Walnuts, salmon and sika deer: Exploring the evolution and diversification of Jōmon “c~~C~~ulinary” traditions in prehistoric Hokkaidō

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Abstract

The goal of this contribution is to stimulate a wider reflection on the role of food consumption practices throughout prehistory. We focussed on the Jōmon communities of Hokkaidō Island in Northern Japan since these mobile foragers underwent a process of economic diversification and intensification, eventually leading to higher levels of sedentism across the Pleistocene-Holocene transition. Moreover, dynamic social settings and expansion of the subsistence base at the start of the Holocene would have provided rich opportunities for novel food combinations, and potentially, the rise of diverse regional cuisines. We investigated tool kits and resource landscapes, and sampled pottery from a range of sites, phases and regions. We then applied organic residue analysis to confirm the actual spatiotemporal patterning in cuisine. Although we predicted that ruminants and nuts would have played a major role in local cuisine, especially in inland areas, our results indicate that aquatic resources were central to pottery-based cuisines across the island, and that other food groups had probably been processed in other ways. While organic residue analysis enabled us to reconstruct some major patterns in Jōmon cuisine, we conclude that archaeologists will need to look “beyond the cooking pot” to fully appreciate the full diversity of local foodways.

Keywords: Hunter-gatherers; Jōmon; Japan; Hokkaidō; Pottery; Economic diversification and intensification; Cuisine; Nuts; Environmental change; Adaptation; Plant foods; Salmon

1 Introduction: Calories versus “c~~C~~uisine”

Archaeologists are exploring new ways to examine how prehistoric hunter-gatherers used local ecological resources. With the application of biomolecular approaches opening up avenues for higher-resolution studies of processing and consumption, there is scope for understanding forager “foodways” as a cultural expression, rather than the cost-benefit modelling of calories to explain mobility, procurement and storage strategies. In this contribution we focus on the theme of “cuisine”, which asks how and why different sets of ingredients are creatively combined into household- and regional-scale food traditions, and how these practices evolved over time (Isaksson et al., 2019; Saul et al., 2014).

We focussed on the Jōmon hunter-gatherer communities of the large northernmost island of Hokkaidō in the Japanese archipelago. The Hokkaidō Jōmon sequence has its own chronology, cultural dynamics and inter-regional diversity (Abe et al., 2016), but is less well represented in the international literature compared with the more southerly parts of Japan (Habu, 2004). Our aim was to investigate diversity and change in the cooking practices of Hokkaidō Jōmon societies.

There are three reasons for this focus: (a) currently, little is known about Jōmon diet in this northern island, and the few stable isotopic studies undertaken on human remains have focussed on coastal sites, leaving the diet of inland groups particularly uncertain; (b) the Hokkaidō Jōmon archaeological sequence has been the focus of intensive excavation efforts, generating detailed datasets that exhibit significant temporal and regional variability, and as such offer rich social and cultural contexts in which to attempt a higher-resolution study of diversity and change in local foodways; (c) the Hokkaidō Jōmon made and used an extensive array of clay cooking pots, and organic residue analysis of the lipids preserved in these sherds enables us to directly reconstruct cooking practices at both coastal and inland sites.

1.1 The culinary spectrum in prehistoric Hokkaidō: Walnuts, salmon and sika deer

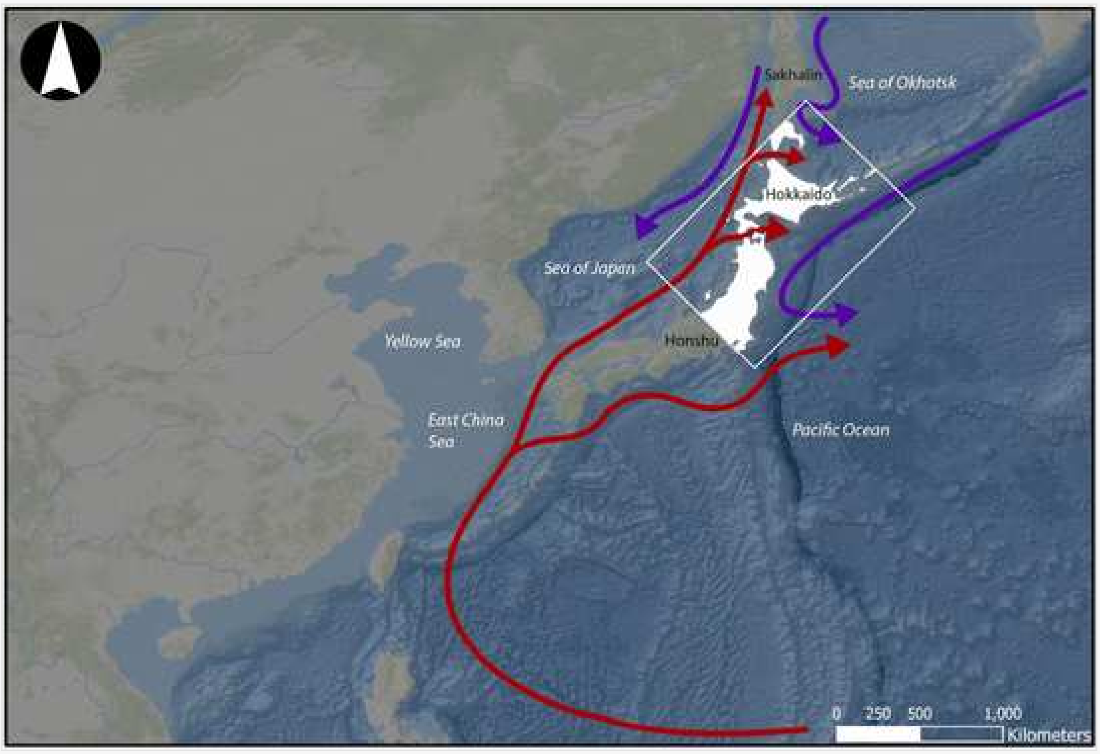
In his seminal contribution to the study of hunter-gatherer mobility systems Binford recounts how Nunamiut elders spoke of “willow smoke and dogs tails” to capture their enduring memories of the seasonal round (1980). What would Hokkaidō Jōmon elders have spoken about? The archaeological evidence points to major economic transformations from the Late Glacial to Early Holocene. This starts ~~,~~ with a “diversification” away from the traditional Palaeolithic focus on big game hunting combined~~,~~ with innovation in harvesting and processing technologies adding new plant, fish and marine resources to the diet. This is~~,~~ followed by local “intensification” in these different branches of the economy, which eventually supported larger populations and increasingly settled and socially-complex communities (Abe et al., 2016; Habu, 2004, 2014). We entitle our case-study “walnuts, salmon and sika deer” as nuts, aquatic resources and ruminants are broadly representative of the main food groups that would have been available to Hokkaidō’s prehistoric communities at both coastal and inland sites, although, of course, seafoods would also have been available to coastal groups. The ways in which these different kinds of resources were processed and combined into specific kinds of dishes remains uncertain, and the contribution aims to clarify some of the broader patterns in pottery-based cooking throughout the different parts of Hokkaidō.

To contextualise this study of food-processing traditions we looked first at the climate and natural environments of Hokkaidō, before summarising the local chronology of the six main Jōmon periods, their changing pottery traditions and the contrasting cultural trajectories that played out in the different regions of Hokkaidō. We then chose a representative selection of archaeological sites from each of the major regions and periods, including coastal and inland sites in the Late Pleistocene and Early Holocene, and inland sites dating to the Mid-Holocene, as inland food practices are largely poorly understood. Subsistence and foodways have seen only limited attention from local archaeologists, and to generate specific predictions about the different kinds of cooking traditions at each site and in each period, we investigated ecological locations, faunal and botanical remains and the characteristics of resource harvesting and processing equipment. We then sampled sherds from each site and applied organic residue analysis to test these predictions and confirm the actual spatiotemporal patterns of pottery-based cooking practices.

1.2 The climate and geography of Hokkaidō

Hokkaidō is located on the southern border of the subarctic environment of the North-west Pacific, and lies between *ca*. [Instruction: I suspect the '-' are based entirely on the type-setting. Please check]45.5~~-~~–41.4°N and 139.4~~-~~–145.8°E, bounded by the Sea of Japan, Sea of Okhotsk and Pacific Ocean (Fig. 1). Sakhalin Island is located to the north, and the Kuril Islands extend to the north-east, where they eventually meet Kamchatka. South of Hokkaidō is the main Japanese island of Honshu, which has always been separated by the deep-water Tsugaru Strait. In contrast, Hokkaidō was joined to Sakhalin and the Southern Kurils during the lower sea levels of the ~~Late~~ Last Glacial maximum, while North Sakhalin was also joined to the Asian continent, forming the extended “Paleo-Sakhalin-Hokkaidō-Kuril Peninsula” (Buvit et al., 2016). Sea levels rose again during the steady warming of the Late Glacial, and the bridge between Sakhalin and Hokkaidō was eventually breached to form the Soya Strait (Nakazawa et al., 2011).

Fig. 1



Location map of the island of Hokkaidō, with Sakhalin Island to the north, and Honshu to the south. The white box marks the area of interest (see Fig. 2). The arrows show the main warm (red) and cold (blue) ocean currents that influence Hokkaidō’s climate and ecology (after Abe et al., 2016). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

These changing sea levels eventually led to the establishment of the modern sea currents at the start of the Holocene, which continue to have a major impact on Hokkaidō’s climate of cool summers and cold winters: (a) the Tsushima Current brings warmer waters from the south, which then flow south and also north of Hokkaidō as the Tsugaru and Soya Currents; (b) the Oyashio Current brings cold northern waters to the eastern side of Hokkaidō. As a result, the surface temperature of the sea to the west of Hokkaidō ranges from *ca*. 19–20 °C in summer to *ca*. 6–7 °C in the winter, but is colder in the east, with an average of *ca*. 15–16 °C in summer and just above freezing in winter. Under these influences, the mean annual temperature in the warmer western regions of Hokkaidō is *ca*. 6–10 °C, but falls away to *ca*. 2–6 °C in the eastern lowlands (Abe et al., 2016:1628). Drift ice from the Sea of Okhotsk frequently blocks the northern coastline in winter and inland lakes and rivers mostly freeze up in the winter.

Hokkaidō’s climate - and especially precipitation patterns - are further influenced by the East Asian Monsoon system. In winter, cold continental air flows over the island from the north and north-west, where it meets with humid air masses that have been generated by the warm Tsushima current. This results in much higher levels of snowfall in Western Hokkaidō (up to 10 m) as well as deep and long-lasting snow banks throughout most of the island. In summer, warm moist air arrives over the island from the south and south-east (Abe et al., 2016:1628).

Topographically, the island is formed of mountain ridges and a high volcanic plateau, interspaced with large plains, which include extensive wetlands that are drained by major river systems, including the Ishikari, Teshio, Tokachi and Kushiro, which are rich in freshwater fish. Northern areas contain stands of subarctic taiga forest, but deciduous forests predominate in the lowlands further south. Whilst acorn (*Quercus* sp.), sweet chestnut (*Castanea crenata*), horse chestnut (*Aesculus turbinata*), walnut (*Juglans* sp.), and hazelnut (*Corylus* sp.) are present alongside a range of edible fruits, roots and berries (Crawford, 2011), the extent of this broad-leaved forest has shifted considerably in relation to Holocene climate change (Abe et al., 2016:1640). The principal terrestrial mammals include the Hokkaidō brown bear (*Ursus arctos yesoensis*), a local subspecies of the Sika deer (*Cervus nippon yesoensis*), and red fox (*Vulpes vulpes*). Numerous other small mammal species are also present.

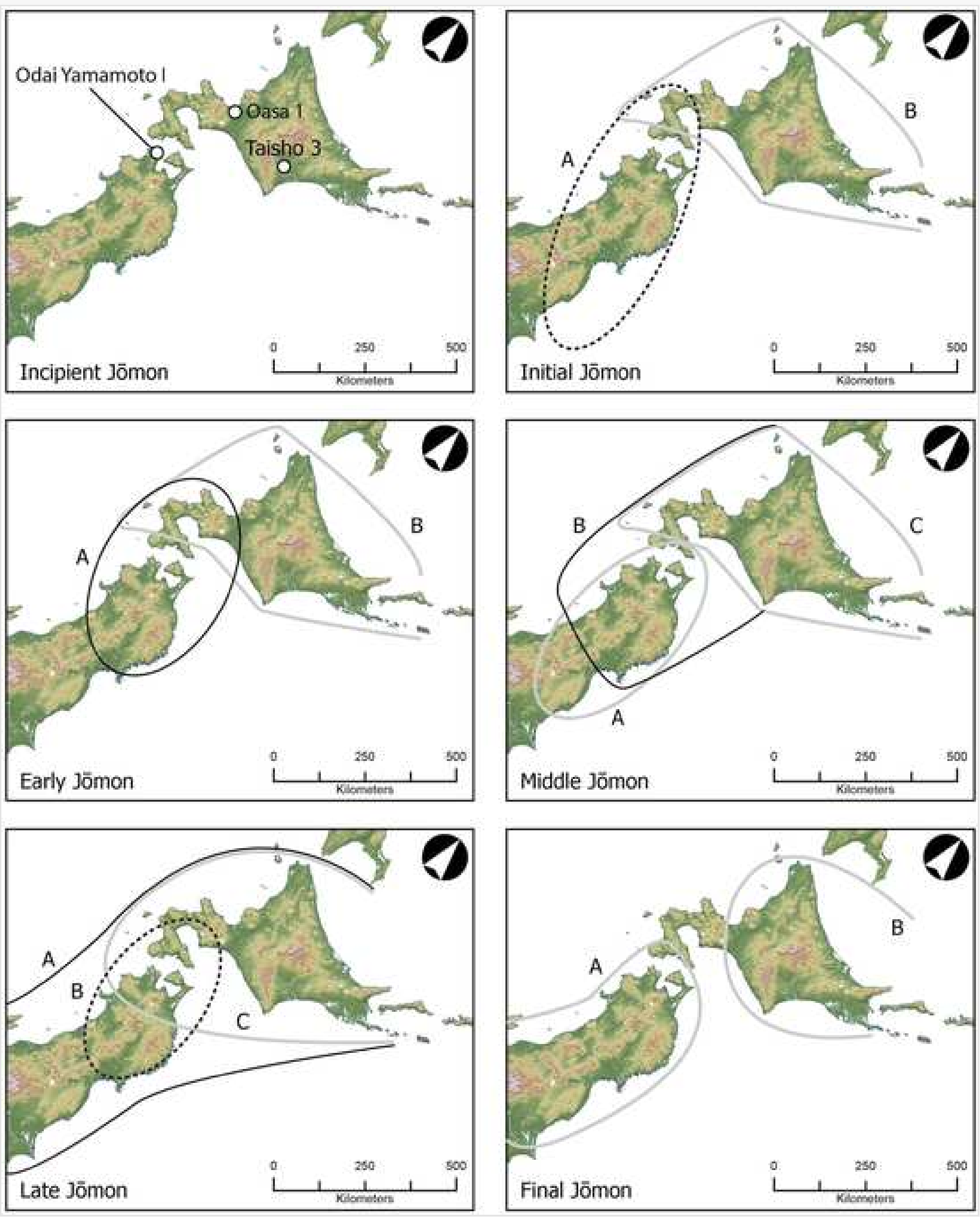
The seas surrounding Hokkaidō are rich in marine resources, and include bastard halibut (*Paralichthys olivaceus*), herring (Clupeidae), northern fur seal (*Callorhinus ursinus*), ringed seal (*Phoca hispida*), harbour seal (*Phoca vitulina*), as well as dolphins and whales (Takase, 2020). There are over 200 salmon rivers in Hokkaidō, many of which penetrate deep into inland areas, providing spawning grounds to several native anadromous *Oncorhynchus* spp., including chum (*Oncorhynchus keta*), pink (*Oncorhynchus gorbuscha*), and masu salmon (*Oncorhynchus masou*). Most of the offshore catch of pink salmon is from the Okhotsk Sea coast, whilst most masu salmon are currently caught in the Japan Sea and Western Pacific coasts. Chum salmon are caught on the majority of the coastlines, though less so along the shores of ~~on the one bordering~~ the Sea of Japan (Morita et al., 2006).

1.3 The Hokkaidō Jōmon: Periodisation, pottery traditions and absolute chronology

1.3.1 Jōmon periodisation

The Jōmon sequence is traditionally divided into six periods, based on the high-resolution analysis of pottery typologies (Fig. 2) (Habu, 2004; Imamura, 1996; Kobayashi, 1989). This framework was first established for Central Japan, and then applied to Hokkaidō. Whilst the application was easier in the south-western parts of Hokkaidō as this region shares many pottery traditions with Northern Honshu (Fig. 2), by contrast, the northern and eastern parts of Hokkaidō evolved their own pottery traditions, often sharing them with Sakhalin and the Kuril Islands.

Fig. 2



Topographic map of Hokkaidō (modern sea levels) showing the distributions of the major pottery traditions during the six Jōmon periods (based on Kobayashi, 1989:256-257): **Incipient Jōmon:** the sites of Oasa 1 and Taisho 3 in Hokkaidō and Odai Yamamoto in Tohoku; **Initial Jōmon**: (a) Kaigara Chinsemon, (b) Hirazoko; **Early Jōmon**: (a) Ento Doki-kaso, (b) Oshigatamon; **Middle Jōmon:** (a) Middle Daigi, (b) Ento Doki-joso, (c) Hokuto; **Late Jōmon:** (a) Horinouchi, (b) Irie-Tokoshinai, (c) Gotenyama; **Final Jōmon:** (a) Kamegaoka (b) Nusamai.

1.3.2 Diversity and change in Hokkaidō's pottery traditions

1.3.2.1 Incipient Jōmon

The oldest pottery yielding archaeological sites in Japan date to *ca*. 16,000–14,000 cal BP, and include Odai Yamamoto in Northern Tohoku, which has yielded 46 plain pottery sherds in association with two shale arrowheads (Keally et al., 2004; Iizuka, 2019). The majority of early pottery sites, however, are located in Honshu and Kyushu, and coincide with a period of extreme cold; they form Taniguchi's Phase 1 (see Kaner and Taniguchi, 2017; Taniguchi, 2004). More pottery-bearing sites appear across mainland Japan in the short Bølling warm period, which forms Taniguchi's Phase 2. In contrast, "Incipient Jōmon" pottery had not been recovered from any of these early phases in Hokkaidō and it was assumed that the island's populations were inherently negative towards this new technology (Taniguchi, 2004).

More recently, an Incipient Jōmon phase in Hokkaidō was confirmed due to the excavations at the site of Taisho 3 (Iizuka, 2019:18, Yamahara, 2006) in the Tokachi Plain (Fig. 2), which yielded pottery in association with bifacial arrowheads (Fig. 3). Radiocarbon dates suggest that pottery appeared in this part of Hokkaidō between *ca*. 15,000–13,600 cal BP (Iizuka, 2019:42), probably in the warmer Allerød phase (*ca*. 14,460–12,000 cal BP), which equates to Taniguchi's Phase 3a, and prior to the return of colder conditions in the Younger Dryas (Iizuka, 2019:42). The vessels were linked to the fingernail-impressed "**Tsumegatamon**" tradition, which has also been recorded at sites in Tohoku, Kanto, Chubu, and Hokuriku (Kobayashi, 1989:255), and suggests that the innovations of pottery and bifacial arrowheads spread northwards out of Tohoku into this region of Hokkaidō, where they co-existed with local groups that maintained older microblade traditions. Only one other pottery assemblage in Hokkaidō has been tentatively linked to this period - the Oasa 1 site in Ebetsu City that has examples of "**Oatsumon**" or "**Oatsu Jōmon**" pottery, and which are decorated with twisted plant fibres that had been pressed into the vessel surfaces (Kaner and Taniguchi, 2017:32). However, the 27 technologically distinctive sherds were recovered from mixed contexts (including the Initial Jōmon), and absolute dating is still needed to confirm their precise age (Iizuka, 2019:19).

Fig. 3

Pottery and lithics from the Taisho 3 site: (a) - left - reconstructed vessels of the Incipient Jōmon "Tsumegatamon" (fingernail-impressed) tradition; (b) - middle - reconstructed vessel in profile; (c) - right - lithic assemblage associated with the pottery (bifacial arrow points, other bifaces, scrapers and burins made from flakes) (images reproduced with permission of Obihiro Centennial City Museum, Hokkaidō).

Pottery use appears to have been abandoned in Hokkaidō prior to the onset of the Younger Dryas (Nakazawa et al., 2011:428), which equates to Taniguchi Phase 3b. This means that Hokkaidō has a short pottery "hiatus" that is not present in most other parts of Japan. In general, the archaeology of this transitional period in Hokkaidōis poorly understood.

1.3.2.2 Initial Jōmon

With the onset of warmer conditions at the start of the Holocene at *ca*. 11,000 cal BP new forms of pottery appear throughout most of Japan, including the "**Yoriitomon**", which marks the advent of the "Initial Jōmon" (Imamura, 1996; Kaner and Taniguchi, 2017:335). In Hokkaidō, however, the onset of the Initial Jōmon is marked by the appearance of two contrasting ceramic traditions (Figs. 4 and 5), which establish a persistent cultural boundary that also divides the north-east and south-west over many subsequent periods (Fig. 2): (1) the south-west parts of Hokkaidō participate in the "**Kaigara Chinsemon**" tradition, which is shared with Northern Honshu and may even originate there. This tradition has a pointed-base, with scraped decorations that generally employ the ark shell (Fig. 4). The first examples appear at sites such as Nakano B between *ca*. 10,000 to 9000 cal BP (Hokkaidō Buried Cultural Property Centre, 1996); (2) the widespread "**Hirazoko**" flat-based pottery is mainly found in Eastern Hokkaidō, which starts with the "**Akatsuki**" tradition that has distinctive scallop shell impressions on the base of the pots (Fig. 5). It is unclear where this particular pottery tradition originates from, as it does not resemble the pointed-based Incipient Jōmon pottery from Taisho 3, nor the pointed-based pottery in South-west Hokkaidō. Although it may represent an "indigenous" phenomenon, appearing slightly earlier than pottery in the south-west, and spanning *ca*. 10,500 to 8300 cal BP (Morisaki et al., 2018:1022), it is interesting to note that similar vessels have been found on Sakhalin (Gibbs et al., 2017).

Fig. 4

Examples of pointed-based "Kaigara Chinsemon" pottery from the Nakano B coastal site in South-west Hokkaidō (Hokkaidō Buried Cultural Property Centre, 1996) (images reproduced with permission of Hokkaidō Buried Cultural Property Centre).

Fig. 5

One of the earliest examples of the flat-based Hirazoko tradition. This example represents the "Akatsuki" pottery tradition and was recovered from the site of Taisho 6 in the interior of Hokkaidō. The pottery tradition starts at *ca*. 10,500 cal BP (Morisaki et al., 2018). Note the scallop shell impression on the base (images reproduced with Permission of Obihiro Centennial City Museum).

The Initial Jōmon is also marked by a vast increase in the scale of pottery use across mainland Japan, and from the middle part of this period, this trend can also be noted at coastal sites in South-west Hokkaidō such as Nakano B (Kaner and Taniguchi, 2017:335; Taniguchi, 2004), but also at some inland sites, for example Yachiyo A that yielded a large pottery assemblage of the Akatsuki tradition (Obihiro Board of Education, 1990; Yamahara, 2018).

1.3.2.3 Early Jōmon

In mainland Japan the onset of the Early Jōmon is marked by the appearance of "cord-marked" pottery, but in Hokkaidō, this tradition can only be detected in some south-west areas, while the rest of the island develops other local traditions, perpetuating the cultural boundaries established in the preceding period: (1) South-west Hokkaidō participates in a cord-impressed cylinder-shaped pottery tradition, called "**Ento Doki-kaso**" ("Lower Cylinder Style"), which is shared with Northern Tohoku; in this period, the vessels had a rather level rim with minimal decoration (Fig. 6a). In contrast (2), other parts of Hokkaidō shift to the general "early-impressed" or "**Oshigatamon**" pottery tradition, which embraces diverse cord-impressed (e.g. "**Tsunamon**") and stamp-impressed variants (e.g. "**Miyamoto**", "**Tayoro**", "**Oshigatamon-sentei**", etc.).

Fig. 6

Typical examples of pottery from South-west Hokkaidō: (a) - left - "Lower Cylinder Pottery" ("Ento Doki-kaso") from the later part of the Early Jōmon, which tend to have simpler decoration and level rims; (b) - right - "Upper Cylinder Pottery" ("Ento Doki-joso") from the early part of the Middle Jōmon, which has heavier decoration on the upper part of the vessels and a more pronounced "wave" in the rims. Both assemblages are from the Tatesaki coastal site (images reproduced with permission of Hokkaidō Buried Cultural Property Centre).

1.3.2.4 Middle Jōmon

In this period the same south-west/north-east boundaries persist (Fig. 2): (1) the extreme south-west tip of Hokkaidō is influenced by the "**Middle Daigi**" tradition, which is centered in Northern Honshu; (2) the general cylinder tradition continues in South-west Hokkaidō and also Northern Tohoku, but now evolves into "Upper Cylinder Style" ("**Ento Doki-joso**"), which has much more elaborate decoration on the upper part of the vessel, often combined with a "wavy" rim (see Fig. 6b); (3) the rest of Hokkaidō evolves its own "Northern Cylinder" pottery tradition called "**Hokuto**".

1.3.2.5 Late Jōmon

By the Late Jōmon there is major diversification in pottery forms and styles with many co-existing (Fig. 2): (1) in the early part of the period, the entirety of Hokkaidō starts to come under the influence of a large-scale "Eastern Japan Pottery Group" called "**Horinouchi**", which consists of vessels with a distinctive "wavy" rim, a tradition that has its core in the Kanto region of Central Japan; in the later part of this period, this tradition evolves in Northern Tohoku and Hokkaidō into the more localised "**Kasori B**" variant; (2) Northern Tohoku and South-west Hokkaidō also participate in the "**Irie-Tokoshinai**" pottery tradition; (3) all of Hokkaidō (apart from the Far North), plus the northern tip of Tohoku, develop the "**Gotenyama**" tradition (for typical examples, see illustrations in Kobayashi, 1989).

1.3.2.6 Final Jōmon

In this period the older cultural boundaries appear once again: (1) a few sites in the extreme south-west of Hokkaidō and Northern Tohoku share the heavily-decorated "**Kamegaoka**" (or "**Ōbora**") tradition, which has its core area in Northern Honshu; in contrast, (2) the rest of Hokkaidō (except for the south-west) falls into the "Eastern Hokkaidō Pottery Group", participating in the general "**Nusamai**" tradition (for typical examples, see illustrations in Kobayashi, 1989).

1.3.3 Absolute chronology

In this case-study we employ the Hokkaidō Jōmon chronology presented by Abe et al., (2016), which draws on several earlier studies (e.g. Habu, 2014; Weber et al., 2013). This framework is relatively coarse-grained, and dates only the boundaries between the different Jōmon periods. In fact, there is still no commonly-accepted absolute chronology for the Jōmon periods in Hokkaidō, especially the first four periods (i.e. Incipient, Initial, Early and Middle), while only a few individual pottery traditions have been properly dated (Morisaki et al., 2018). The establishment of a higher-resolution chronology for Hokkaidō, supported by reliable radiocarbon dates with sufficient spatial and temporal coverage, is still a work in progress. In reality, the relative dating of many sites and regional sequences still relies heavily on the use of local pottery typologies (Abe et al., 2016:1629).

Resolving all of these issues is well beyond the scope of the current contribution, but despite these challenges, we believe that the Abe et al., (2016) chronology is sufficient for the goals of the present study. This is because we undertook a broad-scale comparative study of pottery use across several parts of Hokkaidō over the six Jōmon periods. We do, however, make two minor amendments (see Table 1): (a) the Incipient Jōmon is dated from *ca*. 14,500–13,600 cal BP, and now includes a ceramic hiatus period between *ca*. 13,600–11,000 cal BP, which broadly equates to the Younger Dryas (i.e. rather than running continuously from *ca*. 14,000–10,000 cal BP); (b) following recent updates by Morisaki et al., (2018:1018), the onset of the Initial Jōmon is shifted back to *ca*. 11,000 cal BP (not 10,000 cal BP), and now runs through to the (somewhat earlier) onset of the Early Jōmon at *ca*. 7000 cal BP (not 6000 cal BP). The chronology for the remaining periods remains the same: Early Jōmon (ends at *ca*. 5000 cal BP); Middle Jōmon (*ca*. 5000–4000 cal BP); Late Jōmon (*ca*. 4000–3300 cal BP); and Final Jōmon (*ca*. 3300–2300 cal BP)[1].

Table 1

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[Instruction: I think Table 1 would look better in landscape]The Hokkaidō Jōmon trajectory: summary of the main cultural and environmental shifts (based on Abe et al., 2016, and the sites discussed in Supplementary Data 1 ~~Appendix A~~). Note that all dates are in cal BP.

Period (all dates cal BP)	Palaeoenvironments	Culture, Settlement and Mobility	Subsistence/Technology
Upper Palaeolithic (*ca*. 35,000–14,500)	Cold and dry, alternating tundra and boreal forest. Megafauna (mammoth) present through to the end of the Last Glacial Maximum. Replaced by mid-sized fauna (sika deer).	Mobile campsites (mostly inland areas, some close to modern coastline).	Terrestrial hunting (large then medium game). Various lithic techno-complexes: flake-based; blade complex; microblade complexes.
Incipient Jōmon (*ca*. 14,500–13,600)	Warmer Bølling-Allerød interstadial. Appearance of oak forest in some areas.	Cultural “mosaic” including persistence of microblade traditions alongside a potential “intrusion” of Incipient Jōmon influences from the south. Mobile campsites (mostly inland areas).	Local continuity in terrestrial hunting, microblade complexes. Earliest appearance of pottery at Taisho 3 in combination with bifacial arrowheads and inland fishing.
Pottery Hiatus Period (*ca*. 13,600–11,000)	Younger Dryas, cold and dry conditions.	Disappearance of Incipient Jōmon influences. Mobile campsites (mostly inland areas).	Terrestrial hunting (medium game), microblade complexes. Pottery possibly abandoned.
Initial Jōmon (*ca*. 11,000–7000)	Onset of Holocene warming, rising sea levels, land bridge to Sakhalin flooded.	Open-air sites with early pottery, first pit houses appearing prior to *ca*. 9000. Population levels thin out in northern areas, combined with increasing settlement in the south, especially along coastal zones.	Economic diversification: hunting, fishing and plant processing. Pottery traditions return (diverse styles in the south-west and north-east), arrows and knives, grinding stones in most areas. Fishing net sinkers at many coastal and some inland river sites (>9000).
Tarumae D Tephra (*ca*. 9000)	Progressive climatic amelioration, expansion of oak forest (>9000).	Mobile lifeways but increasing investment in specific locations (e.g. first “villages” along south-west coast (e.g. Nakano A, B, Kakinoshima A, B, plus occasional “hamlets” in inland areas, e.g. Yachiyo A). Storage pits and inhumations.	Dramatic expansion in scale of pottery use.
8200 Cold Event	Briefly colder.	Northern cultural impulses, but wider impacts unclear. House pits remain in use.	Blade-Arrow Culture reaches north and East Hokkaidō.
	Return to warming trend, sea levels rising towards modern levels, with flooded valleys forming sheltered bays.	More hamlets appear, with coastal terraces, bays and lagoons drawing population to the south and south-west, and some parts of the north. Some south-west coastal settlements eventually persist for millennia (e.g. Kakinoshima). Mobile lifeways in inland areas (Ishikari and Tokachi Plains), at times including larger base-camps (e.g. Yachiyo A).	Early evidence for small-scale gathering of shellfish (e.g. Higashi-Kushiro, Tokoro).
Early Jōmon (*ca*. 7000–5000)	Further expansion of oak woodland. Rising sea levels exceed modern levels, the emergence of rich coastal ecosystems.	Increasing coastal settlement, and emergence of larger and possibly fully-sedentary pit-house “villages” along some south-west coastal terraces. Higher mobility persists in many inland areas, especially in the north and east. Extensive marshes form in the Ishikari lowlands, visited on a seasonal basis, with settlement on higher terraces around Ebetsu.	Economic intensification: large shell middens appear in the south-west (e.g. Kitakogane), south-east (e.g. Higashi-Kushiro) and north-east (e.g. Tokoro), many the focus of inhumations and other offerings (e.g. artefacts, land and marine animals. Widespread evidence of plant (nut) processing and storage, with possible cultigens in the south-west.
	Warmth and humidity starting to peak at *ca*. 6000.	Emergence of larger “central place” villages (e.g. Ofune), suggest that south-west communities are entering their highest level of functionality. Some inland regions may already be witnessing decreasing activity levels (Kamikawa Basin, Tokachi Plain).	Location-specific subsistence strategies reflected in diet and technology. Some south-west coastal populations rely almost fully on marine resources (e.g. Kitakogane shell midden), but the diet of other

			groups is unclear (poor bone preservation). Nut exploitation is lower in some areas (e.g. grinding stones absent around Kushiro).
Middle Jōmon (*ca*. 5000–4000)	Starts warm and humid, oak forest and sea levels peaking at *ca*. 5000.	High levels of activity at some coastal villages in the south-west (e.g. Tatesaki), with huge houses built at some of the larger settlements (e.g. Ofune). Creation of large ritual earthworks within villages, which are the focus of diverse "offering" rituals (Ofune, Tatesaki, Kakinoshima).	Fishing weirs built on some rivers (e.g. Ishikari Momoijiyama No. 49). First clear evidence for the construction of pitfall trap systems in diverse areas of Hokkaidō (Kyoei 3, Kiusu 5). Intensive nut and plant processing continue, especially in the south-west, possibly in combination with limited use of cultigens in the area.
4200 Cold Event	Cooling trend sets in, sea levels gradually fall, draining coastal bays (e.g. the Kushiro "palaeobay" shifts to marshland). Retreat of oak forest.	General "Tipping Point": some large south-west settlements persist (Kakinoshima), but many others witness sharp declines in activity (Tatesaki). Many inland areas have already reverted to mobile lifeways (Tokachi Plain), with some largely abandoned (Kamikawa Basin). Activity in some south-east coastal areas also declined (Kushiro Bay).	Diversification and intensification strategies under pressure, especially nut exploitation. Persistence of same general tool-kits, with local variation according to different subsistence strategies.
Late Jōmon (*ca*. 4000–3300)	Cooling trend continues, falling sea levels, and decreasing oak forest.	Sharp decline in settlement. Much of Northern Hokkaidō empties out, with settlement concentrated in the warmer south-west. Some coastal settlements survive from the Initial Jōmon (Kakinoshima). Coeval "boom" in ritual sites and activities, with circular pit cemeteries (e.g. Kiusu 4) and stone circles (e.g. Washinoki) appearing in the south-west/Ishikari Plain, and very rarely in the east (Syuen cemetery) and north-east (Shuen stone circle). Mortuary traditions hint at growing social differentiation (south-west).	Marine and terrestrial hunting, fishing and gathering continue. Persistence of same general tool-kits, with local and regional variation. North and East Hokkaidō focus increasingly on marine resources, with elaboration of bone tools (harpoons).
Final Jōmon (*ca*. 3300–2300)	Cooling continues, falling sea levels, decreasing oak forest.	Major cultural differences between the south-west and north-east. Further decline in overall population, but site numbers pick up again in some inland areas (Tokachi Plain, Kamikawa Basin), perhaps in relation to seasonal hunting. Most larger sites are still concentrated along the coasts and lower rivers.	Marine and terrestrial hunting, fishing and gathering. Persistence of same general tool-kits.

1.4 Tracking Jōmon cultural ~~T~~trajectories: environments, settlement and subsistence

1.4.1 The Jōmon trajectory in mainland Japan

The wider Jōmon cultural trajectory can be understood as a general cultural response to Late Glacial climatic amelioration, rising sea levels, and widespread environmental change, which continued into the early part of the Holocene. Following the onset of sustained climatic cooling after *ca*. 4200 cal BP, the Jōmon socio-economic system underwent fundamental transformation, and eventually disappeared (Habu, 2004; Imamura, 1996). While many of the key innovations, behaviours and practices that supported the Jōmon trajectory over the millennia had deep roots in the Late Pleistocene, a ~~the~~ number of key traits and practices start to coalesce at *ca*. 11,000 cal BP, marking the onset of the Initial Jōmon. These include the spread of pit houses, an increase in the overall number of settlements, the emergence of fishing technologies and shell middens, a sharp increase in the scale of pottery use and the formation of distinctive regional pottery styles, as well as the addition of plants and especially nuts to the diet, alongside stone grinding tools to process them (Kaner and Taniguchi, 2017:335).

The appearance of these innovations did not automatically lead to sedentary societies, but unlocked a chain of cumulative developments (Habu, 2004, 2014). In the Initial Jōmon, essentially mobile hunting societies underwent economic diversification by adding more plant-based foods and aquatic resources to their diet, while still moving seasonally between established resource-extraction points. This is followed in the Early and Middle Jōmon by economic intensification, which involved localised specialisation in particular branches of the economy, including fishing, nut harvesting and possibly hunting, combined with the storage of surplus, and "collector strategies" that involved logistic mobility, and in many areas, a transition to full sedentism (Habu, 2014).

1.4.2 The "~~N~~northern Jōmon" trajectory in Hokkaidō

Societies in Hokkaidō both participated in these general developments, but also exhibited local divergences, including a more "interrupted" sequence of developments. This is primarily related to the island's more northerly location, including more marginal conditions for broad-leaved forests, as well as its proximity to other cultural influences from Sakhalin Island (see Table 1). In addition, Hokkaidō's diverse internal geography and ecology, plus the influence of cold and warm ocean currents (Fig. 1), encouraged separate trajectories of development across different parts of the island.

In the Late Glacial period, Incipient Jōmon cultural traditions including pottery and bifacial arrowheads briefly penetrate into the Tokachi Plain of South-east Hokkaidō during the warmer conditions of the Allerød, where they coexist with local microblade traditions of the Upper Palaeolithic. Pottery is abandoned during the Younger Dryas. With the onset of the Holocene, diverse pottery traditions appear again on Hokkaidō, marking the start of the Initial Jōmon. Population appears to shift from northern areas to the south, and the south-west and southern coasts become the primary focus on activity. House pits and plant grinding tools appear in many areas, with net sinkers at coastal sites. Developments appear to gather pace after *ca*. 9000 cal BP with the first appearance of "hamlets", some with dozens of pit houses appearing in both the south-west, and also at sites such as Yachiyo A in the Tokachi Plain (see ~~Appendix A~~ **Supplementary Data 1**). The short 8200 cal BP cold snap appears to be linked with the short-lived penetration of northern lithic traditions ("Blade Arrow Culture") from Sakhalin into North-east Hokkaidō, but this eventually fades, while other trends such as the construction of house pits and the use of plant resources appears to persist.

The overall impression of the Initial Jōmon, however, is that the Hokkaidō communities remained quite mobile, and that the house pits and hamlets were constructed as important seasonal extraction points, rather than fully sedentary settlements. Further expansion of forest cover out of the south-west into the north-east offered increasingly abundant supplies of acorn, sweet chestnut, horse chestnut, walnut and hazelnut along with other temperate plants producing edible fruits, roots and berries (Abe et al., 2016:1640; Crawford, 2011; Habu, 2004; Yamada and Shibauchi, 1997). Not surprisingly, many sites exhibit evidence (charred nuts and seeds or stone grinding tools) for ~~nut and plant~~ processing plant products. However, while fishing appears to be important along the coastal bays and terraces and along many inland rivers, evidence for the large-scale exploitation of shellfish remains minimal.

This pattern shifts in the Early Jōmon, with the appearance of large shell middens at several coastal sites in the south-west, south-east and north of Hokkaidō. In general, the largest population centres start to form at permanent coastal "villages" in the south-west. While shellfish gathering and the exploitation of marine mammals, especially the northern fur seal (Takase, 2020), are of growing importance, the harvesting and storage of nuts also appears to be a central part of the subsistence economy, with terrestrial hunting also persisting. Although it is easy to focus on these developments in the south-west, other areas of Hokkaidō, including the Kamikawa Basin, are being used in very different ways, and no house pits have ever been recorded here, possibly due to the importance of more mobile strategies that focus on seasonal hunting and fishing.

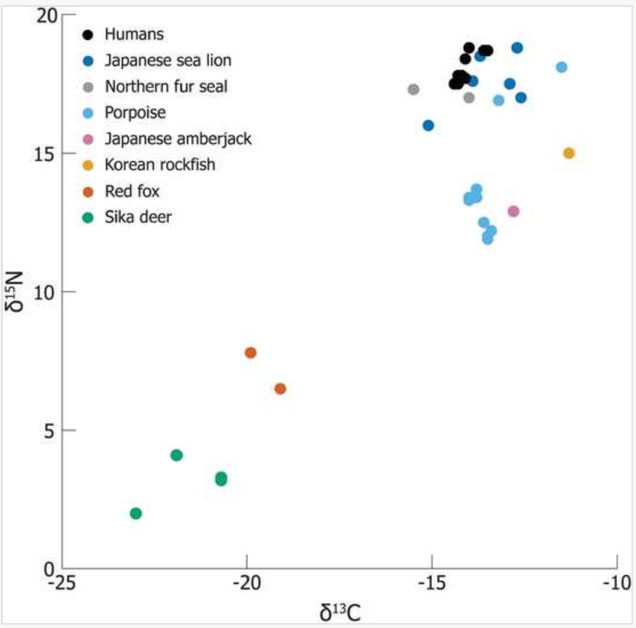
By the start of the Middle Jōmon, climatic conditions in Hokkaidō are at an optimal level, the sea level is highest, and oak forests reach their maximum extent. In addition to the exploitation and active management of nut forests, there is also some evidence of foxtail millet gathering (*Setaria italica*), again in the south-west (Crawford, 2008). Construction of extensive pit-fall hunting systems, large fish weirs and growth of large coastal settlements, many with shell middens or ritual earthworks, all point to peak population levels and the intensive "harvesting" of diverse ecosystems.

By the 4200 cal BP cold event, the warming trend goes into reverse and sea levels start to fall again. This triggers major adjustments, total site numbers fall off dramatically, especially in northern and inland areas, indicating a fundamental restructuring of the entire system, potentially in relation to the decline in nut-bearing forests. In general, South-west Hokkaidō shares many later developments with Northern Tohoku during the Late and Final Jōmon, including the construction of large stone circles, which possibly serve as a focal point for populations becoming increasingly mobile. Collective burials also emerge in the south-west, unique to Hokkaidō, which exhibit evidence for growing social differentiation. In contrast, the north and east appear to follow a different trajectory, focusing increasingly on the exploitation of terrestrial and marine mammals.

2 Investigating diversity and change in Hokkaidō Jōmon foodways

While the general details of the various regional trajectories are clear, much less is known about regional strategies of resource processing and food consumption, and how these changed over time. There are two reasons for this: (a) archaeological excavation and publication efforts are generally organised at the level of local education boards meaning that the main goal is to record and describe sites and sequences, and then to allocate them to the correct period, generally using pottery typologies. Thus, while a wealth of data is available, reconstruction of adaptive strategies and food consumption practices has not been a specific focus of these efforts. It is generally assumed that local communities lived on a mixture of wild plants and animals and fish, along with marine resources along the coastlines; (b) whilst biomolecular techniques for studying palaeodiet (i.e. stable isotope analysis) have been applied with increasing frequency throughout Japan, in general, these studies have largely been undertaken on bone remains recovered from coastal shell midden sites where conditions are conducive to their preservation. To date, only a handful of studies have been undertaken on human remains from Hokkaidō itself (Fig. 7), in which the stable isotope analysis of Early Jōmon individuals interred at the coastal shell midden site of Kitakogane has shown that 79% of their diet was derived from marine protein (Naito et al., 2010; Yoneda et al., 2002; 2004). In contrast, the underlying acidic soils of the island mean that comparative studies from inland sites have not been possible. This results in a major "marine" bias in palaeodietary reconstructions, while inland foodways may have been very different. Analysis of pottery residues represents the only way to directly investigate and potentially reconcile these gaps in current knowledge of local foodways.

Fig. 7



Carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope data obtained on human and faunal bone collagen from the Kitakogane shell midden site (data from Naito et al., 2010, Yoneda et al., 2002, 2004).

2.1 Sampling strategy

Given the strong indications of major spatiotemporal variability in adaptive strategies throughout the different parts of the island (Table 1), our first step was to select five regions that exhibited contrasting features of geography, ecology and prehistoric settlement. These included:

1. **Tokachi Plain**: this inland area has the sole example of Incipient Jōmon pottery from Hokkaidō, and in the Initial Jōmon was the location of pit-house hamlets, although activity levels fall off at the end of the Early Jōmon, and do not pick up again until much later in the Jōmon sequence.
2. **South-west Hokkaidō**: this region witnessed the appearance of numerous coastal hamlets, followed by larger sedentary "villages" in the Early and Middle Jōmon.
3. **The Kamikawa Basin**: has a very different cultural trajectory. Evidence for house pits is absent, ~~No house pits have ever been recorded here~~ and the

area appears to have been used for mobile hunting, and in later periods for funeral and feasting activities. In particular, the palaeoeconomy of these inland areas is poorly understood, especially during the later phases of the Jōmon trajectory.

4. **The Far North**: sites along the Teshio River also appear to have been linked to more mobile lifeways.
5. **The Far East**: coastal settlements here offer a further regional contrast.

Second, we were particularly interested in exploring the potential diversification of foodways at the start of the Holocene, which witnesses the novel addition of plant foods and aquatic resources to the general subsistence package. As a result, we selected sites with diverse Initial, Early or Middle Jōmon occupations, as well as one site that dates to the Incipient Jōmon. Third, from the Late Jōmon onwards, there is a major shift towards coastal occupations (Abe et al., 2016; Takase, 2020), and it becomes clear that these populations were developing specialised maritime adaptations. In contrast, very little is known about the foodways of groups that remain in inland areas, though it is assumed that they relied heavily on hunting. To resolve these gaps we also selected a series of later sites in the Kamikawa Basin, which has a very different cultural trajectory to most coastal areas. On balance, this selection of regions, sites and periods was designed to enable us to focus on exploring some of the general ~~more likely~~ patterns of variability and change in ~~within~~ food processing traditions (see Table 2, Fig. 8).

Table 2

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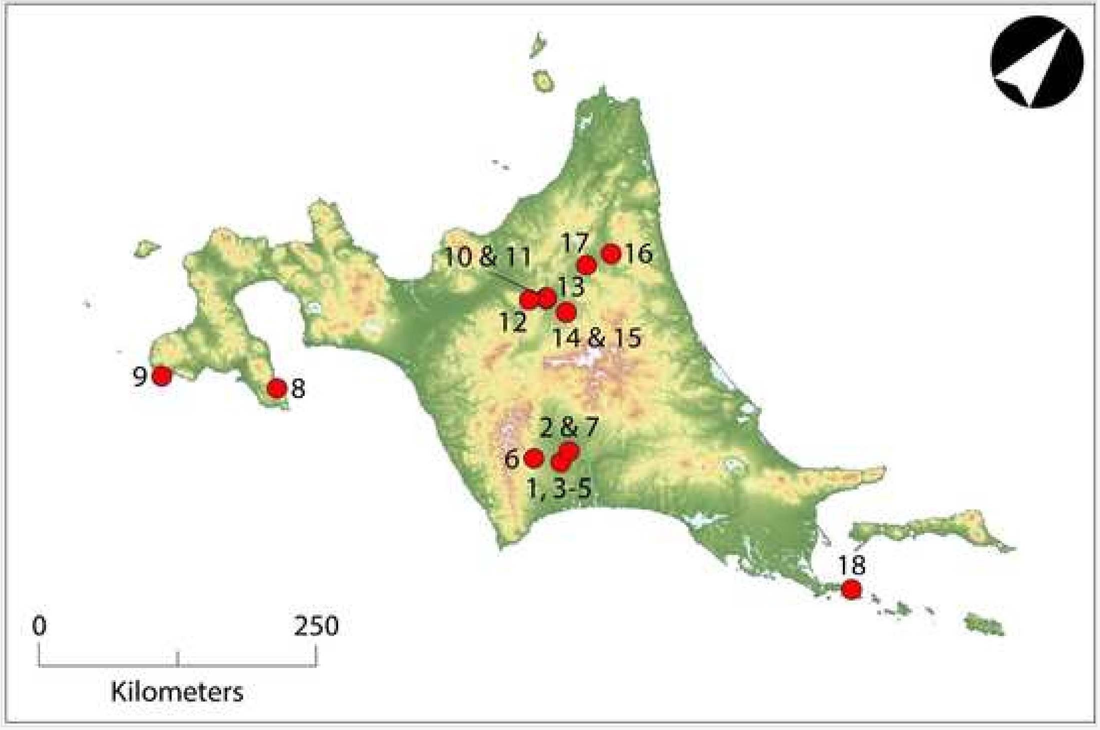
Summary of the selected sites by region and period. Note that the numbers in parentheses correspond to the site numbers mapped in Fig. 8.

Period/region	Tokachi Plain	South-west Hokkaidō	Kamikawa Basin	Far North	Far East
Palaeolithic					
Incipient Jōmon	Taisho 3 (1)				
Pottery *Hiatus*					
Initial Jōmon	Akatsuki (2)	Kakkumi (8)	Midorimachi 1 (10)	Nisshin 33 (16)	Tosanporo (18)
	Taisho 6 (3)				
	Taisho 7 (4)				
	Taisho 8 (5)				
	Yachiyo A (6)				
Early Jōmon	Miyamoto (7)	Tatesaki (9)	Midorimachi 1 (10)	Nisshin 33 (16)	Tosanporo (18)
	Taisho 8 (5)			Tayoro (17)	
Middle Jōmon		Tatesaki (9)	Arashiyama (11)	Nisshin 33 (16)	
Late Jōmon		Tatesaki (9)	Kamuikotan 7 (12)		
Final Jōmon			Arashiyama (11)		
			Hagigaoka (13)		
			Midorimachi 1 (10)		
			Nagayama 4 (14)		
			Nagayama 8 (15)		

Fig. 8



Location of the sites sampled in this study. Refer to Table 2 for site names.

2.2 Tracking variability and change in local subsistence

2.2.1 General culinary predictions

As already noted, very little attention has been directed at understanding regional diversity in foodways. In general, local archaeologists have tended to assume that inland areas relied on a broad mix of hunting, fishing and gathering, while coastal areas combined this with the exploitation of shellfish and marine mammals. As a result, we had no specific pre-existing hypotheses to test other than the Jōmon developed site-specific adaptive strategies that exhibited broad coastal-inland variation, and that nuts and shellfish became increasingly important over time, especially in the Early and Middle Jōmon (see Abe et al., 2016). Given the major ecological and climatic variability of the island, we therefore predicted that there would be different patterns of pottery use between coastal and inland sites, and northern and southern regions. In contrast, we are not aware of any hypotheses regarding the different pottery types being used to process contrasting sets of resources. As mapped in Fig. 2, most of the major pottery traditions extend over large areas, and are often present at both coastal and inland sites.

2.2.2 Generating specific culinary “p~~P~~redictions”

To equip our case-study with a more specific set of testable predictions we worked closely with Japanese site reports to build up a more detailed picture of local resource processing strategies at each sampling site. For each site and occupation phase we extracted a standard inventory of information pertaining to the following themes:

- **Tool-kits**: an overview of tool diversity and frequency, especially net sinkers, hunting gear (e.g. arrows, spears), and plant processing tools such as hand-held grinders and stone base plates, nut crackers or other hammer stones.
- **Resources**: presence of botanical and faunal remains (charred seeds, bone materials).
- **Site Location**: how the site was situated within the landscape, including access to surrounding resources, especially coastlines and rivers, but also migration routes of animals.
- **Structures**: presence or absence of house pits and storage pits. This may indicate whether a site was a specialist extraction point or a more general base-camp.
- **Other**: contextual information including information on other cooking and processing activities (e.g. roasting pits, heat-treated rocks).

This qualitative exercise revealed both similarity and variability in the subsistence strategies and food processing activities conducted at each site:

- Almost all of the sites were located close to either inland rivers or coastlines, often just a few tens of metres away, but in some inland areas, up to 2.5 km from the nearest river, suggesting differing site functions within wider settlement systems.
- Irrespective of coastal or inland location, all sites appear to have had a common set of tools and equipment, which point towards mixed subsistence activities: hunting gear was present at all sites, suggesting that terrestrial meat remained important, even at large coastal sites; plants (and probably nuts) appear to have been very important, with cracking and grinding tools present at coastal and inland sites (and often embedded within house pit floors); more predictably, net sinkers were more common at coastal sites, but also appear at some inland locations, though many river-edge camp sites did not have them (fish could have been harvested with nets, weirs, hooks or harpoons).
- The occasional recovery of plant and bone material also points to the mixed exploitation of nuts, terrestrial and marine animals as well as a range of fish at many sites.
- Several sites had evidence of roasting pits and fire-cracked rocks, suggesting that food could have been prepared without being processed in pottery.

Beyond the obvious distinctions between coastal and inland areas, there also appeared to be substantial differences in the *relative* importance of terrestrial hunting versus nut processing and fishing. While many inland sites were located at or near river banks, with fishing confirmed by the presence of net sinkers, others were located much further away and appear to have been focused on upland hunting (e.g. Miyamoto site). A full contextual description of each site can be found in **Supplementary Data 1**~~Appendix A~~.

These insights enabled us to define a more specific set of site-by-site culinary predictions, which are presented in Table 3. This table combines all the available information per site and period, ranging from specific kinds of nuts or animal or fish bones, through to the presence of net sinkers, arrows and grinding stones. The right-hand column lists the most likely food combinations at each site, listed in order of relative importance. For example, the inland Yachiyo A site in the Tokachi Plain has clear evidence of hunting and also plant use (walnuts and acorns), but is located far from a river and has no net sinkers, hence the cooking of terrestrial animals along with nuts is the predicted cuisine. In contrast, the Akatsuki site is closer to a major river and has net sinkers, plant processing tools and arrows, and so we predict that pottery use here was orientated towards the processing of a combination of fish, plants and terrestrial animals.

Table 3

The table layout displayed in this section is not how it will appear in the final version. The representation below is solely purposed for providing corrections to the table. To preview the actual presentation of the table, please view the Proof.

[Instruction: I think Table 3 would look better in landscape]Predicted pottery-based cuisine at each sampling site (based on interpretation of site function, and analysis of site locations, tool kits and other faunal and botanical data); refer to the **Supplementary Data 1 ~~Information~~** for further details. *Definitions: **Camp** (stopping point on a seasonal round); **Station** (more established point on a seasonal round, with house pits); **Hamlet** (resembles a fully sedentary settlement, with numerous house pits, and (possibly) smaller task groups sent out into the surrounding landscape).

Region/Site Name	Period	Site type*	House pits	Distance from the river or coast (m)	Fishing (net sinkers)	Hunting (arrows)	Plant processing (grinding stones)	Species (plants, animals)	Predicted Cuisine (i.e. food groups in order of importance)
Tokachi Plain									
Taisho 3	Incipient	Campsite	0	500	N	Y	N	–	Terrestrial animals, freshwater fish?
Akatsuki	Initial	Station	2	300	Y	Y	Y	–	Freshwater fish, plants, terrestrial animals
Taisho 6	Initial	Camp/station?	1?	350	N	Y	Y	–	Terrestrial animals, plants, freshwater fish?
Taisho 7	Initial	Camp/station	3 ~~(built later)~~	500	N	Y	Y	–	Terrestrial animals, plants, freshwater fish?
Taisho 8	Initial	Camp/station	7 ~~(built later)~~	500	N	Y	Y	–	Terrestrial animals, plants, freshwater fish?
Yachiyo A	Initial	Hamlet	103	1200	N	Y	Y	Walnut, acorn.	Terrestrial animals, plants
Miyamoto	Early	Station	4	2500	N	Y	Y	–	Terrestrial animals, plants
Taisho 8	Early	Station	3	500	N	Y	Y	–	Terrestrial animals, plants, freshwater fish?
South-west Hokkaidō									
Kakkumi	Initial	Hamlet (?)	6	200	Y	Y	Y	–	Freshwater/marine fish, plants, terrestrial animals?
Tatesaki	Early	Hamlet	50	500	Y	Y (+harpoons)	Y	Marine mammals, shellfish, fish, birds, chestnut, walnut, sika deer	Marine resources, plants, terrestrial animals
Tatesaki	Middle	Hamlet	(see above)	500	(see above)	(see above)	(see above)	(see above)	(see above – late Early Jōmon-early Middle Jōmon layers mixed)
Kamikawa Basin									
Midorimachi 1	Initial	Station	0	10	N	Y	Y?	–	Terrestrial animals, plants(?), freshwater fish?
Midorimachi 1	Early	Station	0	10	N	Y	Y?	–	Terrestrial animals, plants(?), freshwater fish?
Arashiyama	Middle	Station	0	15	Y	Y	N	–	Freshwater fish, terrestrial animals
Kamuikotan 7	Late	Station	0	10	N	Y	Y	–	Terrestrial animals, plants, freshwater fish?
Nagayama 4	Late	Cemetery	0	1200	N	Y	Y	Sika deer, carp fish	Terrestrial animals, freshwater fish
Arashiyama	Final	Station	0	15	Y	Y	N	–	Freshwater fish, terrestrial animals
Hagigaoka	Final	Station	0	200	N	Y	Y	–	Terrestrial animals, plants, freshwater fish?

Midorimachi 1	Final	Station	0	10	N	Y	Y?	–	Terrestrial animals, plants(?), freshwater fish?
Nagayama 8	Final	Station	0	2000	Y	Y	N	–	Terrestrial animals, freshwater fish?
Far North									
Nisshin 33	Initial	Station	0	50	N	Y	Y	–	Freshwater fish, plants, terrestrial animals
Nisshin 33	Early	Station	0	50	N	Y	Y	–	Freshwater fish, plants, terrestrial animals
Nisshin 33	Middle	Station	0	50	N	Y	Y	–	Freshwater fish, plants, terrestrial animals
Tayoro	Early	Station	0	500	N	Y	N	–	Terrestrial animals, freshwater fish?
Tayoro	Middle	Station	0	500	N	Y	N	–	Terrestrial animals, freshwater fish?
Far East									
Tosanporo	Initial	Station	3	30	Y	Y	Y	–	Marine resources, plants, terrestrial animals
Tosanporo	Early	Hamlet	15	30	Y	Y	Y	–	Marine resources, plants, terrestrial animals

Although this was an entirely qualitative exercise, it highlighted the broad-based character of subsistence at almost all the sites, and that some sites may have had a more specific economic function (e.g. fishing or hunting stations versus general base-camps). On the basis of this exercise, our overall prediction was that: (a) pottery was being used at all sites to prepare mixed dishes, and that (b) the relative contributions of the three major food groups at the different sites would form an expression of local culinary traditions.

3 Materials and methods

To test these predictions we sampled a total of 91 interior absorbed residues and 78 carbonised surface deposits (i.e. interior 'foodcrusts' and exterior 'sooted-crusts') for organic residue analysis. A summary of the sampled vessels and analyses performed is provided in Table 4. The bulk carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope data, and fatty acid $\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ were complemented with data published elsewhere (Craig et al., 2013; Kunikita et al., 2013; Lucquin et al., 2018).

Table 4

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Summary of the samples analysed in this study.

Site	Period	N	Elemental Analysis-Isotope Ratio Mass Spectrometry	Gas Chromatography-Mass Spectrometry	Gas Chromatography-Combustion-Isotope Ratio Mass Spectrometry
Akatsuki	Initial	5		5	
Arashiyama	Final	2	1	2	1
Arashiyama	Middle	1		1	
Hagigaoka	Final	2		2	
Kakkumi	Initial	22		22	14
Kamuikotan 7	Late	2		2	
Midorimachi 1	Initial	1		1	
Midorimachi 1	Early	2		2	
Midorimachi 1	Final	1		1	
Miyamoto	Early	8		8	2
Nagayama 4	Final	4		4	

Nagayama 8	Final	2		2	1
Nisshin 33	Initial	2		2	1
Nisshin 33	Early	2		2	
Nisshin 33	Middle	5		5	
Taisho 3	Incipient	7	2	7	4
Taisho 6	Initial	2	2	1	
Taisho 7	Initial	5		5	
Taisho 8	Initial	15	1	15	
Taisho 8	Early	11		10	3
Tatesaki	Early	5	5	5	
Tatesaki	Middle	12	12	10	4
Tatesaki	Late	1	1	1	1
Tayoro	Early	10	10	10	2
Tosanporo	Initial	14	12	8	2
Tosanporo	Early	16	15	15	1
Yachiyo A	Initial	10	6	10	
Totals		**169**	**67**	**158**	**36**

3.1 Bulk isotope ratio mass spectrometry analysis

In this study, bulk $\delta^{13}C$ and $\delta^{15}N$ stable isotope analysis was performed on 47 carbonised surface deposits (Fig. 9). Measurements were carried out at two institutions: the University of Bradford (UK) and the University of York (UK). The carbonised surface deposits were removed directly from the pottery sherds by a scalpel and homogenised in a mortar and pestle. Then, they were weighed into tin capsules and analysed without any pre-treatment. The samples were analysed in duplicate, and the values averaged. At Bradford, an ANCA-SL Elemental Analyser linked to a PDZ Europa 20/20 Mass Spectrometer was used. At York, a Sercon GSL Analyser coupled to a Sercon 20/22 Mass Spectrometer was employed. Calibrations and measurement uncertainty are discussed elsewhere (Craig et al., 2013; Lucquin et al., 2018).

Fig. 9

The inner rim sherd of an Early Jōmon "Oshigatamon-sentei" vessel from the coastal site of Tosanporo in Eastern Hokkaidō. The interior foodcrust was sampled (TOS-206). Scale – 5 cm.

3.2 Organic residue analysis

Lipids were extracted and methylated with acidified methanol according to established methods (Craig et al., 2013; Lucquin et al., 2016a, Lucquin et al., 2018). Briefly, methanol (1 or 4 mL) was added to either the homogenised carbonised surface deposits (10–20 mg) or ceramic powders (0.5–1.0 g) drilled (2–5 mm depth) from the interior or exterior surfaces of the sherds. The samples were sonicated in a water bath for 15 min, and acidified with concentrated sulphuric acid (200 or 800 µL). The suspension was then heated in a block for 4 h at 70 °C. Lipids were extracted with *n*-hexane (3 × 2 mL), and subsequently analysed by GC-MS and GC-C-IRMS. Details concerning the instrumentation employed are provided in Supplementary Data 1. Appendix A.

3.3 Non-parametric tests

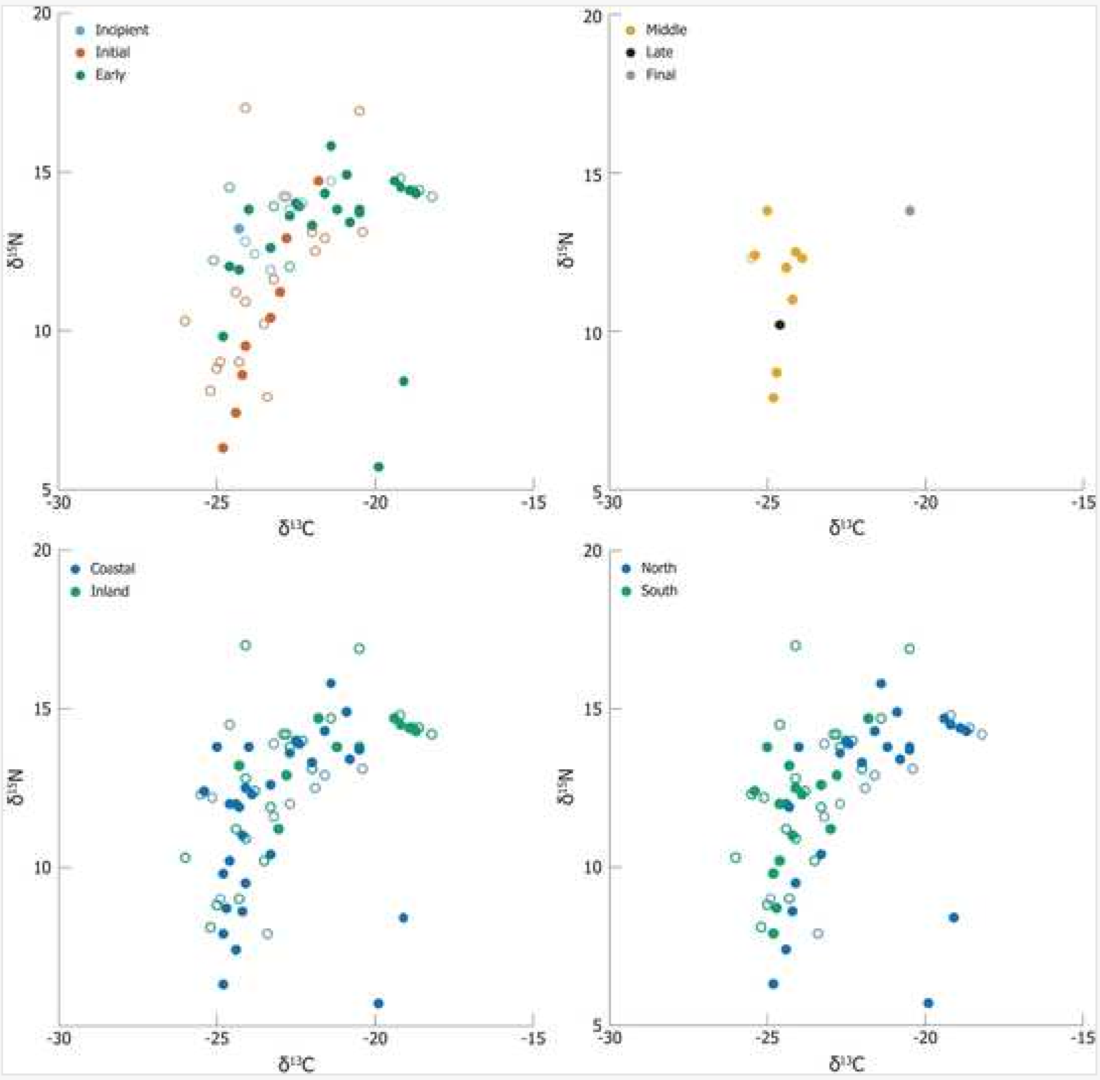
The PAST (PAleontological STatistics) programme was used to test for differences in the data over time, specifically between the six periods (Incipient, Initial, Early, Middle, Late and Final). Initially we used the non-parametric Kruskall-Wallis test followed by Dunn's *post hoc* test. To examine the potential impacts of distance from the coast (coastal versus inland), latitude (north versus south) and longitude (east versus west), we employed the non-parametric Mann-Whitney *U* test.

4 Results

4.1 Bulk carbon and nitrogen stable isotope analysis

The results of the ~~B~~bulk $\delta^{13}C$ and $\delta^{15}N$ stable isotope analysis of the ~~data were obtained from carbonised surface deposits adhering to~~ 47 carbonised surface deposits ~~vessels~~ sampled in this study [Instruction: Supplementary Data 2?](Fig. 10, Supplementary Data 1)~~.~~ ~~These data~~ were combined with published data (n = 32) ~~reported elsewhere~~ (Craig et al., 2013; Kunikita et al., 2013; Lucquin et al., 2018). Of these, only four yielded unreliable data (i.e. <10% C and/or <1% N). Given the broad range of $\delta^{13}C$ and $\delta^{15}N$ values (−26.0 to −18.2‰ and 5.7 to 17.0‰ respectively), a variety of products conceivably encompassing aquatic organisms from both freshwater and marine environments as well as terrestrial resources, including plants (see below), are likely to have been processed in the vessels. When the data were disaggregated according to period (Fig. 10), there was significant variation in the median $\delta^{13}C$ (Kruskal-Wallis $\chi^2 = 23.25$; $p = 0.000035$) and $\delta^{15}N$ (Kruskal-Wallis $\chi^2 = 16.75$; $p = 0.00079$) values between the four periods[2].

Fig. 10



Bulk $\delta^{13}C$ and $\delta^{15}N$ stable isotope data obtained from carbonised surface residues adhering to Jōmon vessels recovered from Hokkaidō. The data have been disaggregated according to period, distance from the coast and latitude. Closed circle - sample with aquatic biomarkers and/or phytanic acid SRR ratio > 75.5%, open circle - sample without aquatic biomarkers and/or phytanic acid SRR ratio < 75.5% (see below).

In general, the Incipient, Initial and Early Jōmon vessels had higher $\delta^{13}C$ and $\delta^{15}N$ values when compared with the Middle Jōmon vessels (Table 5) suggesting differences in pottery use as well as the environments in which the processed resources had been residing in, i.e. marine compared with freshwater. When the data were disaggregated according to location (Fig. 10), this observation was reinforced; there was a significant difference in the $\delta^{13}C$ (Mann-Whitney U test; $U = 476$; $p = 0.019$) and $\delta^{15}N$ (Mann-Whitney U test; $U = 432$; $p = 0.0044$) values between the coastal and inland sites. On the whole, the inland vessels had a broader range of $\delta^{13}C$ values (−26.0 to −18.2‰; mean = −22.8‰; n = 34) compared with the coastal vessels (−25.5 to −19.1‰; mean = −22.5‰; n = 41). In contrast, the coastal vessels had a broader range of $\delta^{15}N$ values (5.7 to 15.8‰; mean = 11.6‰; n = 41) compared with the inland vessels (8.1 to 17.0‰; mean = 13.1‰; n = 34). Despite these small, albeit statistically significant differences, the overlapping $\delta^{13}C$ and $\delta^{15}N$ values likely indicate that freshwater fish as well as organisms enriched in ^{13}C (i.e. migratory salmonids) were being caught and then processed inland, whereas at the coast, marine resources and salmonids were the primary source of the residues. Alternatively, either the vessels, or indeed marine resources (e.g. dried, smoked or preserved marine fish or shellfish), had been transported from the coast to the interior. When the data were disaggregated according to latitude (Fig. 10), there was a significant difference in the $\delta^{13}C$ values between the north and south of the island (Mann-Whitney U test; $U = 242$; $p = 0.00010$). Overall, the vessels derived from northern localities had elevated $\delta^{13}C$ values (−24.9 to −18.2‰; mean = −22.6‰; n = 37) compared with those from the southern sites (−26.0 to −20.5‰; mean = −22.8‰; n = 38), which may reflect a greater input of marine-derived protein or indeed different species of salmon exhibiting different life histories and habitat uses.

Table 5

ⓘ The table layout displayed in this section is not how it will appear in the final version. The representation below is solely purposed for providing corrections to the table. To preview the actual presentation of the table, please view the Proof.

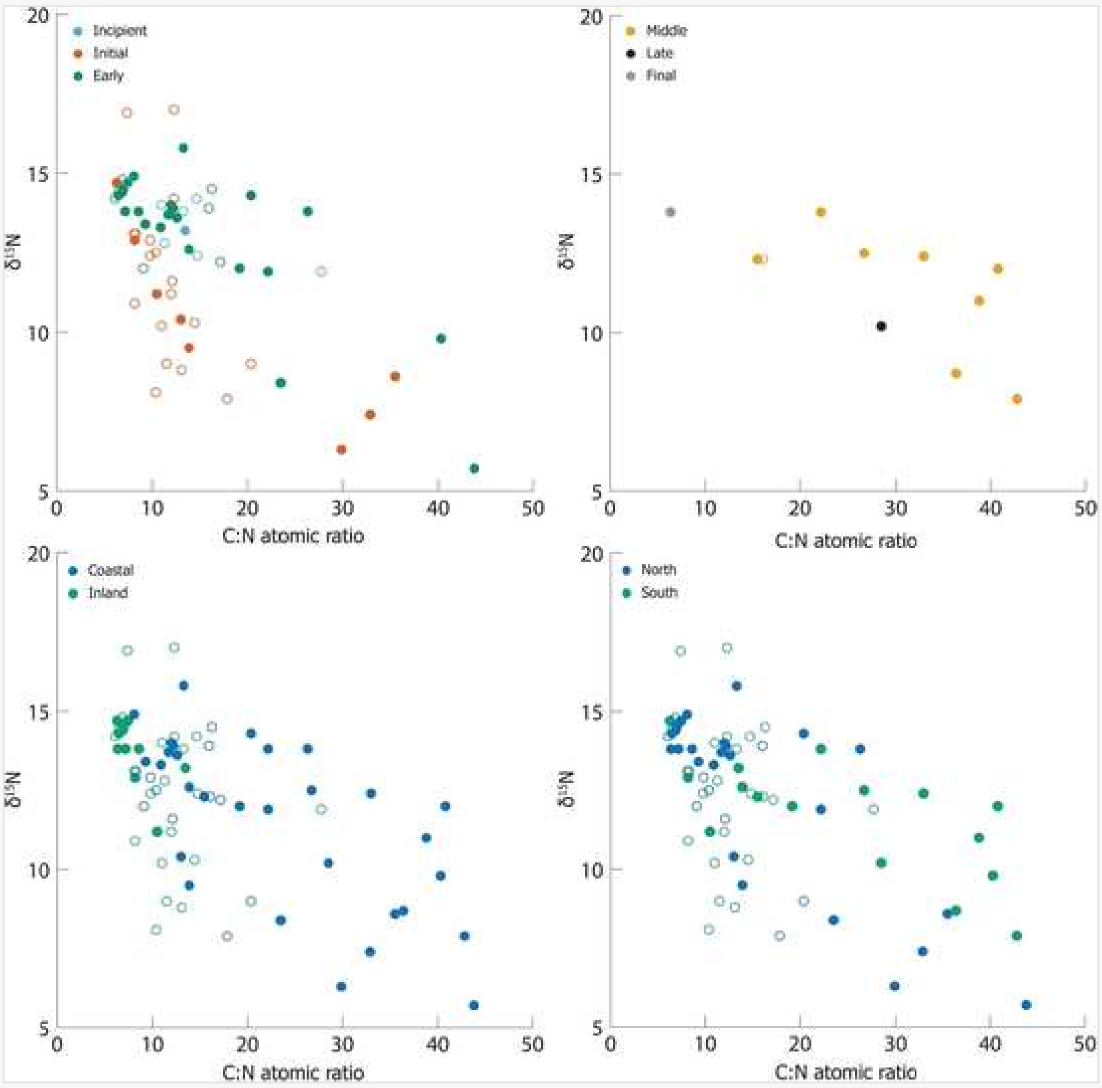
Summary of the bulk $\delta^{13}C$ and $\delta^{15}N$ stable isotope data.

Period	$\delta^{13}C$ range	$\delta^{15}N$ range	C:N atom	Median $\delta^{13}C$	Median $\delta^{15}N$	Median C:N atom	N
Incipient	−24.3 to −21.4‰	11.9 to 14.7‰	7.5 to 27.7	−23.1‰	13.5‰	13.4	8

Initial	−26.0 to −20.4‰	6.3 to 17.0‰	6.3 to 35.5	−23.4‰	12.4‰	12.8	26
Early	−25.1 to −18.2‰	5.7 to 15.8‰	6.1 to 43.8	−23.2‰	12.6‰	13.9	30
Middle	−25.5 to −23.9‰	7.9 to 13.8‰	15.5 to 42.8	−24.7‰	12.3‰	33.0	9
Late	n/a	n/a	n/a	−24.6‰	10.2‰	28.5	1
Final	n/a	n/a	n/a	−20.5‰	13.8‰	6.4	1

To investigate whether plants had been processed in the vessels, the C:N atomic ratios, which broadly indicate the abundance of carbohydrates or fats/oils relative to protein, and $\delta^{15}N$ values, in which protein is the main contributor, were examined (Fig. 11). Despite the broad range of C:N atomic ratios (6.1 to 43.8), which indicates that some vessels may have had a greater input of plant products (i.e. C:N atomic ratios > 30, see Heron et al., 2016; Yoshida et al., 2013), the $\delta^{15}N$ values (5.7 to 17.0‰), and molecular analysis (see below) provided additional evidence that aquatic resources were the main contributor to the residues. When the data were disaggregated according to period (Fig. 11), there was, however, significant variation in the median C:N atomic ratios (Kruskal-Wallis $\chi^2 = 16.01$; $p = 0.0011$) between the four periods (see Footnote 2). In general, the Incipient, Initial and Early Jōmon vessels had lower C:N atomic ratios suggesting a lower input of plant products when compared with the Middle Jōmon vessels (Table 5). Further, when the data were disaggregated according to location (Fig. 11), there was a significant difference in the C:N atomic ratios (Mann-Whitney U test; $U = 197.5$; $p = 0.00010$) between the coastal and inland sites. Overall, the coastal vessels had higher C:N atomic ratios (8.1 to 43.8; mean = 16.4; n = 41) compared with the inland vessels (6.1 to 27.7; mean = 15.9; n = 34), which likely indicates a greater input of plant products, from, for example, seaweed. It is interesting to note that the majority of the evidence for plant processing was identified in the vessels sampled from the coastal sites (see below).

Fig. 11



C:N atomic ratios and bulk $\delta^{15}N$ values obtained from carbonised surface residues adhering to Jōmon vessels recovered from Hokkaidō. The data have been disaggregated according to period, distance from the coast and latitude. Closed circle - sample with aquatic biomarkers and/or phytanic acid SRR ratio > 75.5%, open circle - sample without aquatic biomarkers and/or phytanic acid SRR ratio < 75.5% (see below).

4.2 Molecular analysis

To distinguish pottery use further, a total of 158 samples were analysed by GC-MS utilising a non-polar column [Instruction: Please change to (see **Supplementary Data 1 and 2**).](see ~~Appendix A,~~ Supplementary Data 2). Of these, 65 (41.1%) yielded appreciable quantities of lipids for interpretation following the established criteria (>5 µg g^{-1} for potsherds and >100 µg g^{-1} for carbonised residues, Craig et al., 2013; Evershed, 2008).

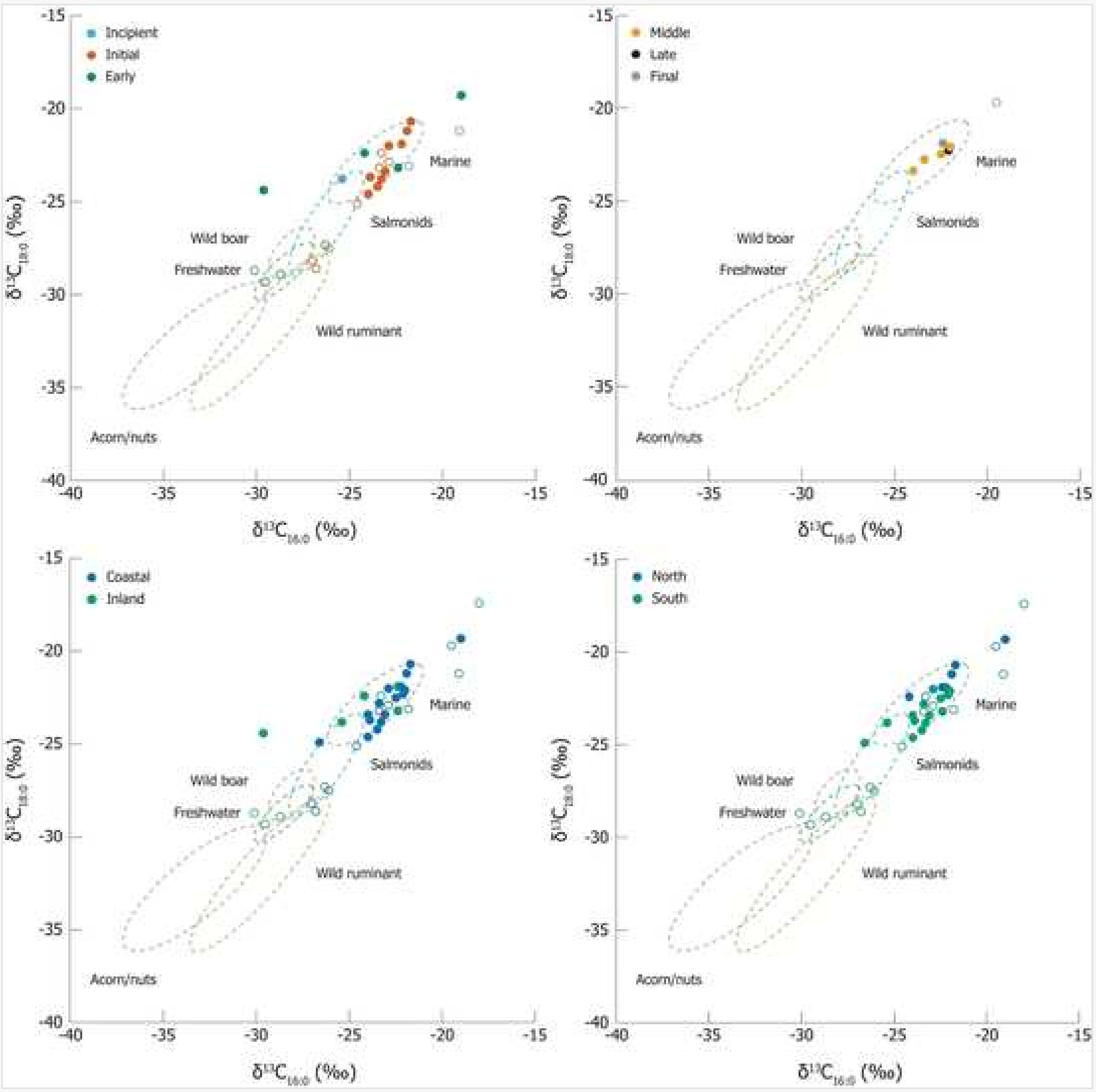
To detect compounds associated with aquatic products (Hansel et al., 2004; Evershed et al., 2008), 44/158 (27.8%) samples were analysed using a polar column operating in Selected Ion Monitoring mode [Instruction: Please replace with (**Supplementary Data 1 and 2**).](~~Appendix A,~~ Supplementary Data 2). Of these, 27 (41.5%) met the established criteria, including the presence of ω-(o-alkylphenyl)alkanoic acids (APAAs) with C_{18} and C_{20} carbon atoms alongside at least one isoprenoid fatty acid (either phytanic, pristanic or 4,8,12-trimethyltridecanoic acid) (Hansel et al., 2004; Evershed et al., 2008), indicating that aquatic foodstuffs had been processed in the pottery. A further two samples partially met the established criteria, including the presence of the C_{18} APAAs alongside one isoprenoid fatty acid (Hansel et al., 2004; Evershed et al., 2008), and as such had probably been used to process aquatic foodstuffs. Since previous studies have demonstrated that APAAs form through the protracted heating of aquatic organisms in pottery (Hansel et al., 2004; Evershed et al., 2008), their presence confirms the use of pottery for the processing of these resources. This analysis also enabled us to measure the ratio of the two naturally occurring phytanic acid diastereomers (%SRR), which permits further discrimination between aquatic and ruminant foodstuffs (Lucquin et al., 2016b). In total, 29 (65.9%) samples yielded a SRR% >75.5%, conservative limit (95% confidence for the exclusion of ruminant fat) for the presence of aquatic oils (Lucquin et al., 2018). Of the remainder, 13 (29.5%) samples yielded a SRR% between <75.5% and >64.0% (75% confidence for the exclusion of ruminant fat) whilst two (4.6%) samples yielded a SRR% <64.0% (75% confidence for the exclusion of aquatic oil). Since these samples could not be confidently assigned to either source, aquatic oils, ruminant fats or indeed mixtures thereof are envisaged.

In general, evidence for plant processing was infrequent. A total of 15 Initial Jōmon vessels from the coastal site of Kakkumi yielded leafy plant-derived lipids, including long-chain odd-numbered alkanes dominated by C_{29}. Indeed, these data corroborate the archaeological evidence and abundance of grinding tools recovered from the site (see **Supplementary Data 1**~~Appendix A~~). Furthermore, long-chain even-numbered fatty acids were present in 15 samples (1 × Incipient vessel from Taisho 3, 5 × Initial vessels from Kakkumi, 2 × Initial vessels from Nisshin 33, 7 × Initial vessels from Tosanporo), similarly demonstrating plant processing, albeit on a much reduced scale compared with the processing of aquatic organisms.

4.3 Analysis of individual fatty acids

In order to further distinguish the origins of the different foodstuffs, the fatty acid $\delta^{13}C$ values ($C_{16:0}$ and $C_{18:0}$) of 36 samples were analysed by GC-C-IRMS [Instruction: Supplementary Data 2?](~~Appendix A,~~ Supplementary Data 3). These data are plotted alongside data obtained from modern authentic reference fats from Japan (Ackman and Hooper, 1968; Craig et al., 2013; Evershed et al., 2008; Hansel et al., 2004; Lucquin et al., 2016a) in Fig. 12.

Fig. 12

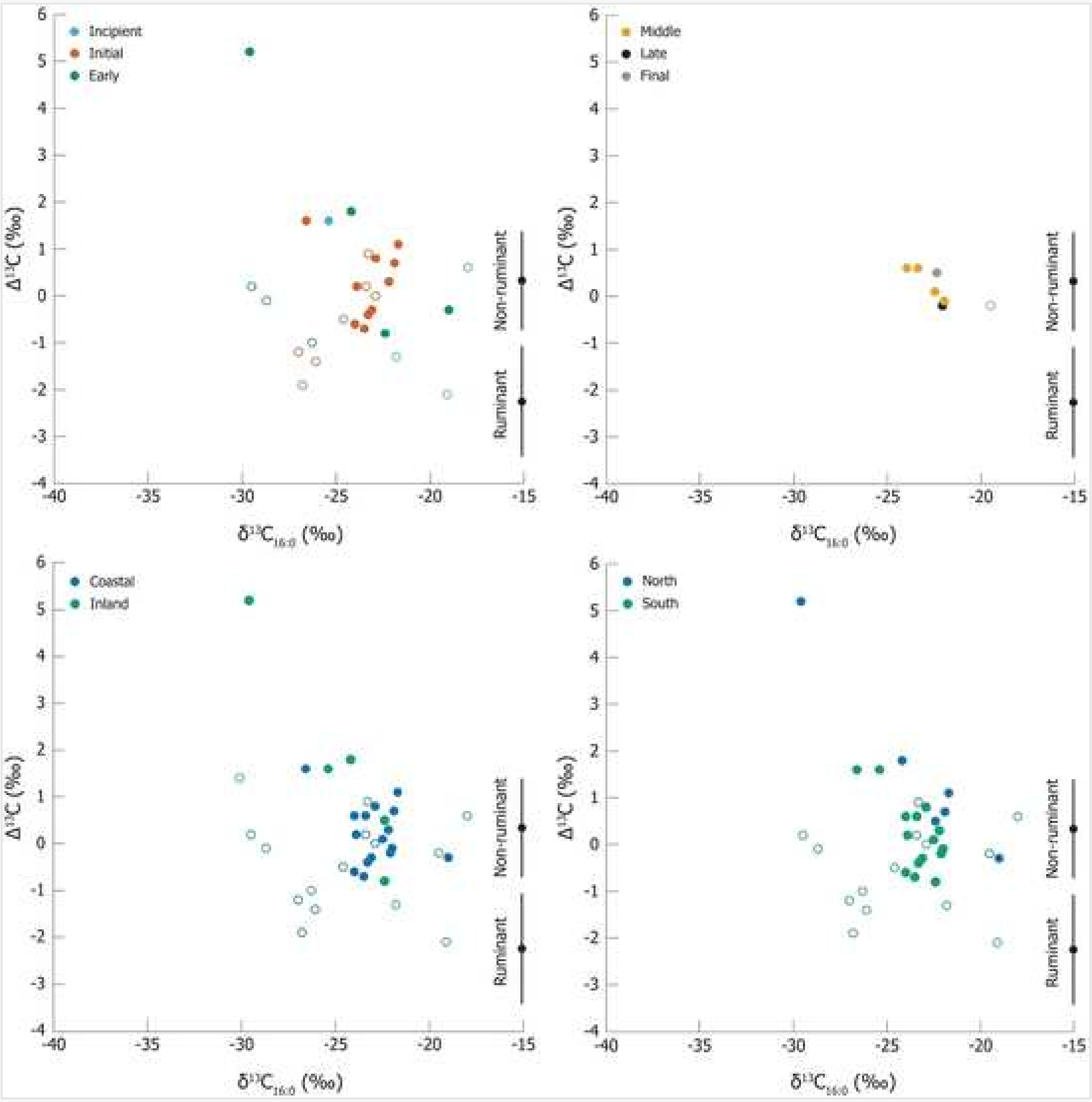


$\delta^{13}C$ values of $C_{16:0}$ and $C_{18:0}$ *n*-alkanoic acids obtained from Jōmon vessels recovered from Hokkaidō. The ranges are derived from fats obtained from modern Japanese animals and are plotted at 95% confidence. Closed circle - sample with aquatic biomarkers and/or phytanic acid SRR ratio > 75.5%, open circle - sample without aquatic biomarkers and/or phytanic acid SRR ratio < 75.5% (see below).

Despite the broad range of $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$ values (−30.1 to −18.0‰ and −29.3 to −17.4‰ respectively), the data largely corroborate the presence of aquatic biomarkers in many of the samples with the majority plotting within the ranges for marine organisms, salmonids and freshwater fish (Fig. 12) regardless of period, location, latitude and longitude. In contrast, there was no evidence for nut or plant processing in the pottery based on the $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$ values. Interestingly, one Incipient vessel from the inland site of Taisho 3 (KT3-J34) yielded the highest $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$ values (Fig. 12). Whilst these data likely indicate that migratory salmonids (enriched in ^{13}C) had been caught nearby and then processed at the site, it is possible that marine resources or vessels had been transported from the coast to the interior.

There was, however, evidence to suggest that wild ruminant carcass fats (i.e. sika deer) had been processed when the difference ($\Delta^{13}C$) in the the $\delta^{13}C$ values between the two fatty acids was calculated ($\delta^{13}C_{18:0}$-$\delta^{13}C_{16:0}$) (Fig. 13). Since a $\Delta^{13}C$ value < -1.0‰ is considered the upper threshold for wild ruminant carcass fats (Dudd and Evershed, 1998; Copley et al., 2003; Craig et al., 2012; Robson et al., 2019), we were able to confirm that wild ruminant carcass fats had been processed in a total of six vessels (2 × Incipient vessels from the inland site of Taisho 3, 3 × Initial vessels from the coastal site of Kakkumi, 1 × Early vessel from the inland site of Miyamoto) (Fig. 13). When the data were disaggregated according to latitude, there was a significant difference in the $\Delta^{13}C$ values between the north and south of the island (Mann-Whitney *U* test; $U = 49$; $p = 0.014$). Overall, the vessels derived from northern localities had higher $\Delta^{13}C$ values (−0.3 to 5.2; mean = 1.2; n = 8) compared with those from the southern sites (−2.1 to 1.6; mean = −0.2; n = 28). These data indicate a greater input of non-ruminant lipids (i.e. aquatic resources) in the north, which may be related to cultural choice or indeed differences in the geography and ecology of the island as well as productivity of the aquatic biomes due to the influence of cold ocean currents (Fig. 1).

Fig. 13



$\delta^{13}C$ values of $C_{16:0}$ *n*-alkanoic acids and $\Delta^{13}C$ ($\delta^{13}C_{18:0}$-$\delta^{13}C_{16:0}$) values obtained from Jōmon vessels recovered from Hokkaidō. The ranges are derived from fats obtained from modern Japanese animals and are plotted at 95% confidence. Closed circle - sample with aquatic biomarkers and/or phytanic acid SRR ratio > 75.5%, open circle - sample without aquatic biomarkers and/or phytanic acid SRR ratio < 75.5% (see below).

5 Discussion

5.1 An overview of Hokkaidō Jōmon cuisine

Together, the combined results appear to indicate that Hokkaidō Jōmon pottery was predominantly used to process aquatic resources, and that this formed the basis of local cuisine. This relationship emerges with the earliest pottery at Taisho 3 in the Incipient Jōmon, and continues throughout the Initial, Early and Middle Jōmon periods at both coastal and inland sites. Despite the smaller number of samples, this cultural association appears to persist until the Late and Final Jōmon periods at the inland sites in the Kamikawa Basin, though further research is recommended to ascertain how pervasive this practice was throughout Hokkaidō. Equally importantly, the association between pottery and aquatic resources also appears to span a wide range of ceramic typological traditions, including the pointed-based wares in South-western Hokkaidō and the flat-based pottery traditions of North-east Hokkaidō (Fig. 2).

On balance, we suggest that the prehistoric pottery was probably used to prepare "hot pot" dishes with aquatic resources as the main ingredient. Indeed, these may have resembled contemporary "nabemono" dishes in which terrestrial plants and animals or seafood are then added to the aquatic broths to create ~~mixed creating~~ a range of tastes and textures.

The contrasting patterns of pottery use between coastal (aquatic mixtures) and inland sites (mainly salmonids) also appears to confirm our current understanding of the role of seafood in Hokkaidō Jōmon subsistence: (a) at coastal sites, northern fur seal was the primary focus throughout the Jōmon, with offshore harpoon-based hunting emerging by the end of the Early Jōmon, though the relative importance of salmon and other fish species varied from site to site (Takase, 2020); (b) in contrast, the exploitation of annual salmon runs appears to have been much more important at inland sites.

5.2 Aquatic resources and early pottery use in E~~e~~ast Asia

The association we note between early pottery and aquatic resources appears to have deep cultural roots and extends over large parts of East Asia, including other parts of Late Glacial Japan (Craig et al., 2013) and the Lower Amur (Shoda et al., 2020), plus the Early Holocene of Japan (Lucquin et al., 2016a, 2018), Korea (Shoda et al., 2017) and Sakhalin Island (Gibbs et al., 2017). In general, much of the earliest pottery in Japan appears to have involved mobile groups gathering seasonally to harvest fish runs, which would have diversified subsistence during periods of extreme cold (Morisaki et al., 2019), but may also have involved group feasts and other rituals, as has been suggested in other world regions (Taché and Craig, 2015). However, the aquatic relationship also persists into warmer periods of the Late Glacial (Craig et al., 2013), and more surprisingly, across the major climatic and environmental shifts between the Pleistocene and Holocene, when warmer climates and expanding broad-leaved forest cover would have provided abundant new plant and animal resources such as nuts and wild ruminants (Lucquin et al., 2018). Indeed, organic residue analysis of over 800 sherds from 46 sites located throughout Japan identified two important trends: (a) pots continued to be used for the processing of aquatic resources, irrespective of ecological location; (b) a wider range of aquatic resources were being processed in Early Holocene pottery, including freshwater fish, shellfish and other marine taxa, possibly linked to the rise of coastal adaptations (Lucquin et al., 2018). Additional research into a 9000-year sequence of pottery use at the waterlogged shell-midden site of Torihama in Central Japan suggests that this relationship also persisted well into the Holocene (Lucquin et al., 2016a), although this is perhaps not unexpected given the site's strategic location among a chain of coastal lakes and marine bays.

Our new results confirm that a similar pattern existed at both coastal and inland sites throughout Hokkaidō, with pottery used for the processing of aquatic resources well into the Holocene, and also through to the Final Jōmon at inland sites in the Kamikawa Basin. In fact, this relationship may only start to break down much later in Hokkaidō's cultural trajectory (Junno et al., 2020).

Further afield, research into hunter-gatherer pottery use in Alaska, North America and some regions of the Baltic Sea basin aligns with this general aquatic pattern (Anderson et al., 2017; Courel et al., 2020; Farrell et al., 2014; Isaksson et al., 2019; Papakosta and Pesonen, 2019; Papakosta et al., 2019; Taché and Craig, 2015; Taché et al., 2017, 2019). However, new results from continental sites, including the Middle Amur (Shoda et al., 2020) and Cis Baikal (Bondetti et al., accepted,) regions of Asia, and European Russia (Bondetti et al., 2020) all point to other strategies of early pottery use: at Gromatukha, Late Glacial pottery was used to process ruminants and not fish; at Gorelyi Les, Early Holocene pottery functioned as general purpose containers and were used to process mixtures of plants, fish and game; and, at Zamostje 2 the earliest use of pottery involved mixed plant and fish recipes, with a specialised focus on fishing only emerging later.

5.3 Cuisine "b~~B~~eyond the cooking p~~P~~ot"

While our results confirm that fish-based **"hot pots"** may have played a central role in Jōmon cuisine, it is important not to overlook the wider process of economic diversification and specialisation that was taking place over the Jōmon trajectory (Table 1). Moreover, our analysis of the tool-kits, plant and faunal remains (Table 3, and **Supplementary Data 1**~~Appendix A~~) confirms that nuts and probably the sika deer were also making important contributions to local foodways, and yet these food types appear to be under-represented in the organic residue analyses. This suggests that there may be a major "aquatic" bias in the use of pottery, and perhaps even that pottery was produced for this explicit purpose. This, in turn, raises questions about how other kinds of plant and terrestrial animal resources were being processed.

5.3.1 Pottery and aquatic resources

Marine resources are both diverse and abundant along Hokkaidō's extended coastlines, and pottery would have been ideal for efficiently processing shellfish, fish and marine mammals such as the northern fur seal (e.g. at the sites of Kakkumi, Tatesaki and Tosanporo). Explaining the link between pottery and aquatic resources at inland sites is more difficult. Almost all of the inland sites are located within a short walking distance of Hokkaidō's major salmon rivers (Table 3), and the pots themselves may have been used during the harvesting of the annual fish runs, either for cooking fish, or for rendering oil at specialised fishing stations (e.g. Akatsuki and Arashiyama, which have net sinkers). Another scenario is that fish were harvested but then dried, smoked or fermented at riverside stations to preserve them for the lean winter season. These stores could have been cached locally, or transported to storage facilities at more distant "base-camp" sites, which typically have more durable house pits. Pottery may then have been used to rehydrate dried or smoked fish via slow simmering in water to produce the stock for rich and oily salmon hot-pots like contemporary "Ishikari Nabe" dishes. Fired clay vessels are ideal for this kind of slow cooking. Stocks of stored salmon may also have been a winter staple at the large inland hamlet site of Yachiyo A, which is 1.2 km from the nearest river, raising important questions about storage, mobility and intensification strategies in the Initial Jōmon (see discussions in Tushingham and Bettinger, 2013 in relation to salmon and nut exploitation in California). Interestingly, residues typical of salmon were previously identified in Incipient and Initial Jōmon pottery sampled from the upland hunting site of Yukura Cave in Honshu (Lucquin et al., 2018), which is located *ca*. 15 km away from the nearest river (Kaner, 2009).

5.3.2 How essential is pottery for the processing of ruminant fats and nuts?

It seems likely that terrestrial meat was mainly processed by other technologies, although ruminant fats may occasionally have been added to the pots to make what essentially appear to have been fish-based soups and stews. Alternative meat-processing strategies could have included smoking and drying to produce "jerky", although the presence of fire-cracked rocks and pit features - some with ruminant bones in - at many sites may suggest that earth ovens and roasting pits were in widespread use (e.g. Midorimachi 1, Nagayama 4, Nagayama 8, see **Supplementary Data 1** ~~Appendix A~~). Extraction of marrow and bone grease may also have been conducted at the sites, and pottery is by no means essential for these operations (e.g. Karr et al., 2015). Archaeological studies of "grease stations" suggests that the most important tools are cracking stones and anvils. A shallow pit is then lined with either clay or hide and then shattered bone is mixed with hot water to render grease which is skimmed off and stored in leather bags, pots or other waterproof containers. The water can be heated with hot stones, or boiled in pots and then poured into the pit (Karr et al., 2015:5).

These insights suggest that although pottery did not appear to play a major role in the processing of ruminant carcass fats, more work is required to better understand the function of the numerous pit features (see Heron et al., 2010 for organic residue analysis of 'slab-lined pits' in Arctic Norway), and heat treated rock (see Lucquin, 2007) that existed at most sites. The same goes for the ubiquitous hammer and anvil stones, which are often assumed to be used for nut processing, but may have been used for cracking bone to render grease.

Finally, ethnobotanical research indicates that all of the main nut species that were available in prehistoric Hokkaidō could easily have been processed without the need for sustained boiling in clay pots (see Hosoya, 2011). We therefore assume that when plants were added to the stews, it was to add flavour and texture, thereby reflecting local culinary traditions. Interestingly, the use of plants in the dishes appears to increase until the Middle Jōmon, which was also the point at which broad-leaved forest cover reached its maximum extent (Abe et al., 2016).

5.3.3 Understanding Hokkaidō Jōmon f~~F~~oodways: Walnuts, salmon and sika deer

To summarise, our extended pilot-study has succeeded in outlining the major patterns of Hokkaidō Jōmon cuisine. Pottery was primarily used to process aquatic resources for the preparation of "nabemono" style hot pots, and in some cases these dishes included additions of plants and ruminant fats. As perhaps was expected, pottery at coastal sites was involved in the general processing of marine resources, which would have been available year-round. The importance of marine resources to coastal communities is further reinforced by the stable isotopic analysis of human bone collagen (e.g. Naito et al., 2010; Yoneda et al., 2002). A more focused use of aquatic resources emerges at interior sites, with cooking pots probably being used to process salmonids, which may have been harvested, stored and then consumed as nourishing fish-based soups in the lean season.

Importantly, these results also highlight a major cultural bias in pottery use. Clearly, the vessels do not appear to have been used for the large-scale processing of walnuts, acorns and other plant resources, despite the ubiquitous presence of cracking and grinding tools in all the sites investigated. The widespread nut-processing complex was evidently a central feature of local foodways, but must have involved other kinds of organic container technologies. Nor do the pots appear to have been used for the specialised processing of ruminants, which appear to have been cooked in other ways, probably with hot stones and roasting pits.

6 Conclusions

This contribution has explored the evolution and diversification of Jōmon cuisine in prehistoric Hokkaidō. With clay cooking pots forming a central technology in this extended hunter-gatherer cultural trajectory, the application of organic residue analysis appeared to offer a direct route into understanding the full diversity of local foodways. The results were surprising, and suggested that the clay cooking pots were the focus of an enduring "aquatic-based cuisine" that probably centred on "nabemono" hot pots. In some instances, plant and nut resources may also have been added to these stews, and much more rarely, ruminant fats. Salmon appear to have formed the basis for this cuisine in inland areas, while a wider range of aquatic resources were used along the coast. At the same time, our careful site-by-site analysis of tool-kits highlighted the centrality of nut exploitation plus the important contribution made by terrestrial hunting. Clearly, these food groups must have been processed and consumed in different ways, employing other kinds of technologies whose designs and potential archaeological traces remain poorly understood.

These gaps in knowledge generate new questions about subsistence diversification and intensification among Late Pleistocene and Early Holocene foragers, and especially the role played by novel food processing technologies, which have become increasingly dominated by organic residue analysis of early pottery. Much of the pioneering work on this theme has focussed primarily on dating the oldest pottery sites, stimulating debates about macro-scale origins and dispersal models. Later efforts have shifted towards a more contextual approach, asking "what was being cooked in the pots" (Kaner and Taniguchi, 2017:341). However, the growing body of research from across North-east Asia is beginning to indicate that these early cooking pots must have played a very particular role in prehistoric cuisine. While this is an interesting phenomenon in itself, our new results from Hokkaidō now highlight the importance of explaining what was *not* being cooked in these ancient vessels, and that perhaps paradoxically, we need to start looking "beyond pottery" to better understand the full hunter-gatherer culinary spectrum.

Clearly, much more research will be needed on this theme, both in Hokkaidō and beyond, including higher-resolution sampling and analysis of pottery from a wider range of periods, sites and typologies that may yet revise the emerging picture that is presented here. At the same time, we also need to cultivate a more holistic and ethnographically-informed appreciation of the potential range and diversity of hunter-gatherer food-processing technologies, using additional methods and concepts to explore and integrate other lines of archaeological evidence, many of which may remain ambiguous or "invisible" unless approached with a more coherent set of culinary questions.

~~Uncited references~~

~~Crawford (1983).~~

CRediT authorship contribution statement

Harry K. Robson: Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **Alexandre Lucquin:** Formal analysis, Investigation, Writing - review & editing. **Kevin Gibbs:** Investigation, Writing - review & editing. **Hayley Saul:** Investigation, Writing - review & editing. **Tetsuhiro Tomoda:** Resources, Writing - review & editing. **Yu Hirasawa:** Resources, Writing - review & editing. **Hirofumi Kato:** [Instruction: Please add "Conceptualization" before Resources for Kato!]Resources, Writing - review & editing. **Sven Isaksson:** Investigation, Writing - review & editing. **Oliver E. Craig:** Formal analysis, Investigation, Writing - review & editing, Funding acquisition. **Peter D. Jordan:** Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Funding acquisition.

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Declaration of Competing Interest

None.

Appendix A[Instruction: Is it possible to have this as 'Supplementary material'?] Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaa.2020.101225.

References

The corrections made in this section will be reviewed and approved by a journal production editor. The newly added/removed references and its citations will be reordered and rearranged by the production team.

Abe, C., Leipe, C., Tarasov, P.E., Müller, S., Wagner, M., 2016. Spatio-temporal distribution of hunter-gatherer archaeological sites in the Hokkaido region (northern Japan): An overview. The Holocene 26 (10), 1627–1645. doi:10.1177/0959683616641745.

Ackman, R.G., Hooper, S.N., 1968. Examination of isoprenoid fatty acids as distinguishing characteristics of specific marine oils with particular reference to whale oils. Comp. Biochem. Physiol. 24 (2), 549–565. doi:10.1016/0010-406X(68)91008-6.

Anderson, S.L., Tushingham, S., Buonasera, T.Y., 2017. Aquatic adaptations and the adoption of Arctic pottery technology: Results of residue analysis. Am. Antiq. 82 (3), 452–479. doi:10.1017/aaq.2017.8.

Binford, L., 1980. Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. Am. Antiq. 45 (1), 4–20. doi:10.2307/279653.

Bondetti, M., Scott, S., Lucquin, A., Meadows, A., Lozovskaya, O., Dolbunova, E., Jordan, P., Craig, O.E., 2020. Fruits, fish and the introduction of pottery in the Eastern European plain: Lipid residue analysis of ceramic vessels from Zamostje 2. Quat. Int. 541, 104–114. doi:10.1016/j.quaint.2019.05.008.

Bondetti, M., Lucquin, A., Savel'ev, N.A., Weber, A.W., Craig, O.E., Jordan, P.D., (accepted). Resource-Processing, Early Pottery and the Emergence of Kitoi Culture in Cis Baikal: Insights from Lipid Residue Analysis of an Early Neolithic Ceramic Assemblage from the Gorelyi Les Habitation Site, Eastern Siberia. Archaeological Research in Asia.

Buvit, I., Izuho, M., Terry, K., Konstantinov, M.V., Konstantinov, A.V., 2016. Radiocarbon dates, microblades and Late Pleistocene human migrations in the Transbaikal, Russia and the Paleo-Sakhalin-Hokkaido-Kuril Peninsula. Quat. Int. 425, 100–119. doi:10.1016/j.quaint.2016.02.050.

Copley, M.S., Berstan, R., Dudd, S.N., Docherty, G., Mukherjee, A.J., Straker, V., Payne, S., Evershed, R.P., 2003. Direct chemical evidence for widespread dairying in prehistoric Britain. Proc. Natl. Acad. Sci. 100 (4), 1524–1529. doi:10.1073/pnas.0335955100.

Courel, B., Robson, H.K., Lucquin, A., Dolbunova, E., Oras, E., Adamczak, K., Andersen, S.H., Astrup, P.M., Charniauski, M., Czekaj-Zastawny, A., Ezepenko, I., Hartz, S., Kabaciński, J., Kotula, A., Kukawka, S., Loze, I., Mazurkevich, A., Piezonka, H., Piličiauskas, G., Sørensen, S.A., Talbot, H.M., Tkachou, A., Tkachova, M., Wawrusiewicz, A., Meadows, J., Heron, C.P., Craig, O.E., 2020. Organic residue analysis shows sub-regional patterns in the use of pottery by Northern European hunter-gatherers. R. Soc. Open Sci. 7 (4), 192016. doi:10.1098/rsos.192016.

Craig, O.E., Allen, R.B., Thompson, A., Stevens, R.E., Steele, V.J., Heron, C., 2012. Distinguishing wild ruminant lipids by gas chromatography/combustion/isotope ratio mass spectrometry. Rapid Commun. Mass Spectrom. 26 (19), 2359–2364. doi:10.1002/rcm.6349.

Craig, O.E., Saul, H., Lucquin, A., Nishida, Y., Taché, K., Clarke, L., Thompson, A., Altoft, D.T., Uchiyama, J., Aijmoto, M., Gibbs, K., Isaksson, S., Heron, C.P., Jordan, P., 2013. Earliest evidence for the use of pottery. Nature 496 (7445), 351–354. doi:10.1038/nature12109.

~~Crawford, G.W., 1983. Paleoethnobotany of the Kameda Peninsula Jomon. The University of Michigan Press, Ann Arbor.~~

Crawford, G.W., 2008. The Jomon in early agriculture discourse: issues arising from Matsui, Kanehara and Pearson. World Archaeology 40 (4), 445–465. doi:10.1080/00438240802451181.

Crawford, G.W., 2011. Advances in understanding early agriculture in Japan. Curr. Anthropol. 52 (S4), S331–S345. doi:10.1086/658369.

Crema, E.R., Habu, J., Kobayashi, K., Madella, M., 2016. Summed probability distribution of ^{14}C dates suggests regional divergences in the population dynamics of the jomon period in eastern Japan. PLoS One 11 (4), e0154809. doi:10.1371/journal.pone.0154809.

Dudd, S.N., Evershed, R.P., 1998. Direct demonstration of milk as an element of archaeological economies. Science 282 (5393), 1478–1481. doi:10.1126/science.282.5393.1478.

Evershed, R.P., 2008. Organic residue analysis in archaeology: the archaeological biomarker revolution. Archaeometry 50 (6), 895–924. doi:10.1111/j.1475-4754.2008.00446.x.

Evershed, R.P., Copley, M.S., Dickson, L., Hansel, F.A., 2008. Experimental evidence for the processing of marine animal products and other commodities containing polyunsaturated fatty acids in pottery vessels. Archaeometry 50 (1), 101–113. doi:10.1111/j.1475-4754.2007.00368.x.

Farrell, T.F.G., Jordan, P., Taché, K., Lucquin, A., Gibbs, K., Jorge, A., Britton, K., Craig, O.E., Knecht, R., 2014. Specialized Processing of Aquatic Resources in Prehistoric Alaskan Pottery? A Lipid-Residue Analysis of Ceramic Sherds from the Thule-Period Site of Nunalleq, Alaska. Arctic Anthropol. 51 (1), 86–100. doi:10.3368/aa.51.1.86.

Gibbs, K., Isaksson, S., Craig, O.E., Lucquin, A., Grishchenko, V.A., Farrell, T.F.G., Thompson, A., Kato, H., Vasilevski, A.A., Jordan, P.D., 2017. Exploring the emergence of an 'Aquatic' Neolithic in the Russian Far East: organic residue analysis of early hunter-gatherer pottery from Sakhalin Island. Antiquity 91 (360), 1484–1500. doi:10.15184/aqy.2017.183.

Habu, J., 2004. Ancient Jomon of Japan. Cambridge University Press, Cambridge.

Habu, J., 2014. Post-Pleistocene transformations of hunter-gatherers in East Asia: The Jomon and Chulmun. In: Cummings, V., Jordan, P., Zvelebil, M. (Eds.), The Oxford Handbook of the Archaeology and Anthropology of hunter-gatherers. Oxford University Press, Oxford, pp. 507–520. doi:10.1093/oxfordhb/9780199551224.013.043.

Hansel, F.A., Copley, M.S., Madureira, L.A.S., Evershed, R.P., 2004. Thermally produced ω-(*o*-alkylphenyl) alkanoic acids provide evidence for the processing of marine products in archaeological pottery vessels. Tetrahedron Lett. 45 (14), 2999–3002. doi:10.1016/j.tetlet.2004.01.111.

Heron, C., Nilsen, G., Stern, B., Craig, O., Nordby, C., 2010. Application of lipid biomarker analysis to evaluate the function of 'slab-lined pits' in Arctic Norway. J. Archaeol. Sci. 37, 2188–2197. doi:10.1016/j.jas.2010.03.016.

Heron, C., Habu, J., Katayama Owens, M., Yumiko, I., Eley, Y., Lucquin, A., Radini, A., Saul, H., Debono Spiteri, C., Craig, O.E., 2016. Molecular and isotopic investigations of pottery and 'charred remains' from Sannai Maruyama and Sannai Maruyama No. 9, Aomori Prefecture, Japan. Japanese J. Archaeol. 4, 29–52.

Hokkaidō Buried Cultural Property Centre, 1996. Nakano B Site. Archaeological Field Report of Hokkaidō Buried Cultural Property Centre. Report Number 97. Hokkaidō Buried Cultural Property Centre, Sapporo, Hokkaidō, Japan.

Hosoya, L.A., 2011. Staple or famine food?: Ethnographic and archaeological approaches to nut processing in East Asian prehistory. Archaeol. Anthropolog. Sci. 3, 7–17. doi:10.1007/s12520-011-0059-y.

Iizuka, F., 2019. The Timing and Behavioral Context of the Late-Pleistocene Adoption of Ceramics in Greater East and Northeast Asia and the First People (Without Pottery) in the Americas. PaleoAmerica 4 (4), 267–324. doi:10.1080/20555563.2018.1563406.

Imamura, K., 1996. Prehistoric Japan: New Perspectives on Insular East Asia. University of Hawaii Press, Honolulu.

Isaksson, S., Gibbs, K., Jordan, P., 2019. Maritime Nomads of the Baltic Sea: Ceramic Traditions, Collective Identities and Prehistoric Cuisine. In: Jordan, P., Gibbs, K. (Eds.), Ceramics in Circumpolar Prehistory: Technology, Lifeways and Cuisine. Cambridge University Press, Cambridge, pp. 63–80.

Junno, A., Kato, H., Isaksson, S., Jordan, P.D., 2020. Evidence of increasing functional differentiation in pottery use among Late Holocene maritime foragers in northern Japan. Archaeolog. Res. Asia 22, 100194. doi:10.1016/j.ara.2020.100194.

Kaner, S., 2009. Long-term innovation: The appearance and spread of pottery in the Japanese Archipelago. In: Jordan, P., Zvelebil, M. (Eds.), Ceramics Before Farming: The Dispersal of Pottery Among Prehistoric Eurasian Hunter-Gatherers. Left Coast Press, Walnut Creek, CA, pp. 93–119.

Kaner, S., Taniguchi, Y., 2017. The development of pottery and associated technological developments in Japan, Korea, and the Russian Far East. In: Habu, J., Lape, P.V., Olsen, J.W. (Eds.), Handbook of East and Southeast Asian Archaeology. Springer, New York, pp. 321–345.

Karr, L.P., Short, A.E.G., Hannus, L.A., Outram, A.K., 2015. A bone grease processing station at the Mitchell Prehistoric Indian Village: Archaeological evidence for the exploitation of bone fats. Environ. Archaeol. 20 (1), 1–12. doi:10.1179/1749631414Y.0000000035.

Keally, C.T., Taniguchi, Y., Kuzmin, Y.V., Shewkomud, I.Y., 2004. chronology of the beginning of pottery manufacture in East Asia. Radiocarbon 46 (1), 345–351.

Kobayashi, T., 1989. Jomon doki no yoshiki to keishiki, keishiki [Jomon Pottery and Style, Type and Form]. In: Kobayashi, T. (Ed.), Jomon Doki Taikan, vol. 4. Shogakukan, Tokyo, pp. 248–257.

Kunikita, D., Shevkomud, I., Yoshida, K., Onuki, S., Yamahara, T., Matsuzaki, H., 2013. Dating charred remains on pottery and analyzing food habits in the Early Neolithic period in Northeast Asia. Radiocarbon 55 (2–3), 1334–1340. doi:10.1017/S0033822200048244.

Lucquin, A., 2007. Etude physico-chimique des méthodes de cuisson pré et protohistorique. Université de Rennes 1, Rennes: Unpublished PhD Thesis.

Lucquin, A., Gibbs, K., Uchiyama, J., Saul, H., Ajimoto, M., Eley, Y., Radini, A., Heron, C.P., Shoda, S., Nishida, Y., Lundy, J., Jordan, P., Isaksson, S., Craig, O.E., 2016. Ancient lipids document continuity in the use of early hunter–gatherer pottery through 9,000 years of Japanese prehistory. Proc. Natl. Acad. Sci. 113 (15), 3991–3996. doi:10.1073/pnas.1522908113.

Lucquin, A., Colonese, A.C., Farrell, T.F., Craig, O.E., 2016. Utilising phytanic acid diastereomers for the characterisation of archaeological lipid residues in pottery samples. Tetrahedron Lett. 57 (6), 703–707. doi:10.1016/j.tetlet.2016.01.011.

Lucquin, A., Robson, H.K., Eley, Y., Shoda, S., Veltcheva, D., Gibbs, K., Heron, C.P., Isaksson, S., Nishida, Y., Taniguchi, Y., Nakajima, S., Kobayashi, K., Jordan, P., Kaner, S., Craig, O.E., 2018. The impact of environmental change on the use of early pottery by East Asian hunter-gatherers. Proc. Natl. Acad. Sci. 115 (31), 7931–7936. doi:10.1073/pnas.1803782115.

Morisaki, K., Kunikita, D., Sato, H., 2018. Holocene climatic fluctuation and lithic technological change in northeastern Hokkaido (Japan). J. Archaeolog. Sci.: Rep. 17, 1018–1024. doi:10.1016/j.jasrep.2016.04.011.

Morisaki, K., Oda, N., Kunikita, D., Sasaki, Y., Kuronuma, Y., Iwase, A., Yamazaki, T., Ichida, N., Sato, H., 2019. Sedentism, pottery and inland fishing in Late Glacial Japan: a reassessment of the Maedakochi site. Antiquity 93 (372), 1442–1459. doi:10.15184/aqy.2019.170.

Morita, K., Toshihiko, S., Miyakoshi, Y., Fukuwaka, M., Nagasawa, T., Kaeriyama, M., 2006. A review of Pacific salmon hatchery programmes on Hokkaido Island, Japan. ICES J. Marine Sci. 63 (7), 1353–1363. doi:10.1016/j.icesjms.2006.03.024.

Naito, I.Y., Honch, N.V., Chikaraishi, Y., Ohkouchi, N., Yoneda, M., 2010. Quantitative Evaluation of Marine Protein Contribution in Ancient Diets Based on Nitrogen Isotope Ratios of Individual Amino Acids in Bone Collagen: An Investigation at the Kitakogane Jomon Site. Am. J. Phys. Anthropol. 143 (1), 31–40. doi:10.1002/ajpa.21287.

Nakazawa, Y., Iwase, A., Akito, F., Masami, I., 2011. Human responses to the Younger Dryas in Japan. Quat. Int. 242 (2), 416–433. doi:10.1016/j.quaint.2010.12.026.

Obihiro Board of Education, 1990. Obihiro Yachiyo A Site. Obihiro Archaeological Records No. 8. Obihiro Board of Education, Obihiro, Hokkaidō, Japan.

Omoto, K., Takeishi, K., Nishida, S., Fukui, J., 2010. Calibrated ^{14}C Ages of Jomon Sites, NE Japan, and their Significance. Radiocarbon 52 (2), 534–548. doi:10.1017/S0033822200045574.

Papakosta, V., Pesonen, P., 2019. Lipid resides in early hunter-gatherer ceramics from Finland. In: Mannermaa, K., Manninen, M. A., Pesonen, P., Seppänen, L. (Eds.), Helsinki Harvest: Proceedings of the 11th Nordic Conference on the Application of Scientific Methods in Archaeology. Helsinki: Archaeological Society of Finland, pp. 32–47.

Papakosta, V., Oras, E., Isaksson, S., 2019. Early pottery use across the Baltic - A comparative lipid residue study on Ertebølle and Narva ceramics from coastal hunter-gatherer sites in southern Scandinavia, northern Germany and Estonia. J. Archaeolog. Sci.: Rep. 24, 142–151.

doi:10.1016/j.jasrep.2019.01.003.

Robson, H.K., Skipitytė, R., Piličiauskienė, G., Lucquin, A., Heron, C., Craig, O.E., Piličiauskas, G., 2019. Diet, cuisine and consumption practices of the first farmers in the southeastern Baltic. Archaeol. Anthropol. Sci., 11(8), 4011–4024. Doi: 10.1007/s12520-019-00804-9, 2019.

Saul, H., Glykou, A., Craig, O.E., 2014. Stewing on a Theme of Cuisine: Biomolecular and Interpretive Approaches to Culinary Changes at the Transition to Agriculture. In: Whittle, A., Bickle, P. (Eds.), Early Farmers: The View from Archaeological Science. Oxford University Press, Oxford, pp. 197–213. doi:10.5871/bacad/9780197265758.003.0011.

Shoda, S., Lucquin, A., Ahn, J.H., Hwang, C.J., Craig, O.E., 2017. Pottery use by early Holocene hunter-gatherers of the Korean peninsula closely linked with the exploitation of marine resources. Quat. Sci. Rev. 170, 164–173. doi:10.1016/j.quascirev.2017.06.032.

Shoda, S., Lucquin, A., Yanshina, O., Kuzmin, Y., Shevkomud, I., Medvedev, V., Derevianko, V., Lapshina, Z., Craig, O.E., Jordan, P., 2020. Late Glacial hunter-gatherer pottery in the Russian Far East: Indications of diversity in origins and use. Quat. Sci. Rev. 229, 106124. doi:10.1016/j.quascirev.2019.106124.

Taché, K., Craig, O.E., 2015. Cooperative harvesting of aquatic resources and the beginning of pottery production in north-eastern North America. Antiquity 89 (343), 177–190. doi:10.15184/aqy.2014.36.

Taché, K., Burke, A., Craig, O.E., 2017. From Molecules to Clay Pot Cooking at the Archaic-Woodland Transition: A Glimpse from Two Sites in the Middle St. Lawrence Valley, QC. Can. J. Archaeol. 41 (2), 212–237.

Taché, K., Bondetti, M., Lucquin, A., Admiraal, M., Craig, O.E., 2019. Something fishy in the Great Lakes? A reappraisal of early pottery use in north-eastern North America. Antiquity 93 (371), 1339–1349. doi:10.15184/aqy.2019.128.

Takase, K., 2020. Long-term marine resource use in Hokkaido, Northern Japan: New insights into sea mammal hunting and fishing. World Archaeol. doi: 10.1080/00438243.2019.1699854.

Tushingham, S., Bettinger, R.L., 2013. Why foragers choose acorns before salmon: Storage, mobility, and risk in aboriginal California. J. Anthropol. Archaeol. 32 (4), 527–537. doi:10.1016/j.jaa.2013.09.003.

Taniguchi, Y., 2004. Calibrated ^{14}C dates of the earliest pottery in Japan and changes in the quantities of pottery. Kokogaku J. (The Archaeology Journal) 519, 4–10.

Weber, A.W., Jordan, P., Kato, H., 2013. Environmental change and cultural dynamics of Holocene hunter-gatherers in Northeast Asia: Comparative analyses and research potentials in Cis-Baikal (Siberia, Russia) and Hokkaido (Japan). Quat. Int. 290–291, 3–20. doi:10.1016/j.quaint.2012.07.021.

Yamada, G., Shibauchi, S., 1997. Hokkaido no jomon jidai iseki kara shutudosita kenkarui- kuri ni tsuite [Nuts excavated from Jomon sites in Hokkaido]. Hokkaido Kaitaku Kinenkan Kiyo 25, 17–30.

Yamahara, T., 2006. Taisho 3 Site: the discovery of the earliest ceramic culture in Hokkaido. Curr. Res. Pleistocene 23, 35–37.

Yamahara, T., 2018. Outline of the re-examination of the archaeological remains from Yachiyo A site, Obihiro. Report of the Obihiro Centennial City Museum 36, 19–29.

Yoneda, M., Tanaka, A., Shibata, Y., Morita, M., Uzawa, K., Hirota, M., Uchida, M., 2002. Radiocarbon Marine Reservoir Effect in Human Remains from the Kitakogane Site, Hokkaido, Japan. J. Archaeol. Sci. 29 (5), 529–536. doi:10.1006/jasc.2001.0764.

Yoneda, M., Shibata, Y., Morita, M., Hirota, M., Suzuki, R., Uzawa, K., Ohshima, N., Dodo, Y., 2004. Interspecies comparison of marine reservoir ages at the Kitakogane shell midden, Hokkaido, Japan. Nucl. Instrum. Methods Phys. Res. B 223–224, 376–381. doi:10.1016/j.nimb.2004.04.073.

Yoshida, K., Kunikita, D., Miyazaki, Y., Nishida, Y., Miyao, T., Matsuzaki, H., 2013. Dating and Stable Isotope Analysis of Charred Residues on the Incipient Jomon Pottery (Japan). Radiocarbon 55 (2–3), 1322–1333. doi:10.1017/S0033822200048232.

Footnotes

Text Footnotes

[1] For an alternative version, see Crema et al., (2016:4), which has the following boundaries: Early Jōmon ([Instruction: Italicise ca.]ca. 6950–5470 cal BP), Middle Jōmon ([Instruction: Italicise ca.]ca. 5470–4420 cal BP), Late Jōmon ([Instruction: Italicise ca.]ca. 4420–3220 cal BP), and Final Jōmon ([Instruction: Italicise ca.]ca. 3220–2300 cal BP). See Omoto et al., (2010) for another version that has minor variations in the chronological boundaries.

Highlights

- This study explores the cuisine of Hokkaidō Jōmon hunter-gatherer societies.
- We combine in-depth analysis of tool-kits and site locations to predict culinary traditions at 18 different sites in five regions spanning the full Hokkaidō Jōmon sequence (*ca*. 14,500–2300 cal BP).
- These predictions are tested via organic residue analysis of 169 sherds from prehistoric cooking pots.

- Despite compelling evidence that diverse tool-kits had supported a broad-based subsistence economy at both coastal and inland sites, the results demonstrate that pottery had primarily been used to process aquatic resources, including salmonids at inland sites, and marine resources along the coast.
- In contrast, evidence for the processing of plants and terrestrial game in the cooking pots was infrequent, and it seems that these resources were being processed in other ways.
- The insights confirm the potential of organic residue analysis, but also suggest that archaeologists should look "beyond the cooking pot" to fully understand the origins and regional diversification of Jōmon cuisine.

Appendix A Supplementary material

The following are the Supplementary data to this article:

Multimedia Component 1

Supplementary data 1

Multimedia Component 2

Supplementary data 2

Queries and Answers

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