



Early Holocene presence of *Picea abies* at high latitudes in Scandinavia: the genetic story of ancient clones in the Scandes

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Introduction

Data on postglacial population expansion and recolonization is crucial to estimate future spread of boreal trees under climate change¹. The glacial refugia theory (trees surviving at high latitudes) has been put forward to explain early presence of spruce trees in central Sweden.

What do we know?

- Glacial refugia for Fennoscandian Norway spruce (*Picea abies* L. Karst) were located in the east of the Russian plains.
- Spruce (pollen) reached central Sweden ~3000 yr BP; potential satellite populations were present in early Holocene.²
- Numerous macrofossils were found under clonal trees in the Scandinavian mountains, carbon-dated up to 9500 cal. yr.³
- A mtDNA haplotype unique to Scandinavian was recovered in ancient sediments in central Sweden and Norway at 10300 yr BP. ⁴

Research aims

- **Ancient DNA:** Confirm local presence of spruce trees in Fennoscandia and Russia using DNA from lake sediment, peat, and permafrost sediments.
- **Modern DNA:** Genotype the mtDNA locus in clonal and spruce forest populations in central Sweden/Norway.

Methods

- **Ancient DNA:** 13 sites in Fennoscandia and 2 sites in Russia, 122 samples total (Table 1) were screened for mtDNA haplotype using 8 qPCR repeats for each sample.
- **Modern DNA:** needles from 261 spruce trees from 13 natural populations (Table 2), genotyped for the mtDNA with high resolution melting curve analysis, MIG-seq ⁵ analysis for SNPs (not presented here).

Table 1. Ancient lake sediment samples.

Location	N	Age range yr. PB	Sediment type	Earliest date hap A
North-west Finland	3	42000	Peat	42000 yr. PB
East-Finnish Lapland #1	1	9450+/-60	Peat	Not detected
East-Finnish Lapland #2	1	43200+/-1600	Peat	Not detected
Southern Finland	12	6200-172	Lake	5150 yr. BP
Central Norway	9	10400-900	Lake	7800 yr BP
Central Sweden Lake #1	9	10400-900	Lake	10400 yr. BP
Central Sweden Lake #2	18	9120-2470	Lake	7410 yr. BP
Central Sweden Lake #3	14	9390-440	Lake	5300 yr BP
Central Sweden Lake #4	16	10295-460	Lake	9450 yr BP
Central Sweden Lake #5	11	9450-945	Lake	6930 yr BP
Southwest Sweden	12	15300-11000	lake/peat	15000 yr BP
North-east Russia	10	8500-6000	Peat	Not detected
Southern Russia	6	13500-4500	Lake	Not detected

* Dated trees not sampled.



Spruce clone at Drevfjället



Old Tjikko at Fulufjället



Spruce clone at Lilla Skarvarna

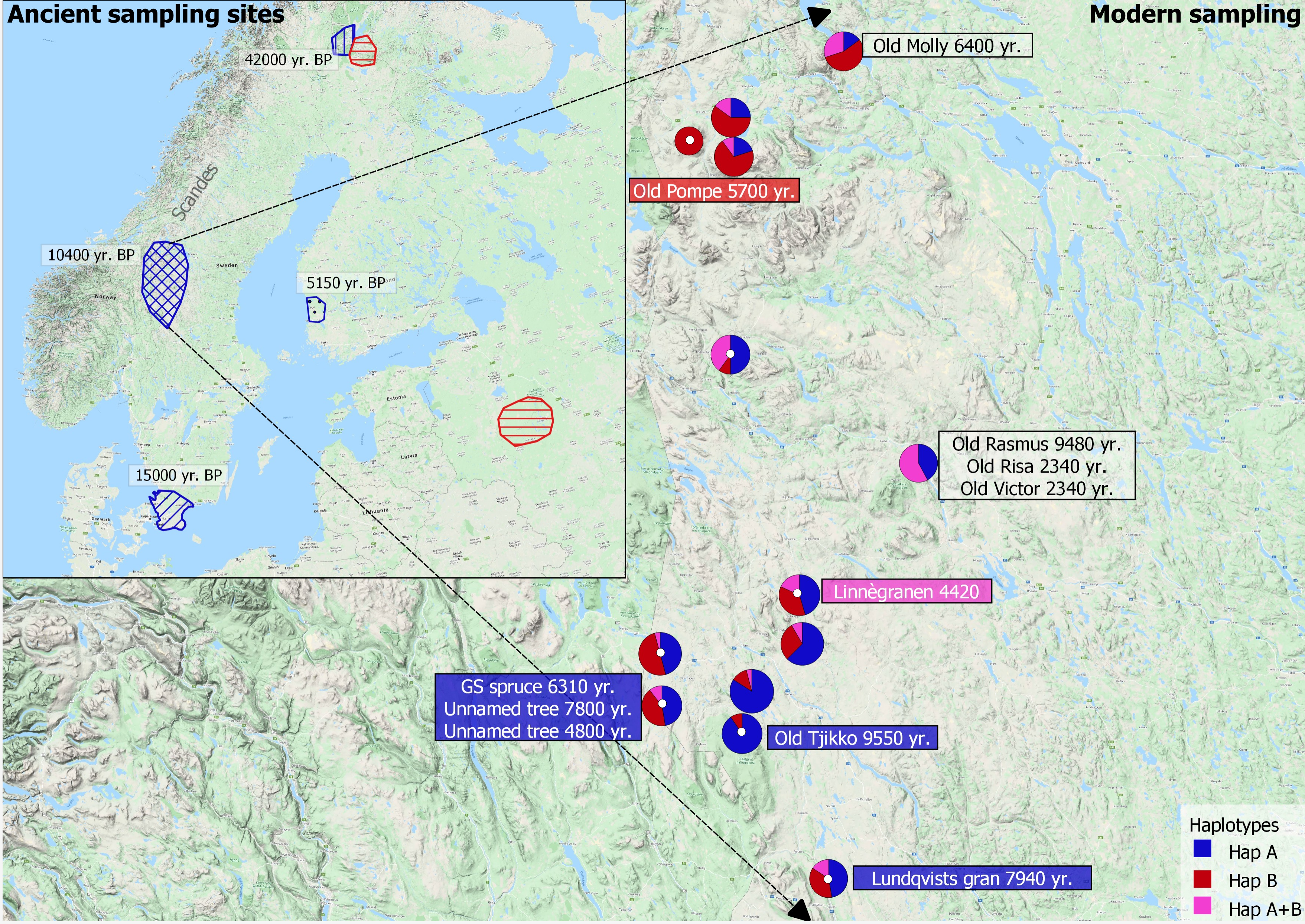


Figure 1. Pie charts show the mtDNA haplotype frequencies in spruce forest and clonal (white dot) populations. The size of the pie charts is scaled to population size. Haplotypes and age of dated clonal trees (Table 2) are placed close to the respective population. Results from ancient DNA are shown in the inset map in the left corner, in blue areas haplotype A was recovered. The north-east Russian site (red) is not shown on the map.

Results

Ancient DNA: The blue haplotype A unique to Scandinavia (figure 1) was not found at the two Russian sites but was recovered in lake and peat samples from:

- North-west Finland at 42 kyr BP.
- Southern Sweden at 15 kyr BP.
- Central Sweden and Norway from 10400 yr BP (6 sites)
- Southern Finland at 5150, at low frequency.

Modern DNA: The blue haplotype A unique to Scandinavia was dominant in southern populations (Fulufjället has the highest frequency). The two populations in the middle show a high proportion of trees with both haplotypes (heteroplasmy). All dated sampled clone trees had the blue haplotype with the exception of Linnégranen and Old Pompe.

Table 2. Overview clonal (C) and spruce forest (F) populations.

Location	Country	C/F	N	Altitude a.s.l (mean)	Dated clones – age yr. BP
Fulufjället	Sweden	C	20	897-926 (915)	Old Tjikko – 9550
		F	27	<862	
Städjan	Sweden	C	21	899-948 (910)	Old Linnegranen – 4420
		F	26	<898	
Drevfjället	Norway	C	27	888-1004 (939)	
Härjehögarna	Sweden	C	20	921-986 (958)	Gunnar Samuelsson spruce – 6310
					Unnamed tree – 7890
					Unnamed tree – 4800
Sälen	Sweden	C	20	778-826 (808)	Gunnar Lundqvists gran – 7940
Hårdäggen	Sweden	C/F	20	634-795 (688)	
Getryggen	Sweden	C	5	765-830 (793)	Old Pompe – 5700
Snåсахögarna	Sweden	F	20	549-685 (621)	
Åreskutan	Sweden	F	20	613-763 (678)	Old Molly* – 6400
Lilla Skarvarna	Sweden	C	20	880-975 (994)	
Sonfjället	Sweden	F	19	-	Old Rasmus* – 9480 Old Risa* – 2340 Old Victor* – 2340

Conclusions:

- We found earlier (Pleniglacial) presence of the blue mtDNA haplotype in Scandinavia (42000 yr BP).
- Evidence for the presence of spruce in southern Sweden already at 15000 yr BP and 10400 yr BP in central Sweden.
- MtDNA frequencies are similar in clonal and close-by forest populations.
- Highest mtDNA Hap A frequency in Fulufjället with decreasing trend with distance.
- Possible early spruce migration from the south?

Future plans

Genome-wide SNP analysis to investigate more in-depth the relation between clonal and forest populations.

Acknowledgements

aDNA work: Matias Tasel, Anne van Woerkom; DNA, extraction/fieldwork: Alessandro Nobile; DNA extraction: Elisa Pierfederici, Tamara van Steijn; fieldwork: Urban Gunnarsson. **Funding:** The Swedish Phytogeographical Society and Stiftelsen Extensus.

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