



Comparative study of ragweed pollen seasons (2008–2017) in the air of Croatian tourist cities of Zagreb (continental area) and Zadar (Mediterranean area)

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Abstract The majority of tourists visit Croatia during the summer months, which overlaps with the ragweed pollination season, and this might be the main health issue, which could affect Croatian tourism. Therefore, the aim of this research was to perform the preliminary analyses of ragweed pollen seasons in two different Croatian tourist cities—continental Zagreb and Mediterranean Zadar, and to define researched areas according to the allergenic risk assessment. The research was performed during a 10-year period (2008–2017), and aerobiological samplings, as well as qualitative and quantitative analyses, were carried out by standard methodology recommended by EAN/REA. The results showed differences between cities in the seasonal pollen integral (SPIn) and intradiurnal variations index (IDI) of ragweed pollen, and similarities in the features of the main pollen seasons (MPS). The SPIn was higher in the air of Zagreb during the whole studied period; it was on average 2899 pg/m³ in

Zagreb and 579 pg/m³ in Zadar. The MPS in both cities were similar (from the first half of August until the mid-September) and relatively short, around 40 days. The IDI indicates that *Ambrosia* pollen in Zagreb derives from local sources, whilst in Zadar is probably a result of long-range transport. According to the allergenic risk assessment, Zagreb is placed in the intermediate-risk area and Zadar in the low-risk area. Relatively short exposure times during the summer periods enable both cities to be favourable tourist destinations even during the ragweed seasons, especially Zadar, with its low ragweed pollen concentrations.

Keywords Allergenic pollen · *Ambrosia artemisiifolia* L. · Tourism · Lowland Croatia · Mediterranean Croatia

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1 Introduction

Allergic diseases have increased rapidly during the past decades, and the prevalence of pollen allergy is estimated at about 40% of the European population (D'Amato et al. 2007). *Ambrosia artemisiifolia* L. (ragweed), one of the most important pollen allergens, is an invasive plant that has spread terribly and affected parts of Europe over the last century (Šikoparija et al. 2017). Lowland parts of Croatia are

highly infested with ragweed, whilst in the coastal area it is mainly concentrated on bands along the communication lines (Nikolić 2018). The study performed over the period from 2012 to 2014 showed that *Ambrosia* sensitisation is strongly associated with areas with *Ambrosia* pollen at levels over 5000 pg/m³ per year (Agnew et al. 2018). In addition, some authors tried to identify allergenic risk regions in Europe, determining the minimum ragweed concentrations triggering an allergic reaction and the time of exposure above a certain threshold (e.g. Liu et al. 2016).

Croatia overlaps three different geographical areas (lowland, Alpine and Mediterranean). Touristic activities are mostly related to the coastal part of the country, and recently, the Dalmatian city of Zadar was named as one of the top ten destinations in 2019 (<https://www.europeanbestdestinations.com/destinations/>). However, in the past several years, continental tourism is experiencing a notable increase, and an especially frequent destination is the capital city of Zagreb. Considering that the majority of tourists visit Croatia during the summer months (July to September), which overlaps with the ragweed pollination season (Šikoparija et al. 2017), ragweed pollen might be the main health issue which could affect Croatian tourism. Therefore, the aim of this research was to perform the first preliminary analyses of ragweed pollen seasons for the past 10 years in two different Croatian tourist cities—lowland Zagreb and Mediterranean Zadar, and to define researched areas according to the allergenic risk assessment.

2 Materials and methods

2.1 Study areas

The researched areas are located in the north-western part of continental lowland Croatia (city of Zagreb) and the northern part of Dalmatia (city of Zadar) on the Adriatic coast. The city of Zagreb (45°49'N; 15°59'E) is the capital of Croatia situated at the outermost south-western part of the Pannonian Plain, with a typical continental climate. It is the largest Croatian city and the largest urban region in Croatia, which dates back to the middle Ages. The city of Zadar (44°07'N; 15°14'E) is the second largest city in the Mediterranean part of Croatia, with a typical

Mediterranean climate. It is located in the central part of the eastern Adriatic coast (northern Dalmatia) and is one of the oldest towns in Croatia with an urban tradition of over 2000 years.

2.2 Pollen data analysis

The aerobiological data were collected with a 7-day Hirst-volumetric spore trap, during the period from 2008 to 2017. The data for the Zadar station are incomplete in 2012 (September 1 to 25, the malfunction of the sampler). Standardized aerobiological methods of qualitative and quantitative analyses (Galán et al. 2014, 2017) were applied. Obtained results were expressed as the mean daily pollen concentrations: pollen count per m³ of air per day during the main pollen season in the investigation period. The main pollen season (MPS) was defined according to Jato et al. (2006). For the intradiurnal distribution index (IDI), methodology proposed by Trigo et al. (1997) was used, and the values are expressed as percentages. Affiliations to a certain area of allergy risk for both cities were determined according to Liu et al. (2016). The Croatian Meteorological and Hydrological Service provided the meteorological data (temperature, precipitation, humidity and wind speed). Correlations between ragweed pollen concentrations (for the MPS) and particular meteorological parameters were calculated by Spearman's correlation analysis (using the StatSoft, Inc. (2016) STATISTICA software).

3 Results and discussion

The results showed the apparent difference in ragweed pollen concentrations between the continental and coastal parts of Croatia, and the seasonal pollen integral (SPIn) of ragweed was higher in the air of Zagreb during the whole studied period, on average five times higher in the city of Zagreb than in the city of Zadar (Table 1). This could be expected due to the *Ambrosia* distribution in Croatia (Nikolić 2018), because the city of Zagreb is geographically at the southwest border of the Pannonian Plain, which has been identified as one of the most important sources of ragweed pollen (Šikoparija et al. 2017). During the studied period, the SPIn in the city of Zadar did not show a visible pattern. However, in the city of Zagreb

Table 1 The main characteristics of the *Ambrosia* pollen seasons in the air of the cities of Zagreb and Zadar, 2008–2017 (MPS main pollen season, SPIn seasonal pollen integral)

	Zagreb						Zadar					
	MPS start	MPS end	MPS length	SPIn (pg/m ³)	Max pollen concentration (pg/m ³)	Max pollen conc. (date)	MPS start	MPS end	MPS length	SPIn (pg/m ³)	Max pollen concentration (pg/m ³)	Max pollen conc. (date)
2008	10.08	13.09	35	4179	363	27.08	17.08	27.09	42	414	76	29.08
2009	10.08	16.09	38	3654	248	19.08	04.08	27.09	55	1010	88	20.08
2010	10.08	21.09	43	3557	299	24.08	16.08	15.09	31	526	73	25.08
2011	13.08	19.09	38	3698	268	29.08	02.08	27.09	57	544	85	28.08
2012	06.08	18.09	44	3841	205	19.08	07.08	31.08	25	250 ^a	68	30.08
2013	05.08	24.09	51	1942	213	07.09	09.08	11.09	34	1078	155	02.09
2014	09.08	16.09	39	1776	175	25.08	02.08	09.09	39	193	33	29.08
2015	10.08	24.09	46	1637	293	02.09	06.08	22.09	48	660	86	08.09
2016	09.08	20.09	43	2196	212	28.08	08.08	14.09	38	795	109	31.08
2017	08.08	26.09	50	2513	180	28.08	13.08	07.09	26	320	53	29.08
Average	09.08	20.09	43	2899	246	27.08	09.08	15.09	40	579	82	29.08

^aZadar SPIn for 2012 was calculated from the dataset with missing data (1st–25th September 2012)

SPIn showed a pattern of a multi-year increase and decrease in pollen concentrations (Table 1), probably due to more or less successful actions of ragweed removal. Namely, over the past decade preventative measures (legal regulation, public awareness, eradication) were undertaken in the continental part of Croatia (Bullock et al. 2012). Low SPIn in Zadar might be explained by the scarce distribution of *Ambrosia* plants in that area (Nikolić 2018).

The MPS in both Croatian cities starts at the same time (Fig. 1), in the first half of August and ends in mid-September (Table 1). Moreover, it lasts approximately equally (around 40 days), and the peak of the MPS also starts at the same time (the end of August). The duration of the MPS in both cities is even shorter than in another Dalmatian city of Split (54 days on average) (Puljak et al. 2016). However, Šikoparija et al. (2017) placed the city of Zagreb within the second largest category regarding the number of days with ragweed pollen, although according to our results Zagreb is placed at the bottom line of this category.

The intradiurnal variations showed further differences between researched cities (Fig. 2). In the period from around 10 a.m. to 6 p.m., maximum values of pollen concentrations were marked in Zagreb and minimum in Zadar. Such results (Fig. 2) implicate that the presence of ragweed pollen in the air of Zagreb originated from local sources, whilst in the air of Zadar it is probably affected by long-range transport. Namely, it is known that *Ambrosia* plants start with pollen emission early in the morning and peaks of its pollen concentrations recorded during the morning/early afternoon are likely to be from a local source, whilst peaks recorded during the evening/night may have arrived via long-range transport (e.g. Šikoparija et al. 2009). The mountain of Velebit, located behind the Zadar plateau, represents a natural boundary that probably does not allow the breakthrough of pollen from the inland of Croatia to the coastal part. Therefore, further researches regarding the long-range transport of ragweed pollen to Dalmatia might make it clearer whether this pollen arrived from the east, as it

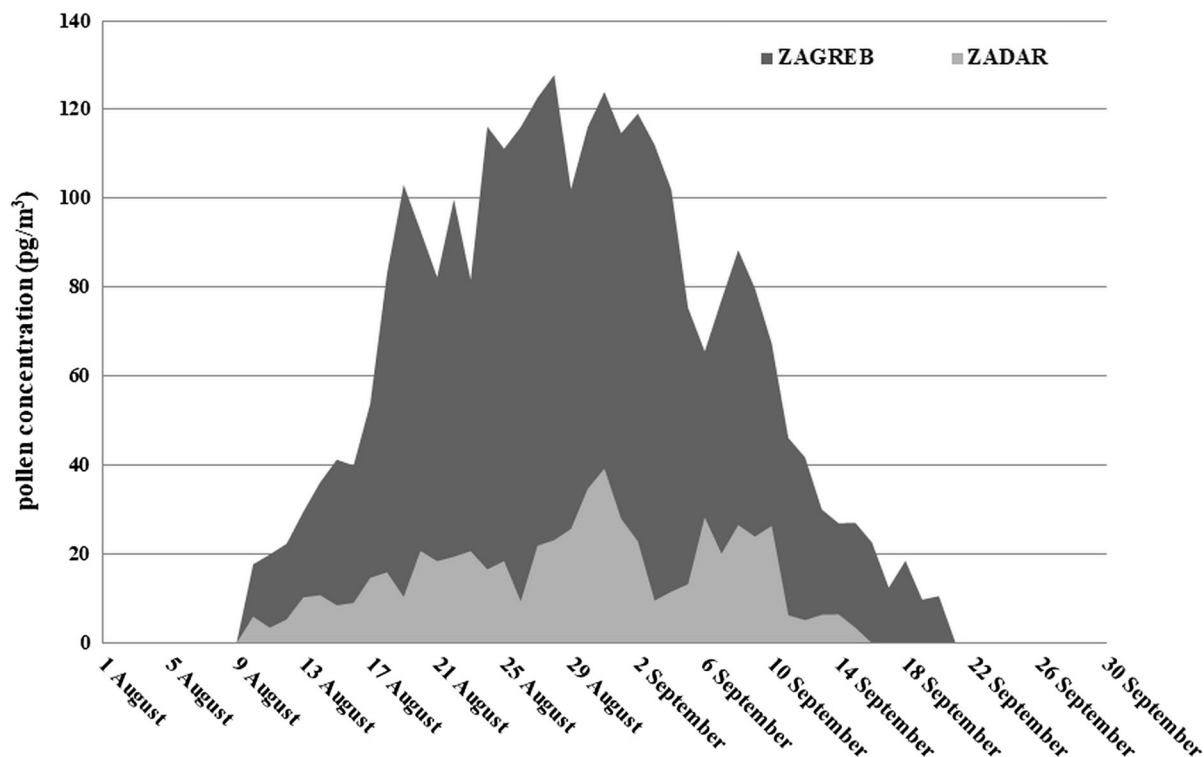


Fig. 1 Seasonal dynamics of the *Ambrosia* pollen in the air of the cities of Zadar and Zagreb (pollen calendar for the MPS main pollen seasons, based on average daily pollen values), 2008–2017

was suggested for some other taxa by Mandrioli et al. (1982) or from another direction.

The results of Spearman's correlation analysis showed some known trends, in general a positive correlation between *Ambrosia* pollen concentrations and temperature, and a negative correlation for precipitation, humidity and wind speed. However, the intensity of correlations was rather low and this analysis did not give us information suitable enough for interpreting relationships between the ragweed pollen seasons in both cities. Therefore, results of this correlation analysis are not shown here.

Applying the criteria for ragweed concentrations and thresholds for the onset of symptoms after exposure to ragweed pollen (Bullock et al. 2012; Liu et al. 2016), the city of Zagreb can be grouped in the intermediate-risk area and the city of Zadar in the low-risk area (cf. Liu et al. 2016). Although the SPIn is much higher in the city of Zagreb, both Croatian cities showed a relatively low risk of time of exposure to ragweed pollen in comparison with some other European cities (Liu et al. 2016).

Considering the fact that the total contribution of travel and tourism to the Croatian GDP in 2017 was 25%, which is anticipated to grow in the future (Turner 2018), the obtained results can be very useful for a better planning of tourism on both the national and global scale. Namely, they are incorporated in the Croatian Aerobiology Network (member of the EAN), which provides up to date pollen data, also available on the mobile application "Pollen forecast" (On Croatian: "Peludna prognoza").

4 Conclusions

The ragweed pollen concentrations measured in Zagreb and Zadar for the past 10 years showed that the biggest differences between them can be observed in the seasonal pollen integral (which is on average five times higher in the city of Zagreb) and intradiurnal "behaviour" of ragweed pollen, which indicate that in Zagreb it derives from a local source, whilst in Zadar is probably a result of long-range transport. Similarity

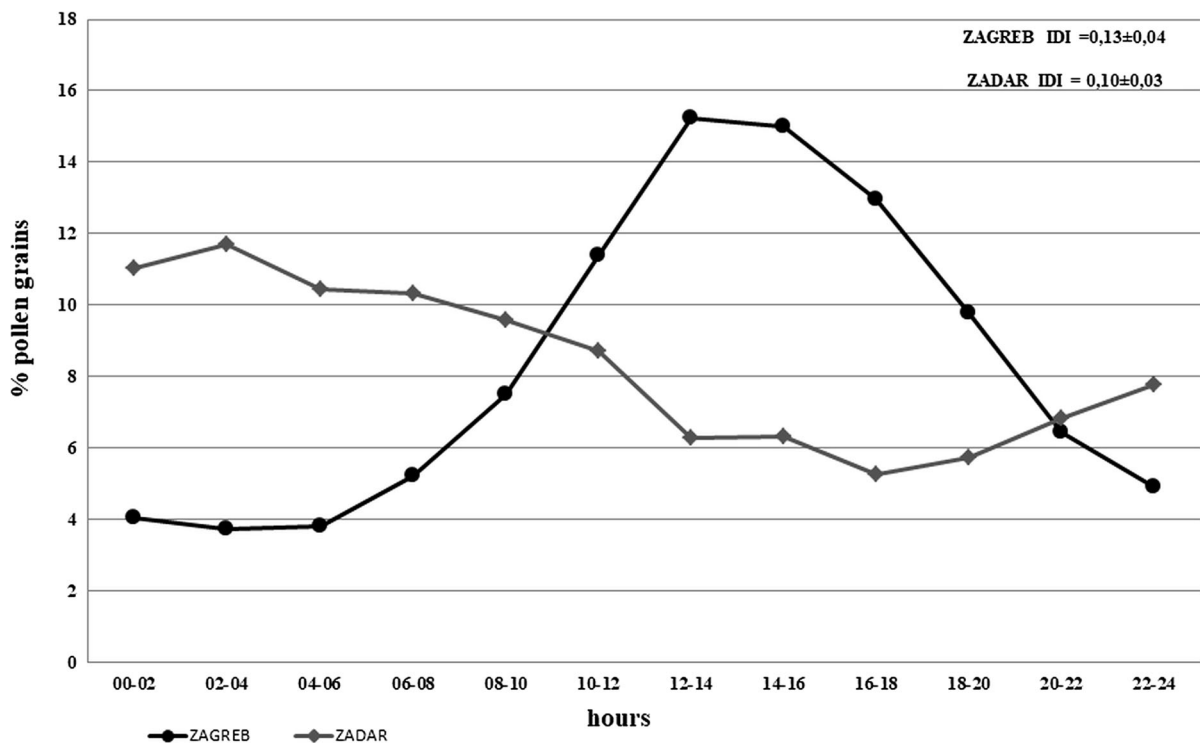


Fig. 2 Intradiurnal distribution patterns of ragweed pollen in the air of the cities of Zadar and Zagreb, 2008–2017

was noticed for the exposure time during the researched ragweed pollination seasons (short MPS, around 40 days). According to the allergenic risk assessment, Zagreb can be placed in the intermediate-risk area and Zadar in the low-risk area. Thanks to that, and a relatively short exposure time, both Croatian cities might be favourable areas even for allergic people (including tourists) during summer periods, but especially the Mediterranean city of Zadar.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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