To the Editor

Regional calendars and seasonal statistics for the United Kingdom's main pollen allergens

Key words: hay fever, pollen calendar, pollen forecast

Pollen calendars are an effective way of bringing seasonal information to patients, healthcare professionals and pharmaceutical companies[1]. Until now there has only been one generalized pollen calendar available for the United Kingdom[2] and very limited access to any recent seasonal statistics[3]. Here we present a set of regional pollen calendars and associated statistics to bring up-to-date information to patients and other users and to demonstrate spatial variation in the pollen seasons.

The regional pollen calendars (Figure 1) were constructed using pollen data for the main allergenic types from the period 2004-2013, chosen as a period of time with a good representation of pollen monitoring sites and a wide variety of climatic conditions. Pollen station location, associated region and data details (Figure S1 & Table S1), plus additional methods, are provided in Supporting Information.

An important element of these calendars is to show ranges so that the user can see the time period for potential exposure to the various taxa. This will allow for future planning of treatments, trials or personal activities. The season range (given in light green in the calendars) indicates the earliest to latest appearance of each pollen type for the time period analysed but with non-seasonal tails removed, e.g. resuspended pollen at the end of the season or long-distance transport events[4]. The range bars for onset/end of season (given in darker green in the calendars) cover the earliest date for onset and the latest date for end of season using the 2.5/97.5% method of calculation. The range bars for the time-periods of likelihood of high and very high pollen counts (given in blue and purple respectively in the calendars) also show the earliest to the latest appearances for the years studied. Therefore, these duration bars show the periods of *potential* risk. Given that seasons vary in their start and end dates from year to year, in reality the season experienced in any one year will probably be shorter.

Seasonal statistics were calculated as mean values for each region, for various factors and presented with the regional calendars (Figure 1). Mean values for total pollen catch, the first high count day and the total number of high count days (high plus very high) were also calculated. The term 'high' is used when all hay fever sufferers are likely to be affected and 'very high' when many sufferers are likely to experience extensive symptoms and is the terminology used in pollen forecasting in the UK[5], which the public understand and are used to, although patients can vary in their individual response[6]. The indices are given as grains per cubic metre of air, daily average and are as follows: hazel, alder, ash, oak, plane and grass: Low ≤ 29, Moderate 30-49, High 50-149, Very High ≥ 150; birch and nettle family: Low ≤ 39, Moderate 40-79, High 80-199, Very High ≥ 200.

In addition, the averages for onset and end of season, mean number of high days and the mean first high count appearance, per pollen type, are presented to show seasonal variation across the UK (Tables S2-S7). The West Midlands region receives the greatest pollen burden, followed by South-Central, South-East England, East England and East Midlands, while Scotland carries the lowest risk (Figure S2).

Alder pollen had limited data but sufficient to show that Scotland has a substantially later start compared to other parts of the country (Scotland 13 March, other available regions 1 – 8 February)

(Table S2). The first high days for ash occur from first week of April but high counts don't occur in the Northern regions for this type (Table S3).

Birch pollen is an important aeroallergen in the UK, affecting at least 25% of hay fever sufferers[7]. The earliest mean onset usually occurs in South-East England with other regions in England and Wales just a few days behind. Scotland, Northern Ireland and the North of England have a short lag with the onset often occurring around 10-14th April (Table S4). Birch pollen seasons are often very mild in Scotland and Northern Ireland while those in the West Midlands and South-East England tend to be the most severe. The South-East region has the greatest amount of birch but also plane tree pollen, which particularly affects central London where this tree lines many streets. Oak tree pollen seasons are also very variable in their onset and severity both spatially and temporally (average difference 13 days between Scotland and the South-East of England) (Table S5), partly due to the differences in species growing in each region[8].

Grass pollen is the most important aeroallergen in the UK[9], with the onset occurring in late April if the Spring is very mild, but more usually in mid-late May, with the first high counts in late May to early June, or mid-June in Scotland and the far North of England (Table S6). Scotland, Northern Ireland and South-West England have milder seasons compared to other regions, while the West Midlands, the North-West and South-Central England are the regions of greatest risk. Nettle family pollen tends to follow a similar pattern to that of grass, with the mildest seasons in Scotland and Wales (Table S7).

Conclusion

Regional pollen calendars have been constructed and, along with the associated statistics, have provided accessible data for health care professionals (e.g. www.worcester.ac.uk/pollen). In addition, spatial and temporal differences and similarities in the UK's allergenic pollen seasons have been exposed. It is clear from this study that the West Midlands region experiences the greatest pollen burden overall, with both the largest number of high days and the greatest pollen integral for most pollen types. South-Central England, South-East England and East Midlands are also regions of extensive pollen load, while South-East England carries the greatest risk for tree pollen sufferers. The regions of the North-West, North-East, East England and South-West England receive plenty of pollen but their seasons don't tend to be quite so severe. Fewer high days and lower pollen integrals are found in the most northerly and western regions, including Scotland, Wales and Northern Ireland.

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Conflicts of interest

Carsten Ambelas Skjøth reports grants and personal fees from Natural Environment Research Council and Catherine Pashley reports grants and personal fees from Pulmocide Ltd, both outside the submitted work. None of the other authors have anything to declare.

Supplementary information

Additional methods

Although only one site is used for each region, it was deemed more user-friendly to use the name of the associated region in the study, rather than the lesser known pollen stations, which are detailed in Table S1. In total, data from 11 regional pollen stations were used from the period January to September for the years 2004-2013. Pollen stations that are in similar climatic/land-use regions can be a proxy for each other and therefore regional interpolation is feasible[10]. However, there will always be some very localized differences that a calendar cannot demonstrate. The regions and pollen stations used are the same as those included in the UK pollen forecasting system and broadly similar to those of the UK Met Office's weather forecast regions. Land-use, planting, land management and climate changes mean that earlier years of data are not representative of the more current years[11], consequently further updates will be required in years to come.

The data, measured in grains per cubic metre of air, daily average, had been collected using Burkard 7-day volumetric pollen and spore traps and standard pollen monitoring methods[12], which had been collated by the University of Worcester up to 2010 and by the UK Met Office from 2011 onwards.

At most UK pollen stations, only a particular suite of allergenic pollen types is monitored and collated between mid-March and September, apart from at Worcester and Leicester, which currently operate all year and count a wider range of types. Preston and Plymouth operated from January to September during the time period used here so have some earlier flowering pollen types available too. As a result, the types included in this research are as follows: ash (*Fraxinus* spp.), birch (*Betula* spp.), oak (*Quercus* spp.), grass (Poaceae) and nettle family (Urticaceae) for all regions; hazel (*Corylus* spp.) for North-West England, West and East Midlands and South-West England; alder (*Alnus* spp.) for Scotland, North-West England, West and East Midlands and SW England and plane (*Platanus* spp.) for the West and East Midlands, East England and South-East England.

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Scotland	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Alder										13/03	17/04			58
Ash										11/04	05/05		1	354
Birch										13/04	16/05	20/04	2	817
Oak										02/05	08/06		0	191
Grass										01/06	12/08	15/06	11	1920
Nettle family										09/06	24/08	29/06	5	1953

N Ireland	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Ash										05/04	06/05		2	567
Birch										09/04	11/05		1	475
Oak										06/05	31/05		0	183
Grass										25/05	11/08	07/06	17	3382
Nettle family										02/06	30/08	23/06	8	3036

NW England	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Hazel										21/01	28/03			193
Alder										01/02	22/03		2	875
Ash										12/04	11/05		2	858
Birch										10/04	04/05	14/04	7	1883
Oak										30/04	31/05	01/05	4	869
Grass										26/05	07/08	31/05	29	5747
Nettle family										02/06	02/09	09/06	24	5644

NE England	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Ash										01/04	09/05		2	787
Birch										09/04	11/05	13/04	7	2099
Oak										22/04	29/05	04/05	5	1090
Grass										21/05	08/08	11/06	19	3544
Nettle family										02/06	25/08	09/06	13	3029

Wales	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Ash										29/03	28/04	04/04	6	2043
Birch										05/04	04/05	15/04	7	2013
Oak										21/04	29/05	28/04	4	1206
Grass										27/05	05/08	04/06	21	3142
Nettle family										03/06	28/08	02/07	4	1700

W Midlands	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Hazel										19/01	07/04	12/02	1	461
Alder										05/02	25/03	23/02	5	1602
Ash										30/03	03/05	11/04	8	2252
Birch										04/04	04/05	05/04	13	3759
Plane										19/04	14/05	20/04	1	392
Oak										27/04	14/06	30/04	14	3979
Grass										21/05	14/08	02/06	31	6179
Nettle family										01/06	04/09	06/06	30	8077

E Midlands	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Hazel										30/01	04/04		0	222
Alder										04/02	04/04	22/02	4	1023
Ash										23/03	26/04	11/04	7	1150
Birch										08/04	08/05	13/04	8	2438
Plane										24/04	15/05	21/04	4	838
Oak										26/04	27/05	03/05	9	1710
Grass										24/05	08/08	03/06	24	4254
Nettle family										02/06	31/08	03/06	28	6800

E England	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Ash										01/04	02/05	06/04	5	1236
Birch										07/04	04/05	12/04	10	2816
Plane										19/04	15/05	25/04	3	871
Oak										25/04	06/06	29/04	5	1633
Grass										23/05	02/08	03/06	21	3556
Nettle family										02/06	28/08	04/06	34	7574

SW England	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Hazel										28/01	09/04			221
Alder										08/02	03/04	07/03	1	469
Ash										01/04	30/04	16/04	3	887
Birch										06/04	11/05	17/04	10	756
Oak										24/04	08/06	07/05	2	708
Grass										21/05	02/08	02/06	15	2697
Nettle family										28/05	25/08	05/06	12	3205

SC England	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Ash										30/03	08/05	07/04	5	1338
Birch										04/04	05/05	08/04	6	1797
Oak										24/04	06/06	30/04	7	2092
Grass										15/05	07/08	27/05	30	5076
Nettle family										15/05	27/08	30/05	32	6909

SE England	J	F	M	A	M	J	J	A	S	S	E	FH	NH	PI
Ash										28/03	08/05		5	1307
Birch										03/04	01/05	05/04	14	5475
Plane										17/04	17/05	21/04	12	4793
Oak										19/04	29/05	28/04	10	2556
Grass										22/05	06/08	22/05	24	3961
Nettle family										30/05	15/08	30/05	25	6504

Key to ranges/phases:

	Range from first low to last low count.
	Range season duration 2.5 - 97.5% method
	Phase when high counts can occur
	Phase when very high counts can occur

Fig. 1. Regional pollen calendars for the main types of allergenic pollen in the UK (January to September). The colour bars show ranges of likelihood of presence of pollen in the air for the studied time period (2004-2013), season start and end for 2.5/97.5% method, and phases when high and very high counts are possible (see key). Also shown are the mean start (S) and end (E) dates for each season, the mean first high (FH) date, mean number of high count days (NH) and mean pollen integral (PI).

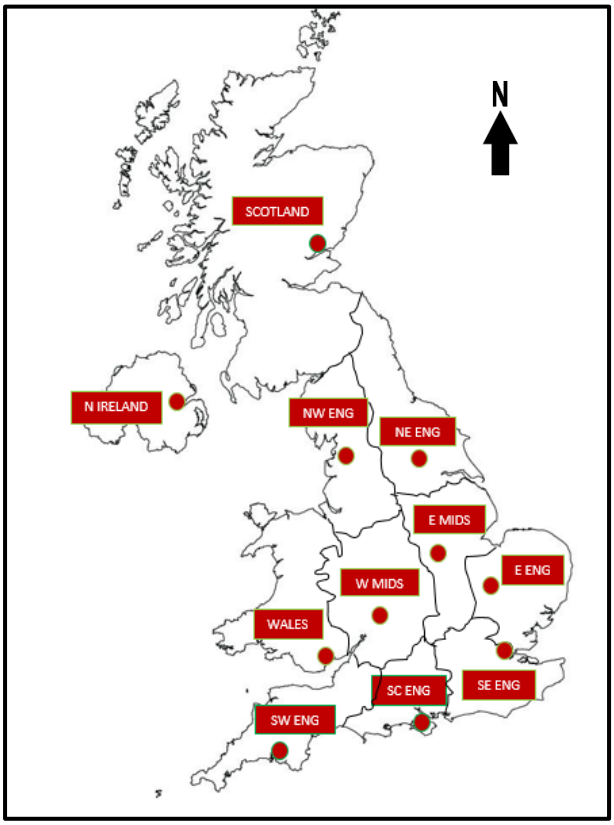

Fig. S1. Pollen forecast regions for the United Kingdom, with red dots showing pollen station locations.

Table S1. Pollen monitoring stations used in the study (2004-2013), per region, with height above sea level (ASL) in metres (m) and location co-ordinates. Eight pollen types were analysed, including hazel, alder, ash, birch, plane, oak, grass and nettle family. Years/types for which data was unavailable or too low to be included are shown in 'Unavailable data' column.

Region	Pollen monitoring station name and ASL (m)	Co-ordinates: Longitude/Latitude		Unavailable data
Scotland	Invergowrie (40)	-3.0687	56.4576	Hazel, plane.
Northern Ireland	Belfast (22)	-5.9314	54.6064	2010-11. Hazel, alder, plane.
North-East England	York (26)	-1.0535	53.9484	2004-07. Hazel, alder, plane.
North-West England	Preston (58)	-2.7	53.76667	2010-13. Plane.
Wales	Cardiff (31)	-3.2121	51.4958	Hazel, alder, plane.
West Midlands	Worcester (42)	-2.24207	52.19699	
East Midlands	Leicester (96)	-1.1227	52.6231	Oak, birch: 2004-05.
East England	Cambridge (25)	0.1349	52.2116	Hazel, alder.
South-West England	Plymouth (59)	-4.11986	50.354	Hazel, alder: 2009-13. Plane.
South-Central England	Isle of Wight (36)	-1.3009	50.7111	Hazel, alder, plane.
South-East England	London (Islington) (50)	-0.10356	51.54416	Hazel, alder.

Table S2: Average (mean) onset and end of season, first high and number of high days (data given as Julian days and dates) for alder (*Alnus* spp) pollen. (Hyphen indicates too few incidences to provide averages or data not available). For onset and end of season, the earliest and latest date for the study period (2004-2013) is given.

Alder (*Alnus* spp)	Onset 2.5%			End 97.5%			First High		No. High days
	Day	Date	Earliest	Day	Date	Latest	Day	Date	No.
Scotland	72	13 Mar	15 Feb	108	18 Apr	22 May	-	-	-
N Ireland	-	-		-	-		-	-	-
NW England	32	1 Feb	19 Jan	82	23 Mar	31 Jan	-	-	2
NE England	-	-		-	-		-	-	-
Wales	-	-		-	-		-	-	-
W Midlands	36	5 Feb	21 Jan	85	26 Mar	11 Apr	54	23 Feb	5
E Midlands	35	4 Feb	18 Jan	95	5 Apr	2 May	53	22 Feb	4
E England	-	-		-	-		-	-	-
SW England	39	8 Feb	30 Jan	94	4 Apr	5 May	67	8 Mar	1
SC England	-	-		-	-		-	-	-
SE England	-	-		-	-		-	-	-

Table S3: Average (mean) onset and end of season, first high and number of high days (data given as Julian days and dates) for ash (*Fraxinus* spp) pollen. (Hyphen indicates too few incidences to provide averages or data not available). For onset and end of season, the earliest and latest date for the study period (2004-2013) is given.

Ash (*Fraxinus* spp)	Onset 2.5%			End 97.5%			First High		No. High days
	Day	Date	Earliest	Day	Date	Latest	Day	Date	No.
Scotland	102	12 Apr	25 Mar	126	6 May	21 May	-	-	1
N Ireland	96	6 Apr	28 Mar	127	7 May	20 May	-	-	2
NW England	103	13 Apr	31 Mar	132	12 May	12 Jun	-	-	2
NE England	92	2 Apr	21 Mar	130	10 May	21 May	-	-	2
Wales	89	30 Mar	18 Mar	119	29 Apr	23 May	95	5 Apr	6
W Midlands	90	31 Mar	13 Mar	124	4 May	10 May	102	12 Apr	8
E Midlands	83	24 Mar	15 Mar	117	27 Apr	7 May	102	12 Apr	7
E England	92	2 Apr	24 Mar	123	3 May	19 May	97	7 Apr	5
SW England	92	2 Apr	21 Mar	121	1 May	11 May	107	17 Apr	3
SC England	90	31 Mar	18 Mar	129	9 May	23 May	98	8 Apr	5
SE England	88	29 Mar	14 Mar	129	9 May	15 May	-	-	5

Table S4: Average (mean) onset and end of season, first high and number of high days (data given as Julian days and dates) for birch (*Betula* spp) pollen. (Hyphen indicates too few incidences to provide averages or data not available). For onset and end of season, the earliest and latest date for the study period (2004-2013) is given.

Birch (*Betula* spp)	Onset 2.5%			End 97.5%			First High		No. High days
	Day	Date	Earliest	Day	Date	Latest	Day	Date	No.
Scotland	104	14 Apr	27 Mar	137	17 May	1 Jun	111	21 Apr	2
N Ireland	100	10 Apr	28 Mar	132	12 May	28 May	-	-	1
NW England	101	11 Apr	02 Apr	125	5 May	14 May	105	15 Apr	7
NE England	100	10 Apr	27 Mar	132	12 May	25 May	104	14 Apr	7
Wales	96	6 Apr	26 Mar	125	5 May	25 May	106	16 Apr	7
W Midlands	95	5 Apr	25 Mar	125	5 May	17 May	96	6 Apr	13
E Midlands	99	9 Apr	28 Mar	129	9 May	21 May	104	14 Apr	8
E England	98	8 Apr	28 Mar	125	5 May	10 May	103	13 Apr	10
SW England	97	7 Apr	27 Mar	132	12 May	29 May	108	18 Apr	10
SC England	95	5 Apr	20 Mar	126	6 May	18 May	99	9 Apr	6
SE England	94	4 Apr	23 Mar	122	2 May	10 may	96	6 Apr	14

Table S5: Average (mean) onset and end of season, first high and number of high days (data given as Julian days and dates) for oak (*Quercus* spp) pollen. (Hyphen indicates too few incidences to provide averages or data not available). For onset and end of season, the earliest and latest date for the study period (2004-2013) is given.

Oak (*Quercus* spp)	**Onset 2.5%**			**End 97.5%**			**First High**		**No. High days**
	Day	Date	Earliest	Day	Date	Latest	Day	Date	No.
Scotland	123	3 May	16 Apr	160	9 Jun	27 Jun	-	-	0
N Ireland	127	7 May	17 Apr	152	1 Jun	04 Jul	-	-	0
NW England	121	1 May	20 Apr	152	1 Jun	26 Jun	122	2 May	4
NE England	113	23 Apr	07 Apr	150	30 May	17 Jun	125	5 May	5
Wales	112	22 Apr	09 Apr	150	30 May	20 Jun	119	29 Apr	4
W Midlands	118	28 Apr	15 Apr	166	15 Jun	22 Jun	121	1 May	14
E Midlands	117	27 Apr	13 Apr	148	28 May	01 Jul	124	4 May	9
E England	116	26 Apr	18 Apr	158	7 Jun	16 Jun	120	30 Apr	5
SW England	115	25 Apr	27 Mar	160	9 Jun	19 Jun	128	8 May	2
SC England	115	25 Apr	13 Apr	158	7 Jun	05 Jul	121	1 May	7
SE England	110	20 Apr	6 Apr	150	30 May	04 Jun	119	29 Apr	10

Table S6: Average (mean) onset and end of season, first high and number of high days (data given as Julian days and dates) for grass (Poaceae) pollen. For onset and end of season, the earliest and latest date for the study period (2004-2013) is given.

Grass (Poaceae)	Onset 2.5%			End 97.5%			First High		No. High days
	Day	Date	Earliest	Day	Date	Latest	Day	Date	No.
Scotland	153	2 Jun	16 May	225	13 Aug	29 Aug	167	16 Jun	11
N Ireland	146	26 May	9 May	224	12 Aug	19 Aug	159	8 Jun	17
NW England	147	27 May	21 May	220	8 Aug	13 Aug	152	1 Jun	29
NE England	142	22 May	11 May	221	9 Aug	20 Aug	163	12 Jun	19
Wales	148	28 May	11 May	218	6 Aug	11 Aug	156	5 Jun	21
W Midlands	142	22 May	2 May	227	15 Aug	2 Sep	154	3 Jun	31
E Midlands	145	25 May	5 May	221	9 Aug	23 Aug	155	4 Jun	24
E England	144	24 May	12 May	215	3 Aug	8 Aug	155	4 Jun	21
SW England	142	22 May	22 Apr	215	3 Aug	20 Aug	154	3 Jun	15
SC England	136	16 May	30 Apr	220	8 Aug	30 Aug	148	29 May	30
SE England	143	23 May	3 Apr	219	7 Aug	21 Aug	143	24 May	24

Table S7: Average (mean) onset and end of season, first high and number of high days (data given as Julian days and dates) for nettle family (Urticaceae) pollen. For onset and end of season, the earliest and latest date for the study period (2004-2013) is given.

Nettle family (Urticaceae)	Onset 2.5%			End 97.5%			First High		No. High days
	Day	Date	Earliest	Day	Date	Latest	Day	Date	No.
Scotland	161	10 Jun	1 Jun	237	25 Aug	2 Sep	181	30 Jun	5
N Ireland	154	3 Jun	3 May	243	31 Aug	11 Sep	175	24 Jun	8
NW England	154	3 Jun	31 May	246	3 Sep	9 Sep	161	10 Jun	24
NE England	154	3 Jun	22 May	238	26 Aug	30 Aug	161	10 Jun	13
Wales	155	4 Jun	30 May	241	29 Aug	10 Aug	184	3 Jul	4
W Midlands	153	2 Jun	28 May	248	5 Sep	9 Sep	158	7 Jun	30
E Midlands	154	3 Jun	29 May	244	1 Sep	10 Sep	155	4 Jun	28
E England	154	3 Jun	25 May	241	29 Aug	6 Sep	156	5 Jun	34
SW England	149	29 May	21 May	238	26 Aug	8 Sep	157	6 Jun	12
SC England	136	16 May	18 May	240	28 Aug	8 Sep	151	31 May	32
SE England	151	31 May	22 May	228	16 Aug	8 Sep	151	31 May	25