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GEOGRAPHY

Changes in the Northern Boundary of the Eurasian Beaver (*Castor fiber* Linnaeus, 1758, Rodentia, Mammalia) Range on the Yamal Peninsula (Western Siberia) during the Holocene

P. A. Kosintsev[a],*, R. M. Hantemirov[a], and V. V. Kukarskih[a]

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Abstract—Fragments of birch (*Betula pubescens* ssp. *tortuosa* (Ledeb.) Nyman) and spruce (*Picea obovata* Ledeb.) trunks with traces of gnawing by the Eurasian beaver (*Castor fiber* Linnaeus, 1758) were found in the modern tundra zone on the Yamal Peninsula. Tree fragments were dated by the radiocarbon and tree-ring methods. At the beginning of the Middle Holocene, the northern boundary of the beaver's range was at 68°39′ N. At the end of the Middle Holocene, it was at 67°33′ N. At the beginning of the Late Holocene, it was 66°33′ N. Changes of the boundary followed the formation of closed forests on the Yamal Peninsula. As they became established, the beaver's range moved northward. As the woody vegetation boundary retreated to the south, the beaver's range also retreated to the south. Stabilization of the northern boundary of the beaver range took place at the beginning of the Subatlantic climatic stage of the Late Holocene following the stabilization of the southern boundary of the forest–tundra zone.

Keywords: Eurasian beaver, *Castor fiber*, woody vegetation, tundra, range, Holocene, Western Siberia

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A range change reflects the response of a species to the dynamics of significant environmental conditions and is one of the forces behind the formation of faunas. One of the species, the range of which has changed significantly over the last millennia, is the Eurasian beaver (*Castor fiber* Linnaeus, 1758). The beaver is an obligate dendrophilous; i.e., its biology is closely related to woody vegetation. In the Holocene, this species inhabited almost the entire northern Eurasia [1–3], but in the eighteenth and nineteenth centuries, its range was significantly reduced and fragmented [1, 4]. The main reason for the beaver's decline in range was the human influence (hunting) [4]. Since the early twenty-first century, the beaver range has begun to recover rapidly [5]. The oldest remains of beaver bones in the northern part of Western Siberia are known from localities in the present-day forest–tundra zone, dated to the beginning of the Subatlantic climatic stage of the Late Holocene (2600–1800 years ago) [6]. It inhabited this area until the beginning of the 18th century [4, 6]. Thus, in Western Siberia, the northern boundary of beaver distribution from the beginning of the Late Holocene (Subatlantic phase 1) to the beginning of the 18th century was along the forest–tundra zone [6], and during the 18th century, it shifted significantly to the south [4]. Until recently, it was impossible to determine the position of the northern boundary of the beaver's range in earlier Holocene periods here, as there are no bone remains for these periods.

From the 1980s to the 2000s, subfossil wood samples were collected in the Yamal Peninsula for tree-ring research [7]. Among the samples collected from several locations (Fig. 1), we identified examples with specific shapes and distinctive gnawing marks (Fig. 2). The gnaw marks have a slightly concave profile in cross section with a width of 5–6 mm. The shape of the edges of the wood fragments and the marks on them clearly indicate that they were left by the Eurasian beaver [8].

Samples with traces of gnawing were dated using radiocarbon and dendrochronological methods. Radiocarbon dating was carried out at the Laboratory of Archaeological Technology, Institute of the History of Material Culture, Russian Academy of Sciences (St. Petersburg), using the liquid scintillation method (laboratory index of samples LE-). The samples were cleaned and processed according to standard meth-

[a] *Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, Yekaterinburg, 620144 Russia*
**e-mail: kpa@ipae.uran.ru*

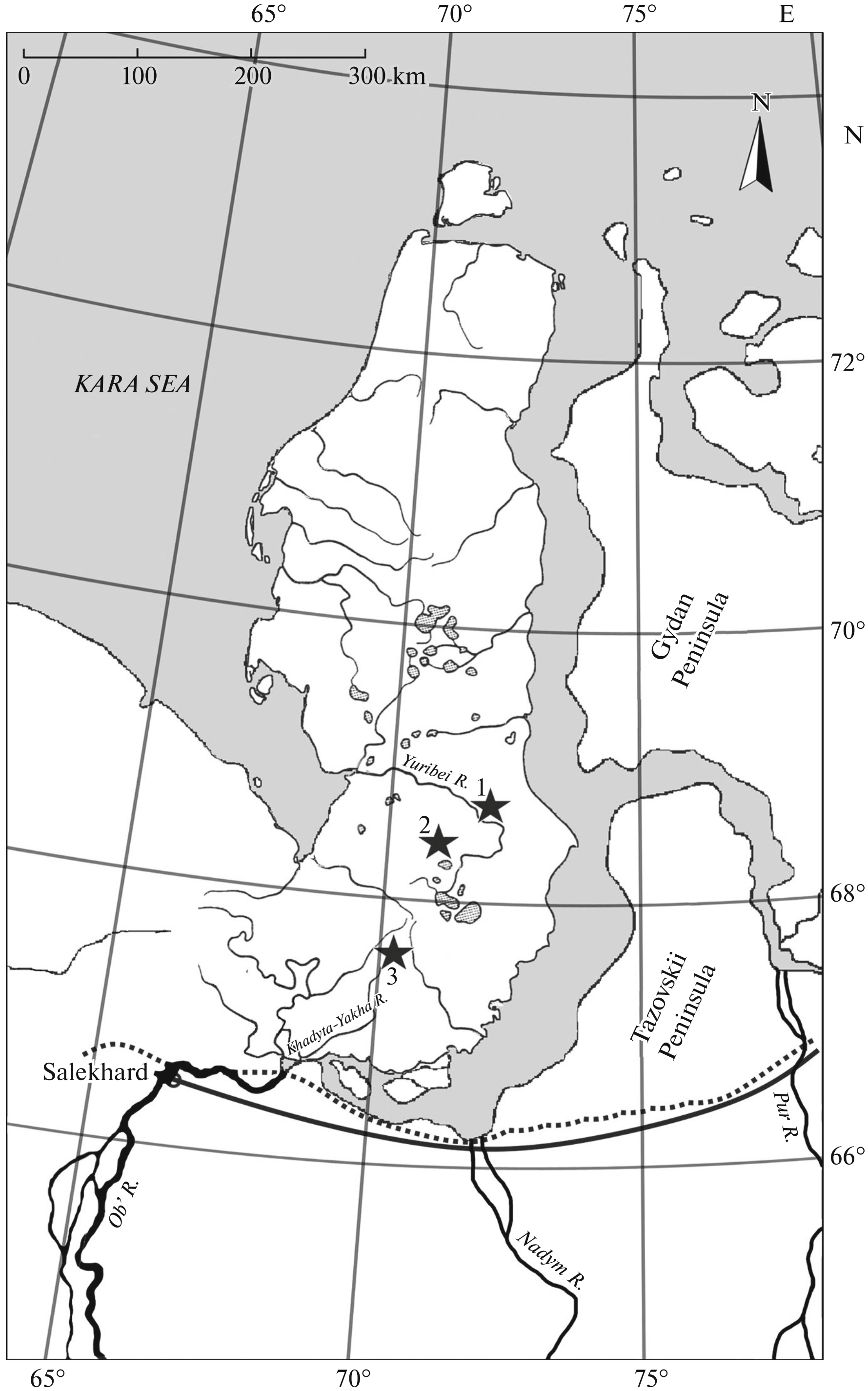

Fig. 1. Locations of subfossil wood with traces of gnawing by beavers. ★—evidence of beaver (1, Meretayakha; 2, Yangoreyngynesyo; 3, Khadyta-Yakha; — northern boundary of the beaver's range at the beginning of the 18th century [3, 4, 6]; the dotted line shows the recent southern boundary of the forest tundra [14].

ods. Benzene was used as a counting substance according to the method of Kh.A. Arslanov [9]. Measurement of counting substance activity was performed on an ultra-low-background liquid-scintillation alpha/beta spectrometer-radiometer Quantulus 1220. All radiocarbon dates were calibrated with the CALIB 8.0 software using the IntCal20 calibration curve [10] to convert from the radiocarbon age to the calendar age. Dendrochronological dating was carried out by comparing the ring width variability [11] of gnawed samples with the master chronology for the studied area [7].

Figure 1 shows the locations of subfossil wood with traces of gnawing by beavers. *Location Meretayakha* (1): Two pieces of birch trunks (*Betula pubescens* ssp. *tortuosa* (Ledeb.) Nyman) were found on the Yuribei River bank at the site of an eroded buried peat bog with trunks of tree birch (*B. pubescens*), willow shrubs (*Salix* sp.), and alder (*Alnus alnobetula* (Ehrh.) K. Koch s.l.). The radiocarbon age of one of the birch fragments is 7060 ± 40 years, LE-8034 (Table 1). *Location Yangoreyngynesyo* (2): A piece of spruce trunk (*Picea obovata* Ledeb.) was found in deposits of the Yangoreyngynesyo River, a left tributary of the Left Yuribei River. The radiocarbon age of this sample is 6850 ± 60 years, LE-8035 (Table 1). *Location Khadyta* (3): A piece of the trunk of a birch (*B. pubescens*) was found on the bank of the Khadyta-Yakha River. The lifespan of this tree, according to the tree-ring dating, was 4078–3979 BC (Table 1).

All locations are in the southern part of the Yamal Peninsula in river valleys, 5–50 km from their sources. The basins of the Yuribei, Left Yuribei, and Khadyta-Yakha rivers are within the Yamal Peninsula. This excludes the arrival of tree fragments with traces of gnawing by beavers from southern areas.

Dendrochronological and radiocarbon dates indicate that in Western Siberia the northern boundary of the beaver range in the Holocene was significantly north of its position in the historical time. At the beginning of the Atlantic period (AT 1), the beaver inhabited the Yuribei River basin (68°39′ N). In the upper reaches of the Khadyta-Yakha River (67°33′ N), it lived in the mid-Subboreal period (SB 2). At the beginning of the Subatlantic period (SA 1), the northern boundary of the beaver's range was approximately at the Arctic Circle (66°33′ N) [6]. It remained at this latitude until the beginning of the 18th century [4].

Woody vegetation on the Yamal Peninsula appeared at the beginning of the Holocene, in the second half of the Preboreal period (PB 2, 9600–9300 BP) [12, 13]. At the end of the Boreal Period (BO 3, 8250 BP), it extended to the northern Yamal Peninsula [12]. In the first half of the Atlantic period (AT 1–2),

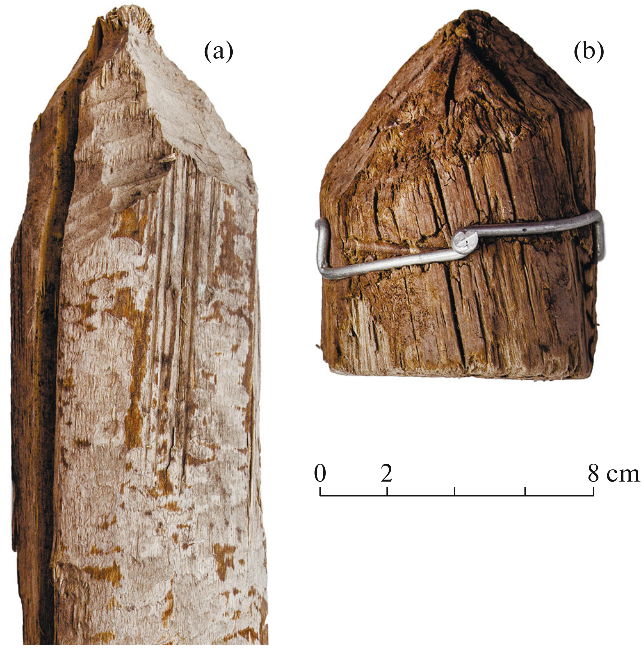

Fig. 2. Birch (*B. pubescens*) trunks with traces of beaver gnawing: (a) present-day wood, (b) subfossil wood from the Khadyta-Yakha location.

a larch–spruce–birch forest zone was formed on the Yamal Peninsula south of 69° N [12]. Beaver life is closely related to woody vegetation, and its range moved northwards as closed forests formed on the Yamal Peninsula. In the Subboreal period (SB 1–2, 4600–3200 BP) the woody vegetation on Yamal began to degrade [12] and its boundary in the period from 4400 to 3500 years ago moved far to the south [7, 13]. Along with it, the beaver habitat shifted to the south.

The chronological and geographical distribution of beaver-gnawed wood fragments found on Yamal reflects changes in the northern boundary of the range during the Middle and Late Holocene. These changes followed the formation of closed forests on the Yamal Peninsula. As the forests became established, the beaver's range moved northward. As the border of woody vegetation retreated to the south, the beaver's range

Table 1. Dates of tree trunk fragments that have been gnawed by beaver (*Castor fiber*)

No.	Location	Coordinates	Species	^{14}C age, years BP	Calibrated age (±2σ), years BC	Dendrochronological age, years BC
1	Meretayakha	68°39′ N, 71°55′ E	Birch (*B. pubescens*)	7060 ± 40, LE-8034[1]	6020–5840 BC	–
2	Yangoreyngynesyo	68°24′ N, 71°33′ E	Spruce (*P. obovata*)	6850 ± 60, LE-8035[1]	5880–5630 BC	–
3	Khadyta-Yakha	67°33′ N, 70°07′ E	Birch (*B. pubescens*)	–	–	3979 BC

[1]LE-8034, LE-8035 are laboratory sample numbers.

also retreated to the south. Stabilization of the northern boundary of the beaver range took place at the beginning of the Subatlantic climatic stage of the Late Holocene in connection with stabilization of the southern boundary of the forest–tundra zone.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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