Electronic Supplementary Material (ESM) 1

A Systematic Review of the Effects of Temperature and Precipitation on Global Pollen Trends Concentrations and Season Timing and Implications for Human Health

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ESM 1: Table outlining characteristics of studies that were included for analysis.

Reference	Continent	Country	City	Pollen Species	Pollen Category	First Year of Data	Last Year of Data	Number Years of Data
Aguilera et al. (2015)	Africa	Tunisia	Zarzis	Olea	Tree	1993	2011	19
	Europe	Italy	Perugia	Olea	Tree	1993	2011	19
		Spain	Jaen	Olea	Tree	1993	2011	19
Alcázar et al. (2011)	Europe	Spain	Almeria	Platanus	Tree	1998	2010	13
			Cadiz	Platanus	Tree	2000	2010	11
			Cordoba	Platanus	Tree	1992	2010	19
			Granada	Platanus	Tree	1992	2010	19

			Huelva	Platanus	Tree	1993	2010	18
			Jaen	Platanus	Tree	1993	2010	18
			Malaga	Platanus	Tree	1992	2010	19
			Seville	Platanus	Tree	1993	2010	18
Alcázar et al. (2009)	Europe	Poland	Poznan	Chenopodiaceae-Amaranthaceae	Weed	1995	2005	11
				Plantago	Weed	1995	2005	11
				Rumex	Weed	1995	2005	11
				Urticaceae	Weed	1995	2005	11
		Spain	Cordoba	Chenopodiaceae-Amaranthaceae	Weed	1995	2005	11
				Plantago	Weed	1995	2005	11
				Rumex	Weed	1995	2005	11
				Urticaceae	Weed	1995	2005	11
Ariano et al. (2010)	Europe	France	Bordighera	Betula	Tree	1981	2007	27
				Cupressaceae	Tree	1981	2007	27
				Olea	Tree	1981	2007	27
				Urticaceae	Weed	1981	2007	27
				Poaceae	Grass	1981	2007	27
Astray et al. (2016)	Europe	Spain	Orense	Castanea	Tree	1993	2012	20
Bogawski et al. (2014)	Europe	Poland	Poznan	Artemisia	Weed	1996	2011	16
				Rumex	Weed	1996	2011	16
				Urticaceae	Weed	1996	2011	16
				Poaceae	Grass	1996	2011	16
Bogdziewicz et al. (2017a)	Europe	Spain	Barcelona	Quercus	Tree	1998	2009	12
			Bellaterra	Quercus	Tree	1998	2009	12
Bogdziewicz et al. (2017b)	Europe	Poland	3 Sites	Fagus	Tree	1997	2015	19
				Quercus	Tree	1997	2015	19
Bonini et al. (2015)	Europe	Italy	3 Sites	Ambrosia	Weed	2000	2013	14
			Legnano	Cannabaceae	Weed	2000	2013	14
				Urticaceae	Weed	2000	2013	14
Bortenschlager and Bortenschlager (2005)	Europe	Austria	2 Sites	Alnus	Tree	1980	2001	22
				Betula	Tree	1980	2001	22

				Corylus	Tree	1980	2001	22
				Fraxinus	Tree	1980	2001	22
				Pinaceae	Tree	1980	2001	22
				Poaceae	Grass	1980	2001	22
Breton et al. (2006)	North America	Canada	Montreal	Ambrosia	Weed	1994	2002	9
Bruffaerts et al. (2017)	Europe	Belgium	Brussels	Alnus	Tree	1982	2015	34
				Betula	Tree	1982	2015	34
				Carpinus	Tree	1982	2015	34
				Corylus	Tree	1982	2015	34
				Fagus	Tree	1982	2015	34
				Fraxinus	Tree	1982	2015	34
				Platanus	Tree	1982	2015	34
				Quercus	Tree	1982	2015	34
				Artemisia	Weed	1982	2015	34
				Urticaceae	Weed	1982	2015	34
				Poaceae	Grass	1982	2015	34
Calderon-Ezquerro et al. (2016)	North America	Mexico	Mexico City	Alnus	Tree	2008	2013	6
				Cupressaceae	Tree	2008	2013	6
				Fraxinus	Tree	2008	2013	6
				Urticaceae	Weed	2008	2013	6
				Poaceae	Grass	2008	2013	6
Camacho et al. (2015)	Europe	Portugal	Funchal City	Poaceae	Grass	2003	2012	10
Camacho et al. (2016)	Europe	Portugal	Madiera Island	Betula	Tree	2003	2009	7
				Olea	Tree	2003	2009	7
				Urticaceae	Weed	2003	2009	7
				Poaceae	Grass	2003	2009	7
Cariñanos et al. (2013)	Europe	Spain	Sierra Nevada	Artemisia	Weed	1992	2011	20
Carinanos et al. (2016)	Europe	Spain	Granada	Acer	Tree	1992	2013	22
				Corylus	Tree	1992	2013	22
				Cupressaceae	Tree	1992	2013	22
				Pinaceae	Tree	1992	2013	22

				Quercus	Tree	1992	2013	22
				Ulmus	Tree	1992	2013	22
Cariñanos et al. (2014)	Europe	Spain	Cordoba	Chenopodiaceae-Amaranthaceae	Weed	1991	2011	21
Cebrino et al. (2016)	Europe	Spain	Cordoba	Poaceae	Grass	2000	2013	14
Clot (2001)	Europe	Switzerland	Neuchatel	Betula	Tree	1980	1997	18
Corden and Millington (1999)	Europe	United Kingdom	Derby	Quercus	Tree	1970	1997	28
Dabrowska et al. (2016)	Europe	Poland	Lublin	Tilia	Tree	2001	2014	14
Damialis et al. (2007)	Europe	Greece	Thessaloniki	Alnus	Tree	1987	2005	19
				Carpinus	Tree	1987	2005	19
				Corylus	Tree	1987	2005	19
				Cupressaceae	Tree	1987	2005	19
				Olea	Tree	1987	2005	19
				Pinaceae	Tree	1987	2005	19
				Platanus	Tree	1987	2005	19
				Populus	Tree	1987	2005	19
				Quercus	Tree	1987	2005	19
				Ambrosia	Weed	1987	2005	19
				Artemisia	Weed	1987	2005	19
				Chenopodiaceae-Amaranthaceae	Weed	1987	2005	19
				Plantago	Weed	1987	2005	19
				Rumex	Weed	1987	2005	19
				Urticaceae	Weed	1987	2005	19
				Poaceae	Grass	1987	2005	19
Deák et al. (2013)	Europe	Hungary	Szeged	Betula	Tree	1997	2007	11
				Morus	Tree	1997	2007	11
				Populus	Tree	1997	2007	11
				Ambrosia	Weed	1997	2007	11
				Artemisia	Weed	1997	2007	11
				Chenopodiaceae-Amaranthaceae	Weed	1997	2007	11

				Urticaceae	Weed	1997	2007	11
				Poaceae	Grass	1997	2007	11
de la Cruz et al. (2015)	Europe	Spain	Salamanca	Cupressaceae	Tree	2000	2007	8
de León et al. (2015)	Europe	Spain	Cordoba	Poaceae	Grass	1982	2012	31
Díaz de la Guardia et al. (2003)	Europe	Spain	Cordoba	Olea	Tree	1992	2000	9
			Granada	Olea	Tree	1992	2000	9
			Jaen	Olea	Tree	1993	2000	8
			Malaga	Olea	Tree	1992	2000	9
Domínguez et al. (1993)	Europe	Spain	Cordoba	Olea	Tree	1982	1991	10
Donders et al. (2014)	Europe	Netherlands	Helmond	Alnus	Tree	1975	2014	40
				Betula	Tree	1975	2014	40
				Corylus	Tree	1975	2014	40
				Fraxinus	Tree	1975	2014	40
				Quercus	Tree	1975	2014	40
				Plantago	Weed	1975	2014	40
			Leiden	Alnus	Tree	1969	2014	46
				Betula	Tree	1969	2014	46
				Corylus	Tree	1969	2014	46
				Fraxinus	Tree	1969	2014	46
				Quercus	Tree	1969	2014	46
				Plantago	Weed	1969	2014	46
Emberlin et al. (2002)	Europe	Austria	Vienna	Betula	Tree	1980	2000	21
		Belgium	Brussels	Betula	Tree	1982	2000	19
		Finland	Kevo	Betula	Tree	1980	2000	21
			Turku	Betula	Tree	1982	2000	19
		Switzerland	Zurich	Betula	Tree	1976	2000	25
		United Kingdom	London	Betula	Tree	1970	2000	29
Emberlin et al. (1997)	Europe	United Kingdom	Cardiff	Betula	Tree	1954	1995	42
			Derby	Betula	Tree	1969	1995	27
			London	Betula	Tree	1961	1995	31
Emberlin et al. (1993)	Europe	United Kingdom	London	Poaceae	Grass	1961	1990	30

Emberlin et al. (2007)	Europe	United Kingdom	Worcester	Alnus	Tree	1996	2005	10
				Corylus	Tree	1996	2005	10
Fernandez-Rodriguez et al. (2016a)	Europe	Spain	Badajoz	Poaceae	Grass	1993	2015	23
Fernandez-Rodriguez et al. (2016b)	Europe	Spain	Badajoz	Quercus	Tree	1994	2013	20
Fernandez-Rodriguez et al. (2016c)	Europe	Spain	Badajoz	Olea	Tree	1994	2013	20
Frei (1998)	Europe	Switzerland	Basel	Betula	Tree	1969	1996	28
				Corylus	Tree	1969	1996	28
				Poaceae	Grass	1969	1996	28
Fuhrmann et al. (2016)	North America	United States	Raleigh	Multiple	Tree	1999	2012	14
				Multiple	Weed	1999	2012	14
				Poaceae	Grass	1999	2012	14
García-Mozo et al. (2010)	Europe	Spain	Almeria	Poaceae	Grass	1998	2008	11
			Cadiz	Poaceae	Grass	2001	2008	8
			Cordoba	Poaceae	Grass	1982	2008	27
			Granada	Poaceae	Grass	1992	2008	17
			Huelva	Poaceae	Grass	1998	2008	11
			Jaen	Poaceae	Grass	1993	2008	16
			Malaga	Poaceae	Grass	1992	2008	17
			Sevilla	Poaceae	Grass	1993	2008	16
García-Mozo et al. (2006)	Europe	Spain	Barcelona	Quercus	Tree	1994	2001	8
			Cordoba	Quercus	Tree	1992	2001	10
			Girona	Quercus	Tree	1996	2001	6
			Granada	Quercus	Tree	1992	2001	10
			Jaen	Quercus	Tree	1996	2001	6
			Leon	Quercus	Tree	1994	2001	8
			Lleida	Quercus	Tree	1996	2001	6
			Madrid	Quercus	Tree	1993	2001	9
			Malaga	Quercus	Tree	1992	2001	10
			Ourense	Quercus	Tree	1993	2001	9
			Priego	Quercus	Tree	1994	2001	8

			Santiago	Quercus	Tree	1993	2001	9
			Tarragona	Quercus	Tree	1996	2001	6
			Vigo	Quercus	Tree	1995	2001	7
Garcia-Mozo et al. (2016)	Europe	Spain	Cordoba	Cupressaceae	Tree	1996	2010	15
				Morus	Tree	1996	2010	15
				Myrtaceae	Tree	1996	2010	15
				Olea	Tree	1996	2010	15
				Pinaceae	Tree	1996	2010	15
				Platanus	Tree	1996	2010	15
				Populus	Tree	1996	2010	15
				Quercus	Tree	1996	2010	15
				Amaranthaceae	Weed	1996	2010	15
				Asteraceae	Weed	1996	2010	15
				Parietaria	Weed	1996	2010	15
				Plantago	Weed	1996	2010	15
				Rumex	Weed	1996	2010	15
				Urticaceae	Weed	1996	2010	15
				Poaceae	Grass	1996	2010	15
García-Mozo et al. (2014)	Europe	Spain	Cordoba	Olea	Tree	1982	2011	30
Ghosh et al. (2016)	North America	United States	Texas Panhandle	Multiple	Multiple	2002	2011	10
González-Parrado et al. (2014)	Europe	Spain	Leon	Plantago	Weed	1995	2011	17
Grewling et al. (2014)	Europe	Poland	Poznan	Quercus	Tree	1996	2011	16
Grewling et al. (2012)	Europe	Poland	Poznan	Betula	Tree	1996	2010	15
Grundström et al. (2017)	Europe	Sweden	Gothenburg	Betula	Tree	2006	2012	7
			Malmo	Betula	Tree	2006	2012	7
Ianovici (2015)	Europe	Romania	Timisoara	Poaceae	Grass	2000	2010	11
Jato et al. (2009)	Europe	Spain	Lugo	Poaceae	Grass	1999	2007	9
			Ourense	Poaceae	Grass	1993	2007	15
			Santiago	Poaceae	Grass	1993	2007	15
			Vigo	Poaceae	Grass	1995	2007	13
Jato et al. (2015)	Europe	Spain	Lugo	Quercus	Tree	1999	2012	14

			Ourense	Quercus	Tree	1993	2012	20
			Santiago	Quercus	Tree	1993	2012	20
			Vigo	Quercus	Tree	1995	2012	18
Kalinovych et al. (2016)	Europe	Ukraine	Lviv	Alnus	Tree	2011	2015	5
				Corylus	Tree	2011	2015	5
Kasprzyk (2016)	Europe	Poland	Rzeszow	Betula	Tree	2000	2015	16
Kaszewski et al. (2008)	Europe	Poland	Lublin	Alnus	Tree	2001	2007	7
			Rostocze	Alnus	Tree	1998	2007	10
Makra et al. (2011)	Europe	Hungary	Szeged	Alnus	Tree	1997	2007	11
				Betula	Tree	1997	2007	11
				Juglans	Tree	1997	2007	11
				Morus	Tree	1997	2007	11
				Pinaceae	Tree	1997	2007	11
				Platanus	Tree	1997	2007	11
				Populus	Tree	1997	2007	11
				Quercus	Tree	1997	2007	11
				Taxus	Tree	1997	2007	11
				Tilia	Tree	1997	2007	11
				Ulmus	Tree	1997	2007	11
				Ambrosia	Weed	1997	2007	11
				Artemisia	Weed	1997	2007	11
				Cannabaceae	Weed	1997	2007	11
				Chenopodiaceae-Amaranthaceae	Weed	1997	2007	11
				Plantago	Weed	1997	2007	11
				Rumex	Weed	1997	2007	11
				Urticaceae	Weed	1997	2007	11
				Poaceae	Grass	1997	2007	11
Malkiewicz et al. (2016)	Europe	Poland	Wroclaw	Alnus	Tree	2003	2013	11
				Betula	Tree	2003	2013	11
				Corylus	Tree	2003	2013	11
Maya-Manzano et al. (2017)	Europe	Spain	Badajoz	Platanus	Tree	1997	2015	19
			Caceres	Platanus	Tree	1997	2001	5

Medek et al. (2016)	Australia	Australia and New Zealand	14 sites	Poaceae	Grass	1988	2012	17
Mercuri et al. (2013)	Europe	Italy	Vignola	Taxus	Tree	1993	2002	6
Murray and Galan (2016)	South America	Argentina	Bahia Blanca	Olea	Tree	2001	2011	11
Negrini et al. (2011)	Europe	Italy	Genoa	Betula	Tree	1981	2010	30
				Olea	Tree	1981	2010	30
				Urticaceae	Weed	1981	2010	30
				Graminaea	Grass	1981	2010	30
Newnham et al. (2013)	Europe	United Kingdom	London	Betula	Tree	1995	2010	16
			Plymouth	Betula	Tree	1995	2010	16
			Worcester	Betula	Tree	1995	2010	16
Novara et al. (2016)	Europe	Italy	Turin	Alnus	Tree	1996	2014	19
				Corylus	Tree	1996	2014	19
Oikonen et al. (2005)	Europe	Finland	Kevo	Betula	Tree	1977	2001	25
Orlandi et al. (2009)	Europe	Italy	16 sites	Olea	Tree	1999	2007	9
Piotrowska and Kubik-Komar (2012)	Europe	Poland	Lublin	Betula	Tree	2001	2010	10
Puc et al. (2015)	Europe	Poland	Krakow	Betula	Tree	2001	2014	14
			Lodz	Betula	Tree	2003	2014	12
			Lublin	Betula	Tree	2001	2014	14
			Poznan	Betula	Tree	2001	2014	14
			Rzeszow	Betula	Tree	2001	2013	13
			Sosnowiec	Betula	Tree	2001	2014	14
			Szczecin	Betula	Tree	2001	2014	14
			Wroclaw	Betula	Tree	2003	2014	12
Puljak et al. (2016)	Europe	Croatia	Split	Carpinus	Tree	2005	2013	9
				Cupressaceae	Tree	2005	2013	9
				Olea	Tree	2005	2013	9
				Pinaceae	Tree	2005	2013	9
				Platanus	Tree	2005	2013	9
				Quercus	Tree	2005	2013	9
				Ambrosia	Weed	2005	2013	9

				Urticaceae	Weed	2005	2013	9
				Poaceae	Grass	2005	2013	9
Recio et al. (2010)	Europe	Spain	Malaga	Poaceae	Grass	1991	2007	17
Robichaud and Comtois (2017)	North America	Canada	Montreal	Betula	Tree	1996	2012	17
Rojo et al. (2016)	Europe	Spain	Guadalajara	Multiple	Tree	2008	2013	6
				Multiple	Weed	2008	2013	6
Rojo et al. (2017)	Europe	Spain	Toledo	Poaceae	Grass	2006	2014	9
Sabo et al. (2015)	Europe	Serbia	Subotica	Multiple	Multiple	2009	2013	5
Sabo et al. (2016)	Europe	Serbia	Subotica	Urticaceae	Weed	2009	2013	5
Sicard et al. (2012)	Europe	France	Nice	Olea	Tree	1990	2009	20
Šikoparija et al. (2012)	Europe	Poland	13 sites	Artemisia	Weed	2000	2009	10
Silva-Palacios et al. (2016)	Europe	Spain	Badajoz	Cupressaceae	Tree	1993	2013	21
Simoleit et al. (2016)	Europe	Germany	Delmenhorst	Fagus	Tree	1982	2014	33
			Oberjoch	Fagus	Tree	1982	2014	33
Sofia et al. (2017)	Europe	Italy	Perugia	Poaceae	Grass	1982	2014	33
Spieksma et al. (1995)	Europe	Austria	Vienna	Betula	Tree	1976	1993	18
		Netherlands	Leiden	Betula	Tree	1969	1993	25
		Sweden	Stockholm	Betula	Tree	1973	1993	21
		Switzerland	Basel	Betula	Tree	1969	1993	25
		United Kingdom	London	Betula	Tree	1961	1993	30
Stach et al. (2007)	Europe	Poland	Poznan	Artemisia	Weed	1995	2004	10
Ste¸ palska et al. (2008)	Europe	Poland	Cracow	Ambrosia	Weed	1995	2006	12
Tedeschini et al. (2006)	Europe	Italy	Perugia	Platanus	Tree	1982	2003	22
			Torino	Platanus	Tree	1985	2003	19
		Spain	Santiago	Platanus	Tree	1992	2003	12
			Vigo	Platanus	Tree	1994	2003	10
Teranishi et al. (2006)	Asia	Japan	Toyama City	Cupressaceae	Tree	1983	2003	21
Teranishi et al. (2000)	Asia	Japan	Toyama City	Cupressaceae	Tree	1983	1998	16
Tormo-Molina et al. (2010)	Europe	Spain	Badajoz	Cupressaceae	Tree	1994	2008	15
				Olea	Tree	1994	2008	15
				Platanus	Tree	1994	2008	15
				Quercus	Tree	1994	2008	15

				Chenopodiaceae-Amaranthaceae	Weed	1994	2008	15
				Plantago	Weed	1994	2008	15
				Poaceae	Grass	1994	2008	15
Toro et al. (2015)	South America	Chile	Santiago	Multiple	Tree	2009	2013	5
				Multiple	Weed	2009	2013	5
				Poaceae	Grass	2009	2013	5
Ugolotti et al. (2015)	Europe	Italy	Parma	Alnus	Tree	1994	2011	18
				Betula	Tree	1994	2011	18
				Corylus	Tree	1994	2011	18
				Cupressaceae	Tree	1994	2011	18
				Platanus	Tree	1994	2011	18
				Ambrosia	Weed	1994	2011	18
				Artemisia	Weed	1994	2011	18
				Chenopodiaceae-Amaranthaceae	Weed	1994	2011	18
				Plantago	Weed	1994	2011	18
				Urticaceae	Weed	1994	2011	18
				Poaceae	Grass	1994	2011	18
Van Vliet et al. (2002)	Europe	Netherlands	Leiden	Betula	Tree	1977	2000	24
				Fraxinus	Tree	1974	2000	27
				Juniper	Tree	1977	2000	24
				Pinaceae	Tree	1969	2000	32
				Populus	Tree	1969	2000	32
				Quercus	Tree	1969	2000	32
				Salix	Tree	1966	2000	33
				Ulmus	Tree	1977	2000	24
				Adoxaceae	Weed	1969	2000	30
				Artemisia	Weed	1969	1998	30
				Chenopodiaceae-Amaranthaceae	Weed	1969	1998	28
				Rumex	Weed	1969	1998	30

				Urticaceae	Weed	1969	1998	30
				Poaceae	Grass	1969	2000	32
Vara et al. (2016)	Europe	Spain	Ourense	Fraxinus	Tree	2009	2013	5
Zhang et al. (2014)	North America	United States	Cherry Hill	Betula	Tree	1995	2010	13
				Quercus	Tree	1995	2010	13
			College Station	Betula	Tree	2003	2010	6
				Quercus	Tree	1997	2010	10
			Fargo	Betula	Tree	1997	2010	11
				Quercus	Tree	1996	2010	11
			Newark	Betula	Tree	1994	2011	11
				Quercus	Tree	1994	2011	11
			Omaha	Betula	Tree	1995	2010	5
				Quercus	Tree	1994	2010	10
			Pleasanton	Betula	Tree	1997	2010	10
				Quercus	Tree	1994	2010	10
Zhang et al. (2015)	North America	United States	19 sites	Betula	Tree	1994	2010	15
			2 sites	Artemisia	Weed	1994	2010	15
			20 sites	Ambrosia	Weed	1994	2010	15
			26 sites	Poaceae	Grass	1994	2010	15
			28 sites	Quercus	Tree	1994	2010	15
Ziello et al. (2012)	Europe	Multiple	97 sites	Alnus	Tree	1977	2009	28
				Betula	Tree	1977	2009	28
				Carpinus	Tree	1977	2009	28
				Castanea	Tree	1977	2009	28
				Corylus	Tree	1977	2009	28
				Cupressaceae	Tree	1977	2009	28
				Fagus	Tree	1977	2009	28
				Fraxinus	Tree	1977	2009	28
				Olea	Tree	1977	2009	28
				Pinaceae	Tree	1977	2009	28
				Platanus	Tree	1977	2009	28
				Populus	Tree	1977	2009	28

				Quercus	Tree	1977	2009	28
				Salix	Tree	1977	2009	28
				Tilia	Tree	1977	2009	28
				Ulmus	Tree	1977	2009	28
				Ambrosia	Weed	1977	2009	28
				Artemisia	Weed	1977	2009	28
				Chenopodiaceae-Amaranthaceae	Weed	1977	2009	28
				Plantago	Weed	1977	2009	28
				Rumex	Weed	1977	2009	28
				Urticaceae	Weed	1977	2009	28
				Poaceae	Grass	1977	2009	28
Ziska et al. (2011)	North America	Canada	1 Site	Ambrosia	Weed	1995	2009	15
		United States	9 Sites	Ambrosia	Weed	1995	2009	15

ESM 2: Full search strategy used for systematic review

Database	**Strategy**
Environmental Science Collection ProQuest 1967-	TI,AB(pollen N/3 (quantit* OR producti* OR increase* OR release* OR amount* OR concentration* OR elevat* OR measure* OR detection OR trend* OR count* OR change* OR variation* OR data OR "cubic meter*" OR "cubic metre*" OR scale OR level* OR index OR indices OR grains OR records OR total* OR emission)) AND TI,AB(Season* OR Phenolog* OR Spring OR Autumn OR Fall OR flowering OR start OR peak OR onset OR temperature* OR climate OR aerobiolog* OR forecast* OR pattern*)
Scopus 1996-	TITLE-ABS((pollen) W/3 (quantit* OR producti* OR increase* OR release* OR amount* OR concentration* OR elevat* OR measure* OR detection OR trend* OR count* OR change* OR variation* OR data OR "cubic meter*" OR "cubic metre*" OR scale OR level* OR index OR indices OR grains OR records OR total* OR emission)) AND TITLE-ABS(Season* OR Phenolog* OR Spring OR Autumn OR Fall OR flowering OR start OR

	peak OR onset OR temperature* OR climate OR aerobiolog* OR forecast* OR pattern*) AND (LIMIT-TO (EXACTKEYWORD , "Pollen"))
CAB Abstracts OVID 1973-	((pollen OR aero-allerg* OR aeroallerg*) ADJ3 (quantit* OR producti* OR increase* OR release* OR amount* OR concentration* OR elevat* OR measure* OR detection OR trend* OR count* OR change* OR variation* OR data OR cubic meter* OR cubic metre* OR scale OR level* OR index OR indices OR grains OR records)).ti,ab. AND (Season* OR Phenolog* OR Spring OR Autumn OR Fall OR flowering OR start OR peak OR onset OR temperature* OR climate OR aerobiolog* OR forecast* OR pattern*).ti,ab.

ESM 3: Full list of studies included in the systematic review

Aguilera F, Orlandi F, Ruiz-Valenzuela L, Msallem M, Fornaciari MJA, Meteorology F (2015) Analysis and interpretation of long temporal trends in cumulative temperatures and olive reproductive features using a seasonal trend decomposition procedure 203:208-216

Alcázar P et al. (2011) Platanus pollen season in Andalusia (southern Spain): trends and modeling 13:2502-2510

Alcázar P, Stach A, Nowak M, Galán CJA (2009) Comparison of airborne herb pollen types in Córdoba (Southwestern Spain) and Poznan (Western Poland) 25:55-63

Ariano R, Canonica GW, Passalacqua GJAoA, Asthma, Immunology (2010) Possible role of climate changes in variations in pollen seasons and allergic sensitizations during 27 years 104:215-222

Astray G, Fernández-González M, Rodríguez-Rajo FJ, López D, Mejuto JC (2016) Airborne castanea pollen forecasting model for ecological and allergological implementation Science of the Total Environment 548-549:110-121 doi:10.1016/j.scitotenv.2016.01.035

Bogawski P, Grewling Ł, Nowak M, Smith M, Jackowiak BJIjob (2014) Trends in atmospheric concentrations of weed pollen in the context of recent climate warming in Poznań (Western Poland) 58:1759-1768

Bogdziewicz M, Fernández-Martínez M, Espelta JM, Bonal R, Belmonte J (2017a) The Moran effect and environmental vetoes: Phenological synchrony and drought drive seed production in a Mediterranean oak Proceedings of the Royal Society B: Biological Sciences 284 doi:http://dx.doi.org/10.1098/rspb.2017.1784

Bogdziewicz M et al. (2017b) Masting in wind-pollinated trees: system-specific roles of weather and pollination dynamics in driving seed production Ecology 98:2615-2625 doi:http://dx.doi.org/10.1002/ecy.1951

Bonini M et al. (2015) Is the recent decrease in airborne Ambrosia pollen in the Milan area due to the accidental introduction of the ragweed leaf beetle Ophraella communa? 31:499-513

Bortenschlager S, Bortenschlager IJG (2005) Altering airborne pollen concentrations due to the Global Warming. A comparative analysis of airborne pollen records from Innsbruck and Obergurgl (Austria) for the period 1980–2001 44:172-180
Breton M-C, Garneau M, Fortier I, Guay F, Louis JJSotTE (2006) Relationship between climate, pollen concentrations of Ambrosia and medical consultations for allergic rhinitis in Montreal, 1994–2002 370:39-50
Bruffaerts N et al. (2017) Comparative long-term trend analysis of daily weather conditions with daily pollen concentrations in Brussels, Belgium International Journal of Biometeorology:1-9 doi:10.1007/s00484-017-1457-3
Calderon-Ezquerro MC et al. (2016) First airborne pollen calendar for Mexico City and its relationship with bioclimatic factors Aerobiologia 32:225-244 doi:http://dx.doi.org/10.1007/s10453-015-9392-4
Camacho I, Grinn-Gofro A, Camacho R, Berenguer P, Sady M (2016) Madeira-a tourist destination for asthma sufferers International Journal of Biometeorology 60:1739-1751 doi:http://dx.doi.org/10.1007/s00484-016-1163-6
Camacho IC, Câmara R, Camacho RJAA (2015) Main features of Poaceae pollen season in Madeira region (Portugal) 68
Cariñanos P, Alcázar P, Galán C, Domínguez EJSotTE (2014) Environmental behaviour of airborne Amaranthaceae pollen in the southern part of the Iberian Peninsula, and its role in future climate scenarios 470:480-487
Carinanos P, Casares-Porcel M, Diaz de la Guardia AV, Cruz-Marquez Rdl, Diaz de la Guardia C (2016) Charting trends in the evolution of the La Alhambra forest (Granada, Spain) through analysis of pollen-emission dynamics over time Climatic Change 135:453-466
Cariñanos P, de la Guardia CD, Algarra JA, De Linares C, Irurita JMJCc (2013) The pollen counts as bioindicator of meteorological trends and tool for assessing the status of endangered species: the case of Artemisia in Sierra Nevada (Spain) 119:799-813
Cebrino J, Galan C, Dominguez-Vilches E (2016) Aerobiological and phenological study of the main Poaceae species in Cordoba City (Spain) and the surrounding hills Aerobiologia 32:595-606 doi:http://dx.doi.org/10.1007/s10453-016-9434-6
Clot BJA (2001) Airborne birch pollen in Neuchâtel (Switzerland): onset, peak and daily patterns 17:25-29
Corden J, Millington WJA (1999) A study of Quercus pollen in the Derby area, UK 15:29-37
Dabrowska A, Piotrowska-Weryszko K, Weryszko-Chmielewska E, Sawicki R (2016) Flowering phenology of selected linden (Tilia L.) taxa in relation to pollen seasons Journal of Apicultural Science 60:193-207
Damialis A, Halley JM, Gioulekas D, Vokou DJAE (2007) Long-term trends in atmospheric pollen levels in the city of Thessaloniki, Greece 41:7011-7021
de la Cruz DR, Sánchez-Reyes E, Sánchez-Sánchez JJA (2015) A contribution to the knowledge of Cupressaceae airborne pollen in the middle west of Spain 31:435-444
de León DG, García-Mozo H, Galán C, Alcázar P, Lima M, González-Andújar JLJSotTE (2015) Disentangling the effects of feedback structure and climate on Poaceae annual airborne pollen fluctuations and the possible consequences of climate change 530:103-109
Deák ÁJ, Makra L, Matyasovszky I, Csépe Z, Muladi BJSotte (2013) Climate sensitivity of allergenic taxa in Central Europe associated with new climate change related forces 442:36-47
Díaz de la Guardia C, Alba F, Del Mar Trigo M, Galán C, Ruíz L, Sabariego SJG (2003) Aerobiological analysis of Olea europaea L. pollen in different localities of southern Spain: Forecasting models 42:234-243

Domínguez VE, Infante G-PF, Galán SC, Guerra PF, Villamandos dlTFJJoia, immunology c (1993) Variations in the concentrations of airborne Olea pollen and associated pollinosis in Córdoba (Spain): a study of the 10-year period 1982-1991 3:121

Donders TH, Hagemans K, Dekker SC, de Weger LA, De Klerk P, Wagner-Cremer FJPo (2014) Region-specific sensitivity of anemophilous pollen deposition to temperature and precipitation 9:e104774

Emberlin J, Detandt M, Gehrig R, Jaeger S, Nolard N, Rantio-Lehtimäki AJIjob (2002) Responses in the start of Betula (birch) pollen seasons to recent changes in spring temperatures across Europe 46:159-170

Emberlin J, Mullins J, Corden J, Millington W, Brooke M, Savage M, Jones SJG (1997) The trend to earlier birch pollen seasons in the UK: a biotic response to changes in weather conditions? 36:29-33

Emberlin J, Savage M, Jones SJC, Allergy E (1993) Annual variations in grass pollen seasons in London 1961–1990: trends and forecast models 23:911-918

Emberlin J, Smith M, Close R, Adams-Groom BJIJoB (2007) Changes in the pollen seasons of the early flowering trees Alnus spp. and Corylus spp. in Worcester, United Kingdom, 1996–2005 51:181

Fernandez-Rodriguez S, Duran-Barroso P, Silva-Palacios I, Tormo-Molina R, Maya-Manzano JM, Gonzalo-Garijo A (2016a) Forecast model of allergenic hazard using trends of Poaceae airborne pollen over an urban area in SW Iberian Peninsula (Europe) Natural Hazards 84:121-137

Fernandez-Rodriguez S, Duran-Barroso P, Silva-Palacios I, Tormo-Molina R, Maya-Manzano JM, Gonzalo-Garijo A (2016b) Quercus long-term pollen season trends in the southwest of the Iberian Peninsula. (Special Issue: Air pollution control and waste management.) Process Safety and Environmental Protection:101152-101159

Fernandez-Rodriguez S, Duran-Barroso P, Silva-Palacios I, Tormo-Molina R, Maya-Manzano JM, Gonzalo-Garijo A (2016c) Regional forecast model for the Olea pollen season in Extremadura (SW Spain) International Journal of Biometeorology 60:1509-1517 doi:10.1007/s00484-016-1141-z

Frei TJG (1998) The effects of climate change in Switzerland 1969–1996 on airborne pollen quantities from hazel, birch and grass 37:172-179

Fuhrmann CM, Sugg MM, Konrad CE, II (2016) Airborne pollen characteristics and the influence of temperature and precipitation in Raleigh, North Carolina, USA (1999-2012) Aerobiologia 32:683-696 doi:http://dx.doi.org/10.1007/s10453-016-9442-6

García-Mozo H et al. (2010) Trends in grass pollen season in southern Spain 26:157-169

García-Mozo H et al. (2006) Quercus pollen season dynamics in the Iberian Peninsula: response to meteorological parameters and possible consequences of climate change 13:209

Garcia-Mozo H, Oteros JA, Galan C (2016) Impact of land cover changes and climate on the main airborne pollen types in Southern Spain Science of the Total Environment 548:549221-549228

García-Mozo H, Yaezel L, Oteros J, Galán CJSotTE (2014) Statistical approach to the analysis of olive long-term pollen season trends in southern Spain 473:103-109

Ghosh N, Bennert, Saadeh (2016) Global Warming, Early Flowering, Increase In Allergy Cases And Ahpco To Improve The Indoor Air Quality European Scientific Journal June 2016

González-Parrado Z, Valencia-Barrera RM, Vega-Maray AM, Fuertes-Rodríguez CR, Fernández-González DJIjob (2014) The weak effects of climatic change on Plantago pollen concentration: 17 years of monitoring in Northwestern Spain 58:1641-1650
Grewling Ł, Jackowiak B, Nowak M, Uruska A, Smith MJG (2012) Variations and trends of birch pollen seasons during 15 years (1996–2010) in relation to weather conditions in Poznań (western Poland) 51:280-292
Grewling Ł, Jackowiak B, Smith MJA (2014) Variations in Quercus sp. pollen seasons (1996–2011) in Poznań, Poland, in relation to meteorological parameters 30:149-159
Grundström M, Dahl Å, Ou T, Chen D, Pleijel H (2017) The relationship between birch pollen, air pollution and weather types and their effect on antihistamine purchase in two Swedish cities Aerobiologia 33:457-471 doi:10.1007/s10453-017-9478-2
Ianovici NJAA (2015) Relation between Poaceae pollen concentrations and meteorological factors during 2000-2010 in Timisoara, Romania 68
Jato V, Rodríguez-Rajo F, Fernandez-González M, Aira MJIjob (2015) Assessment of Quercus flowering trends in NW Spain 59:517-531
Jato V, Rodríguez-Rajo F, Seijo M, Aira MJIJoB (2009) Poaceae pollen in Galicia (NW Spain): characterisation and recent trends in atmospheric pollen season 53:333
Kalinovych N, Voloshchuk K, Vorobets N (2016) Corylus and Alnus pollen concentration in air of Lviv (Western Ukraine). (Special Issue: Climate change impact on plant, plant communities, and crop production.) Acta Agrobotanica 69
Kasprzyk I (2016) The variation of the onset of Betula pendula (Roth.) flowering in Rzeszow, SE Poland: fluctuation or trend? (Special Issue: Climate change impact on plant, plant communities, and crop production.) Acta Agrobotanica 69
Kaszewski BM, Pidek IA, Piotrowska K, Weryszko-Chmielewska EJAA (2008) Annual pollen sums of Alnus in Lublin and Roztocze in the years 2001-2007 against selected meteorological parameters 61
Makra L, Matyasovszky I, Deák ÁJJAE (2011) Trends in the characteristics of allergenic pollen circulation in central Europe based on the example of Szeged, Hungary 45:6010-6018
Malkiewicz M, Drzeniecka-Osiadacz A, Krynicka J (2016) The dynamics of the Corylus, Alnus, and Betula pollen seasons in the context of climate change (SW Poland) Science of the Total Environment:573740-573750
Maya-Manzano JM, Fernandez-Rodriguez S, Monroy-Colin A, Silva-Palacios I, Tormo-Molina R, Gonzalo-Garijo A (2017) Allergenic pollen of ornamental plane trees in a Mediterranean environment and urban planning as a prevention tool Urban Forestry & Urban Greening
Medek DE et al. (2016) Regional and seasonal variation in airborne grass pollen levels between cities of Australia and New Zealand Aerobiologia 32:289-302 doi:http://dx.doi.org/10.1007/s10453-015-9399-x
Mercuri AM, Torri P, Casini E, Olmi LJPB (2013) Climate warming and the decline of Taxus airborne pollen in urban pollen rain (Emilia Romagna, northern Italy) 15:70-82
Murray MG, Galan C (2016) Effect of the meteorological parameters on the Olea europaea L. pollen season in Bahia Blanca (Argentina) Aerobiologia 32:541-553 doi:http://dx.doi.org/10.1007/s10453-016-9431-9
Negrini AC, Negrini S, Giunta V, Quaglini S, Ciprandi GJAjor, allergy (2011) Thirty-year survey on airborne pollen concentrations in Genoa, Italy: relationship with sensitizations, meteorological data, and air pollution 25:e232-e241
Newnham R, Sparks T, Skjøth C, Head K, Adams-Groom B, Smith MJIjob (2013) Pollen season and climate: Is the timing of birch pollen release in the UK approaching its limit? 57:391-400

Novara C, Falzoi S, Morgia VL, Spanna F, Siniscalco C (2016) Modelling the pollen season start in Corylus avellana and Alnus glutinosa Aerobiologia 32:555-569 doi:http://dx.doi.org/10.1007/s10453-016-9432-8
Oikonen MK, Hicks S, Heino S, Rantio-Lehtimäki AJG (2005) The start of the birch pollen season in Finnish Lapland: separating non-local from local birch pollen and the implication for allergy sufferers 44:181-186
Orlandi F, Sgromo C, Bonofiglio T, Ruga L, Romano B, Fornaciari MJT, climatology a (2009) A comparison among olive flowering trends in different Mediterranean areas (south-central Italy) in relation to meteorological variations 97:339
Piotrowska K, Kubik-Komar AJA (2012) The effect of meteorological factors on airborne Betula pollen concentrations in Lublin (Poland) 28:467-479
Puc M et al. (2015) Fluctuation of birch (Betula L.) pollen seasons in Poland 68
Puljak T, Mamić M, Mitić B, Hrga I, Hruševar D (2016) First aerobiological study in Mediterranean part of Croatia (Dalmatia): pollen spectrum and seasonal dynamics in the air of Split Aerobiologia 32:709-723 doi:10.1007/s10453-016-9444-4
Recio M, Docampo S, García-Sánchez J, Trigo M, Melgar M, Cabezudo BJA, Meteorology F (2010) Influence of temperature, rainfall and wind trends on grass pollination in Malaga (western Mediterranean coast) 150:931-940
Robichaud A, Comtois P (2017) Statistical modeling, forecasting and time series analysis of birch phenology in Montreal, Canada Aerobiologia 33:529-554 doi:10.1007/s10453-017-9488-0
Rojo J, Rapp A, Lara B, Sabariego S, Fernandez-Gonzalez F, Perez-Badia R (2016) Characterisation of the airborne pollen spectrum in Guadalajara (central Spain) and estimation of the potential allergy risk Environmental Monitoring and Assessment 188
Rojo J, Rivero R, Romero-Morte J, Fernandez-Gonzalez F, Perez-Badia R (2017) Modeling pollen time series using seasonal-trend decomposition procedure based on LOESS smoothing International Journal of Biometeorology 61:335-348
Sabo NČ, Kiš T, Janaćković P, Đorđević D, Popović A (2016) Pollution by Urticaceae pollen—influence of selected air pollutants and meteorological parameters Environmental Science and Pollution Research 23:10072-10079 doi:10.1007/s11356-016-6163-x
Sabo NČ, Popović A, Đorđević DJW, Air,, Pollution S (2015) Air pollution by pollen grains of Anemophilous Species: influence of chemical and meteorological parameters 226:292
Sicard P, Thibaudon M, Besancenot J-P, Mangin AJG (2012) Forecast models and trends for the main characteristics of the Olea pollen season in Nice (south-eastern France) over the 1990–2009 period 51:52-62
Šikoparija B et al. (2012) Variation in Artemisia pollen seasons in Central and Eastern Europe 160:48-59
Silva-Palacios I, Fernández-Rodríguez S, Durán-Barroso P, Tormo-Molina R, Maya-Manzano JM, Gonzalo-Garijo Á (2016) Temporal modelling and forecasting of the airborne pollen of Cupressaceae on the southwestern Iberian Peninsula International Journal of Biometeorology 60:297-306 doi:10.1007/s00484-015-1026-6
Simoleit A, Wachter R, Gauger U, Werchan M, Werchan B, Zuberbier T, Bergmann K-C (2016) Pollen season of European beech (Fagus sylvatica L.) and temperature trends at two German monitoring sites over a more than 30-year period Aerobiologia 32:489-497 doi:http://dx.doi.org/10.1007/s10453-016-9421-y
Sofia G, Emma T, Veronica T, Giuseppe F (2017) Climate change: consequences on the pollination of grasses in Perugia (Central Italy). A 33-year-long study International Journal of Biometeorology 61:149-158

Spieksma FTM, Emberlin J, Hjelmroos M, Jäger S, Leuschner RJG (1995) Atmospheric birch (Betula) pollen in Europe: trends and fluctuations in annual quantities and the starting dates of the seasons 34:51-57
Stach A, García-Mozo H, Prieto-Baena J, Czarnecka-Operacz M, Jenerowicz D, Silny W, Galán CJJIACI (2007) Prevalence of Artemisia species pollinosis in western Poland: Impact of climate change on aerobiological trends 17:39-47
Ste¸ palska D, Myszkowska D, Wołek J, Piotrowicz K, Obtułowicz KJG (2008) The influence of meteorological factors on Ambrosia pollen loads in Cracow, Poland, 1995–2006 47:297-304
Tedeschini E, Javier RodrÍguez-Rajo F, Caramiello R, Jato V, Frenguelli GJG (2006) The influence of climate changes in Platanus spp. pollination in Spain and Italy 45:222-229
Teranishi H, Katoh T, Kenda K, Hayashi SJA (2006) Global warming and the earlier start of the Japanese-cedar (Cryptomeria japonica) pollen season in Toyama, Japan 22:90-94
Teranishi H, Kenda Y, Katoh T, Kasuya M, Oura E, Taira HJCR (2000) Possible role of climate change in the pollen scatter of Japanese cedar Cryptomeria japonica in Japan 14:65-70
Tormo-Molina R, Gonzalo-Garijo M, Silva-Palacios I, Muñoz-Rodríguez AJJoia, immunology c (2010) 5 general trends in airborne pollen production and pollination periods at a Mediterranean site (Badajoz, southwest Spain) 20:567
Toro R, Córdova A, Canales M, Mardones PJPo (2015) Trends and threshold exceedances analysis of airborne pollen concentrations in Metropolitan Santiago Chile 10:e0123077
Ugolotti M, Pasquarella C, Vitali P, Smith M, Albertini RJA (2015) Characteristics and trends of selected pollen seasons recorded in Parma (Northern Italy) from 1994 to 2011 31:341-352
Van Vliet AJ, Overeem A, De Groot RS, Jacobs AF, Spieksma FTJIJoCAJotRMS (2002) The influence of temperature and climate change on the timing of pollen release in the Netherlands 22:1757-1767
Vara A, Fernández-González M, Aira MJ, Rodríguez-Rajo FJ (2016) Fraxinus pollen and allergen concentrations in Ourense (South-western Europe) Environmental Research 147:241-248 doi:10.1016/j.envres.2016.02.014
Zhang Y, Bielory L, Georgopoulos PGJIjob (2014) Climate change effect on Betula (birch) and Quercus (oak) pollen seasons in the United States 58:909-919
Zhang Y, Bielory L, Mi Z, Cai T, Robock A, Georgopoulos PJGcb (2015) Allergenic pollen season variations in the past two decades under changing climate in the United States 21:1581-1589
Ziello C et al. (2012) Changes to airborne pollen counts across Europe 7:e34076
Ziska L et al. (2011) Recent warming by latitude associated with increased length of ragweed pollen season in central North America 108:4248-4251