



*Supplement of*

**Diverse phenotypes of Late Glacial–Early Holocene downy birch  
(*Betula pubescens* Erh.) and the morphology of early Preboreal  
tree stands in southern Schleswig-Holstein**

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## Supplementary material

Macrofossil data by Hartmut Usinger is provided in table S1-S5.

Location Hasenmoor	-	N 54.312108, E 9.934099
Location Kirchmoor	-	N 54.223851, E 10.064958
Location Krögensmoor	-	N 54.407600, E 9.888869
Location Ruchmoor	-	N 54.415852, E 9.719514
Location Stauner Moor	-	N 54.413441, E 10.049310

In each individual case the depth refers to depth below the bog surface. The age estimate is based on pollen stratigraphy and refers to regional biostratigraphic terms (Krüger et al., 2020).

Legend to the macrofossils schedules:

MEI/D1	- (biostratigraphic) Meiendorf/ Dryas 1 period
AL	- (biostratigraphic) Allerød period
D3	- (biostratigraphic) Dryas 3 period
PB	- (biostratigraphic) Preboreal period
BO	- (biostratigraphic) Boreal period
AT	- (biostratigraphic) Atlantic period
SB	- (biostratigraphic) Subboreal period
postgl.	- postglacial period (undefined)
x	- macrofossil present (unquantified)
p	- macrofossil present (semi-quantified)
a	- macrofossil abundant (semi-quantified)

**table S1**  
**Hasenmoor**

	pollen zone	depta (cm)	Selaginella selaginoides	Dryas octopetala	Salix polaris	Hippopae rhamnoides	Betula nana	Betula pubescens	Betula alba	Populus tremula	Pinus sylvestris	Potamogeton filiformis	Potamogeton berchtoldii	Potamogeton obtusifolius	Potamogeton natans	Potamogeton sp.	Batrachium	Nymphaeae	Typha sp.	Alismataceae	Equisetum fluviatile	Thelypteris palustris	Catocarpium nigrum	Distichium capillaceum	Fontinalis antipyretica	Drepanocladus fluitans	Drepanocladus sp.	Calliergon stramineum	Amblystegiaceae	Polytrichum juniperinum	Sphagnum sp.	Polygonum sp.	Carex sp.	Juncus sp.					
SB	365							1 p							22 p		a				p			p	p		p		p					1					
SB	385							p							p		a					p			p	p		p		p					1				
SB	430							p									p	p																					
SB	480							1 a									p		1 p					p						a			p		p				
SB	530							p									p													p									
AT	580							p		1						p									p				p										
AT	630						a	p		p							p													p									
BO	680								6	1 p			60			p		p	p																				
PB	730							a	p	p		12	1				p				a			p										p					
PB	755						a	4	1							p																							
D3	780							5				1				a									a											1			
D3	819							11								p	p																						
AL	830							a	1							a																							
AL	841						a																																
AL	851	1			5		2					3				p									a														
MEI/D1	858		2		5		1					p												p	a														
MEI/D1	863		1			p										p									p		p												
MEI/D1	868		3																					p	p		p										1		
MEI/D1	873		3																						p														
MEI/D1	878	1	2	3												p								p	a									1	1				
MEI/D1	883		2									2												p	a														
MEI/D1	888	p																																					
MEI/D1	893																							p															

**table S2**  
**Kirchmoor**

	pollen zone	depta (cm)	Selaginella selaginoides	Dryas octopetala	Salix polaris	Betula nana	Betula alba	Betula pubescens	Pinus sylvestris	Tilia sp.	Potamogeton filiformis	Potamogeton alpinus	Potamogeton berchtoldii	Potamogeton natans	Najas marina	Batrachium	Ceratophyllum demersum	Myriophyllum sp.	Nuphar sp.	Nymphaea sp.	Schoenoplectus lacustris	Typha sp.	Sparganium emersum	Alisma sp.	Eleocharis sp.	Lycopus europaeus	Cicuta virosa	Eupatorium cannabinum	Thelypteris palustris	Carex rostrata	Menyanthes trifoliata	Polygonum lapataifolium	Rumex maritimus	Bidens cernua	Ranunculus scleratus	Urtica dioica	Distichium capillaceum	Sphagnum sp.											
postgl.	324								1					a					5		1					1	1	p											1										
postgl.	340						3							a		2			3																														
postgl.	356						6							a		3			1																														
postgl.	380						8							a					p			3																											
postgl.	405						3							a					3			10																											
postgl.	431						19	1				1	147	114					p		1	75					1		p																				
postgl.	455						60	1					9	5	a	a		1	a		40	1	1	1	1	4		p				4	16			4													
postgl.	475						71		1					23	a	p		1	a		69	1	6	1	2	2	1	2	p	3		10	3		34	5													
D3	505	2						26										p																															
D3	530						1											p																															
D3	555															4		p																															
D3	580					1	10									3		p																															
AL	605					1	46	12								1															1																		
MEI/D1	630		4	2								2																																					
MEI/D1	638		1		1																																												
MEI/D1	646																																																
MEI/D1	655		1	8																																													
MEI/D1	663		8	9								5																																					



**table S5**  
**Stauner Moor**

	pollen zone	depth (cm)	Salix polaris	Salix sp.	Dryas octopetala	Hippophae rhamnoides	Betula nana	Juniperus sp.	Betula pubescens	Betula sp.	Betula alba	Populus tremula	Ranunculus aquatilis	Myriophyllum sp.	Potamogeton filiformis	Potamogeton praelongus	Potamogeton obtusifolius	Potamogeton sp.	Najas marina	Najas minor	Nymphaea sp.	Characeae	Carex sp.	Eleocharis	Menyanthes sp.	Typha sp.	Caryophyllaceae
BO		420																									
BO		430									x												x		x		
BO		440																									
BO		450																									
BO		460																									
BO		470																	x	x			x	x			
BO		480																	x	x			x		x		
BO		490	x							x						x			x	x			x				
BO		500						x	x	x						x	x		x	x	x		x	x			
BO		510						x			x					x			x	x	x		x	x			
PB		520									x												x				
PB		530						x		x									x								
PB		540						x		x																x	
PB		550						x		x	x										x						
PB		560						x		x																	
PB		570	x					x		x																	
PB		580						x				x						x									
D3		590				x			x	x																	
D3		600				x		x																			
D3		610																									
D3		620																									
D3		630	x			x					x		x										x				
D3		640				x	x	x					x										x				
D3		650				x							x														
D3		660	x			x							x										x				
D3		670				x		x																			
D3		680				x					x		x														
D3		690						x		x																	
AL		700							x	x		x	x		x		x										
AL		710						x	x	x	x	x			x		x										
AL		720						x		x													x				
AL		730		x		x		x																			
MEI/D1		740		x	x	x								x	x	x		x					x		x		
MEI/D1		750	x			x	x								x												
MEI/D1		760	x		x	x									x												x

**table S6**

species	fallspeed	ppe	PPE.errors
Betula	0,024	3	0,30
Picea	0,056	0,5	0,05
Pinus	0,031	2	0,20
Artemisia	0,025	1	0,10
Calluna	0,038	0,5	0,05
Cyperaceae	0,035	0,3	0,03
Plantago	0,029	0,25	0,03
Rumex acetosa	0,018	0,25	0,03
Poaceae	0,035	1	0,10
Helianthemum	0,043	0,1	0,01
Hippophae	0,029	0,2	0,02
Salix	0,022	0,8	0,08
Filipendula	0,02	0,5	0,05
Betula nana	0,022	0,75	0,08
Juniperus	0,019	0,5	0,05
Empetrum	0,038	0,6	0,06
Potentilla	0,024	0,2	0,02
Chenopodiaceae	0,025	0,8	0,08
Ranunculus	0,023	0,2	0,02
Thalictrum	0,023	0,5	0,05
Galium	0,02	0,1	0,01

### Migration of *Betula* species into the study area

The article gives special reference to *Betula pubescens*. However, in the course of the Lateglacial and the Early Holocene the migration of different *Betula* species occurred. These different *Betula* species had different shares in the composition of the vegetation on a diachronic scale. Thus, when focusing on *Betula pubescens* only, it is important to distinguish between the different present *Betula* species in the region. Palynologically this is either hardly possible (e.g. between *B. pubescens* and *B. pendula*) or often not performed (*B. pubescens* and *B. nana*). It follows that pollen studies of the Lateglacial and early Holocene in Schleswig-Holstein mainly only classify *Betula* pollen on genus level. As a further complication, different species names and name renewals for different *Betula* species occur in the literature.

*Betula* species that are proven to be present during the Lateglacial and Early Holocene based on macrofossil data across the study region are dwarf birch (*Betula nana*), downy birch (*B. pubescens*) and silver birch (*B. pendula*). However, the migration of the latter occurred most probably exclusively in the course of the early Holocene (Krüger et al., 2020; Usinger, 1981b, a; Usinger and Wolf, 1982). *Betula pubescens* ssp. *tortuosa* that is recorded in different datasets can be regarded as resulting from hybridisation between *B. pubescens* and *B. nana* (Karlsson and Weih, 1996). Furthermore, works of Schütrumpf (1937, 1943, 1955) in the focus area document finds of *B. verrucosa* – a synonymous species name for *B. pendula*, which only expanded in the area from the Preboreal period onwards as a result of increasing temperature. The earliest proven presence of *Betula pubescens* of the Lateglacial in the Nahe palaeolake record dates to 13.770 cal BP (Krüger et al., 2020) and, hence, 2000 years prior to the period of investigation.

To conclude: *Betula pubescens* is present in the study area prior to the studied time interval and remains being present until today. *Betula nana* is present in the study area since shortly after deglaciation, throughout the Lateglacial and into the early Holocene. *Betula pendula* is present in the study area only by the beginning of the Holocene but the timing of its first appearance in the Early Holocene is unknown.

**supplementary figures**

The pictures are taken in growth favoring locations for *Betula pubescens* in different places of southern Greenland (see 3.1 Fieldwork) by the author. They underline how stands of *Betula pubescens* could have formed a barrier in the landscape and illustrate the predominantly occurring multi-branched growth-form in *Betula pubescens* stands.



figure S1



figure S2



figure S3



figure S4