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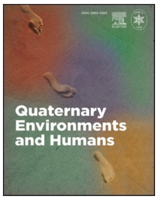

The great divide? Differences in environmental and hunter-gatherer responses to the 8.2 ka BP event between northwestern and northeastern Eurasia

Rick J. Schulting [a,*], Pavel E. Tarasov [b], Andrzej W. Weber [c,d]

[a] School of Archaeology, University of Oxford, Oxford, UK
[b] Institute of Geological Sciences, Paleontology Section, Freie Universität Berlin, Malteserstraße 74–100, Building D, Berlin 12249, Germany
[c] Department of Anthropology, University of Alberta, Edmonton, Canada
[d] Research Centre "Baikal Region", Irkutsk State University, Irkutsk, Russia

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ABSTRACT

In this contribution we provide an overview of the potential impacts of the 8.2 ka BP cooling event on hunter-gatherer societies in northwestern Europe and northern/eastern Eurasia. There seems to be a division between the two parts of the continent, with Atlantic Europe generally seeing a stronger climatic and environmental impact compared to continental Eurasia. This plausibly relates to the greater effects on oceanic weather patterns, particularly those of the North Atlantic. The palaeoenvironmental record is more limited for the Pacific coast of northeast Asia, but the evidence to date does not suggest as strong an impact there. We then focus on a case study of the hunter-gatherers of Cis-Baikal in southern Siberia. While the archaeological record for the period pre-8200 cal BP is patchy, we find no clear evidence for any impact on the region's hunter-gatherer communities. Major visible changes occur only with the appearance of the Kitoi culture from ca. 7600 cal BP, which sees the introduction of pottery, the bow and arrow, and large cemeteries. This appears to be an internal socio-technological development unrelated to any abrupt changes in the regional climate and environment at this time.

1. Introduction

The 8.2 ka BP event is the largest climatic anomaly in the Holocene. The massive influx of freshwater into the northwestern Atlantic following the breaching of ice dams interrupted the North Atlantic Drift, with temperatures dropping by 3–6 °C for a period of ca. 160 years as recorded in Greenland ice cores (Alley et al., 1997; Kobashi et al., 2007; Matero et al., 2017; Parker and Harrison, 2022; Vellinga and Wood, 2002; Von Grafenstein et al., 1998). Its impact was widespread in the northern hemisphere, leading to more continental climates along the seaboards, with colder winters and cooler, dryer summers. One of the clearest responses is seen in vegetation records, with a decrease in temperate deciduous tree/shrub pollen and corresponding increase in boreal taxa pollen (Ghilardi and O'Connell, 2013; Li et al., 2019; McKay et al., 2024; Schubert et al., 2023; Tinner and Lotter, 2001; Zhao et al., 2022). At a continental scale, its effects were strongest along latitudinal and altitudinal ecotones (Evans and Brown, 2017; Paus et al., 2019).

Despite its demonstrable impact on climate and vegetation, the response – or lack thereof – of human communities to the 8.2 ka BP is still debated. In this paper, we briefly review hunter-gatherer responses to this event in northwestern (NW) Europe, where the North Atlantic is a dominant climatic factor, before presenting a case study from Cis-Baikal in southern Siberia (Cis-Baikal refers to western side of Lake Baikal). The region holds one of the largest concentrations of prehistoric hunter-gatherer burials in northern Eurasia, providing the opportunity for high-resolution chronologies at the meso-scale relevant for investigating the human response to relatively rapid climatic change, linked with stable isotopic (δ^{13}C and δ^{15}N) data informing on potential shifts in subsistence adaptations as part of this response. It also has the advantage of having a considerable body of palaeoenvironmental research relating to the Early Holocene. We conclude with a comparison of Cis-Baikal to the Mesolithic cemetery of Yuzhniy Oleniy Ostrov in northwest Russia, as the two populations share a degree of reliance on riverine and lake resources within a boreal forest setting, yet seem to show very different responses to the 8.2 ka BP event.

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* Corresponding author.
E-mail address: rick.schulting@arch.ox.ac.uk (R.J. Schulting).

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2. Hunter-gatherer response to the 8.2 ka BP event

Changes in precipitation and the start and length of the growing season caused by the 8.2 ka BP cooling event can be expected to have had the greatest impact on farming societies. However, the vast majority of northern Eurasia this time was occupied not by farmers, but by hunter-gatherers. An important point to emphasise from the outset is that a climate cooling event does not necessarily represent a 'deterioration' or 'downturn' (as should be clear from the direction of the current climate crisis), despite these terms being often used. While some species (and this would apply to cereals, given their origins in southwest Asia) and indeed entire ecosystems may be negatively affected, others would be positively impacted: the retraction of some species goes hand-in-hand with the expansion of others. Such changes would have correspondingly either negative or positive effects from the perspective of human adaptations.

There are considerable challenges in investigating hunter-gatherer responses to Holocene climate events. Generally living in small, mobile groups, they are often characterised – or even defined – by their flexibility both in terms of subsistence practices and social organisation, with one re-enforcing the other (Kelly, 2013). Thus, for example, flexibility in kinship relations can be drawn upon to respond to challenges brought about by environmental perturbations through individual and group mobility. Low population densities, high residential mobility and flexible social arrangements offer communities many alternatives in response to both short- and longer-terms fluctuations in resource availability. Groups may aggregate or disperse, and broaden or narrow their subsistence focus as circumstances change. Hence, for the most part, we would expect that generalised hunter-gatherers would be highly resilient to challenges such as those posed by the 8.2 ka BP event, through adaptability built into their subsistence strategies and the support of a large regional social network.

However, hunter-gatherers with greater reliance on aquatic resources, whether marine or freshwater, have a stronger attachment to place and so are somewhat less flexible than more generalised hunter-gatherers. Such groups often exhibit greater social differentiation with reduced residential mobility, greater resource intensification and increased use of storage, leading to higher population densities (Binford, 2001; Kelly, 2013). A consequence of this is an increased concern with territoriality (Elder, 2010; Rowley-Conwy, 1998; Schulting, 2010). Whether this would lead to reduced resilience to climate change depends on the severity and duration of the resulting stressors and on available options (e.g. the feasibility of higher mobility and dispersal), which in turn depend on regional population density and structure. Our expectation is that there would be a more tangible response by less mobile, more specialised (sometimes called 'complex') hunter-gatherers to climate events in cases where critical resources were affected negatively. Aquatic resources (marine and freshwater) may be buffered to some extent against climate events affecting primarily terrestrial ecosystems, but they often require greater investment in technology for initial acquisition and processing, including labour bottlenecks to prepare surplus catches for storage (Ames and Maschner, 1999; Bettinger, 2009; Testart, 1982; Woodburn, 1982). The degree to which this will be archaeologically visible will vary.

Robinson et al. (2013) highlight well some of the key problems in inferring a convincing causal relationship between climate change and human cultural change. Chronology must be the first and foremost consideration, for without a robust and high-resolution chronology it is impossible to link the two in a cause-and-effect relationship and hence to even begin the discussion. This is a necessary but not sufficient condition. Equally important is specifying how the relevant regional environment was affected (cf. Nieuwenhuyse et al., 2016), and if so its timing (i.e. whether there was a time lag from the distant ice core record that defines the 8.2 ka BP event). And finally, it should be possible to infer, at least broadly, the kinds of stresses this would have created for the human socioeconomic system and what kind of solutions (social and/or technological) were available to cope with them.

3. The 8.2 ka BP event among northern Eurasian hunter-gatherers

A number of studies have addressed the question of whether a response to the 8.2 ka BP climate event can be discerned amongst northern Eurasian hunter-gatherers. In brief, the answer to this question seems to be 'sometimes'. Both the existence and the nature of the response varies regionally, and may also be influenced by different interpretations of the same data.

Moreover, very different impacts are expected for NW Europe and eastern Eurasia. The former is affected by its proximity to the Atlantic, while the latter is on the northern edge of the vast region affected by monsoon circulation. Yet there is conflicting information depending on the proxies being examined and the spatiotemporal scale of the analysis. Meta-analysis of speleothem δ^{18}O data suggests colder conditions in western Eurasia but warmer conditions in eastern Eurasia (Parker and Harrison, 2022), and global climate modelling has inferred wetter conditions for NW Europe and drier conditions for SE Asia (Morrill et al., 2013). Both scenarios, however, are at odds with a number of regional studies. Wang et al. (2009) found evidence for warmer but wetter conditions in east Asia. Park et al. (2019, 2018) in contrast identify clear evidence for cooling in pollen records from coastal South Korea. Among the most convincing accounts for the climate impact of the 8.2 ka BP event in east Asia are the speleothem records from Dongge, Huangyuan, and Heshang Caves in North and Central China, all showing positive excursions in δ^{18}O values indicating increased aridity (Duan et al., 2024; Dykoski et al., 2005; Liu et al., 2013).

Stebich et al. (2015) reconstructed Holocene vegetation and climate dynamics of NE China based on the detailed (i.e. average temporal resolution of ca. 55 years) and accurately dated (i.e. AMS ^{14}C dates and varve counting) pollen record from Sihailongwan Maar Lake (42°17' N, 126°36' E; 797 m a.s.l.). Their pollen record shows a marked decline in *Juglans* (walnut) pollen percentages shortly after 8200 cal BP with a minimum in *Juglans* and *Quercus* (oak) around 8000 cal BP followed shortly afterwards by a sharp increase in *Ulmus* (elm) and *Fraxinus* (ash) pollen. However, these marked changes in forest composition likely represent winter and early spring cooling associated with the 8.2 ka BP event, while the quantitative reconstruction (Stebich et al., 2015) suggests higher than present temperature for the warmest month, and lower than present annual precipitation during the early Holocene. Maximum remote dust accumulation rates recorded in the Sihailongwan Maar Lake sediments prior to 8000 cal BP, and the absence of dust layers thereafter, may reflect high frequency of cold air surges and enhanced winter monsoon activity promoting springtime dust storms in NE China during the 8.2 ka BP episode and a basic change in the atmospheric circulation and/or increasing vegetation coverage in the dust source region at that time (Zhu et al., 2013).

3.1. Northwestern Europe

Breivik et al. (2018) found no evidence for a decline in site numbers across the 8.2 ka BP event on the outer Oslo fjord of southeast Norway. In fact, the Late Mesolithic Nøstvet phase, from ca. 8300 cal BP, is characterised by increased sedentism as inferred from greater site size and diversity of finds compared to earlier periods. Given that the sites by definition are shore-bound – as they have been mainly dated by shoreline displacement, though supported by radiocarbon dating – this could suggest an increased reliance on marine resources, albeit from what was likely already a high level of reliance. This approach was subsequently extended to the inner Oslo fjord by Fossum (2020) who also found no decline in site numbers during the cooling event. Importantly, there is good evidence for the impact of the 8.2 ka event in regional terrestrial climate records in Norway from multiple proxies, including evidence of re-advancing glaciers, a decline in temperate deciduous tree species, and lower summer temperatures through chironomid records (Antonsson and Seppä 2007; Dahl and Nesje, 1994; Paus, 2010; Velle et al., 2005). Thus, this seems to be a good example of coastal communities being buffered against climate change affecting primarily the terrestrial environment.

By contrast, using summed probability distributions (SPDs) of ^{14}C dates from the island of Gotland in the Baltic Sea, Apel et al. (2018) inferred a decline in human activity corresponding to the 8.2 ka BP event. The local impact of the cooling event is confirmed locally by a δ^{18}O record on varved lake carbonates on the island (Mörner and Wallin, 1977). Nevertheless, the connection with the 8.2 ka event is not straightforward. Firstly, the island's hunter-gatherers were heavily reliant on aquatic resources (seals, marine and freshwater fish), which would not respond to the cooling event in the same way as terrestrial resources. And secondly, there is an equally marked decline in the SPD at ca. 7600 cal BP that corresponds with *higher* temperatures as seen from the lake's δ^{18}O record. Moreover, there is a complete absence of radiocarbon dates between ca. 7000 and 6400 cal BP, during the Middle Holocene climatic optimum (Apel et al., 2018, fig. 4). While other factors are of course at play, this must call into question any simple link between climate and the intensity of human activity on Gotland, and/or the ability of SPDs to capture it.

Using Bayesian modelling of radiocarbon dates from Mesolithic sites on the west coast of Scotland, Wicks and Mithen (2014) identified evidence for a marked decrease in activity at the onset of the 8.2 ka BP event, inferring from this a demographic collapse. However, a number of issues have been raised with this interpretation (Schulting, 2018). Firstly, it is not clear why a relatively minor decrease in temperature should create such a problem for what were coastal hunter-gatherers, given that colder waters hold more oxygen and so all else being equal are more productive (Breitburg et al., 2018). Increasing storminess may have limited access to offshore waters, but there is no evidence for a rebound in the summed probability distribution of the radiocarbon dates until after ca. 7000 cal BP. It is hard to imagine why a short-term cooling event lasting only a century or two would lead to the near-abandonment of a productive coastal environment for a millennium. It may be that other locations along the coast became more attractive for settlement and marine resource exploitation (e.g., in response to changing sea levels).

Using a similar 'dates as data' approach (Rick, 1987) but working on a much larger spatial scale, Griffiths and Robinson (2018) found no convincing evidence for an impact of the 8.2 ka BP event on hunter-gatherers in NW Europe (Denmark, Belgium, Britain and France). Hoebe et al. (2023) examined population dynamics at a similar scale (Denmark, Germany, The Netherlands, Belgium and Britain) and again found no clear relationship, seeing a decline in a kernel density estimation (KDE) plot but one that both preceded and persisted after 8.2 ka BP. In more regionally-focussed studies, Robinson et al. (2013) and Van Maldegem et al. (2021) used summed radiocarbon distributions to examine Mesolithic population dynamics and mobility in the Rhine-Meuse-Scheldt region and Scheldt basin, respectively, again finding no clear evidence that the observed changes were related to either the 9.3 or 8.2 ka BP cooling events. They do not discount the relevance of climate change – and resulting environmental change – altogether, but see it more in the context of longer-term human responses.

Taking a different approach, also within the Rhine-Meuse-Scheldt region, Crombé (2019), Robinson et al. (2013) linked changes in projectile point styles to abrupt cooling events at 10.3, 9.3 and 8.2 ka BP, marking typo-chronological shifts between phases within the Early Mesolithic in the first instance, between the Early and Middle Mesolithic in the second, and between the Middle and Late Mesolithic in the third. Changes in projectile point styles were thus related to increased expressions of territoriality (Crombé 2019). This differs importantly from the more typical search for 'demographic collapse' or the 'abandonment' of a region in response to climatic change. In part this search is itself arguably a product of the recent emphasis on the 'dates as data' approach, given its limitation to tracing population increases and decreases (assuming a straightforward relationship between radiocarbon dates and intensity of activity, in turn related to population density).

A comparable emphasis on a socioeconomic response to the 8.2 ka BP event was recently proposed by Schulting et al. (2022b) for the large Mesolithic cemetery of Yuzhniy Oleniy Ostrov, located on a small island of the same name in Lake Onega, northwest Russia. Although inland, Lake Onega is near enough to the Atlantic coast to be affected by its weather patterns, and this extends to the impact of the 8.2 ka BP event. Both palaeoenvironmental records and modelling have supported an impact of this cooling event on vegetation across NW Europe (Davis et al., 2003; Heikkilä and Seppä 2010; Jones et al., 2004; Paus et al., 2019; Veski et al., 2015; Wiersma and Renssen, 2006). A recent palynological study at Razlomnoe Peat (62°27′53″N, 34°26′4″E) located on the northern shore of Lake Onega, 65 km northwest of Yuzhniy Oleniy Ostrov, confirms an impact on vegetation during the 8.2 ka BP event. Between 8300 and 8000 cal BP, *Betula* sect. *Albae* (tree birch) shows a marked increase in pollen percentage, while *Pinus sylvestris* (Scots pine) experiences a marked decrease (Krikunova et al., 2024b). This change in vegetation, the most prominent of the entire record, can be explained by severe winter cooling and dry continental climate with relatively low precipitation and thin snow cover associated with the impact of the 8.2 ka BP event in the North Atlantic region (Li et al., 2019; Matero et al., 2017; Wiersma and Renssen, 2006). The normal development of Scots pine requires summer thawing of the active layer down to a depth of 1.5–2 m (Parfenova et al., 2021). It is possible that strong winter cooling in combination with intensified forest fires, reconstructed in Finland and Russian Karelia for the 8.2 ka BP event (Clear et al., 2015), created less favourable conditions for the reproduction (including decreased pollen productivity) and spread of pine, while the fast-growing birch occupying moist habitats benefited most from this situation (Krikunova et al., 2024b).

A radiocarbon dating programme has provided strong evidence that the main period of the cemetery's use coincided remarkably closely with both the start and end of the 8.2 ka BP event, effectively bracketed by it (Schulting et al., 2022b). To account for this, it was proposed that the microenvironment created by the lake itself lessened the impact of the 8.2 ka event on the surrounding vegetation and hence was particularly attractive to large game, most notably the elk (*Alces alces*) that seems to have featured strongly both in diet and ritual (Mantere and Kashina, 2020). In addition the lake's depth would have protected its waters from becoming hypoxic, a condition known to lead to winter fish kills that can require years to recover (Tonn et al., 2004). The importance of fish to the human communities is amply demonstrated by the human δ^{13}C and δ^{15}N results. Access to this crucial resource – made even more important by the 8.2 ka BP event – may have been contested between what were previously more dispersed communities focussing on the region's smaller lakes and rivers. Burial at Yuzhniy Oleniy Ostrov would have created a shared sense of a community that could have eased tensions and facilitated sharing of the resource (Saxe, 1970). When the need for this was obviated by improved climatic conditions after ca. 8000 cal BP, it seems that people returned to a previous pattern of smaller, more dispersed groups. Use of the cemetery sharply declined, with only a few graves dating to the subsequent centuries (Schulting et al., 2022b). The most convincing aspect of this study in terms of a human response to climate change lies in how the radiocarbon dates for burials coincide with both the onset and end of the 8.2 ka BP event.

3.2. Northern and eastern Eurasia

The literature on the impact of the 8.2 ka BP event on the regional environments and hunter-gatherer populations in northern and eastern Eurasia is more limited. Recent work has tentatively linked the appearance of fortified settlements and ritual mounds in hunter-gatherer contexts in western Siberia with the onset of the 8.2 ka BP event, thus far most clearly documented at the promontory fort of Amnya (Piezonka et al., 2023; Schreiber et al., 2022). This is interpreted as reflecting an increased expression of territoriality relating to the exploitation of abundant, predictable riverine fish and waterfowl resources amenable to mass capture and storage. Thus far, however, the nature and causality of the relationship remain unclear, and it may be that the interest in defence and/or marking places relates more to the rapid amelioration in climate immediately following the 8.2 ka BP event, rather than being instigated by it, or indeed that their apparent co-occurrence is coincidental, and that other processes are responsible (Piezonka et al., 2023).

At the eastern end of Eurasia, Morisaki et al. (2018) relate the appearance of a blade technology on Hokkaido, northern Japan, to the 8.2 ka BP event, since it presents a clear break with the flake-based lithic technologies that preceded and succeeded it. As blade technologies were already known earlier on Sakhalin Island to the north of Hokkaido, it is possible that changing climate conditions encouraged population movements from the north. While the chronological coincidence is suggestive, the causal mechanisms remain unclear, particularly in the absence of robustly dated proxy records for environmental change at this time on Hokkaido (Abe et al., 2016; Igarashi, 2016; Igarashi et al., 2011). However, the long sedimentary record from the Khoe Peat (51.34°N, 142.14°E, 15 m a.s.l) in Sakhalin shows a noticeable peak in the herbaceous pollen percentage curve accompanied with a marked increase in spruce and heath pollen between 8300 and 8000 cal BP. These changes coincide with the 8.2 ka cooling event, which interrupted what was otherwise the warmest and wettest interval of the Holocene, between 8700 and 5200 cal BP (Leipe et al., 2015). There is also pollen evidence for a decrease in temperate broad-leafed trees dated ca. 8200–8000 cal BP in three peat cores from the Lower Amur region on the adjacent mainland across from Sakhalin, leading Morisaki and Sato (Morisaki and Sato, 2015) to suggest that climate change may have led to increased mobility of hunter-gatherer communities there, though they acknowledge that the chronology of the relevant sites is too imprecise to make a strong case.

While possible links with climate change have been discussed for the long-lasting Jomon hunter-gatherer cultures of the main Japanese island of Honshū (Kawahata et al., 2009), no clear evidence of any significant impact of the 8.2 ka event has emerged.

3.3. *The 8.2 ka BP event in Cis-Baikal*

Lake Baikal is the world's largest freshwater lake by volume, measuring 636 by 79 km with a surface area of 31,722 km^2 (Fig. 1). The region's climate is strongly continental, though the lake itself creates a microenvironment, with lakeshore temperatures cooler in summer and warmer in winter than further inland from the lake. Winters are cold and long, lasting some five months, while summers are brief but relatively warm. Precipitation is relatively low, averaging ca. 300 mm per annum but again is variable spatially. Unsurprisingly, given the sheer size of the lake and the presence of surrounding mountain ranges, there is considerable environmental variability (see summaries in Kobe et al. (2020), Weber (2003), White and Bush (2010)). The vegetation is zoned south to north and west to east, as well as by altitude. It encompasses boreal cold deciduous and taiga forest, forest-steppe, and, at the highest elevations, alpine tundra environments.

The Lake Baikal region has been the subject of numerous

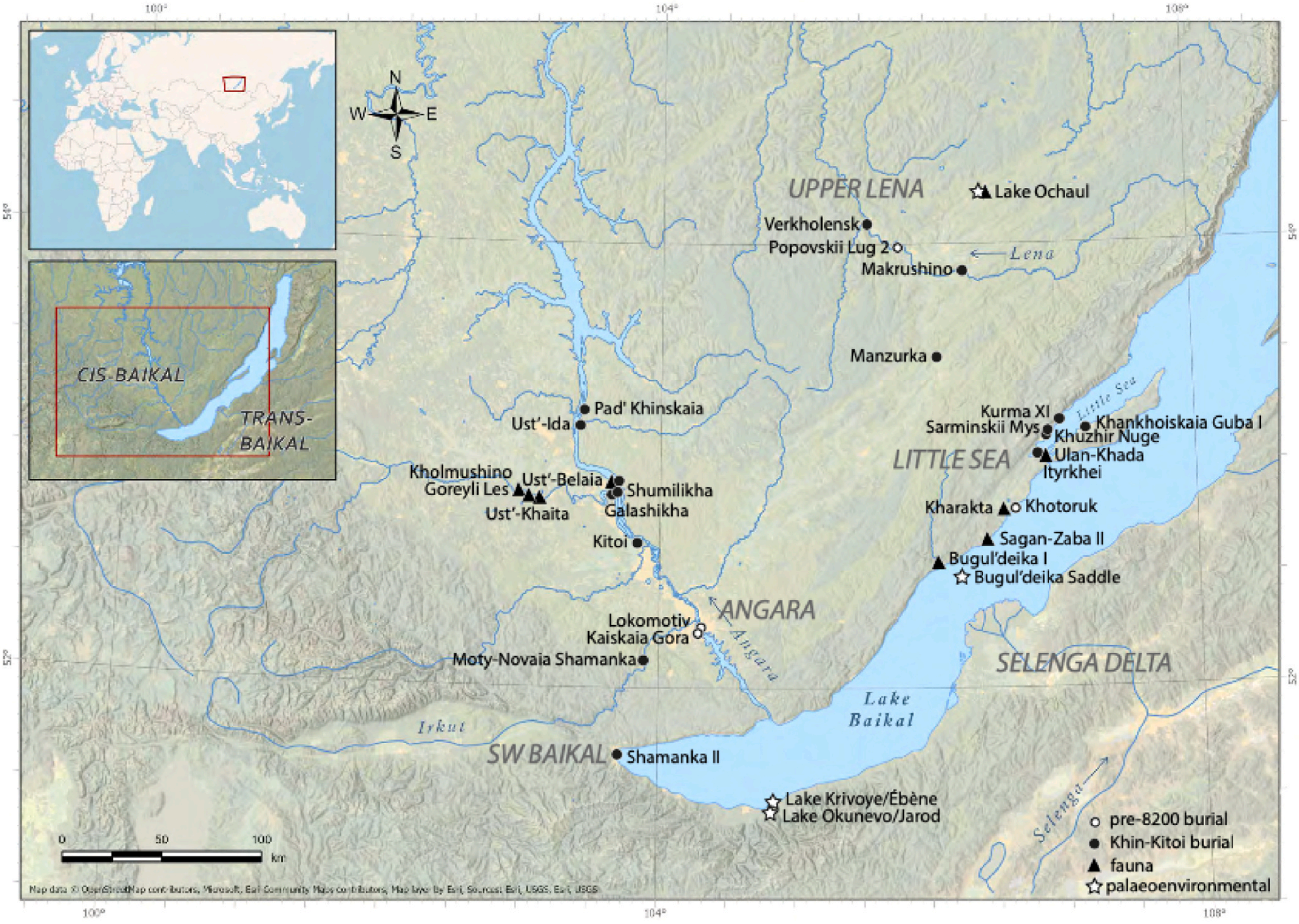

Fig. 1. Cis-Baikal showing microregions and the locations of sites featuring in the paper (base map courtesy of Karolina Werens).

palaeoenvironmental studies, including a number addressing the impact of the 8.2 ka BP climate event (Demske et al., 2005; Katsuta et al., 2018; Mackay et al., 2022; Shichi et al., 2013; Tarasov et al., 2007). This appears to have been marked by both cooling and decreased precipitation within an otherwise relatively wet Early Holocene, but determining the corresponding effect on vegetation is complicated by high variability within the region. A detailed study recently undertaken at Lake Ochaul, within the Upper Lena drainage to the north of the Lake Baikal, found that the cooling episode is only weakly visible in the pollen record by small peaks in Poaceae and *Artemisia* and a drop in total pollen concentration, suggesting rather limited effect on the regional vegetation during that time (Kobe et al., 2020; Kobe et al., 2022). Nevertheless, the micro-charcoal record from the same core demonstrates a peak in concentrations and accumulation rates contemporary with the 8.2 ka event (Krikunova et al., 2024a). A rapid expansion of *Betula* and *Artemisia* pollen in a core taken from Buguldeika Saddle in Lake Baikal itself has been linked with more frequent fires around 8.2 ka BP (Shichi et al., 2013). Another charcoal record from Lake Ébène (Krivoye) in the southernmost part of Lake Baikal also demonstrates an increase in the fire frequency and magnitude towards the Holocene maximum, yet this was not seen at Lake Jarod (Okunevo), less than 4 km further south (Barhoumi et al., 2021).

Overall, there is evidence for considerable variability in the palaeoenvironmental records from Lake Baikal, such that changes observed at one location may not necessarily be duplicated at others (Harding et al., 2020). While some studies have suggested an impact from the 8.2 ka BP event, it does not appear to have led to marked, widespread changes in vegetation; in fact, a more dramatic impact appears to have occurred regionally at ca. 6.5 ka BP (Katsuta et al., 2018; Tarasov et al., 2007).

The Baikal Archaeological Project (BAP: https://baikalproject.artsrn.ualberta.ca/) has been conducting research in the Cis-Baikal region for over three decades (Weber, 1995, 2020). The project's main focus has been the systematic radiocarbon dating and isotopic (primarily δ^{13}C and δ^{15}N) analysis of human remains from hunter-gatherer cemeteries in order to address spatiotemporal variation in adaptive strategies. Here too the 'dates as data' approach cannot be applied here in any straightforward way, as there are clear socioeconomic factors underlying the accumulation of large numbers of burials in single locations ('cemeteries') that may or may not bear a direct relationship with population size. But, as BAP has systematically radiocarbon dated the vast majority of prehistoric human remains in the region ($n = 607$ ^{14}C dates on post-weaning age individuals), biases towards certain cemeteries or periods are avoided, other than those inherent in past behaviour, e.g., the presence of large cemeteries in certain periods, versus smaller cemeteries in others.

Spatiotemporal variability in the mortuary record of Cis-Baikal has been previously explored at various scales and in considerable detail (Bronk Ramsey et al., 2021; Weber et al., 2021, 2016a, 2016b). Here, we reflect on this record primarily in terms of the 8.2 ka BP event. We introduce a new element by considering previously published faunal dates from occupation sites. Occupation sites have seen far less investigation, but nevertheless some data are available, permitting a comparison of two independent proxies for human activity. To emphasise this, we omit dates on faunal remains directly associated with burials, obtained in order to provide corrections for the freshwater reservoir effect (Schulting et al., 2015, 2014, 2022a). Applying chronometric hygiene, we exclude radiocarbon determinations on bone samples lacking quality assurance measures (e.g., C:N values), charred bone, unidentified bulk charcoal and 'ashy soil' that have all been noted as problematic (Goriunova and Novikov, 2018). Also excluded are a small number of dates on food crusts, due to uncertainties over reservoir effects. The resulting faunal dataset ($n = 184$, reduced to 117 considering only the Early and early Middle Holocene) is far too small to be robust (Michczyńska and Pazdur, 2004) and is used here only in an exploratory fashion. Kernel density estimation (KDE) is used in preference to SPDs to explore the datasets, as they are less affected by features of the calibration curve (Bronk Ramsey, 2017; McLaughlin, 2019). KDE models in OxCal v4.4 automatically consider a range of bandwidths (smoothing) described by the shaping parameter *g* (Figs. A1–3), with an upper limit defined by the Silverman (1998) estimate captured by the ± 1σ confidence band based on multiple MCMC iterations of the model and shown as dark and light shaded colours above and below a central line as described in Bronk Ramsey (2017).

The 8.2 ka event falls within the Late Mesolithic period (8630–7560 cal BP) in the culture history of Cis-Baikal, characterised by the Khin mortuary tradition (Weber, 2020). An immediate issue is that there are few burial sites known for this period, and they tend to be small with only a few graves. This is in marked contrast to the following Early Neolithic (defined by the appearance of pottery) Kitoi mortuary tradition (7560–6660 cal BP), featuring a range of cemeteries from small to a few very large examples, most notably Lokomotiv on the Angara River and Shamanka II on the shore of southwest Lake Baikal (Bazaliiskii, 2010; Weber et al., 2024, 2016a). Only four Khin graves pre-date 8200 cal BP (Fig. 2; Table S1), followed by something of a gap between 8200 and 8000 cal BP with only one dated individual from the whole of Cis-Baikal, at Kurma XI (KUR_2003.024), in what was otherwise primarily an Early Bronze Age cemetery (Weber et al., 2012). It is not until after ca. 7600 cal BP that there are large numbers of dated individuals, driven mainly by the two largest known Kitoi cemeteries of Lokomotiv and Shamanka II. The period between 8000 and 7200 cal BP is represented by a small number of burials from various sites in the Little Sea and Upper Lena microregions. While they overlap chronologically with the Kitoi in the Angara and SW Baikal microregions, they have more in common with the preceding Khin mortuary tradition (Weber et al., 2021).

This begs the question of why larger cemeteries are *not* known from the Early Holocene (i.e., pre-8.2 ka BP). The landscape was becoming more densely forested during this period, which would have diminished the returns from large-game hunting but might be expected to have made good fishing locations more desirable, leading to larger, semi-sedentary settlements and cemeteries in their vicinity (Weber, 2020). This expectation is not met: while the very small number of burials from disparate locations thus far identified makes it is difficult to characterise pre-8.2 ka BP diets as a whole, it can be tentatively suggested that aquatic resources made only a minor contribution compared to post-8.2 ka BP Khin/Kitoi communities (Fig. 3). However, interpretation is complicated by a temporal gap of some six centuries between pre- and post-8.2 individuals from the Angara/SW Baikal microregions, and the

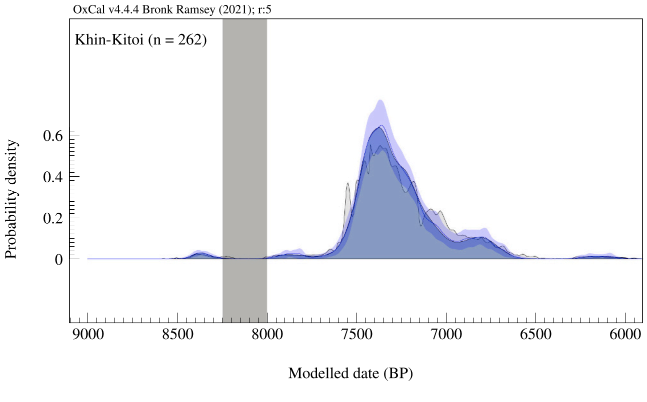

Fig. 2. KDE model and summed probability distribution (thin black line) for all Khin and Kitoi human dates from Cis-Baikal, corrected for the FRE using the regression equation for the microregion in which they were found. The shaded light and dark blue colours represent a ± 1σ confidence band for the KDE based on multiple runs with varying bandwith. The grey band marks the 8.2 ka BP event (data: (Schulting et al. 2015; Weber et al. 2021, 2016a, 2016b; White et al. 2020); see Appendix 1 for OxCal code). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

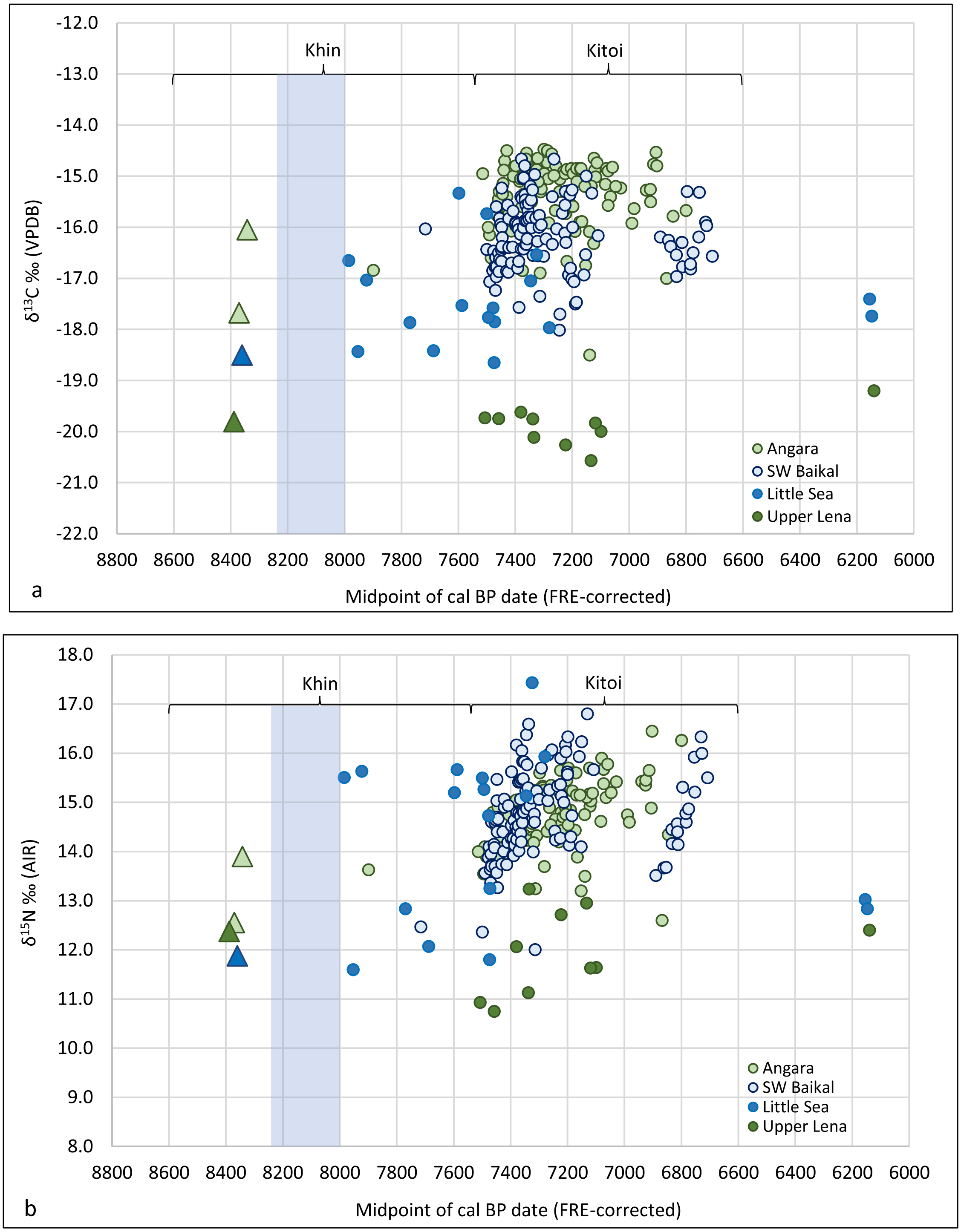

Fig. 3. Post-weaning age human (a) δ^{13}C and (b) δ^{15}N values plotted against median of KDE-modelled cal BP range ($n = 262$). The shaded box marks the 8.2 ka event. The timespans of the Khin and Kitoi mortuary traditions are shown, though it should be noted that there is regional variability in their expression. Large triangle symbols have mean FRE–corrected dates pre-8200 cal BP from their respective colour-coded microregions (data: (Weber et al. 2021, 2016a, 2016b; White et al. 2020)).

post-8.2 ka BP dietary pattern in the Little Sea appears to be already divided into the 'Game-Fish' and 'Game-Fish-Seal' diets that feature so strongly in this microregion in the Early Bronze Age, divided by a δ^{15}N value of ca. 13 ‰ (Weber and Goriunova, 2013; Weber et al., 2021; White et al., 2020). Thus, the 'Game-Fish' diet seen in the single pre-8.2 ka BP burial from Khotoruk on the Little Sea is also found in a minority of later individuals and hence may be unrelated to the 8.2 ka event.

Very few Mesolithic and Early Neolithic graves have been identified along the southern Upper Lena microregion. Of these, only one, from Popovskii Lug 2, pre-dates 8200 cal BP. For comparison there are eight EN burials, in all cases significantly post-dating 8200 cal BP. In contrast to the upper Angara and Little Sea, the individual from Popovskii Lug 2 has a higher δ^{15}N value (12.4 ‰) than the later group (11.2 ± 0.4 ‰; $n = 8$), suggesting a greater reliance on fishing. But it is impossible to infer a general trend from a single result.

The paucity of known formal burials does not reflect the extent of human activity in the region pre-8200 cal BP. Other datasets are more limited given BAP's focus on cemeteries, but pre-pottery sites are certainly known (Medvedev, 1971), and a small number of multiperiod occupation sites have been excavated and have provided reasonably large numbers of radiocarbon dates on fauna. Nevertheless, the numbers are still too few for a robust analysis given the millennial timespans involved, particularly when restricted to the period of interest, so that what follows is exploratory only.

Faunal ^{14}C dates from the Little Sea microregion are dominated by two open lake sites: Bugul'deika and Sagan-Zaba II, with smaller numbers of from one to five dates from Berloga, Ityrkhei, Kharakta I, Kulara III and Shrakshura III, all located in shallow coves of the Little Sea (Berdnikov et al., 2020; Goriunova and Novikov, 2018; Losey et al., 2016, 2017b; Nomokonova et al., 2013; Novikov et al., 2023a). Restricting the dates to the period of interest (i.e., from the start of the Holocene to ca. 5700 cal BP) greatly reduces the number of both human (n = 18) and faunal (n = 65) dates, but provides a stronger temporal focus (Table S2). The largest site with fauna data, Sagan-Zaba II, includes a number of dates (n = 20) on seal bone (*Phoca sibirica*), adjusted here for the freshwater reservoir effect by subtracting 700 years from the ^{14}C determination (Nomokonova et al., 2013; Schulting et al., 2014), and multiplying the error term by 1.5 to take into account additional uncertainty in this figure.

The Middle Neolithic mortuary hiatus (Weber, 1995; Weber et al., 2006, 2002) appears to begin here before 7000 cal BP, earlier than in the Angara/SW Baikal microregions (Figs. 3 and 4). There are two burials from Ulan Khada IV dated to ca. 6100 cal BP, to which it is possible that a different freshwater reservoir correction should be applied, i.e., that for the Angara making them slightly younger (White et al., 2020). Following this (not shown on Figs. 3 and 4) there is another gap of some four centuries before the next burials belonging to the Isakovo and Serovo mortuary traditions of the Late Neolithic.

The faunal dates confirm the presence of human activity in the Little Sea microregion many centuries before the mortuary record. There is a decline in the KDE from ca. 8400 cal BP, but as it precedes 8.2 ka BP by approximately two centuries it is unlikely to be linked with it; a similar drop in the KDE is seen at ca. 7500 cal BP. While there is some indication that a cooling phase may have begun as early as 8600 cal BP (Rohling and Pälike, 2005), it is far less marked than what occurred at ca. 8.2 ka BP; moveover, most studies, including recent modelling, support this later onset (Matero et al., 2017; Parker and Harrison, 2022; Thomas et al., 2007). The clearest pattern post-8200 cal BP is the gap in dated fauna ca. 6500–5900, broadly coinciding with the mortuary hiatus, after which they increase. Interpretation, however, is exacerbated by the fact that the majority of the dates from the Little Sea microregion derive from only two sites, Sagan-Zaba II and Bugul'deika I, both of which may have been subject to severe taphonomic biases resulting from landslides, leading to the complete loss of archaeological deposits from certain periods (Novikov et al., 2023b).

Five sites from the upper Angara microregion have dates on fauna (n = 52): Gorelyi Les, Kholmushino III, Shumilikha, Ust'-Belaia, and Ust'-Khaita (Berdnikov, 2024; Berdnikov et al., 2020, 2017; Losey et al., 2017a; Ulanov et al., 2024) (Table S3). The largest contribution comes from Ust'-Khaita (n = 28), located on the banks of the Belaia River, a large tributary of the Angara ca. 140 km north of the latter's headwaters in Lake Baikal. Sites here were not subject to the same taphonomic processes as those seen on the steep shores of the Little Sea microregion, although other processes may come into play, e.g., river bank erosion. While this is again a very small sample, they form a tight spatial cluster within a radius of ca. 50 km. There are smaller numbers of dates on fauna (n = 6) from the sites of Ust'-Ilir, Martynova and Ust-Yodarma II further north on the Angara that are not included in the KDE due to their distance of some 300–600 km upriver from the Belaia cluster (Berdnikov, 2024; Berdnikov et al., 2017). Their calibrated median ages range from ca. 9300–6200 cal BP.

The KDE model shows intermittent ^{14}C evidence for activity from the Late Pleistocene into the Early Holocene, with a peak centring on 9000 cal BP (Fig. 5). This is important in demonstrating the presence of human activity well before it becomes evident in the mortuary record. The drop in the SPD at ca. 8200–8000 cal BP is at repeated various other points in the distribution (Fig. 5), and is more plausibly explained by random variation due to the low number of dates. A second decline after ca. 6700 cal BP broadly coincides with the Middle Neolithic mortuary hiatus in Cis-Baikal (6600–6050 cal BP), with a complete absence of dates thereafter (the situation differs further north along the Angara). This millennia-long absence is unlikely to be explained purely by

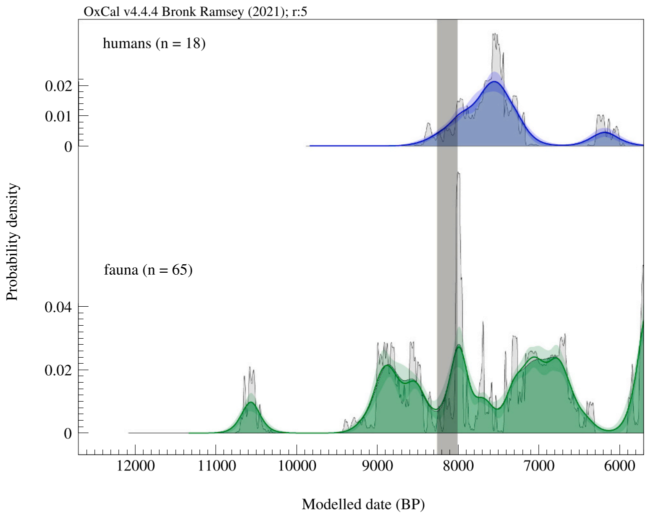

Fig. 4. KDE models for Little Sea humans and fauna (to 5700 cal BP) superimposed on summed probability distributions (thin black line). The shaded light and dark colours represent a ± 1σ confidence band for the KDE based on multiple runs with varying bandwith. The grey band marks the 8.2 ka BP event (see Appendix 2 for OxCal code). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

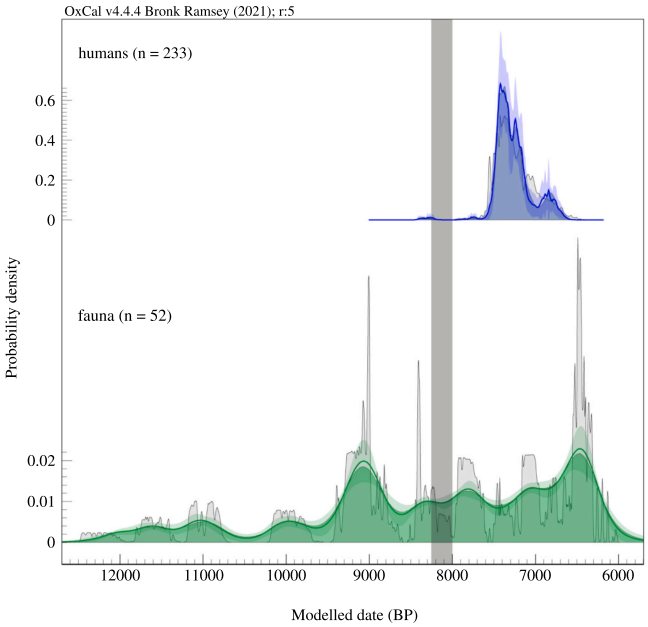

Fig. 5. KDE models for Angara/SW Baikal humans and upper Angara fauna (to 5700 cal BP). The shaded light and dark colours represent a ± 1σ confidence band for the KDE based on multiple runs with varying bandwith. The grey band marks the 8.2 ka BP event (see Appendix 3 for OxCal code). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

taphonomic factors, particularly when it is paralleled in the much larger dataset of ^{14}C-dated human burials (n = 233) (Fig. 5). The latter highlights the remarkable, but relatively short-lived, florescence of Kitoi mortuary activity, which is followed by a shift in the focus of cemeteries from the Angara/SW Baikal to the Little Sea (Bronk Ramsey et al., 2021; Weber et al., 2021). This is certainly not to say that the Angara/SW Baikal microregions were entirely abandoned, although a population decline does seem highly probable given the mortuary hiatus. Nevertheless, the effect may be exaggerated, for example by a re-organisation of the settlement pattern, with different locations on the landscape being emphasised (Weber, 2020). This has also been suggested by Ulanov and colleagues (Ulanov et al., 2022), who find Middle Neolithic pottery traditions to differ substantially from those of the Early Neolithic, suggesting that they were the product of another cultural group. Additionally, the need to maintain formal disposal areas for the dead (i.e., cemeteries) may have been less pressing with reduced population density (Dyson-Hudson and Smith, 1978; Elder, 2010; Sack, 1986; Saxe, 1970). A degree of population replacement has long been suggested for the re-appearance of cemeteries of the Late Neolithic Serovo mortuary tradition (Weber, 1995; Weber et al., 2002). In any case, this is a separate question to the main focus here.

The faunal ^{14}C data for both microregions confirm human activity long before the 8.2 ka BP event. While the datasets are small, there is no convincing evidence for any impact from the cooling event (see Appendix 4 for the heuristic application of a Monte Carlo hypothesis-testing approach using the *R* package *rcarbon*, https://cran.r-project.org/web/packages/rcarbon/). Also seen in both microregions is a sharp decline in faunal dates from ca. 6500–6400 cal BP, which do not increase again until after 6000 cal BP in the Little Sea, and remain absent altogether in the upper Angara. This seems to correspond to the Middle Neolithic mortuary hiatus, and at face value suggests that the hiatus involved more than just a change in mortuary behaviour (Weber, 2020). While we do not enter into the ongoing debate concerning the existence of the Middle Neolithic mortuary hiatus, it is worth noting that the faunal ^{14}C data appear to provide supporting evidence in its favour. A robust response to the critiques by Berdnikov (Berdnikov, 2024) and Kuzmin (Kuzmin, 2007) has been recently given regarding the reality of the hiatus in terms of mortuary sites, which seems indisputable for Cis-Baikal (Weber and Bazaliiskii, 2023), though the situation may differ to the north of the region, towards the Angara-Yenisei confluence.

4. Conclusions

A comparison of western and eastern Eurasia suggests that there may have been a greater impact on hunter-gatherer societies of the 8.2 ka event in Atlantic Europe. This could be related to the stronger effects on oceanic currents and their concomitant influence on the terrestrial environment. Nevertheless, palaeoenvironmental records from China attest to the existence of the 8.2 ka event in eastern Eurasia. It may be that the question has simply received more attention in the recent European literature. If so, future work may redress this imbalance.

While having one of the richest mortuary records for prehistoric hunter-gatherers in northern Eurasia, the vast majority of the burials across Cis-Baikal post-date the 8.2 ka BP event. The settlement record is both less well-known and less well-dated. What little evidence there is for an impact in the Little Sea faunal ^{14}C record pre-dates 8200 cal BP by one or two centuries, though this is based on only a small number of dates from sites subject to taphonomic biases. No comparable impact is seen on faunal record from the Angara microregion. Whether there is an environmental tipping point after ca. 7600 cal BP that resulted in the formation of the Kitoi mortuary tradition is unclear. There do not appear to be any changes in the palaeoenvironmental record commensurate with this level of re-structuring of human settlement and mortuary practices. Instead, this may reflect a socioeconomic re-organisation made possible by the introduction of the bow and arrow at the beginning of the Early Neolithic (Weber, 2020), paradoxically permitting a focus on aquatic resources to a far greater extent than previously possible, and hence leading to a greater concern with territoriality. Why this did not also occur in the Little Sea microregion remains unclear, but may relate to differences in the kinds of fisheries there (Weber, 2020).

The lack of evidence – thus far – for any significant impact of the 8.2 ka event on the human population in Cis-Baikal may reflect its mitigation by the lake itself and its location in the middle of the Eurasian continent. Indeed, the significance of the 8.2 ka event's impact on the region's environment is still debated. The few well-dated pollen records show an increase in birch and corresponding decrease in coniferous pollen percentages and some other minor changes. But this may only mean that the regional boreal forest habitat was resistant to the century-scale drop in temperature. However, we still lack detailed knowledge on the effects on the other parts of the ecosystem, and particularly the aquatic habitats that were an important aspect of the hunter-gatherer subsistence economy. In a NW European (and Atlantic) context, such impacts are strongly suggested by Yuzhniy Olenii Ostrov on Lake Onega.

CRediT authorship contribution statement

Weber Andrzej: Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Conceptualization. **Tarasov Pavel:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Schulting Rick:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.qeh.2025.100067.

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