Laidlaw Pollen Research Summary:

An investigation into Grass and Birch pollen season trends between coastal and landlocked locations.

Introduction:

There are a wide variety of pollens globally, all with the potential to trigger allergic rhinitis (hay fever). Grass (*Poaceae)* pollen is the most widely distributed aeroallergen across Europe with some of the highest concentrations recorded in the UK (Emberlin et al., 1999). Birch (*Betula)* pollen is the most prevalent tree pollen in northern and central Europe, affecting at least 25% of hay fever sufferers in the UK (Adams-Groom et al., 2020) and the allergenic impacts of grass pollen affect an even greater 95% of all UK hay fever sufferers. Hence, the taxa *Poaceae* and *Betula* have been identified as a primary cause for concern to human respiratory health within Europe. Around 10% of the Belgian population suffer from allergies due to pollen emitted by birch trees (Verstraeten et al., 2019). Consequently, allergic rhinitis affects up to 40% of the European population and 10-20% of the total global population, making allergic rhinitis the most prevalent chronic non-communicable disease (Kurganskiy et al., 2021).

Climate change is predicted to result in a range shift of global vegetation zones. Increasing temperatures due to global warming will cause plants, that produce pollen to reproduce, to migrate towards the poles. Such shifts will have significant impacts to public health as more locations may be exposed to a wider variety of pollen producing species resulting in an increased exposure to larger quantities of pollen, increasing the risk to the respiratory health of sensitised individuals resulting in more cases of allergic rhinitis. Changes to airborne pollen counts across Europe have already been recorded during some long-term studies (Ziello et al., 2012; Hobeke et al., 2018) so it will be vital to understand what factors will influence the seasonal pollen counts to allow for successful management of the risks which aeroallergens pose to human health.

Novel literature has identified the need for more regional analyses of pollen trends to assist the ongoing and accurate monitoring of pollen seasons (Adams-Groom et al., 2020). This report seeks to contribute novel insight into how the *Poaceae* and *Betula* pollen seasons may vary between coastal and landlocked regions. Such knowledge will assist in providing a greater understanding of the factors which can influence the intensity and length of pollen season and thus, will aid future management of the risks pollen poses to public respiratory health via allergic rhinitis. Ultimately, results of this study may aid individuals who are more sensitised to allergenic *Poaceae* and *Betula* pollens as they may wish to consider living in locations with lower pollen indexes to mitigate some of the risks to their health, which could vastly improve their quality of life. Moreover, management of pollen allergy could be more specifically tailored with use of the results from this investigation as better foreplaning is possible with a greater understanding of which areas are more likely to be susceptible to pollen quantities that can trigger greater numbers and more intense cases of allergic rhinitis.

Methods:

To carry out this investigation into *Poaceae* and *Betula* pollen season trends from coastal and landlocked sites, data was obtained from two countries, the UK and Belgium. Four locations from each country were studied using data that was kindly provided by the UK Meteorological Office (MET office) (© Crown Copyright, 2013-2021) and the Belgian aerobiological surveillance network, Sciensano (Bruffaerts, N., 2022). The final study locations were chosen based on how continuous the data recorded was when considering missing and incomplete daily pollen readings. The final eight locations that were used for this study were deemed to be the most robust and contain the fewest amount of missing daily pollen counts from the records available to this analysis.

Table 1: The chosen sites studied during this analysis and their respective information regarding their pollen traps and how they were classified during this study.

Location	Brussels	*De Haan*	*Genk*	*Invergowrie*	*Isle of Wight (IOW)*	*Leicester*	*Marche-en-famenne*	*York*
Country	Belgium	Belgium	Belgium	UK	UK	UK	Belgium	UK
Site type	Landlocked	Coastal	Landlocked	Coastal	Coastal	Landlocked	Coastal	Landlocked
Pollen Trap coordinates (Latitude, Longitude)	50.824214, 4.381881	51.268630, 3.015197	50.965337, 5.494754	56.457558, 3.068737	50.711101, 1.300887	52.621919, 1.12381	50.201263, 5.312947	53.948419, 1.053544

Coastal sites were defined as such if they were less than or equal to 50km away from the open sea (table 1). Conversely, sites were deemed landlocked provided they were located greater than 50km away from open sea (table 1). All measurements and definitions were chosen considering the locations of each pollen trap from which the daily pollen data was collected.

Burkard Volumetric Spore Sampler units (e.g., Burkard, 2022) were used by the Sciensano and the MET office to collect pollen and fungal spores from each Belgian station 24 hours a day set to capture spores at 10l per minute which corresponds to the average human respiration rate. All samplers were located on the building's roofs so data from each station is representative of a 20-30km area around the station. Such sampling provided this study with daily pollen counts recorded as grains/m^3/24 hours which was then used in this study to equate the seasonal pollen integral and the pollen season length in days for both *Betula* and *Poaceae* pollen.

The European Academy of Allergy and Clinical Immunology (EAACI) definition of pollen season (Karatzas, K, Katsifarakis, N, Riga, M, et al, 2018) was used to characterise the start and end dates of the birch and pollen seasons for all the locations. These dates were then used to equate the season length in days and the seasonal pollen integral (SPIn) was calculated by summing the daily pollen concentrations between and including the determined season start and end dates as per Galán et al., (2017). Data was obtained from the years 2013-2021, although some locations had missing data for some years and 2021 pollen counts were limited for *Poaceae* pollen season as the data provided didn't span the entire season for some of the locations. These limitations were considered during this investigation and these omissions were correct for during the statistical analysis, although caution should be taken when considering the outcomes of this study due to the limitations of some of the data and its availability. Microsoft excel (Microsoft Corporation, 2018) was used to calculate SPIn, season length, and to graph the corresponding results.

Statistical analysis was then performed using SPSS (IBM Corp, 2021) to determine any significant differences in the pollen season trends analysed. 1-sample Kolmogorov-Smirnov tests were used in conjunction with Levene's tests to determine the distribution of the data and equal variances repetitively. 2-way ANOVAs were then performed to evaluate statistical significance of the SPIn and season lengths for both pollen types between the costal and landlocked sited under investigation across the years studied.

Results:

Poaceae:

Poaceae season integrals significantly differed between the Belgian and UK sites studied. Whether a location is either coastal or landlocked didn't yield a significant difference between the seasonal pollen integrals however, 2-way ANOVA revealed that the interaction between which country that the pollen was recorded from and if it was coastal or landlocked was significant (table 2), affecting both the *Poaceae* SPIn and season length.

Table 2: Results of the 2-way ANOVA for *Poaceae* SPIn and season length.

SPIn	*Site*	*Year*	*Site*Year*	*country*	*Country* year*	*Country* site*	*Country* year*site*
F	1.588	1.033	0.889	4.461	0.2	11.487	0.870
p	0.214	0.426	0.533	0.044**	0.983	0.002**	0.524

Season Length	*Site*	*Year*	*Site*Year*	*country*	*Country* year*	*Country* site*	*Country* year*site*
F	4.774	2.367	0.685	1.191	0.740	4.676	1.173
p	0.034**	0.031**	0.703	0.283	0.640	0.038**	0.347

**indicates statistical significance P<0.05 in the 2-way ANOVA.

Data wasn't available across all the sites for all the study years as highlighted in figure 1, so caution must be taken when interpreting this. 2015 experienced the highest total *Poaceae* pollen counts during the season despite the lack of data from De Hann for this year which perhaps highlights the higher quantities of pollen recorded during the 2015 season.

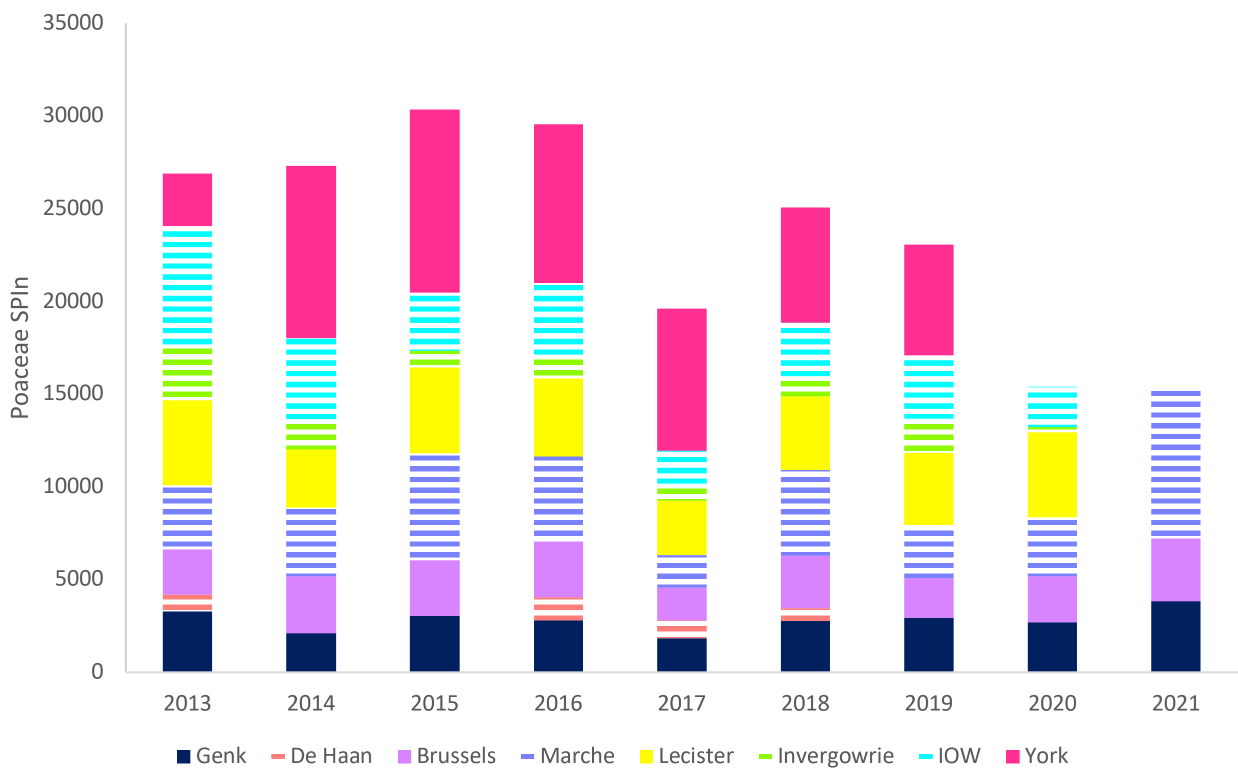

Figure 1- *Poaceae* seasonal pollen integrals from all the coastal (striped bars) and landlocked (solid bars) study sites in the UK and Belgium.

Poaceae season length experienced more significant changes than the SPIn; the total number of days which the *Poaceae* season lasted was significantly different between coastal and landlocked sites. Season length also significantly differed across the nine years that were investigated. A significant interaction between the country and site type was also identified which may lead to further explanation in the fluctuations of the *Poaceae* season duration (table 2).

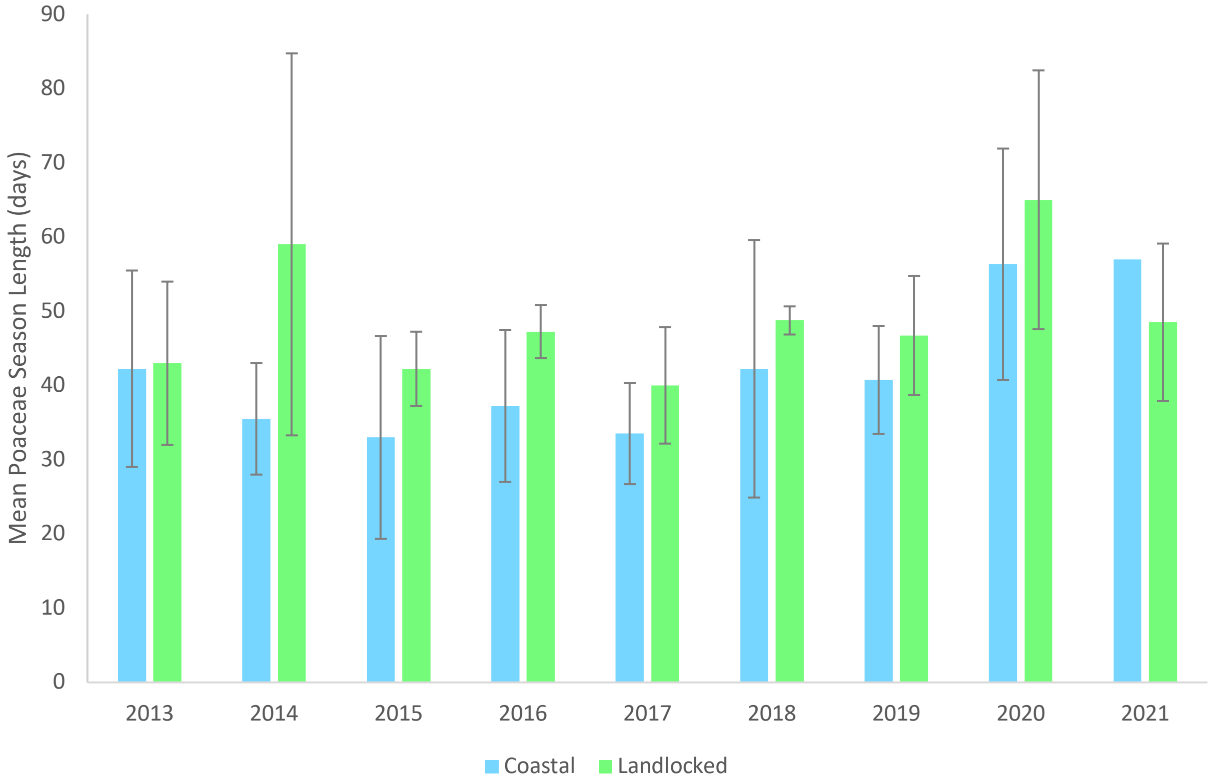

Figure 2- Mean Poaceae pollen season length each year, 2013-2021, from the coastal (blue) and landlocked (green) study sites. Standard deviation is displayed by the error bars. N.B., Standard deviation couldn't be calculated for the coastal sites in 2021 due to a lack of data.

Betula:
Betula SPIn significantly differed between the UK and Belgium F=36.344, p<0.001 (table 3; figure 3) but nonetheless, the type of site (coastal vs landlocked) did not result in significant affects to SPIn (p>0.05) between the study sites. In the year 2017, a much lower SPIn was recorded in comparison to the general trends of the previous and subsequent years although caution should be taken when interpreting these results as there were some issues with the data set whereby daily pollen counts for some sites were missing. To overcome this, these omissions were accounted for in the statistical tests to allow for better observations of the data available.

Table 3: Results of the 2-way ANOVA for *Betula* SPIn and Season Length.

SPIn	*site*	*year*	*country*	*Site*year*	*Site* country*	*Year* country*	*Site*year* country*
F	0.638	1.053	36.344	0.400	12.751	0.626	0.395
p	0.431	0.420	<0.001**	0.912	0.001**	0.749	0.915

Season Length	*site*	*year*	*country*	*Site* year*	*Site* country*	*Year* country*	*Site*year* country*
F	0.556	5.689	11.152	0.476	13.902	1.548	0.203
p	0.462	<0.001**	0.002**	0.863	<0.001**	0.183	0.988

**indicates statistical significance p<0.05 in the 2-way ANOVA.

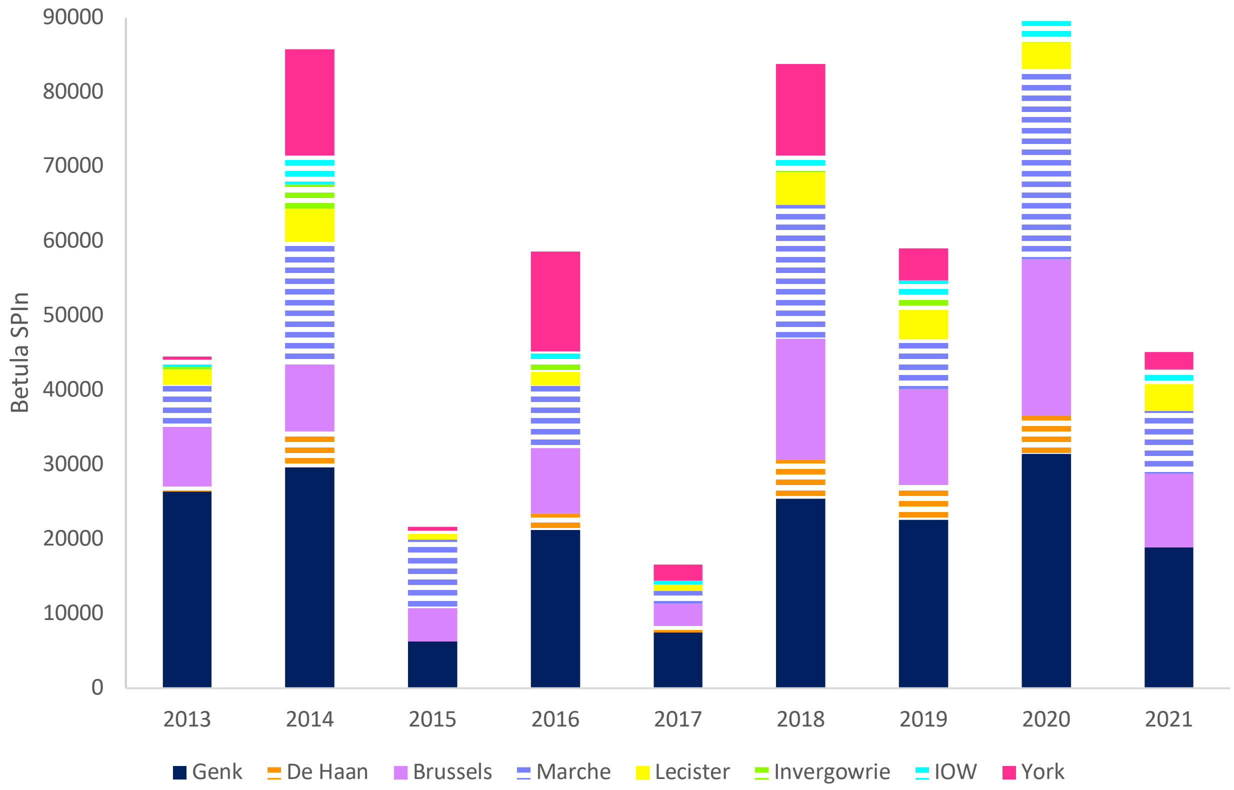

Figure 3- Betula seasonal pollen integral from 2013-2021. Coastal sites are represented by the striped bars and landlocked sites are displayed by the solid bars.

The length of the *Betula* pollen season did not differ significantly between the coastal or landlocked sites studied (figure 4). However, it was revealed that the interaction between a locations site type (coastal vs landlocked) and the country which it is from did have significant affects (table 3). *Betula* pollen season length significantly differed across the years analysed in this study (F=5.689, p<0.001). Season length between the UK and Belgium also experienced significant differences (F=11.152, p=0.002).

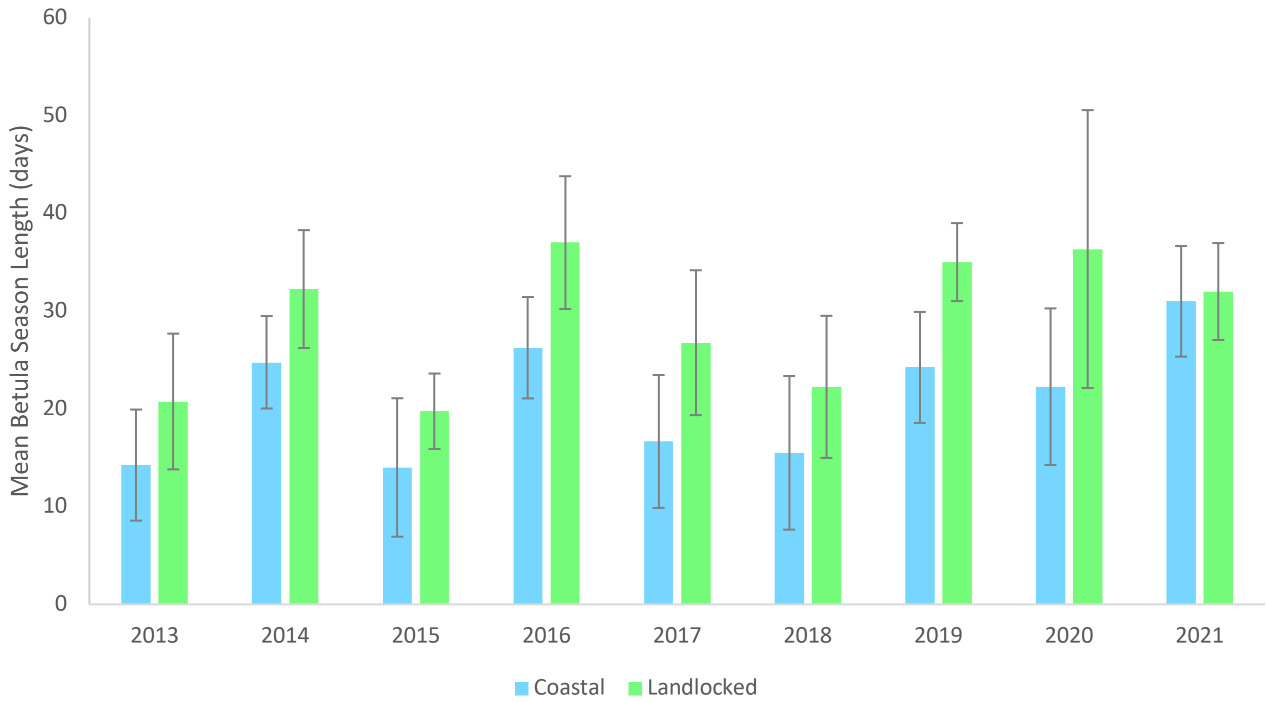

Figure 4- Mean *Betula* season length for each of the study years in the coastal (blue) and landlocked (green) sites analysed. Standard deviation is displayed by the error bars.

<u>Discussion:</u>

Poaceae and *Betula* season pollen integrals significantly differed between the UK and Belgian sites. Previous research has highlighted various climactic factors and weather conditions such as higher temperatures in the earlier months of the year encourage *Poaceae* growth (Emberlin, 1994; Emberlin et al., 1999) hence, the warmer climate in Belgium compared to that of the milder UK may be responsible for some of the differences observed between the pollen seasons of the two countries. Furthermore, the parameters identified to be responsible for driving *Poaceae* SPIn in a statistical model tested by Kurganskiy et al., (2021) were the pre-seasonal air temperature and precipitation and as these parameters differ between the UK and Belgium this may offer explanation as to the significant differences identified between the countries under investigation.

Betula SPIn was not significantly different across the years studies which is concordant with a 34-year analysis of various pollen types from 1982-2015 in which *Betula* pollen index did not significantly increase (Hobeke et al., 2018). However, a significant increase in the number of annual days per season experiencing >80 pollen grains/m^3 was observed (Hobeke et al., 2018) which is a cause for concern given the frequency of allergic rhinitis across Europe and the risk to public health presented by increased exposure to pollen and possible sensitisation (Lake et al., 2017; Emberlin, 1994).

During the Hobeke et al., study (2018) *Poaceae* pollen seasons were observed to decrease in severity over the 34 years studied, with a temporal shift in season length to the pollen seasons beginning and ending earlier. The aforementioned findings perhaps mirror those of this study which revealed *Poaceae* season length to significantly differ between the years 2013-2021. Further investigation is required and may be insightful to determine if the temporal shift observed by Hobeke et al., (2018) is continued in the results of this study.

With regards to the pollen season trends observed between the coastal and landlocked locations analysed, only *Poaceae* season length was found to be significantly different between the two site types. This may be due to a variety of climactic and environmental factors (Ziello, 2012; Emberlin et al., 1999; Aadms-Groom 2020) but notably, air pollution and elevated CO_2 in particular, has been shown to directly impact *Poaceae* pollen production (Hobeke et al., 2018; Ziello, 2012) thus, further investigation into the air pollution and CO_2 levels present at coastal compared to landlocked locations may be insightful into what factors may best describe and explain the significant differences observed.

Although some differences have been indicated between coastal and landlocked sites across the UK and Belgium, *Poaceae* and *Betual* pollen seasons do differ between regions (Adams-Groom et al., 2020) hence, to create more thorough and in-depth management strategies for allergic rhinitis sufferers perhaps more regional specific comparisons should be undertaken to progress the findings of this research.

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