tradition | Age | Sex | Element | Collagen Yield | % C by weight | C/ N | $\delta^{13}\text{C}$ (‰) | $\delta^{15}\text{N}$ (‰) | Reference |
|----------------------------------|------------------|---------|--------|------------------|-----------------|--------------------|-----------------|-----|------------------|----------------|---------------|------|---------------------------|---------------------------|----------------------------|
| Late Neolithic Mainland | | | | | | | | | | | | | | | |
| Sarminskii Mys | SMS_1986.009 | 4732 | 32 | 4350 | 61 | Serovo | Adult | PM | unknown | 8.9 | 42.8 | 3.2 | -17.2 | 16.3 | Weber <i>et al.</i> , 2016 |
| Sarminskii Mys | SMS_1986.011A.02 | 4665 | 28 | 4220 | 59 | Serovo | Adult | M | fibula | 8.2 | 44.8 | 3.2 | -17.5 | 16.5 | Weber <i>et al.</i> , 2016 |
| Sarminskii Mys | SMS_1986.019.02 | 4751 | 32 | 4283 | 61 | Serovo | Adult | M | femur | 6.7 | 44.7 | 3.3 | -18.4 | 15.6 | Weber <i>et al.</i> , 2016 |
| Sarminskii Mys | SMS_1987.029.01 | 4793 | 39 | 4326 | 65 | Serovo | Adult | M | cranium | 1.9 | 42.8 | 3.3 | -17.6 | 16.6 | this study |
| Sarminskii Mys | SMS_1986.011B.01 | 4816 | 21 | 4353 | 56 | Serovo | Adult | M | clavicle | 9.6 | 45.8 | 3.2 | -18.6 | 15.4 | Weber <i>et al.</i> , 2016 |
| Sarminskii Mys | SMS_1986.011A.04 | 4747 | 29 | 4359 | 59 | Serovo | Adult | PM | femur | 8.1 | 43.9 | 3.2 | -17.0 | 16.6 | Weber <i>et al.</i> , 2016 |
| Sarminskii Mys | SMS_1986.017 | 4680 | 32 | 4412 | 61 | Serovo | Adult | M | humerus | 12.7 | 46.7 | 3.2 | -17.4 | 14.8 | Weber <i>et al.</i> , 2016 |
| Sarminskii Mys | SMS_1987.031.01 | n/a | n/a | 4449 | 45 | Serovo | Adult | M | foot bones, rib | 8.4 | 44.0 | 3.2 | -17.4 | 16.3 | this study |
| Sarminskii Mys | SMS_1987.031.03 | 4892 | 35 | 4458 | 63 | Serovo | Adult | PF | cranium | 6.3 | 43.2 | 3.3 | -17.9 | 15.9 | this study |
| Sarminskii Mys | SMS_1986.019.01 | 4846 | 33 | 4507 | 61 | Serovo | Adoles. | M | femur | 2.9 | 35.0 | 3.3 | -17.7 | 15.2 | Weber <i>et al.</i> , 2016 |
| Sarminskii Mys | SMS_1986.019.03 | 4877 | 36 | 4508 | 63 | Serovo | Adult | PM | cranium | 4.3 | 43.1 | 3.3 | -17.5 | 15.7 | this study |
| Sarminskii Mys | SMS_1986.019.05 | 4781 | 33 | 4546 | 61 | Serovo | Adult | F | fibula | 7.2 | 43.6 | 3.2 | -16.9 | 15.2 | Weber <i>et al.</i> , 2016 |
| Khuzhir-Nuge VI | KN6_2005.006 | 4798 | 32 | 4428 | 61 | Serovo | Adult | U | fibula | 4.2 | 44.0 | 3.3 | -17.7 | 15.6 | this study |
| Late Neolithic Island | | | | | | | | | | | | | | | |
| Budun IV | BUD_1986.027B | 4741 | 33 | 4066 | 61 | Serovo | Adult | U | femur | 6.8 | 42.5 | 3.4 | -19.0 | 17.0 | this study |
| Budun IV | BUD_2015.001 | 4759 | 31 | 4144 | 60 | Serovo | Adult | PM | foot bones | 10.3 | 42.6 | 3.2 | -18.5 | 17.0 | this study |
| Budun IV | BUD_2015.006 | 4801 | 31 | 4193 | 60 | Serovo | Adult | PF | leg & foot bones | 12.0 | 50.8 | 3.3 | -18.6 | 16.8 | this study |
| Budun IV | BUD_2015.004 | 4757 | 25 | 4214 | 58 | Serovo | Adoles. | U | rib | 8.4 | 44.6 | 3.2 | -18.8 | 15.9 | this study |
| Budun IV | BUD_1986.027.01 | 4779 | 29 | 4226 | 59 | Serovo | Adult | PM | cranium | 7.2 | 41.8 | 3.3 | -18.3 | 16.7 | this study |
| Budun IV | BUD_1986.028.00 | 4793 | 29 | 4230 | 59 | Serovo | Adult | PF | cranium | 10.5 | 43.4 | 3.4 | -18.6 | 16.4 | this study |
| Budun IV | BUD_1986.027A | 4877 | 32 | 4277 | 61 | Serovo | Adult | U | femur | 3.7 | 42.9 | 3.3 | -18.6 | 16.8 | this study |
| Budun IV | BUD_2005.002 | 4628 | 30 | 4111 | 60 | Serovo | Adoles. | U | femur | 7.6 | 45.2 | 3.3 | -18.7 | 15.7 | this study |
| Shamanskii Mys | SHM_1976.001.01 | 4902 | 33 | 4572 | 61 | Serovo | Adult | U | humerus | 4.0 | 45.8 | 3.3 | -16.9 | 16.2 | Weber <i>et al.</i> , 2016 |
| Early Bronze Age Mainland | | | | | | | | | | | | | | | |
| Khuzhir-Nuge XIV | K14_1999.059.01 | 3547 | 32 | 3357 | 61 | Glazkovo | Adult | U | cranium | 4.1 | 45.4 | 3.3 | -19.7 | 11.0 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1998.027.01 | 3694 | 32 | 3391 | 61 | Glazkovo | Adult | M | femur | 2.8 | 41.9 | 3.3 | -19.3 | 12.7 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_2001.085 | 3662 | 32 | 3420 | 61 | Glazkovo | Adult | U | femur | 8.1 | 43.5 | 3.3 | -18.9 | 12.6 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1998.035.01 | 3770 | 32 | 3514 | 61 | Glazkovo | Adoles. | PM | femur | 4.9 | 42.1 | 3.4 | -19.0 | 12.6 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_2000.061 | 3836 | 32 | 3529 | 61 | Glazkovo | Adult | U | femur | 7.7 | 42.5 | 3.2 | -19.2 | 12.8 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1993.004 | 3837 | 32 | 3532 | 61 | Glazkovo | Adoles. – Adult | U | cranium | 2.8 | 44.7 | 3.3 | -20.1 | 11.7 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1998.037.02 | 3727 | 22 | 3538 | 56 | Glazkovo | Adoles. | U | tibia | 3.7 | 41.8 | 3.2 | -19.2 | 11.7 | Weber <i>et al.</i> , 2016 |
| Khuzhir-Nuge XIV | K14_1998.032 | 3831 | 31 | 3577 | 60 | Glazkovo | Adult | F | tibia | 1.4 | 42.9 | 3.3 | -19.6 | 11.8 | Weber <i>et al.</i> , 2020 |

(continued on next page)

Table 1 (continued)

| Cemetery | Master ID | Date BP | Date ± | Mean Cal Date BP | Mean Cal Date ± | Mortuary Tradition | Age | Sex | Element | Collagen Yield | % C by weight | C/ N | δ ¹³ C (‰) | δ ¹⁵ N (‰) | Reference |
|------------------|-----------------|---------|--------|------------------|-----------------|--------------------|---------|-----|----------|----------------|---------------|------|-----------------------|-----------------------|----------------------------|
| Khuzhir-Nuge XIV | K14_1998.036.01 | 3800 | 30 | 3582 | 60 | Glazkovo | Adult | U | femur | 4.8 | 42.2 | 3.2 | -18.9 | 12.4 | Weber <i>et al.</i> , 2016 |
| Khuzhir-Nuge XIV | K14_2000.068 | 3830 | 32 | 3584 | 61 | Glazkovo | Adult | PM | femur | 2.1 | 43.0 | 3.2 | -19.5 | 11.8 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1998.034 | 3865 | 40 | 3587 | 65 | Glazkovo | Adult | M | humerus | 5.0 | 43.3 | 3.3 | -19.6 | 12.0 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_2001.082 | 3840 | 34 | 3598 | 62 | Glazkovo | Adult | U | femur | 7.3 | 44.6 | 3.2 | -19.2 | 12.2 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_2001.083 | 3862 | 23 | 3610 | 57 | Glazkovo | Adult | U | tibia | 5.8 | 42.7 | 3.3 | -19.3 | 12.2 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_2001.081 | 3859 | 32 | 3618 | 61 | Glazkovo | Adult | PM | tibia | 2.4 | 44.4 | 3.3 | -19.2 | 12.2 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_2001.087 | 3833 | 30 | 3637 | 60 | Glazkovo | Adult | PM | rib | 5.1 | 43.1 | 3.2 | -18.4 | 12.8 | Weber <i>et al.</i> , 2016 |
| Khuzhir-Nuge XIV | K14_2000.066 | 3843 | 34 | 3665 | 62 | Glazkovo | Adult | M | femur | 7.1 | 44.1 | 3.2 | -19.1 | 11.7 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1998.037.01 | 3803 | 31 | 3690 | 60 | Glazkovo | Adoles. | U | tibia | 2.4 | 40.9 | 3.2 | -19.0 | 11.1 | Weber <i>et al.</i> , 2016 |
| Khuzhir-Nuge XIV | K14_2000.070 | 3903 | 34 | 3737 | 62 | Glazkovo | Adult | U | cranium | 6.8 | 45.6 | 3.3 | -19.3 | 11.3 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1999.060 | 3675 | 34 | 3271 | 62 | Glazkovo | Adult | PF | femur | 2.2 | 41.3 | 3.4 | -18.3 | 15.1 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1997.021 | 3740 | 32 | 3342 | 61 | Glazkovo | Adult | U | tibia | 0.8 | 42.5 | 3.3 | -18.7 | 14.5 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1999.044 | 3818 | 33 | 3392 | 61 | Glazkovo | Adult | M | femur | 4.2 | 43.7 | 3.3 | -17.8 | 15.9 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_2000.080.02 | 3729 | 33 | 3414 | 61 | Glazkovo | Adult | M | femur | 1.5 | 43.5 | 3.3 | -18.1 | 14.5 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1999.059.02 | 3738 | 23 | 3441 | 57 | Glazkovo | Adoles. | M | femur | 5.5 | 43.8 | 3.3 | -18.6 | 13.6 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1997.023 | 3869 | 33 | 3486 | 61 | Glazkovo | Adult | U | femur | 2.0 | 42.0 | 3.2 | -17.1 | 16.5 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1999.057.01 | 3780 | 32 | 3492 | 61 | Glazkovo | Adoles. | F | rib 3–10 | 1.9 | 44.1 | 3.3 | -18.4 | 13.7 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1997.022 | 3840 | 32 | 3495 | 61 | Glazkovo | Adult | U | femur | 6.7 | 43.4 | 3.3 | -18.0 | 14.9 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1997.014 | 3867 | 32 | 3499 | 61 | Glazkovo | Adult | PM | femur | 4.7 | 46.1 | 3.2 | -18.4 | 14.5 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1999.055 | 3864 | 32 | 3505 | 61 | Glazkovo | Adult | PM | femur | 6.4 | 44.0 | 3.2 | -17.7 | 15.4 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1999.049 | 3888 | 30 | 3506 | 60 | Glazkovo | Adult | U | tibia | 7.8 | 45.0 | 3.2 | -17.6 | 15.8 | Weber <i>et al.</i> , 2016 |
| Khuzhir-Nuge XIV | K14_2000.075 | 3980 | 34 | 3507 | 62 | Glazkovo | Adult | U | femur | 7.1 | 43.5 | 3.3 | -18.0 | 16.2 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1997.011 | 3973 | 33 | 3518 | 61 | Glazkovo | Adult | M | femur | 16.5 | 45.4 | 3.2 | -18.4 | 15.5 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1997.012 | 3818 | 33 | 3523 | 61 | Glazkovo | Adult | U | femur | 1.6 | 42.2 | 3.3 | -18.3 | 13.9 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_1999.046 | 3856 | 33 | 3527 | 61 | Glazkovo | Adult | M | femur | 4.6 | 43.4 | 3.3 | -18.4 | 14.2 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_2001.086 | 3881 | 31 | 3528 | 60 | Glazkovo | Adult | U | fibula | 7.6 | 43.5 | 3.3 | -19.4 | 13.1 | Weber <i>et al.</i> , 2020 |
| Khuzhir-Nuge XIV | K14_2000.063 | 3838 | 34 | 3529 | 62 | Glazkovo | Adoles. | U | femur | 3.4 | 46.0 | 3.3 | -17.1 | 15.6 | Weber <i>et al.</i> , 2020 |
| | K14_1999.058.02 | 3822 | 24 | 3532 | 57 | Glazkovo | Adult | PM | femur | 5.0 | 44.4 | 3.2 | -17.4 | 15.0 | |

(continued on next page)

Table 1 (continued)

| Cemetery | Master ID | Date BP | Date ± | Mean Cal Date BP | Mean Cal Date ± | Mortuary Tradition | Age | Sex | Element | Collagen Yield | % C by weight | C/ N | δ ¹³ C (‰) | δ ¹⁵ N (‰) | Reference |
|------------------|-----------------|---------|--------|------------------|-----------------|--------------------|-----------------|-----|------------|----------------|---------------|------|-----------------------|-----------------------|--------------------|
| Khuzhir-Nuge XIV | | | | | | | | | | | | | | | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1998.029 | 3916 | 32 | 3537 | 61 | Glazkovo | Adult | M | femur | 13.9 | 48.9 | 3.2 | -17.9 | 15.4 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_2000.062.01 | 3896 | 35 | 3560 | 63 | Glazkovo | Adult | M | femur | 7.9 | 43.5 | 3.2 | -16.8 | 16.4 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1999.050 | 3860 | 33 | 3563 | 61 | Glazkovo | Adoles. | U | femur | 8.7 | 44.6 | 3.2 | -17.4 | 15.2 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1999.053 | 3879 | 33 | 3585 | 61 | Glazkovo | Adult | M | femur | 3.5 | 45.3 | 3.2 | -17.2 | 15.4 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1997.019 | 3850 | 32 | 3593 | 61 | Glazkovo | Adult | F | femur | 2.7 | 44.0 | 3.2 | -16.7 | 15.7 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1998.038 | 3893 | 31 | 3618 | 60 | Glazkovo | Adult | M | tibia | 4.0 | 43.3 | 3.2 | -18.4 | 13.6 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1997.009 | 3967 | 34 | 3622 | 62 | Glazkovo | Adult | M | femur | 4.0 | 44.9 | 3.2 | -18.5 | 14.2 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_2000.076 | 4057 | 35 | 3627 | 63 | Glazkovo | Adult | U | tibia | 6.1 | 43.7 | 3.2 | -18.5 | 15.1 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1999.052 | 3982 | 34 | 3628 | 62 | Glazkovo | Adult | U | foot bones | 6.5 | 45.6 | 3.3 | -17.4 | 15.8 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_2000.064 | 3901 | 33 | 3637 | 61 | Glazkovo | Adult | M | femur | 2.4 | 43.3 | 3.2 | -17.4 | 14.8 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1999.057.02 | 3969 | 29 | 3639 | 59 | Glazkovo | Adult | PM | tooth 38 | 11.9 | 43.6 | 3.3 | -16.6 | 16.6 | Weber et al., 2016 |
| Khuzhir-Nuge XIV | K14_1999.051 | 3930 | 33 | 3645 | 61 | Glazkovo | Adoles. | M | femur | 4.8 | 44.6 | 3.2 | -17.6 | 14.8 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_2000.073 | 4023 | 35 | 3695 | 63 | Glazkovo | Adult | U | femur | 6.2 | 42.5 | 3.3 | -18.0 | 14.7 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_2000.078 | 4052 | 35 | 3708 | 63 | Glazkovo | Adult | U | fibula | 5.6 | 43.8 | 3.2 | -17.5 | 15.5 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1999.058.01 | 3947 | 33 | 3710 | 61 | Glazkovo | Adult | U | humerus | 6.4 | 47.0 | 3.2 | -17.2 | 14.8 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_2000.074 | 4080 | 33 | 3710 | 61 | Glazkovo | Adult | M | tibia | 11.4 | 43.7 | 3.2 | -17.8 | 15.4 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1997.015 | 4001 | 31 | 3715 | 60 | Glazkovo | Adult | M | femur | 9.4 | 42.9 | 3.2 | -17.4 | 15.0 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_2000.072 | 4021 | 34 | 3716 | 62 | Glazkovo | Adult | U | femur | 1.7 | 41.6 | 3.4 | -17.0 | 15.8 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_2000.079 | 3982 | 33 | 3726 | 61 | Glazkovo | Adult | U | femur | 3.2 | 43.9 | 3.2 | -17.8 | 14.2 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1997.010 | 4035 | 32 | 3759 | 61 | Glazkovo | Adult | U | femur | 2.1 | 45.2 | 3.3 | -18.5 | 13.4 | Weber et al., 2020 |
| Khuzhir-Nuge XIV | K14_1998.031 | 4170 | 32 | 3797 | 61 | Glazkovo | Adult | U | femur | 11.9 | 43.2 | 3.1 | -18.5 | 14.5 | Weber et al., 2020 |
| Kurma XI | KUR_2002.015 | 4078 | 30 | 3741 | 60 | Glazkovo | Adoles. | M | foot bones | 11.1 | 43.9 | 3.1 | -19.5 | 12.8 | Weber et al., 2016 |
| Kurma XI | KUR_2002.001 | 3954 | 31 | 3773 | 60 | Glazkovo | Adult | M | radius | 12.1 | 43.6 | 3.2 | -19.1 | 11.7 | Weber et al., 2016 |
| Kurma XI | KUR_2002.012 | 3979 | 33 | 3804 | 61 | Glazkovo | Adult | U | femur | 11.8 | 42.6 | 3.2 | -19.3 | 11.4 | Weber et al., 2016 |
| Kurma XI | KUR_2002.004 | 4132 | 22 | 3667 | 56 | Glazkovo | Adult | M | vertebra | 13.8 | 44.5 | 3.2 | -18.4 | 15.6 | Weber et al., 2016 |
| Kurma XI | KUR_2002.016 | 4169 | 27 | 3679 | 58 | Glazkovo | Adoles. – Adult | F | fibula | 11.4 | 43.2 | 3.3 | -19.0 | 15.0 | Weber et al., 2016 |
| Kurma XI | KUR_2002.006 | 4157 | 32 | 3757 | 61 | Glazkovo | Adult | F | vertebra | 15.2 | 44.3 | 3.1 | -18.6 | 14.7 | |

(continued on next page)

Table 1 (continued)

| Cemetery | Master ID | Date BP | Date ± | Mean Cal Date BP | Mean Cal Date ± | Mortuary Tradition | Age | Sex | Element | Collagen Yield | % C by weight | C/ N | $\delta^{13}\text{C}$ (‰) | $\delta^{15}\text{N}$ (‰) | Reference |
|----------------|-----------------|---------|--------|------------------|-----------------|--------------------|-----------------|-----|--------------------|----------------|---------------|------|---------------------------|---------------------------|----------------------------|
| Kurma XI | KUR_2003.019 | 4121 | 25 | 3759 | 58 | Glazkovo | Adult | M | unknown | 2.9 | 43.2 | 3.4 | -19.4 | 13.2 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2003.017 | 4289 | 25 | 3790 | 58 | Glazkovo | Adult | M | unknown | 5.1 | 43.5 | 3.3 | -18.2 | 16.2 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2002.007.02 | 4240 | 34 | 3797 | 62 | Glazkovo | Adult | M | foot bones | 12.5 | 43.3 | 3.2 | -18.5 | 15.2 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2002.005 | 4204 | 31 | 3801 | 60 | Glazkovo | Adult | U | fibula | 12.8 | 43.9 | 3.1 | -18.2 | 15.2 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2002.003 | 4207 | 33 | 3811 | 61 | Glazkovo | Adult | U | foot bones | 3.2 | 43.0 | 3.2 | -17.9 | 15.5 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2002.010 | 4300 | 26 | 3820 | 58 | Glazkovo | Adult | M | foot bones | 7.9 | 42.6 | 3.2 | -17.5 | 17.0 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2002.014 | 4158 | 28 | 3826 | 59 | Glazkovo | Adult | F | radius | 7.8 | 43.4 | 3.3 | -18.9 | 13.6 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2002.013 | 4189 | 31 | 3831 | 60 | Glazkovo | Adult | U | fibula | 8.9 | 43.8 | 3.1 | -18.7 | 14.0 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2002.007.01 | 4181 | 36 | 3844 | 63 | Glazkovo | Adult | F | rib | 6.0 | 45.3 | 3.3 | -18.0 | 14.7 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2003.018 | 4233 | 31 | 3869 | 60 | Glazkovo | Adoles. | M | femur | 16.3 | 43.0 | 3.2 | -18.7 | 14.1 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2003.026 | 4283 | 27 | 3930 | 58 | Glazkovo | Adult | U | unknown | 3.7 | 43.0 | 3.1 | -17.7 | 15.4 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2003.025 | 4414 | 30 | 3938 | 60 | Glazkovo | Adult | U | femur | 14.9 | 43.8 | 3.1 | -18.2 | 15.9 | Weber <i>et al.</i> , 2016 |
| Kurma XI | KUR_2002.009 | 4515 | 21 | 4076 | 56 | Glazkovo | Adult | U | fibula | 7.1 | 44.0 | 3.1 | -18.9 | 14.6 | Weber <i>et al.</i> , 2016 |
| Ulan Khada IV | UK4_1959.005.02 | 4129 | 35 | 3954 | 63 | Glazkovo | Adult | U | mandible | 6.1 | 44.1 | 3.3 | -19.0 | 11.8 | White <i>et al.</i> , 2020 |
| Ulan Khada IV | UK4_1959.005.03 | 4324 | 35 | 4066 | 63 | Glazkovo | Adult | M | cranium | 10.1 | 44.4 | 3.2 | -18.9 | 12.8 | White <i>et al.</i> , 2020 |
| Khadarta IV | KHA_2010.006 | 4015 | 30 | 3494 | 60 | Glazkovo | Adult | U | tibia | 8.4 | 43.0 | 3.2 | -19.0 | 15.4 | Weber <i>et al.</i> , 2016 |
| Khadarta IV | KHA_2010.007 | 4091 | 31 | 3556 | 60 | Glazkovo | Adult | U | long bone frags. | 10.1 | 42.7 | 3.2 | -18.6 | 16.0 | Weber <i>et al.</i> , 2016 |
| Khadarta IV | KHA_2003.003 | 4048 | 22 | 3614 | 56 | Glazkovo | Adult | PM | rib | 16.3 | 43.5 | 3.2 | -18.3 | 15.4 | Weber <i>et al.</i> , 2016 |
| Khadarta IV | KHA_2010.012 | 4001 | 29 | 3664 | 59 | Glazkovo | Adult | PF | cranium | 8.2 | 42.4 | 3.2 | -18.6 | 14.0 | Weber <i>et al.</i> , 2016 |
| Khadarta IV | KHA_2010.008 | 4191 | 30 | 3714 | 60 | Glazkovo | Adult | U | radius/ulna frags. | 12.3 | 43.8 | 3.1 | -18.1 | 16.1 | Weber <i>et al.</i> , 2016 |
| Khadarta IV | KHA_2010.009 | 4019 | 31 | 3745 | 60 | Glazkovo | Adult | F | ulna | 9.4 | 43.1 | 3.2 | -18.1 | 14.0 | Weber <i>et al.</i> , 2016 |
| Khadarta IV | KHA_2010.005 | 4114 | 31 | 3783 | 60 | Glazkovo | Adult | PM | rib | 12.0 | 43.3 | 3.2 | -17.8 | 15.0 | Weber <i>et al.</i> , 2016 |
| Khadarta IV | KHA_2010.015 | 4111 | 31 | 3849 | 60 | Glazkovo | Adult | PF | femur | 17.1 | 42.5 | 3.2 | -17.7 | 14.4 | Weber <i>et al.</i> , 2016 |
| Khadarta IV | KHA_2010.011 | 4137 | 31 | 3868 | 60 | Glazkovo | Adult | M | rib | 12.3 | 43.1 | 3.2 | -17.2 | 15.1 | Weber <i>et al.</i> , 2016 |
| Kulgana | KUL_1977.001 | 4230 | 31 | 3835 | 60 | Glazkovo | Adoles. – Adult | U | fibula | 10.8 | 43.6 | 3.3 | -19.2 | 13.7 | Weber <i>et al.</i> , 2016 |
| Mys Uiuga | MUG_2016.002.01 | 4467 | 27 | 4029 | 58 | Glazkovo | Adult | M | tooth 12 | 9.6 | 42.2 | 3.2 | -17.1 | 17.1 | Weber <i>et al.</i> , 2020 |
| Sarminskii Mys | SMS_1986.002 | 3876 | 31 | 3545 | 60 | Glazkovo | Adult | PF | cranium | 8.7 | 45.0 | 3.2 | -19.1 | 13.3 | this study |

(continued on next page)

Table 1 (continued)

| Cemetery | Master ID | Date BP | Date ± | Mean Cal Date BP | Mean Cal Date ± | Mortuary Tradition | Age | Sex | Element | Collagen Yield | % C by weight | C/N | δ ¹³ C (‰) | δ ¹⁵ N (‰) | Reference |
|--------------------------------|-----------------|---------|--------|------------------|-----------------|--------------------|-------|-----|-----------------|----------------|---------------|-----|-----------------------|-----------------------|--------------------|
| Sarminskii Mys | SMS_1986.004 | 4147 | 31 | 3574 | 60 | Glazkovo | Adult | U | mandible | 4.2 | 42.9 | 3.3 | −19.2 | 15.6 | this study |
| Sarminskii Mys | SMS_1986.013 | 4221 | 31 | 3737 | 60 | Glazkovo | Adult | U | femur | 13.7 | 43.0 | 3.2 | −18.7 | 15.4 | Weber et al., 2016 |
| Sarminskii Mys | SMS_1987.033 | 4065 | 27 | 3789 | 58 | Glazkovo | Adult | F | unknown | 8.2 | 43.5 | 3.2 | −18.3 | 13.8 | Weber et al., 2016 |
| Sarminskii Mys | SMS_1986.012 | 4092 | 30 | 3796 | 60 | Glazkovo | Adult | U | unknown | 7.6 | 41.2 | 3.2 | −17.5 | 15.0 | Weber et al., 2016 |
| Sarminskii Mys | SMS_1987.021 | 3813 | 27 | 3594 | 58 | Glazkovo | Adult | F | humerus | 13.0 | 42.9 | 3.2 | −19.1 | 12.1 | Weber et al., 2016 |
| Sarminskii Mys | SMS_1986.010 | 4079 | 30 | 3701 | 60 | Glazkovo | Adult | U | cranium | 8.4 | 43.2 | 3.3 | −20.3 | 12.1 | this study |
| Shide I | SH1_2013.015 | 4559 | 32 | 4166 | 61 | Glazkovo | Adult | U | patella | 11.1 | 46.4 | 3.3 | −17.9 | 15.5 | Weber et al., 2020 |
| Ulan Khada II | UK2_1959.002 | 3977 | 35 | 3684 | 63 | Glazkovo | Adult | PM | radius | 5.4 | 45.1 | 3.3 | −18.3 | 14.0 | White et al., 2020 |
| Ulan Khada II | UK2_1959.003 | 4169 | 35 | 3831 | 63 | Glazkovo | Adult | PM | cranium | 12.5 | 44.9 | 3.2 | −18.2 | 14.7 | White et al., 2020 |
| Ulan Khada III | UK3_1959.001 | 4149 | 33 | 3890 | 61 | Glazkovo | Adult | U | mandible | 10.2 | 45.3 | 3.3 | −18.6 | 13.4 | White et al., 2020 |
| Ulan Khada IV | UK4_1959.004.E | 4304 | 38 | 3947 | 64 | Glazkovo | Adult | PM | mandible | 10.6 | 43.0 | 3.3 | −18.1 | 14.9 | White et al., 2020 |
| Ulan Khada IV | UK4_1959.004.D | 4346 | 37 | 4075 | 64 | Glazkovo | Adult | PM | femur | 9.9 | 44.2 | 3.2 | −18.0 | 14.0 | White et al., 2020 |
| Ulan Khada IV | UK4_1959.004.C | 4326 | 36 | 4075 | 63 | Glazkovo | Adult | U | mandible | 5.0 | 43.8 | 3.3 | −18.1 | 13.9 | White et al., 2020 |
| Ulan Khada IV | UK4_1959.004.A | 4461 | 37 | 4109 | 64 | Glazkovo | Adult | PM | occipital | 5.4 | 44.0 | 3.3 | −17.7 | 15.4 | White et al., 2020 |
| Ulan Khada IV | UK4_1959.004.B | 4469 | 36 | 4183 | 63 | Glazkovo | Adult | PM | occipital | 13.8 | 44.7 | 3.3 | −17.8 | 14.7 | White et al., 2020 |
| Early Bronze Age Island | | | | | | | | | | | | | | | |
| Shamanskii Mys | SHM_1973.003.01 | 4010 | 30 | 3474 | 60 | Glazkovo | Adult | PF | humerus | 9.5 | 44.5 | 3.2 | −18.6 | 16.1 | Weber et al., 2016 |
| Shamanskii Mys | SHM_1973.004 | 4056 | 30 | 3575 | 60 | Glazkovo | Adult | U | radius | 11.1 | 45.1 | 3.2 | −18.4 | 15.7 | Weber et al., 2016 |
| Shamanskii Mys | SHM_1972.001.01 | 4045 | 31 | 3582 | 60 | Glazkovo | Adult | PF | rib | 16.9 | 47.3 | 3.2 | −18.8 | 15.1 | Weber et al., 2016 |
| Shamanskii Mys | SHM_1972.002 | n/a | n/a | 3634 | 43 | Glazkovo | Adult | M | radius, ulna | 16.7 | 46.8 | 3.2 | −18.9 | 14.7 | Weber et al., 2016 |
| Shamanskii Mys | SHM_1973.002 | 4150 | 30 | 3657 | 60 | Glazkovo | Adult | F | ulna | 13.5 | 46.2 | 3.3 | −18.7 | 15.5 | Weber et al., 2016 |
| Shamanskii Mys | SHM_1973.001 | 4153 | 32 | 3747 | 61 | Glazkovo | Adult | M | radius | 4.5 | 45.5 | 3.2 | −18.1 | 15.4 | Weber et al., 2016 |
| Shamanskii Mys | SHM_1975.001 | n/a | n/a | 4410 | 43 | Glazkovo | Adult | M | skull, vertebra | 10.3 | 45.0 | 3.3 | −17.3 | 17.6 | Weber et al., 2016 |

Table 2
Mean $\delta^{13}\text{C}$ & $\delta^{15}\text{N}$ values for Little Sea Groups.

| Spatiotemporal Group | n | $\delta^{13}\text{C}$ (‰) (SD) | $\delta^{15}\text{N}$ (‰) (SD) |
|----------------------------------|-----|--------------------------------|--------------------------------|
| Serovo Mainland | 13 | -17.6 (0.49) | 15.8 (0.60) |
| Serovo Island | 9 | -18.4 (0.61) | 16.5 (0.48) |
| Glazkovo Mainland A ¹ | 105 | -18.4 (0.78) | 14.2 (1.49) |
| Glazkovo Mainland B ¹ | 29 | -18.4 (0.69) | 14.4 (1.27) |
| Glazkovo Island | 7 | -18.4 (0.55) | 15.7 (0.94) |

¹ A contains all burials; B excludes those from the larger cemeteries of Khuzhir–Nuge XIV and Kurma XI.

were excluded (Waters-Rist et al., 2011). While comparatively few cemeteries exist containing Serovo individuals with stable isotope data (only 22 individuals), as noted, this is still the largest sample size available to date. The Glazkovo mortuary tradition is represented by 112 individuals. One-hundred eighteen individuals come from cemeteries on the Mainland (13 Serovo; 105 Glazkovo), while 16 come from cemeteries on the Island (9 Serovo, 7 Glazkovo). The large sample of Mainland Glazkovo individuals is due to two cemeteries in particular, Khuzhir Nuge XIV ($n = 57$) and Kurma XI ($n = 19$). Certain statistical analyses are performed with and without these large cemeteries to ensure they are not obscuring patterns that exist in the smaller cemeteries, both between the Serovo and Glazkovo and between the Mainland and Island.

Bone samples for isotopic analysis of collagen were taken from a range of elements (Table 1) based on availability, preservation, and the avoidance of diagnostic traits, pathological lesions, and elements needed for other research. Samples that contain more cancellous (trabecular, spongy) bone likely contain more collagen that formed more recently in life than bone samples composed of only or mostly cortical bone (Tsutaya and Yoneda, 2013). Nonetheless, the collagen of adults will represent a long-term average of dietary intake, probably on the order of more than ten years (Hedges et al., 2007). The bones of growing adolescents represent a somewhat shorter period but would still include tissue formed over several years (Tsutaya and Yoneda, 2013). It has been demonstrated that the carbon in collagen is primarily derived from the protein part of the diet (Ambrose and Norr, 1993; Tieszen and Fagre, 1993). Fernandes et al. (2012) estimate a ratio of three-quarter protein to one-quarter carbohydrate and lipid. Nitrogen isotopes are derived from the amino acids making up proteins. Hence, the isotope data explored in this paper are most informative about variation in proteins sources over time and space.

3. Methods

Stable carbon and nitrogen isotopes of bone collagen provide information about the types of plants and animals consumed by humans (DeNiro and Epstein, 1978, 1981; Schoeninger and DeNiro, 1984). The $\delta^{13}\text{C}$ values of plants vary mostly depending on photosynthetic pathway (C3, C4, CAM), but also depending on certain environmental factors such as temperature and humidity (Kohn and Cerling, 2002; Lee-Thorp, 2008). In the Cis-Baikal region, the overwhelming majority of plants use

a C3 photosynthetic pathway. The aridity of the Little Sea area may have been conducive to a small amount of C4 grasses, which have comparatively enriched (less negative) $\delta^{13}\text{C}$ values. Such grasses are unlikely to have been consumed directly by humans, but possibly made their way into the food chain if consumed by herbivores. Freshwater plants use a different carbon source (mostly dissolved bicarbonate) than terrestrial plants (which use atmospheric CO_2), causing their $\delta^{13}\text{C}$ values to be less negative (Chisholm, 1989). Freshwater aquatic ecosystems are complex and have wide-ranging $\delta^{13}\text{C}$ values because of differences in terrestrial carbon input, oxidation of organic matter, light and nutrient availability, lake depth, size, hydrology, and temperature (Casey and Post, 2011; France, 1995; Fry, 1991). Katzenberg and Weber (Katzenberg and Weber, 1999; Katzenberg et al., 2010; Weber et al., 2002, 2011) analyzed hundreds of modern and archaeological faunal remains to understand the isotopic variation in Lake Baikal and the Cis-Baikal rivers. They found considerable $\delta^{13}\text{C}$ variation among benthic (deep water), littoral (shallow water), and pelagic (open water) fish from Lake Baikal, both between species, as expected, but also within species as fish diets vary with age and habitat throughout their lives (Katzenberg et al., 2010). Pelagic and benthic species typically have lower $\delta^{13}\text{C}$ values (Katzenberg and Weber, 1999). Littoral species, including many that inhabit the shallower waters of the Little Sea, have higher $\delta^{13}\text{C}$ values (Katzenberg and Weber, 1999). The Little Sea microregion has a wide range of fish $\delta^{13}\text{C}$ values because of its wide range of lake depths and habitats (includes shallow coves and lagoons, a gulf, and nearby access to open coast littoral- and deep-water pelagic fish) – this variability is passed onto human consumers (Weber et al., 2011).

The $\delta^{15}\text{N}$ values of terrestrial plants reflect nitrogen sources in the air, soil, and water where they grow (Ambrose, 1991; Lee-Thorp, 2008). Leguminous plants that have symbioses with N-fixing bacteria have lower $\delta^{15}\text{N}$ values than non-leguminous plants (DeNiro, 1985). Stable nitrogen isotope values then exhibit a stepwise trophic shift in food webs of +2–6‰, averaging ~3‰, from plants to herbivores to carnivores; omnivores have $\delta^{15}\text{N}$ values between herbivores and carnivores (DeNiro and Epstein, 1981; Schoeninger and DeNiro, 1984). Marine and freshwater ecosystems have higher $\delta^{15}\text{N}$ values because there are more steps in the food chain and the base of that chain has more elevated $\delta^{15}\text{N}$ values (Schoeninger and DeNiro, 1984). The Baikal seal occupies the top trophic position with a mean $\delta^{15}\text{N}$ value of 13.9‰ ($n = 13$; SD = 1.9), but because it feeds on benthic (deep water) fish (golomianka; *Comphorus sp.*) it has low $\delta^{13}\text{C}$ values ($n = 13$, $\bar{x} = -22.0$ ‰, SD = 0.9) (Katzenberg et al., 2010). High trophic level fish from the lake include perch, pike and sturgeon, while lower trophic level fish are burbot, whitefish, and ide (Katzenberg and Weber, 1999; Katzenberg et al., 2010). Terrestrial herbivores have $\delta^{15}\text{N}$ values from 2 to 6‰ (Katzenberg et al., 2010).

This research uses stable isotope and FRE-corrected carbon-14 dates contained in the Baikal Archaeology Master Database (the reference column in Table 1 refers to the source of the stable isotope data). Bone collagen samples were prepared for radiocarbon dating and $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements according to the procedure outlined by Brock et al. (2010), involving an acid, base, acid treatment, followed by

Table 3
Statistical Comparison of $\delta^{15}\text{N}$ values among Spatiotemporal Groups. Significant Results are in Bold.

| | Serovo Mainland | Serovo Island | Glazkovo Mainland A ¹ | Glazkovo Mainland B ¹ | Glazkovo Island |
|----------------------------------|-----------------|--------------------------|----------------------------------|----------------------------------|--------------------------|
| Serovo Mainland | -- | H = -23.090; $p = 1.000$ | H = 55.315; $p = 0.001$ | H = 52.491; $p = 0.009$ | H = 8.863; $p = 1.000$ |
| Serovo Island | | -- | H = 78.405; $p = 0.000$ | H = 75.580; $p = 0.000$ | H = 31.952; $p = 1.000$ |
| Glazkovo Mainland A ¹ | | | -- | H = -2.824; $p = 1.000$ | H = -46.452; $p = 0.116$ |
| Glazkovo Mainland B ¹ | | | | -- | H = 43.628; $p = 0.280$ |
| Glazkovo Island | | | | | -- |

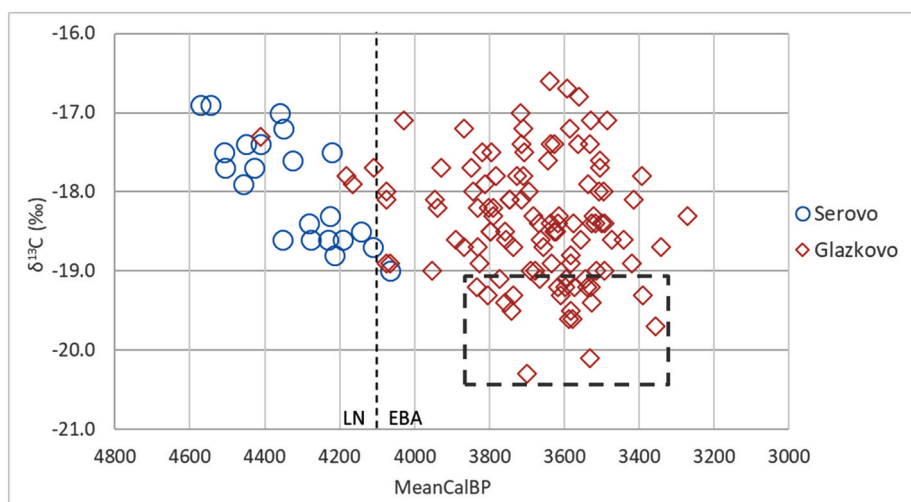


Fig. 2. Serovo and Glazkovo $\delta^{13}\text{C}$ values by FRE corrected ^{14}C date. Box indicates Glazkovo $\delta^{13}\text{C}$ values that do not overlap with Serovo $\delta^{13}\text{C}$ values.

gelatinization, ultrafiltration, and freeze-drying. Radiocarbon dates are obtained from the Oxford Radiocarbon Accelerator Unit (ORAU), University of Oxford, UK, with $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurement taking place at the Research Laboratory for Archaeology and the History of Art (RLAHA) via a combustion elemental analyzer and a gas-source isotope-ratio mass spectrometer (Brock et al., 2010). All stable isotope results have acceptable collagen preservation indicators (C/N ratio 2.9–3.6; %C by wt. >35%; %N by weight > 11%; and all but 1 sample (K14_1999.044) has a yield >1%) (DeNiro, 1985; van Klinken, 1999). When there was enough sample, stable isotope analyses were done in duplicate or triplicate, with the average reported here. A subset of 55 samples were run with a two-point calibration using in-house cow and seal collagen standards, which were then referenced to international standards (Schulting et al., 2014; Weber et al., 2016). Analytical precision for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ was better than $\pm 0.2\text{‰}$. Isotopic ratios are reported as delta (δ) per mil (‰) relative to the VPDB standard for carbon and the AIR standard for nitrogen. The aquatic ecosystem of Lake Baikal has an old carbon reservoir effect, and Weber et al. (2016) provide a FRE-correction to the radiocarbon dates obtained on human bones for the Little Sea Microregion based on formulae produced by Schulting et al. (2014, 2015).

Statistical analyses are conducted with SPSS v. 25. When sample

sizes are larger than 10 and data have a normal distribution (as assessed by a Shapiro-Wilk test), parametric statistics (i.e. independent samples t -test; ANOVA; ANCOVA) are used. If either of the above criteria are not met, the non-parametric version of the test is used (i.e. Mann-Whitney U; Kruskal Wallis H).

4. Results

Table 2 shows the mean $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values and standard deviations (SD) for the Little Sea spatiotemporal groups. The Glazkovo Mainland cemeteries are shown including the large (i.e., Khuzhir-Nuge XIV, Kurma XI) plus small cemeteries (A) and the small cemeteries only (B). Category (B) is created to better match the size of cemeteries in the other groups and to assess if the two large Glazkovo Mainland cemeteries have a different isotopic mean relative to smaller cemeteries. As they do not, subsequent analyses only use the full Glazkovo Mainland A dataset. There is a significant, moderate correlation between the two isotopes ($r^2 = 0.473$; $p = 0.000$; $df = 132$).

All groups have a $\delta^{13}\text{C}$ mean of -18.4 except the Serovo Mainland group, with a mean of -17.6‰ , thus differing by $+0.8\text{‰}$. This difference is statistically significant ($H = 13.722$; $p = 0.008$) with pairwise differences being significant between the Serovo Mainland and Serovo

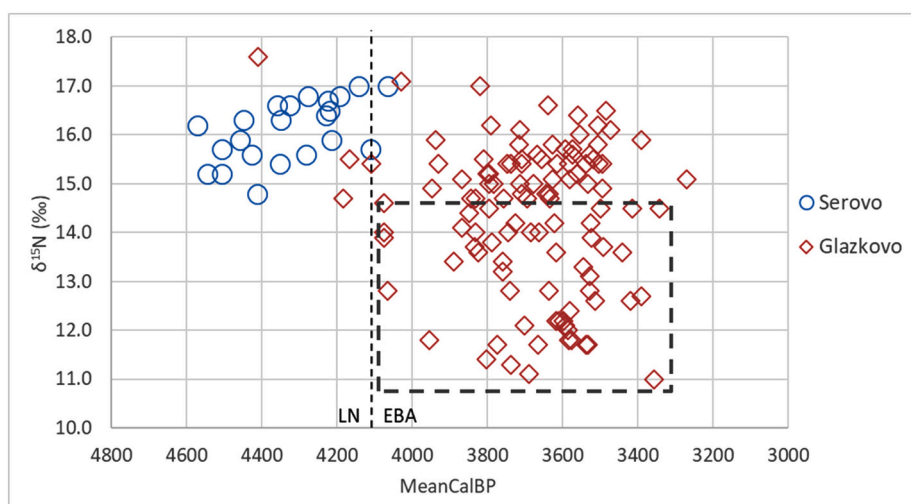


Fig. 3. Serovo and Glazkovo $\delta^{15}\text{N}$ values by FRE-corrected C^{14} date. Box indicates Glazkovo $\delta^{15}\text{N}$ values that do not overlap with Serovo $\delta^{15}\text{N}$ values.

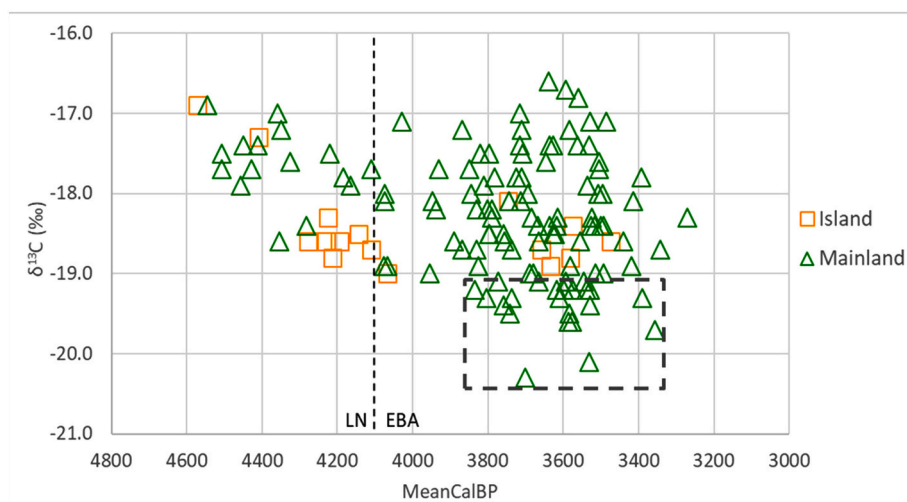


Fig. 4. Island and Mainland $\delta^{13}\text{C}$ values by FRE-corrected C^{14} date.

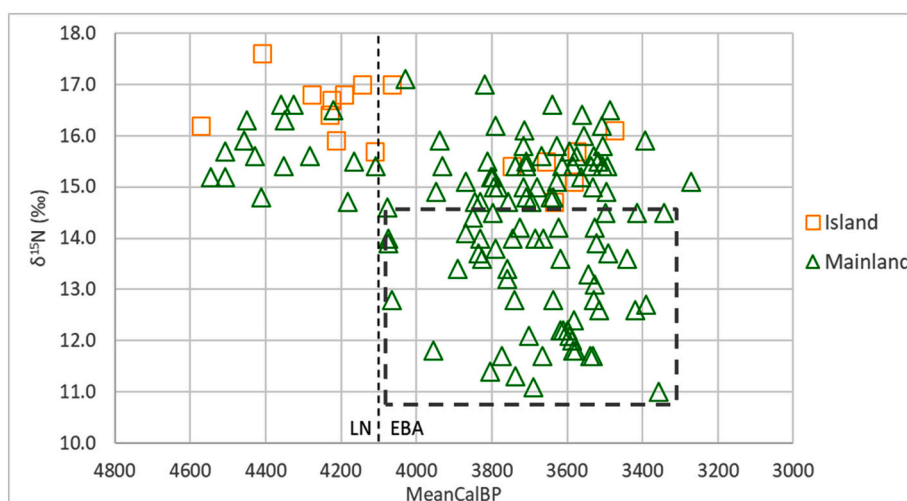


Fig. 5. Island and Mainland $\delta^{15}\text{N}$ values by FRE-corrected C^{14} date.

Island ($H = 59.1711$; $p = 0.038$) and Serovo Mainland and Glazkovo Mainland A and B (A: $H = 49.968$; $p = 0.004$; B: $H = 47.684$; $p = 0.024$). The Serovo Mainland to Glazkovo Island comparison does not meet statistical significance largely because of the small sample sizes ($H = 54.044$; $p = 0.145$).

There is more variation in $\delta^{15}\text{N}$ means among groups, with the Glazkovo Mainland A having the lowest mean ($14.2 \pm 1.49\%$) and the Serovo Island group having the highest mean ($16.5 \pm 0.48\%$). The overall difference is significant ($H = 40.395$; $p = 0.000$) and table 3 displays the pairwise comparisons (adjusted by the Bonferroni correction for multiple tests) between all spatiotemporal groups.

The significant differences in $\delta^{15}\text{N}$ means are only between the Serovo groups (Mainland and Island) and the Glazkovo Mainland groups A and B. The Serovo Mainland is not significantly different from the Serovo Island group, and the individuals from Glazkovo Island are not significantly different from any other spatiotemporal group (Table 3). The small sample size of the Glazkovo Island group ($n = 7$) is certainly contributing to this lack of significance, as its $\delta^{15}\text{N}$ mean (15.7%) is actually quite different from the Glazkovo Mainland means (A = 14.2% ; B = 14.4%).

To visualize the isotopic variation among the two temporal groups,

Figs. 2 and 3 plot $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values by the FRE-corrected radiocarbon dates² for each individual as coded according to their designation as belonging to the Serovo or Glazkovo mortuary tradition. All Serovo individuals plot in the higher range of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values. In contrast, while many Glazkovo individuals overlap the range of the Serovo, some Glazkovo individuals have lower $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (dashed boxes).

These figures clearly show the shift in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values over time. Only after ~ 3900 calBP do we see $\delta^{13}\text{C}$ values $\leq -19.0\%$ (Fig. 2), and only after ~ 4100 calBP do we see individuals with $\delta^{15}\text{N}$ values $\leq 14.6\%$ (Fig. 3). This corresponds almost exactly with the shift from Serovo to Glazkovo mortuary traditions in the Little Sea; the temporal nature of the dietary shift has not been revealed this clearly before. More specifically, while some Glazkovo individuals maintained a diet similar to their Serovo predecessors, a large number of Glazkovo individuals

² Note that these dates are the conventional carbon-14 dates corrected for FRE prior to Bayesian analysis. As such, the timing of the LN/EBA transition observed here (ca. 4100 cal. BP) differs from the Bayesian-statistically modelled timing (ca. 4955–4485 cal. BP) reported in Weber et al. (2020). This does not affect our interpretation.

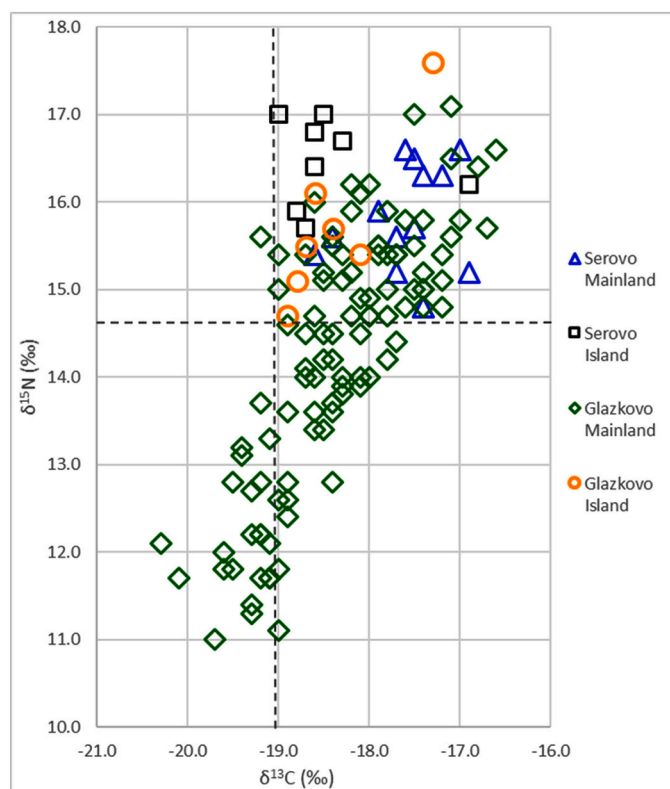


Fig. 6. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for Serovo Mainland, Serovo Island, Glazkovo Mainland, and Glazkovo Island. Dotted line on x- and y-axes demarcating the new isotopic values of subsample of Glazkovo Mainlanders as determined in Figs. 2 and 3.

appear to have taken up a different diet resulting in an isotopic profile not seen during Serovo times. The high standard deviations of the Mainland Glazkovo groups (A and B) reflect this isotopic diversity, which is not seen in any other spatiotemporal group. The $\delta^{13}\text{C}$ boundary of this new diet ($\leq -19.0\text{‰}$) is similar to that of Weber and colleagues (2011) GF diet ($\text{GF} = \leq -18.9\text{‰}$; $\text{GFS} = \geq -19.3\text{‰}$), but the $\delta^{15}\text{N}$ boundary ($\leq 14.6\text{‰}$) is considerably higher ($\text{GF} = \leq 12.8\text{‰}$; $\text{GFS} = \geq 13.2\text{‰}$). This is explored further below. First, an examination of the spatial differences between these diets adds useful information.

To assess the overall isotopic variation between spatial groups, Figs. 4 and 5 plot the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of Mainland vs. Island burials. The range of $\delta^{13}\text{C}$ values for all Island burials (-19.0 to -16.9‰) lies within the range for Mainland burials (-20.3 to -16.6‰). In the LN, the Island and Mainland burials have roughly similar ranges (Serovo Island: -19.0 to -16.9‰ ; Serovo Mainland: -18.6 to -16.9‰) but this is due

to a single Island individual with a high $\delta^{13}\text{C}$ value of -16.9‰ (SHM_1976.001.01). Excluding this individual, the LN Islanders have a narrower and more negative $\delta^{13}\text{C}$ range of -19.0 to -18.3‰ , which leads to the two groups having statistically different means (-18.4 and -17.6‰ , respectively). It is the EBA Glazkovo Mainland individuals that display the widest range of $\delta^{13}\text{C}$ values (-20.3 to -16.6‰), whereas the Glazkovo Island individuals have $\delta^{13}\text{C}$ values (-18.9 to -17.3‰) similar to the Serovo Island and Mainland individuals. The much larger sample size of individuals from the Glazkovo Mainland is likely contributing to the greater range in $\delta^{13}\text{C}$ values relative to other groups. Nonetheless, it is the Glazkovo Mainland that stands apart from both Island groups and the Serovo Mainland, indicating the Glazkovo Mainland group is the prime reason for the difference in $\delta^{13}\text{C}$ values over time and space.

In terms of $\delta^{15}\text{N}$ data, there is more variation compared to the $\delta^{13}\text{C}$ data, and the wide spread of $\delta^{15}\text{N}$ values (11.0 to 17.8‰) comes mostly from Mainlanders in the EBA period, where we see many Glazkovo individuals with values $\leq 14.6\text{‰}$. This contributes to Island individuals as a whole having a significantly higher $\delta^{15}\text{N}$ mean than Mainland individuals ($n = 16$; $\bar{x} = 16.2 \pm 0.79\text{‰}$ vs. $n = 118$, $\bar{x} = 14.4 \pm 1.50\text{‰}$; hypothesis of normality rejected $W = 0.950$, $p = 0.000$ so non-parametric Mann-Whitney applied, $U = 1615.5$, $p = 0.000$). However, the Serovo Mainland individuals ($\bar{x} = 15.8 \pm 0.60\text{‰}$, range 14.8 to 16.6‰) cluster with the Island individuals with a mean in between the Serovo Island ($\bar{x} = 16.5 \pm 0.48\text{‰}$; range 15.7 to 17.0‰) and Glazkovo Island ($\bar{x} = 15.7 \pm 0.94\text{‰}$, range 14.7 to 17.6‰) groups. Hence, it is the Glazkovo Mainland that is driving the significant difference between Island and Mainland groups, with many individuals having lower $\delta^{15}\text{N}$ values resulting in a significantly lower mean ($\bar{x} = 14.2 \pm 1.49\text{‰}$, range 11.0 to 17.1‰).

When we separate the four spatiotemporal groups by mortuary tradition, as shown in Fig. 6, differences become most clear. Beginning with the Serovo, we see that the Island and Mainland individuals have partially overlapping $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ ranges. The non-overlapping portion of the ranges is mostly the result of a significant difference in $\delta^{13}\text{C}$ means (Island = -18.4‰ ; Mainland = -17.6‰), with $\delta^{15}\text{N}$ means also differing but not significantly (Island = 16.5‰ ; Mainland = 15.8‰). These data suggest the Serovo Islanders were eating a somewhat different diet than the Serovo Mainlanders. Next, we see the Glazkovo Islanders with a $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ range roughly between the two Serovo groups (and means in the same range; $\delta^{13}\text{C}$ $\bar{x} = -18.4\text{‰}$; $\delta^{15}\text{N}$ $\bar{x} = 15.7\text{‰}$). In comparing the two Island groups, while their $\delta^{15}\text{N}$ means do vary by 0.8‰ , this difference is not statistically significant, and their $\delta^{13}\text{C}$ means are also not significantly different (as they are both -18.4‰), suggesting considerable continuity in the diets of Islanders over time. Possibly, the Glazkovo consumed slightly less high trophic level food like seal, but larger sample sizes and data from additional cemeteries (which may not exist) will be needed to assess this. Finally, clearly the Mainland Glazkovo have the widest range of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$

Table 4
Percentage of Glazkovo Individuals with the ‘Low C and/or N Isotope Diet’ at Mainland Cemeteries (n in brackets).

| Cemetery | Total number individuals | % individuals with ‘low C & N isotope diet’ ($\delta^{13}\text{C} \leq -19.0\text{‰}$ and $\delta^{15}\text{N} \leq 14.6\text{‰}$) | % individuals with ‘low C isotope diet’ only ($\delta^{13}\text{C} \leq -19.0\text{‰}$ but $\delta^{15}\text{N}$ not $\leq 14.6\text{‰}$) | % individuals with ‘low N isotope diet’ only ($\delta^{15}\text{N} \leq 14.6\text{‰}$ but $\delta^{13}\text{C}$ not $\leq -19.0\text{‰}$) | Total |
|----------------------------|--------------------------|--|---|---|-------------------|
| Khuzhir-Nuge XIV | 57 | 28.1% (16) | 0 | 26.3% (15) | 54.4% (31) |
| Kurma XI | 19 | 21.1% (4) | 5.3% (1) | 21.1% (4) | 47.4% (9) |
| Ulan Khada II, III & IV | 10 | 10.0% (1) | 0 | 50.0% (5) | 60.0% (6) |
| Khadarta IV | 9 | 0 | 11.1% (1) | 33.3% (3) | 44.4% (4) |
| Sarminskii Mys | 7 | 42.9% (3) | 0 | 14.3% (1) | 57.1% (4) |
| Other Cemeteries Combined* | 3 | 33.3% (1) | 0 | 0 | 33.3% (1) |
| Total | 105 | 23.8% (25) | 1.9% (2) | 26.7% (28) | 52.4% (55) |

* includes Shide I (n = 1), Mys Uiuga (n = 1) and Kulgana (n = 1).

values, with the addition of a group of individuals whose $\delta^{13}\text{C}$ values are $\leq -19.0\text{‰}$ and $\delta^{15}\text{N}$ values $\leq 14.6\text{‰}$. Many Glazkovo individuals have isotopic values that overlap with the other spatiotemporal groups, so not everyone was consuming a different diet. That said, nearly 24% (25/105) of Glazkovo Mainlanders are distinct in both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, while even more are distinct in one isotope but not the other: 26% (27/105) for $\delta^{13}\text{C}$ and 50.5% (53/105) for $\delta^{15}\text{N}$. Over 52% (55/105) of individuals have a low $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ value (Table 4).

Fig. 7 shows the isotopic values of the four cemeteries that constitute the Serovo sample (to facilitate clear comparison, the axes display the same range of values as used for the subsequent figure that shows the Mainland Glazkovo cemeteries). Two cemeteries dominate the Serovo sample: Sarminskii Mys on the Mainland ($n = 12$) and Budun IV on the Island ($n = 8$). Budun IV has higher $\delta^{15}\text{N}$ ($\bar{x} = 16.5 \pm 0.50\text{‰}$) and lower $\delta^{13}\text{C}$ ($\bar{x} = -18.6 \pm 0.21\text{‰}$) means than Sarminskii Mys ($\delta^{15}\text{N} \bar{x} = 15.8 \pm 0.62\text{‰}$; $\delta^{13}\text{C} \bar{x} = -17.6 \pm 0.51\text{‰}$).

To determine if the large group of Mainland Glazkovo individuals with the new isotopic profile (lower $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values) were concentrated in some cemeteries but not others, the cemeteries with the largest sample sizes (Khuzhir-Nuge XIV $n = 57$; Kurma XI $n = 19$; Ulan Khada II-IV $n = 10$; Khadarta IV $n = 9$; Sarminskii Mys $n = 7$) are compared statistically. There are no significant differences in $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ means between these cemeteries ($\delta^{13}\text{C}$: $H = 5.465$, $p = 0.243$; $\delta^{15}\text{N}$: $H = 4.834$, $p = 0.305$), meaning that individuals with lower and higher $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values were rather equally distributed among all the Glazkovo Mainland cemeteries (although they may have been buried in different areas of the cemeteries). This is depicted in Fig. 8, with polygons representing the range of isotope values of the other spatiotemporal groups shown in the background to better contextualize the results. However, when both isotopes are considered together in an ANCOVA analysis, Kurma XI and Khuzhir-Nuge XIV do differ significantly (ANCOVA $F = 20.938$, $p = 0.000$, $\eta_p^2 = 0.223$). Fig. 8 shows that Kurma XI individuals generally have slightly higher $\delta^{15}\text{N}$ and lower $\delta^{13}\text{C}$ values compared to Khuzhir-Nuge XIV individuals. It also appears that Khadarta IV has higher $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values than Khuzhir-Nuge XIV, however, when both isotopes are considered together this difference does not meet statistical significance (Quade's test $F = 2.927$, $p = 0.092$). Despite showing greater dissimilarity in $\delta^{15}\text{N}$ than $\delta^{13}\text{C}$ values, their $\delta^{15}\text{N}$ data also do not differ significantly ($U = 170.0$, $p = 0.106$).

To summarize the results: (1) During Serovo times, Islanders and Mainlanders consumed moderately distinct diets; (2) During Glazkovo times, the Islanders maintained a broadly similar diet to their Serovo predecessors; and (3) Around ~ 4100 calBP a major dietary change occurs with the appearance of a group of Glazkovo Mainlanders consuming a diet with low $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values. To facilitate discussion, this new diet will be referred to as the 'low C & N isotope diet', while the unchanged diet, meaning the diet demarcated by similarly high $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values throughout the LN and EBA will be referred to as the 'high C & N isotope diet'. Our analyses find the new 'low C & N isotope diet' is identified by $\delta^{15}\text{N}$ values that are $\leq 14.6\text{‰}$ and $\delta^{13}\text{C}$ values that are $\leq -19.0\text{‰}$.

5. Discussion

These data support previous research noting cemeteries from the LN-EBA Little Sea Microregion contained individuals with diverse diets (Shepard, 2012; Weber et al., 2011). Our intention is not to explain in detail the contributions of different foods that result in dietary diversity, as this was presented by Weber et al. (2011) in their description of the GFS vs. GF diet. Nor do we suggest the isotopic ranges of our 'high and low C & N isotope diets' be used to modify or replace the GFS and GF isotopic ranges (Weber et al., 2011) more generally, as this was not the intention of our research and we do not employ the same statistical methods. Rather, as enabled by larger sample sizes and FRE-corrected carbon-14 dates since Weber and colleagues (2011) publication, we explore if there are significant differences in $\delta^{13}\text{C}$ or $\delta^{15}\text{N}$ values within

or across the Serovo and Glazkovo mortuary traditions and between individuals buried on Ol'khon Island and the Mainland. An unequivocal difference was found in both cases. This work thus offers a new and improved understanding of how Cis-Baikal hunter-gatherer diets varied over time and space.

Both the Mainland and Island Serovo and the Island Glazkovo only have isotope values categorized as belonging to the 'high C & N isotope diet'. The higher $\delta^{15}\text{N}$ values in these three spatiotemporal groups are no doubt due to the consumption of more Baikal seal and/or more high trophic level fish, like perch, lenok, pike, and sturgeon (Katzenberg and Weber, 1999; Katzenberg et al., 2010; Weber et al., 2011). However, $\delta^{13}\text{C}$ values indicate the dietary difference between these three spatiotemporal groups and the Glazkovo Mainland group is not as simple as more vs. less seal. This is because seal has a low $\delta^{13}\text{C}$ value so, while its reduced consumption has the effect of lowering $\delta^{15}\text{N}$ values, as seen, it would also raise $\delta^{13}\text{C}$ values, which is not seen. Rather, the $\delta^{13}\text{C}$ means of the Serovo and Glazkovo Islanders are the same as the Glazkovo Mainlanders, at -18.4‰ (the Serovo Mainland group has a higher $\delta^{13}\text{C}$ mean, which is discussed below). What can explain variation in $\delta^{15}\text{N}$ but not $\delta^{13}\text{C}$ means in this scenario? The answer comes from the similar $\delta^{13}\text{C}$ values of seal and terrestrial game (which of course have markedly different $\delta^{15}\text{N}$ values). An increase in the consumption of terrestrial game would keep $\delta^{13}\text{C}$ values low and also serve to lower $\delta^{15}\text{N}$ values, in concert with the lowering of $\delta^{15}\text{N}$ values from less seal consumption. The contribution of freshwater fish in the Glazkovo Mainland diet may also have decreased, necessitating that protein requirements be met by more consumption of terrestrial game than ever before (see Weber et al., 2011 for more extensive discussion).

The Serovo Mainland group has the highest $\delta^{13}\text{C}$ mean at -17.6‰ , which differs significantly from the Serovo Islander mean of -18.4‰ (the two groups also differ in $\delta^{15}\text{N}$ means, being 15.8‰ and 16.5‰ , respectively, but the difference does not reach statistical significance largely due to small sample sizes). This tells us the Serovo Mainland diet contained the most shallow-water fish of any group, and probably included a considerable amount of seal even though $\delta^{15}\text{N}$ values suggest it was less than that of the Islanders. This interpretation is based firstly, on shallow-water fish having higher $\delta^{13}\text{C}$ values than seal and deep- and

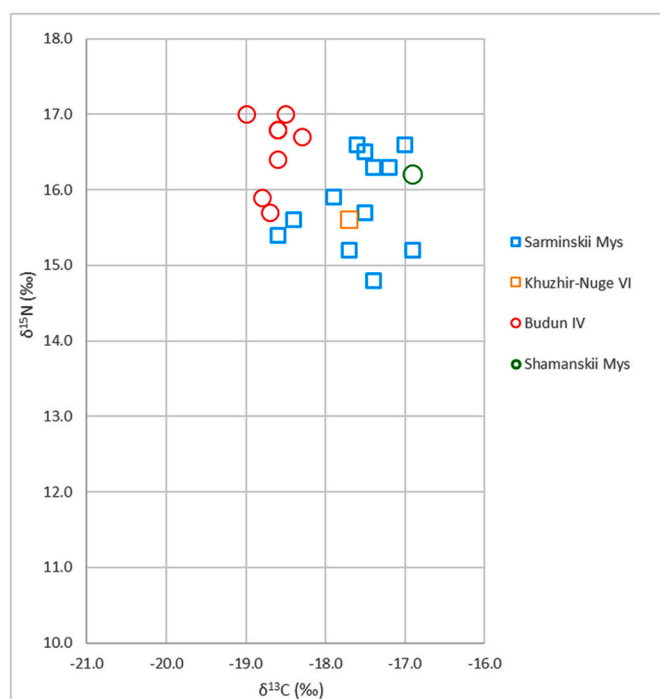


Fig. 7. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for LN Mainland (demarcated by squares) and Island (demarcated by circles) sites.

open-water fish (Katzenberg and Weber, 1999; Katzenberg et al., 2010; Weber et al., 2002, 2011). Secondly, while shallow-water fish have $\delta^{15}\text{N}$ values that are usually lower than seal, the difference is sometimes minimal, at only 1 or 2‰, and will vary depending upon the fishes' trophic position in the food chain (Katzenberg and Weber, 1999; Katzenberg et al., 2010; Weber et al., 2002, 2011). In particular, perch and pike, the former probably being frequently consumed, often have quite high $\delta^{15}\text{N}$ values (Weber et al., 2011). Thirdly, analyses of the faunal remains from campsites on the Little Sea shoreline of the lake show a preponderance of shallow-water fish (Losey et al., 2016). In contrast, the Island Serovo show evidence of the most seal and probably less shallow-water fish consumption based on a lower $\delta^{13}\text{C}$ mean and the highest $\delta^{15}\text{N}$ mean, although the consumption of freshwater fish is harder to detect because its $\delta^{15}\text{N}$ contribution is somewhat masked by the high $\delta^{15}\text{N}$ values of the seals. This finding is also supported by zooarchaeological research at island campsites and cemeteries, where seal remains are very common (e.g. Tyshkine II/III and Shamanskii Mys) (Weber et al., 1998).

As the Serovo sample is the smallest, we must caution that these interpretations are the least certain. We have no way of assessing if the analyzed individuals are representative of the whole population. It is entirely possible (but impossible to evaluate given the available data) that individual cemeteries constitute small groups (e.g., families or extended kin-groups) that differed in diet from other such groups. Indeed, the Island Budun IV cemetery is thought to have been used for only one to a few generations (Bronk Ramsey et al., 2020) which may suggest it holds a kin-group, possibly sharing a fairly similar diet. This is also a possibility at the Mainland Sarminskii Mys cemetery where 6/13 graves are found in a parallel row of graves. Rows of graves are known from several cemeteries across Cis-Baikal and have been interpreted as representing kin-groups (Goriunova et al., 2020). If the interpretation of kin-groups is correct, and if different kin-groups had somewhat different diets, this could potentially complicate spatiotemporal comparisons. However, if the kin-group's burial site is fairly representative of the broader area in which they lived, then it is likely that their stable isotope data will still be a useful representation of the diet of peoples in the area. Given the limited range of foods in the Cis-Baikal, there is only so much individual and kin-group dietary variation possible.

There is also a temporal difference between the major Serovo Mainland (Sarminskii Mys; 4546 ± 61 to 4220 ± 59 calBP) and Island (Budun IV; 4277 ± 61 to 4066 ± 61 calBP) cemeteries. It is beyond the scope of this paper to explore their use patterns in detail, but to summarize, Bronk Ramsey et al. (2020) found that Sarminskii Mys was used earlier and for a longer duration than Budun IV, and that there was little to no overlap in their usage. Thus, if there was a broad temporal change in diet driven by climatic or environmental changes that affected the distribution and abundance of dietary resources, this could reduce the comparability of the two cemeteries. However, it appears any such changes were gradual and slight (Tarasov et al., 2015; White and Bush, 2010) so the extent of climatic or environmental change across these approximately 500 years is likely minimal. This implies that environmentally-driven temporal changes in Serovo diet were minor and our comparison of a Mainland to Island cemetery offers useful insights into spatial differences in diet. Yet, the possibility of culturally-driven temporal changes in diet remains, but cannot be evaluated without additional Serovo data.

The EBA Glazkovo Island sample is also small and derives entirely from the cemetery of Shamanskii Mys. Several features of this cemetery suggest it may have functioned as a more specialized rather than community burial ground: the paucity of nonadults with the single child skeleton having arrowheads embedded in its scapula; the cemetery's highly visible and unique location on a narrow peninsula with a large rock protrusion; and a high number of seal carcasses, including of newborns, near the human graves (McKenzie, 2010; Weber et al., 1993, 1998). Since these seals would have been caught on the eastern Baikal side of the island, they would have had to be transported a considerable

distance over land to reach the cemetery (Weber et al., 1993, 1998). Thus, the Glazkovo Island may not be particularly representative of the entire population living at the time. It is conceivable Shamanskii Mys was a specialized burial ground for individuals that focussed on seal hunting and/or spent an above average amount of their lives living on Ol'khon island. Indeed, Konopatskii (1982) hypothesized that at least some of the Islanders were specialized seal hunters who spent far more of their annual round living on the Island than did the rest of the population.

The two Island groups have lower $\delta^{13}\text{C}$ means (-18.4‰) than the Serovo Mainland group (-17.6‰) which is consistent with higher reliance on the Baikal seal given its quite low $\delta^{13}\text{C}$ values. However, the Glazkovo Island group has a $\delta^{15}\text{N}$ mean that is lower than the Serovo Island group by 0.8‰ . Although this does not reach a statistically significant level, the $\delta^{15}\text{N}$ difference may suggest that while the Glazkovo Islanders continued to have a diet high in seal like their Serovo predecessors, they perhaps also consumed more terrestrial herbivores, fish from a lower trophic level, and/or fish of the same species but derived from a different habitat associated with lower $\delta^{15}\text{N}$ values and similarly low $\delta^{13}\text{C}$ values. While rarer than seal and fish remains, terrestrial herbivore remains are found at Ol'khon Island campsites and cemeteries (Losey and Nomokonova, 2017; Losey et al., 2016). Perhaps there was increase in exchange (or sharing) of terrestrial herbivores for seals in the Glazkovo period that could explain the Islanders slightly lower $\delta^{15}\text{N}$ values and similarly low $\delta^{13}\text{C}$ values. Such exchange could also partly account for the high $\delta^{15}\text{N}$ values of some Glazkovo Mainlanders. If the isotopic change is due to fish, it is unlikely they came from the Little Sea, as fish from this body of water typically have higher $\delta^{13}\text{C}$ values than seen in the Islanders (Katzenberg et al., 2012; Weber et al., 2002). However, fish caught from deep and/or open waters, as is possible from the southern coast of Ol'khon Island, typically have lower $\delta^{13}\text{C}$ values, in the range of the Islanders. So, while it is not clear that such species could be caught in high numbers, even a small increase in their consumption could also be contributing to the slightly lower $\delta^{15}\text{N}$ values and unchanged $\delta^{13}\text{C}$ values of the Glazkovo Islanders³ (Katzenberg et al., 2012; Weber et al., 2002). Regardless, the high consumption of seal by Islanders in both time periods fits with Katzenberg and Weber's (1999) suggestion that, in the Little Sea Microregion, Island individuals had better access to seal. Zooarchaeological research of campsites in both the Little Sea and further south along the open shoreline of Lake Baikal have shown a marked decrease in seal remains in the EBA (Losey et al., 2016; Nomokonova and Losey, 2017; Nomokonova et al., 2015, 2017). We suggest that the EBA decrease in sealing did occur on the island, but that it was much less pronounced compared to the mainland. Unlike the marked shift in stable isotope values that occurs on the mainland, the diet of individuals buried on the island did not change as much over time. This may suggest that, despite their proximity, Islanders and Mainlanders were distinct in some aspect of sociopolitical economy and that this distinction did not change much even when there was a shift on the Mainland.

While the certainty of interpretations are constrained by small sample sizes, the lack of major isotopic changes of Islanders across the LN and EBA suggest that specialized seal hunters indeed occupied the island and that they continued to live (and die) in this area for thousands of years. Campsites such as Tyshkine II and III on the southern Baikal shore of Ol'khon Island were used primarily as spring seal hunting locations (Weber et al., 1998). During these hunts it is likely that enough food could have been caught to sustain a large aggregation of people for

³ The increased consumption of white grayling (*Thymallus arcticus brevipinnis*), omul (*Coregonus autumnalis migratorius*), or several other fish species caught in Baikal waters (not the Little Sea) by Glazkovo Islanders could account for both a lower $\delta^{15}\text{N}$ mean and an unchanged $\delta^{13}\text{C}$ mean relative to the Serovo Islanders (using modern fish values, corrected for the Suess effect; Katzenberg et al., 2012; Weber et al., 2002).

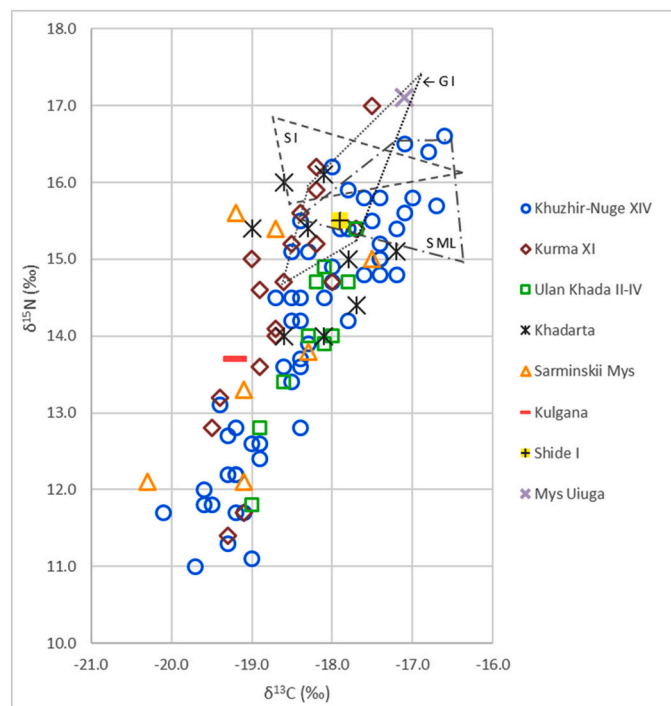


Fig. 8. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for EBA Mainland Sites. S=Serovo; G = Glazkovo; ML = Mainland; I=Island.

several weeks (Weber et al., 2011). It is not yet known how extensively the Island and Mainland individuals interacted, but the likelihood of a feasting ritual that drew people from all around (Konopatskii, 1982; Weber et al., 1998), and the high utility of seal for food, fuel, and other materials at an otherwise lean time of year, suggests interaction would have been common for the purposes of exchange (e.g., of seal and other foods, raw materials, manufactured items, marriage partners, etc.; see Weber, 2020). Seals are also known to be important in local cosmologies for contemporary Buriat peoples in the Baikal region, and the archaeological record of the area contains seal representations as far back as 7000–8000 years ago suggesting that humans have ancient long-standing relationships with seals (Nomokonova et al., 2013).

It is not known if Island individuals were genetically related, such as an extended family or kin-group, or if certain qualities caused them to be chosen as seal hunters to live more of their lives on the island than the rest of the population. Using strontium isotopes of molar enamel, Scharlotta and Weber (2014) explored the birthplace and migration of three Shamanskii Mys individuals. While each individual had a different pattern of $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, their childhood locales are suggested to be in the Little Sea and possibly the Upper Lena Microregions. Future ancient DNA research may illuminate the genetic relatedness of Island burials and isotopic geochemical research of more samples could begin to explore if Island individuals differed in birthplace, mobility and/or migration relative to Mainlanders. Shepard (2012) found lower $^{87}\text{Sr}/^{86}\text{Sr}$ values for terrestrial environmental samples from Ol'khon Island compared to the Mainland suggesting a likely distinction in strontium background values between areas.

Our research is the first to show that it is only during the EBA period, and with the appearance of the Glazkovo mortuary tradition, that individuals with the new 'low C & N isotope diet' appeared, and these individuals are restricted to Mainland cemeteries, not appearing on Ol'khon Island. The presence of some Glazkovo Mainlanders with this new 'low C & N isotope diet' is what leads to this group having the lowest $\delta^{15}\text{N}$ mean of all groups: $14.2 \pm 1.49\text{‰}$ when individuals from the large and small cemeteries are included ($n = 105$) and $14.4 \pm 1.27\text{‰}$ when only including individuals from the small cemeteries ($n = 29$). The

low $\delta^{15}\text{N}$ mean indicates lower consumption of seal and/or high trophic level fish and increased consumption of terrestrial game. Yet, this was not the case for every individual as many individuals had high $\delta^{15}\text{N}$ values and would be categorized as having a 'high C & N isotope diet' like their predecessors and neighbors on Ol'khon Island. As noted, nearly 24% (25/105) of Glazkovo Mainlanders have the new 'low C & N isotope diet', with more individuals being distinct in one isotope but not the other (55/105 = 52.4%). In looking at the isotope data for just the Glazkovo Mainlanders with the 'low C & N isotope diet', they have a $\delta^{15}\text{N}$ mean of $12.2 \pm 0.71\text{‰}$ and a $\delta^{13}\text{C}$ mean of $-19.3 \pm 0.32\text{‰}$. This compares to the Glazkovo Mainlanders with the 'high C & N isotope diet' who have $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ means of $15.5 \pm 0.59\text{‰}$ and $-17.8 \pm 0.56\text{‰}$, respectively. Thus, there is clearly a mix of individuals with quite different diets in the Glazkovo Mainland sample. What could have caused this pattern?

Weber and Goriunova (2013) found a mix of individuals with different geochemical signatures of birthplace and childhood locality for the EBA Mainland individuals of Khuzhir-Nuge XIV (and see Haverkort et al., 2008; Scharlotta et al., 2013; Weber et al., 2011). This, combined with the range of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values indicating the GFS and GF diet, is what led them to suggest there was regular travel between the Little Sea and a non-local area, possibly the Upper Lena Microregion (Weber and Goriunova, 2013; Weber et al., 2011). Individuals from the Upper Lena Microregion have $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values that are in the same range as Little Sea individuals consuming a GF diet (Weber et al., 2011) and that are also similar to the Glazkovo Mainlanders consuming the 'low C & N isotope diet' (albeit the Upper Lena individuals have lower $\delta^{15}\text{N}$ values). Using strontium isotope and trace element data, Scharlotta and Weber (2014) stated that the Upper Lena micro-region is the birthplace of most Khuzhir-Nuge XIV non-locals (all those with first molar strontium isotope ratios around 0.710) (Scharlotta et al., 2013). However, Schulting et al. (2020) have recently suggested this may not be the case, as the two regions have different old-carbon reservoir corrections, and different relationships between the reservoir effect carbon-14 offset and $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, that complicate interpretations. New models are considering travel from elsewhere, including the forested region around the Little Sea (e.g. Weber, 2020), and strontium isotope research is ongoing.

Regardless, Weber and colleagues proposed that movement between the Upper Lena (and/or other regions) and Little Sea occurred both during and outside of sealing season and was part of a regular cycle of inter-regional movement (Weber and Goriunova, 2013; Weber et al., 2011). Even with a new modified interpretation (see Weber, 2020) it seems certain that at least some non-local individuals were coming to the Little Sea. If individuals from our analyses with a 'low C & N isotope diet' are from the Upper Lena Microregion or another non-local area, then their presence at all EBA Mainland cemeteries with multiple individuals suggests that movement between regions was somewhat common by that time-period. It also suggests these non-locals lived everywhere the local Little Sea individuals did, except for Ol'khon Island.

There is some variation in the percentage of individuals with low $\delta^{15}\text{N}$ and/or low $\delta^{13}\text{C}$ values in the Mainland Glazkovo cemeteries as shown in Table 4. If just looking at individuals with both low $\delta^{15}\text{N}$ ($\leq 14.6\text{‰}$) and low $\delta^{13}\text{C}$ ($\leq -19.0\text{‰}$) values, the range extends from a lack of such individuals at Khadarta IV (0/9) to 43% at Sarminskii Mys (3/7). Weber et al. (2020) discuss Khadarta IV as a cemetery that contains only GFS individuals and thus has more dietary homogeneity than other Mainland Glazkovo cemeteries. They propose this may be due to use of the cemetery by the same group of locally born biological kin across several generations. A more thorough indication of the prevalence of individuals with dietary change comes from including those with only one low isotope value (i.e. $\delta^{15}\text{N} \leq 14.6\text{‰}$ or $\delta^{13}\text{C} \leq -19.0\text{‰}$). In this case, the prevalence ranges from 44% (4/9) at Khadarta IV to 60% (6/10) at Ulan Khada II-IV. Khadarta IV still has the lowest prevalence of individuals with dietary change, but the cemetery is no longer that

distinct from the others. These results indicate individuals with the new 'low C & N isotope diet' are common at every Mainland Glazkovo cemetery containing multiple individuals. We suggest this indicates these individuals were fully incorporated into society. As we know that some of these individuals are non-local, it further suggests that the inclusion of newcomers to the Little Sea microregion was a regular part of the Glazkovo socio-political-economic system.

At the two largest cemeteries, 54% (31/57) of Khuzhir-Nuge individuals and 47% (9/19) of Kurma XI individuals had a low $\delta^{15}\text{N}$ and/or low $\delta^{13}\text{C}$ value. In statistical comparisons among cemeteries, only Kurma XI was significantly different from another cemetery, that being Khuzhir-Nuge XIV. Kurma XI individuals had slightly higher $\delta^{15}\text{N}$ and lower $\delta^{13}\text{C}$ values. This could be explained by a diet containing slightly more seal, which is associated with locals rather than non-locals. Kurma XI is also distinctive in terms of the age range of interred individuals (lacking individuals under 15 and over 50 years) and grave good characteristics (being larger, more diverse and more unique) which McKenzie (2010) suggests may indicate it was a more exclusive cemetery than others in the region, like Khuzhir-Nuge XIV. Perhaps individuals who took on leadership roles or achieved high status in some other way were buried at Kurma XI, and high status was more likely to be achieved by locals. On the other hand, at Khuzhir-Nuge XIV in the East Sector there is a cluster of individuals with low $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, suggesting they may be non-local, who have many high-value grave goods. In this case, perhaps high status was achieved by non-locals (Weber and Goriunova, 2013). This remains speculative until future isotope work determines which individuals from these cemeteries are actually non-local.

The question remains, however, as to what prompted the rather sudden influx of non-locals into the Little Sea Microregion around the beginning of the EBA. Weber et al. (2011) note that it is only the Little Sea Microregion that shows evidence for partial mixing of foods from other microregions, and we show that this phenomenon only began in the EBA Glazkovo and only occurred on the Mainland. Paleoenvironmental data show minimal climatic variation from the LN to EBA, suggesting this was not the cause of changing patterns of mobility or migration (Tarasov et al., 2015; White and Bush, 2010). Perhaps an increase in population size drove this change. Weber and Bettinger (2010) discuss the likely difference in LN and EBA population sizes as inferred from cemetery sizes and demographic patterning and suggest that an increase may indeed have affected subsistence and resource procurement. Weber, (2020) suggests this increase in population size is partially the result of the immigration of hunter-gatherers living in the forests along the Cis-Baikal who were attracted to the new prosperous communities (population size also increased internally from the LN to EBA); these forest individuals would have had diets that isotopically fall into our 'low C & N isotope diet' and Weber and colleagues (2011) GF group. Shepard (2012) posits that there was a shift from corporate- to network-oriented political economy strategies in the Serovo to Glazkovo groups, wherein political actors devoted considerable resources to competing for prestige and political recognition, which can involve seeking support over long-distances. Weber, (2020) argues against a change in sociopolitical differentiation in favor of a change in socio-economic organization that created prosperous and peaceful communities attractive to outsiders. Whatever the ultimate cause, there is a concomitant influx of non-locals, appearance of a new 'low C & N isotope diet', and a shift in mortuary practices, all suggesting more influence from areas outside the Little Sea Microregion.

6. Conclusions

This research provided insights into the interrelationships between subsistence, mobility, and sociopolitical structure of Middle Holocene hunter-gatherers from Cis-Baikal. Additional isotopic data for the LN Serovo period, and from Ol'khon Island, yielded ever more fine-scale insights into the diets and lifeways of these foragers. Our analysis

revealed that the previously identified GF diet, herein likened to the category of 'low C & N isotope diet' with $\delta^{15}\text{N}$ values of $\leq 14.6\text{‰}$ and $\delta^{13}\text{C}$ values of $\leq 19.0\text{‰}$, is an exclusively EBA-Glazkovo-Mainland phenomenon. This shift is likely related to the immigration of non-local individuals. All LN Serovo individuals fall into the 'high C & N isotope diet', as do a large proportion of EBA Glazkovo individuals, including all of those from the Island and about 50% of those on the Mainland. The Islanders continue to have the 'high C & N isotope diet' throughout the LN and EBA and may represent specialized seal hunters that followed a different annual round than the rest of the Little Sea population. Small sample sizes prevented investigation of possible sex and age differences, and limit the certainty of these results and interpretations, thereby highlighting the need for more excavation and analyses of both LN cemeteries and Island cemeteries from the LN and EBA. Nonetheless, this research has shown spatial and temporal differences in the use of dietary resources which improves our understanding of economic and socio-political systems. Dietary patterns revealed the complex, heterogeneous, and adaptable lifeways of these ancient foragers.

Statement of Authorship

Conceptualization: A.L. Waters-Rist, H.G. McKenzie, A.R. Lieveise, A.G. Novikov

Data Curation: H.G. McKenzie, A.R. Lieveise, A.G. Novikov, O.I. Goriunova, A.A. Kharinskii

Formal Analysis: A.L. Waters-Rist, H.G. McKenzie, A.R. Lieveise, A.G. Novikov, O.I. Goriunova, A.A. Kharinskii

Funding Acquisition: H.G. McKenzie, A.R. Lieveise, A.G. Novikov, A.L. Waters-Rist

Methodology: A.L. Waters-Rist, H.G. McKenzie

Resources: H.G. McKenzie, A.R. Lieveise, A.G. Novikov, O.I. Goriunova, A.A. Kharinskii

Writing - original draft: A.L. Waters-Rist, H.G. McKenzie, A.R. Lieveise

Writing - review & editing: A.L. Waters-Rist, H.G. McKenzie, A.R. Lieveise

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgements

The authors gratefully acknowledge support from the Social Sciences and Humanities Research Council of Canada (Insight Development Grant 4303013 743), as well as from the University of Saskatchewan and MacEwan University. Much thanks to Erin Jessup for creating the map and to Andrzej Weber for his insights while preparing this manuscript. We thank Andrzej Weber and Rick Schulting for valuable feedback on the first draft and thank the anonymous reviewers for helping to further improve this manuscript.

References

- Ambrose, S.H., 1991. Effects of diet, climate and physiology on nitrogen isotope abundances in terrestrial foodwebs. *J. Archaeol. Sci.* 18 (3), 293–317.
- Ambrose, S.H., Norr, L., 1993. Experimental evidence for the relationship of the carbon isotope ratios of whole diet and dietary protein to those of bone collagen and carbonate. In: *Prehistoric Human Bone*. Springer, Berlin, Heidelberg, pp. 1–37.
- Brock, F., Higham, T., Ditchfield, P., Ramsey, C.B., 2010. Current pretreatment methods for AMS radiocarbon dating at the Oxford radiocarbon accelerator unit (ORAU). *Radiocarbon* 52 (1), 103–112.
- Bronk Ramsey, C., Schulting, R.J., Bazaliiskii, V.I., Goriunova, O.I., Weber, A.W., 2020. Spatio-temporal patterns of cemetery use among middle Holocene hunter-gatherers of Cis-Baikal. In: *Eastern Siberia. Asia (Submitted)*, *Archaeological Research in Asia*.
- Casey, M.M., Post, D.M., 2011. The problem of isotopic baseline: reconstructing the diet and trophic position of fossil animals. *Earth Sci. Rev.* 106 (1–2), 131–148.

- Chisholm, B.S., 1989. Variation in diet reconstructions based on stable carbon isotopic evidence. In: Bone, Price T.D. (Ed.), *The Chemistry of Prehistoric Human*. Cambridge University Press, Cambridge, pp. 10–37.
- DeNiro, M.J., 1985. Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature* 317 (6040), 806.
- DeNiro, M.J., Epstein, S., 1978. Influence of diet on the distribution of carbon isotopes in animals. *Geochim. Cosmochim. Acta* 42 (5), 495–506.
- DeNiro, M.J., Epstein, S., 1981. Influence of diet on the distribution of nitrogen isotopes in animals. *Geochim. Cosmochim. Acta* 45 (3), 341–351.
- Fernandes, R., Nadeau, M.J., Grotes, P.M., 2012. Macronutrient-based model for dietary carbon routing in bone collagen and bioapatite. *Archaeol. Anthropol. Sci.* 4 (4), 291–301.
- France, R.L., 1995. Carbon-13 enrichment in benthic compared to planktonic algae: foodweb implications. *Mar. Ecol. Prog. Ser.* 124, 307–312.
- Fry, B., 1991. Stable isotope diagrams of freshwater food webs: ecological archives E072-003. *Ecology* 72 (6), 2293–2297.
- Goriunova, O.I., Novikov, A.G., Weber, A.W., 2020. Middle Holocene hunter-gatherer mortuary practices in the Little Sea micro-region on Lake Baikal. In: Part II: Late Neolithic. *Asia* (Submitted), Archaeological Research in Asia.
- Haverkort, C.M., Weber, A., Katzenberg, M.A., Goriunova, O.I., Simonetti, A., Creaser, R. A., 2008. Hunter-gatherer mobility strategies and resource use based on strontium isotope ($^{87}\text{Sr}/^{86}\text{Sr}$) analysis: a case study from middle Holocene Lake Baikal, Siberia. *J. Archaeol. Sci.* 35 (5), 1265–1280.
- Hedges, R.E., Clement, J.G., Thomas, C.D.L., O'Connell, T.C., 2007. Collagen turnover in the adult femoral mid-shaft: Modeled from anthropogenic radiocarbon tracer measurements. *Am. J. Phys. Anthropol.* 133 (2), 808–816.
- Katzenberg, M.A., Weber, A., 1999. Stable isotope ecology and palaeodiet in the Lake Baikal region of Siberia. *J. Archaeol. Sci.* 26, 651–659.
- Katzenberg, M.A., Goriunova, O., Weber, A., 2009. Paleodiet reconstruction of Bronze age Siberians from the mortuary site of Khuzhir-Nuge XIV, Lake Baikal. *J. Archaeol. Sci.* 36 (3), 663–674.
- Katzenberg, M.A., Bazaliiskii, V.I., Goriunova, O.I., Savel'ev, N.A., Weber, A.W., 2010. Diet reconstruction of prehistoric hunter-gatherers in the Lake Baikal region. In: Weber, A.W., Katzenberg, M.A., Schurr, T. (Eds.), *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*. University of Pennsylvania Museum Press, pp. 175–191.
- Katzenberg, M.A., McKenzie, H.G., Losey, R.J., Goriunova, O.I., Weber, A., 2012. Prehistoric dietary adaptations among hunter-fisher-gatherers from the Little Sea of Lake Baikal, Siberia, Russian Federation. *J. Archaeol. Sci.* 39 (8), 2612–2626.
- Kohn, M.J., Cerling, T.E., 2002. Stable isotope compositions of biological apatite. *Rev. Mineral. Geochem.* 48 (1), 455–488.
- Konopatskii, A.V., 1982. *Drevnie kul'tury Baikala*. Novosibirsk: Nauka.
- Lee-Thorp, J.A., 2008. On isotopes and old bones. *Archaeometry* 50 (6), 925–950.
- Losey, R.J., Nomokonova, T. (Eds.), 2017. *Holocene Zooarchaeology of Cis-Baikal. Archaeology in China and East Asia Volume 6* (M. Wagner, Series Editor) and Northern Hunter-Gatherer Research Series Volume 7. Verlag Philipp von Zabern, Darmstadt.
- Losey, R.J., Nomokonova, T., Goriunova, O.I., 2008. Fishing ancient Lake Baikal: inferences from the reconstruction of harvested perch (*Perca fluviatilis*) size at Itrykhei, Siberia. *J. Archaeol. Sci.* 35 (3), 577–590.
- Losey, R.J., Nomokonova, T., White, D., 2012. Fish and fishing in Holocene Cis-Baikal, Siberia: a review. *J. Island Coast. Archaeol.* 7 (1), 126–145.
- Losey, R.J., Nomokonova, T., Savel'ev, N.A., 2016. Humans and animals at Bugul'deika I, a trans-Holocene habitation site on the shore of Lake Baikal, Russia. *Quat. Int.* 419 (17), 62–73.
- McKenzie, H.G., 2010. Variability in Bronze age mortuary practices in the Little Sea microregion of Cis-Baikal. In: Weber, A.W., Katzenberg, M.A., Schurr, T.G. (Eds.), *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia Bioarchaeological Studies of Past Life Ways*. University of Pennsylvania Press, pp. 77–106.
- Moeder, K.P., Thompson, T.A., Weber, A.W., Bazaliiskii, V.I., Bamforth, F.J., 2010. Uncovering the genetic landscape of prehistoric Cis-Baikal. In: Weber, A.W., Katzenberg, M.A., Schurr, T.G. (Eds.), *Prehistoric Hunter-Gatherers of the Lake Baikal Region. Bioarchaeological Studies of Past Lifeways*. University of Pennsylvania Museum Press, Siberia, pp. 107–119.
- Moussa, N.M., McKenzie, H.G., Bazaliiskii, V.I., Goriunova, O.I., Bamforth, F., Weber, A. W., 2020. Insights into Lake Baikal's ancient populations from genetic evidence at the Early Bronze age cemetery Kurma XI and the Early Neolithic Shamanka II. *Archaeological Research in Asia* (submitted).
- Nomokonova, T., Losey, R.J., 2017. Little Sea shoreline and Ol'khon island. In: Losey, R. J., Nomokonova, T. (Eds.), *Holocene Zooarchaeology of Cis-Baikal. Archaeology in China and East Asia Volume 6* (M. Wagner, Series Editor) and Northern Hunter-Gatherer Research Series Volume 7. Darmstadt, Verlag Philipp von Zabern, pp. 81–103.
- Nomokonova, T., Losey, R.J., Iakunaeva, V.N., Emel'ianova, I.A., Baginova, E.A., Pastukhov, M.V., 2013. People and seals at Siberia's Lake Baikal. *J. Ethnobiol.* 33 (2), 259–280.
- Nomokonova, T., Losey, R.J., Goriunova, O.I., Novikov, A.G., Weber, A.W., 2015. A 9,000 year history of seal hunting on Lake Baikal, Siberia: the zooarchaeology of Sagan-Zaba II. *PLoS One* 10 (5).
- Nomokonova, T., Losey, R.J., Weber, A.W., 2017. Sagan Zaba II. In: Losey, R.J., Nomokonova, T. (Eds.), *Holocene Zooarchaeology of Cis-Baikal. Archaeology in China and East Asia Volume 6* (M. Wagner, Series Editor) and Northern Hunter-Gatherer Research Series Volume 7. Darmstadt, Verlag Philipp von Zabern, pp. 53–69.
- Scharlotta, I., Weber, A., 2014. Mobility of middle Holocene foragers in the Cis-Baikal region, Siberia: individual life history approach, strontium ratios, rare earth and trace elements. *Quat. Int.* 348, 37–65.
- Scharlotta, I., Goriunova, O.I., Weber, A., 2013. Micro-sampling of human bones for mobility studies: diagenetic impacts and potentials for elemental and isotopic research. *J. Archaeol. Sci.* 40 (12), 4509–4527.
- Schoeninger, M.J., DeNiro, M.J., 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. *Geochim. Cosmochim. Acta* 48 (4), 625–639.
- Schulting, R.J., Bronk Ramsey, C., Bazaliiskii, V.I., Goriunova, O.I., Weber, A.W., 2014. Freshwater reservoir offsets investigated through paired human-faunal ^{14}C dating and stable carbon and nitrogen isotope analysis at Lake Baikal, Siberia. *Radiocarbon* 56 (3), 991–1008.
- Schulting, R.J., Bronk Ramsey, C., Bazaliiskii, V.I., Weber, A.W., 2015. Highly variable freshwater reservoir offsets found along the upper Lena watershed, Cis-Baikal, Southeast Siberia. *Radiocarbon* 57 (4), 581–594.
- Schulting, R.J., Bronk Ramsey, C., Scharlotta, I., Richards, M., Weber, A.W., 2020. *submitted*. Freshwater Reservoir Effects in Cis-Baikal: An Overview. This volume. *Archaeological Research in Asia*.
- Shepard, B.A., 2012. Political economic reorganization among non-state societies: a case study using middle Holocene mortuary data from the Cis-Baikal, Russia. *J. Anthropol. Archaeol.* 31, 365–380.
- Shepard, B.A., Goriunova, O.I., Novikov, A.G., Tiutrin, A.A., Weber, A.W., 2016. Macroregional interconnections among ancient hunter-gatherers of the Cis-Baikal, eastern Siberia (Russia). *Quat. Int.* 419, 140–158.
- Tarasov, P.E., Bezrukova, E.V., Müller, S., Kostrova, S.S., White, D., 2015. Climate and vegetation history. In: Losey, R.J., Nomokonova, T. (Eds.), *Holocene Zooarchaeology of Cis-Baikal. Archaeology in China and East Asia*, vol. 6. Mainz (DE), Nünnerich-Asmus Verlag & Media GmbH, pp. 15–26.
- Tieszen, L.L., Fagre, T., 1993. Effect of diet quality and composition on the isotopic composition of respiratory CO_2 , bone collagen, bioapatite, and soft tissues. In: Bone, Lambert J.B., Grupe, G. (Eds.), *Prehistoric Human*. Springer, Berlin, Heidelberg, pp. 121–155.
- Tsutaya, T., Yoneda, M., 2013. Quantitative reconstruction of weaning ages in archaeological human populations using bone collagen nitrogen isotope ratios and approximate Bayesian computation. *PLoS One* 8 (8), e7327.
- van Klinken, G.J., 1999. Bone collagen quality indicators for paleodietary and radiocarbon measurements. *J. Archaeol. Sci.* 26 (6), 687–695.
- Waters-Rist, A.L., Bazaliiskii, V.I., Weber, A.W., Katzenberg, M.A., 2011. Infant and child diet in Neolithic hunter-fisher-gatherers from Cis-Baikal, Siberia: intra-long bone stable nitrogen and carbon isotope ratios. *Am. J. Phys. Anthropol.* 146 (2), 225–241.
- Waters-Rist, A.L., Bazaliiskii, V.I., Goriunova, O.I., Weber, A.W., Katzenberg, M.A., 2015. Evaluating the biological discontinuity hypothesis of Cis-Baikal Early versus Late Neolithic-Early Bronze age populations using dental non-metric traits. *Quat. Int.* 405, 122–133.
- Weber, A.W., 1995. The Neolithic and Early Bronze age of the Lake Baikal region: a review of recent research. *J. World Prehist.* 9 (1), 99–165.
- Weber, A.W., 2020. Middle Holocene hunter-gatherers of Cis-Baikal, Eastern Siberia: Combined impacts of the boreal forest, bow-and-arrow, and fishing. In: *Archaeological Research in Asia* (submitted).
- Weber, A.W., Bettinger, R.L., 2010. Middle Holocene hunter-gatherers of Cis-Baikal, Siberia: an overview for the new century. *J. Anthropol. Archaeol.* 29, 491–506.
- Weber, A.W., Goriunova, O.I., 2013. Hunter-gatherer migrations, mobility and social relations: a case study from the Early Bronze age Baikal region, Siberia. *J. Anthropol. Archaeol.* 32, 330–346.
- Weber, A.W., Goriunova, O.I., Konopatskii, A.K., 1993. Prehistoric seal hunting on Lake Baikal: methodology and preliminary results of the analysis of canine sections. *J. Archaeol. Sci.* 20 (6), 629–644.
- Weber, A.W., Link, D.W., Goriunova, O.I., Konopatskii, A.K., 1998. Patterns of prehistoric procurement of seal at Lake Baikal: a zooarchaeological contribution to the study of past foraging economies in Siberia. *J. Archaeol. Sci.* 25 (3), 215–227.
- Weber, A.W., Link, D.W., Katzenberg, M.A., 2002. Hunter-gatherer culture change and continuity in the middle Holocene of the Cis-Baikal, Siberia. *J. Anthropol. Archaeol.* 21, 230–299.
- Weber, A.W., White, D., Bazaliiskii, V.I., Goriunova, O.I., Savel'ev, N.A., Katzenberg, M. A., 2011. Hunter-gatherer foraging ranges, migrations, and travel in the middle Holocene Baikal region of Siberia: insights from carbon and nitrogen stable isotope signatures. *J. Anthropol. Archaeol.* 30, 523–548.
- Weber, A.W., Schulting, R.J., Bronk Ramsey, C., Bazaliiskii, V.I., Goriunova, O.I., Berdnikova, N.E., 2016. Chronology of middle Holocene hunter-gatherers in the Cis-Baikal region of Siberia: corrections based on examination of the freshwater reservoir effect. *Quat. Int.* 419, 74–98.
- Weber, A.W., Bronk Ramsey, C., Schulting, R.J., Bazaliiskii, V.I., Goriunova, O.I., 2020. Middle Holocene hunter-gatherers of Cis-Baikal, Eastern Siberia: Chronology and dietary trends. In: *Archaeological Research in Asia* (submitted).
- White, D., Bush, A.B.G., 2010. Holocene climate, environmental variability and Neolithic biocultural discontinuity in the Lake Baikal region. In: Weber, A.W., Katzenberg, M. A., Schurr, T. (Eds.), *Prehistoric Hunter-Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Lifeways*. University of Pennsylvania Press, Philadelphia, pp. 1–26.
- White, J.A., Schulting, R.J., Hommel, P., Lythe, A., Bronk Ramsey, C., Moiseyev, V., Khartanovich, V., Weber, A.W., 2020. Integrated stable isotopic and radiocarbon analyses of Neolithic and Bronze age hunter-gatherers from the Little Sea and upper Lena micro-regions, Cis-Baikal, Siberia. *J. Archaeol. Sci.* 119 <https://doi.org/10.1016/j.jas.2020.105161>.