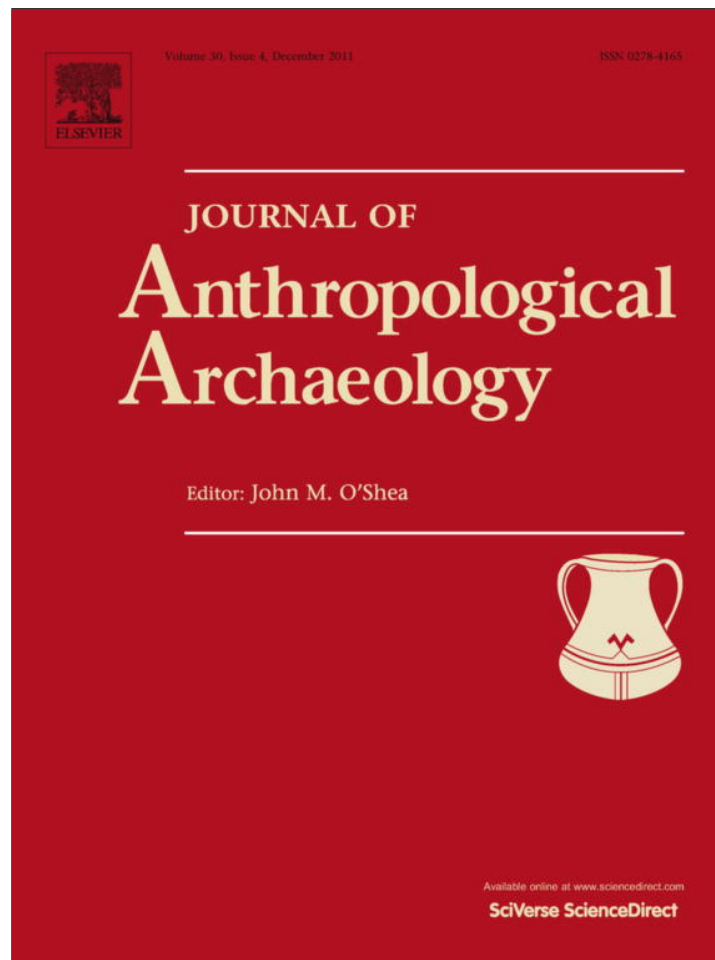


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## Hunter–gatherer foraging ranges, migrations, and travel in the middle Holocene Baikal region of Siberia: Insights from carbon and nitrogen stable isotope signatures

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## ABSTRACT

Foraging ranges, migrations, and travel among Middle Holocene hunter–gatherers in the Baikal region of Siberia are examined based on carbon and nitrogen stable isotope signatures obtained from 350 human and 203 faunal bone samples. The human materials represent Early Neolithic (8000–6800 cal BP), Late Neolithic (6000–5000 cal BP), and Early Bronze Age periods (~5000–4000 cal BP) and come from the following four smaller areas of the broader region: the Angara and upper Lena valleys, Little Sea of Baikal's northwest coast, and southwest Baikal. Forager diets from each area occupy their own distinct position within the stable isotope spectrum. This suggests that foraging ranges were not as large as expected given the distances involved and the lack of geographic obstacles between the micro-regions. All examined individuals followed a similar subsistence strategy: harvesting game and local fishes, and on Lake Baikal also the seal, and to a more limited extent, plant foods. Although well established in their home areas, exchange networks with the other micro-regions appear asymmetrical both in time and direction: more travel and contacts between some micro-regions and less between others. The Angara valley seems to be the only area with the possibility of a temporal change in the foraging strategy from more fishing during the Early Neolithic to more ungulate hunting during the Late Neolithic–Early Bronze Age. However, the shift in stable isotope values suggesting this change can be viewed also as evidence of climate change affecting primary productivity of the Baikal–Angara freshwater system.

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### 1. Introduction

Since the development of the bone chemistry methods in the 1970s and 1980s, carbon ( $\delta^{13}\text{C}$ ) and nitrogen ( $\delta^{15}\text{N}$ ) stable isotope signatures in human bone collagen have become the most direct and dependable method of evaluating diet and subsistence aspects of past adaptations (Katzenberg, 2008; Lee-Thorp, 2008). While early studies focused on the transition to farming around the world and the relative contributions from major food groups such as terrestrial vs. marine, plant vs. meat, or  $\text{C}_3$  vs.  $\text{C}_4$  plants (e.g., Chisholm et al., 1982; Tauber, 1981; Vogel and van der Merwe, 1977; Schoeninger et al., 1983), over the last 10–20 years the field has greatly expanded its breadth. Recent applications include questions of diet variability and use of more specific food resources,

mobility and migrations, as well as social structure and marriage patterns in a wide variety of geographic and archaeological settings. Particularly relevant to our case are those that involve past hunter–gatherers (e.g., Fornander et al., 2008; Eriksson et al., 2008; Fischer et al., 2007; Kusaka et al., 2008, 2009; Schulting and Richards, 2001; Schulting, 2010). This work has documented substantial dietary variability among past hunter–gatherers and revealed many new insights about economic, social, and political complexity and diversity in past foraging adaptations.

In addition to the presentation of a uniquely large set of stable isotope data from a single archaeological research area, the current study represents the next step in our ongoing examination of dietary, subsistence, and socio-economic patterns among Baikal's past foraging groups (e.g., Haverkort et al., 2008; Katzenberg and Weber, 1999; Katzenberg et al., 2009, 2010, in press; Lam, 1994; Waters-Rist et al., in press; Weber and Goriunova, in preparation; Weber et al., 2002, 2010a, and the references therein). Given the environmental

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and archaeological contexts of the Cis-Baikal region (area northwest of Lake Baikal), this examination contributes also to the ongoing research on prehistoric hunter-gatherer adaptations of the boreal zone. Of particular interest are aquatic settings such as Northwestern Europe and Scandinavia, northern Pacific Rim, inland northern Eurasia and North America, and southern South America (Chisholm et al., 1983; Eriksson and Lidén, 2003; Eriksson et al., 2003; Kusaka et al., 2008, 2010; Kuzmin et al., 2002; Milner et al., 2004; Minagawa and Akazawa, 1992; Richards and Hedges, 1999; Roksandic et al., 1988; Schulting, 1998; Yesner et al., 2003; Yoneda et al., 2002, 2004).

Another relatively new development in bone chemistry studies is emphasis on individual variability rather than population averages, and accumulation of a maximum amount of information on the life of a particular individual (Meiklejohn and Zvelebil, 1991; Sealy et al., 1995). This approach, referred to as archaeology of individual life histories, includes an array of bioarchaeological

(e.g., osteological, dental, and genetic), archaeological (e.g., mortuary), and geochemical techniques. Together, these techniques provide long strings of information about lives of specific persons to be analyzed further in the context of life histories of other individuals (e.g., Corr et al., 2009; Haak et al., 2008; Smits et al., 2010; Zvelebil and Weber, in preparation).

In its general goal to document and explain the nature of culture change among the middle Holocene hunter gatherers of the Baikal region in Siberia, the Baikal Archaeology Project (BAP) fully subscribes to this novel approach (Weber and McKenzie, 2003; Weber et al., 2010a). To date, this research model has been employed most comprehensively in the examination of the Early Bronze Age (EBA) Khuzhir-Nuge XIV cemetery for which a large set of geochemical ( $^{87}\text{Sr}/^{86}\text{Sr}$ ,  $^{14}\text{C}$ ,  $^{13}\text{C}$ , and  $^{15}\text{N}$ ) and mortuary data has been obtained (Haverkort et al., 2008; Katzenberg et al., 2009; Weber and Goriunova, in preparation; Weber et al., 2005, 2007,

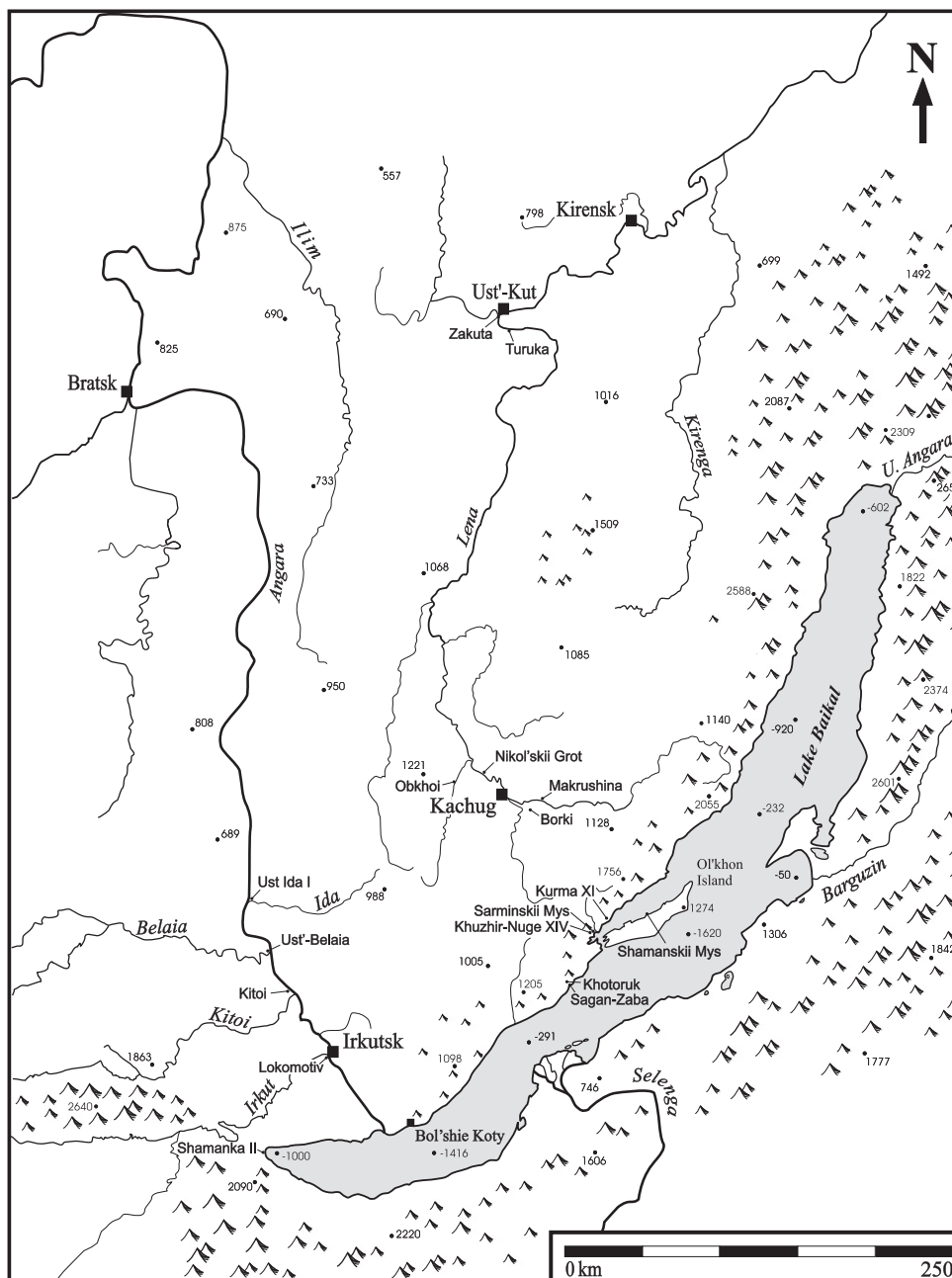


Fig. 1. Map of the study area and location of the Middle Holocene cemetery samples examined in the paper.

2008). Analyzed at the individual level, and in the context of demographic data (Lieverse et al., 2007) and spatial arrangements within the cemetery, this material revealed a number of entirely new insights about hunter–gatherer adaptive strategies in the region. Briefly, the area of origin, i.e., local or non-local place of birth, was an important cultural variable well marked in the various smaller spatial arrangements such as the rows and clusters of graves and two distinct diet types were identified at the site: one composed mostly of game, fish, and seal (GFS diet) and another focusing on game and fish (GF diet) – an important point to which we return a few times in this paper.

Although some analyses are still in progress and archaeological data for a few of the cemeteries are not yet available, examination of the Khuzhir-Nuge XIV material demonstrates not only the benefits of the life history approach but also, given the large volume of stable isotope data generated to date for the middle Holocene foragers in the Baikal region, underscores the need to assess such data sets from the perspective of intra-site variability. Therefore, the more specific goals of this study are: (1) to develop a general framework of reference for detailed analysis and interpretation of smaller data sets; and (2) to assess our earlier notions about the extent of food procurement territories, and levels of regional mobility and migrations.

## 2. Materials and methods of analysis

BAP databases have compiled information on c. 180 middle Holocene hunter–gatherer cemeteries with the total of ~1000 graves and 1250 individuals. Regrettably, most of the materials excavated prior to the ~1970s are not available for the individual life history approach. Nevertheless, the subsequent fieldwork and the most recent excavations conducted by the BAP produced collections that do meet the analytical requirements of this approach. The current study is based on results obtained for 350 middle Holocene individuals from 17 localities representing 25 spatio-temporally distinct cemeteries (Fig. 1), a large data set that allows for a major expansion of the previous work. Geographically these sites represent the following four micro-regions: the Angara river valley, the upper Lena river valley, the Little Sea part of Lake Baikal, and southwest Baikal. The chronological framework for the period of interest has been established based on an extensive radiocarbon dating program (Table 1; Weber et al., 2006, 2010b). Such large cemeteries as Lokomotiv, Shamanka II, Ust'-Ida I, Khuzhir-Nuge XIV, and Kurma XI form the core of the analyses conducted by the BAP (Weber et al., 2010b and the references therein), and the remaining smaller samples provide comparative context. In this regard, it is also useful that many cemeteries produced graves from more than one period. Additional information about the analyzed cemeteries can be obtained either from a few summaries published recently in English (e.g., Bazaliiskii, 2003, 2010; Bazaliiskiy and Savelyev, 2003; McKenzie, 2010; Weber et al., 2006), Russian site reports (Bazaliiskii and Ineshin, 1995; Bazaliiskii et al., 1996; Goriunova, 1997; Goriunova et al., 1998; Konopatskii, 1982; Tiutrin and Bazaliiskii, 1996), or the English-language site monographs (Weber et al., 2007, 2008, in press).

In order to understand better the human data, an additional 203 bone specimens representing avian ( $n = 4$ ), aquatic ( $n = 96$ ), and terrestrial ( $n = 103$ ) fauna of the Baikal region were analyzed (Tables 2 and 4; Katzenberg et al., in press). Samples represent surface finds or were collected either from the existing archaeological collections, obtained from local people, purchased from local vendors, or harvested by BAP scholars (fishes). A deliberate attempt was made to collect as many species potentially used for subsistence by prehistoric hunter–gatherers as possible to obtain a broad representation of the various trophic levels, body sizes, and migrations patterns, and to sample a similar range of species from each micro-region. Much of the sampling of both ecosystems was done with the assistance of a fish biologist (Dr. Vitalii Ostroumov, an associate of the BAP at the time) and, therefore, identification of most fish specimens is considered quite reliable. Nevertheless, in some instances the subspecies was not recorded and in a few others, when Dr. Ostroumov was not involved in acquiring the fish specimens, there is a potential for misidentification of species of similar appearance to a non-expert (e.g., white and black graylings). Species misidentification is also possible with regard to a few specimens representing the terrestrial ecosystem, particularly when the collected bones were small or of low diagnostic utility (e.g., ribs). Provenience of the aquatic samples was recorded consistently relative to the three major ecosystems (Angara, Lena, and Baikal). Baikal fishes come from two main locations: Bol'shie Koty, a small village on the northwest coast c. 20 km east from the source of the Angara, and the Little Sea area where much archaeological fieldwork was conducted by the BAP from 1997 to 2003. Results for a few specimens obtained from street markets for which exact source was not available are presented in Table 4 but excluded from analysis.

All stable isotope tests were performed at the University of Calgary under the supervision of M.A. Katzenberg. Descriptions of the employed laboratory protocols are available in the previous publications on the subject (Katzenberg and Weber, 1999; Katzenberg et al., 2009, 2010, in press). Although the analysis of human data is limited to the results within the 2.9–3.6 C/N ratio range, results outside of this range (2.5–4.0) are included in the tables for comparative purposes and record keeping. The principles of the carbon and nitrogen stable isotopes techniques and guidelines for data analysis and interpretation have been discussed in the literature on numerous occasions and therefore are omitted from the current study in order to save space.

## 3. Summary of previous findings

While the stable isotope ecology of Lake Baikal has seen some research, including tests conducted by the BAP (Katzenberg and Weber, 1999; Katzenberg et al., 2009, 2010, in press; Kiyashko et al., 1991, 1998; Ogawa et al., 2000; Weber et al., 2002; Yioshii et al., 1999), little to no information is available for the Angara, Lena, and Selenga river systems or the numerous small rivers discharging into Lake Baikal. What has been published suggests a very wide range of variability in  $\delta^{13}\text{C}$  at the lowest trophic levels in Lake Baikal (i.e., plankton) spanning ~20‰ (from  $-30.5 \pm 2.2\text{‰}$  to  $-10.9 \pm 2.4\text{‰}$ ) and that this variability is passed onto organisms of the higher trophic levels including the lake's fishes and seal pop-

**Table 1**  
Culture history model for the middle Holocene Baikal region (after Weber et al., 2010a, b).

Period	Mortuary tradition	Angara and South Baikal (cal BP)	Upper Lena (cal BP)	Little Sea (cal BP)
Late Mesolithic	Lack of archaeologically visible mortuary sites	8800–8000	8800–8000	8800–8000
Early Neolithic	Kitoy and other	8000–7000/6800	8000–7200	8000–7200
Middle Neolithic	Lack of archaeologically visible mortuary sites	7000/6800–6000/5800	7200–6000/5800	7000/6800–6000/5800
Late Neolithic	Isakovo, Serovo	6000/5800–5200	6000/5800–5200/5000	6000/5800–5200/5000
Early Bronze Age	Glazkovo	5200/5000–4000	5200/5000–3400	5200/5000–4000

**Table 2**  
Stable isotope data for terrestrial and avian fauna from the Baikal region: archaeological and modern specimens.

No.	Common name	Latin name	Site	Microregion	ESAMP_ID	C/N	Coll. yield	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	References
<i>Ungulates: archaeological specimens</i>										
1	Moose	<i>Alces alces</i>	Tudugu	Little Sea	1991.054	3.4	15.9	-19.2	3.7	Weber et al. (2002)
2	Red deer	<i>Cervus elaphus</i>	Gorelyi Les	Angara	1993.081	3.4	65.9	-19.1	5.1	Weber et al. (2002)
3	Red deer	<i>Cervus elaphus</i>	Gorelyi Les	Angara	1993.080	3.5	20.1	-18.7	4.9	Weber et al. (2002)
4	Red deer	<i>Cervus elaphus</i>	Gorelyi Les	Angara	1993.094	3.6	11.4	-20.2	3.1	Weber et al. (2002)
5	Red deer	<i>Cervus elaphus</i>	Sagan-Zaba	Little Sea	1993.152	3.5	14.2	-18.6	5.7	Weber et al. (2002)
6	Red deer	<i>Cervus elaphus</i>	Shamanskii Mys	Little Sea	1991.108	3.4	12.0	-19.1	6.6	Weber et al. (2002)
7	Red deer	<i>Cervus elaphus</i>	Shamanskii Mys	Little Sea	1991.104	3.5	12.8	-18.6	5.0	Weber et al. (2002)
8	Roe deer	<i>Capreolus capreolus</i>	Gorelyi Les	Angara	1993.087	3.5	11.0	-21.1	4.6	Weber et al. (2002)
9	Roe deer	<i>Capreolus capreolus</i>	Gorelyi Les	Angara	1993.088	3.5	19.1	-20.3	6.0	Weber et al. (2002)
10	Roe deer	<i>Capreolus capreolus</i>	Gorelyi Les	Angara	1993.150	3.5	26.0	-20.1	6.3	Weber et al. (2002)
11	Roe deer	<i>Capreolus capreolus</i>	Gorelyi Les	Angara	1993.091	3.6	13.6	-19.9	5.2	Weber et al. (2002)
12	Roe deer	<i>Capreolus capreolus</i>	Gorelyi Les	Angara	1993.092	3.6	9.8	-20.6	5.2	Weber et al. (2002)
13	Roe deer	<i>Capreolus capreolus</i>	Sagan-Zaba	Little Sea	1993.153	3.6	12.6	-20.0	4.2	Weber et al. (2002)
14	Roe deer	<i>Capreolus capreolus</i>	Shamanskii Mys	Little Sea	1991.102	3.5	4.9	-19.4	6.9	Weber et al. (2002)
15	Roe deer	<i>Capreolus capreolus</i>	Shamanskii Mys	Little Sea	1991.107	3.6	10.7	-19.7	4.6	Weber et al. (2002)
<i>Ungulates: modern specimens</i>										
1	Moose	<i>Alces alces</i>	Batchai	Angara	2001.750	3.2	17.4	-20.8	1.1	Katzenberg et al. (in press)
2	Moose	<i>Alces alces</i>	Batchai	Baikal	1993.051	3.4	17.6	-19.9	1.5	Weber et al. (2002)
3	Moose	<i>Alces alces</i>	Batchai	Baikal	1993.050	3.5	24.7	-21.8	1.4	Weber et al. (2002)
4	Moose	<i>Alces alces</i>	Sarminskaiia peshchera	Little Sea	1991.116	3.3	17.5	-19.9	3.1	Weber et al. (2002)
5	Musk deer	<i>Moschus moschiferus</i>	Batchai	Angara	2001.668	3.2	21.0	-20.3	6.8	Katzenberg et al. (in press)
6	Musk deer	<i>Moschus moschiferus</i>	Batchai	Irkutskaiia Oblast	1995.202	3.4	13.4	-20.9	5.5	Katzenberg et al. (in press)
7	Musk deer	<i>Moschus moschiferus</i>	Sarminskaiia peshchera	Little Sea	1991.118	3.1	18.1	-20.0	6.2	Katzenberg et al. (in press)
8	Red deer	<i>Cervus elaphus</i>	Bratsk	Angara	2001.774	3.1	14.3	-23.1	4.3	Katzenberg et al. (in press)
9	Red deer	<i>Cervus elaphus</i>	Bratsk	Angara	2001.760	3.4	12.6	-22.3	6.0	Katzenberg et al. (in press)
10	Red deer	<i>Cervus elaphus</i>	Bratsk	Angara	2001.773	3.4	20.9	-22.7	4.3	Katzenberg et al. (in press)
11	Red deer	<i>Cervus elaphus</i>	Bratsk	Baikal	1995.198	3.1	8.8	-23.0	3.0	Katzenberg et al. (in press)
12	Red deer	<i>Cervus elaphus</i>	Bratsk	Irkutskaiia Oblast	1995.199	3.1	11.8	-21.1	2.6	Katzenberg et al. (in press)
13	Red deer	<i>Cervus elaphus</i>	Bratsk	Irkutskaiia Oblast	1993.052	3.5	24.4	-22.1	3.4	Weber et al. (2002)
14	Red deer	<i>Cervus elaphus</i>	Bratsk	Irkutskaiia Oblast	1993.053	3.5	24.9	-20.4	3.1	Weber et al. (2002)
15	Red deer	<i>Cervus elaphus</i>	Bratsk	Irkutskaiia Oblast	1993.066	3.5	22.5	-22.7	3.1	Weber et al. (2002)
16	Red deer	<i>Cervus elaphus</i>	Bratsk	Baikal, southwest	2002.315	3.1	18.8	-22.8	3.4	Katzenberg et al. (in press)
17	Red deer	<i>Cervus elaphus</i>	Bol'shie Koty	Baikal, west coast	2001.782	2.9	5.7	-22.9	2.6	Katzenberg et al. (in press)
18	Red deer	<i>Cervus elaphus</i>	Bol'shie Koty	Baikal, west coast	2001.780	3.0	19.3	-23.2	5.6	Katzenberg et al. (in press)
19	Red deer	<i>Cervus elaphus</i>	Bol'shie Koty	Baikal, west coast	1993.149	3.3	25.3	-22.1	5.0	Weber et al. (2002)
20	Red deer	<i>Cervus elaphus</i>	Bol'shie Koty	Baikal, west coast	2001.781	3.4	14.0	-23.5	5.4	Katzenberg et al. (in press)
21	Red deer	<i>Cervus elaphus</i>	Bratsk	Little Sea	2001.733	3.0	8.1	-20.2	8.5	Katzenberg et al. (in press)
22	Red deer	<i>Cervus elaphus</i>	Bratsk	Little Sea	2001.736	3.2	14.4	-19.8	3.6	Katzenberg et al. (in press)
23	Red deer	<i>Cervus elaphus</i>	Bratsk	Little Sea	2001.740	3.2	9.1	-21.7	6.5	Katzenberg et al. (in press)
24	Red deer	<i>Cervus elaphus</i>	Bratsk	Little Sea	2001.738	3.3	12.6	-21.5	6.8	Katzenberg et al. (in press)
25	Red deer	<i>Cervus elaphus</i>	Bratsk	Little Sea	2001.739	3.4	11.9	-21.4	6.7	Katzenberg et al. (in press)
26	Roe deer	<i>Capreolus capreolus</i>	Batchai	Angara	2001.657	2.9	15.2	-23.4	4.3	Katzenberg et al. (in press)
27	Roe deer	<i>Capreolus capreolus</i>	Batchai	Angara	2001.656	3.1	14.5	-22.4	7.6	Katzenberg et al. (in press)
28	Roe deer	<i>Capreolus capreolus</i>	Batchai	Angara	2001.658	3.1	10.8	-21.0	3.6	Katzenberg et al. (in press)
29	Roe deer	<i>Capreolus capreolus</i>	Batchai	Angara	2001.659	3.1	12.0	-22.5	6.0	Katzenberg et al. (in press)
30	Roe deer	<i>Capreolus capreolus</i>	Ida River	Angara	2002.421	3.3	12.0	-20.4	9.9	Katzenberg et al. (in press)
31	Roe deer	<i>Capreolus capreolus</i>	Ida River	Angara	2002.422	3.3	11.0	-20.8	9.1	Katzenberg et al. (in press)
32	Roe deer	<i>Capreolus capreolus</i>	Ida River	Angara	2002.424	3.3	16.0	-21.3	3.6	Katzenberg et al. (in press)
33	Roe deer	<i>Capreolus capreolus</i>	Ida River	Angara	2002.423	3.4	8.5	-21.7	5.0	Katzenberg et al. (in press)
34	Roe deer	<i>Capreolus capreolus</i>	Ida River	Angara	2001.687	2.9	10.7	-23.3	3.6	Katzenberg et al. (in press)
35	Roe deer	<i>Capreolus capreolus</i>	Irkutsk	Irkutskaiia Oblast	1993.062	3.5	21.3	-22.9	2.6	Weber et al. (2002)
36	Roe deer	<i>Capreolus capreolus</i>	Irkutsk	Baikal	1993.060	3.3	23.0	-20.4	3.6	Weber et al. (2002)
37	Roe deer	<i>Capreolus capreolus</i>	Irkutsk	Baikal	1993.057	3.4	20.8	-20.6	5.4	Weber et al. (2002)
38	Roe deer	<i>Capreolus capreolus</i>	Irkutsk	Baikal	1993.061	3.4	19.6	-20.4	9.7	Weber et al. (2002)
39	Roe deer	<i>Capreolus capreolus</i>	Irkutsk	Baikal	1993.058	3.6	17.0	-20.0	7.8	Weber et al. (2002)
40	Roe deer	<i>Capreolus capreolus</i>	Irkutsk	Baikal	1993.059	3.6	23.3	-21.6	3.6	Weber et al. (2002)
41	Roe deer	<i>Capreolus capreolus</i>	Bol'shie Koty	Baikal, west coast	2001.785	3.0	13.9	-21.7	5.1	Katzenberg et al. (in press)
42	Roe deer	<i>Capreolus capreolus</i>	Bol'shie Koty	Baikal, west coast	2001.787	3.3	14.3	-23.3	4.0	Katzenberg et al. (in press)
43	Roe deer	<i>Capreolus capreolus</i>	Bratsk	Little Sea	2001.728	2.9	13.8	-21.4	7.7	Katzenberg et al. (in press)
44	Roe deer	<i>Capreolus capreolus</i>	Bratsk	Little Sea	2001.726	3.2	13.2	-21.4	9.1	Katzenberg et al. (in press)
45	Roe deer	<i>Capreolus capreolus</i>	Bratsk	Little Sea	2001.729	3.2	3.2	-20.6	7.7	Katzenberg et al. (in press)
46	Roe deer	<i>Capreolus capreolus</i>	Bratsk	Little Sea	2002.456	3.3	12.7	-18.9	10.6	Katzenberg et al. (in press)
47	Roe deer	<i>Capreolus capreolus</i>	Upper Lena	Upper Lena	2002.363	2.9	7.8	-22.5	8.7	Katzenberg et al. (in press)
48	Roe deer	<i>Capreolus capreolus</i>	Upper Lena	Upper Lena	2002.365	2.9	13.8	-23.8	5.3	Katzenberg et al. (in press)
49	Roe deer	<i>Capreolus capreolus</i>	Upper Lena	Upper Lena	2002.368	2.9	15.9	-22.9	6.9	Katzenberg et al. (in press)
50	Roe deer	<i>Capreolus capreolus</i>	Upper Lena	Upper Lena	2002.371	2.9	17.2	-23.3	4.1	Katzenberg et al. (in press)
<i>Other species: archaeological specimens</i>										
1	Dog	<i>Canis familiaris</i>	Khotoruk	Little Sea	1997.282	3.3	22.1	-18.8	9.8	Katzenberg et al. (in press)
2	Dog	<i>Canis familiaris</i>	Sagan-Zaba	Little Sea	1997.285	3.3	16.0	-19.1	8.7	Katzenberg et al. (in press)
3	Dog	<i>Canis familiaris</i>	Shamanskii Mys	Little Sea	1997.278	3.3	8.1	-18.3	13.0	Katzenberg et al. (in press)
4	Dog	<i>Canis familiaris</i>	Shamanskii Mys	Little Sea	1997.279	3.3	20.5	-18.5	12.9	Katzenberg et al. (in press)
5	Dog	<i>Canis familiaris</i>	Shamanskii Mys	Little Sea	1997.281	3.3	10.9	-17.5	13.1	Katzenberg et al. (in press)



Table 2 (continued)

No.	Common name	Latin name	Site	Microregion	ESAMP_ID	C/N	Coll. yield	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	References
6	Dog	<i>Canis familiaris</i>	Obkhoi	Upper Lena	1991.013	3.2	20.0	-19.1	9.7	Weber et al. (2002)
<i>Other species: modern specimens</i>										
1	Badger	<i>Meles meles</i>	Batchai	Angara	2001.751	3.1	12.7	-20.1	7.7	Katzenberg et al. (in press)
2	Badger	<i>Meles meles</i>	Irkutsk	Angara	2001.690	3.3	16.5	-20.7	4.9	Katzenberg et al. (in press)
3	Bear	<i>Ursus sp.</i>	Bratsk	Angara	2001.757	3.2	15.7	-19.7	4.9	Katzenberg et al. (in press)
4	Black bear	<i>Ursus arctos</i>		Baikal	1993.065	3.6	22.7	-19.7	4.2	Weber et al. (2002)
5	Black bear	<i>Ursus thibetanus</i>		Baikal	1993.064	3.4	26.5	-20.3	6.5	Weber et al. (2002)
6	Black bear	<i>Ursus thibetanus</i>		Baikal	1993.063	3.5	23.0	-19.5	4.5	Weber et al. (2002)
7	Black bear	<i>Ursus thibetanus</i>		Krasnoiorskii Krai	1991.122	3.5	12.7	-20.1	1.5	Katzenberg et al. (in press)
8	Brown bear	<i>Ursus arctos</i>		Irkutskiaia Oblast	1995.194	3.5	20.3	-17.8	4.6	Katzenberg et al. (in press)
9	Fox	Canidae family	Batchai	Angara	2001.685	3.4	16.3	-23.2	9.2	Katzenberg et al. (in press)
10	Fox	Canidae family	Bol'shie Koty	Baikal, west coast	2001.691	3.3	25.8	-21.6	13.9	Katzenberg et al. (in press)
11	Ground squirrel	<i>Citellus parryi</i>	Belaia River	Angara	2002.396	3.0	15.1	-23.2	2.4	Katzenberg et al. (in press)
12	Ground squirrel	<i>Citellus parryi</i>	Ida River	Angara	2002.415	3.0	16.5	-23.5	11.0	Katzenberg et al. (in press)
13	Ground squirrel	<i>Citellus parryi</i>	Ida River	Angara	2002.414	3.3	15.9	-23.1	9.8	Katzenberg et al. (in press)
14	Ground squirrel	<i>Citellus parryi</i>	Ida River	Angara	2002.418	3.5	4.6	-22.2	9.9	Katzenberg et al. (in press)
15	Ground squirrel	<i>Citellus parryi</i>	Kultuk	Baikal, southwest	2002.392	3.3	16.4	-19.9	4.8	Katzenberg et al. (in press)
16	Ground squirrel	<i>Citellus parryi</i>		Little Sea	2001.699	3.0	9.9	-22.5	7.8	Katzenberg et al. (in press)
17	Ground squirrel	<i>Citellus parryi</i>		Little Sea	2001.702	3.0	14.3	-21.7	4.8	Katzenberg et al. (in press)
18	Ground squirrel	<i>Citellus parryi</i>		Little Sea	2001.701	3.1	0.7	-23.0	6.0	Katzenberg et al. (in press)
19	Ground squirrel	<i>Citellus parryi</i>		Little Sea	2001.700	3.2	17.9	-22.0	7.7	Katzenberg et al. (in press)
20	Hare	<i>Lepus timidus</i>	Batchai	Angara	2001.676	3.0	11.3	-23.8	6.9	Katzenberg et al. (in press)
21	Hare	<i>Lepus timidus</i>	Batchai	Angara	2001.677	3.1	12.4	-23.7	6.6	Katzenberg et al. (in press)
22	Hare	<i>Lepus timidus</i>	Batchai	Angara	2001.671	3.2	13.1	-24.7	3.7	Katzenberg et al. (in press)
23	Hare	<i>Lepus timidus</i>	Batchai	Angara	2001.672	3.2	11.8	-24.4	2.2	Katzenberg et al. (in press)
24	Hare	<i>Lepus timidus</i>	Batchai	Angara	2001.670	3.3	11.0	-24.2	1.7	Katzenberg et al. (in press)
25	Hare	<i>Lepus timidus</i>	Ida River	Angara	2002.384	3.2	8.3	-25.0	4.0	Katzenberg et al. (in press)
26	Hare	<i>Lepus timidus</i>	Irkutsk	Angara	2001.688	3.1	11.1	-23.7	2.6	Katzenberg et al. (in press)
27	Herring gull	<i>Larus argentatus</i>	Khuzhir-Nuge	Little Sea	1997.399	3.3	21.9	-21.3	14.1	Katzenberg et al. (in press)
28	Herring gull	<i>Larus argentatus</i>	Khuzhir-Nuge	Little Sea	1997.402	3.5	18.1	-19.5	13.7	Katzenberg et al. (in press)
29	Herring gull	<i>Larus argentatus</i>	Khuzhir-Nuge	Little Sea	1997.062	3.6	23.7	-20.6	13.5	Katzenberg et al. (in press)
30	Lynx	<i>Felix lynx</i>		Upper Lena	2002.360	3.0	13.5	-21.9	7.2	Katzenberg et al. (in press)
31	Muskrat	<i>Ondatra zibethicus</i>		Upper Lena	2002.359	3.3	10.3	-22.5	8.2	Katzenberg et al. (in press)
<i>Records removed from analysis due to possible species misidentification</i>										
1	Hare	<i>Lepus timidus</i>	Ida River	Angara	2002.438	3.6	13.6	-17.8	12.1	Katzenberg et al. (in press)
2	Hare	<i>Lepus timidus</i>	Bol'shie Koty	Baikal, west coast	2002.460	3.0	5.9	-19.7	15.2	Katzenberg et al. (in press)
3	Herring gull	<i>Larus argentatus</i>		Little Sea	2002.455	3.1	8.3	-20.7	5.4	Katzenberg et al. (in press)
4	Red deer	<i>Cervus elaphus</i>	Shamanskii Mys	Little Sea	1991.103	3.5	11.6	-18.3	14.9	Weber et al. (2002)
5	Roe deer	<i>Capreolus capreolus</i>	Shamanskii Mys	Little Sea	1991.099	3.4	17.2	-18.9	14.7	Weber et al. (2002)

Table 3

Descriptive statistics for stable isotope data for terrestrial fauna from the Baikal region: archaeological and modern ungulates.

	Archaeological		Modern	
	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
Mean	-19.6	5.1	-21.7	5.3
Standard deviation	0.8	1.0	1.2	2.4
Range	2.5	3.8	4.9	9.5
Minimum	-21.1	3.1	-23.8	1.1
Maximum	-18.6	6.9	-18.9	10.6
Count	15	15	50	50

ulation. Consequently, the  $\delta^{13}\text{C}$  values in Baikal fauna vary rather considerably depending on the occupied habitat (Katzenberg et al., 2010). This explains why different subspecies or populations of the same species display rather variable  $\delta^{13}\text{C}$  signatures.

On the other hand, the  $\delta^{15}\text{N}$  values in the lake fishes appear to be consistent with the expectations based on their trophic level (Weber et al., 2002). For example, the cyprinids (e.g., roach, dace, and ide; 7.3–9.4‰) place at the lower range, the graylings and lenok (9.1–11.7‰) occupy the middle, and the omul' and piscivore perch and pike (10.8–12.2‰) fall a little higher. The seal (11.4–15.6‰) occupies the top of the Baikal food chain.

For the terrestrial ecosystem, no stable isotope data have been published beyond those obtained by the BAP (Katzenberg and Weber, 1999; Katzenberg et al., in press; Weber et al., 2002). Although limited in scope and number, this information revealed

a limited range of variability in  $\delta^{13}\text{C}$  values (-22.9‰ to -18.3‰) as expected in a setting dominated by  $\text{C}_3$  plants and a range of  $\delta^{15}\text{N}$  signatures (3.1–6.9‰) predicted by the species' trophic position (Weber et al., 2002). An offset of c. 2.0‰ in the  $\delta^{13}\text{C}$  values between archaeological and modern specimens of ungulates was also identified. This offset is attributable to the combustion of fossil fuels during the industrial era and is consistent with data available from elsewhere (Sealy and van der Merwe, 1992).

Previous assessments of carbon and nitrogen stable isotope data, environmental and human (Katzenberg and Weber, 1999; Katzenberg et al., 2009, 2010; Weber et al., 2002; Weber and Bettinger, 2010; Weber and Goriunova, in preparation), provided the following insights: (1) middle Holocene hunter-gatherer groups of all micro-regions and periods lived on diets that included substantial, although spatio-temporally variable, amounts of aquatic foods, mostly fishes and to some extent the Baikal seal; (2) The Early Neolithic (EN) cemetery samples displayed greater degree of inter-site variability across the Baikal region likely reflecting reliance on local freshwater fish that differ substantially in kind, abundance, and carbon stable isotope signatures across the region; (3) The Late Neolithic (LN) and EBA cemeteries evinced the pattern of greater inter-site similarities between the various micro-regions (Angara, Lena, and Little Sea on Baikal) and particularly so with regard to the  $\delta^{13}\text{C}$  results, a pattern best explicable in terms of the relatively greater dependence on herbivores which regionally vary less in abundance, kind, and  $\delta^{13}\text{C}$  signatures; (4) The  $\delta^{15}\text{N}$  data obtained for young children indicated different ages for the onset of weaning, later for the EN groups and earlier for the

**Table 4**  
Stable isotope data for aquatic fauna from the Angara and Lena Rivers, and Lake Baikal.

No.	Common name	Latin name	Site	Age	ESAMP ID	C/N	Coll. yield	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	References
<i>Angara fishes</i>										
1	Arctic grayling	<i>Thymallus arcticus</i>	Angarsk	Modern	2001.753	3.4	10.7	-16.4	12.9	Katzenberg et al. (in press)
2	Arctic grayling	<i>Thymallus arcticus</i>	Angarsk	Modern	2001.755	3.2	13.3	-16.4	12.0	Katzenberg et al. (in press)
3	Burbot	<i>Lota lota</i>	Ida River	Modern	2002.448	3.4	2.8	-23.6	12.4	Katzenberg et al. (in press)
4	Burbot	<i>Lota lota</i>	Ida River	Modern	2002.450	3.5	15.0	-21.7	10.6	Katzenberg et al. (in press)
5	Burbot	<i>Lota lota</i>	Ida River	Modern	2002.451	3.2	11.5	-19.7	13.6	Katzenberg et al. (in press)
6	Freshwater perch	<i>Perca fluviatilis</i>	Bratsk	Modern	2001.762	3.2	6.6	-25.6	11.4	Katzenberg et al. (in press)
7	Freshwater perch	<i>Perca fluviatilis</i>	Bratsk	Modern	2001.769	3.3	14.3	-24.9	11.5	Katzenberg et al. (in press)
8	Freshwater perch	<i>Perca fluviatilis</i>	Bratsk	Modern	2001.772	2.9	7.9	-25.4	11.8	Katzenberg et al. (in press)
9	Lenok	<i>Brachymystax lenok</i>	Batchai	Modern	2001.752	3.5	7.6	-15.6	13.7	Katzenberg et al. (in press)
10	Northern pike	<i>Esox lucius</i>	Angara	Modern	1997.029	3.4	4.2	-19.2	18.5	Katzenberg et al. (in press)
11	Northern pike	<i>Esox lucius</i>	Angara	Modern	1997.030	3.3	5.0	-20.2	20.6	Katzenberg et al. (in press)
12	Northern pike	<i>Esox lucius</i>	Bratsk	Modern	2001.778	3.1	15.2	-22.0	9.8	Katzenberg et al. (in press)
13	Omul'	<i>Coregonus a. m.</i>	Bratsk	Modern	2001.763	3.0	11.8	-21.8	10.7	Katzenberg et al. (in press)
14	Omul'	<i>Coregonus a. m.</i>	Bratsk	Modern	2001.764	2.9	15.3	-24.0	11.6	Katzenberg et al. (in press)
15	Prussian carp	<i>Carassius auratus</i>	Ida River	Modern	2002.441	3.3	0.5	-24.1	7.8	Katzenberg et al. (in press)
16	Siberian roach	<i>Rutilus rutilus l.</i>	Irkutsk	Modern	2001.756	3.2	16.5	-16.4	12.0	Katzenberg et al. (in press)
17	Siberian roach	<i>Rutilus rutilus l.</i>	Bratsk	Modern	2001.759	3.0	14.9	-25.2	8.4	Katzenberg et al. (in press)
18	Siberian roach	<i>Rutilus rutilus l.</i>	Bratsk	Modern	2001.768	2.9	9.3	-25.8	8.9	Katzenberg et al. (in press)
19	Siberian roach	<i>Rutilus rutilus l.</i>	Ust-Ilimsk	Modern	2002.339	3.2	9.9	-24.1	7.7	Katzenberg et al. (in press)
20	Siberian roach	<i>Rutilus rutilus l.</i>	Ust-Ilimsk	Modern	2002.340	3.3	11.6	-24.5	7.5	Katzenberg et al. (in press)
21	Siberian roach	<i>Rutilus rutilus l.</i>	Ust-Ilimsk	Modern	2002.341	3.2	9.6	-26.6	7.8	Katzenberg et al. (in press)
<i>Lena fishes</i>										
1	Dace	<i>Leuciscus leuciscus</i>	Upper Lena	Modern	2002.355	3.3	9.6	-25.6	10.2	Katzenberg et al. (in press)
2	Lenok	<i>Brachymystax lenok</i>	Upper Lena	Modern	2002.351	3.0	13.7	-27.0	10.8	Katzenberg et al. (in press)
3	Lenok	<i>Brachymystax lenok</i>	Upper Lena	Modern	2002.352	3.0	8.4	-26.7	11.5	Katzenberg et al. (in press)
4	Northern pike	<i>Esox lucius</i>	Ust-Kut	Modern	2002.389	3.3	3.0	-24.0	11.2	Katzenberg et al. (in press)
<i>Baikal fishes from the Little Sea</i>										
1	Freshwater perch	<i>Perca fluviatilis</i>	Khuzhir-Nuge	Modern	2000.544	3.4	11.6	-16.3	11.5	Katzenberg et al. (in press)
2	Freshwater perch	<i>Perca fluviatilis</i>	Khuzhir-Nuge	Modern	2001.795	3.0	10.0	-13.6	11.3	Katzenberg et al. (in press)
3	Freshwater perch	<i>Perca fluviatilis</i>	Khuzhir-Nuge	Modern	2001.720	3.2	9.8	-11.9	10.6	Katzenberg et al. (in press)
4	Northern pike	<i>Esox lucius</i>	Khuzhir-Nuge	Modern	1997.403	3.3	6.9	-17.0	11.5	Katzenberg et al. (in press)
5	Northern pike	<i>Esox lucius</i>	Khuzhir-Nuge	Modern	1997.057	3.3	6.8	-16.0	11.6	Katzenberg et al. (in press)
6	Grayling	<i>Thymallus sp.</i>	Khuzhir-Nuge	Modern	2001.712	3.2	10.1	-19.7	10.8	Katzenberg et al. (in press)
7	Grayling	<i>Thymallus sp.</i>	Khuzhir-Nuge	Modern	2001.713	3.1	6.2	-12.7	9.5	Katzenberg et al. (in press)
8	Grayling	<i>Thymallus sp.</i>	Khuzhir-Nuge	Modern	2001.714	3.1	7.1	-11.9	10.4	Katzenberg et al. (in press)
9	White grayling	<i>Thymallus arct. b. br.</i>	Khuzhir-Nuge	Modern	2001.797	3.1	11.9	-9.9	10.0	Katzenberg et al. (in press)
10	White grayling	<i>Thymallus arct. b. br.</i>	Khuzhir-Nuge	Modern	2001.798	3.0	11.1	-10.8	9.9	Katzenberg et al. (in press)
11	White grayling	<i>Thymallus arct. b. br.</i>	Khuzhir-Nuge	Modern	2001.801	3.0	7.3	-13.0	9.8	Katzenberg et al. (in press)
12	White grayling	<i>Thymallus arct. b. br.</i>	Khuzhir-Nuge	Modern	2001.802	3.0	7.5	-11.0	9.7	Katzenberg et al. (in press)
13	Omul'	<i>Coregonus a. m.</i>	Khuzhir-Nuge	Modern	1997.394	3.3	14.3	-18.9	9.3	Katzenberg et al. (in press)
14	Omul'	<i>Coregonus a. m.</i>	Khuzhir-Nuge	Modern	2001.710	3.0	12.4	-16.2	9.5	Katzenberg et al. (in press)
15	Omul'	<i>Coregonus a. m.</i>	Khuzhir-Nuge	Modern	2001.709	3.4	11.1	-15.9	9.4	Katzenberg et al. (in press)
16	Omul'	<i>Coregonus a. m.</i>	Khuzhir-Nuge	Modern	1997.396	3.3	10.7	-14.0	9.2	Katzenberg et al. (in press)
17	Whitefish	<i>Coregonus l. b.</i>	Khuzhir-Nuge	Modern	2001.703	3.0	7.6	-20.5	12.3	Katzenberg et al. (in press)
18	Whitefish	<i>Coregonus l. b.</i>	Khuzhir-Nuge	Modern	2001.791	3.3	13.3	-20.5	11.5	Katzenberg et al. (in press)
19	Whitefish	<i>Coregonus l. b.</i>	Khuzhir-Nuge	Modern	2001.789	3.1	14.2	-20.4	11.9	Katzenberg et al. (in press)
20	Whitefish	<i>Coregonus l. b.</i>	Khuzhir-Nuge	Modern	2001.792	3.1	12.4	-19.2	12.0	Katzenberg et al. (in press)
21	Whitefish	<i>Coregonus l. b.</i>	Khuzhir-Nuge	Modern	2001.790	3.1	13.7	-18.2	11.1	Katzenberg et al. (in press)
22	Whitefish	<i>Coregonus l. b.</i>	Khuzhir-Nuge	Modern	1997.079	3.3	18.9	-17.5	12.6	Katzenberg et al. (in press)
23	Whitefish	<i>Coregonus l. b.</i>	Khuzhir-Nuge	Modern	2001.704	2.9	21.3	-16.8	11.3	Katzenberg et al. (in press)
<i>Baikal fishes from Bol'shie Koty</i>										
1	Black grayling	<i>Thymallus arct. b.</i>	Bol'shie Koty	Modern	1995.210			-13.5	9.9	Weber et al. (2002)
2	Black grayling	<i>Thymallus arct. b.</i>	Bol'shie Koty	Modern	1995.211			-12.4	9.1	Weber et al. (2002)
3	Black grayling	<i>Thymallus arct. b.</i>	Bol'shie Koty	Modern	1995.213			-15.0	10.4	Weber et al. (2002)
4	Black grayling	<i>Thymallus arct. b.</i>	Bol'shie Koty	Modern	1995.214			-13.9	10.3	Weber et al. (2002)
5	Freshwater perch	<i>Perca fluviatilis</i>	Bol'shie Koty	Modern	1998.007	3.5	14.8	-11.3	10.6	Katzenberg et al. (in press)
6	Freshwater perch	<i>Perca fluviatilis</i>	Bol'shie Koty	Modern	1998.008	3.6	16.7	-9.6	10.2	Katzenberg et al. (in press)
7	Ide	<i>Leuciscus idus</i>	Bol'shie Koty	Modern	1995.221			-13.0	9.4	Weber et al. (2002)
8	Ide	<i>Leuciscus idus</i>	Bol'shie Koty	Modern	1995.222			-12.8	9.4	Weber et al. (2002)
9	Lenok	<i>Brachymystax lenok</i>	Bol'shie Koty	Modern	1995.223			13.9	11.5	Weber et al. (2002)
10	Lenok	<i>Brachymystax lenok</i>	Bol'shie Koty	Modern	1995.224			-14.5	10.2	Weber et al. (2002)
11	Lenok	<i>Brachymystax lenok</i>	Bol'shie Koty	Modern	1995.225			-13.3	11.0	Weber et al. (2002)
12	Lenok	<i>Brachymystax lenok</i>	Bol'shie Koty	Modern	1995.226			-15.2	11.7	Weber et al. (2002)
13	Baikal sturgeon	<i>Acipenser baerii st.</i>	Bol'shie Koty	Modern	1998.014	3.3	12.3	-22.3	14.1	Katzenberg et al. (in press)
14	Black grayling	<i>Thymallus arct. b.</i>	Bol'shie Koty	Modern	1998.011	3.5	2.6	-23.2	11.0	Katzenberg et al. (in press)
15	Black grayling	<i>Thymallus arct. b.</i>	Bol'shie Koty	Modern	1998.012	3.5	3.1	-22.5	12.0	Katzenberg et al. (in press)
16	Freshwater perch	<i>Perca fluviatilis</i>	Bol'shie Koty	Modern	1995.227			-20.5	12.2	Weber et al. (2002)
17	Freshwater perch	<i>Perca fluviatilis</i>	Bol'shie Koty	Modern	1995.228			-21.5	11.5	Weber et al. (2002)
18	Freshwater perch	<i>Perca fluviatilis</i>	Bol'shie Koty	Modern	1998.009	3.4	5.4	-23.6	12.7	Katzenberg et al. (in press)
19	Northern pike	<i>Esox lucius</i>	Bol'shie Koty	Modern	1995.219			-21.5	11.9	Weber et al. (2002)

Table 4 (continued)

No.	Common name	Latin name	Site	Age	ESAMP ID	C/N	Coll. yield	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	References
20	Northern pike	<i>Esox lucius</i>	Bol'shie Koty	Modern	1995.220			-22.5	12.0	Weber et al. (2002)
21	Northern pike	<i>Esox lucius</i>	Bol'shie Koty	Modern	1998.006	3.5	1.6	-22.8	12.0	Katzenberg et al. (in press)
22	Omul'	<i>Coregonus a. m.</i>	Bol'shie Koty	Modern	1995.215			-24.6	12.2	Weber et al. (2002)
23	Omul'	<i>Coregonus a. m.</i>	Bol'shie Koty	Modern	1995.216			-24.0	10.8	Weber et al. (2002)
24	Omul'	<i>Coregonus a. m.</i>	Bol'shie Koty	Modern	1995.217			-24.9	11.9	Weber et al. (2002)
25	Omul'	<i>Coregonus a. m.</i>	Bol'shie Koty	Modern	1995.218			-24.7	11.0	Weber et al. (2002)
26	Omul'	<i>Coregonus a. m.</i>	Bol'shie Koty	Modern	2001.749	3.1	9.0	-22.5	10.6	Katzenberg et al. (in press)
27	Prussian carp	<i>Carassius auratus</i>	Bol'shie Koty	Modern	1995.230			-21.4	7.3	Weber et al. (2002)
28	White grayling	<i>Thymallus arct. b. br.</i>	Bol'shie Koty	Modern	1995.209			-20.4	13.7	Weber et al. (2002)
29	White grayling	<i>Thymallus arct. b. br.</i>	Bol'shie Koty	Modern	1995.212			-21.1	10.8	Weber et al. (2002)
<i>Baikal seal</i>										
1	Baikal seal	<i>Phoca sibirica</i>	Tyshkine 2	Archaeological	1993.024	3.4	16.8	-23.2	15.6	Weber et al. (2002)
2	Baikal seal	<i>Phoca sibirica</i>	Shamanskii Mys	Archaeological	1991.106	3.5	8.4	-22.9	11.4	Weber et al. (2002)
3	Baikal seal	<i>Phoca sibirica</i>	Shamanskii Mys	Archaeological	1991.100	3.4	16.8	-22.8	14.0	Weber et al. (2002)
4	Baikal seal	<i>Phoca sibirica</i>	Tyshkine 2	Archaeological	1991.068	3.4	16.1	-22.7	15.2	Weber et al. (2002)
5	Baikal seal	<i>Phoca sibirica</i>	Tyshkine 3	Archaeological	1993.035	3.5	16.9	-22.2	13.4	Weber et al. (2002)
6	Baikal seal	<i>Phoca sibirica</i>	Tyshkine	Archaeological	2000.549	3.2	13.0	-22.2	13.4	
7	Baikal seal	<i>Phoca sibirica</i>	Tyshkine 2	Archaeological	1993.023	3.5	12.8	-22.2	13.8	Weber et al. (2002)
8	Baikal seal	<i>Phoca sibirica</i>	Tyshkine 3	Archaeological	1991.073	3.5	18.6	-21.2	13.6	Weber et al. (2002)
9	Baikal seal	<i>Phoca sibirica</i>	Tyshkine 3	Archaeological	1993.034	3.6	17.5	-21.1	13.7	Weber et al. (2002)
10	Baikal seal	<i>Phoca sibirica</i>		Modern	1993.104	3.5	38.7	-21.6	13.5	Weber et al. (2002)
11	Baikal seal	<i>Phoca sibirica</i>		Modern	1993.099	3.4	38.2	-21.0	13.1	Weber et al. (2002)
<i>Records removed from analysis due to unknown source (fish obtained from street markets)</i>										
1	Siberian roach	<i>Rutilus rutilus l.</i>		Modern	1997.028	3.4	18.7	-28.6	6.2	Katzenberg et al. (in press)
2	Freshwater perch	<i>Perca fluviatilis</i>		Modern	1997.018	3.5	19.6	-25.8	10.6	Katzenberg et al. (in press)
3	Freshwater perch	<i>Perca fluviatilis</i>		Modern	1997.019	3.5	19.2	-26.0	10.0	Katzenberg et al. (in press)
4	Ide	<i>Leuciscus idus</i>		Modern	1997.010	3.5	22.0	-25.3	12.4	Katzenberg et al. (in press)
5	Ide	<i>Leuciscus idus</i>		Modern	1997.011	3.4	26.3	-25.5	9.8	Katzenberg et al. (in press)
<i>Records removed from analysis due to possible species misidentification (archaeological seal) or outlying value (modern seal)</i>										
1	Baikal seal	<i>Phoca sibirica</i>	Tyshkine	Archaeological	2000.550	3.3	12.3	-20.9	9.0	Katzenberg et al. (in press)
2	Baikal seal	<i>Phoca sibirica</i>	Tyshkine	Archaeological	2000.551	3.3	8.6	-17.8	9.4	Katzenberg et al. (in press)
3	Baikal seal	<i>Phoca sibirica</i>	Little Sea	Modern	2001.698	2.9	22.1	-22.8	6.1	Katzenberg et al. (in press)

LN groups (at 4 and 2 years of age, respectively); and (5) Overall, the dietary, mortuary and demographic data considered together at the regional level suggested that the EN cultural pattern emphasized heterogeneity, while the LN and EBA patterns appeared to be emphasizing cultural homogeneity (Weber and Bettinger, 2010). Importantly, due to the limited number of human individuals analyzed at the time, these conclusions were all drawn from the assessment of sample means rather than from examination of individual variability.

Recent examination (Katzenberg et al., 2009; Weber and Goriunova, in preparation) of individual variability in the largest sample available to date – the EBA Khuzhir-Nuge XIV cemetery from the Little Sea area – revealed a distinct pattern of intra-sample variation that is best interpreted, as mentioned, in terms of the presence of two diets: one including the Baikal seal and showing  $\delta^{15}\text{N}$  values in the range of  $\sim 13.5$ – $16.5\%$  (GFS diet) and one likely excluding the seal and with lower  $\delta^{15}\text{N}$  signatures ( $\sim 10.3$ – $12.6\%$ , GF diet). These two diet types displayed differential spatial distribution within the site: the West Sector consisted exclusively of individuals living on the GFS diet while the East and Centre Sectors included a mix of individuals with the GFS and GF diet. Lastly, all individuals identified as born locally subsisted on the GFS diet, while roughly half of those who are believed to be born elsewhere lived on the GF and half on the GFS diet. Evidently, assessment of individual variability holds the potential to provide insights about Lake Baikal middle Holocene hunter-gatherers that go much beyond those resulting from focusing on sample means.

#### 4. Stable isotope signatures of terrestrial and aquatic foods in the Baikal region

The new environmental data offer the potential to expand and sharpen our understanding of the terrestrial and aquatic stable iso-

tope ecology of the entire Baikal region, a task that goes outside the scope of this study. Instead, this material will be used here in the capacity of a general framework of reference to address key archaeological questions. In order to avoid repetition, the focus of this section is on the most general trends while the more specific patterns, directly relevant for the assessment of the human foraging behavior, are discussed later in the paper.

##### 4.1. Terrestrial fauna

Variation in stable isotope signatures of the examined terrestrial fauna within the entire Baikal region is limited, particularly with respect to the ungulate species considered to have been one of the two main sources of food for the middle Holocene foragers in the region (Tables 2–5 and Figs. 2 and 3). Due to the effects of trophic level enrichment, the main dimension of variability is on the nitrogen scale (13.0‰ range) rather than on the carbon axis (7.5‰ range), a pattern consistent with an environment characterized by  $\text{C}_3$  plants. Perhaps due to the anthropogenic factors (human refuse, fertilizers), several modern specimens of roe deer and a few red deer display higher than expected values of  $\delta^{15}\text{N}$  (6.9–9.1‰ and 6.5–8.5‰, respectively). Specimens with these enriched values are documented across the entire Baikal region.

While the modern data set offers the advantage of being much larger and more diverse in terms of species composition than the available archaeological material, the carbon signatures of the modern data set are lighter compared to the archaeological one by 2–3‰ and also more variable (7.2‰ range) relative to the archaeological data set (3.6‰ range). The same is observed for the ungulates. Carbon signatures of the modern specimens are lighter by 2.1‰ and also more scattered (4.9‰ range) relative to the archaeological ones (2.5‰ range). Nitrogen values for the set of archaeological ungulates too show less than half the dispersion



**Table 5**  
Descriptive statistics for stable isotope data for aquatic fauna from the Baikal: a. Angara and Lena Rivers, and Lake Baikal. b. Lake Baikal habitats. c. Lake Baikal species and habitats.

Table 5a						
	Angara		Lena		Baikal	
	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
Mean	-22.1	11.5	-25.8	10.9	-18.8	11.3
Standard deviation	3.5	3.3	1.4	0.6	4.8	1.7
Range	11.0	13.1	3.0	1.3	19.0	9.4
Minimum	-26.6	7.5	-27.0	10.2	-28.6	6.2
Maximum	-15.6	20.6	-24.0	11.5	-9.6	15.6
Count	21	21	4	4	68	68

Table 5b						
	Gulf Little Sea		Open coast 1 Bol'shie Koty		Open coast 2 Bol'shie Koty	
	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
Mean	-15.7	10.7	-22.6	11.6	-13.2	10.3
Standard deviation	3.4	1.1	1.4	1.5	1.6	0.8
Range	10.6	3.4	4.5	6.8	5.6	2.6
Minimum	-20.5	9.2	-24.9	7.3	-15.2	9.1
Maximum	-9.9	12.6	-20.4	14.1	-9.6	11.7
Count	23	23	17	17	12	12

Table 5c										
	Cove-and-lagoon Little Sea		Gulf Little Sea		Graylings <sup>a</sup> Gulf, Little Sea		Graylings 1 Open coast, Bol'shie Koty		Graylings 2 Open coast, Bol'shie Koty	
	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
Mean	-15.0	11.3	-16.0	10.6	-11.6	9.9	-21.8	11.9	-13.7	9.9
Standard deviation	2.1	0.4	3.7	1.1	1.2	0.3	1.3	1.3	1.1	0.6
Range	5.1	1.0	10.6	3.4	3.1	0.9	2.8	2.9	2.6	1.3
Minimum	-17.0	10.6	-20.5	9.2	-13.0	9.5	-23.2	10.8	-15.0	9.1
Maximum	-11.9	11.6	-9.9	12.6	-9.9	10.4	10.4	13.7	-12.4	10.4
Count	5	5	18	18	6	6	4	4	4	4

<sup>a</sup>Excluding the specimen with light carbon value.

Table 5c continued										
	Whitefish Gulf, Little Sea		Omul' Gull, Little Sea		Omul' Pelagic, Bol'shie Koty		Lenok Open coast, Bol'shie Koty		Seal Pelagic	
	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
Mean	-19.0	11.8	-16.3	9.4	-24.1	11.3	-14.2	11.1	-22 A	13.7
Standard deviation	1.5	0.5	2.0	0.1	1.50	0.7	0.8	0.7	0.8	1.1
Range	3.7	1.5	4.9	0.3	2.4	1.6	1.9	1.5	2.2	4.2
Minimum	-20.5	11.1	-18.9	9.2	-24.9	10.6	-15.2	10.2	-23.2	11.4
Maximum	-16.8	12.6	-14.0	9.5	-22.5	12.2	-13.3	11.7	-21.0	15.6
Count	7	7	4	4	5	5	4	4	11	11

Source data in Table 4.

present in the modern reference data (3.8‰ vs. 9.5‰ range). Thus, devoid of the modern anthropogenic effects, the less numerous and less diverse archaeological data set, particularly the ungulate results, offers the better framework of reference from which to assess the prehistoric hunter-gatherer dietary and foraging behavior.

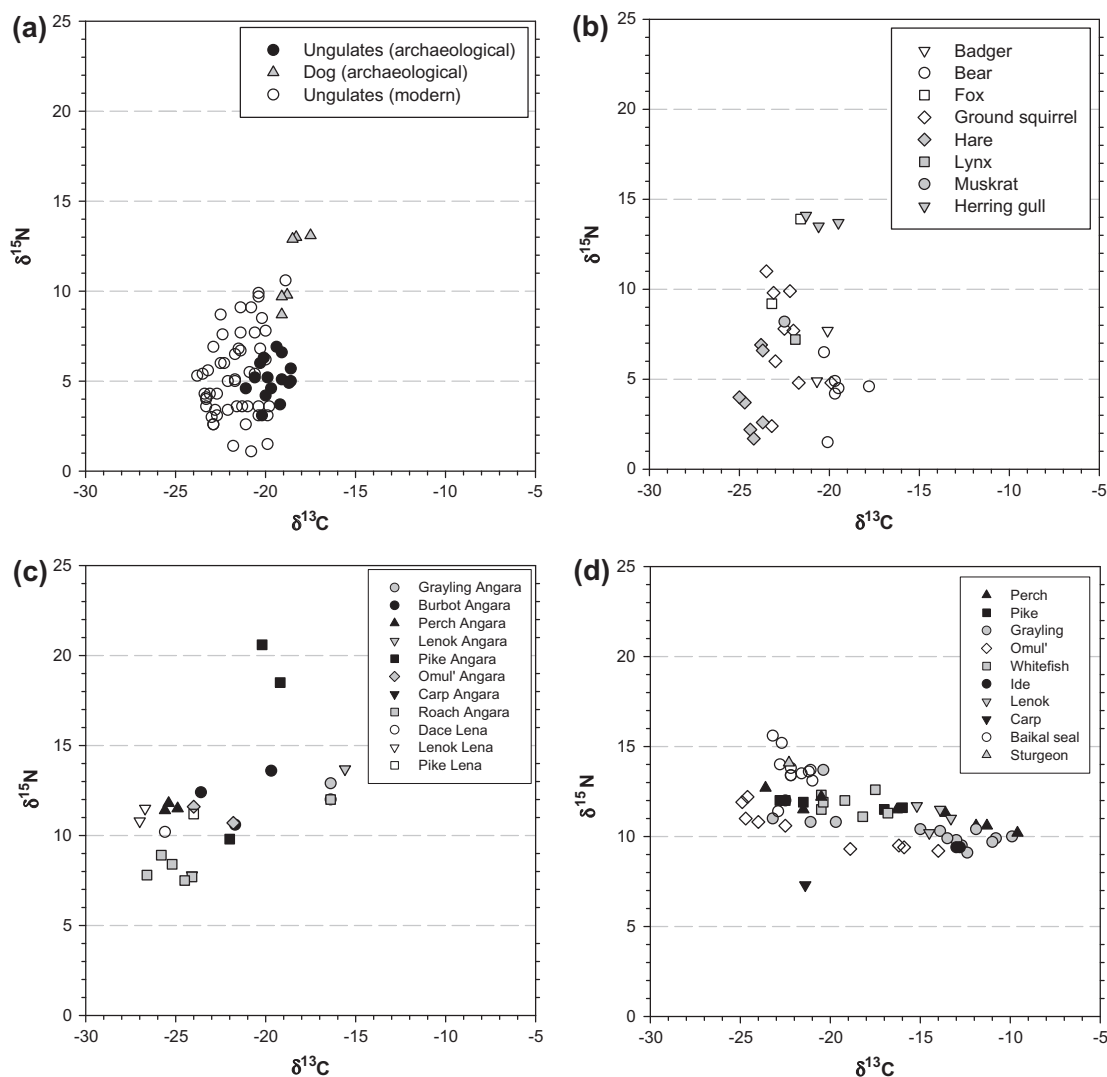
Based on  $\delta^{15}\text{N}$  values, the archaeological specimens sort themselves into three distinct clusters (Fig. 2a): the first around ~13.0‰ consisting of three dog specimens, the second in the 9.0–10.0‰ range consisting of three dogs too, and the third group consisting exclusively of ungulates and showing values between ~3.0‰ and 7.0‰. Noticeable in this pattern is the ~3‰ separation between each group and that the two dog clusters overlap with the two human diets (GF and GFS) identified at the EBA Khuzhir-Nuge XIV cemetery.

## 4.2. Aquatic foods

A glance at the stable isotope data obtained for the aquatic fauna from Lake Baikal and the Angara and Lena rivers (Fig. 2c and d) shows a substantial amount of variability between these three systems along the carbon axis but particularly within the Baikal data set, and much less variability along the nitrogen axis. As such, the following discussion focuses on understanding the distribution of  $\delta^{13}\text{C}$  results in the three relevant aquatic systems.

### 4.2.1. Variability in $\delta^{13}\text{C}$ values

Primary productivity in freshwater ecosystems is the subject of ongoing extensive research, the comprehensive review of which is beyond the scope of this paper and the expertise of the authors.



**Fig. 2.** Stable isotope results for terrestrial, avian and aquatic fauna from the Baikal region. (a) Ungulates (archaeological and modern specimens) and dogs (archaeological). (b) Terrestrial and avian fauna: modern specimens (by species). (c) Aquatic fauna from the Angara and Lena Rivers (by species). (d) Aquatic fauna from the Lake Baikal (by species).

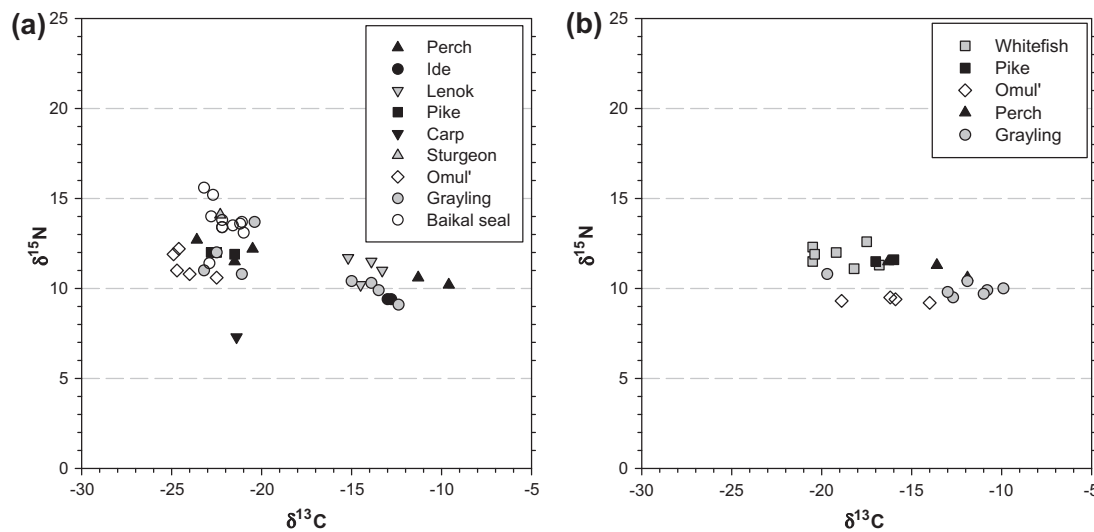
Instead, it is more practical to present a few general relationships that are directly relevant to the archaeological matters at hand. Primary productivity in freshwater environments is controlled mainly by light, carbon, temperature, and nutrients, the first two essential elements of photosynthesis (Brönmark and Hansson, 1998; Giller and Malmqvist, 1998). Since photosynthesis discriminates against the heavy carbon isotope, photosynthetic organisms are forced to use more  $^{13}\text{C}$ , in spite of the discrimination effect, when the local carbon supply is restricted and  $^{12}\text{C}$  becomes gradually depleted. Therefore,  $\delta^{13}\text{C}$  levels in the consumers (i.e., fauna) are affected in such a way that the lower the primary productivity the more negative (lighter) the values, and the higher the primary productivity the more positive (heavier) the values (Boutton, 1991; France, 1995).

In lakes and rivers, access to light (energy) is controlled mostly by bathymetry such that its availability decreases rapidly with depth depending also on water clarity (Brönmark and Hansson, 1998; Giller and Malmqvist, 1998). Carbon is provided by mixing of the atmospheric  $\text{CO}_2$ , nutrients are supplied by external water flowing into the system (tributaries, runoff, and ground water)

and by organic detritus of terrestrial origin deposited into bodies of water, both of which are also an additional source of  $\text{CO}_2$ . Thermal stratification, currents, and wind-generated turbulences play an important role in distribution of  $\text{CO}_2$ , nutrients, and energy provided by light and heat (mostly via insolation).

In order to relate these processes to our study area, it is important to recognize that the freshwater ecosystems of Lake Baikal and the Angara and Lena rivers are ecologically very different from one another: the first is lentic (i.e., standing water), the other two are lotic (i.e., flowing water). Baikal is not only the deepest (~1635 m) and the largest by volume lake in the world (20–25% of the world freshwater reserves) but also ecologically a much more diverse system than the two rivers due primarily to its complex bathymetry (Kozhov, 1963). This matter is discussed in more detail later.

The Angara is a lake outlet and a braided mature river from its source at Baikal where it is ~1 km wide (i.e., prior to damming in Irkutsk in the 1950s). It is fed primarily by Baikal's surface water and flows through a mosaic of forest (near Baikal), steppe-forest and steppe vegetation before reaching vast expanses of the taiga



**Fig. 3.** Stable isotope results for aquatic fauna from Lake Baikal. (a) Baikal seal and Bol'shie Koty fishes sorted by species and habitat. (b) Little Sea fishes sorted by species and habitat.

~380 km downstream. The Angara was well-known for its enormous fishery during historic times (Kozhov, 1950).

The upper Lena is a single channel immature river and not a very rich fishery (Kozhov, 1950). Between the headwaters and Kachug (the first ~160 km) the Lena flows through upland taiga and has a distinct character of a mountain river. The landscape opens up somewhat between Kachug and Zhigalovo (~130 km), particularly along the Anga, Ilga, Kulenga, and Manzurka tributaries, but further downstream dense taiga is present all the way to Kirensk (the next ~370 km). While accumulating more volume and developing a wider trough (100–200 m), the Lena maintains much of its mountain character.

The Lena is, of course, disconnected from the other two systems, and Baikal and the Angara are independent fisheries in the sense that fishes from one do not migrate to another, save for the Angara's source section and the adjacent part of Baikal which have been documented as sharing large populations of black grayling and lenok (Kozhov, 1950). It is worth noting that this summary of the region's vegetation and rivers, and the subsequent similar references, draw on Kozhov's research (1950) which relates to the period prior to the Soviet industrial growth and emphasizes the natural rather than modern anthropogenic characteristics of the Baikal region that are of interest to this study (cf. Weber, 2003).

Linking the factors controlling photosynthesis in freshwater ecosystems with the ecological characteristics of Lake Baikal and the Angara and Lena rivers, it is reasonable to expect the following two general patterns in primary productivity:

- Higher rates of photosynthesis will be facilitated by wide coastal plains and rolling hills, sparse vegetation (e.g., steppe or steppe-forest), large affluents, significant erosion, and places with strong winds (all expected to provide more nutrients), as well as shallow coves or gulfs where the water is warmer.
- Lower rates of photosynthesis will occur under conditions of narrow plains, steep cliffs, lush vegetation (e.g., dense forest or brush), small affluents, areas with less erosion, and open places sheltered from wind (all expected to provide less nutrients), as well as the cold waters of the open coast littoral and pelagic habitats or fast flowing rivers.

#### 4.2.2. Expected variability in $\delta^{13}\text{C}$ values

Lake Baikal is an oligotrophic ecosystem with diverse bathymetry and coastline, well developed thermal stratification, and water supplied by an array of rivers from hundreds of small and seasonal streams through a few medium-size rivers (e.g., Barguzin) to the vast drainage of the Selenga River, and a system of gale force winds (e.g., Sarma in the Little Sea, Kultuk on southwest Baikal, and Barguzin on the east coast). As such, one would expect substantial variability in primary productivity between its various habitats and parts. Indeed such differential distribution of primary productivity and, consequently, a broad range of  $\delta^{13}\text{C}$  values in their fauna and clear separation between the littoral and pelagic habitats have been documented for many oligotrophic lakes in various environmental settings (e.g., Briones et al., 1998; France, 1995; Syväranta et al., 2006) including Lake Baikal (e.g., Goldman et al., 1996; Kiyashko et al., 1991, 1998).

In this sense, it is useful to adopt a modified version of Kozhov's (1963) definition of the following five distinct, though not discontinuous, habitats:

- Shallow cove-and-lagoons (<5 m).
- Gulfs (e.g., Little Sea, up to 250 m deep).
- Large river estuaries or deltas (e.g., Selenga, up to ~250 m deep).
- Narrow open coast littoral (up to 400 m wide and ~250 m deep).
- Pelagic (the rest of the lake up to the depth of ~1600 m).

Access to light and bathymetry as well as the effects of the other factors affecting photosynthesis being much less variable along river courses, the lotic systems of the Angara and Lena are expected to be that much less variable than Baikal in terms of their primary productivity and thus less variable in  $\delta^{13}\text{C}$  values in their fauna. However, the two rivers are expected to be somewhat different from each other due to the differences in their nutrient content – richer in the Angara (mature river, lake outlet, more open landscape, and larger catchment) than in the upper Lena (immature river, more forested landscape, and smaller catchment).

Based on the discussion above, it is possible to make predictions regarding the expected range of variability in  $\delta^{13}\text{C}$  signatures characterizing the fauna in these three aquatic systems:

- (1) The fishes of Lake Baikal should display the greatest range of  $\delta^{13}\text{C}$  variability from lightest values in the pelagic waters to heaviest in the shallow cove-and-lagoons and deltas of large rivers, with open coast littoral, gulfs, and smaller river estuaries occupying the middle of the range, perhaps overlapping a little with the other two.
- (2) The fishes of the Angara should display a relatively narrow range in  $\delta^{13}\text{C}$  values, somewhat more positive relative to Baikal's light end and the heaviest within the section close to its source.
- (3) The low primary productivity of the Lena should be reflected in a very narrow range of  $\delta^{13}\text{C}$  values in its fishes, one that is more negative relative to the Angara and closer to Baikal's light end.

#### 4.2.3. Results – Lake Baikal

The data obtained for modern aquatic fauna from Lake Baikal and the Lena generally meet these expectations, but those for the Angara do not (Tables 4 and 5, Fig. 2c and d). Overall, the  $\delta^{13}\text{C}$  signatures for Baikal span a large range of 19.0‰ from –28.6‰ to –9.6‰. Breaking down the entire data set into smaller units defined on the basis of sample collection sites, habitats and species, and excluding the specimens for which exact provenience is lacking, demonstrates that  $\delta^{13}\text{C}$  values in Baikal fauna indeed covary with primary productivity of the dominant habitat, as predicted by the model above (Table 5, Fig. 3).

The fish samples collected at Bol'shie Koty form two distinct groups separated from each other on the carbon scale by a gap of ~5‰ (Fig. 3a). This is best explained by the bathymetric particulars at this and many other similar locations along the open coast Baikal. Namely, the shallow littoral zone is very narrow and the transition to the pelagic habitat is rapid: at Bol'shie Koty, already a few hundred meters away from the shore the bottom drops to ~1400 m. In fact, Kozhov (1963) divides this zone into two: littoral (0–20 m) and sub-littoral (>20 m). While the group with the heavier  $\delta^{13}\text{C}$  values is dominated by species with preferences for shallower waters (perch, ide, lenok, and black grayling) and the isotopically light cluster by species favoring deeper habitats (white grayling, omul', and sturgeon), the pike somewhat unexpectedly belongs to the lighter group. The perch sorts itself into both groups consistent with habitat separation similar to that observed for the grayling (Kozhov, 1972). The four black graylings, as expected, are isotopically heavier than the two white graylings, but the two additional black graylings show light  $\delta^{13}\text{C}$  signatures suggesting possible subspecies misidentification. The fact that most black graylings and the lenok are both simultaneously enriched in carbon and nitrogen heavy isotopes is particularly significant in the context that these two species account for ~95% of the Angara fishery along its upper section adjoining Baikal, only ~20 km to the west of Bol'shie Koty, the remaining 5% attributed to the taimen (Kozhov, 1950). The fact that this fishery, despite the relatively high primary productivity, is dominated by two species only is consistent with the pattern of lowered biodiversity documented for lake-outlet-rivers at their source section (Giller and Malmqvist, 1998).

The distribution of  $\delta^{13}\text{C}$  values for the Little Sea sample is different from the one obtained for Bol'shie Koty in that it is continuous (Fig. 3b) rather than bimodal, a pattern consistent with much more gradual gradient of change in bathymetry of the Little Sea gulf. In the south, there are extensive (up to ~5 km wide) shallow coves in the Mukhor and Kurkut Bays and the depth of the gulf gradually reaches ~250 m at the northern end with a number of shallow but small coves along both the mainland and the Ol'khon's northwest coast. The fishes known to be foraging in the open waters of the Little Sea (whitefish and omul') occupy the light half of the distribution and those preferring shallows (perch) are isotopically heavier. The pike, like at Bol'shie Koty, is lighter than the perch, and

the graylings, also like at Bol'shie Koty, form two clusters although, according to our data, it is the white, not black, grayling that is isotopically heavier. This suggests that some specimens, all collected from local fishermen, could have been misidentified.

However, one perhaps should not be too perplexed by the confusion created by the grayling results. The two subspecies, black and white graylings, are defined primarily based on the differences in habitat preferences facilitated locally and secondarily based on morphology (Kozhov, 1963, 1972). What is important is that based on  $\delta^{13}\text{C}$  values the graylings do sort themselves into two very distinct clusters (4–5‰ apart) in a manner that is entirely consistent with our predictions. Kozhov (1972) notes similar habitat separation for the perch and burbot, the former visible too in our data from Bol'shie Koty. In fact,  $\delta^{13}\text{C}$  analysis may be viewed as a more reliable approach to subspecies identification, or habitat preferences, than the morphological criteria. And what is perhaps even more important is that the fishes harvested by middle Holocene foragers near the shore at open coast locations, such as Bol'shie Koty, and at coves of the Little Sea gulf, would pass their variability in  $\delta^{13}\text{C}$  values onto humans.

In regards to the variability in  $\delta^{15}\text{N}$  values, this much larger sample of aquatic fauna from Baikal provides data (Tables 4 and 5) that are consistent with our previous findings (Weber et al., 2002) as summarized earlier in the paper (Section 3). A few of the analyzed fish species are mainly detritivorous or plantivorous, most are omnivorous, and some are predominantly piscivorous. The trophic level indices range from 2.5 to 2.8 for the roach, Prussian carp, and dace, from 3.0 to 3.8 for the ide, grayling, lenok, omul', sturgeon, and whitefish, and from 3.2 to 4.5 for the burbot, perch, pike, and taimen. Some of the rarer species (e.g., burbot and taimen) have not been analyzed but their  $\delta^{15}\text{N}$  values are expected to be similar to that of pike. The single result obtained for the sturgeon, showing the highest among the Baikal fish specimens  $\delta^{15}\text{N}$  value of 14.1‰, needs confirmation via more tests. The only aquatic fauna that has scored with consistency  $\delta^{15}\text{N}$  values in the 13–15‰ range is the seal, an aquatic mammal feeding almost exclusively on a few species of Baikal pelagic sculpins (Table 4; Pastukhov, 1993, pp. 171–185).

#### 4.2.4. Results – Angara

It is unsurprising that the data obtained for the Angara fishes do not bear out our predictions, which, to be sure, relate to the situation prior to the industrial development of the river (Tables 4 and 5a, Fig. 2c). Construction of three dams (Irkutsk, Bratsk, and Ilmsk) irreversibly changed the bathymetry, ecology, and primary productivity of the Angara as well as fish abundance, migration, and distribution patterns. Pollution from urban centers, agriculture, and heavy industry along the river is another major anthropogenic factor to reckon with, particularly regarding the  $\delta^{15}\text{N}$  results. In this context, the  $\delta^{13}\text{C}$  values of most of the analyzed specimens may be lighter than prior to the damming and the  $\delta^{15}\text{N}$  signatures, while generally consistent with the species' trophic level position, appear to be too heavy in a few instances. Overall, this material provides less assistance in the interpretation of the archaeological data. Notably, the signatures obtained for the grayling and lenok, both heavier on the  $\delta^{13}\text{C}$  scale than the rest of the Angara specimens, generally meet the model expectations.

#### 4.2.5. Results – Lena

Although the reference sample from the Lena River is small, it is nonetheless informative (Tables 4 and 5a, Fig. 2c). First, due to the low primary productivity of the Lena's upper section, all specimens display very light  $\delta^{13}\text{C}$  values. And second, the lenok from the Lena is lighter relative to the lenok from Bol'shie Koty on Lake Baikal and from the Angara where primary productivity is higher than on the Lena.



#### 4.2.6. Guidelines for understanding human $\delta^{13}\text{C}$ values

Based on these data, it is possible to make the following three predictions with regard to the range of  $\delta^{13}\text{C}$  signatures in humans depending on the location of fishing activities:

- (1) A narrow range of  $\delta^{13}\text{C}$  values is expected if fishing involved locations with access only to open coast fisheries.
- (2) Potentially wider if practiced in coves of the Little Sea gulf.
- (3) Wider still if done in locations allowing access to both habitats.

Combining the shallow water group from Bol'shie Koty (the deep water fishes unlikely a target of middle Holocene fishing at open coast locations) with the Little Sea sample gives  $\sim 10\text{‰}$  range (from  $-10\text{‰}$  to  $-20\text{‰}$ ), and including the seal extends the range even further toward the light end (Fig. 3). In sum, the potential for substantial variability along the carbon axis in humans harvesting Lake Baikal fauna is quite evident.

Comparing the results for the two locations (Fig. 3, Table 5) shows that the light end for the Bol'shie Koty sample is  $\sim 5\text{‰}$  lighter than for the Little Sea sample, the heavy ends are marked by similar  $\delta^{13}\text{C}$  values (c.  $-10\text{‰}$ ) representing a few of the same species (perch and grayling). The omul' from Bol'shie Koty is lighter than the Little Sea population, graylings at either location form two clusters separated by  $\sim 5\text{‰}$ , and the variability range in  $\delta^{13}\text{C}$  values for the Little Sea sample ( $10.6\text{‰}$ ) is twice that recorded for either of the two Bol'shie Koty groups ( $4.5\text{‰}$  and  $5.6\text{‰}$ ). Lastly, stable isotope results for the Baikal seal, the highly migratory inhabitant of the pelagic niche throughout the entire lake (only for convenience presented with the fish sample collected at Bol'shie Koty) fit with the isotopically light group at this locality (Fig. 3a, Table 5c).

It is worth noting that an offset in  $\delta^{13}\text{C}$  values due to the combustion of fossil fuels is applicable both to the terrestrial and aquatic ecosystems. Based on examination of Baikal omul' scales collected from museum specimens, Ogawa et al. (2000) and YOSHII et al. (1999) reported a decrease between 1947 and 1995 in  $\delta^{13}\text{C}$  values from  $-21.7\text{‰}$  to  $-23.3\text{‰}$ , a drop of  $\sim 1.6\text{‰}$ . However, our own tests on the Baikal seal do not seem to show similar offset although the modern sample is small (Table 5).

## 5. Human diets in the Baikal region

Of the two main approaches to the examination of the human data, i.e., chronological and geographic, which involve, respectively, analysis of each culture historical period and each micro-region separately, the geographic focus is preferred for the following reasons. First, the aquatic foods in the Baikal region display substantial regional variability. Second, one of the main goals of this examination is to gain new insights about foraging ranges, migrations, and travel between the different areas of the Baikal region. Third, a strong imprint of local diets was recently demonstrated in two samples (Khuzhir-Nuge XIV and Kurma XI) from the Little Sea micro-region (Katzenberg et al., 2009, 2010; Weber, in press). Finally, initial assessment of scatter plots of all human data suggests that in each micro-region different diets may have been in use. The focus of this examination is on adults ( $n = 276$ ) and older sub-adults ( $n = 35$ ) whose stable isotope signatures probably do not show the effects of breastfeeding in infancy. Infant diets are the subject of a forthcoming study by Waters-Rist et al. (in press). For the record, however, all results are presented in Tables 6–9.

As before, it is useful to precede analysis with a few predictions:

- (1) Existence of any differences along the  $\delta^{13}\text{C}$  vector between the various units of analysis identified in the human data set, spatial or temporal, would have to be the consequence

of differential contribution of the aquatic foods rather than of the ungulates, the latter showing very limited variability in this regard.

- (2) Existence of any differences on the  $\delta^{15}\text{N}$  scale would have to be the consequence of differential balance between the following three food groups: ungulates ( $\delta^{15}\text{N} \sim 3\text{–}7\text{‰}$ ), fishes ( $\delta^{15}\text{N} \sim 6\text{–}13\text{‰}$ ) and Baikal seal ( $\delta^{15}\text{N} \sim 12\text{–}16\text{‰}$ ).
- (3) Since the aquatic foods show generally much higher  $\delta^{15}\text{N}$  values than the ungulates, lower  $\delta^{15}\text{N}$  signatures in humans suggest diets with more ungulate meat, while those with higher  $\delta^{15}\text{N}$  values imply diets with more aquatic food.
- (4) In a model of 'perfect mixing', or extensive foraging by the middle Holocene hunter-gatherers throughout the entire Baikal region – not an unlikely scenario considering the distances involved and the lack of major geographic obstacles – all human samples should essentially form a relatively tight cluster within the stable isotope variability space.
- (5) Any significant departures from the 'perfect mixing' model will have to be considered an evidence for foraging ranges smaller than the whole region.

The next group of predictions regards the qualitative aspects of food procurement, mostly game hunting and fishing, during the Baikal middle Holocene (Weber and Bettinger, 2010). Clearly, some combination of the ungulates would have been available within any of the smaller areas of the Baikal region. Although the archaeological data do not have enough detail to assess any spatial differences in relative abundances of the harvested species (e.g., moose relative to roe and red deer) or the seasonality and hunting techniques, such information is not necessary for this analysis to proceed.

However, due to the differential spatial distribution of various aquatic resources, particularly in Lake Baikal, a few comments on the fishing technology will be useful. Hooks, harpoons, and nets are all confirmed archaeologically and weirs, traps and fences are not but all could be used, although with varying success, in all three aquatic systems (Novikov and Goriunova, 2005; Weber and Bettinger, 2010). Ice fishing could have been used everywhere too although this technique is not very efficient. Simple watercraft technology may have been employed as suggested by the indirect evidence from human bone morphology (Stock et al., 2010) and musculoskeletal stress markers (Lieverse et al., 2009, 2011). But a more intensive use of boats currently lacks support in other kinds of cultural traits one would expect to appear in the archaeological record (e.g., storage, larger camps with more durable housing) had watercraft technology reached a critical point at which its economic impact would have been significant (Ames, 2002). Together, any configuration of these harvesting techniques would likely sample all species available in the Angara and Lena but not so in Baikal where the fishes sort themselves into various habitats, some (cove-and-lagoon) more accessible than others (open coast littoral, gulf, and estuaries), and some not accessible at all (pelagic).

Recent examination of middle Holocene fishing in the shallow coves of the Little Sea (Losey et al., 2008; Nomokonova et al., 2006, 2009a,b) demonstrated that the cove-and-lagoon perch (65%) and cyprinids (28%, roach and dace) made up 93% of the catch, the remaining proportion consisting of *Coregonidae* (omul' and whitefish) and pike (5% and 2%, respectively). The size range of the perch was narrow and limited to adult specimens (20–30 cm long) suggesting the use of nets deployed likely close to the shore. The perch size range was consistent throughout all Mesolithic and Neolithic layers implying no changes to the harvesting approach and, perhaps, no significant pressure on the resource. These findings confirm also the lack of employment of watercraft in fishing which would allow better access to the lake's deeper waters. Overall, it is quite realistic to assume that all middle Holocene

Table 6

Human archaeological and geochemical data from the Angara valley.

No.	Cemetery name	Master ID	Archaeological age	Sex	Age of individual	HSAMP ID	C/N	Coll. yield	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	Reference
1	Lokomotiv	LOK_1980.002.01	Early Neolithic	Female	20–25 years	1992.008	3.2	8.7	-14.7	15.2	Weber et al. (2002)
2	Lokomotiv	LOK_1980.002.02	Early Neolithic	Undetermined	35–39 years	1992.009	3.2	11.0	-16.3	13.9	
3	Lokomotiv	LOK_1980.002.04	Early Neolithic	Undetermined	25–35 years	2001.272	3.1	8.9	-16.2	13.9	
4	Lokomotiv	LOK_1980.004	Early Neolithic	Female	25–35 years	1992.011	3.3	7.6	-15.9	14.3	Weber et al. (2002)
5	Lokomotiv	LOK_1980.007	Early Neolithic	Female	35–50 years	1992.012	3.3	15.7	-15.3	14.8	Weber et al. (2002)
6	Lokomotiv	LOK_1980.008	Early Neolithic	Female	35–50 years	1992.013	3.3	19.3	-15.0	14.9	Weber et al. (2002)
7	Lokomotiv	LOK_1980.009	Early Neolithic	Female	20+ years	2001.112	3.6	3.8	-17.1	12.9	
8	Lokomotiv	LOK_1980.010.01	Early Neolithic	Male	20–25 years	1992.015	3.2	17.8	-15.2	14.9	
9	Lokomotiv	LOK_1980.010.02	Early Neolithic	Male	20–25 years	1992.016	3.1	6.3	-15.2	14.7	
10	Lokomotiv	LOK_1980.010.03	Early Neolithic	Female	50+ years	1992.017	3.1	15.5	-14.8	15.1	Weber et al. (2002)
11	Lokomotiv	LOK_1980.010.04	Early Neolithic	Male	30–35 years	2001.233	3.1	8.8	-15.6	14.6	
12	Lokomotiv	LOK_1980.011	Early Neolithic	Male	50+ years	1992.019	3.1	15.5	-14.7	15.1	Weber et al. (2002)
13	Lokomotiv	LOK_1980.012	Early Neolithic	Female	18–22 years	2001.230	3.1	15.1	-15.5	14.2	
14	Lokomotiv	LOK_1980.014.01	Early Neolithic	Male	50+ years	1992.021	3.2	20.9	-14.7	14.7	Weber et al. (2002)
15	Lokomotiv	LOK_1980.014.03	Early Neolithic	Undetermined	10–11 years	2001.247	3.2	14.0	-15.9	13.6	
16	Lokomotiv	LOK_1980.014.04	Early Neolithic	Male	19–22 years	1992.024	3.1	18.8	-16.2	14.0	
17	Lokomotiv	LOK_1980.015	Early Neolithic	Male	20–35 years	1992.025	3.3	1.5	-15.2	14.4	
18	Lokomotiv	LOK_1980.016	Early Neolithic	Male	45–55 years	2001.238	3.2	18.1	-15.2	14.4	
19	Lokomotiv	LOK_1980.017	Early Neolithic	Male	35–50 years	1992.027	3.1	18.3	-15.6	14.2	Weber et al. (2002)
20	Lokomotiv	LOK_1980.018	Early Neolithic	Female	20+ years	1992.028	3.2	13.0	-15.7	14.7	Weber et al. (2002)
21	Lokomotiv	LOK_1980.019	Early Neolithic	Male	50+ years	2001.098	3.1	15.1	-15.2	15.0	
22	Lokomotiv	LOK_1980.020.01	Early Neolithic	Female	20–29 years	1992.030	3.1	14.9	-15.3	13.7	
23	Lokomotiv	LOK_1980.020.02	Early Neolithic	Male	35–50 years	2001.089	3.1	17.4	-15.4	13.9	
24	Lokomotiv	LOK_1980.021	Early Neolithic	Female	50+ years	1992.032	3.6	17.1	-14.7	15.3	Weber et al. (2002)
25	Lokomotiv	LOK_1981.013	Early Neolithic	Male	25–30 years	2001.139	3.2	6.7	-16.2	15.1	
26	Lokomotiv	LOK_1981.023	Early Neolithic	Male	20–25 years	1992.039	3.2	7.2	-15.4	14.4	
27	Lokomotiv	LOK_1981.024.01	Early Neolithic	Undetermined	12–15 years	1992.040	3.1	15.4	-15.3	13.8	
28	Lokomotiv	LOK_1981.024.02	Early Neolithic	Male	40–45 years	2001.324	3.1	15.5	-15.0	14.7	
29	Lokomotiv	LOK_1981.024.04	Early Neolithic	Undetermined	7.5–11.5 years	2001.151	3.2	7.1	-14.7	14.5	
30	Lokomotiv	LOK_1981.024.05	Early Neolithic	Male	25–35 years	1992.044	3.3	10.8	-16.1	13.9	Weber et al. (2002)
31	Lokomotiv	LOK_1981.024.06	Early Neolithic	Undetermined	7–10 years	2001.110	3.2	13.6	-15.7	14.0	
32	Lokomotiv	LOK_1981.025.02	Early Neolithic	Female	20–22 years	1992.047	3.2	2.2	-15.4	14.3	
33	Lokomotiv	LOK_1981.025.03	Early Neolithic	Probable Female	25–35 years	1992.048	3.2	8.3	-15.2	14.5	
34	Lokomotiv	LOK_1981.025.04	Early Neolithic	Male	35–45 years	1992.049	3.1	17.3	-18.3	11.7	
35	Lokomotiv	LOK_1983.026	Early Neolithic	Male	20+ years	1992.050	3.2	5.3	-15.6	14.5	
36	Lokomotiv	LOK_1984.027	Early Neolithic	Male	15–18 years	2001.262	3.2	11.6	-16.8	13.3	
37	Lokomotiv	LOK_1984.028	Early Neolithic	Female	35–40 years	2001.257	3.1	13.3	-16.1	14.1	
38	Lokomotiv	LOK_1984.029	Early Neolithic	Probable Female	30–40 years	2001.220	3.2	9.8	-15.6	14.2	
39	Lokomotiv	LOK_1985.030.02	Early Neolithic	Male	35–40 years	1992.055	3.1	10.5	-15.9	13.9	
40	Lokomotiv	LOK_1985.031.01	Early Neolithic	Female	20+ years	1992.056	3.1	17.8	-16.2	14.2	Weber et al. (2002)
41	Lokomotiv	LOK_1985.031.02	Early Neolithic	Male	25–30 years	1992.057	3.1	14.0	-16.9	13.1	
42	Lokomotiv	LOK_1985.033	Early Neolithic	Male	35–50 years	1992.058	3.1	8.8	-15.9	14.2	Weber et al. (2002)
43	Lokomotiv	LOK_1985.034	Early Neolithic	Female	35–45 years	2001.115	3.2	8.2	-15.9	14.3	
44	Lokomotiv	LOK_1985.035	Early Neolithic	Undetermined	20+ years	2001.166	3.1	4.2	-15.4	14.9	
45	Lokomotiv	LOK_1985.036	Early Neolithic	Female	20–25 years	2001.264	3.2	14.7	-15.8	14.5	
46	Lokomotiv	LOK_1986.037	Early Neolithic	Female	25–29 years	2001.188	3.1	14.1	-15.9	14.5	
47	Lokomotiv	LOK_1988.038.01	Early Neolithic	Female	50+ years	2001.363	3.1	15.5	-14.7	14.7	
48	Lokomotiv	LOK_1988.038.02	Early Neolithic	Female	35–45 years	2001.365	3.2	14.5	-15.9	14.6	
49	Lokomotiv	LOK_1988.039	Early Neolithic	Female	20–25 years	1992.065	3.3	12.7	-15.6	14.6	Weber et al. (2002)
50	Lokomotiv	LOK_1990.040	Early Neolithic	Male	20+ years	2001.334	3.1	17.7	-16.1	13.6	
51	Lokomotiv	LOK_1990.041.01	Early Neolithic	Female	15–20 years	1992.067	3.1	12.8	-16.3	13.2	
52	Lokomotiv	LOK_1990.041.03	Early Neolithic	Undetermined	20+ years	1992.069	3.0	6.9	-16.2	13.6	
53	Lokomotiv	LOK_1990.042	Early Neolithic	Male	35–50 years	1992.070	3.3	10.9	-15.7	14.6	Weber et al. (2002)
54	Lokomotiv	LOK_1990.043.02	Early Neolithic	Female	35–50 years	1992.071	3.0	14.2	-14.9	14.6	Weber et al. (2002)
55	Lokomotiv	LOK_1990.044.01	Early Neolithic	Male	35–39 years	2001.254	3.1	12.7	-15.5	14.1	
56	Lokomotiv	LOK_1990.044.02	Early Neolithic	Male	30–39 years	1992.073	3.1	13.2	-15.7	13.8	
57	Lokomotiv-Raisovet	LOR_1980.001	Early Neolithic	Male	30–34 years	2001.267	3.1	13.7	-15.8	14.4	
58	Lokomotiv-Raisovet	LOR_1980.003.01	Early Neolithic	Male	30–35 years	1992.001	3.2	11.0	-16.7	12.8	
59	Lokomotiv-Raisovet	LOR_1991.006.01	Early Neolithic	Male	35–39 years	1992.003	3.2	12.8	-15.8	14.0	
60	Lokomotiv-Raisovet	LOR_1991.006.02	Early Neolithic	Male	50+ years	1992.004	3.3	18.0	-15.6	15.1	Weber et al. (2002)
61	Lokomotiv-Raisovet	LOR_1991.007.01	Early Neolithic	Male	50+ years	1992.006	3.4	7.8	-15.1	14.2	Weber et al. (2002)
62	Lokomotiv-Raisovet	LOR_1991.007.02	Early Neolithic	Female	15–20 years	1992.007	3.1	19.5	-18.9	11.9	
63	Lokomotiv-Raisovet	LOR_1997.009	Early Neolithic	Undetermined	6–7 years	2001.307	3.1	14.0	-15.9	13.3	
64	Lokomotiv-Raisovet	LOR_1997.011	Early Neolithic	Female	20–25 years	2001.283	3.2	9.5	-15.1	14.6	
65	Lokomotiv-Raisovet	LOR_1997.011	Early Neolithic	Female	20–25 years	2001.284	3.2	8.4	-16.3	14.7	
66	Lokomotiv-Raisovet	LOR_1998.012	Early Neolithic	Undetermined	10–12 years	2001.293	3.1	11.1	-15.2	13.4	
67	Lokomotiv-Raisovet	LOR_1998.013.01	Early Neolithic	Undetermined	6–8 years	2001.300	3.1	11.1	-15.8	13.8	
68	Lokomotiv-Raisovet	LOR_1998.013.02	Early Neolithic	Undetermined	8–12 years	2001.297	3.1	11.4	-16.2	13.7	
69	Lokomotiv-Raisovet	LOR_1998.013.03	Early Neolithic	Female	25–35 years	2001.291	3.1	8.2	-16.3	13.6	
70	Lokomotiv-Raisovet	LOR_1998.013.04	Early Neolithic	Female	20–25 years	2001.226	3.2	6.1	-16.4	13.3	
71	Lokomotiv-Raisovet	LOR_998.014	Early Neolithic	Male	30–39 years	2001.120	3.2	5.2	-15.4	14.2	
72	Lokomotiv-Raisovet	LOR_998.015.01	Early Neolithic	Female	20–35 years	2001.303	3.2	16.5	-16.9	13.1	
73	Ust' Belaia	UBE_1962.005	Early Neolithic	Undetermined	20+ years	1992.119	3.2	16.6	-17.4	13.2	Weber et al. (2002)
74	Ust' Belaia	UBE_1962.008	Early Neolithic	Undetermined	20+ years	1992.121	3.3	9.2	-16.9	13.6	Weber et al. (2002)
75	Ust' Belaia	UBE_1962.009.00	Early Neolithic	Undetermined	20+ years	1992.122	3.3	8.9	-16.8	13.9	Weber et al. (2002)

(continued on next page)

Table 6 (continued)

No.	Cemetery name	Master ID	Archaeological age	Sex	Age of individual	HSAMP ID	C/N	Coll. yield	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	Reference
76	Kitoi	KIT_0000.000	Early Neolithic	Undetermined	20+ years	1997.275	3.3	14.7	-17.3	14.5	
77	Ust' Ida	UID_1987.001.01	Late Neolithic	Female	20+ years	1992.074	3.4	19.1	-19.9	8.9	Weber et al. (2002)
78	Ust' Ida	UID_1987.005	Late Neolithic	Undetermined	7–9 years	1992.077	3.3	17.8	-17.5	12.3	
79	Ust' Ida	UID_1987.006	Late Neolithic	Male	35–50 years	1992.078	3.3	13.5	-17.4	11.7	
80	Ust' Ida	UID_1987.010	Late Neolithic	Undetermined	7.5–11.5 years	1992.082	3.2	21.5	-17.7	12.2	Weber et al. (2002)
81	Ust' Ida	UID_1987.011	Late Neolithic	Female	35–50 years	2001.169	3.3	14.7	-18.0	11.1	
82	Ust' Ida	UID_1987.012	Late Neolithic	Male	50+ years	1992.084	3.1	21.9	-18.3	11.5	Weber et al. (2002)
83	Ust' Ida	UID_1988.014	Late Neolithic	Male	18–20 years	1992.085	3.2	14.1	-18.1	11.0	
84	Ust' Ida	UID_1988.016.01	Late Neolithic	Male	25–35 years	1992.087	3.2	17.2	-18.8	11.7	
85	Ust' Ida	UID_1988.016.02	Late Neolithic	Male	50+ years	1992.088	3.3	23.2	-19.2	11.5	Weber et al. (2002)
86	Ust' Ida	UID_1988.018	Late Neolithic	Undetermined	11–13 years	1992.090	3.2	21.7	-18.3	11.7	
87	Ust' Ida	UID_1989.020.01	Late Neolithic	Male	18–24 years	1991.053	3.2	15.9	-17.2	12.7	
88	Ust' Ida	UID_1989.020.02	Late Neolithic	Female	20–40 years	2001.182	3.3	16.8	-17.7	11.1	
89	Ust' Ida	UID_1989.022	Late Neolithic	Female	15–20 years	1992.095	3.3	21.6	-18.7	11.7	Weber et al. (2002)
90	Ust' Ida	UID_1989.025.03	Late Neolithic	Undetermined	7.5–11.5 years	2001.203	3.3	14.5	-18.0	11.6	
91	Ust' Ida	UID_1989.026.01	Late Neolithic	Undetermined	13–15 years	2001.191	3.3	18.8	-17.5	11.3	
92	Ust' Ida	UID_1989.026.04	Late Neolithic	Undetermined	10–12 years	2001.134	3.3	18.0	-17.6	11.9	
93	Ust' Ida	UID_1989.030	Late Neolithic	Female	50+ years	2001.122	3.2	19.1	-18.8	11.9	
94	Ust' Ida	UID_1989.031	Late Neolithic	Undetermined	10–12 years	1992.108	3.3	17.0	-18.0	12.0	
95	Ust' Ida	UID_1989.032	Late Neolithic	Undetermined	8–10 years	2001.196	3.1	18.7	-18.5	11.0	
96	Ust' Ida	UID_1989.032	Late Neolithic	Undetermined	7.5–11.5 years	1992.109	3.2	20.0	-18.1	11.4	Weber et al. (2002)
97	Ust' Ida	UID_1990.033.02	Late Neolithic	Undetermined	13–16 years	2001.218	3.3	17.7	-17.5	11.7	
98	Ust' Ida	UID_1991.036.02	Late Neolithic	Female	30–40 years	2001.339	3.2	19.9	-17.9	11.3	
99	Ust' Ida	UID_1993.044.01	Late Neolithic	Undetermined	9–10 years	2001.341	3.3	17.4	-17.4	12.5	
100	Ust' Ida	UID_1993.044.03	Late Neolithic	Undetermined	11–12 years	2001.137	3.3	16.8	-17.0	12.6	
101	Ust' Ida	UID_1994.052	Late Neolithic	Female	60+ years	2001.332	3.3	18.9	-16.5	12.8	
102	Ust' Ida	UID_1994.053.01	Late Neolithic	Undetermined	9.5–11.5 years	2001.194	3.3	7.7	-17.0	12.3	
103	Ust' Ida	UID_1994.054	Late Neolithic	Male	50+ years	1995.007	3.1	17.3	-17.9	12.5	
104	Ust' Ida	UID_1994.055.02	Late Neolithic	Male	15–18 years	2001.357	3.3	16.1	-17.3	11.6	
105	Ust' Ida	UID_1995.056.01	Late Neolithic	Male	35–50 years	2001.184	3.3	17.2	-17.5	12.4	
106	Ust' Ida	UID_1985.056.02	Late Neolithic	Undetermined	9–11 years	2001.370	3.3	14.7	-18.6	11.1	
107	Ust' Ida	UID_1987.007	Early Bronze Age	Male	20+ years	2001.127	3.3	12.9	-17.4	12.2	
108	Ust' Ida	UID_1989.019	Early Bronze Age	Male	30–35 years	1992.091	3.3	15.7	-18.7	12.3	
109	Ust' Ida	UID_1989.029	Early Bronze Age	Male	50+ years	1992.106	3.3	15.6	-17.3	11.8	
110	Ust' Ida	UID_1991.037	Early Bronze Age	Female	35–50 years	1992.112	3.3	23.0	-19.6	10.0	Weber et al. (2002)
111	Ust' Ida	UID_1991.039	Early Bronze Age	Female	25–35 years	2001.330	3.3	13.3	-17.9	11.7	
112	Ust' Ida	UID_1991.040.01	Early Bronze Age	Female	25–35 years	1992.115	3.4	19.0	-21.0	9.2	Weber et al. (2002)
113	Ust' Ida	UID_1991.042	Early Bronze Age	Female	50+ years	1992.117	3.2	21.8	-20.5	11.4	Weber et al. (2002)
114	Ust' Ida	UID_1993.045	Early Bronze Age	Male	25–35 years	1993.070	3.2	21.4	-19.3	11.3	
115	Ust' Ida	UID_1994.047	Early Bronze Age	Male	30–40 years	1994.004	3.3	12.8	-18.6	10.9	
116	Ust' Ida	UID_1994.049	Early Bronze Age	Probable Female	20+ years	2001.117	3.3	15.8	-17.8	11.7	
117	Ust' Ida	UID_1994.051	Early Bronze Age	Male	20+ years	1995.003	3.3	14.7	-17.7	12.0	
118	Lokomotiv	LOK_1980.005	Early Bronze Age	Undetermined	9–11 years	2001.273	3.4	4.9	-18.0	12.5	
119	Ust' Belaia	UBE_1987.002	Early Bronze Age	Undetermined	20+ years	1992.123	3.2	21.2	-19.2	11.1	Weber et al. (2002)
<i>Infants or young children</i>											
120	Lokomotiv-Raisovet	LOR_1982.005	Early Neolithic	Undetermined	-0.5–0 years	1992.002	3.2	19.4	-20.4	19.1	Weber et al. (2002)
121	Lokomotiv-Raisovet	LOR_1991.007.03	Early Neolithic	Undetermined	2–3 years	1992.005	3.3	16.1	-16.1	14.4	Weber et al. (2002)
122	Lokomotiv-Raisovet	LOR_1997.010	Early Neolithic	Undetermined	3–4 years	2001.285	3.1	11.4	-15.6	14.0	
123	Lokomotiv	LOK_1981.024.03	Early Neolithic	Undetermined	4–7 years	1992.042	3.2	15.2	-15.0	14.2	Weber et al. (2002)
124	Lokomotiv	LOK_1990.041.02	Early Neolithic	Undetermined	4–7.5 years	1992.068	3.2	19.1	-16.7	13.9	Weber et al. (2002)
125	Ust' Ida	UID_1989.026.02	Late Neolithic	Undetermined	0.5–2 years	1992.101	3.1	19.3	-18.2	14.6	Weber et al. (2002)
126	Ust' Ida	UID_1987.003.01	Late Neolithic	Undetermined	0–6/7 years	1992.075	3.4	13.0	-17.4	13.0	Weber et al. (2002)
127	Ust' Ida	UID_1994.046	Early Bronze Age	Undetermined	0–6/7 years	1993.071	3.2	15.4	-19.8	12.8	Weber et al. (2002)
128	Ust' Ida	UID_1987.004	Late Neolithic	Undetermined	2–4 years	1992.076	3.4	23.6	-19.2	12.7	Weber et al. (2002)
129	Ust' Ida	UID_1988.017	Late Neolithic	Undetermined	2–4 years	1992.089	3.1	19.4	-17.1	13.7	Weber et al. (2002)
130	Ust' Ida	UID_1989.021.01	Late Neolithic	Undetermined	2–4 years	1992.094	3.1	21.1	-15.0	13.4	Weber et al. (2002)
131	Ust' Ida	UID_1989.026.03	Late Neolithic	Undetermined	2–4 years	1992.102	3.3	18.2	-17.4	10.9	Weber et al. (2002)
132	Ust' Ida	UID_1994.055.01	Late Neolithic	Undetermined	2–4 years	2001.201	3.3	16.5	-17.3	13.3	
133	Ust' Ida	UID_1989.023	Late Neolithic	Undetermined	3.5–5.5 years	2001.213	3.3	17.1	-17.3	11.9	
134	Ust' Ida	UID_1991.036.01	Late Neolithic	Undetermined	3–4 years	2001.145	3.2	17.2	-18.4	12.5	
135	Ust' Ida	UID_1994.053.02	Late Neolithic	Undetermined	4–6 years	2001.165	3.3	18.8	-17.8	11.4	
136	Ust' Ida	UID_1987.008	Late Neolithic	Undetermined	4–7.5 years	1992.080	2.9	18.7	-17.7	11.4	Weber et al. (2002)
137	Ust' Ida	UID_1987.009	Late Neolithic	Undetermined	4–7.5 years	1992.081	3.0	22.0	-17.4	11.5	Weber et al. (2002)
138	Ust' Ida	UID_1988.015	Late Neolithic	Undetermined	4–7.5 years	1992.086	3.1	19.4	-16.3	12.6	Weber et al. (2002)
139	Ust' Ida	UID_1989.025.02	Late Neolithic	Undetermined	4–7.5 years	1992.098	3.2	20.7	-18.0	10.7	Weber et al. (2002)
140	Ust' Ida	UID_1989.026.05	Late Neolithic	Undetermined	4–7.5 years	1992.104	3.1	21.1	-17.4	11.3	Weber et al. (2002)
141	Ust' Ida	UID_1993.044.02	Early Bronze Age	Undetermined	4–7.5 years	1993.068	3.2	23.2	-19.7	11.1	
142	Ust' Ida	UID_1989.021.02	Late Neolithic	Undetermined	5–7 years	2001.373	3.3	15.0	-16.9	12.6	
<i>Individual removed from analysis due to the outlier result (<math>\delta^{15}\text{N}</math>)</i>											
143	Lokomotiv	LOK_1981.025.01	Early Neolithic	Female	35–40 years	1992.046	3.2	1.7	-14.8	6.4	
<i>Results removed from analysis due to the C/N ratio outside of the acceptable 2.9–3.6 range</i>											
144	Ust' Ida	UID_1989.025.03	Late Neolithic	Undetermined	7.5–11.5 years	1992.099	2.4	20.7	-18.3	10.3	Weber et al. (2002)



**Table 7**  
zHuman archaeological and geochemical data from the Little Sea.

No.	Cemetery name	Master ID	Archaeological age	Sex	Age of individual	HSAMP ID	C/N	Coll. yield	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	Diet	Reference
1	Kurma XI	KUR_2003.022	Early Neolithic	Probable Female	50+ years	2003.027	3.3	8.2	-19.0	12.0	GF	Katzenberg et al. (in press)
2	Khuzhir-Nuge XIV	K14_1997.007	Late Neolithic	Probable Male	25–25 years	1997.198	3.6	4.9	-19.6	11.9	GF	Katzenberg et al. (2009)
3	Khuzhir-Nuge XIV	K14_1998.027.01	Early Bronze Age	Male	35–50 years	1998.387	3.5	6.2	-19.7	11.8	GF	Katzenberg et al. (2009)
4	Khuzhir-Nuge XIV	K14_1998.028	Early Bronze Age	Female	20+ years	1998.307	3.4		-19.1	12.7	GF	Katzenberg et al. (2009)
5	Khuzhir-Nuge XIV	K14_1998.032	Early Bronze Age	Female	50+ years	1998.310	3.4	3.1	-19.5	11.6	GF	Katzenberg et al. (2009)
6	Khuzhir-Nuge XIV	K14_1998.034	Early Bronze Age	Male	25–35 years	1998.390	3.4	6.0	-19.8	11.9	GF	Katzenberg et al. (2009)
7	Khuzhir-Nuge XIV	K14_1998.035.01	Early Bronze Age	Male	18–20 years	2001.597	3.3	4.3	-19.6	11.7	GF	Katzenberg et al. (2009)
8	Khuzhir-Nuge XIV	K14_1998.035.02	Early Bronze Age	Undetermined	8–10 years	1998.313	3.3	5.0	-19.4	11.4	GF	Katzenberg et al. (2009)
9	Khuzhir-Nuge XIV	K14_1998.036.01	Early Bronze Age	Undetermined	35–50 years	1998.325	3.3	19.8	-19.1	12.8	GF	Katzenberg et al. (2009)
10	Khuzhir-Nuge XIV	K14_1998.037.01	Early Bronze Age	Undetermined	14–17 years	1998.320	3.4	7.4	-19.4	11.5	GF	Katzenberg et al. (2009)
11	Khuzhir-Nuge XIV	K14_1998.037.02	Early Bronze Age	Undetermined	14–17 years	1998.393	3.3	4.7	-19.5	11.4	GF	Katzenberg et al. (2009)
12	Khuzhir-Nuge XIV	K14_1999.059.01	Early Bronze Age	Undetermined	35–50 years	1999.148	3.6	8.1	-20.0	11.0	GF	Katzenberg et al. (2009)
13	Khuzhir-Nuge XIV	K14_2000.061	Early Bronze Age	Undetermined	20+ years	2000.160	3.3	5.4	-19.1	12.1	GF	Katzenberg et al. (2009)
14	Khuzhir-Nuge XIV	K14_2000.066	Early Bronze Age	Male	35–50 years	2000.152	3.3	14.6	-19.3	11.1	GF	Katzenberg et al. (2009)
15	Khuzhir-Nuge XIV	K14_2000.070	Early Bronze Age	Undetermined	35–50 years	2000.155	3.3	14.1	-19.0	10.7	GF	Katzenberg et al. (2009)
16	Khuzhir-Nuge XIV	K14_2000.071	Early Bronze Age	Undetermined	12–15 years	2000.147	3.4	10.0	-18.9	12.6	GF	Katzenberg et al. (2009)
17	Khuzhir-Nuge XIV	K14_2000.077	Early Bronze Age	Undetermined	12–15 years	2000.169	3.4	1.6	-19.3	10.3	GF	Katzenberg et al. (2009)
18	Khuzhir-Nuge XIV	K14_2000.080.01	Early Bronze Age	Undetermined	Undetermined	2000.122	3.4	0.2	-19.4	11.8	GF	Katzenberg et al. (2009)
19	Khuzhir-Nuge XIV	K14_2001.081	Early Bronze Age	Male	35–50 years	2001.617	3.3	1.6	-19.2	12.6	GF	Katzenberg et al. (2009)
20	Khuzhir-Nuge XIV	K14_2001.082	Early Bronze Age	Undetermined	20–25 years	2001.610	3.3	8.9	-19.4	12.3	GF	Katzenberg et al. (2009)
21	Khuzhir-Nuge XIV	K14_2001.083	Early Bronze Age	Undetermined	20+ years	2001.607	3.6	9.0	-20.1	12.1	GF	Katzenberg et al. (2009)
22	Khuzhir-Nuge XIV	K14_2001.084	Early Bronze Age	Undetermined	13–19 years	2001.611	3.3	11.9	-19.3	11.2	GF	Katzenberg et al. (2009)
23	Khuzhir-Nuge XIV	K14_2001.085	Early Bronze Age	Undetermined	20+ years	2001.609	3.3	10.9	-19.2	12.2	GF	Katzenberg et al. (2009)
24	Khuzhir-Nuge XIV	K14_2001.086	Early Bronze Age	Undetermined	20–25 years	2001.614	3.4	17.9	-19.6	12.3	GF	Katzenberg et al. (2009)
25	Khuzhir-Nuge XIV	K14_2001.087	Early Bronze Age	Male	35–50 years	2001.616	3.6	9.2	-19.4	12.6	GF	Katzenberg et al. (2009)
26	Kurma XI	KUR_2002.001	Early Bronze Age	Male	25–30 years	2002.110	3.2	10.3	19.5	11.5	GF	Katzenberg et al. (in press)
27	Kurma XI	KUR_2002.009	Early Bronze Age	Undetermined	20+ years	2002.151	3.2	12.3	-19.7	12.6	GF	Katzenberg et al. (in press)
28	Kurma XI	KUR_2002.012	Early Bronze Age	Undetermined	20+ years	2002.127	3.2	11.0	-19.8	11.7	GF	Katzenberg et al. (in press)
29	Kurma XI	KUR_2002.015	Early Bronze Age	Probable Male	17–18 years	2002.135	3.2	13.9	-19.3	12.7	GF	Katzenberg et al. (in press)
30	Kurma XI	KUR_2003.019	Early Bronze Age	Probable Male	20–30 years	2003.012	3.2	5.6	-19.4	11.3	GF	Katzenberg et al. (in press)
31	Sarminskii Mys	SMS_1987.021	Early Bronze Age	Female	20+ years	1994.023	3.3	20.9	-19.5	12.2	GF	Katzenberg et al. (in press)
32	Khotoruk	KHO_1977.003.01	Early Neolithic	Undetermined	20+ years	1991.043	3.5	2.4	-17.0	14.1	GFS	Weber et al. (2002)
33	Kurma XI	KUR_2003.024	Early Neolithic	Probable Female	20–35 years	2003.035	3.5	5.9	-18.0	15.2	GFS	Katzenberg et al. (in press)
34	Shamanskii Mys	SHM_1972.003	Early Neolithic	Undetermined	20+ years	1995.232	3.3	10.8	-18.3	13.7	GFS	Katzenberg et al. (in press)
35	Sarminskii Mys	SMS_1986.011.01	Late Neolithic	Undetermined	8–13 years	1994.008	3.5	5.4	-17.7	16.0	GFS	Katzenberg et al. (in press)
36	Sarminskii Mys	SMS_1986.011.02	Late Neolithic	Male	20–35 years	1994.009	3.4	15.6	-18.3	16.4	GFS	Katzenberg et al. (in press)
37	Sarminskii Mys	SMS_1986.011.04	Late Neolithic	Probable Male	20–35 years	1994.011	3.4	11.0	-17.6	16.1	GFS	Katzenberg et al. (in press)
38	Sarminskii Mys	SMS_1986.019.01	Late Neolithic	Male	14–19 years	1994.013	3.5	36.9	-18.7	15.0	GFS	Katzenberg et al. (in press)
39	Sarminskii Mys	SMS_1986.019.05	Late Neolithic	Female	35–50 years	1994.017	3.4	18.0	-17.6	15.6	GFS	Katzenberg et al. (in press)
40	Sarminskii Mys	SMS_1987.024	Late Neolithic	Male	35–50 years	1994.025	3.5	2.6	-18.7	14.9	GFS	Katzenberg et al. (in press)
41	Khuzhir-Nuge XIV	K14_1997.009	Early Bronze Age	Male	50+ years	1997.199	3.4	6.6	-18.7	14.2	GFS	Katzenberg et al. (2009)
42	Khuzhir-Nuge XIV	K14_1997.010	Early Bronze Age	Undetermined	20–25 years	1997.200	3.4	5.2	19.0	13.8	GFS	Katzenberg et al. (2009)
43	Khuzhir-Nuge XIV	K14_1997.011	Early Bronze Age	Male	35–50 years	1997.201	3.3	8.9	-18.3	15.6	GFS	Katzenberg et al. (2009)
44	Khuzhir-Nuge XIV	K14_1997.012	Early Bronze Age	Undetermined	25–35 years	1997.202	3.4	4.8	-18.6	13.6	GFS	Katzenberg et al. (2009)
45	Khuzhir-Nuge XIV	K14_1997.014	Early Bronze Age	Male	35–50 years	1997.203	3.5	5.6	-18.9	14.9	GFS	Katzenberg et al. (2009)
46	Khuzhir-Nuge XIV	K14_1997.015	Early Bronze Age	Male	25–35 years	1997.204	3.4	10.1	-17.7	15.4	GFS	Katzenberg et al. (2009)
47	Khuzhir-Nuge XIV	K14_1997.016	Early Bronze Age	Undetermined	7–9 years	2001.604	3.3	9.4	-17.8	15.5	GFS	Katzenberg et al. (2009)
48	Khuzhir-Nuge XIV	K14_1997.019	Early Bronze Age	Female	35–50 years	1997.206	3.5	3.2	-18.1	15.6	GFS	Katzenberg et al. (2009)
49	Khuzhir-Nuge XIV	K14_1997.023	Early Bronze Age	Undetermined	20+ years	2001.602	3.3	1.5	-17.4	16.1	GFS	Katzenberg et al. (2009)
50	Khuzhir-Nuge XIV	K14_1998.027.02	Early Bronze Age	Undetermined	9–11 years	2001.590	3.3	2.4	-18.0	14.6	GFS	Katzenberg et al. (2009)
51	Khuzhir-Nuge XIV	K14_1998.031	Early Bronze Age	Undetermined	20+ years	1998.309	3.3	14.5	-18.7	14.5	GFS	Katzenberg et al. (2009)
52	Khuzhir-Nuge XIV	K14_1998.038	Early Bronze Age	Male	35–50 years	1998.326	3.4	4.6	-17.7	14.3	GFS	Katzenberg et al. (2009)
53	Khuzhir-Nuge XIV	K14_1998.039	Early Bronze Age	Undetermined	9–11 years	1998.323	3.5	5.1	-18.4	15.6	GFS	Katzenberg et al. (2009)
54	Khuzhir-Nuge XIV	K14_1999.045	Early Bronze Age	Undetermined	8–10 years	1999.155	3.4	5.5	-18.5	14.3	GFS	Katzenberg et al. (2009)
55	Khuzhir-Nuge XIV	K14_1999.046	Early Bronze Age	Male	25–35 years	1999.128	3.4	10.0	-18.1	14.1	GFS	Katzenberg et al. (2009)
56	Khuzhir-Nuge XIV	K14_1999.048	Early Bronze Age	Undetermined	7–9 years	2001.629	3.6	8.9	-18.5	16.5	GFS	Katzenberg et al. (2009)
57	Khuzhir-Nuge XIV	K14_1999.049	Early Bronze Age	Undetermined	50+ years	2001.634	3.3	9.8	-18.4	14.7	GFS	Katzenberg et al. (2009)
58	Khuzhir-Nuge XIV	K14_1999.050	Early Bronze Age	Undetermined	15–18 years	1999.187	3.3	4.4	-17.1	15.6	GFS	Katzenberg et al. (2009)
59	Khuzhir-Nuge XIV	K14_1999.051	Early Bronze Age	Male	18–20 years	1999.138	3.3	4.6	-17.5	13.5	GFS	Katzenberg et al. (2009)
60	Khuzhir-Nuge XIV	K14_1999.053	Early Bronze Age	Male	35–50 years	1999.144	3.3	2.8	-17.5	15.6	GFS	Katzenberg et al. (2009)
61	Khuzhir-Nuge XIV	K14_1999.055	Early Bronze Age	Male	35–50 years	1999.143	3.4	3.6	-17.8	15.3	GFS	Katzenberg et al. (2009)
62	Khuzhir-Nuge XIV	K14_1999.057.01	Early Bronze Age	Female	18–20 years	1999.182	3.3	14.8	-18.8	14.0	GFS	Katzenberg et al. (2009)
63	Khuzhir-Nuge XIV	K14_1999.057.02	Early Bronze Age	Male	35–50 years	2001.635	3.4	3.7	-18.7	13.7	GFS	Katzenberg et al. (2009)
64	Khuzhir-Nuge XIV	K14_1999.058.01	Early Bronze Age	Undetermined	25–35 years	2001.633	3.2	6.9	-16.7	14.8	GFS	Katzenberg et al. (2009)
65	Khuzhir-Nuge XIV	K14_1999.058.02	Early Bronze Age	Male	35–50 years	1999.181	3.3	5.5	-17.6	14.8	GFS	Katzenberg et al. (2009)
66	Khuzhir-Nuge XIV	K14_1999.059.02	Early Bronze Age	Male	18–20 years	1999.186	3.4	8.5	-18.9	13.9	GFS	Katzenberg et al. (2009)
67	Khuzhir-Nuge XIV	K14_1999.060	Early Bronze Age	Female	50+ years	1999.178	3.5	3.8	-19.1	14.2	GFS	Katzenberg et al. (2009)
68	Khuzhir-Nuge XIV	K14_2000.062.01	Early Bronze Age	Male	20+ years	2000.136	3.3	5.0	-17.1	16.2	GFS	Katzenberg et al. (2009)
69	Khuzhir-Nuge XIV	K14_2000.062.02	Early Bronze Age	Undetermined	8–10 years	2001.631	3.4	6.4	-16.2	15.3	GFS	Katzenberg et al. (2009)
70	Khuzhir-Nuge XIV	K14_2000.063	Early Bronze Age	Undetermined	16–18 years	2000.145	3.4	5.8	-17.9	15.4	GFS	Katzenberg et al. (2009)
71	Khuzhir-Nuge XIV	K14_2000.064	Early Bronze Age	Male	25–35 years	2000.129	3.3	2.6	-17.6	15.4	GFS	Katzenberg et al. (2009)
72	Khuzhir-Nuge XIV	K14_2000.073	Early Bronze Age	Undetermined	20+ years	2000.154	3.3	11.1	-17.9	13.7	GFS	Katzenberg et al. (2009)
73	Khuzhir-Nuge XIV	K14_2000.074	Early Bronze Age	Male	25–35 years	2000.163	3.3	1.0	-17.8	14.9	GFS	Katzenberg et al. (2009)
74	Khuzhir-Nuge XIV	K14_2000.075	Early Bronze Age	Undetermined	20+ years	2000.165	3.3	9.8	-18.6	16.1	GFS	Katzenberg et al. (2009)
75	Khuzhir-Nuge XIV	K14_2000.076	Early Bronze Age	Undetermined	20+ years	2000.120	3.4	8.8	-18.7	15.0	GFS	Katzenberg et al. (2009)
76	Khuzhir-Nuge XIV	K14_2000.078	Early Bronze Age	Undetermined	20+ years	2000.131	3.4	7.3	-17.2	14.9	GFS	Katzenberg et al. (2009)
77	Khuzhir-Nuge XIV	K14_2000.079	Early Bronze Age	Undetermined	20+ years	2000.121	3.5	3.4	-18.5	14.3	GFS	Katzenberg et al. (2009)

(continued on next page)



Table 7 (continued)

No.	Cemetery name	Master ID	Archaeological age	Sex	Age of individual	HSAMP ID	C/N	Coll. yield	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	Diet	Reference
78	Khuzhir-Nuge XIV	K14_2000.080.02	Early Bronze Age	Male	50+ years	2000.125	3.4	3.6	-18.0	13.9	GFS	Katzenberg et al. (2009)
79	Kurma XI	KUR_2002.003	Early Bronze Age	Undetermined	20+ years	2002.130	3.2	13.1	-18.3	15.0	GFS	Katzenberg et al. (in press)
80	Kurma XI	KUR_2002.004	Early Bronze Age	Male	35–44 years	2002.117	3.2	9.2	-15.0	17.4	GFS	Katzenberg et al. (in press)
81	Kurma XI	KUR_2002.005	Early Bronze Age	Undetermined	30–35 years	2002.141	3.2	15.7	-18.4	15.1	GFS	Katzenberg et al. (in press)
82	Kurma XI	KUR_2002.006	Early Bronze Age	Female	20–29 years	2002.113	3.2	5.5	-18.7	14.9	GFS	Katzenberg et al. (in press)
83	Kurma XI	KUR_2002.007.01	Early Bronze Age	Undetermined	20+ years	2002.090	3.2	7.4	-18.4	15.9	GFS	Katzenberg et al. (in press)
84	Kurma XI	KUR_2002.007.02	Early Bronze Age	Male	20–29 years	2002.103	3.2	12.8	-18.5	14.2	GFS	Katzenberg et al. (in press)
85	Kurma XI	KUR_2002.010	Early Bronze Age	Probable Male	18–25 years	2002.101	3.2	6.4	-17.2	15.8	GFS	Katzenberg et al. (in press)
86	Kurma XI	KUR_2002.013	Early Bronze Age	Male	40+ years	2002.122	3.2	10.0	-19.2	14.6	GFS	Katzenberg et al. (in press)
87	Kurma XI	KUR_2002.014	Early Bronze Age	Female	30–39 years	2002.096	3.2	16.2	-19.2	13.2	GFS	Katzenberg et al. (in press)
88	Kurma XI	KUR_2002.016	Early Bronze Age	Probable Female	20–30 years	2002.145	3.2	11.0	-19.3	14.3	GFS	Katzenberg et al. (in press)
89	Kurma XI	KUR_2003.017	Early Bronze Age	Probable Male	20+ years	2003.016	3.2	9.7	-18.3	16.7	GFS	Katzenberg et al. (in press)
90	Kurma XI	KUR_2003.018	Early Bronze Age	Probable Female	17–19 years	2003.006	3.3	9.7	-18.1	15.0	GFS	Katzenberg et al. (in press)
91	Kurma XI	KUR_2003.025	Early Bronze Age	Undetermined	20+ years	2003.041	3.6	3.8	-18.8	15.2	GFS	Katzenberg et al. (in press)
92	Kurma XI	KUR_2003.026	Early Bronze Age	Probable Male	35–50 years	2003.036	3.4	7.1	-18.2	15.2	GFS	Katzenberg et al. (in press)
93	Shamanskii Mys	SHM_1972.001.01	Early Bronze Age	Female	20+ years	1991.023	3.3	21.1	-18.3	14.0	GFS	Weber et al. (2002)
94	Shamanskii Mys	SHM_1972.002	Early Bronze Age	Male	20+ years	1991.003	3.4	20.7	-18.4	13.9	GFS	Weber et al. (2002)
95	Shamanskii Mys	SHM_1973.001	Early Bronze Age	Male	25–35 years	1991.024	3.3	23.0	-17.7	13.7	GFS	Weber et al. (2002)
96	Shamanskii Mys	SHM_1973.002	Early Bronze Age	Female	20+ years	1991.022	3.4	23.2	-18.8	14.5	GFS	Weber et al. (2002)
97	Shamanskii Mys	SHM_1973.003.01	Early Bronze Age	Probable Female	20+ years	1991.002	3.2	15.1	-18.4	14.6	GFS	Weber et al. (2002)
98	Shamanskii Mys	SHM_1973.004	Early Bronze Age	Undetermined	20+ years	1991.021	3.5	16.9	-18.6	14.9	GFS	Weber et al. (2002)
99	Sarminskii Mys	SMS_1986.012	Early Bronze Age	Female	20+ years	1997.002	3.4	6.2	-18.1	15.4	GFS	Katzenberg et al. (in press)
100	Sarminskii Mys	SMS_1986.013	Early Bronze Age	Male	20+ years	1997.003	3.3	15.5	-18.7	14.9	GFS	Katzenberg et al. (in press)
101	Sarminskii Mys	SMS_1987.009	Early Bronze Age	Male	20+ years	1997.001	3.4	3.0	-18.1	16.1	GFS	Katzenberg et al. (in press)
<i>Infants or young children</i>												
102	Khuzhir-Nuge XIV	K14_1998.040	Early Bronze Age	Undetermined	2–3 years	2001.589	3.5	11.8	-18.0	19.1		Katzenberg et al. (2009)
103	Khuzhir-Nuge XIV	K14_1999.047	Early Bronze Age	Undetermined	3–4 years	2001.650	3.4	18.8	-18.4	15.0		Katzenberg et al. (2009)
104	Khuzhir-Nuge XIV	K14_1998.033	Early Bronze Age	Undetermined	3–5 years	2001.591	3.3	3.0	-18.1	15.0		Katzenberg et al. (2009)
105	Khuzhir-Nuge XIV	K14_1998.026	Early Bronze Age	Undetermined	4–6 years	2001.608	3.3	4.4	-18.5	14.2		Katzenberg et al. (2009)
106	Khuzhir-Nuge XIV	K14_1998.027.03	Early Bronze Age	Undetermined	4–6 years	1998.306	3.3	12.6	-18.4	14.5		Katzenberg et al. (2009)
107	Khuzhir-Nuge XIV	K14_1998.036.02	Early Bronze Age	Undetermined	4–6 years	2001.818	3.3	6.5	-19.6	12.7		Katzenberg et al. (2009)
108	Khuzhir-Nuge XIV	K14_2000.065	Early Bronze Age	Undetermined	5–6 years	2001.642	3.5	7.4	-18.5	14.3		Katzenberg et al. (2009)
109	Khuzhir-Nuge XIV	K14_1997.017	Early Bronze Age	Undetermined	5–7 years	2001.600	3.4	3.1	-17.6	14.8		Katzenberg et al. (2009)
110	Sarminskii Mys	SMS_1986.011.03	Late Neolithic	Undetermined	0–7 years	1994.010	3.4	5.9	-17.5	16.3		Katzenberg et al. (in press)
111	Sarminskii Mys	SMS_1987.032	Early Bronze Age	Undetermined	0–7 years	1997.005	3.4	12.8	-19.0	12.2		Katzenberg et al. (in press)
<i>Results removed from analysis due to the C/N ratio outside of the acceptable 2.9–3.6 range</i>												
112	Khuzhir-Nuge XIV	K14_2000.068	Early Bronze Age	Probable Male	25–35 years	2000.135	3.7	1.4	-19.9	12.1		Katzenberg et al. (2009)
113	Khuzhir-Nuge XIV	K14_1997.022	Early Bronze Age	Undetermined	20+ years	1997.235	6.8	1.9	-24.4	13.9		Katzenberg et al. (2009)

hunter–gatherers examined here had essentially similar access to the MN technologies both spatially and temporally, including the MN foragers for which the archaeological record is scant.

Lastly, the Baikal seal could have been harvested by all middle Holocene groups but only on a seasonal basis (winter and early spring) as confirmed by Weber et al. (1993, 1998, 2002). This resource would have been available essentially everywhere on the lake although on a temporal gradient controlled by the ice regime (timing of the freeze-up and break-up) resulting from the generally meridional orientation of Lake Baikal, i.e., longer seal hunting seasons in the north and shorter in the south.

### 5.1. The Angara river valley

As it displays a very distinct pattern, the Angara valley is a good place to begin (Table 6, Fig. 4a and b). Taken as a group, all individuals ( $n = 119$ ) from this micro-region show a high correlation between  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values and a continuous gradient of variability (linear regression:  $\delta^{15}\text{N} = 28.69 + 0.93 \times \delta^{13}\text{C}$ ,  $R^2 = 0.85$ ,  $n = 119$ ). The pattern holds too for the two largest samples from the valley analyzed separately: the EN Lokomotiv (linear regression:  $\delta^{15}\text{N} = 26.19 + 0.77 \times \delta^{13}\text{C}$ ,  $R^2 = 0.66$ ,  $n = 72$ ); and LN–EBA Ust'-Ida cemeteries (linear regression:  $\delta^{15}\text{N} = 23.10 + 0.63 \times \delta^{13}\text{C}$ ,  $R^2 = 0.54$ ,  $n = 41$ ). The EN and LN–EBA distributions are essentially non-overlapping: the former occupies the heavier half while the latter holds the lighter half. Two EN individuals from Lokomotiv fall outside of the distribution for the entire Angara EN sample, fitting with the LN–EBA component of this micro-region (Fig. 4b, Table 6) and the outliers from the EN Shamanka II cemetery on southwest Baikal (Fig. 4d, Table 9).

The pattern of high correlation between carbon and nitrogen values, documented also in a few other aquatic settings (e.g., Eriksson et al., 2008; Kusaka et al., 2008), is best explained by a diet consisting of two main food groups: one characterized by simultaneously much heavier carbon and nitrogen isotopic values and another showing simultaneously lighter isotopic signatures. In our case, the fishes of the Angara, expected to show a narrow  $\delta^{13}\text{C}$  variability range to begin with and to give a relatively high  $\delta^{15}\text{N}$  signature when averaged across several species (most of them omnivorous), must be the isotopically heavier food while the ungulates must be the isotopically lighter food. Thus, it would seem that during the EN, the Angara fishes formed a larger portion of the hunter–gather diet than during the LN–EBA or, alternatively, the ungulates contributed more food to the diet during the LN–EBA than during the EN. Evidently, in the Angara valley the Baikal seal was not a significant part of the hunter–gather diet during either period, for addition of another food with very distinct stable isotope signature (N-heavy and C-light) would corrupt the strong correlation between the carbon and nitrogen values.

Six additional individuals come from locations other than the dominant cemeteries but they fit well into the pattern described above. The four EN individuals from Ust'-Belaia and Kitoi fall within the Lokomotiv distribution range while the two EBA persons from Ust'-Belaia and Lokomotiv fit within the LN–EBA Ust'-Ida range. This implies that specific location along the Angara River was less important as a factor shaping the diet of these foragers, their archaeological age being the main difference. Lastly, a few individuals from the Ust'-Ida cemetery displaying much lighter carbon and nitrogen values than the rest of the sample overlap entirely with LN–EBA component from the Lena valley (Fig. 4a and d).

## 5.2. Little Sea

The Little Sea sample differs from the Angara River in a few important aspects: the distribution of stable isotope signatures is not continuous – rather it shows two separate groups, in neither of these two groups are the carbon and nitrogen values correlated with each other, and the entire distribution is shifted on the  $\delta^{13}\text{C}$  axis toward the lighter end by c. 3–5‰ relative to the Angara pattern (Table 7, Fig. 4a and c) (but see Katzenberg et al., in press for an alternate interpretation).

The discontinuous distribution of the human stable isotope signatures in the Little Sea micro-region has been already recognized (Weber and Bettinger, 2010; Weber and Goriunova, in preparation) and mentioned in this paper. The two clusters are different enough to suggest that they correspond to two different diets drawing on different food groups and perhaps on two different ecosystems. The cluster with heavier  $\delta^{15}\text{N}$  values, wider ( $\sim 4\text{‰}$ ) and a little heavier  $\delta^{13}\text{C}$  distribution seems to be best explicable in terms of a diet consisting of aquatic foods of Baikal origin (seal, and cove-and-lagoon fishes) and the ungulates. It appears that it is the seal, the top predator in the lake, which drives this distribution up on the nitrogen scale and simultaneously down on the carbon scale. On the other hand, the cove-and-lagoon fishes, showing the heaviest carbon values of all Baikal habitats, drive the distribution up on the carbon scale. Thus, a human diet consisting of variable combinations of these three main components – Baikal seal, cove-and-lagoon fishes, and ungulates – each with distinct carbon and nitrogen signatures would result in a distribution of stable isotope values that are not correlated with each other, scattered rather widely on both scales, and placed on the carbon scale between the seal and the cove-and-lagoon fishes. Overall then, it is the seal and cove-and-lagoon fishes of the Little Sea, the former carbon-light and the latter carbon-heavy, that make the carbon and nitrogen values of this distribution not correlated and more widely scat-

tered than otherwise expected. As mentioned, this group is referred to as the game-fish-seal (GFS) diet and its stable isotope characteristics seem to reflect strongly the aquatic foods available locally.

Subtracting the seal component, while useful for descriptive purposes, for two reasons is insufficient to account fully for the distribution of stable isotope values among the GF diet group. First, all other things being equal, the lack of the seal in the diet would push the carbon values in the GF group toward the heavy end, not the lighter one, the latter being the case here. And second, the variable bathymetry of the Little Sea gulf, and perhaps access to some littoral fishes there, would make the distribution on the carbon scale somewhat wider relative to the very narrow range of 1.2‰ documented among the members of the GF diet (Table 10). Thus, the aquatic component of the GF diet seems to be of non-local, i.e., non-Baikal, character. Considering the lack of correlation between the nitrogen and carbon values among the individuals included in the GF diet, and recollecting the strong correlation between the stable isotope signatures documented among the foragers of the Angara valley, the aquatic ecosystem of the upper Lena, or a similar one, where the fishes show the lightest carbon values in the entire Cis-Baikal (Fig. 4a and c), appears to be a better candidate for the source of the fish component of the GF diet in the Little Sea micro-region.

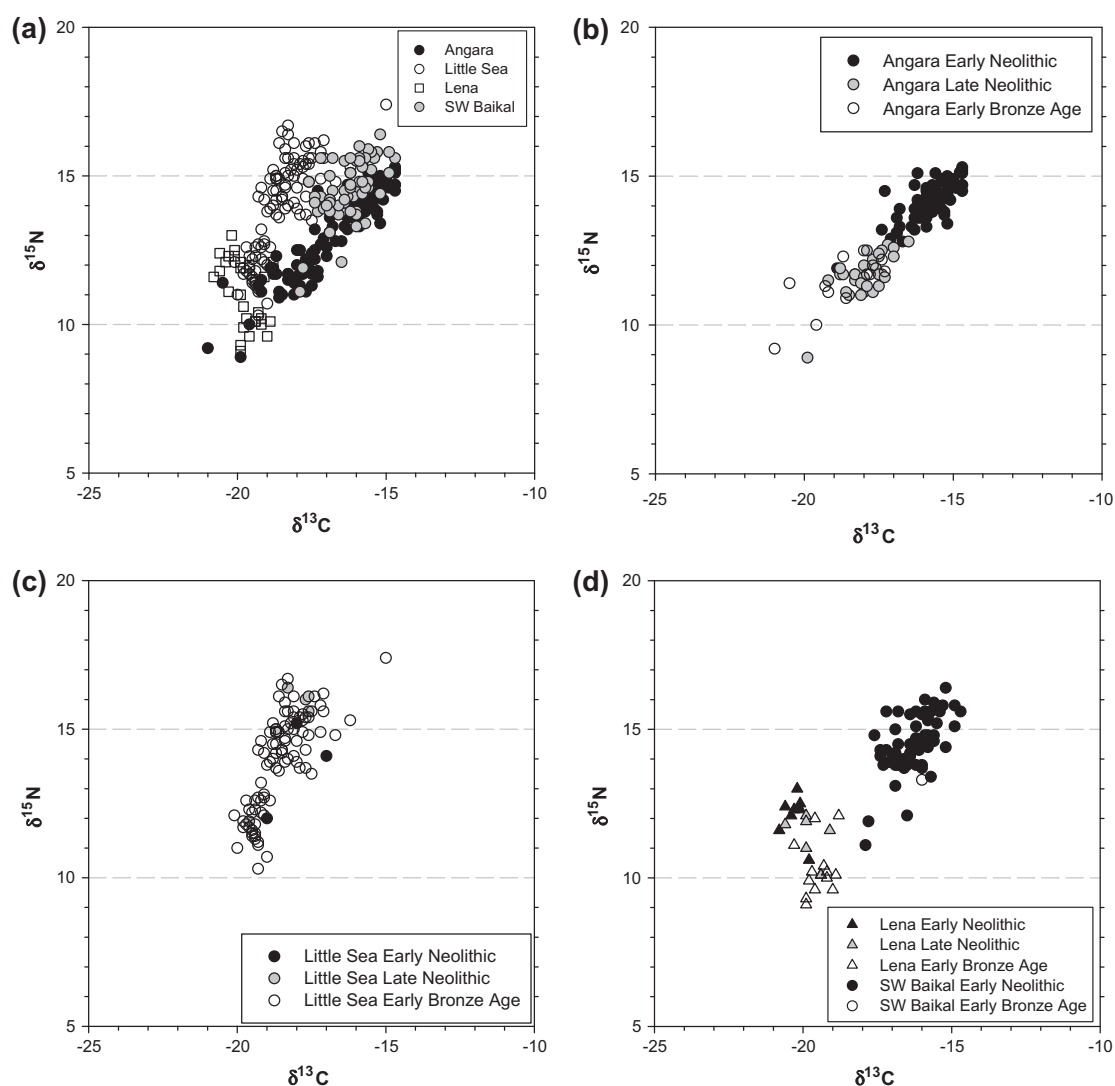
The large amount of information already published for the Little Sea allows for a few additional inferences. Of particular relevance is that during the EBA the Little Sea hunter-gatherer population appears to be heterogeneous both in terms of diet and place of birth (Haverkort et al., 2008; Katzenberg et al., 2009; Weber, in press; Weber and Goriunova, in preparation). All individuals in the Khuzhir-Nuge XIV EBA sample whose place of birth, based on strontium isotope ratios in first molars, was identified as local ( $n = 11$ ) invariably displayed the GFS diet. In contrast, among the individuals identified as born outside of the Little Sea, roughly half

**Table 8**  
Human archaeological and geochemical data from the Upper Lena.

No.	Cemetery name	Archaeological age	Master ID	Sex	Age of individual	HSAMP ID	C/N	Coll. yield	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	Reference
1	Makrushina	Early Neolithic	MAK_1989.001	Undetermined	20+ years	1992.124	3.4	14.7	-19.8	10.6	Weber et al. (2002)
2	Turuka	Early Neolithic	TUR_1992.001	Undetermined	20+ years	1993.072	3.6	1.5	-20.6	12.4	Weber et al. (2002)
3	Turuka	Early Neolithic	TUR_1992.002	Undetermined	20+ years	1993.073	3.5	4.9	-20.8	11.6	Weber et al. (2002)
4	Turuka	Early Neolithic	TUR_1992.003	Undetermined	20+ years	1992.127	3.5	9.0	-20.1	12.5	Weber et al. (2002)
5	Turuka	Early Neolithic	TUR_1992.004	Undetermined	20+ years	1992.128	3.6	0.7	-20.4	12.1	Weber et al. (2002)
6	Turuka	Early Neolithic	TUR_1993.005	Undetermined	20+ years	1993.074	3.5	7.1	-20.1	12.3	Weber et al. (2002)
7	Turuka	Early Neolithic	TUR_1993.009	Undetermined	20+ years	1993.077	3.5	0.9	-20.2	13.0	Weber et al. (2002)
8	Turuka	Early Neolithic	TUR_1993.010	Undetermined	35–50 years	1993.078	3.5	6.0	-20.3	12.3	Weber et al. (2002)
9	Nikolskii Grot	Late Neolithic	NGT_0000.000	Undetermined	20+ years	1992.133	3.4	22.8	-19.9	11.0	Weber et al. (2002)
10	Nikolskii Grot	Late Neolithic	NGT_1982.001.01	Undetermined	20+ years	1992.129	3.4	21.7	-19.1	11.6	Weber et al. (2002)
11	Nikolskii Grot	Late Neolithic	NGT_1982.002.01	Undetermined	20+ years	1992.131	3.4	21.8	-19.4	10.1	Weber et al. (2002)
12	Zakuta	Late Neolithic	ZAK_1992.001	Undetermined	Adult	1994.001	3.4	12.6	-19.9	12.1	
13	Zakuta	Late Neolithic	ZAK_1994.002	Undetermined	Adult	1994.002	3.3	20.6	-19.9	11.9	
14	Zakuta	Late Neolithic	ZAK_1994.003	Undetermined	Adult	1994.003	3.3	17.7	-20.6	11.8	
15	Borki 1	Early Bronze Age	BO1_1971.001.01	Undetermined	20+ years	1991.028	3.4	23.4	-19.8	9.9	Weber et al. (2002)
16	Borki 1	Early Bronze Age	BO1_1971.002.01	Undetermined	20+ years	1991.027	3.3	22.2	-19.7	10.2	
17	Borki 2	Early Bronze Age	BO2_1971.001.01	Undetermined	20+ years	1991.019	3.4	20.3	-19.2	10.2	Weber et al. (2002)
18	Borki 2	Early Bronze Age	BO2_1971.002.01	Undetermined	20+ years	1991.018	3.5	20.5	-19.4	10.1	Weber et al. (2002)
19	Borki 2	Early Bronze Age	BO2_1971.003.01	Undetermined	20+ years	1991.026	3.4	23.5	-19.0	9.6	Weber et al. (2002)
20	Makrushina	Early Bronze Age	MAK_1989.003	Undetermined	20+ years	1992.126	3.4	13.3	-18.8	12.1	Weber et al. (2002)
21	Obkhoi	Early Bronze Age	OBK_1971.001.01	Undetermined	20+ years	1991.008	3.3	23.1	-19.2	10.0	Weber et al. (2002)
22	Obkhoi	Early Bronze Age	OBK_1971.001.02	Undetermined	50+ years	1991.012	3.3	15.7	-19.6	9.6	Weber et al. (2002)
23	Obkhoi	Early Bronze Age	OBK_1971.003	Undetermined	20+ years	1991.007	3.3	21.4	-19.9	9.1	Weber et al. (2002)
24	Obkhoi	Early Bronze Age	OBK_1971.003.04	Undetermined	20+ years	1991.016	3.4	19.7	-19.3	10.4	
25	Obkhoi	Early Bronze Age	OBK_1971.005	Undetermined	20+ years	1991.033	3.4	26.6	-19.9	9.3	Weber et al. (2002)
26	Obkhoi	Early Bronze Age	OBK_1971.010	Undetermined	25–35 years	1991.025	3.4	17.9	-19.6	12.0	Weber et al. (2002)
27	Obkhoi	Early Bronze Age	OBK_1971.013	Undetermined	20–25 years	1991.014	3.3	19.5	-20.3	11.1	Weber et al. (2002)
28	Obkhoi	Early Bronze Age	OBK_1971.014	Undetermined	20+ years	1991.029	3.5	20.1	-18.9	10.1	Weber et al. (2002)
<i>Results removed from analysis due to the C/N ratio outside of the acceptable 2.9–3.6 range</i>											
29	Makrushina	Early Neolithic	MAK_1989.002	Undetermined	20+ years	1992.125	3.7	6.6	-19.7	10.5	Weber et al. (2002)
30	Turuka	Early Neolithic	TUR_993.006	Undetermined	20+ years	1993.075	3.8	0.1	-21.0	12.5	Weber et al. (2002)

**Table 9**  
Human archaeological and geochemical data from Southwest Baikal.

No.	Cemetery name	Master_ID	Archaeological age	Sex	Age of individual	HSAMP_ID	C/N	Coll. yield	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
1	Shamanka	SHA_1999.007	Early Neolithic	Probable Female	20–30 years	2002.204	3.2	15.1	−16.9	13.1
2	Shamanka	SHA_2000.008	Early Neolithic	Male	35–40	2002.174	3.2	15.7	−16.8	15.6
3	Shamanka	SHA_2000.010	Early Neolithic	Male	25–35 years	2002.213	3.2	13.6	−16.9	14.2
4	Shamanka	SHA_2001.011.01	Early Neolithic	Female	18–20 years	2002.165	3.2	16.0	−17.6	14.8
5	Shamanka	SHA_2001.011.02	Early Neolithic	Male	30–40 years	2002.164	3.2	1.0	−16.9	15.0
6	Shamanka	SHA_2001.013.01	Early Neolithic	Probable Female	25–35 years	2003.652	3.2	19.3	−15.8	15.4
7	Shamanka	SHA_2001.013.02	Early Neolithic	Male	35–50 years	2003.650	3.2	18.8	−16.4	15.5
8	Shamanka	SHA_2001.013.03	Early Neolithic	Probable Female	18–19 years	2002.192	3.2	14.6	−15.2	14.4
9	Shamanka	SHA_2001.014.01	Early Neolithic	Male	25–30 years	2002.178	3.2	11.2	−15.3	15.8
10	Shamanka	SHA_2001.014.02	Early Neolithic	Female	20–25 years	2002.180	3.2	11.6	−15.4	15.6
11	Shamanka	SHA_2001.015	Early Neolithic	Male	25–35 years	2002.207	3.2	17.5	−15.5	15.8
12	Shamanka	SHA_2001.016	Early Neolithic	Undetermined	20–25 years	2002.189	3.2	15.5	−15.9	14.5
13	Shamanka	SHA_2001.017.01	Early Neolithic	Male	30–40 years	2002.201	3.2	12.2	−15.6	14.6
14	Shamanka	SHA_2001.017.02	Early Neolithic	Male	20–22 years	2002.198	3.2	7.6	−14.7	15.6
15	Shamanka	SHA_2001.018	Early Neolithic	Male	25–29 years	2002.186	3.2	20.1	−16.8	14.5
16	Shamanka	SHA_2001.019	Early Neolithic	Male	25–30 years	2002.183	3.2	15.7	−14.9	15.8
17	Shamanka	SHA_2001.021.03	Early Neolithic	Undetermined	16–18 years	2002.244	3.3	3.4	−16.0	13.8
18	Shamanka	SHA_2001.021.01	Early Neolithic	Male	25–30 years	2002.238	3.2	13.8	−16.5	12.1
19	Shamanka	SHA_2002.021.02	Early Neolithic	Male	25–30 years	2002.241	3.2	15.0	−16.8	13.8
20	Shamanka	SHA_2002.022	Early Neolithic	Male	19–22 years	2002.232	3.3	0.2	−16.0	15.5
21	Shamanka	SHA_2002.023.01	Early Neolithic	Probable Male	35–45 years	2002.227	3.2	14.2	−15.6	15.9
22	Shamanka	SHA_2002.023.02	Early Neolithic	Probable Female	20+ years	2002.218	3.2	16.9	−15.7	15.6
23	Shamanka	SHA_2002.023.04	Early Neolithic	Undetermined	20+ years	2002.221	3.2	17.5	−16.5	13.8
24	Shamanka	SHA_2002.023.05	Early Neolithic	Undetermined	20+ years	2002.223	3.2	20.0	−16.1	14.3
25	Shamanka	SHA_2002.024.01	Early Neolithic	Male	25–35 years	2002.230	3.2	17.9	−15.8	14.4
26	Shamanka	SHA_2002.024.02	Early Neolithic	Undetermined	12–15 years	2002.235	3.2	13.2	−15.6	14.8
27	Shamanka	SHA_2003.025.01	Early Neolithic	Female	20–22 years	2003.562	3.3	17.4	−15.7	14.6
28	Shamanka	SHA_2003.026.01	Early Neolithic	Probable Female	20+ years	2003.538	3.2	15.8	−17.3	13.8
29	Shamanka	SHA_2003.026.02	Early Neolithic	Probable Male	20+ years	2003.539	3.2	13.6	−17.8	11.9
30	Shamanka	SHA_2003.026.03	Early Neolithic	Undetermined	6–8 years	2003.544	3.1	14.9	−16.2	15.1
31	Shamanka	SHA_2003.027.01	Early Neolithic	Male	35–50 years	2003.550	3.0	14.7	−16.3	14.3
32	Shamanka	SHA_2003.027.02	Early Neolithic	Male	25–30 years	2003.553	3.1	15.5	−16.4	14.1
33	Shamanka	SHA_2003.029.01	Early Neolithic	Male	20–30 years	2003.546	3.1	15.2	−15.7	13.4
34	Shamanka	SHA_2003.030	Early Neolithic	Male	35–50 years	2003.560	3.2	18.8	−17.2	14.3
35	Shamanka	SHA_2003.032	Early Neolithic	Male	35–45 years	2003.536	3.2	14.1	−16.6	13.7
36	Shamanka	SHA_2003.033	Early Neolithic	Male	35–45 years	2003.565	3.2	18.0	−16.4	14.1
37	Shamanka	SHA_2004.039	Early Neolithic	Male	40–44 years	2004.001	3.4	16.4	−16.6	14.0
38	Shamanka	SHA_2004.041	Early Neolithic	Male	30–39 years	2004.007	3.4	18.8	−17.4	14.3
39	Shamanka	SHA_2004.042.01	Early Neolithic	Female	40–45 years	2004.013	3.2	20.4	−15.9	14.8
40	Shamanka	SHA_2004.042.02	Early Neolithic	Female	50+ years	2004.019	3.4	16.8	−17.9	11.1
41	Shamanka	SHA_2004.0243	Early Neolithic	Probable Female	35–50 years	2004.024	3.4	19.6	−16.4	14.5
42	Shamanka	SHA_2004.044.01	Early Neolithic	Probable Male	50+ years	2004.027	3.2	14.6	−15.5	15.2
43	Shamanka	SHA_2004.044.02	Early Neolithic	Undetermined	20+ years	2004.030	3.3	17.1	−16.9	14.2
44	Shamanka	SHA_2004.045	Early Neolithic	Male	25–35 years	2004.032	3.5	17.0	−17.1	13.9
45	Shamanka	SHA_2004.046	Early Neolithic	Male	25–29 years	2004.038	3.3	19.7	−15.9	15.6
46	Shamanka	SHA_2004.047	Early Neolithic	Female	20–25 years	2004.044	3.3	16.2	−15.8	15.3
47	Shamanka	SHA_2004.048.01	Early Neolithic	Male	50+ years	2004.137	3.1	16.2	−16.2	14.6
48	Shamanka	SHA_2004.049.01	Early Neolithic	Probable Male	17–20 years	2004.050	3.3	16.1	−16.0	13.7
49	Shamanka	SHA_2004.049.02	Early Neolithic	Undetermined	Adult	2004.056	3.3	18.1	−16.9	14.1
50	Shamanka	SHA_2004.050.01	Early Neolithic	Male	25–35 years	2004.102	3.3	19.9	−16.2	14.7
51	Shamanka	SHA_2004.050.02	Early Neolithic	Male	25–29 years	2004.108	3.2	18.2	−16.9	13.8
52	Shamanka	SHA_2004.050.03	Early Neolithic	Male	30–40 years	2004.116	3.6	17.9	−15.8	14.8
53	Shamanka	SHA_2004.051	Early Neolithic	Male	20–25 years	2004.057	3.4	13.1	−15.9	15.5
54	Shamanka	SHA_2004.052.01	Early Neolithic	Probable Male	20–24 years	2004.130	3.2	18.1	−16.4	14.2
55	Shamanka	SHA_2004.053.01	Early Neolithic	Male	20–25 years	2004.062	3.4	13.4	−16.2	15.6
56	Shamanka	SHA_2004.053.02	Early Neolithic	Male	50+ years	2004.068	3.2	17.6	−15.9	16.0
57	Shamanka	SHA_2004.054.01	Early Neolithic	Female	17–21 years	2004.071	3.3	15.9	−17.2	15.6
58	Shamanka	SHA_2004.054.02	Early Neolithic	Undetermined	Adult	2004.076	3.4	15.2	−17.0	14.0
59	Shamanka	SHA_2004.055.01	Early Neolithic	Male	35–39 years	2004.093	3.4	17.5	−17.4	14.1
60	Shamanka	SHA_2004.057.01	Early Neolithic	Female	25–29 years	2004.119	3.1	16.9	−15.2	16.4
61	Shamanka	SHA_2004.057.02	Early Neolithic	Female	25–35 years	2004.124	3.6	17.9	−14.9	15.1
62	Shamanka	SHA_2004.058.01	Early Neolithic	Male	35–45 years	2004.083	3.3	15.7	−16.2	13.8
63	Shamanka	SHA_2000.009	Early Bronze Age	Probable Female	17–18 years	2002.169	3.2	14.3	−16.0	13.3
64	Shamanka	SHA_2003.027.03	Early Neolithic	Undetermined	2–3 years	2003.556	3.1	13.1	−16.6	14.9
65	Shamanka	SHA_2003.028	Early Neolithic	Undetermined	1.5–3 years	2003.568	3.2	18.6	−16.1	15.7
66	Shamanka	SHA_2003.031	Early Neolithic	Undetermined	3–5 years	2003.570	3.1	18.3	−16.8	14.2
67	Shamanka	SHA_2003.038	Early Neolithic	Undetermined	2–3 years	2003.572	3.1	17.6	−16.2	15.5
68	Shamanka	SHA_2004.055.02	Early Neolithic	Undetermined	5–7 years	2004.099	3.3	19.2	−16.3	14.4
69	Shamanka	SHA_2004.056.01	Early Neolithic	Undetermined	3–5 years	2004.077	3.2	21.5	−16.3	14.9
70	Shamanka	SHA_2004.056.02	Early Neolithic	Undetermined	8–10 years	2004.080	3.3	19.4	−16.0	15.8



**Fig. 4.** Human stable isotope results for middle Holocene foragers in the Baikal region. (a) All micro-regions. (b) Angara valley. (c) Little Sea. (d) Upper Lena and southwest Baikal.

( $n = 6$ ) registered the GFS diet and half ( $n = 7$ ) the GF diet. This lends further support to the notion that the GFS and GF diets are local and non-local, respectively. Next, the GFS and GF diets are present in all culture historical periods (i.e., EN, LN, and EBA) and all examined Little Sea cemeteries except for Shamanskii Mys on Ol'khon Island where only individuals living on the GFS diet have been found. And lastly, with the GF diet apparently a good predictor of the non-local place of birth, it is useful to note that of the 102 Little Sea adults examined, 70 (69%) and 32 (31%) show the GFS and GF diets, respectively, but keep in mind that many of the foragers displaying the GFS diet could have been born outside of the Little Sea. Overall then, the results of the stable isotope and strontium analyses are quite consistent with one another.

Recognizing that Baikal seal is the most seasonally restricted major food item in the region leads to additional considerations. That all Little Sea locals included the seal in their diet but only roughly half of the non-locals did so, may mean that the non-locals entered the Little Sea area following two different rounds of seasonal migration: one overlapping with the sealing season and resulting in the GFS diet, the other outside of it and resulting in the GF diet still showing a strong signature of the other area(s) included in the seasonal migration. Thus, accepting tentatively that all EBA non-locals in the Little Sea area come from the upper Lena, this would consti-

tute the first evidence in the Baikal region for seasonal travel between its various micro-regions. Unfortunately, at present we have no data to address the question of why the upper Lena foragers would develop two different seasonal migration rounds.

### 5.3. The Lena river valley

Although the sample size from the upper Lena micro-region is rather small ( $n = 28$ ) it is nevertheless very informative due to the fact that the six localities are scattered over a long distance and that they represent all three culture historical periods (Tables 8 and 10c, Figs. 1 and 4d). Relative to the other areas, the upper Lena foragers are the lightest both on the nitrogen and carbon scales, the latter due to the very light  $\delta^{13}\text{C}$  values in the Lena fishes. The entire distribution is continuous with most of the EN individuals occupying the upper half (heavier and lighter in  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values, respectively) and most of the LN–EBA individuals on the lower half of the distribution range (lighter and heavier in  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values, respectively). The carbon and nitrogen signatures are weakly correlated (linear regression:  $\delta^{15}\text{N} = -8.90 - 1.01 \times \delta^{13}\text{C}$ ,  $R^2 = 0.23$ ,  $n = 28$ ), the negative correlation being again a product of the very light carbon signatures in the Lena fishes. Overall, this pattern in two respects is somewhat analogous to the one de-



scribed for the Angara valley: it shows a very strong local signal and the EN component is generally higher on the nitrogen scale than the LN–EBA one. Lastly, perhaps even more telling is that the upper Lena's LN–EBA isotopic signatures are similar, although still a little lighter (by  $\sim 0.2\%$ ) on the carbon scale, relative to the GF diet from the Little Sea (Fig. 4a and d).

#### 5.4. Southwest Baikal

This micro-region differs from the other three in that it is represented only by one cemetery (Shamanka II) and, with only one EBA burial examined to date, the sample is essentially limited to the EN period ( $n = 62$ ). The distribution is continuous and, relative to the EN component from the Angara, it is shifted toward the light end of the carbon axis thus effectively filling the gap between the Little Sea's GFS diet and the Angara's EN sample. The  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values are weakly correlated (linear regression:  $\delta^{15}\text{N} = 27.67 + 0.81 \times \delta^{13}\text{C}$ ,  $R^2 = 0.34$ ,  $n = 63$ ), there are a few outliers with much lower  $\delta^{15}\text{N}$  values ( $\sim 11$ – $12\%$ ), and the EBA individual fits with the bulk of the EN distribution (Table 9, Fig. 4a and d).

The fact that the Shamanka stable isotope distribution occupies the space between the Little Sea GFS diet and the Angara's EN diet is significant in that the extensive shallows of the southwest Baikal (only  $\sim 100$  m deep as far as  $\sim 1$  km away from the shore) would produce in its fishes a less variable  $\delta^{13}\text{C}$  signal than the more diverse bathymetry of the Little Sea, with values in the southwest Baikal likely approaching the heavy end of the range documented for the Little Sea. Next, the fact that the correlation between the nitrogen and carbon results at Shamanka is not as strong as among the foragers from the Angara, suggests intake of a food item with nitrogen and carbon values different from the two main food groups – the fishes and the ungulates – thus disrupting the correlation so cleanly documented on the Angara. It seems that the food responsible for this at Shamanka is the Baikal seal. Recollect that among the foragers living on the GFS diet in the Little Sea, the nitrogen and carbon signatures were not correlated due to the presence of two such disrupting foods: one was the seal and the other were the fishes with high and locally variable  $\delta^{13}\text{C}$  values. This suggests that the seal could have been consumed in both micro-regions in rather equitable amounts, as confirmed too by the similar distribution of the  $\delta^{15}\text{N}$  values.

The three outliers, identified by the low  $\delta^{15}\text{N}$  signatures, can be perhaps disregarded on the grounds that they are mere measurement errors but not doing so leads to some interesting considerations. Namely, these three sets of stable isotope values are good candidates to represent a non-local diet among the Shamanka EN sample. As such, the question arises, where is this diet from? This is not an invalid question to ask as non-local diets are also well visible in the data from the Angara valley and the Little Sea. It is unlikely that the non-local diet at Shamanka represents an area somewhere along the coast of the lake because the nitrogen values are too low for the diet to include the Baikal seal, a food item which seems to be harvested by all groups indigenous to the lake and even some travelling to its shores on a seasonal basis. They are unlikely from the Angara valley because the EN diet there, except for two individuals from Lokomotiv, shows much higher nitrogen values due to the high intake of the local fish, and not from the upper Lena either where, while the  $\delta^{15}\text{N}$  signatures are similar, the  $\delta^{13}\text{C}$  values are much lighter. Perhaps, the place of origin of these three individuals is in a different area yet. Two locations come to mind. One is the lower section of the Selenga River some 200 km to the east where the large Fofanovo cemetery functioned during the EN and EBA times (Fig. 1), but no stable isotope data are available for these burials or the fishes in the river. The other is the Irkut River valley immediately to the west (Fig. 1) where surface materials typologically dating to the EN have been reported with consis-

tency, particularly in the Tunka valley, but no cemeteries have been found there and stable isotope data for the fishes are lacking too. The relatively heavy  $\delta^{13}\text{C}$  values documented in the three Shamanka outliers suggest an ecosystem with mature river of high primary productivity, a characteristic of the lower section of the Selenga River rather than the Irkut. Interestingly, two of the Shamanka outliers cluster isotopically with the Lokomotiv outliers, indicating perhaps a common place of origin for these four individuals (Fig. 4b and d) and connections with another larger center of EN hunter–gatherer culture.

With no stable isotope data available for fish from the southwest end of Lake Baikal, interpretation of the Shamanka human data is subject to verification once such a framework of reference becomes available. Nevertheless, even with the comparative data available to date, it is sufficiently clear that, like elsewhere in the region, on southwest Baikal too consumption of aquatic foods locally available is well reflected in the human stable isotope results. And, per analogy with the Little Sea area, at Shamanka too there appear to be two diets present: one local with the seal, the other non-local and without it, however, not as frequent as the GF diet in the Little Sea micro-region.

## 6. Discussion

Of c. 1200 middle Holocene Cis-Baikal individuals recorded in our databases, 350 ( $\sim 30\%$ ) have been tested for carbon and nitrogen stable isotopes and most of them have been also dated by radiocarbon (Weber et al., 2006). With more work in progress, this is already a substantial data set for any prehistoric hunter–gatherers globally from which to assess diet, subsistence, and mobility patterns.

### 6.1. Insights from dog results

The general picture emerging from the analysis of this material is summarized in Table 11 and the data obtained for the six archaeological dogs (Table 2, Fig. 2a), not discussed so far, provide a few additional points. Five and one of these dogs come from mortuary and camp site contexts, respectively: two dogs are from the same EN grave and one is from an EBA grave, all three from the Shamanskii Mys cemetery on Ol'khon Island; one dog is from an EN grave at Khotoruk; one from an EBA grave on the upper Lena (Obkhoi), and one is from the EBA layer at the Sagan-Zaba habitation site on the west-central coast of Baikal. Thus, three dogs are each EN and EBA in age while geographically five and one are from the Little Sea and upper Lena micro-regions, respectively.

Since in most prehistoric societies, dogs are expected to feed mostly on human leftover food, dog stable isotope signatures are frequently accepted as a good measure of human diet at a group level (family, entire camp, settlement or even a village) rather than at the level of any particular person (Cannon et al., 1999; Katzenberg, 1989; Losey et al., 2011). It is thus not particularly surprising that in our case the dog stable isotope signatures fit well with the pattern established for the humans from these two micro-regions: all dogs clearly show some consumption of aquatic foods (fish or seal), like humans they too sort themselves into the GFS and GF diets each with three dogs (Fig. 4c), like all humans from Shamanskii Mys the three dogs from there show the GFS diet too, and lastly, the spatio-temporal distribution of the dog diets is compatible with the distribution of the human diets.

If the argument about the different geographic origins of the GFS (local) and GF (non-local) diets is extended to the dogs too, it is reasonable to suggest that the dogs with the GFS diet (all from Shamanskii Mys) are probably local while those with the GF diet,

**Table 10**

Descriptive statistics for human stable isotope data from the Baikal region: a. Angara b. Little Sea c. Upper Lena and southwest Baikal.

Table 10a. Angara valley												
	EN + LN + EBA		EN		EN Lokomotiv		LN		EBA		LN + EBA	
	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
Mean	-16.7	13.2	-15.8	14.1	-15.7	14.1	-17.9	11.7	-18.7	11.4	-18.2	11.6
Standard deviation	1.4	1.4	0.8	0.7	0.8	0.7	0.7	0.8	1.2	0.9	0.9	0.8
Range	6.3	6.4	4.2	3.6	4.2	3.6	3.4	3.9	3.7	3.3	4.5	3.9
Minimum	-21.0	8.9	-18.9	11.7	-18.9	11.7	-19.9	8.9	-21.0	9.2	-21.0	8.9
Maximum	-14.7	15.3	-14.7	15.3	-14.7	15.3	-16.5	12.8	-17.3	12.5	-16.5	12.8
Count	119	119	76	76	72	72	30	30	13	13	43	43

Table 10b. Little Sea												
	GFS + GF diet		GFS diet		GF diet		LN GFS diet		EBA GFS diet		EBA GF diet	
	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
Mean	-18.2	14.0	-17.6	14.9	-19.4	11.9	-18.1	15.7	-18.1	14.9	-19.4	11.9
Standard deviation	3.8	1.6	4.4	0.9	0.3	0.6	0.5	0.6	0.8	0.9	0.3	0.7
Range	38.4	7.1	37.6	4.2	1.2	2.5	1.1	1.5	4.3	4.2	1.2	2.5
Minimum	-20.1	10.3	-19.3	13.2	-20.1	10.3	-18.7	14.9	-19.3	13.2	-20.1	10.3
Maximum	18.3	17.4	18.3	17.4	-18.9	12.8	-17.6	16.4	-15.0	17.4	-18.9	12.8
Count	101	101	70	70	31	31	6	6	61	61	29	29

Table 10c. Upper Lena and southwest Baikal												
	EN + LN + EBA		EN		LN		EBA		LN + EBA		EN SW Baikal	
	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
Mean	-19.8	11.0	-20.3	12.1	-19.8	11.4	-19.5	10.3	19.6	10.6	-16.3	14.6
Standard deviation	0.5	1.1	0.3	0.7	0.5	0.7	0.4	0.9	0.5	1.0	0.7	1.0
Range	2.0	3.9	1.0	2.4	1.5	2.0	1.5	3.0	1.8	3.0	3.2	5.3
Minimum	-20.8	9.1	-20.8	10.6	-20.6	10.1	-20.3	9.1	-20.6	9.1	-17.9	11.1
Maximum	-18.8	13.0	-19.8	13.0	-19.1	12.1	-18.8	12.1	-18.8	12.1	-14.7	16.4
Count	28	28	8	8	6	6	14	14	20	20	62	62

one each from Khotoruk (EN) and Sagan-Zaba (EBA), are non-local in origin, coming to the Little Sea together with their masters perhaps from the Lena area or, alternatively, subject of exchange between the two micro-regional groups. Note that the dog from the Lena, as all examined humans from that micro-region, shows the GF diet too.

## 6.2. Spatial variability, procurement ranges, and migrations

The dog results are also important in that they are consistent with the most general findings of this study:

- (1) Subsistence activities of all foragers appear to be well based in their own micro-regions.
- (2) Migrations of people occurred between some but not all the micro-regions.
- (3) Chronological shifts in adaptive strategies may have occurred in some but not all micro-regions; or alternatively
- (4) Despite the significant climatic change affecting the region between 7000 and 6000 cal BP, the EN, LN, and EBA hunter-gatherer strategies represent essentially the same basic model.

The first two points are discussed in the following paragraphs, the other two in the next section.

It is evident that a complete mixing mechanism, namely foraging covering all micro-regions and all main food groups available, or even partial mixing, appears unlikely during any of the culture historical periods under examination here. Food procurement of every territorial unit was spatially limited and focused on game and aquatic resources available within each micro-region regardless of the fact that the distances separating these areas, although variable, are never really substantial and the connecting routes lack significant geographic barriers. Forager diets from each micro-region occupy their own quite distinct position within the stable isotope space.

However, exchange networks and travel, as suggested by the presence of grave goods made of exotic materials (e.g., green and white nephrite, copper and bronze) during all periods likely extended far beyond the boundaries of daily subsistence activities.

It seems that food foraging ranges in every case were not as large as one might expect given the relative physical proximity of most of the micro-regions with one another and given what we know ethnographically about forager travel and mobility in boreal settings (e.g., Binford, 2001; Kelly, 1995; Turov, 2010). For example, c. 270 km separates the Angara valley from the Little Sea and the Lena valley, but only c. 100 km the Little Sea from the Lena, and the Angara and southwest Baikal are closer yet (Fig. 1). Considering the presence of natural connections along various river valleys and coasts, and Baikal and many rivers frozen much of the winter, a food foraging territory including the entire Cis-Baikal would not be an entirely unexpected model (Turov, 2010). This is not to say that the food procurement ranges were inordinately small, only that they were not that large.

It has been recently pointed out (Weber and Bettinger, 2010) that the distribution of middle Holocene cemeteries and population in the Cis-Baikal region coincides spatially with two important environmental variables: a mosaic of steppe and forested landscape and good fisheries, riverine (Angara and Lena) or lacustrine (Little Sea and southwest Baikal). In each micro-region stretches of patchy vegetation communities, with simultaneous access to fisheries, could have been quite substantial (up to a few hundred kilometers long), extending perhaps away from the main watercourses along some of the affluents (e.g., lower Irkut, Kitoi, Belaia, and Kuda in the Angara valley, Anga, Ilga, Kulenga, and Manzurka on the upper Lena, and middle Irkut on southwest Baikal; Kozhov, 1950). Only the Little Sea appears somewhat small but even there Ol'khon Island is about 50 km long (10–15 km wide) and the mainland gives today an additional 60–80 km of such more open landscape in places 20–30 km wide, with three of the largest of Baikal's west coast rivers (Sarma, Anga, and Bugul'deika) also located with-

**Table 11**  
Summary of middle Holocene hunter–gatherer diets in the Baikal region.

Period	Angara	Lena	Little Sea	South Baikal
EN	Local GF diet (more fish)	Local GF diet	Local GFS diet Non-local GF diet (from Lena?)	Local GFS diet Non-local GF diet (from Selenga?)
MN	Missing data	Missing data	Missing data	Missing data
LN	Local GF diet (less fish) Non-local GF diet (from Lena?)	Local GF diet	Local GFS diet Non-local GF diet (from Lena?)	Missing data
EBA	Local GF diet (less fish) Non-local GF diet (from Lena?)	Local GF diet	Local GFS diet Non-local GF diet (from Lena?)	Missing data

in the micro-region. While the modern vegetation cannot be viewed as a direct reflection of the past situation, it nevertheless shows where mosaic landscapes likely existed in the past and where they would expand or shrink in response to the middle Holocene climate change (Bezrukova et al., 2005, 2010; Prokopenko et al., 2007; Tarasov et al., 2009; White and Bush, 2010). The matter is further complicated by the fact that nearly all the proxy records on which our understanding of the past vegetation in the region is based come from the Trans-Baikal (area to the southeast of Lake Baikal) rather than from the micro-regions examined in this study. Nevertheless, the point to emphasize is that each of these micro-regions would provide richer game and fish resources than the sea of surrounding taiga. Whether or not these three resource patches (steppe and steppe forest, large rivers and Baikal, and the taiga) were sufficient to support hunter–gatherers on a long term basis is, of course, a question that requires population size to be taken into consideration given that the technology did not change that much from period to period. Thus the set of spatially correlated variables has now expanded from four to five: cemeteries, population centers, mosaic vegetation, fisheries, and food foraging ranges.

The Cis-Baikal middle Holocene hunter–gatherer groups, although well established in the various micro-regions, apparently did exchange individuals and remained in contact with groups in the other micro-regions but in a manner that appears somewhat asymmetrical both in time and direction. The Little Sea consistently received migrants from the upper Lena during all three culture historical periods discussed here but particularly during the EBA. If the data from the Khuzhir-Nuge XIV, tested for both strontium and carbon and nitrogen isotope signatures, are used for guidance, then ~65% of the entire Little Sea EBA population seems to be of non-local birth. On the Angara, however, such evidence is only present for the LN–EBA and there is no evidence of migrants on the upper Lena at all, but the sample there is smaller than elsewhere. Still, there appear to be more contacts between the Little Sea and the Lena than between either one and the Angara.

The overlap between the EN stable isotope distributions on the Angara and southwest Baikal may be the product of either the overlap in stable isotope signatures of the available foods or the movement of people between the two areas: the isotopic overlap very likely the case, the movement of people in need of additional data such as strontium or trace element markers. In any case, movement of people between these two substantial EN centers would not be unexpected given the distance and topography involved. However, what is surprising is that the overlap is not complete, that the EN Angara likely did not receive people from such places as the Little Sea or the Lena, and that the EN Shamanka sample shows evidence of migrants from an area yet to be identified, perhaps from the Selenga valley, but not from the Little Sea or the Lena, both quite afar.

The apparent asymmetry in contacts and migrations between the examined micro-regions relates directly to the question of variability in mortuary record on which much of our knowledge of the Cis-Baikal middle Holocene hunter–gatherer prehistory is predicated. A few recent publications point out, either implicitly (Baz-

aliiskii, 2010) or explicitly (Weber et al., 2010b; Weber and Bettinger, 2010), that the EN mortuary pattern is much more variable across the entire Cis-Baikal than the LN–EBA one. Since the stable isotope data suggest that migrations and travel between the micro-regions were limited in a similar fashion during all periods, these insights are compatible with the proposed EN mortuary heterogeneity but incompatible with the suggested LN–EBA homogeneity. Why would this be the case? First, it is an open question how much short-term travel between the micro-regions is needed before it is registered in various geochemical markers (stable isotope, strontium, and trace elements), which means that there could have been more such travel between the micro-regions than our data seem to suggest. Second, admittedly, the conjectures about the EN and LN–EBA mortuary heterogeneity and homogeneity, respectively, have been formulated based on rather cursory examination of the available evidence focusing on select few cemeteries and characteristics. While it is unlikely that systematic assessment of the entire mortuary material will overturn the EN pattern, the LN and EBA mortuary protocols may very well turn out to be as variable as the EN but along different dimensions.

### 6.3. Chronological change

The last point to consider regards the temporal variability in foraging strategies. The stable isotope evidence shows that the differences are mainly geographic and result from food resources available locally. In other words, all foragers examined here followed pretty much the same subsistence model: they harvested game and fishes, on Lake Baikal also the seal, and, to a limited extent, plant foods (pine nuts, mushroom, berries, etc.). This is rather unsurprising given the limited food choices the effective environment of the middle Holocene offered to the Baikal foragers. Thus, the spatially different stable isotope signatures do not automatically imply differences in foraging strategies as they foremost reflect local foods (i.e., aquatic resources) and their stable isotope values. If the dominant pattern is that of spatial variability, then any evidence of a temporal shift in stable isotope signatures within any of the micro-regions is worth attention for it may imply a change in foraging strategy. It is so because keeping the technology and geographic context constant, which are realistic and simplifying assumptions, respectively, a change in foraging strategy seems the most parsimonious source of such isotopic shifts.

Developing this line of reasoning further, the Angara, as signaled earlier, would be the only micro-region where the EN people clearly consumed more fish than the LN–EBA foragers, the pattern is weak on the upper Lena due to the limited sample size, unobservable on southwest Baikal due to the lack of LN–EBA data, and very different from the Little Sea where the presence of two different diets (GFS and GF) has little to do with the temporal shift in emphasis on game, fish or seal, but results from the place of origin and seasonal migration pattern as discussed above. Besides, the EN and LN samples are very small there which, on its own, is likely of significance warranting examination on a separate occasion.

Comparison between the Angara ( $n = 119$ ) and Little Sea ( $n = 101$ ) data sets, which are quite similar in terms of sample size

although not as much in terms of structure (few EN and LN data from the Little Sea area), leads to an important question: Why was the contribution of fish to the diet higher during the EN than during the LN–EBA on the Angara but not in the Little Sea? It is unlikely that the Angara fish resources, being immense as has been recorded historically (Kozhov, 1950), declined to the extent that the change would directly affect human diet. Recollect that the much smaller fishery of the Lena is still well visible in the stable isotope data in both EN and LN–EBA samples. If so, perhaps it is the changes to the terrestrial environment that are the key to resolving this issue. At least three additional questions appear to be relevant here: (1) Did the quick depletion or fluctuation of game resources due to the EN hunting pressure in the environment, which is assumed to be characterized by greater expanses of forest and smaller tracts of mosaic vegetation along the rivers relative to the later LN–EBA period, impel local EN foragers to turn more of their energy toward the Angara fishes? (2) Similarly, if more of such mosaic landscapes existed in the vicinity of the Angara fishery than during the EN period, was the higher reliance on ungulates during the LN–EBA merely the product of more game available per human capita? And lastly, (3) To what extent did shifts in the pattern and composition of mosaic vegetation along the Angara and its tributaries result in changes in the abundance and distribution of the ungulates and consequently human foraging strategies?

With this we can return to the two assumptions mentioned earlier. The first one regards the lack of significant technological change between the EN, LN and EBA periods of the kind that would redefine the effective environment. There is no compelling evidence speaking against this assumption. To the contrary, all relevant technologies (e.g., the bow-and-arrow, atlatl, micro-blades, composite tools, stone grinding, nets, fishhooks, harpoons, clay vessels, and even boats) are part of the archaeological record throughout the entire region and throughout all culture historical periods. It is tempting to exclude the MN from this generalization but habitation sites provide little in support of significant technological differences between the MN and the other periods. Considered together with the lack of MN mortuary sites, this implies change organizational in character rather than technological. Thus, the assumption about technological spatio-temporal continuity is deemed quite realistic and in no need of relaxing it.

The same, however, cannot be claimed with regard to the assumption about the constancy of the geographic context. The change in middle Holocene climate and environment is rather well documented for the broader region, with proxy records indicating increasing aridity and temperature variability (Bezrukova et al., 2005, 2010; Prokopenko et al., 2007; Tarasov et al., 2009; White and Bush, 2010). This change is believed to be the most significant within the entire Holocene and it seems to have occurred sometime between ~7000 and 6500 cal BP, thus roughly coinciding with the main boundaries of our culture–history model (Table 1). What is in need of further study is the tempo of this change, more precise timing, quantification of various environmental parameters (e.g., amount and distribution of precipitation), and impacts on the spatial distribution and abundance of plant and animal (terrestrial and aquatic) communities, particularly those important for the region's middle Holocene foragers. Thus, relaxing this simplifying assumption is necessary and doing so leads to further insights.

In this regard it is useful to examine our stable isotope data from the perspective in which human foragers are considered the last link in the chain of consumers dependent on the primary productivity (photosynthesis) generated by freshwater ecosystems. In terrestrial environmental settings dominated by  $C_3$  plants, such as the Baikal region,  $\delta^{13}C$  values in primary producers, and higher trophic level consumers, are expected to show limited variability, an expectation borne out by our own isotope data for the ungulates. The samples, which date to both the EN and LN–EBA intervals,

show a variability range of only 2.5‰ (Fig. 2a, Table 3), thus much narrower than the 6.3‰ range displayed by the EN and LN–EBA human samples from the Angara valley. Further, a shift in  $\delta^{13}C$  in end-consumers – in our case humans with substantial freshwater component in their diet – should come not from the change in primary productivity in the terrestrial ecosystem but in the freshwater one. This expectation is further supported by the wide range of variability in  $\delta^{13}C$  signatures documented in one freshwater system examined here – Lake Baikal. Presence of such variability (19‰, Table 5a) suggests also the potential for a shift in  $\delta^{13}C$  signatures in primary producers and higher trophic level consumers in response to climate change affecting the primary factors controlling photosynthesis in freshwater environments.

As such, climate changes affecting light, carbon, temperature, and nutrients directly or indirectly (for example via ice regime and snow cover or longer and colder winters) would invariably lower the intensity of photosynthesis in lakes and rivers. Although it is not expected that all freshwater habitats would be affected to the same degree, this change, if occurring, would still be passed onto higher trophic level consumers including the fishes and middle Holocene humans. Being an immature river, it is not expected that the upper Lena would show such a shift, but the shallow habitats on Lake Baikal probably would as perhaps also would the upper section of the Angara (mature river), the biology of which depends so much on Baikal's surface water. Therefore, the change in  $\delta^{13}C$  values observed between the EN and LN–EBA hunter–gatherers in some areas of the Baikal region may be indicative of climate change, and the resulting shift in  $\delta^{13}C$  values in aquatic fauna, rather than strictly of a shift in human foraging strategies.

Such  $\delta^{13}C$  evidence for change in freshwater primary productivity in the Baikal region is best visible in the Angara valley where the EN and LN–EBA human results, with two exceptions, occupy essentially two abutting segments of a continuous distribution (Fig. 4b). The pattern, not unexpectedly, seems to be absent on the upper Lena although the data set there is rather small (Fig. 4d) and one EN sample is separated from the rest by a relatively large distance. On the shallows of Lake Baikal, where one would expect changes in primary productivity to be quite pronounced, the human  $\delta^{13}C$  signal is influenced by the presence of two different diets (GFS and GF) each related to a different freshwater ecosystem and different sources of carbon. Therefore, such a shift is not visible in our human data from this micro-region: isotopically light pelagic carbon from the seal and heavy carbon from shallow water fishes are mixed in the GFS diet, while in the GF diet the carbon from shallow water fishes is mixed with isotopically still lighter carbon originating likely from an immature river (upper Lena?). Further, of the two main food groups (ungulates and aquatic species) it is the  $\delta^{13}C$  values in the aquatic foods that are expected to be affected most by climatic change. It is also likely that the  $\delta^{13}C$  values of every aquatic food group were influenced to a different degree depending on the specific habitat (cove-and-lagoon and open-coast littoral fishes, pelagic seal, and fishes in mature and immature rivers). This matter requires a dedicated treatment in a separate study.

## 7. Conclusion

This study contributes to the long-term goals of the BAP – documentation and explanation of spatio-temporal variability in middle Holocene hunter–gatherer adaptive strategies in the Baikal region – in at least two general ways. On the one hand, the framework of reference developed here will be of assistance in further implementation and development of the individual life history approach as it has been recently initiated for the Khuzhir–Nuge XIV cemetery (Weber and Goriunova, in preparation). On the other, the findings about travel and migrations between the micro-re-



gions, the size of foraging ranges, and most interestingly the hypothesis about the lack of temporal shift in foraging strategies, will assist in addressing not only the questions already mentioned above but also an array of other ones.

The first group of questions includes the examination of culture transmission mechanisms such as guided variation, biased and frequency dependent transmissions (Boyd and Richerson, 1985, refs.), mechanisms of population growth and regulation (e.g., birth and death rates, and migration), and development of local cultural traditions including mortuary behavior. The first two are important due to the evidently variable population size and density, spatially and temporally, already visible in the archaeological data (Weber and Bettinger, 2010), and the last one is critical for better understanding of the mortuary record, which is bound to remain a significant source of knowledge about the Cis-Baikal middle Holocene hunter-gatherers for many years to come.

The second group of questions, to which the knowledge of the size of a foraging range relates directly, involves the human impact on food resources (particularly the ungulates), patch and prey choices, and the impact of potentially dwindling or fluctuating ungulate populations on human interactions, including competition and cooperation, territorial behavior, and terms of social inequality.

The final set of queries regards the role of the climate and natural environment in these processes. Despite steady progress, the timing, tempo and parameters of middle Holocene climate change in the Baikal region (Bezrukova et al., 2005, 2010; Prokopenko et al., 2007; Tarasov et al., 2009; White and Bush, 2010) still remain difficult to pin down with the detail necessary to model its potentially multiple effects. Understanding of these impacts is essential because they would allow detailed mapping of shifts in the distribution of plant communities, changes in the distribution and abundance of the ungulates and their resilience to human exploitation, and stability of the riverine and lacustrine fisheries. All, in turn, are essential to furthering of our understanding of the human behavior.

The human stable isotope data set, particularly the  $\delta^{13}\text{C}$  results from the Angara valley, may offer a unique opportunity to model the quantitative parameters of the middle Holocene landscape (EN, LN and EBA periods). The data set is relatively large, is much better dated than any other environmental proxy records from the region, and comes from the micro-region where concentration of human middle Holocene foraging activities was particularly high. On the down side, the data set still is spatially limited to only one area of the Baikal region and does not include the MN period, which is so critical to the understanding of the entire environmental and cultural sequence. If available, shallow water fish remains from well stratified and dated habitation sites might assist in circumventing these two problems. At this point, however, we are aware of only one site (Ityrkhei in the Kurkut Bay, Little Sea; Losey et al., 2008) where such work would be possible.

The contention about the lack of major change in hunter-gatherer strategies between the EN, LN and EBA periods does not have to be considered controversial. Recent publications already alluded to the fact that with more research completed the similarities between EN and LN-EBA hunter-gatherers come more and more to the fore (Katzenberg et al., in press; Weber and Bettinger, 2010), while the differences appear to be either the product of not enough work, lack of appropriate context, or merely of secondary adaptive significance. At least three major shifts in foraging strategies still did occur: one transforming the Mesolithic pattern into the EN one, another changing the latter into the MN pattern, and then transforming the MN foraging strategy into the LN-EBA one. Adding to this list the better understanding of the LN-EBA transition, termination of the EBA pattern, and the possibility of rapid shifts within each EN, LN and EBA periods, as well as the meaning of

the differential archaeological manifestations of basically the same foraging strategy, is going to keep many Baikal scholars captivated and busy for a long time.

In sum, there are several important outcomes of this analysis. Forager diets from each micro-region occupy their own distinct position within the stable isotope spectrum suggesting that foraging ranges were not as large as potentially expected. All examined individuals and groups followed essentially the same subsistence strategy: to rely on game and local fishes, on Lake Baikal harvest the seal when seasonally available, and collect some plant foods. Although the foraging groups appear to be well established in their home areas, exchange networks with hunter-gatherers in other micro-regions existed but seem to have functioned in a manner that was asymmetrical both in time and direction: more travel and contacts between some micro-regions and less between others. The Angara valley is the only candidate for the possibility of a temporal change in the foraging strategy from more fishing during the EN to more ungulate hunting during the LN-EBA. However, the shift in stable isotope values suggests that this change can be viewed also as evidence of climate change affecting primary productivity of the Baikal-Angara freshwater system. The utility of these findings reaches beyond guiding future work in the Baikal region. They will provide useful comparative frameworks of reference for other similar case studies around the world in boreal and aquatic settings as well as in places where human stable isotope data are lacking and our understanding of past hunter-gatherer adaptations is based mostly on materials supplied by habitation sites.

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#### Appendix A. Supplementary data

Supplementary data associated with this article (Tables 2, 4, 6–9; Figs. 2–4) can be found, in the online version, at doi:10.1016/j.jaa.2011.06.006.

## References

- Ames, K., 2002. Going by boat: the forager–collector continuum at sea. In: Fitzhugh, B., Habu, J. (Eds.), *Beyond Foraging and Collecting: Evolutionary Change in Hunter–Gatherer Settlement Systems*. Kluwer Academic/Plenum Publishers, New York, pp. 19–52.
- Bazaliiskii, V.I., 2003. The neolithic of the Baikal region on the basis of mortuary materials. In: Weber, A.W., McKenzie, H.G. (Eds.), *Prehistoric Foragers of the Cis-Baikal, Siberia*. Canadian Circumpolar Press, Edmonton, pp. 37–50.
- Bazaliiskii, V.I., 2010. Mesolithic and Neolithic mortuary complexes in the Baikal region of Siberia. 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 of Archaeology and Anthropology, Philadelphia, pp. 51–86.
- Bazaliiskii, V.I., Ineshin, E.M., 1995. Molgil'nik epokhi rannego neolita na severe verkhnei Leny. In: Derevianko, A.P., Larichev, E.E. (Eds.), *Obozrenie 1993. Institut arkhologii i etnografii SO RAN, Novosibirsk*, pp. 190–192.
- Bazaliiskii, V.I., Men'shagin, E.V., Lykhin, Iu.P., 1996. Neoliticheskie zakhroneniia v skal'nykh nishakh v ust'e ruch'ia Nikol'skii na verkhnei Lene. *Arkheologicheskoe nasledie Baikal'skoi Sibiri: Izučenje, okhrana i ispol'zovanie* 1, 33–46.
- Bazaliiskiy, V.I., Savelyev, N.A., 2003. The wolf of Baikal: the “Lokomotiv” Early Neolithic cemetery in Siberia (Russia). *Antiquity* 77, 20–30.
- Bezrukova, E.V., Abzaeva, A.A., Letunova, P.P., Kulagina, N.V., Vershinin, K.E., Belov, A.V., Orlova, L.A., Danko, L.V., Krapivina, S.M., 2005. Post-glacial history of Siberian spruce (*Picea obovata*) in the lake Baikal area and the significance of this species as a paleo-environmental indicator. *Quaternary International* 136, 47–57.
- Bezrukova, E.V., Tarasov, P.E., Solovieva, N., Krivonogov, S.K., Riedel, F., 2010. Last glacial–interglacial vegetation and environmental dynamics in southern Siberia: chronology, forcing and feedbacks. *Palaeogeogr. Palaeoclimatology, Palaeoecology* 296, 185–198.
- Binford, L.R., 2001. *Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets*. University of California Press, Berkeley.
- Boutton, T.W., 1991. Stable carbon isotope ratios of natural materials: II. Atmospheric, terrestrial, marine, and freshwater environments. In: Coleman, D.C., Fry, B. (Eds.), *Carbon Isotope Techniques*. Academic Press, San Diego, pp. 173–185.
- Boyd, R., Richerson, P.J., 1985. *Culture and the Evolutionary Process*. University of Chicago Press, Chicago.
- Briones, E.E., Javier, A., Cienfuegos, E., Morales, P., 1998. Carbon stable isotopes ratios of pelagic and littoral communities in Alchichica crater-lake, Mexico. *International Journal of Salt Lake Research* 7, 345–355.
- Brönmark, C., Hansson, L.-A., 1998. *The Biology of Lakes and Ponds*. Oxford University Press, Oxford.
- Cannon, A., Schwarcz, H.P., Knyf, M., 1999. Marine-based subsistence trends and the stable isotope analysis of dog bones from Namu, British Columbia. *Journal of Archaeological Science* 26, 399–407.
- Chisholm, B.S., Nelson, D.E., Schwarcz, H.P., 1982. Stable carbon as a measure of marine versus terrestrial protein in ancient diets. *Science* 216, 1131–1132.
- Chisholm, B.C., Nelson, D.E., Schwarcz, H.P., 1983. Marine and terrestrial protein in prehistoric diets on the British Columbia coast. *Current Anthropology* 24, 396–398.
- Corr, L.T., Richards, M.P., Grier, C., Mackie, A., Beattie, O., Evershed, R.P., 2009. Probing dietary change of the Kwāda, y Dān Ts'ynchi individual, an ancient glaciator body from British Columbia: II. Deconvoluting whole skin and bone collagen δ<sup>13</sup>C values via carbon isotope analysis of individual amino acids. *Journal of Archaeological Science* 36, 12–18.
- Eriksson, G., Lidén, K., 2003. Skateholm revisited: new stable isotope evidence on humans and fauna. In: Eriksson, G. (Ed.), *Norm and Difference: Stone Age dietary practice in the Baltic region. Theses and Papers in Scientific Archaeology 5*. Archaeological Research Laboratory, Stockholm University, Stockholm, pp. 1–11.
- Eriksson, G., Linderholm, A., Fornander, E., Kanstrup, M., Schoultz, P., Olofsson, H., Lidén, K., 2008. Same island, different diet: cultural evolution of food practice on Öland, Sweden, from the Mesolithic to the Roman Period. *Journal of Anthropological Archaeology* 27, 520–543.
- Eriksson, G., Lougas, L., Zagorska, I., 2003. Stone age hunter–fisher–gatherers at Zvejnieki, northern Latvia: radiocarbon, stable isotope and archaeozoology data. *Before Farming* 2003/1 (2), 1–26.
- Fischer, A., Olsen, J., Richards, M., Heinemeier, J., Sveinbjörnsdóttir, A.E., Bennike, P., 2007. Coaste-inland mobility and diet in the Danish Mesolithic and Neolithic: evidence from stable isotope values of humans and dogs. *Journal of Archaeological Science* 34, 2125–2150.
- Fornander, E., Eriksson, G., Lidén, K., 2008. Wild at heart: approaching Pitted Ware identity, economy and cosmology through stable isotopes in skeletal material from the Neolithic site Korsnäs in Eastern Central Sweden. *Journal of Anthropological Archaeology* 27, 281–297.
- France, R.L., 1995. Differentiation between littoral and pelagic foodwebs in lakes using stable carbon isotopes. *Limnology and Oceanography* 40, 1310–1313.
- Goldman, C.R., Elser, J.J., Richards, R.C., Reuters, J.E., Priscu, J.C., Levin, A.L., 1996. Thermal stratification, nutrient dynamics, and phytoplankton productivity during the onset of spring phytoplankton growth in Lake Baikal, Russia. *Hydrobiologia* 331, 9–24.
- Goriunova, O.I., 1997. Serovskie pogrebeniia Priol'khon'ia. Institut arkhologii i etnografii SO RAN, Novosibirsk.
- Goriunova, O.I., Novikov, A.G., Mamonova, N.N., 1998. Zakhroneniia bronzovogo veka mogil'nika Sarminskii Mys na Baikale. *Gumanitarnye Nauki Sibiri* 3, 13–19.
- Giller, P.S., Malmqvist, B., 1998. *The Biology of Streams and Rivers*. Oxford University Press, Oxford.
- Haak, W., Brandt, G., de Jong, H.N., Meyer, C., Ganslmeier, R., Heyd, V., Hawkesworth, C., Pike, A.W.G., Meller, H., Alt, K.W., 2008. Ancient DNA, strontium isotopes, and osteological analyses shed light on social and kinship organization of the Later Stone Age. *Proceedings of the National Academy Science USA* 105, 18226–18231.
- Haverkort, C., Weber, A.W., Katzenberg, M.A., Goriunova, O.I., Simonetti, A., Creaser, R.A., 2008. Hunter–gatherer mobility strategies and resource use based on strontium isotope (87Sr/86Sr) analysis: a case study from Middle Holocene Lake Baikal, Siberia. *Journal of Archaeological Science* 35, 1265–1280.
- Katzenberg, M.A., 1989. Stable isotope analysis of archaeological faunal remains from southern Ontario. *Journal of Archaeological Science* 16, 319–329.
- Katzenberg, M.A., 2008. Stable isotope analysis, a tool for studying past diet, demography, and life history. In: Katzenberg, M.A., Saunders, S.R. (Eds.), *Biological Anthropology of the Human Skeleton*. Wiley-Liss, Hoboken, pp. 413–442.
- Katzenberg, M.A., Bazaliiskii, V.I., Goriunova, O.I., Savel'ev, N.A., Weber, A.W., 2010. Diet reconstruction and stable isotope ecology 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 of Archaeology and Anthropology, Philadelphia, pp. 175–192.
- Katzenberg, M.A., Goriunova, O.I., Weber, A.W., 2009. Paleodiet reconstruction of Early Bronze Age Siberians from the site of Khuzhir-Nuge XIV, Lake Baikal. *Journal of Archaeological Science* 36, 663–674.
- Katzenberg, M.A., McKenzie, H.G., Losey, R.J., Goriunova, O.I., Weber, A.W., in press. Prehistoric dietary adaptations among hunter–fisher–gatherers from the Little Sea of Lake Baikal, Siberia, Russian Federation. *Journal of Archaeological Science*. doi:10.1016/j.jas.2011.08.010.
- Katzenberg, M.A., Weber, A.W., 1999. Stable isotope ecology and paleodiet in the Lake Baikal region of Siberia. *Journal of Archaeological Science* 26 (6), 651–659.
- Kelly, R.L., 1995. *The Foraging Spectrum: Diversity in Hunter–Gatherer Lifeways*. Smithsonian Institution Press, Washington.
- Kiyashko, S.I., Mamontov, A.M., Chernyshev, M.Zh., 1991. Food web analysis of Lake Baikal fish by ratios of stable carbon isotopes. *Doklady, Biological Sciences* 318, 274–276.
- Kiyashko, S.I., Richard, P., Chandler, T., Kozlovad, T.A., Williams, D.F., 1998. Stable carbon isotope ratios differentiate autotrophs supporting animal diversity in Lake Baikal. *Comptes Rendus de l'Académie des Sciences – Series III – Sciences de la Vie* 321 (6), 509–516.
- Konopatskii, A.K., 1982. *Drevnie kul'tury Baikala (o. Ol'khon)*. Nauka, Novosibirsk.
- Kozhov, M.M., 1950. *Presnye vody Vostochnoi Sibiri (bassein Baikala, Angary, Vitima, verkhnego techenia Leny i Nizhnei Tunguski)*. Irkutskoe oblastnoe gosudarstvennoe izdatel'stvo, Irkutsk.
- Kozhov, M.M., 1963. *Lake Baikal and Its Life*. Junk, The Hague.
- Kozhov, M.M., 1972. *Ocherki po baikalovedeniui (Essays on Lake Baikal)*. Vostochno-Sibirskoe knizhnoe izdatel'stvo, Irkutsk (in Russian).
- Kusaka, S., Ando, A., Nakano, T., Yumoto, T., Ishimaru, E., Yoneda, M., Hyodo, F., Katayama, K., 2009. A strontium isotope analysis on the relationship between ritual tooth ablation and migration among the Jomon people in Japan. *Journal of Archaeological Science* 36, 2289–2297.
- Kusaka, S., Hyodo, F., Yumoto, T., Nakatsukasa, M., 2010. Carbon and nitrogen stable isotope analysis on the diet of Jomon populations from two coastal regions of Japan. *Journal of Archaeological Science* 37 (8), 1968–1977.
- Kusaka, S., Ikarashi, T., Yumoto, T., Hyodo, F., Yumoto, T., Katayama, K., 2008. Variability in stable isotope ratios in two Late–Final Jomon communities in the Tokai coastal region and its relationship with sex and ritual tooth ablation. *Anthropological Science* 116 (2), 171–181.
- Kuzmin, Y.V., Richards, M.P., Yoneda, M., 2002. Palaeodietary and radiocarbon dating of Neolithic populations in the Primorye Province, Russian Far East. *Ancient Biomolecules* 4 (2), 53–58.
- Lam, Y.M., 1994. Isotopic evidence for change in dietary patterns during the Baikal Neolithic. *Current Anthropology* 35 (2), 185–190.
- Lee-Thorp, J.A., 2008. On isotopes and old bones. *Archaeometry* 50, 925–950.
- Lieverse, A. R., Weber A.W., Goriunova, O.I. 2007. Human osteological remains, 1997–2001. In: Weber, A.W., Katzenberg, M.A. and Goriunova, O.I. (Eds.), *Khuzhir-Nuge XIV, A Middle Holocene Hunter-gatherer cemetery on Lake Baikal, Siberia: Osteological Materials*. Northern Hunter-Gatherer s Research Series 3. Canadian Circumpolar Institute Press, Edmonton, pp. 21–216.
- Lieverse, A.R., Bazaliiskii, V.B., Goriunova, O.I., Weber, A.W., 2009. Upper limb musculoskeletal stress markers among Middle Holocene Foragers of Siberia's Cis-Baikal Region. *American Journal of Physical Anthropology* 138, 458–472.
- Lieverse, A.R., Stock, J.T., Katzenberg, M.A., Haverkort, C.M., 2011. The bioarchaeology of habitual activity and dietary change in the Siberian Middle Holocene. In: Pinhasi, R., Stock, J.T. (Eds.), *Human Bioarchaeology of the Transition to Agriculture*. Wiley-Blackwell, Chichester, pp. 265–291.
- Losey, R.J., Bazaliiskii, V.I., Garvie-Lok, S., Germonpré, M., Leonard, J.A., Allen, A.L., Katzenberg, M.A., Sablin, M.V., 2011. Canids as persons: Early Neolithic dog and wolf burials, Cis-Baikal, Siberia. *Journal of Anthropological Archaeology* 30, 174–189.
- Losey, R.J., Nomokonova, T., Goriunova, O.I., 2008. Fishing ancient Lake Baikal, Siberia: inferences from the reconstruction of harvested perch (*Perca fluviatilis*) size. *Journal of Archaeological Science* 35, 577–590.

- McKenzie, H.G., 2010. Variability in Bronze Age (~5200–4000 Cal BP) mortuary practices in the Little Sea microregion, Cis-Baikal. 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 of Archaeology and Anthropology, Philadelphia, pp. 87–106.
- Meiklejohn, C., Zvebil, M., 1991. Health status of European populations at the agricultural transition and the implications for the adoption of farming. In: Bush, H., Zvebil, M. (Eds.), *Health in Past Societies. Biocultural Interpretations of Human Skeletal Remains in Archaeological Contexts*. British Archaeological Reports, International Series, 567, Oxford, pp. 129–145.
- Milner, N., Craig, O.E., Bailey, G.N., Pederson, K., Anderson, S.H., 2004. Something fishy in the Neolithic? A re-evaluation of stable isotope analysis of Mesolithic and Neolithic coastal populations. *Antiquity* 78, 9–22.
- Minagawa, M., Akazawa, T., 1992. Dietary patterns of Japanese Jomon hunter-gatherers: stable nitrogen and carbon isotope analyses of human bones. In: Aikens, C.M., Rhee, S.N. (Eds.), *Pacific Northeast Asia in Prehistory: Research into the Emergence of Hunter–Fisher–Gatherers, Farmers and Socio-Political Elites*. University Washington Press, Washington, pp. 59–68.
- Nomokonova, T.Yu., Losey, R.J., Goriunova, O.I., 2006. Predvaritel'nyi analiz faunisticheskikh materialov s mnogoslainoi stoianki Ityrkhei (Maloe More, ozero Baikal) (Preliminary analysis of faunal remains from the multilayered habitation site Ityrkhei (Little Sea, Lake Baikal)). *Izvestiia Laboratorii Drevnikh Tekhnologii* 4, 166–177.
- Nomokonova, T.Yu., Losey, R.J., Goriunova, O.I., 2009a. Rekonstruktsiia rybnogo promysla na ozero Baikal (analiz ikhtiofauny so stoianki Ityrkhei) (Reconstruction of fish procurement on Lake Baikal (analysis of ichthyofauna from Ityrkhei site)). *Rossiiskaia Arkeologiya* 3, 12–21.
- Nomokonova, T.Yu., Losey, R.J., Goriunova, O.I., 2009b. Prehistoric Fishing on Lake Baikal Siberia: Analyses of Faunal Remains from Ityrkhei Cove. VDM Verlag, Saarbrücken.
- Novikov, A.G., Goriunova, O.I., 2005. Drevnee rybolovstvo na Baikale (po materialam mnogoslainnykh poselenii perioda mezolita-bronzovogo veka). *Izvestiia Laboratorii drevnikh tekhnologii IGTV* 3, 125–134.
- Ogawa, N.O., Yoshii, K., Melnik, N.G., Bondarenko, N.A., Timoshenko, O.A., Smirnova-Zalumi, N.S., Smirnov, V.V., Wada, E., 2000. Carbon and nitrogen isotope studies of pelagic ecosystems and environmental fluctuations of Lake Baikal. In: Minoura, K. (Ed.), *Lake Baikal: A Mirror in Time and Space for Understanding Global Change Processes*. Elsevier, Amsterdam, pp. 262–272.
- Pastukhov, V.D., 1993. Nerpa Baikala (The Baikal Seal). Nauka, Novosibirsk (in Russian).
- Prokopenko, A.A., Khursevich, G.K., Bezrukova, E.V., Kuzmin, M.I., Boes, X., Williams, D.F., Fedenya, S.A., Kulagina, N.V., Letunova, P.P., Abzaeva, A.A., 2007. Paleo-environmental proxy records from Lake Hovsgol, Mongolia, and a synthesis of Holocene climate change in the Lake Baikal watershed. *Quaternary Research* 68, 2–17.
- Richards, M.P., Hedges, R.E.M., 1999. Stable isotope evidence for similarities in the types of marine foods used by Late Mesolithic humans at sites along the Atlantic coast of Europe. *Journal of Archaeological Science* 26, 717–722.
- Roksandic, Z., Minagawa, M., Akazawa, T., 1988. Comparative analysis of dietary habits between Jomon and Ainu hunter-gatherers from stable carbon isotopes of human bone. *Journal of Anthropological Society of Nippon* 96, 391–404.
- Syväranta, J., Hämäläinen, H., Jones, R.J., 2006. Within-lake variability in carbon and nitrogen stable isotope signatures. *Freshwater Biology* 51, 1090–1102.
- Schoeninger, M.J., DeNiro, M.J., Tauber, H., 1983. Stable nitrogen isotope ratios of bone collagen reflect marine and terrestrial components of prehistoric human diet. *Science* 220, 1381–1383.
- Schulting, R.J., 1998. Slighting the sea: stable isotope evidence for the transition to farming in northwestern Europe. *Documenta Praehistorica* XXV, 203–218.
- Schulting, R.J., 2010. Staying home for dinner: an isotopic approach to regionality in Mesolithic Atlantic Europe. In: Barnard, R., Engevik, A., Øye, I. (Eds.), *The Archaeology of Regional Technologies: Case Studies from the Palaeolithic to the Age of the Vikings*. Edwin Mellen Press, Lewiston, pp. 69–88.
- Schulting, R.J., Richards, M.P., 2001. Dating women and becoming farmers: new paleodietary and AMS data from the Breton Mesolithic cemeteries of Tévéc and Hoëdic. *Journal of Anthropological Archaeology* 20, 314–344.
- Sealy, J., Armstrong, R., Schrire, C., 1995. Beyond lifetime averages: analysis of different calcified tissues from archaeological human skeletons. *Antiquity* 69, 290–300.
- Sealy, J.C., van der Merwe, N.J., 1992. On “approaches to dietary reconstruction in the Western Cape: are you what you have eaten?” – a reply to to Parkinson. *Journal of Archaeological Science* 19, 459–466.
- Smits, E., Millard, A.R., Nowell, G., Pearson, D.G., 2010. Isotopic investigation of diet and residential mobility in the neolithic of the Lower Rhine Basin. *European Journal of Archaeology* 13, 5–31.
- Stock, J.T., Bazaliiskii, V.I., Goriunova, O.I., Savel'ev, N.A., Weber, A.W., 2010. Skeletal morphology, climatic adaptation and habitual behavior among the mid-Holocene populations of the Cis-Baikal, relative to other hunter–gatherers. 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 of Archaeology and Anthropology, Philadelphia, pp. 193–216.
- Tarasov, P.E., Bezrukova, E.V., Krivonogov, S.K., 2009. Late glacial and Holocene changes in vegetation cover and climate in southern Siberia derived from a 15 kyr long pollen record from Lake Kotokel. *Climate of the Past Discussion* 5, 127–151.
- Tauber, H., 1981. 13C evidence for dietary habits of prehistoric man in Denmark. *Nature* 292, 31–45.
- Tiutrin, A.A., Bazaliiskii, V.I., 1996. Mogil'nik v ust'e reki Idy v doline Angary. In: Anon (Ed.), *Akheologiya i etnologia Sibiri in Dal'nego Vostoka*, vol. 1. Irkutskii gosudarstvennyi universitet, Irkutsk, pp. 85–90.
- Turov, M.G., 2010. Evenki Economy in the Central Siberian Taiga at the Turn of the 20th Century. Principles of Land Use. Northern Hunter–Gatherers Research Series, vol. 5. Canadian Circumpolar Institute Press, Edmonton.
- Vogel, J.C., van der Merwe, N.J., 1977. Isotopic evidence for early maize cultivation in New York State. *American Antiquity* 42, 238–242.
- Waters-Rist, A.L., Bazaliiskii, V.I., Weber, A.W., Katzenberg, M.A., in press. Infant and child diet in neolithic hunter–fisher–gatherers from Cis-Baikal, Siberia: intralong bone stable nitrogen isotope ratios. *American Journal of Physical Anthropology*. doi:10.1002/ajpa.21568.
- Weber, A.W., in press. Patterns of cemetery use at Kurma XI: Bayesian approach to the examination of radiocarbon dates. In: Weber, A.W., Goriunova, O.I., McKenzie, H.G., Lieverse, A.R. (Eds.), *Kurma XI, A Middle Holocene Hunter–Gatherer Cemetery on Lake Baikal, Siberia*. Canadian Circumpolar Institute Press, Edmonton.
- Weber, A.W., Bettinger, R.L., 2010. Middle Holocene hunter–gatherers of Cis-Baikal, Siberia: an overview for the new century. *Journal of Anthropological Archaeology* 29, 491–506.
- Weber, A.W., Beukens, R., Bazaliiskii, V.I., Goriunova, O.I., Savel'ev, N.A., 2006. Radiocarbon dates from Neolithic and Bronze Age hunter–gatherer cemeteries in the Cis-Baikal region of Siberia. *Radiocarbon* 48 (3), 1–40.
- Weber, A.W., Goriunova, O.I., in preparation. Hunter–gatherer migrations, mobility and social relations: a case study from the Bronze Age Baikal region, Siberia. In: Weber, A.W., Zvebil, M. (Eds.), *Human Bioarchaeology: Group Identity and Individual Life Histories*. *Journal of Anthropological Archaeology (Special Issue)*.
- Weber, A.W., Goriunova, O.I., McKenzie, H.G. (Eds.), 2008. *Khuzhir-Nuge XIV, A Middle Holocene Hunter–Gatherer Cemetery on Lake Baikal, Siberia: Archaeological Materials*. Canadian Circumpolar Institute Press, Edmonton.
- Weber, A.W., Goriunova, O.I., McKenzie, H.G., Lieverse, A.R. (Eds.), in press. *Kurma XI, A Middle Holocene Hunter–Gatherer Cemetery on Lake Baikal, Siberia*. Canadian Circumpolar Institute Press, Edmonton.
- Weber, A.W., Katzenberg, M.A., Goriunova, O.I. (Eds.), 2007. *Khuzhir-Nuge XIV, A Middle Holocene Hunter–Gatherer Cemetery on Lake Baikal, Siberia: Osteological Materials*. Canadian Circumpolar Institute Press, Edmonton.
- Weber, A.W., Katzenberg, M.A., Schurr, T.G. (Eds.), 2010a. *Prehistoric Hunter–Gatherers of the Baikal Region, Siberia: Bioarchaeological Studies of Past Life Ways*. University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia.
- Weber, A.W., Konopatskii, A.K., Goriunova, O.I., 1993. Neolithic seal hunting on Lake Baikal: methodology and preliminary results of the analysis of canine sections. *Journal of Archaeological Science* 20, 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. *Journal of Archaeological Science* 25, 215–227.
- Weber, A.W., Link, D., Katzenberg, M.A., 2002. Hunter–gatherer culture change and continuity in the Middle Holocene of the Cis-Baikal, Siberia. *Journal of Anthropological Archaeology* 21, 230–299.
- Weber, A.W., McKenzie, H.G. (Eds.), 2003. *Prehistoric Foragers of the Cis-Baikal, Siberia*. Canadian Circumpolar Institute Press, Edmonton.
- Weber, A.W., McKenzie, H.G., Beukens, R., 2005. Evaluation of radiocarbon dates from the Middle Holocene hunter–gatherer cemetery Khuzhir-Nuge XIV, Lake Baikal, Siberia. *Journal of Archaeological Science* 32, 1481–1500.
- Weber, A.W., McKenzie, H.G., Beukens, R., 2010b. Radiocarbon dating of Middle Holocene culture history in the Cis-Baikal. 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 of Archaeology and Anthropology, Philadelphia, pp. 27–49.
- 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 Museum of Archaeology and Anthropology, Philadelphia, pp. 1–26.
- Yesner, D., Figuerero-Torres, M.J., Guichon, R.A., Borrero, L.A., 2003. Stable isotope analysis of human bone and ethnohistoric subsistence patterns in Tierra del Fuego. *Journal of Anthropological Archaeology* 22 (3), 279–291.
- Yoshii, K., Melnik, N.G., Timoshkin, O.A., Bondarenko, N.A., Yoshioka, T., Wada, E., 1999. Stable isotope analyses of the pelagic food web in Lake Baikal. *Limnology and Oceanography* 44 (3), 502–511.
- Yoneda, M., Hirota, M., Uchida, M., Tanaka, A., Shibata, Y., Morita, M., Akazawa, T., 2002. Radiocarbon and stable isotope analyses on the earliest Jomon skeletons from the Tochibara rockshelter, Nagano, Japan. *Radiocarbon* 44, 549–557.
- Yoneda, M., Suzuki, R., Shibata, Y., Morita, M., Sukegawa, T., Shigehara, N., Akazawa, T., 2004. Isotopic evidence of inland-water fishing by a Jomon population excavated from the Boji site, Nagano. *Japanese Journal of Archaeological Science* 31, 97–107.
- Zvebil, M., Weber, A.W. (Eds.), in preparation. *Human bioarchaeology: group identity and individual life histories*. *Journal of Anthropological Archaeology (Special Issue)*.