



Supplement of

Patterns in recent and Holocene pollen accumulation rates across Europe – the Pollen Monitoring Programme Database as a tool for vegetation reconstruction

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Tables

Table S1: Excluded trap samples and trap sites for all analysis

Site	year	due to:
CZE/HSS/SA10	1997	<i>Picea, Abies</i>
GEOR/EK/T4	1999	<i>Fagus</i>
GRE/TIM3	2010	<i>Abies</i>
CH/WVDK/A0	whole site	Cyperaceae (1997)
PL/AN/W2	2000	<i>Carpinus, Fraxinus</i>
RUS/PL3	2011	<i>Alnus</i>
RUS/PL4	whole site	<i>Alnus</i> (2011), <i>Picea</i> (2012)
RUS/PL5	2016	<i>Betula</i>
RUS/PL6	whole site	<i>Betula</i> (2016)
RUS/ZV3	2016	<i>Betula</i>
RUS/ZV3	2012	<i>Tilia</i>
S/TG/AS	whole site	sediment trap
S/TG/HS1	whole site	sediment trap
S/TG/HS2	whole site	sediment trap
S/TG/KS1	whole site	sediment trap
S/TG/KS2	whole site	sediment trap
S/TG/RS	whole site	sediment trap
S/TG/STS	whole site	sediment trap
S/TG/STT	whole site	2003 unreliable
S/TG/SVS	whole site	sediment trap
S/TG/TS	whole site	sediment trap
UK/HP/CC7	whole site	<i>Quercus, Corylus</i>

Table S2: Andersen's correction factors

taxa	correction factor
<i>Abies</i>	1
<i>Alnus</i>	0.25
<i>Betula</i>	0.25
<i>Carpinus</i>	0.33
<i>Corylus</i>	0.25
Cyperaceae	1
<i>Fagus</i>	1
<i>Fraxinus</i>	2
<i>Pinus</i>	0.25
Poaceae	1
<i>Quercus</i>	0.25
<i>Tilia</i>	2
<i>Ulmus</i>	0.5

Table S3: List of taxa and sites, where second highest class of fossil PAR was used for the link with modern analogues

taxa	fossil sites
<i>Abies</i>	Malá niva
<i>Alnus</i>	Arkutino 2, Bachalpsee
<i>Betula</i>	Abborrtjärnen, Akuvaara, Prášilské
<i>Carpinus</i>	Shabla, Suminko
<i>Corylus</i>	Malá niva, Rõuge Tõugjärv, Shabla, Suminko
<i>Fagus</i>	Malá niva, Ribno
<i>Fraxinus</i>	Bachalpsee, Shabla, Voulkaria
<i>Juniperus</i>	Abborrtjärnen, Toskaljavri
<i>Picea</i>	Abborrtjärnen, Malá niva
<i>Pinus</i>	Bachalpsee, Malá niva, Prášilské, Tsuolbmajavri
Poaceae	Arkutino 2, Bachalpsee, Malá niva, Prášilské, Rõuge Tõugjärv
<i>Quercus</i>	Sägistalsee, Shabla
<i>Tilia</i>	Rõuge Tõugjärv
tree PAR	Prášilské, Rõuge Tõugjärv, Sägistalsee

Table S4a: Adjusted R² between logarithm of tree PAR (or logarithm of total PAR adjusted by Andersen values, Table S2) and selected environmental variables.

	with Spitsbergen		without Spitsbergen	
	PAR	adjusted PAR	PAR	adjusted_PAR
Latitude	0.11	0.24	0.09	0.22
MAT	0.21	0.28	0.19	0.26
Forest cover 10 km	0.19	0.17	0.18	0.16
latitude+MAT+Forest cover 10 km	0.37	0.44	0.35	0.42
latitude+MAT+Forest cover 10 km+elevation	0.50	0.55	0.49	0.54

Table S4b: Adjusted R² between logarithm of total PAR (or logarithm of tree PAR adjusted by Andersen values, Table S2) and selected environmental variables.

	with Spitsbergen		without Spitsbergen	
	PAR	adjusted PAR	PAR	adjusted_PAR
Latitude	0.19	0.37	0.17	0.36
MAT	0.25	0.34	0.23	0.33
Forest cover 10 km	0.15	0.09	0.14	0.08
latitude+MAT+Forest cover 10 km	0.38	0.48	0.36	0.46
latitude+MAT+Forest cover 10 km+elevation	0.50	0.56	0.49	0.55

Table S5: Comparison of long-distance transport 200 km estimates and pollen dispersal function based of Gaussian plume model, wind speed 3 m/s and characteristic radius (Prentice 1988). DA – distribution area.

	PAR at 200 km from DA	median of PAR within the DA	proportion of LDT at 200 km and PAR within DA	terminal velocity (m/s)	proportion of pollen loading coming from beyond 200 km according to characteristic radius
<i>Carpinus</i>	38.7	195.4	0.198	0.042	0.021
<i>Corylus</i>	14.9	144.2	0.104	0.025	0.100
<i>Fagus</i>	76.0	295.7	0.257	0.057	0.005
<i>Fraxinus</i>	19.3	87.7	0.220	0.022	0.131
<i>Picea</i>	0.3	189.8	0.002	0.056	0.006
<i>Quercus</i>	50.5	268.2	0.188	0.035	0.040
<i>Tilia</i>	4.9	13.5	0.361	0.032	0.052

Table S6: T-test between fossil and trap log (PAR) values and mean values for all trap regions (See Fig. 5).

taxa	region	mean log(fossil PAR)	mean log(trap PAR)	p-value
Abies	nboreal			
Abies	boreal			
Abies	sboreal			
Abies	lowertemp	1.56	3.31	0.04
Abies	middletemp	5.69	3.37	0.00
Abies	hightemp	5.69	3.33	0.00
Abies	south	3.64	4.12	0.38
Alnus	nboreal	2.49	2.34	0.55
Alnus	boreal	2.89	2.92	0.91
Alnus	sboreal	6.11	4.62	0.00
Alnus	lowertemp	7.26	7.09	0.67
Alnus	middletemp	6.06	5.37	0.00
Alnus	hightemp	5.33	4.79	0.00
Alnus	south	3.98	5.65	0.00
Betula	nboreal	5.83	6.45	0.01
Betula	boreal	6.43	7.27	0.00
Betula	sboreal	7.82	7.59	0.26
Betula	lowertemp	8.55	8.62	0.76
Betula	middletemp	6.15	6.27	0.43
Betula	hightemp	3.88	5.75	0.00
Betula	south	3.20	3.68	0.20
Carpinus	nboreal	-1.61	-1.66	
Carpinus	boreal		0.39	
Carpinus	sboreal	1.02	0.12	0.01
Carpinus	lowertemp	4.23	5.30	0.05
Carpinus	middletemp	3.50	3.56	0.82
Carpinus	hightemp		3.60	
Carpinus	south	5.16	6.34	0.00
Corylus	nboreal	0.16	0.12	0.88
Corylus	boreal	1.11	-0.07	0.01
Corylus	sboreal	4.43	0.86	0.00
Corylus	lowertemp	6.82	5.63	0.00
Corylus	middletemp	6.44	3.96	0.00
Corylus	hightemp	5.85	4.80	0.00
Corylus	south	4.38	5.14	0.00

Cyperaceae	nboreal	3.39	4.79	0.00
Cyperaceae	boreal	3.29	5.01	0.00
Cyperaceae	sboreal	3.39	4.62	0.00
Cyperaceae	lowertemp	5.59	5.25	0.08
Cyperaceae	middletemp	3.89	4.50	0.05
Cyperaceae	hightemp	4.31	5.46	0.00
Cyperaceae	south	3.02	4.46	0.00
Fagus	nboreal		-1.60	
Fagus	boreal			
Fagus	sboreal	0.66		
Fagus	lowertemp	3.32	5.22	0.00
Fagus	middletemp	6.42	5.31	0.00
Fagus	hightemp	4.74	4.62	0.70
Fagus	south	3.96	6.14	0.00
Fraxinus	nboreal	-0.65	-1.08	0.42
Fraxinus	boreal		-1.85	
Fraxinus	sboreal	2.12	1.28	0.02
Fraxinus	lowertemp	4.66	4.43	0.45
Fraxinus	middletemp	3.72	3.75	0.93
Fraxinus	hightemp	2.99	5.14	0.00
Fraxinus	south	3.48	5.08	0.00
Juniperus	nboreal	3.16	3.08	0.77
Juniperus	boreal		4.04	
Juniperus	sboreal	2.78	3.75	0.00
Juniperus	lowertemp	2.05	2.84	0.00
Juniperus	middletemp	1.93	1.15	0.01
Juniperus	hightemp	2.69	5.16	0.00
Juniperus	south	2.60	5.62	0.00
Picea	nboreal	1.44	1.16	0.25
Picea	boreal	1.97	4.61	0.00
Picea	sboreal	3.26	5.68	0.00
Picea	lowertemp	4.70	5.22	0.21
Picea	middletemp	7.22	6.40	0.00
Picea	hightemp	5.32	6.96	0.00
Picea	south	2.27	2.63	0.54
Pinus	nboreal	5.97	5.16	0.01
Pinus	boreal	6.27	7.84	0.00
Pinus	sboreal	7.99	8.29	0.07
Pinus	lowertemp	8.39	8.07	0.15
Pinus	middletemp	6.57	6.52	0.82
Pinus	hightemp	5.15	5.81	0.00
Pinus	south	5.28	6.68	0.00
Poaceae	nboreal	2.81	4.50	0.00
Poaceae	boreal	2.30	4.35	0.00
Poaceae	sboreal	3.55	5.34	0.00
Poaceae	lowertemp	5.94	7.74	0.00
Poaceae	middletemp	4.95	7.05	0.00
Poaceae	hightemp	5.87	7.56	0.00
Poaceae	south	5.94	7.45	0.00
Quercus	nboreal	-0.91	-1.17	0.67
Quercus	boreal	0.71	-0.72	0.00
Quercus	sboreal	3.38	1.47	0.00
Quercus	lowertemp	6.22	6.04	0.64
Quercus	middletemp	5.63	5.26	0.01
Quercus	hightemp	3.71	4.95	0.00
Quercus	south	6.63	6.79	0.54
Tilia	nboreal	-0.88		

Tilia	boreal	0.92	-1.68	
Tilia	sboreal	2.52	0.09	0.01
Tilia	lowertemp	5.48	3.78	0.00
Tilia	middletemp	3.85	2.18	0.00
Tilia	hightemp	2.77	2.00	0.02
Tilia	south	3.26	4.27	0.01
tree PAR	nboreal	6.73	6.93	0.32
tree PAR	boreal	7.29	8.42	0.00
tree PAR	sboreal	8.81	8.86	0.77
tree PAR	lowertemp	9.74	9.85	0.49
tree PAR	middletemp	8.86	7.96	0.00
tree PAR	hightemp	7.76	8.04	0.04
tree PAR	south	7.77	9.12	0.00

Figures and text

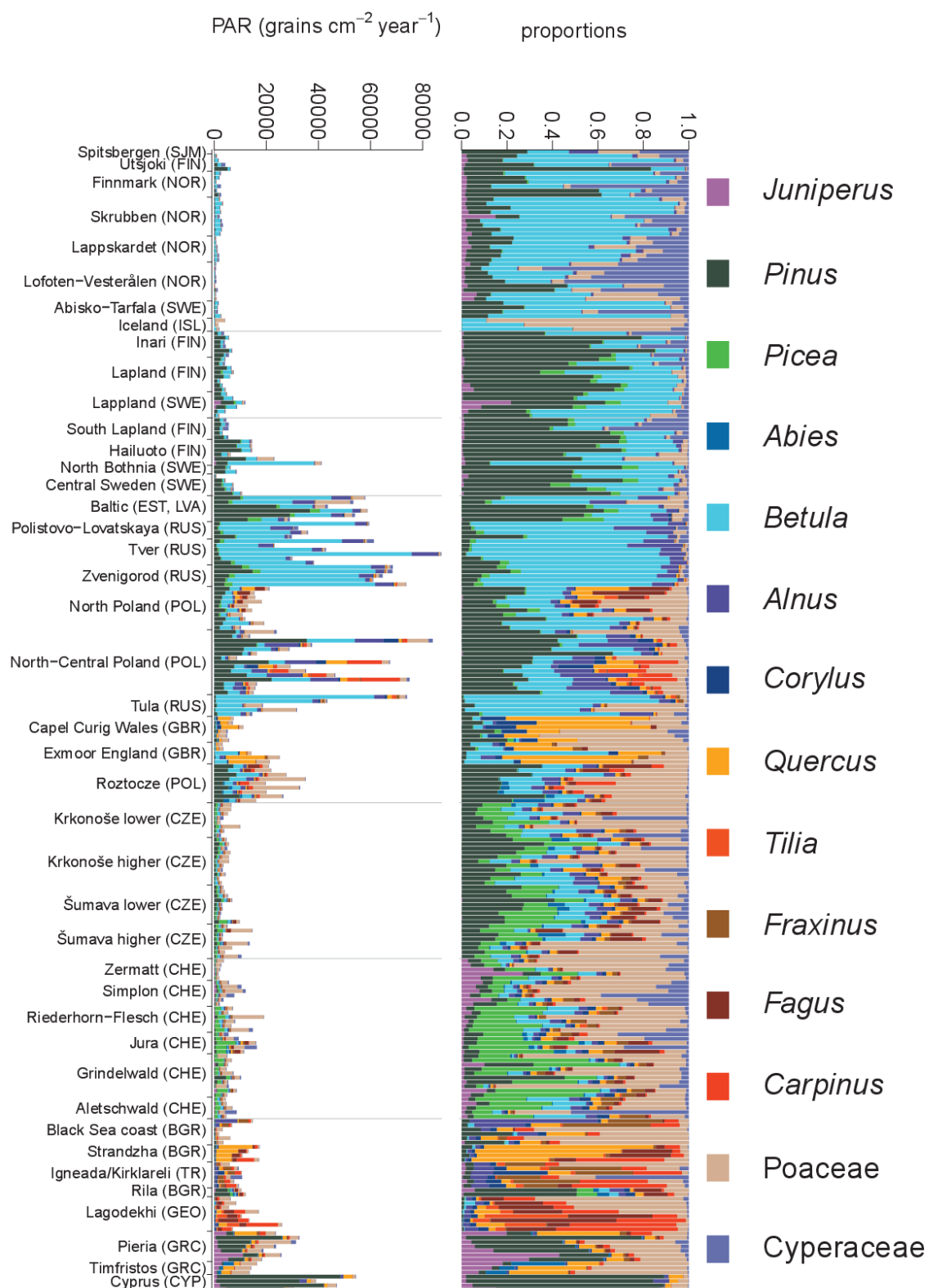


Fig. S1: Absolute and relative average composition in individual traps arranged from north (top) to south (bottom).

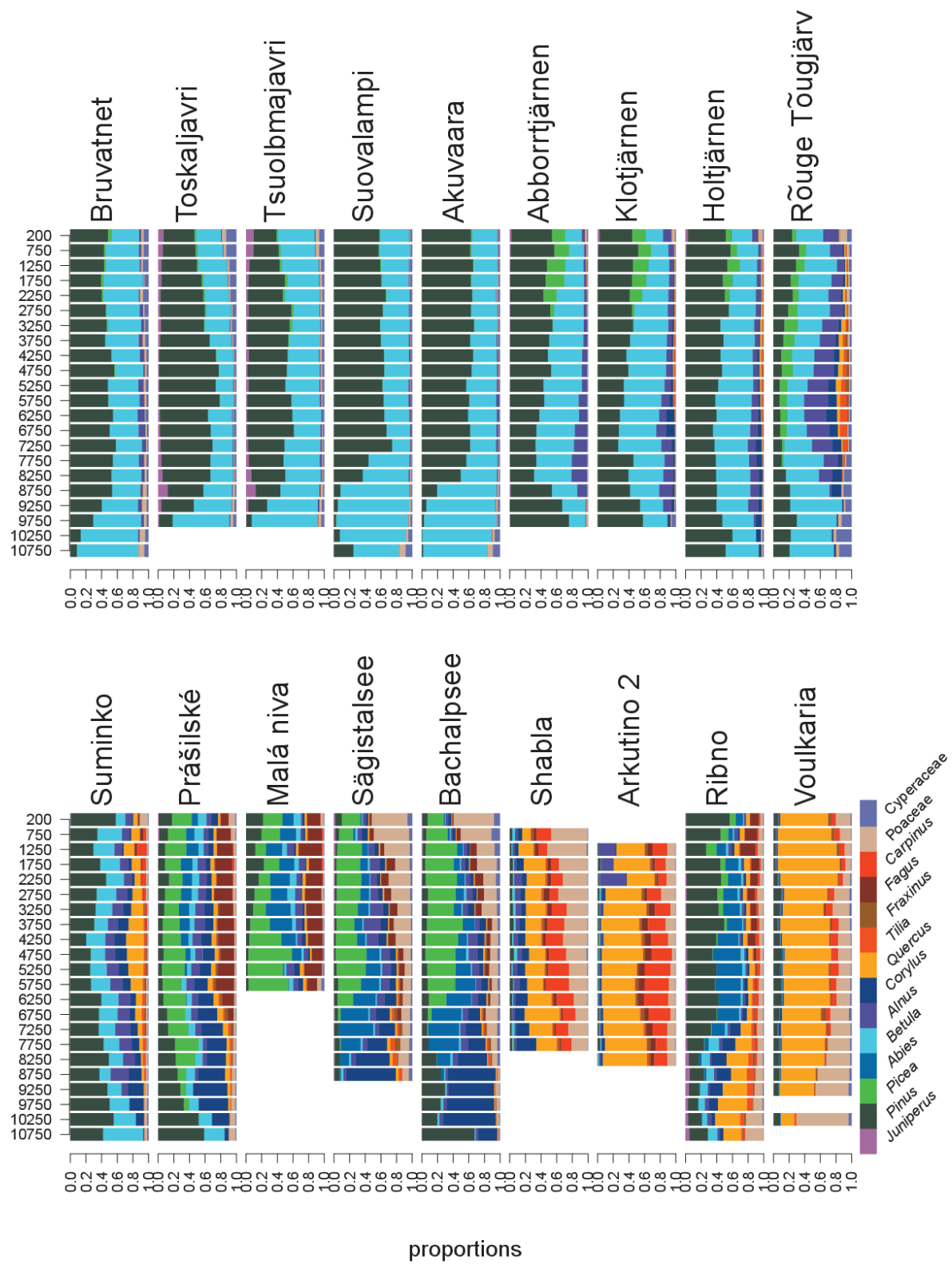


Fig. S2: Relative pollen composition of fossil sites.

Taxa specific linkage of the highest average PAR at fossil sites with individual trap values

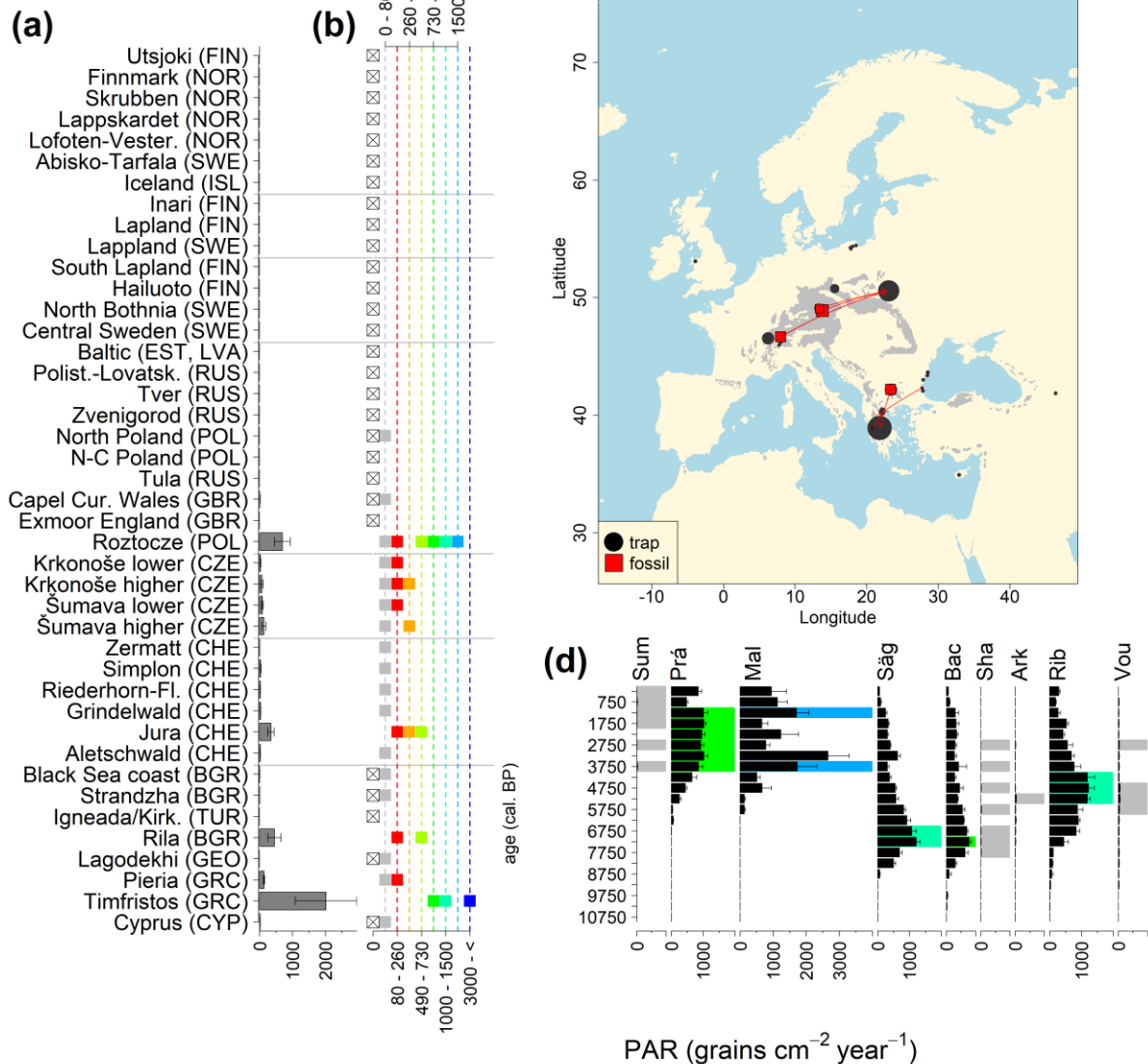
Following pages contain text and figures with this caption:

Fig. S3: Mean modern PAR averaged for each trap area (a). b) Range of mean individual trap values classified by one-dimensional clustering. Crossed squares indicate that pollen of the taxon was not found in any trap from the area. c) Map of Europe with the distribution of the species (gray, Caudullo et al., 2017, Kempeneers et. al., 2012, San-Miguel-Ayanz et al. 2016, see Table S7) falling within the pollen taxa, size of symbols shows classes of PAR in recent and the highest PAR per each fossil record. Arrows show the closest trap with the same class of PAR. d) Fossil PAR values with the highest PAR class per each record (see Table 1 for full name) highlighted by the corresponding colour for the class (see b) Note the scale of the x-axis corresponds to the x-axis scale of graph a).

Table S7 References for distribution maps

pollen taxon	file.shp	species	reference
Abies	Abies_alba_EUFORGEN	<i>Abies alba</i>	(San-Miguel-Ayanz et al., 2016)
Abies	Abies_borisii_regis_EUFORGEN	<i>Abies borisii regis</i>	(San-Miguel-Ayanz et al., 2016)
Abies	Abies_bornmuelleriana_EUFORGEN	<i>Abies bornmuelleriana</i>	(San-Miguel-Ayanz et al., 2016)
Abies	Abies_cephalonica_EUFORGEN	<i>Abies cephalonica</i>	(San-Miguel-Ayanz et al., 2016)
Abies	Abies_cilicica_EUFORGEN	<i>Abies cilicica</i>	(San-Miguel-Ayanz et al., 2016)
Abies	Abies_equi_trojani_EUFORGEN	<i>Abies equi trojani</i>	(San-Miguel-Ayanz et al., 2016)
Abies	Abies_marocana_EUFORGEN	<i>Abies marocana</i>	(San-Miguel-Ayanz et al., 2016)
Abies	Abies_nebrodensis_EUFORGEN	<i>Abies nebrodensis</i>	(San-Miguel-Ayanz et al., 2016)
Abies	Abies_nordmanniana_EUFORGEN	<i>Abies nordmanniana</i>	(San-Miguel-Ayanz et al., 2016)
Abies	Abies_numidica_EUFORGEN	<i>Abies numidica</i>	(San-Miguel-Ayanz et al., 2016)
Abies	Abies_pinsapo_EUFORGEN	<i>Abies pinsapo</i>	(San-Miguel-Ayanz et al., 2016)
Alnus	Alnus_cordata_EUFORGEN	<i>Alnus cordata</i>	(San-Miguel-Ayanz et al., 2016)
Alnus	Alnus_glutinosa_EUFORGEN	<i>Alnus glutinosa</i>	(San-Miguel-Ayanz et al., 2016)
Alnus	alnus_incana2	<i>Alnus incana</i>	(Caudullo et al., 2017)
Betula	Betula_pendula_EUFORGEN	<i>Betula pendula</i>	(San-Miguel-Ayanz et al., 2016)
Betula	betula_pubescens2	<i>Betula pubescens</i>	(Caudullo et al., 2017)
Carpinus	carpinus_betulus	<i>Carpinus betulus</i>	(Caudullo et al., 2017)
Carpinus	carpinus_orientalis	<i>Carpinus orientalis</i>	(Caudullo et al., 2017)
Carpinus	ostrea_carpinifolia3	<i>Carpinus carpinifolia</i>	(Caudullo et al., 2017)
Corylus	corylus	<i>Corylus corylus</i>	(Caudullo et al., 2017)
Fagus	Fagus_orientalis_EUFORGEN	<i>Fagus orientalis</i>	(San-Miguel-Ayanz et al., 2016)
Fagus	Fagus_sylvatica_EUFORGEN	<i>Fagus sylvatica</i>	(San-Miguel-Ayanz et al., 2016)
Fraxinus	Fraxinus_excelsior_EUFORGEN	<i>Fraxinus excelsior</i>	(San-Miguel-Ayanz et al., 2016)
Fraxinus	fraxinus_ornus2	<i>Fraxinus ornus</i>	(Caudullo et al., 2017)
Juniperus	ju_comm	<i>Juniperus communis</i>	(Caudullo et al., 2017)
Juniperus	ju_oxy	<i>Juniperus oxycedrus</i>	(Caudullo et al., 2017)
Juniperus	ju_pho	<i>Juniperus phoenicea</i>	(Caudullo et al., 2017)
Juniperus	ju_thur	<i>Juniperus thurifera</i>	(Caudullo et al., 2017)
Picea	Picea_abies_EUFORGEN	<i>Picea abies</i>	(San-Miguel-Ayanz et al., 2016)
Pinus	Pinus pinea	<i>Pinus pinea</i>	(San-Miguel-Ayanz et al., 2016)
Pinus	Pinus_brutia_EUFORGEN	<i>Pinus brutia</i>	(San-Miguel-Ayanz et al., 2016)
Pinus	Pinus_halepensis_EUFORGEN	<i>Pinus halepensis</i>	(San-Miguel-Ayanz et al., 2016)
Pinus	Pinus_leucodermis_EUFORGEN	<i>Pinus leucodermis</i>	(San-Miguel-Ayanz et al., 2016)
Pinus	Pinus_nigra_EUFORGEN	<i>Pinus nigra</i>	(San-Miguel-Ayanz et al., 2016)
Pinus	Pinus_sylvestris_EUFORGEN	<i>Pinus sylvestris</i>	(San-Miguel-Ayanz et al., 2016)
Quercus	Quercus_cerris_EUFORGEN	<i>Quercus cerris</i>	(San-Miguel-Ayanz et al., 2016)
Quercus	Quercus_petraea_EUFORGEN	<i>Quercus petraea</i>	(San-Miguel-Ayanz et al., 2016)
Quercus	Quercus_robur_EUFORGEN	<i>Quercus robur</i>	(San-Miguel-Ayanz et al., 2016)
Quercus	Quercus_suber_EUFORGEN	<i>Quercus suber</i>	(San-Miguel-Ayanz et al., 2016)
Quercus	quercus_coccifera2	<i>Quercus coccifera</i>	(Caudullo et al., 2017)
Tilia	Tilia_cordata_EUFORGEN	<i>Tilia cordata</i>	(San-Miguel-Ayanz et al., 2016)
Tilia	Tilia_platyphyllos_EUFORGEN	<i>Tilia platyphyllos</i>	(San-Miguel-Ayanz et al., 2016)
trees	forest.tif	trees	(Kempeneers et al., 2012)

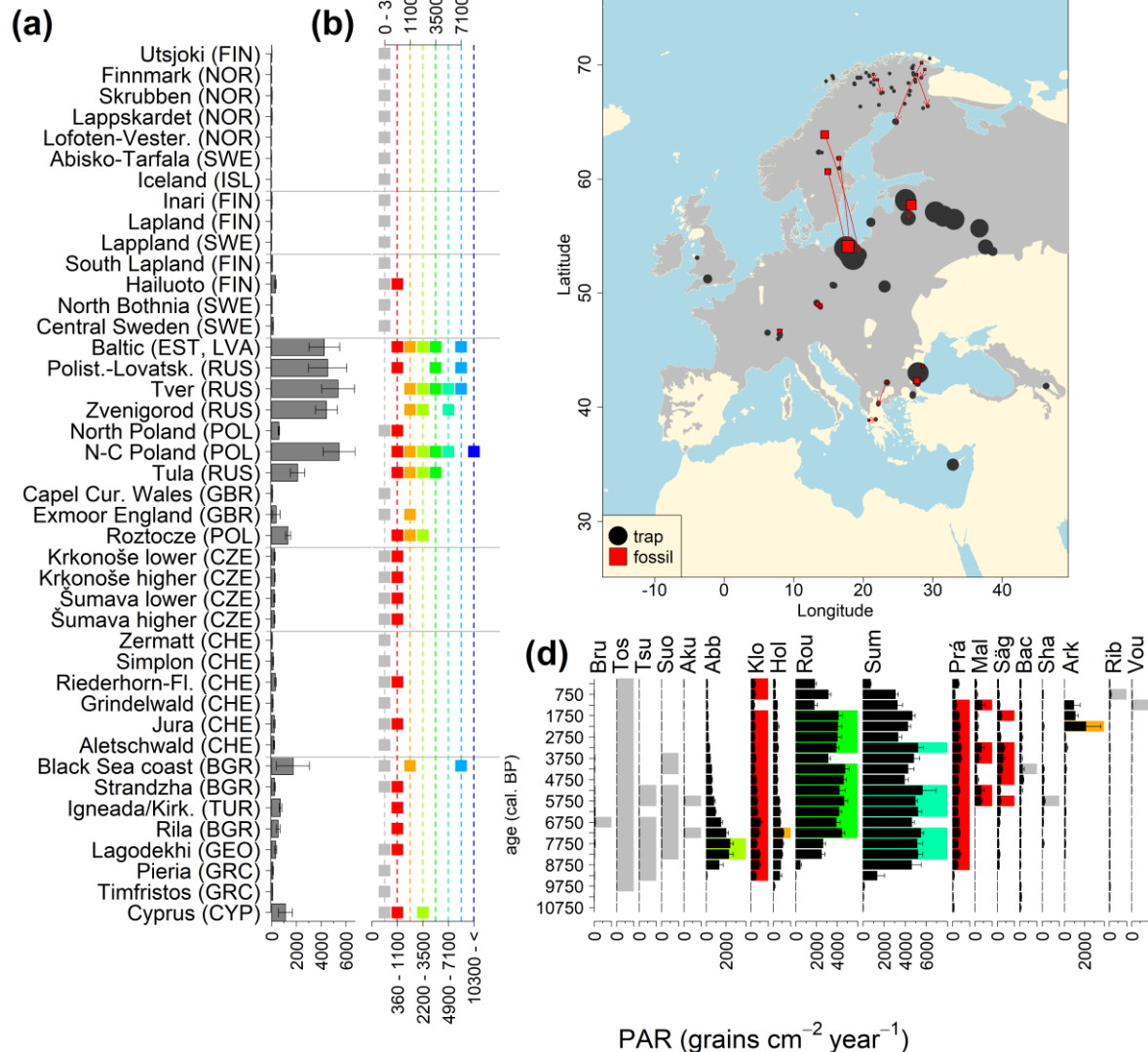
Abies



Abies

Modern PAR of 490-3900 grains cm⁻² y⁻¹ are observed in Roztocze, Jura, Rila and Tymfristos. These values are produced by different species: *Abies alba* in Roztocze and the Jura mountains and *A. cephalonica* in the Rila mountains and on Tymfristos. Generally high fossil values occur in the two Alpine lakes Sägistalsee and Bachalpsee around 7000 years, in Ribno in the Rila mountains around 5000 years and in the two sites in Šumava between 4000 and 1000 years. In all these regions with fossil evidence of high *Abies* populations, the modern PAR values in pollen traps are comparably low documenting that the populations have much declined. The *Abies alba* populations in Roztocze provide modern analogues for how dense *Abies* forests may have been in the Alps and Šumava, although the forests in Roztocze occur at much lower elevations. Pollen traps on Tymfristos mountain provide analogues of the density of Middle Holocene *Abies* forests in the Rila mountains. Pollen traps located far from the distribution limits of *Abies* in Wales, northern Poland, Georgia and Cyprus registered occasional *Abies* pollen grains with PAR of up to 80 grains cm⁻² y⁻¹.

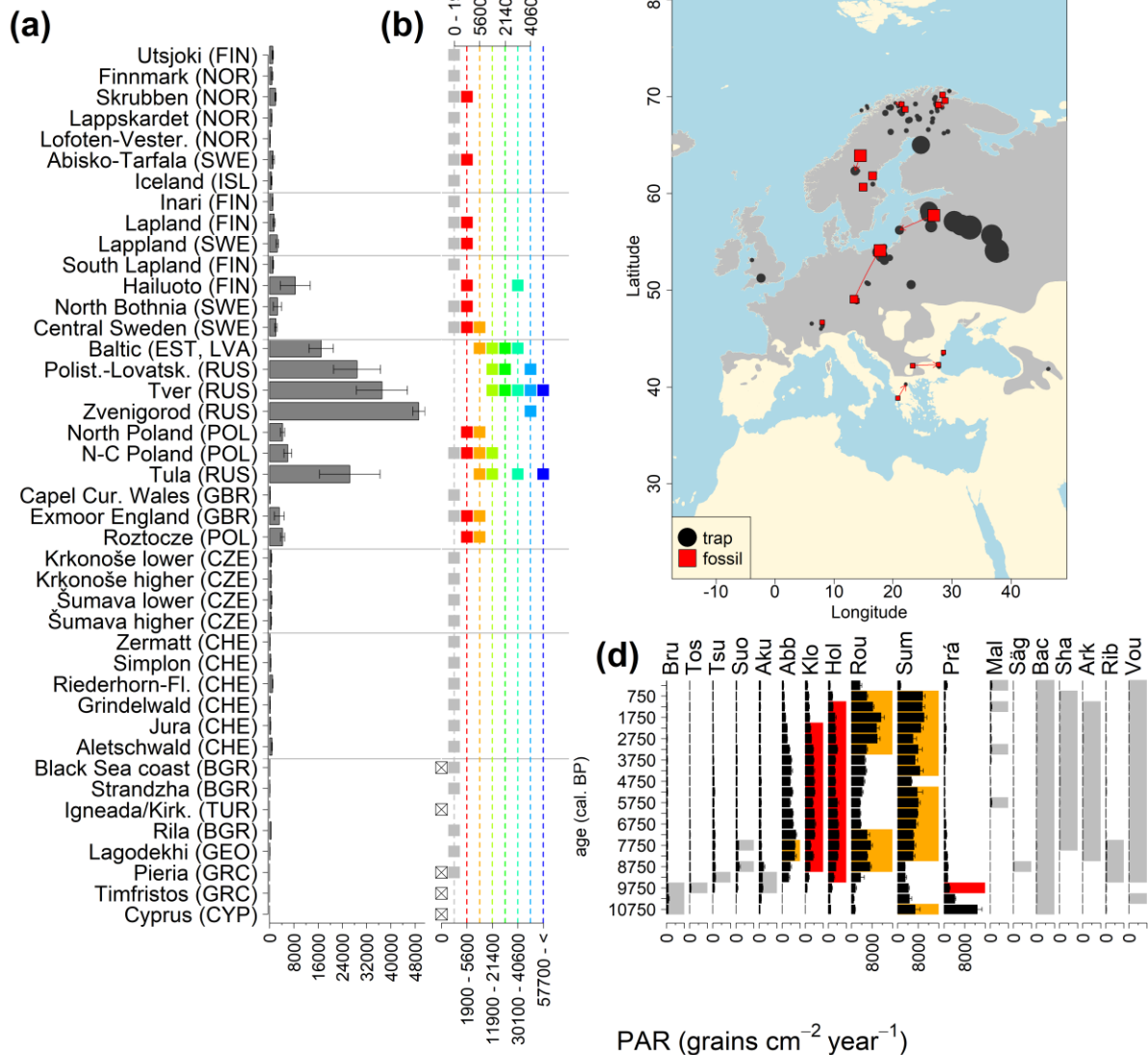
Alnus



Alnus

Since *Alnus viridis* was well distinguished in the Alps, *A. glutinosa* and *A. incana* are the only species considered contributing to the pollen type in north and central Europe. Particularly high fossil PAR of *Alnus* represent mainly *Alnus glutinosa* as this tree is frequently found on waterlogged soils near lakes and wetlands. The highest modern values between 2200-13500 grains cm⁻² y⁻¹ are present in pollen traps from North-central Poland, Baltic's, European Russia as well as from the Black sea coast and Cyprus. Except for the traps on the island of Hailuoto, pollen traps north of 60-degree latitude collected 2-360 grains cm⁻² y⁻¹, even if most of these pollen traps are still within the distribution of *Alnus glutinosa* or *A. incana*. Similarly, low values are collected by pollen traps at high elevations in the Alps, which collect pollen originating from lowland populations of *Alnus glutinosa*. Thus, if PAR above 1000 grains cm⁻² y⁻¹ are encountered they may be interpreted as *Alnus glutinosa* dominated wetlands near a fossil site. Like other thermophilus trees the distribution of *Alnus glutinosa* also shifted southwards in Scandinavia during the Late Holocene. This is documented by the linkage between fossil values from central Sweden and modern PAR from Poland.

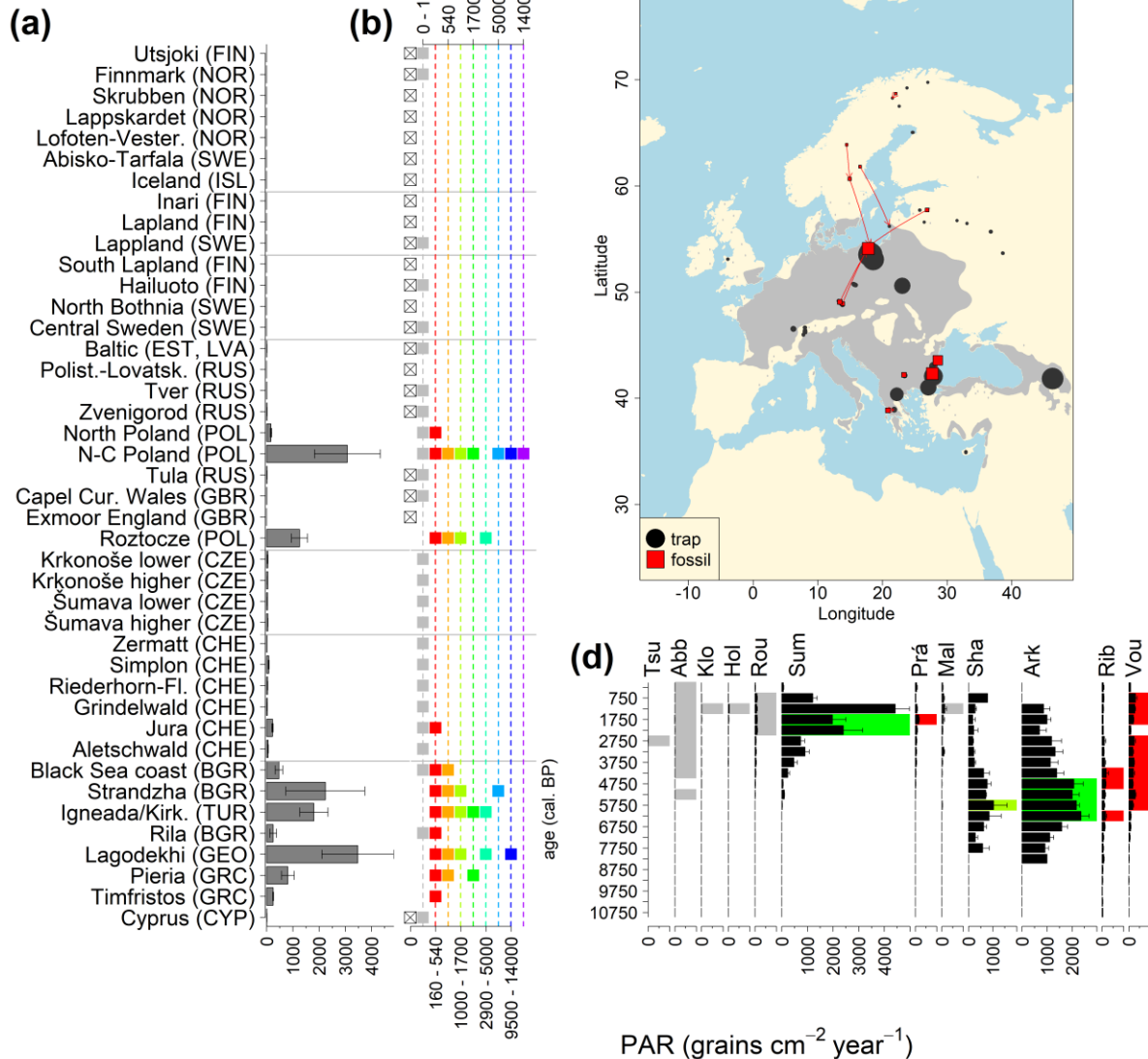
Betula



Betula

Trap sites cover the distribution of *Betula pendula* and *B. pubescens*. Some other *Betula* species can appear around traps in the Caucasus and Turkey. The highest modern values between 11900-73900 grains cm⁻² y⁻¹ are found in Estonia and Russia as well as in one pollen trap from Hailuoto. These modern PAR exceed values from fossil examples. The highest fossil PAR of around 10000 grains cm⁻² y⁻¹ in this comparison come from northern Poland and Estonia and are thus consistent with the area of high modern values. Whether high abundance of *Betula* is a characteristic of the eastern European forests or a result of frequent disturbance at the forest ecotone or due to recent land-use change is difficult to evaluate based on the available data. Modern and fossil values agree for the sites in central Sweden at PAR between 1900-5600 grains cm⁻² y⁻¹.

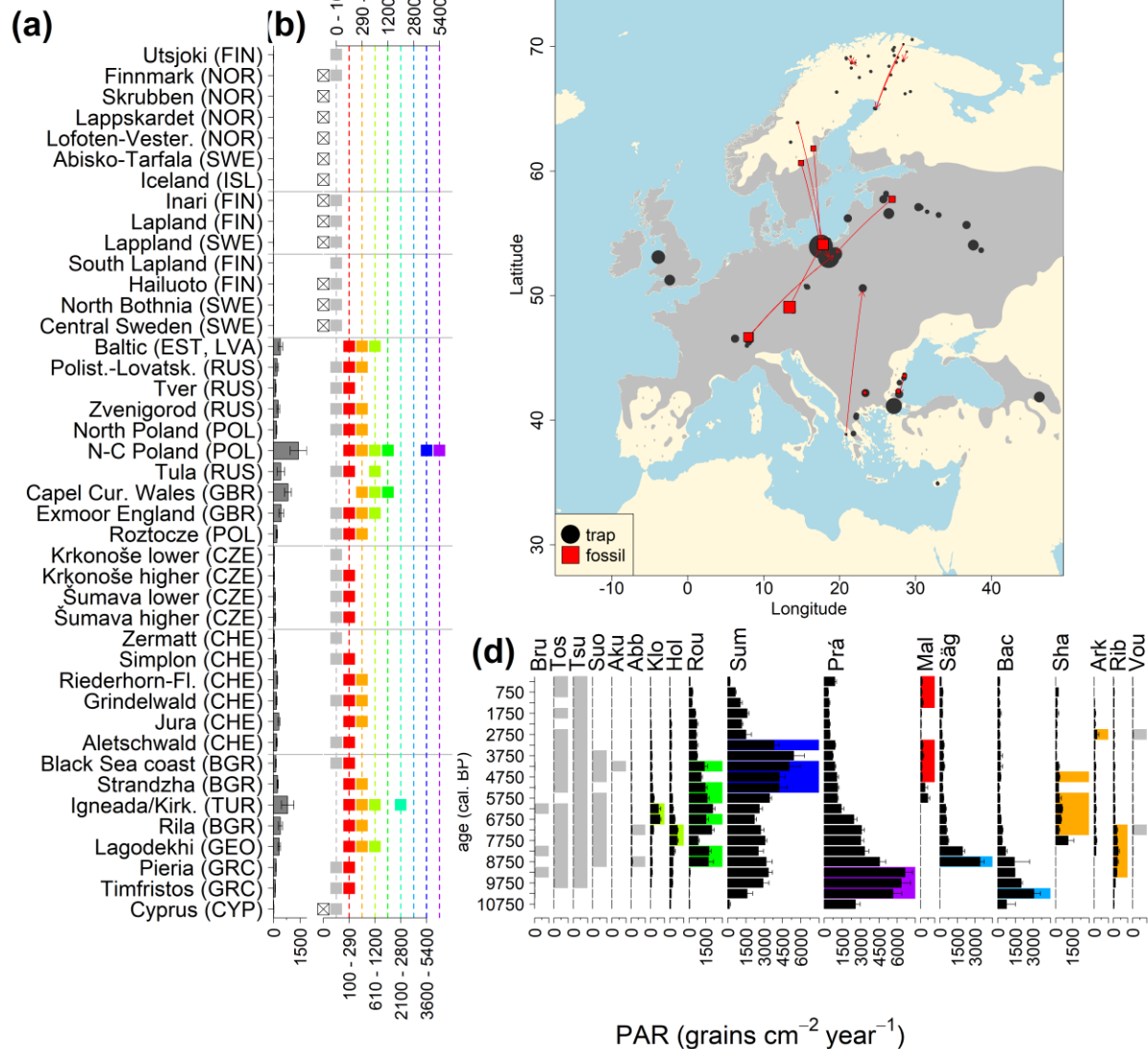
Carpinus



Carpinus

Highest recent PAR for *Carpinus* of 540-15000 grains cm⁻² y⁻¹ are found in pollen traps from three very distant areas: Poland, south-east Europe and Georgia. The signal in Poland is produced solely by *Carpinus betulus* while *C. orientalis* and *Ostrya* occur in the latter two areas. High fossil PAR of 540-1700 grains cm⁻² y⁻¹ occur in sites near the Black Sea coast and find matches with modern trap values from that area even though the fossil abundances decline towards the present. PAR 1700-2900 grains cm⁻² y⁻¹ are estimated for Suminko in northern Poland and here modern situations in the same region also result in similar values of *Carpinus* pollen deposition. Individual *Carpinus* pollen grains were encountered in pollen traps more than 200 km from the distribution while the values in several traps within or near the distribution of parent tree species often stayed below 160 grains cm⁻² y⁻¹.

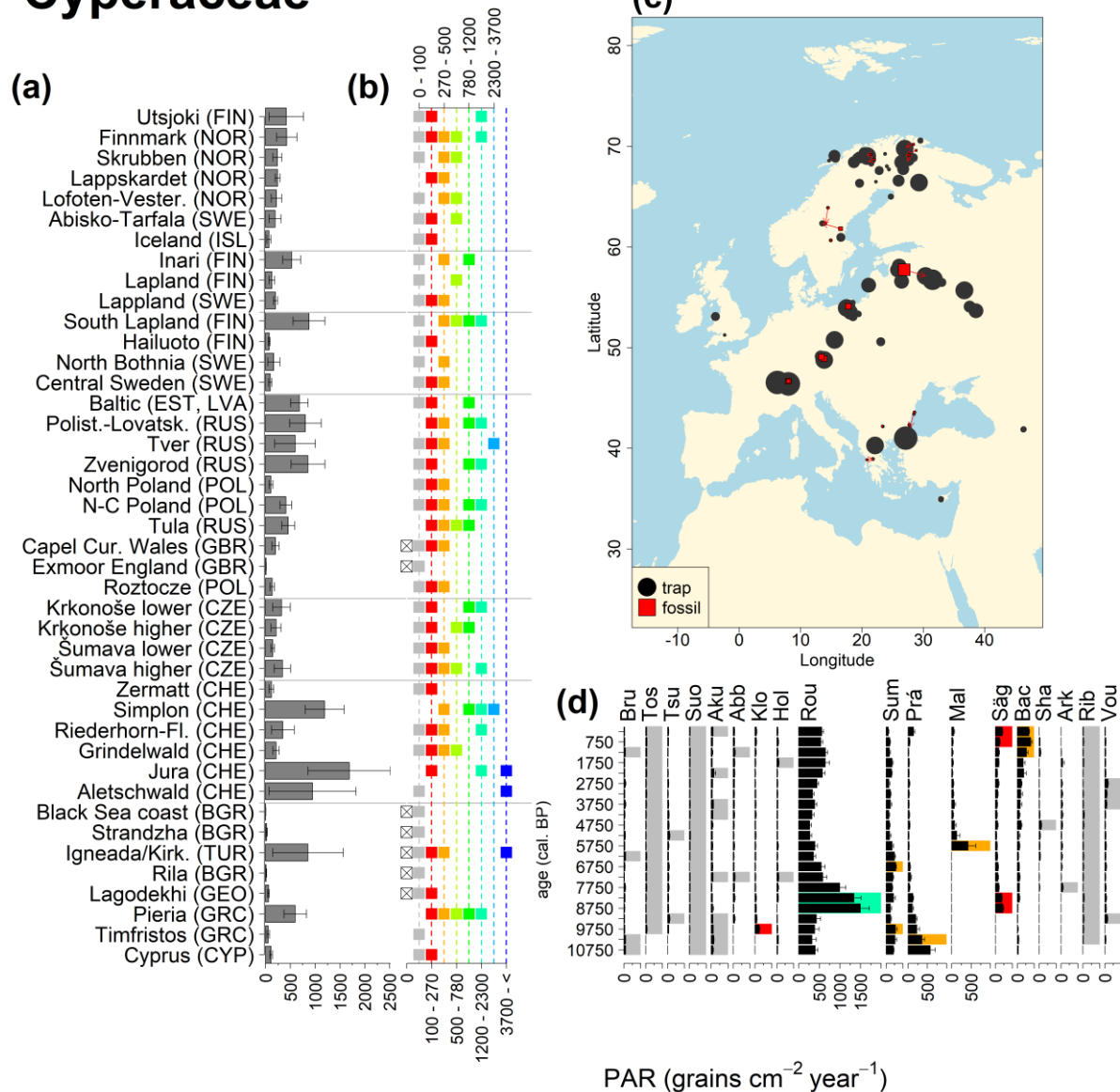
Corylus



Corylus

Modern PAR stay below 2800 grains $\text{cm}^{-2} \text{y}^{-1}$ except for two traps in north-central Poland. Values above 610 grains $\text{cm}^{-2} \text{y}^{-1}$ are also found in pollen traps from the Baltic, Wales, Turkey and Georgia. The pollen type mainly comes from *Corylus avellana*, while *C. maxima* occurs in Greece, and other species in Georgia, Turkey and in plantations or as ornamental trees in the rest of the Europe. The selection of fossil sites did not include studies from western and lowland central Europe where values of 10000 grains $\text{cm}^{-2} \text{y}^{-1}$ are common for the Early Holocene. The highest fossil PAR from the chosen examples were estimated for the Early Holocene from Prášílské situated at 1000 m a.s.l. Thus the high modern values in north-central Poland provide analogues for several fossil situations. Occasional grains and low PAR of *Corylus* pollen are common in traps from boreal regions as well as two traps from the arctic region.

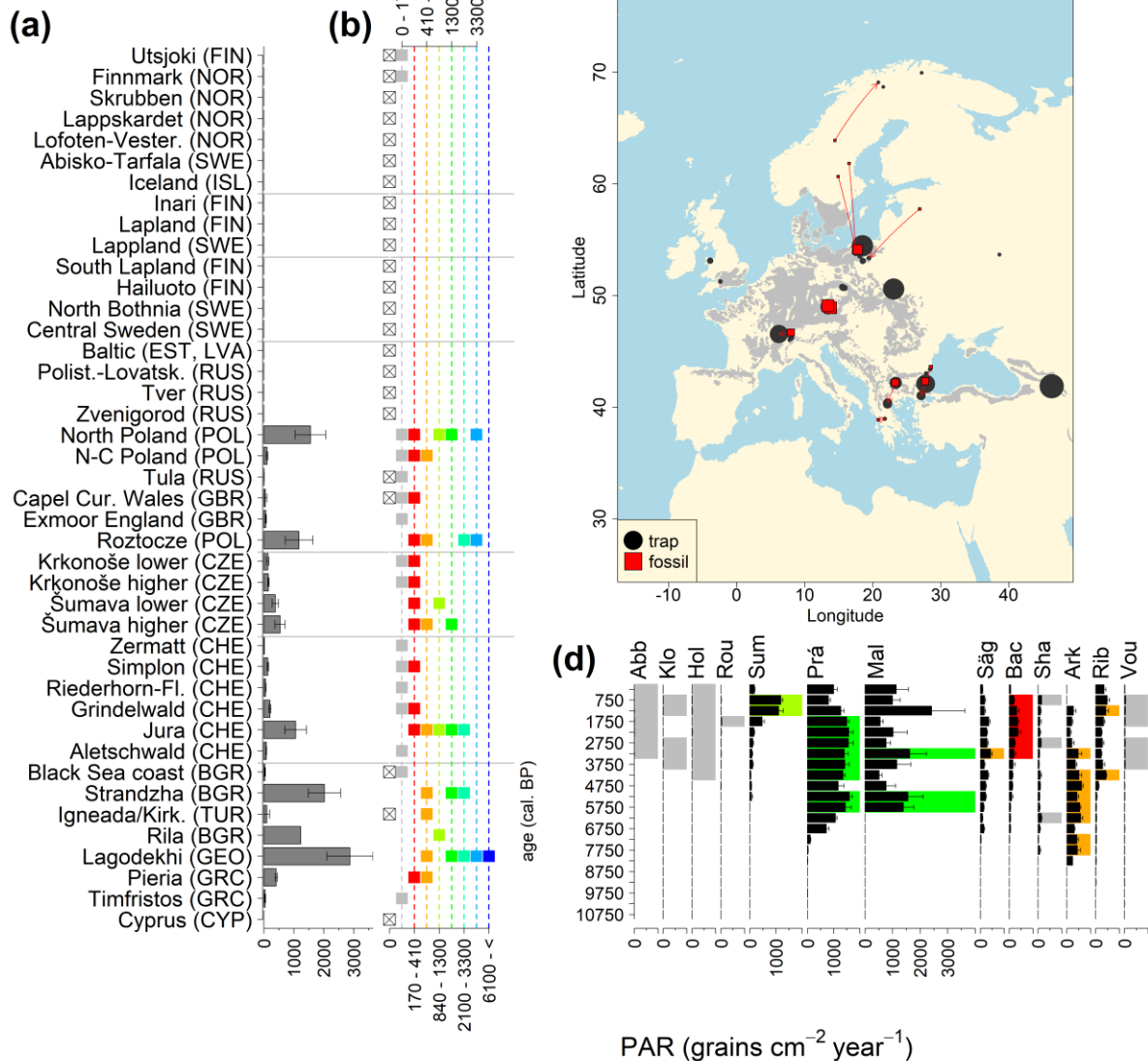
Cyperaceae



Cyperaceae

Modern PAR do not show a strong spatial pattern and values ranging between 470-4700 grains cm⁻² y⁻¹ occur in all regions from northern Scandinavia to Turkey, likely reflecting the local vegetation at the vicinity of the pollen trap. Fossil values are generally much lower than the high modern values, which may be partly explained by individual plants growing over the pollen trap with the pollen dropping directly into the pollen trap. Such local situations would influence individual traps within an area explaining the high range of values per trapping area. The high Early Holocene values at Røuge Töugjävrv around 1500 grains cm⁻² y⁻¹ stand out and are in the range of generally high modern trap values. Perhaps these high fossil values document the fluvial input of *Cyperaceae* pollen from adjacent wetlands.

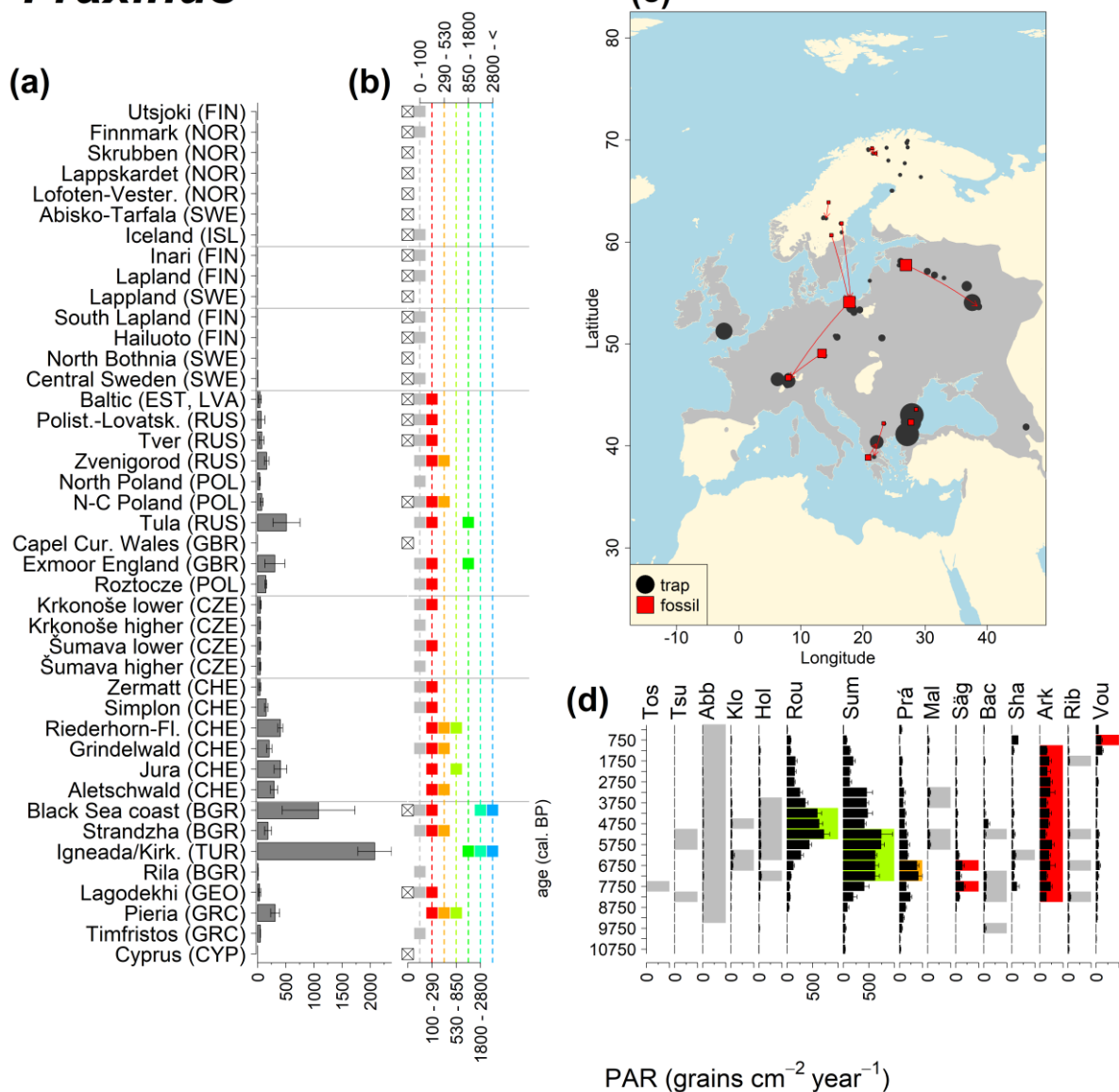
Fagus



Fagus

PAR of more than 3300 grains cm⁻² y⁻¹ are found in pollen traps in Poland and Georgia and values above 2100 occur in traps from the Strandza, Šumava and Jura mountains, in southern Bulgaria, Czechia and Switzerland respectively. Two species of *Fagus* contribute to the pollen type with *Fagus sylvatica* as the dominant tree across much of Europe and *F. orientalis* occurring in southern Bulgaria, Turkey and Georgia. Fossil PAR increase around 8000 cal. BP at the Bulgarian Black Sea coast, around 7000 in the Šumava mountains and 1500 years ago in northern Poland. High values in Šumava and northern Poland match the values in adjacent traps. Hardly any *Fagus* pollen occurs in pollen traps outside its modern distribution except sporadic appearances in Tula and the two northernmost trap areas. However, *Fagus* pollen occurs regularly at fossil sites that were assumed to have never been within the distribution of the tree, such as the sites in central Sweden, where *Fagus* grains occurred regularly over the last 3000 years.

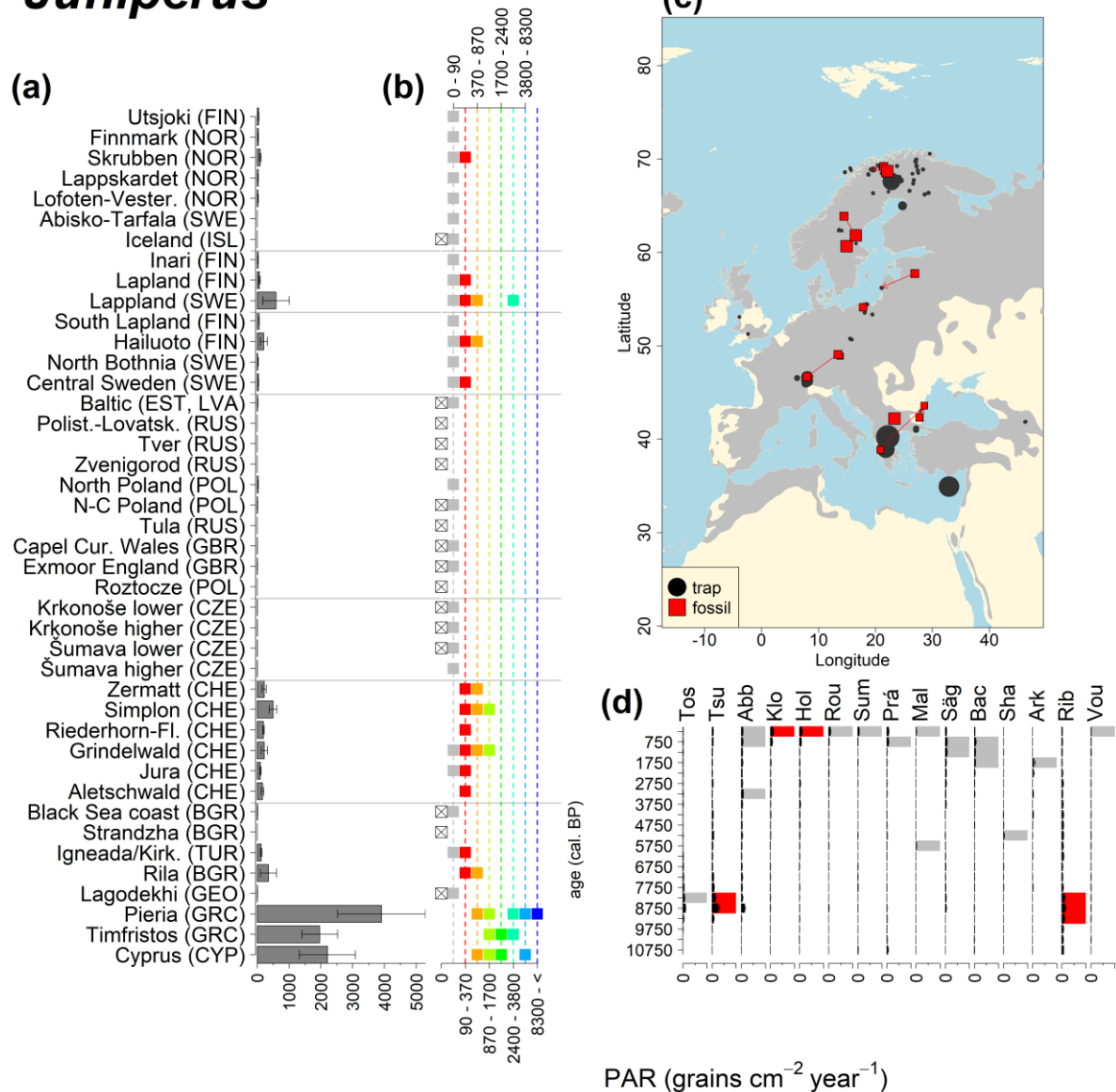
Fraxinus



Fraxinus

Highest PAR of *Fraxinus* 1800-3500 grains cm⁻² y⁻¹ were monitored in stands of *F. angustifolia* near the Black Sea coast and in European Turkey. Both areas also host the rest of the European *Fraxinus* species (*F. excelsior*, *F. pallisea* and *F. ornus*). Maximal PAR of solely *F. excelsior* 850-1800 grains cm⁻² y⁻¹ are found in pollen traps from southern England and Tula (Russia). Fossil PAR from Prášílské (Šumava), Suminko (north Poland), Rõuge Tõugjärv (Estonia) show maxima with up to 290-1800 grains cm⁻² y⁻¹ during the Middle Holocene, which correspond to the average deposition in pollen traps from the Jura and Tula region in Russia. Modern PAR in Šumava and Estonia are lower than fossil values consistent with the interpretation that this warmth demanding tree has shifted its distribution limit south and downslope. PAR above 100 grains cm⁻² y⁻¹ occur at most traps within the distribution of the genus, while traps outside the range collect individual grains of *Fraxinus* pollen.

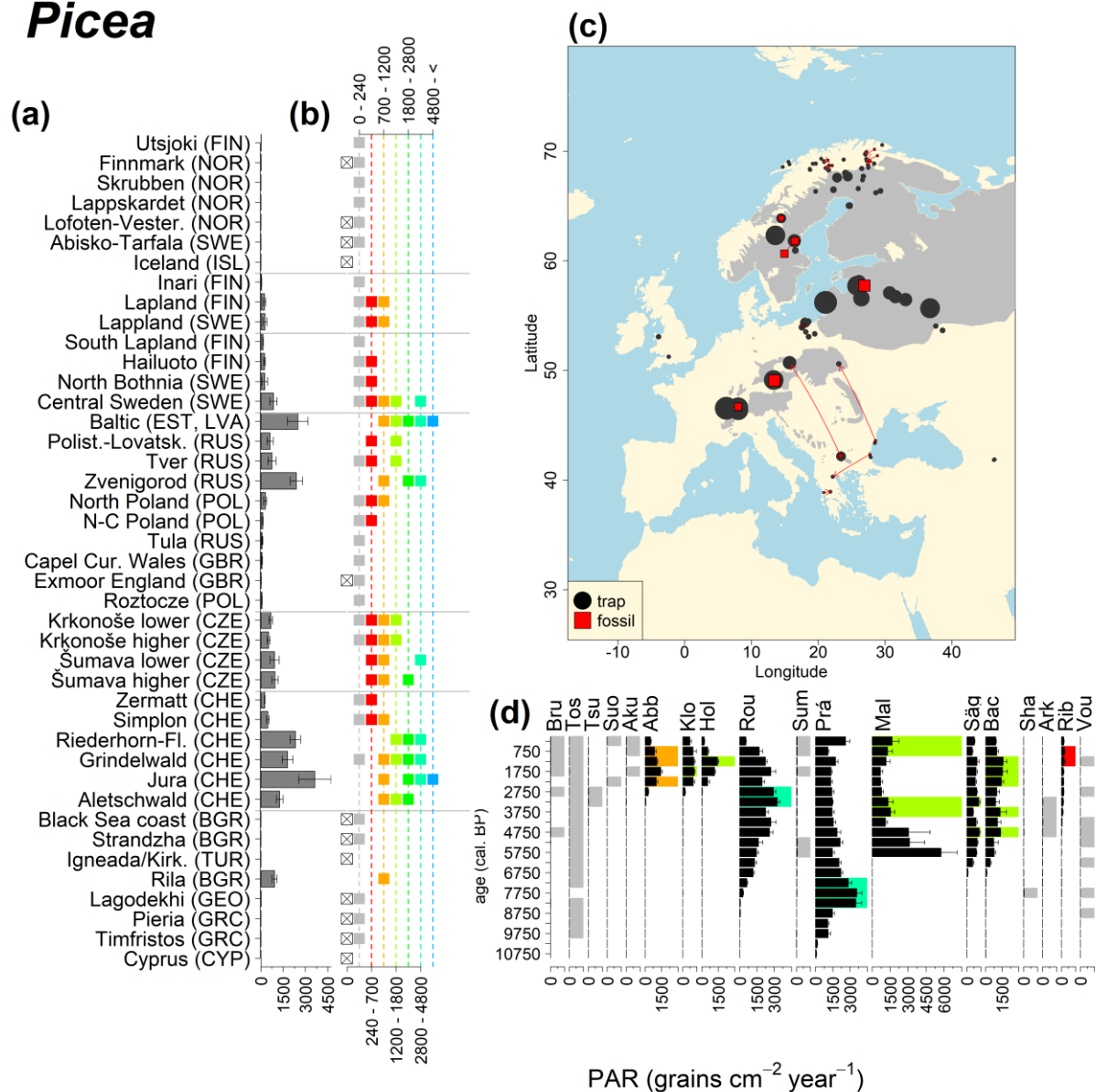
Juniperus



Juniperus

Highest modern PAR above 870 grains cm⁻² y⁻¹ come from treeline situations in Lapland, the Alps and on mountains in Greece and Cyprus. While *Juniperus communis* is the only species in the genus in northern Europe the genus has more species occurring in southern Europe and also pollen of *Cupressus sempervirens* or other ornamental Cupressaceae may be included. Fossil values from the sites selected here range below 370 grains cm⁻² y⁻¹ and date to the early Holocene and the last centuries. Late Glacial pollen records from central and western Europe often show distinct peaks in *Juniperus* pollen either at the time of forest establishment during the Bølling-Allerød and/or during the climate-induced opening of the forest in the Younger Dryas. These peaks may reach values of 4000 to 10,000 grains cm⁻² y⁻¹ (e.g. Soppensee, Lotter 1999) and thus even the closest situations at the treeline do not hold as dense a population of *Juniperus* as must have been present at Late Glacial situations.

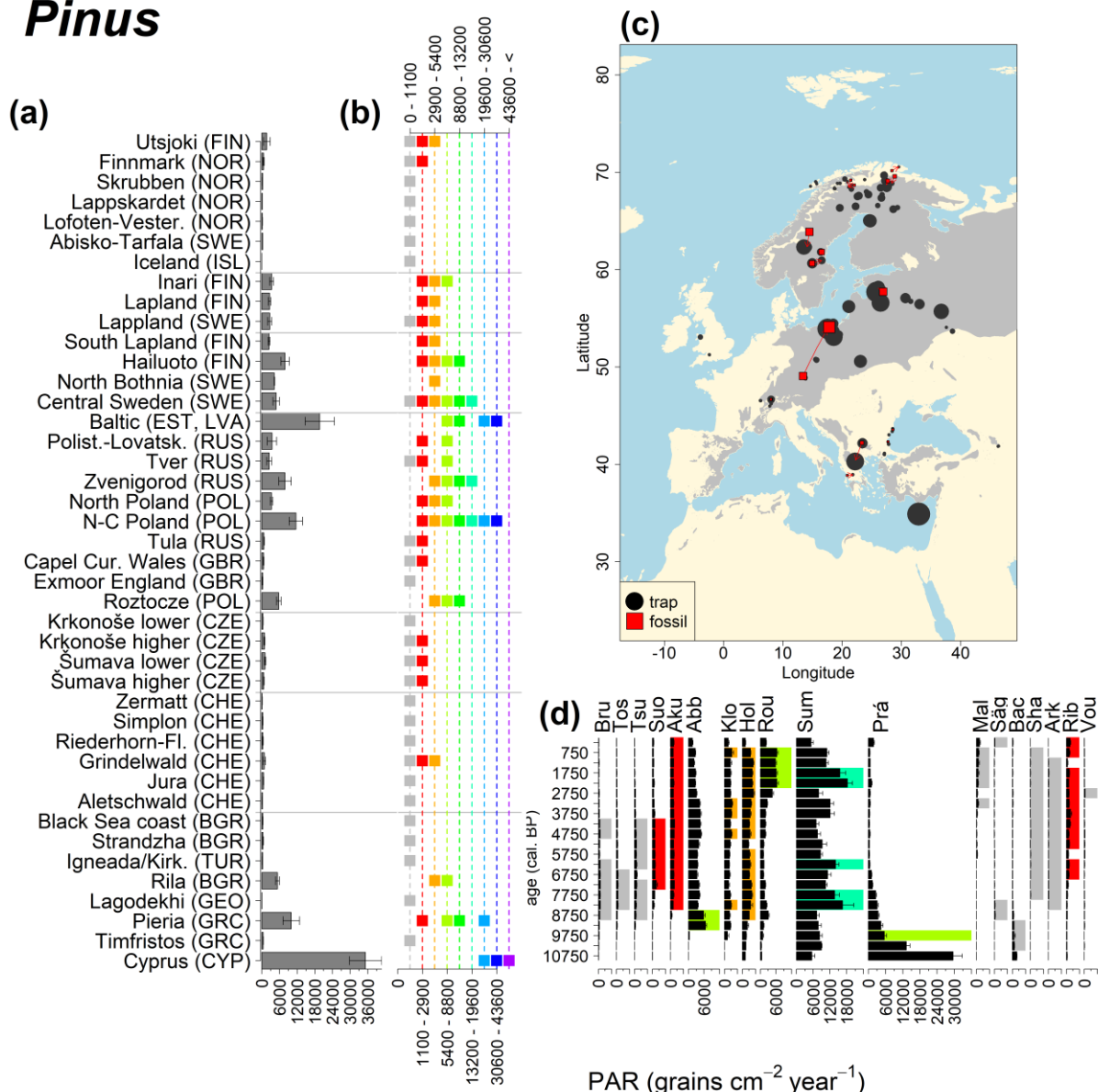
Picea



Picea

Modern *Picea* PAR above 2800 grains cm⁻² y⁻¹ are present in traps from Central Sweden, the Baltic region, Russia, Šumava mountains and the Alps. While some of the modern *Picea* pollen may be released by planted non-native *Picea sitchensis* and *P. pungens*, most of the pollen comes from *Picea abies*, which is also planted in many European regions outside its natural distribution. The highest fossil values in the selection of sites come from the Šumava mountains and are comparable to high trap values from the same region although at lower elevations. Noteworthy are also the generally low fossil *Picea* PAR for sites in Central Sweden and Tver region, where the tree is dominating or co-dominating the forest for the last 2000 years. Most pollen traps from beyond the distribution area of *Picea* collect individual *Picea* pollen.

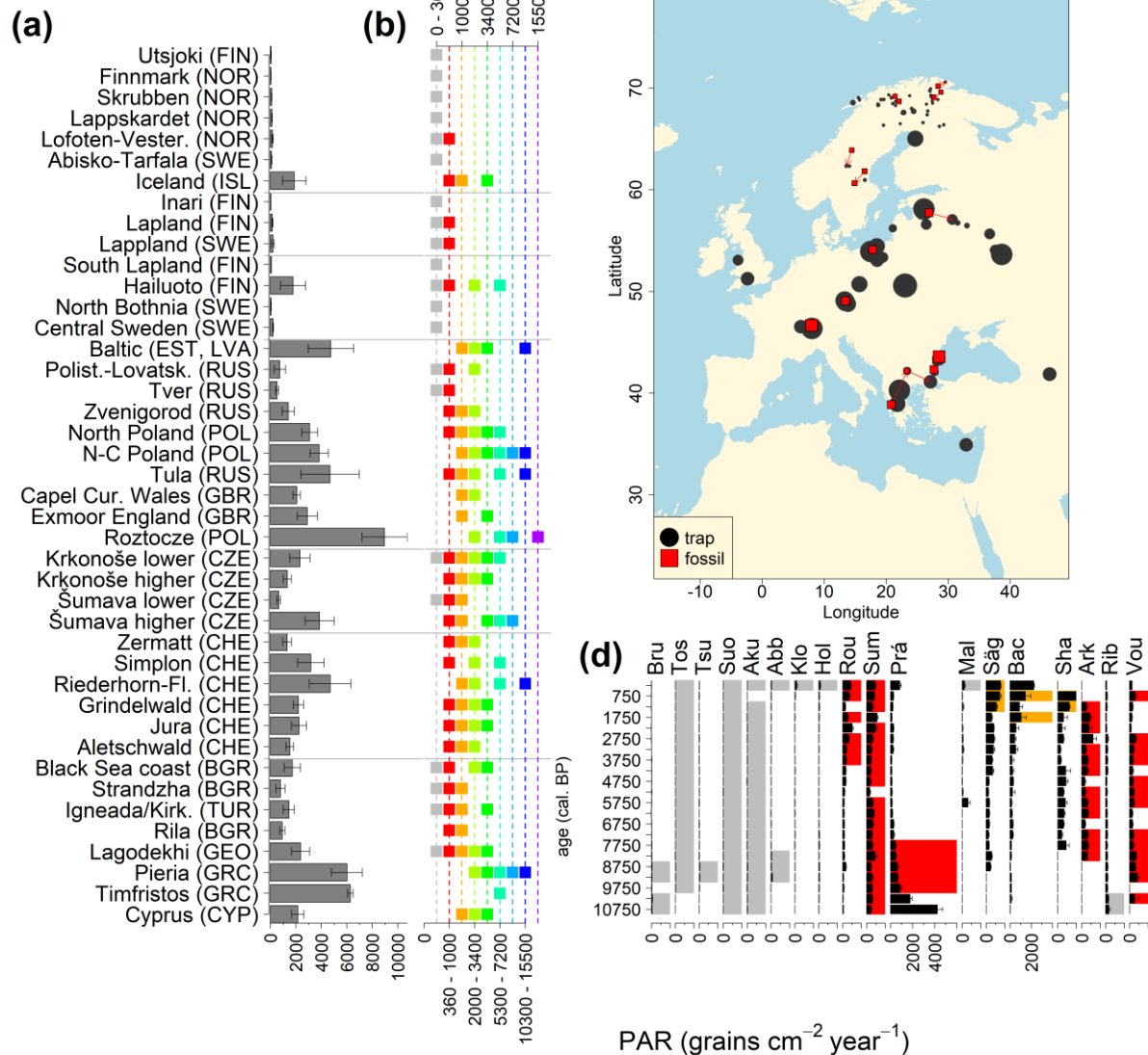
Pinus



Pinus

Highest modern PAR exceeding 43600 grains cm⁻² y⁻¹ are observed in traps on Cyprus, while the values in traps from the northern boreal forest often stay below 5400 grains cm⁻² y⁻¹. *Pinus* PAR values increase from Finnmark (2000 grains cm⁻² y⁻¹) and central Sweden (5000 grains cm⁻² y⁻¹) to the Baltic and north-central Poland with 35000 grains cm⁻² y⁻¹. In northern Europe nearly all *Pinus* pollen comes from *P. sylvestris*, while southern European trapping sites have a higher diversity of trees within the subgenus *Diploxylon* including *P. mugo*, *P. nigra*, *P. brutia* and *P. halapensis*. Pollen of both *Haploxylon* pines *P. cembra* in Alps and *P. peuce* in Rila was separated. High fossil *Pinus* PAR values are estimated for Suminko in northern Poland, matching modern trap values from the same region. In the Šumava mountains *Pinus* was possibly the dominant forest tree during the Early Holocene and declined thereafter, so that modern values from north-central Poland provide the nearest analogue to the Early Holocene situation. The lowest *Pinus* PAR (<125 grains cm⁻² y⁻¹) are found in taps from Iceland (2-5 grains cm⁻² y⁻¹), Lagodekhi and most of the traps from Lofoten-Vesterålen (38-125 grains cm⁻² y⁻¹) and single traps from Lappskaudet, Exmoor England and Zermatt.

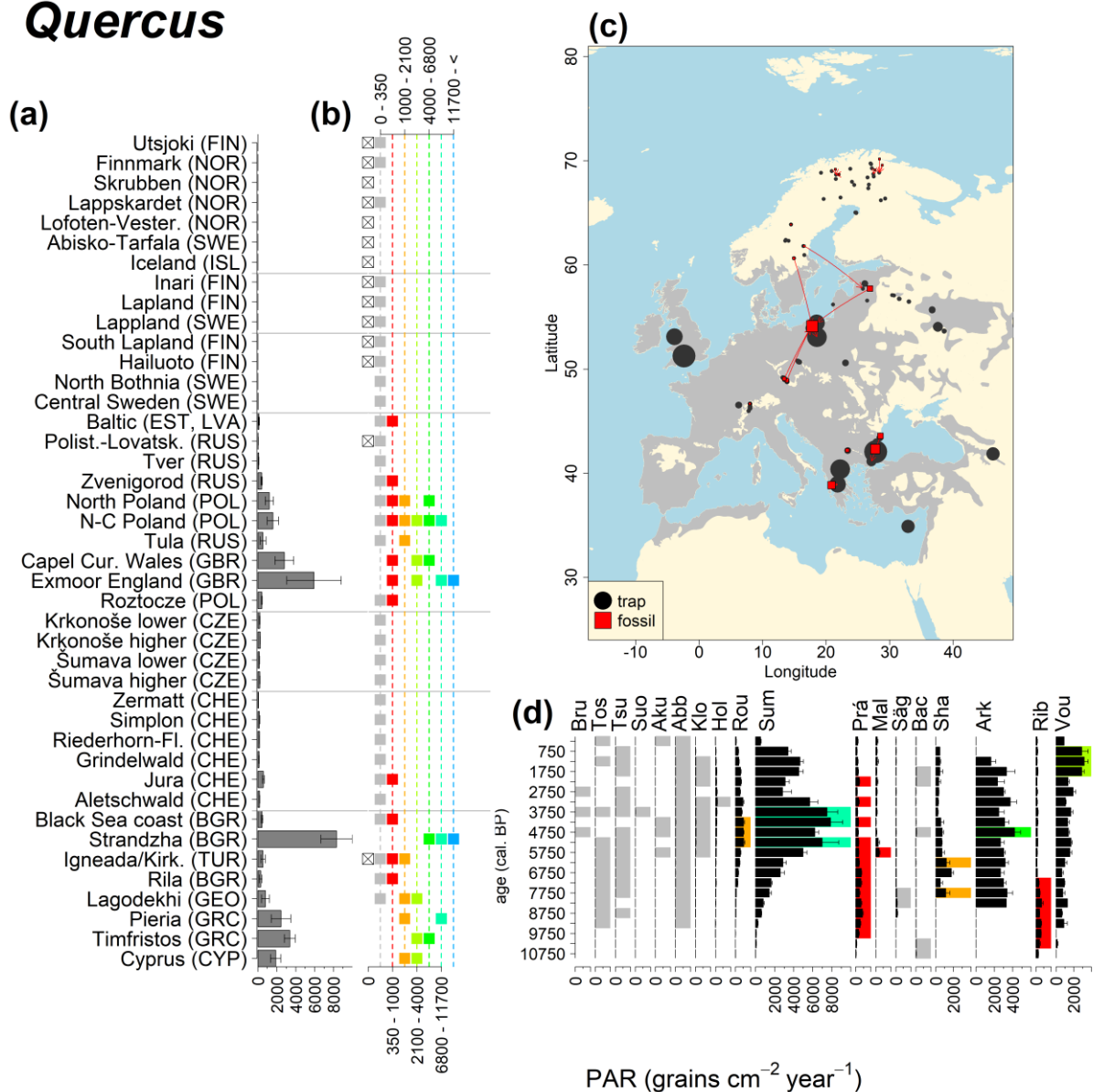
Poaceae



Poaceae

As for Cyperaceae, more Poaceae pollen is deposited in the pollen traps compared to fossil PAR estimates. Pollen traps near the Black Sea coast in northern Bulgaria are placed in situations where tree cover may be naturally low due to shallow soils on limestone. Traps from this area reach average values of up to 5300 grains $\text{cm}^{-2} \text{y}^{-1}$ and may give some guidance on the pollen deposition in low productivity grasslands. Fossil estimates from the two Alpine lakes are interesting as Poaceae PAR increase to values around 1500 grains $\text{cm}^{-2} \text{y}^{-1}$ as the treeline recedes to below the sites. The higher values in the pollen traps from this region, as well as elsewhere, are likely due to the local growth of grasses beside the trap, possibly overgrowing it. Poaceae PAR at Rõuge Tõugjärv increase with the deforestation of the area while at Suminko values are generally high during the Holocene also the PAR for other taxa is generally high at the two sites suggesting that these are caused by lake internal processes values. Middle Holocene values between 500 and 1000 grains $\text{cm}^{-2} \text{y}^{-1}$ at Shabla are consistent with the above interpretation that the vegetation near the Black Sea coast of northern Bulgaria was partly open.

Quercus



Quercus

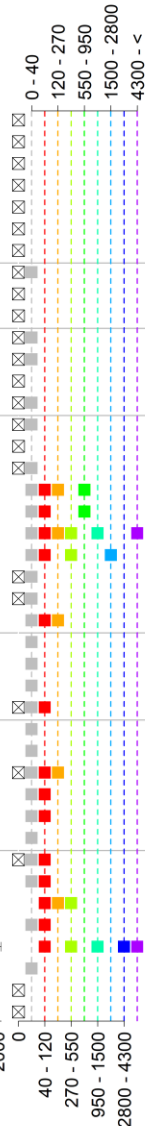
Modern PAR of *Quercus* within the area of distribution of a parent tree in the genus range between 620-15000 grains cm⁻² y⁻¹. The highest modern values (6000-15000 grains cm⁻² y⁻¹) are found in the traps from the UK, Poland and the southern Balkans. The first two areas host only species belonging to the *Q. robur*-type, whereas the two latter also include species from *Q. cerris*-type and *Q. ilex*-type. PAR to about 1300 grains cm⁻² y⁻¹ are estimated for Rõuge Tõugjärv near the distribution limit of *Quercus robur* where the tree only became abundant after 7000 years ago. *Quercus robur* reached its maximum abundance even later in central Sweden where the PAR at Holtjärnen around 3200 years ago suggest its presence. The pollen seems to disperse well and is found in small amounts in most pollen traps beyond its distribution area and fossils samples far to the north of the distribution have also collected *Quercus* pollen during the Holocene, which may be partly due to the abundance of trees of this genus in Europe.

Tilia

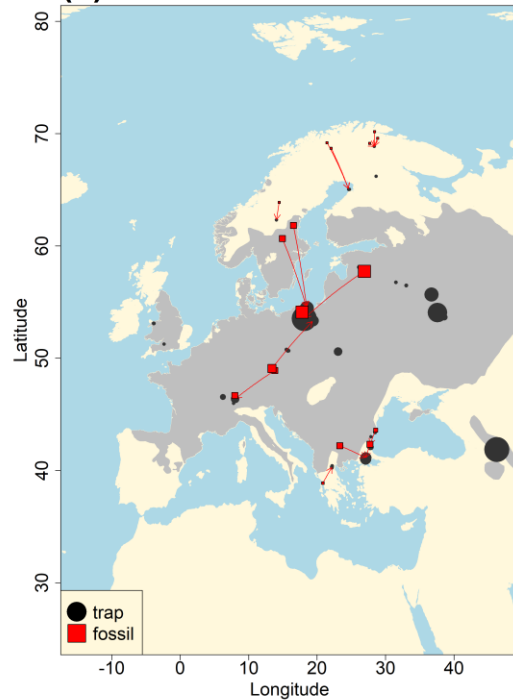
(a)

Utsjoki (FIN)
Finnmark (NOR)
Skrubben (NOR)
Lappskardet (NOR)
Lofoten-Vester. (NOR)
Abisko-Tarfala (SWE)
Iceland (ISL)
Inari (FIN)
Lapland (FIN)
Lapland (SWE)
South Lapland (FIN)
Hailuoto (FIN)
North Bothnia (SWE)
Central Sweden (SWE)
Baltic (EST, LVA)
Polist.-Lovatsk. (RUS)
Tver (RUS)
Zvenigorod (RUS)
North Poland (POL)
N-C Poland (POL)
Tula (RUS)
Capel Cur. Wales (GBR)
Exmoor England (GBR)
Roztocze (POL)
Krkonos lower (CZE)
Krkonos higher (CZE)
Šumava lower (CZE)
Šumava higher (CZE)
Zermatt (CHE)
Simplon (CHE)
Riederhorn-Fl. (CHE)
Grindelwald (CHE)
Jura (CHE)
Aletschwald (CHE)
Black Sea coast (BGR)
Strandzha (BGR)
Igneada/Kirk. (TUR)
Rila (BGR)
Lagodekhi (GEO)
Pieria (GRC)
Timfristos (GRC)
Cyprus (CYP)

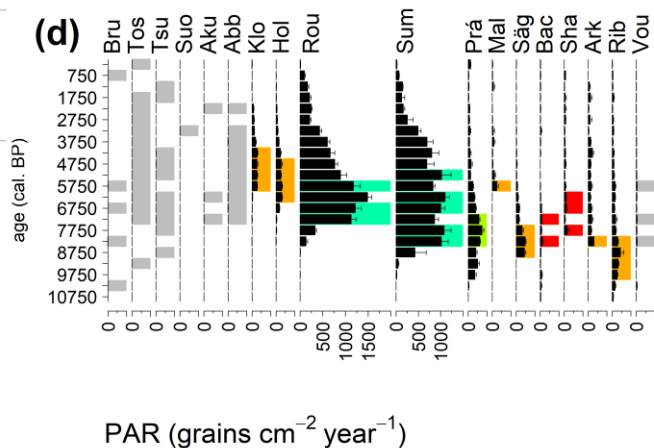
(b)



(c)



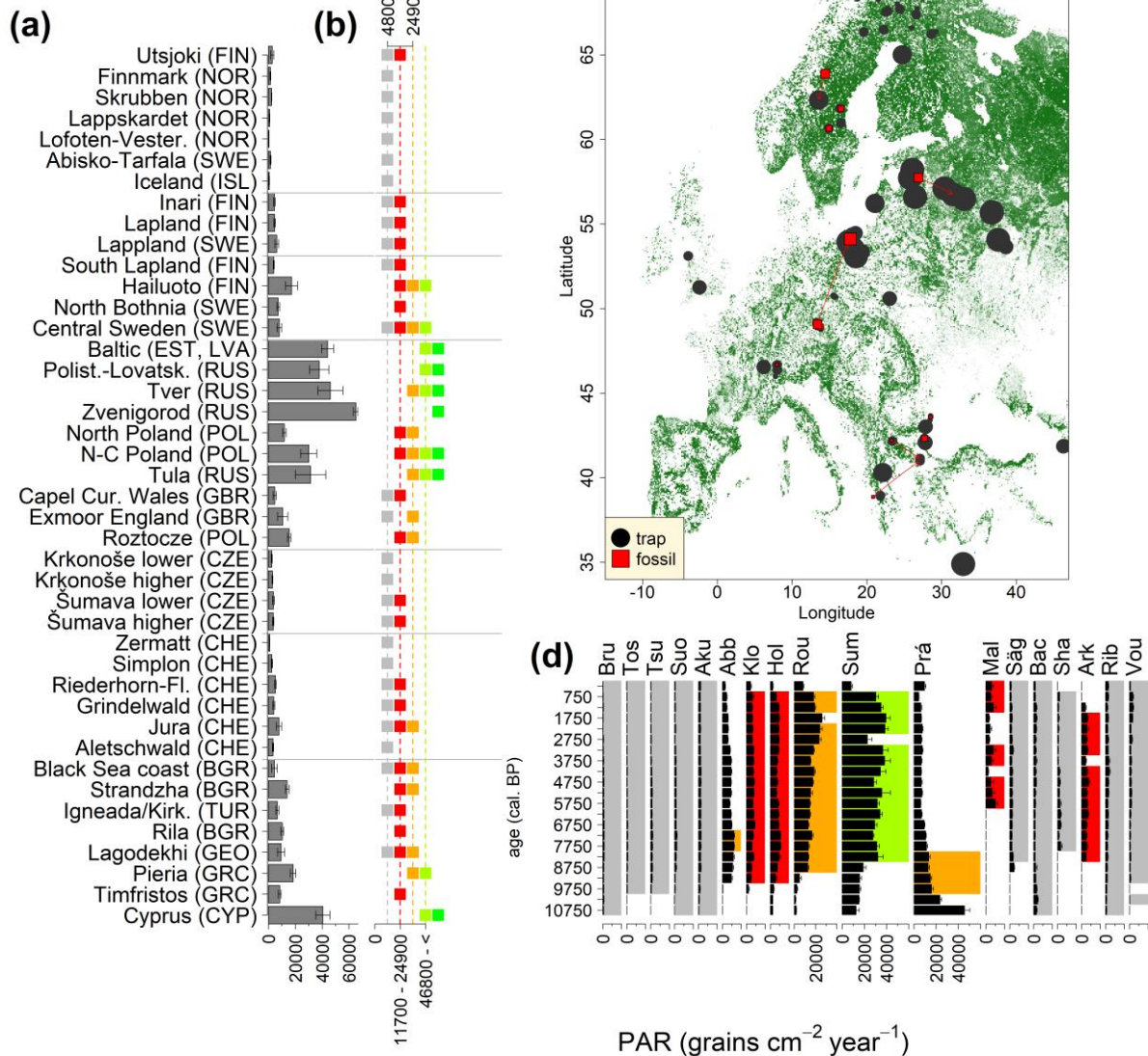
(d)



Tilia

The highest modern PAR 1500–4700 grains $\text{cm}^{-2} \text{y}^{-1}$ was measured in Poland, European Russia (Tula) and Lagodekhi in Georgia; however, this high range has no comparison in the fossil record. Lower values 120–1500 grains $\text{cm}^{-2} \text{y}^{-1}$ were found in traps from European Turkey and the Alps. The highest fossil PAR 270–1500 was measured in middle altitude and lowland temperate zone during the Middle Holocene. The closest trap analogues to them are in North Poland. Sites on the current edge of *Tilia* distribution and in the mountains (Central Sweden, Alps and Rila) show highest PAR range 120–270 grains $\text{cm}^{-2} \text{y}^{-1}$, also during the Middle Holocene. Trap records corresponding to the lowest class and above the LDT (5–40 grains $\text{cm}^{-2} \text{y}^{-1}$) appear in sites within distribution limit of *Tilia* (Baltic, European Russia, Poland), on its edge (Central Sweden, Wales, Black Sea Coast, Greece) or in the mountains (Šumava, Alps).

arboreal pollen



Trees

Here the minimum rather than the maximum values may be of particular interest as PAR were utilized in early applications to distinguish between generally open and forested landscapes (Davis and Deevey, 1964). Trap areas with the lowest mean arboreal pollen influx below 1000 grains cm⁻² y⁻¹ are Iceland, Lofoten-Vesterålen and Zermatt in the Alps. As discussed within the main manuscript highest tree PAR are found in traps from Poland, the Baltic and Russia with values between 46400-86200 grains cm⁻² y⁻¹. Such high PAR are not estimated in any of the fossil sites selected here and may be partly due to traps placed under the canopy of trees as well as the recent carbon dioxide fertilization. The highest fossil values are estimated from the sediments of Suminko. PAR for several individual taxa from this site are the highest in comparison with the other selected fossil sites raising suspicion that lake internal processes such as the focussing of sediments in this steep sided basin may be responsible for the high values rather than the exceptional high abundance and pollen production of trees near the site. Also PAR from Rouge Tougjärv may be biased as the small lake has a big incoming stream bringing waterborne pollen to the lake. It is interesting to note that PAR in sites near the latitudinal treeline are like those from the altitudinal treeline in the Alps. The

comparably low tree PAR from sites near the Black and Ionian Sea coast may be explained by the fact that trees are not growing on water and thus a large proportion of the potential pollen source area is not producing any pollen.

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