

# Historical floras reflect broad shifts in flowering phenology in response to a warming climate

## APPENDIX S1

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## SUPPLEMENTARY TABLES

**Table S1.** Dates of publication of earliest provincial flora for each Swedish province, according to search on the Swedish national library website. July temperatures are the warmest and coolest 4 × 4 km grid square within each province for the 1961-1990 reference period. Note that the number of provinces does not equal 29 (stated in text as total number of Swedish provinces), because Lappland is now divided into a number of smaller sub-provinces for more recent floras.

Province	Year	Min July Temp	Max July Temp	Reference
Ångermanland	1990	12.02		15.6 Mascher, J.W., 1990, Ångermanlands flora, Lund: Svensk botanisk tidskrift Gosselman, C.A., 1865, Blekinges flora, eller systematisk förteckning på de i Blekinge vildt växande fanerogamer och bräkenväxter.
Blekinge	1865	15.33		16.3 Lund: Krook
Bohuslän	1927	15.14		16.74 Palmér, J. E., 1927, Förteckning över Göteborgs och Bohus läns fanerogamer och kärlekryptogamer.
Dalarna	1843	9.98		16.22 Kröningsvärd, C.G., 1843, Flora Darlekarlica: landskapet Dalarnes indigéna phanerogamer och filices.
Dalsland	1859	14.77		16.09 Larsson, L.M., 1859, Flora öfver Wermland och Dal. Carlstad: Kjellin
Gästrikland	1979	14.03		16.21 Lindberg, E., 1979, Gästriklands kärleväxter. Gävle: Naturvännernas fören.
Gotland	1856	15.71		16.42 Hufvuddragen af Gotlands växttopografi och växtgeografi, grundade på en kritisk behandling af dess kärleväxtflora
Halland	1883	14.73		16.46 Neuman, L.M., 1883, Studier öfver Skånes och Hallands flora: botanisk afhandling, Diss. Lund : Univ., Lund
Hälsingland	2019	12.71		15.76 Delin, A., Larsson, A., Wannberg, B., 2019,. Hälsinglands flora. Uppsala: SBF-förlaget
Härjedalen	1994	6.48		14.28 Danielsson, B., 1994, , Härjedalens kärleväxtflora, SBT-förlaget, Lund
Jämtland	1938	6.48		15.05 Lange, T., 1938, Jämtlands kärleväxtflora, Helsingforsiae von Linné, C., 1737, Flora Lapponica exhibens plantas per Lapponiam crescentes, secundum systema sexuale collectas in itinere
Lappland	1737	3.27		15.06 impensis Soc. Reg. Litter. et Scient. Sveciæ A.
Medelpad	1877	12.55		15.53 Seth, K.A.T., 1877, Växtgeografiska bidrag till Medelpads flora, Botaniska notiser 1839: 82-84 Gellerstedt, J. D., 1852, Nerikes flora eller Kort beskrifning af Nerikes vilda växters kännetecken, till den studerande ungdomens tjänst,
Närke	1831	15.08		16.42 Lindh, Örebro
Norrbotten	1956	12.21		15.75 Du Rietz, G. E., 1956, Regionala huvuddrag i Västerbottens och Norrbottens flora, Natur i Västerbotten och Norrbotten: 64-77
Öland	1863	15.78		16.68 Sjöstrand, M.G., 1863, Calmar läns och Ölands flora, Calmar: Almquist
Östergötland	1861	14.89		16.75 Kindberg, N.C., 1861, Östgöta flora: (fanerogamerna). Linköping: Sahlström
Skåne	1838	15.01		16.85 Lilja, N., 1838, Skånes flora
Småland	1864	14.18		16.68 Scheutz, N.J.W., 1864, Smålands flora: innefattande Kronobergs och Jönköpings läns fanerogamer och ormbunkar. Wexjö: Södergren
Södermanland	1852	15.82		17.05 Hofberg, H., 1852,. Södermanlands phanerogamer och filices. Stockholm:
Uppland	1820	15.68		17.05 Wahlenberg, G., 1820, Flora Upsaliensis enumerans plantas circa Upsaliam sponte crescentes. Uppsala: Acad. Typographorum
Värmland	1859	12.33		16.58 Larsson, L.M., 1859, Flora öfver Wermland och Dal. Carlstad: Kjellin
Västerbotten	1933	12.95		15.4 Ilien, G., 1933, Bidrag till kännedomen om Västerbottens flora, Umeå
Västergötland	1967	14.23		16.74 Hasselrot, K., 1967, Västergötlands flora: förteckning över kärleväxter, Statens naturvetenskapliga forskningsråd, Stockholm
Västmanland	1852	14.16		16.70 Wall, W.A., 1852, Westmanlands flora innefattande provinsen Westmanlands vilda phanerogamer och filices. Stockholm: Norstedt

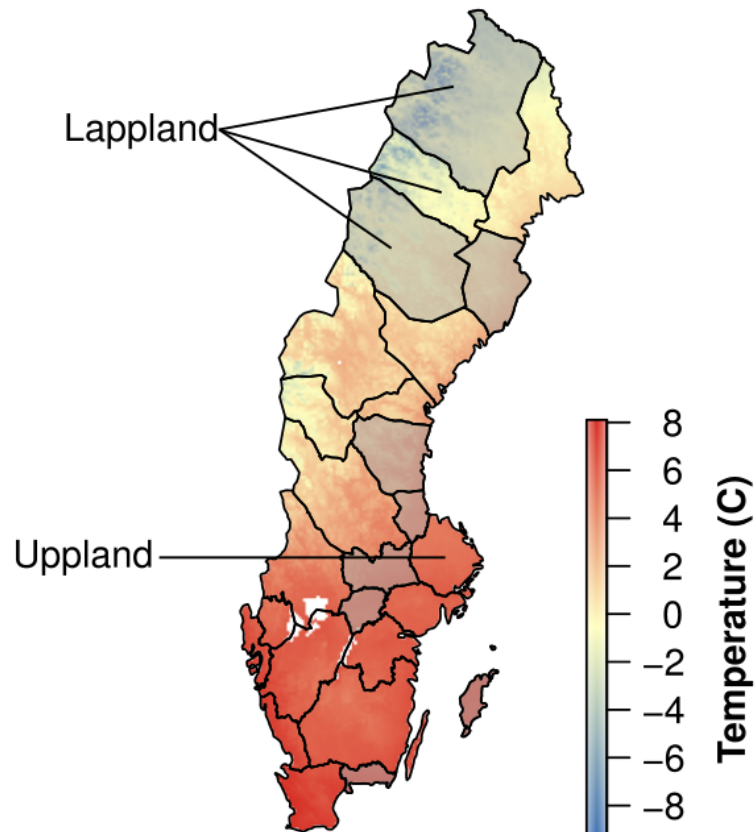
**Table S2.** Outputs of linear mixed models and bootstrapped 95% confidence intervals linking phenological shifts of 241 species (199 random and 42 phenology species) across using data from historical floras. *Time* models use year of publication as response variable and floras from 1798-2018. Rates of change in days per decade reported in the paper are (unrounded) parameter estimates and confidence intervals multiplied by 304. *Temperature* models use temperature anomalies over Sweden for the 30 year period preceding publication for floras published 1901-2018 (temp). HerbResid refers to the residual effect of increasing herbarium samples on flowering phenology (see Methods).

Response	Predictor	Estimate	Standard Error	T-value	CI-lower	CI-upper
<i>Time – all species</i>						
Start	(Intercept)	9.02	0.525	17.2	7.82	10
Start	Year	-0.00162	0.00027	-6	-0.00213	-0.00101
Start	HerbResid	0.00539	0.0181	0.298	-0.0333	0.0438
<i>GLMM R2 Marginal: 0.011 , Conditional: 0.86</i>						
Stop	(Intercept)	2.73	1	2.72	0.759	4.58
Stop	Year	0.00232	0.000518	4.48	0.00134	0.00335
Stop	HerbResid	-0.046	0.0346	-1.33	-0.114	0.0279
<i>GLMM R2 Marginal: 0.016, Conditional: 0.83</i>						
Length	(Intercept)	-5.27	1.03	-5.13	-7.3	-3.06
Length	Year	0.00393	0.000533	7.37	0.00278	0.00498
Length	HerbResid	-0.0468	0.0356	-1.31	-0.12	0.0175
<i>GLMM R2 Marginal: 0.087, Conditional: 0.6</i>						
<i>Time – random species</i>						
Start	(Intercept)	9.34	0.553	16.9	8.18	10.4
Start	Year	-0.00169	0.000285	-5.91	-0.00224	-0.00109
Start	HerbResid	0.00753	0.0192	0.393	-0.028	0.0437
<i>GLMM R2 Marginal: 0.016, Conditional: 0.81</i>						
Stop	(Intercept)	2.33	0.923	2.53	0.422	4.22
Stop	Year	0.00263	0.000478	5.5	0.00166	0.00364
Stop	HerbResid	-0.0284	0.032	-0.886	-0.0878	0.0362
<i>GLMM R2 Marginal: 0.024, Conditional: 0.8</i>						
Length	(Intercept)	-5.98	1.05	-5.7	-7.88	-3.89
Length	Year	0.00431	0.000544	7.91	0.00321	0.0053
Length	HerbResid	-0.0319	0.0365	-0.873	-0.103	0.0419
<i>GLMM R2 Marginal: 0.097, Conditional: 0.62</i>						

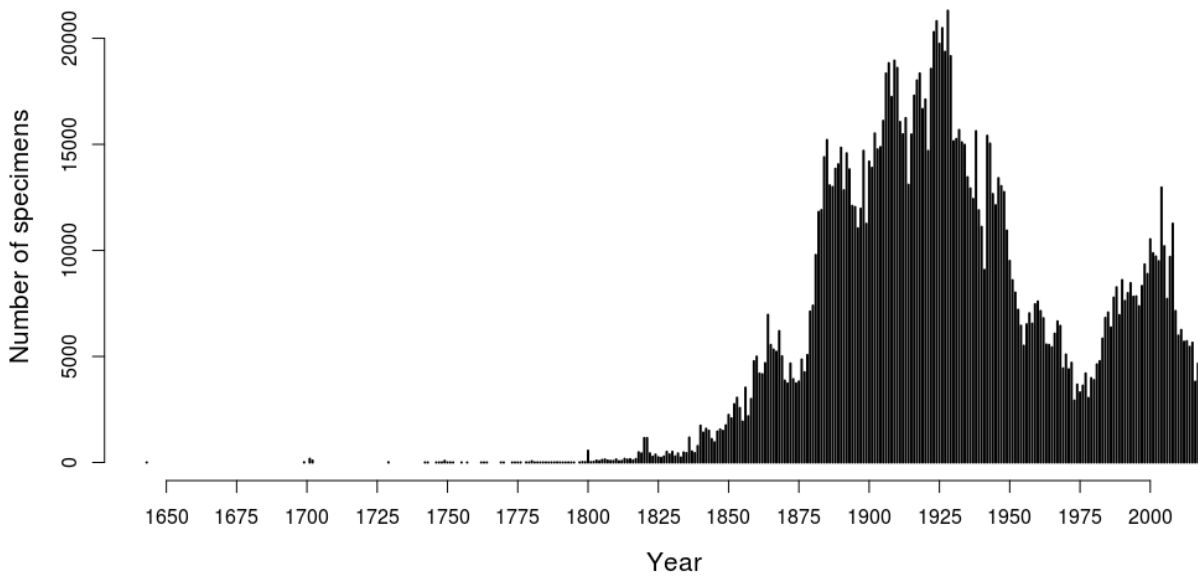
Response	Predictor	Estimate	Standard Error	T-value	CI-lower	CI-upper
<b><i>Time – phenology species</i></b>						
Start	(Intercept)	7.52	0.694	10.8	6.07	8.95
Start	Year	-0.0013	0.000349	-3.74	-0.00201	-0.000608
Start	HerbResid	-0.00807	0.0229	-0.352	-0.0556	0.0397
<i>GLMM R2 Marginal: 0.005, Conditional: 0.9</i>						
Stop	(Intercept)	4.5	1.47	3.06	1.92	7.62
Stop	Year	0.0009	0.000757	1.19	-0.000618	0.0022
Stop	HerbResid	-0.121	0.0499	-2.42	-0.218	-0.0114
<i>GLMM R2 Marginal: 0.009, Conditional: 0.87</i>						
Length	(Intercept)	-1.95	1.1	-1.77	-4.2	0.197
Length	Year	0.00217	0.00057	3.8	0.000999	0.00337
Length	HerbResid	-0.106	0.0375	-2.83	-0.176	-0.0385
<i>GLMM R2 Marginal: 0.052, Conditional: 0.54</i>						
<b><i>Temperature – all species</i></b>						
Start	(Intercept)	5.87	0.0661	88.8	5.75	6
Start	Temp	-0.112	0.0448	-2.49	-0.199	-0.0152
Start	HerbResid	-0.0333	0.0205	-1.62	-0.0743	0.00619
<i>GLMM R2 Marginal: 0.003, Conditional: 0.87</i>						
Stop	(Intercept)	7.29	0.0884	82.5	7.1	7.45
Stop	Temp	0.0292	0.0865	0.337	-0.143	0.221
Stop	HerbResid	-0.016	0.0395	-0.405	-0.0941	0.0659
<i>GLMM R2 Marginal: 0.0002, Conditional: 0.87</i>						
Length	(Intercept)	2.43	0.0583	41.6	2.31	2.55
Length	Temp	0.14	0.0747	1.88	-0.0213	0.282
Length	HerbResid	0.0154	0.0342	0.451	-0.0476	0.0849
<i>GLMM R2 Marginal: 0.005, Conditional: 0.66</i>						
<b><i>Temperature – random species</i></b>						
Start	(Intercept)	6.05	0.0643	94	5.92	6.17
Start	Temp	-0.0854	0.0576	-1.48	-0.194	0.0325
Start	HerbResid	-0.0195	0.0326	-0.6	-0.0813	0.0473
<i>GLMM R2 Marginal: 0.004, Conditional: 0.83</i>						

Response	Predictor	Estimate	Standard Error	T-value	CI-lower	CI-upper
Stop	(Intercept)	7.5	0.0856	87.6	7.33	7.65
Stop	Temp	0.0812	0.0816	0.995	-0.0794	0.259
Stop	HerbResid	-0.0132	0.046	-0.288	-0.103	0.0706
<i>GLMM R2 Marginal: 0.0008 , Conditional:0.84</i>						
Length	(Intercept)	2.45	0.0639	38.4	2.31	2.58
Length	Temp	0.163	0.0802	2.04	-0.00217	0.306
Length	HerbResid	0.00938	0.0455	0.206	-0.0874	0.0953
<i>GLMM R2 Marginal: 0.008 , Conditional: 0.67</i>						
<b><i>Temperature – phenology species</i></b>						
Start	(Intercept)	5.01	0.171	29.3	4.68	5.37
Start	Temp	-0.157	0.0731	-2.14	-0.287	-0.00688
Start	HerbResid	-0.0247	0.0414	-0.597	-0.0988	0.0599
<i>GLMM R2 Marginal: 0.0064, Conditional: 0.91</i>						
Stop	(Intercept)	6.31	0.205	30.7	5.86	6.72
Stop	Temp	-0.0675	0.151	-0.447	-0.371	0.236
Stop	HerbResid	-0.136	0.084	-1.62	-0.316	0.0342
<i>GLMM R2 Marginal: 0.0073, Conditional: 0.89</i>						
Length	(Intercept)	2.3	0.0943	24.4	2.1	2.5
Length	Temp	0.0893	0.113	0.793	-0.159	0.32
Length	HerbResid	-0.113	0.0634	-1.78	-0.228	0.0303
<i>GLMM R2 Marginal: 0.0004, Conditional: 0.57</i>						

## SUPPLEMENTARY FIGURES



**Figure S1.** Sweden's climatic gradient. Map shows gridded temperature data for mean annual temperature during the 1961-1990 reference period. Boundaries indicate the historical provinces of Sweden, with grey-shaded provinces those for which provincial flora data are not available. Labelled provinces are those with the warmest (Uppland) and coolest (Lapland) average temperatures.



**Figure S2.** Fluctuations in Sweden's herbarium record 1600-present. Bars show number of specimens that have been digitised as of spring 2020, which corresponds to approximately 46% of the total national collection. Up-to-date data available from <http://herbarium.emg.umu.se/>.