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Long-term trends in airborne fungal-spore concentrations: a comparison with pollen

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ABSTRACT

We examined the long-term trends in airborne fungal-spore concentrations in Thessaloniki, Greece, over the period 1987–2005. We estimated trends in the spore levels for the 14 taxa that contribute at least 0.1 % to the total airborne spore concentration. We also tested for trends towards earlier, longer or more highly peaked spore seasons. There was decreasing concentration of spores for 11 of the 14 taxa, especially for *Agrocybe*, *Botrytis*, *Cladosporium*, and *Nigrospora*, where this trend was significant. Using ANCOVA, there was a highly significant negative trend overall ($p < 0.001$). Regarding the spore-season related attributes, there were very few significant trends. However, the main spore season tended to start later (for 12 of the 14 taxa) and become shorter (for 10 of the 14 taxa); later onset was more pronounced during the most recent part of the study period. Fungi seem to display a delayed and slower response to climate change than plants and in a direction opposite to that of pollen.

Introduction

Several long-term alterations of ecological processes that have been reported over recent decades (e.g. Penuelas et al., 2002; Walther et al., 2002) are attributed to global change. Some of the longest and most recent datasets of biological origin are aerobiological records, specifically of airborne pollen and fungal spores. Extensive research over the last decade has shown that the rate of pollen production has been increasing with pollen seasons occurring earlier and lasting longer (Clot, 2003; Ziello et al., 2012). Damialis et al. (2007) reported exponentially increasing trends in airborne pollen concentrations in Thessaloniki, Greece, for a wide spectrum of pollen types. These trends are probably the most intense worldwide to date (Ziello et al., 2012).

Current global climate change (and also the projected for the coming decades) is expected to have an impact on fungal biodiversity patterns. Changes may have commensurate

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effects on public health because fungal spores are frequently implicated in respiratory allergy symptoms (D'Amato et al., 1997; Gioulekas et al., 2004; Mari et al., 2003). The frequency and the severity of allergic reactions to pollen in sensitised individuals have increased over recent decades, and this matches the increase in airborne pollen concentration (Linneberg et al., 1999). Compared to pollen, fungi are reported as a neglected and underestimated source of respiratory allergy (Crameri et al., 2014). However, fungal spores are well known to induce respiratory allergy incidents, which are more common among children, manifested with severe symptoms, even as acute respiratory failure (Bush and Prochnau, 2004; Dales et al., 2000). Hence, it is very important to assess and evaluate the trends of airborne fungal spore abundance and the associated health risks.

From a conservation perspective, Helfer (2014) reported that specific fungal types could be susceptible to global environmental change. Fungal sporulation and fruiting are influenced by several meteorological factors, such as rainfall and air temperature (Carlile et al., 2007). Thus, variability of these factors at different stages of fungal reproduction could lead to modifications of the fungal biodiversity patterns. In fact, there are indications that changing climates have significant effects on fungal communities (Corden et al., 2003; Gange et al., 2007; Kauserud et al., 2010).

To date, only Corden et al. (2003) have searched for long-term trends in airborne fungal spore concentrations. To do so, they used a 26-year dataset for *Alternaria* from Derby and Cardiff (UK). They did not find any consistent change in atmospheric concentrations: spore abundance and distribution varied largely between the two study sites depending on regional vegetation and other local factors. Beggs (2004) pointed out the need to examine air particles other than pollen grains, particularly when so little information is available, and Berman (2011) expressed serious concerns regarding the changing biodiversity patterns and concomitant alterations in allergic sensitisation in response to the current and the projected climatic change. Therefore, studies examining data for a wider spectrum of fungal taxa and experimental simulations of fungal performance need to be undertaken in order to elucidate fungal responses to climate change.

In this paper, we investigate long-term trends in airborne fungal spore levels in Thessaloniki, the second largest city of Greece, over the last two decades (1987–2005). To do so, we analysed a comprehensive spectrum of fungal taxa. The dataset we used refers to exactly the same period, with data obtained from the same aerobiological station and analysed in the same way as the pollen data that showed long-term trends (Damialis et al., 2007). A significant rise in air temperature has been observed regionally for Thessaloniki (Fig 1; Université de Thessaloniki, 1991–2007), as it has for Greece overall (Feidas et al., 2004). Therefore, our aim was to explore whether there are any long-term trends in airborne fungal-spore concentrations and if these are commensurate with and can be related to those observed for pollen in the same study area over the same period. Our working hypothesis was that changing environmental factors will have an impact on fungi leading to different patterns of fungal-spore abundance and temporal distribution, as has already been observed for pollen (Damialis et al., 2007).

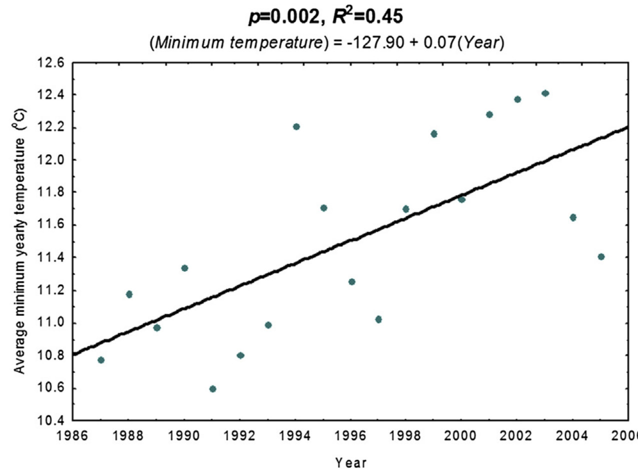

Fig 1 – Minimum annual air temperature over 1987–2005. On the *x*-axis the sampling year is displayed, whereas the y-axis shows the yearly average minimum temperature value in degrees Celsius.

Materials and methods

Study area

Thessaloniki is located to the north of Thermaikos Gulf, in the Aegean Sea (40°37′N, 22°57′E); its climate is Mediterranean, with hot and dry summers and mild winters. Several forests grow close to the northeast, east and southeast. A temperature increase (Fig 1) has been observed in Thessaloniki over the period 1987–2005 (Université de Thessaloniki, 1991–2007). During the study period, there were two notable changes: in July 1997, a great fire burnt 1 500 ha in the nearby Seich Sou forest, with pines, evergreen oaks, cypresses, planes and grasses being mainly affected (Krigas, 2004; Spanos, 1997). Apart from this localised in time event, there is also increasing urbanization. The city grew primarily towards the northwest and southeast, in areas where there were formerly semi-natural grasslands.

Spore collection, identification and counting

To have comparable results, we applied the same sampling, data manipulation and statistical analysis as for pollen (Damialis et al., 2007). The methodology used is typical for fungal-spore data collection, followed by most scientists (e.g. British Aerobiology Federation, 1995). In brief, airborne fungal spores in Thessaloniki were collected by use of a 7 d recording Burkard volumetric trap (Burkard Manufacturing, Rickmansworth, Hertfordshire, England), located on the roof of a 30 m building, in the centre of Thessaloniki. The trap was equipped with a vacuum pump drawing 10 l of air min^{-1} through a narrow orifice. Air particles were trapped on an adhesive-coated (Burkard gelvatol) transparent plastic tape (Melinex), supported on a clockwork-driven drum, which moved at a speed of 2 mm h^{-1} making a complete revolution in 1 week. The tape was then removed and cut in seven equal sections, each representing a day of