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Short communication

Is coal combustion the last chance for vanishing insects of inland drift sand dunes in Europe?

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ABSTRACT

Inland sand dunes rank highly in the most threatened environments throughout Europe, suffering accelerating losses of associated biodiversity. Although there is increasing evidence that vanishing species may find refuges at post-industrial barrens, insects specialised for the highly specific and extreme conditions of drift sands have not been known to colonise any surrogates. Because fly ash deposits share some substrate physical attributes with drift sands, we hypothesised that they could be colonised by drift sand communities. Here, we show that these relatively common landscape structures accompanying coal combustion indeed host insects of extraordinary conservation value. Surveying two fly ash deposits in Central Europe, we found an unusually high diversity of 227 species of bees and wasps, including 72 nationally endangered species (including four thought regionally extinct and 13 critically endangered), and 31 drift sand specialists. This conservation potential seems to diminish with successional overgrowing of the deposited ash. We also document that at the landscape level, the deposits are effectively supplementing the vanishing drift sands. Power-plants producing fly ash deposits, commonly viewed as biotic wastelands, thus paradoxically provide crucial refuges for vanishing biodiversity.

1. Introduction

The European energy industry still substantially depends upon coal combustion. Fly ash deposits, where the solid by-products of power production are stored, are found in nearly every European region, accompanying practically every power station, heating plant and many larger factories. These solid wastes are comprised mainly of fly ash, formed by very fine (average diameter <10 μm) glass-like particles of mineral residua which are carried out of the boiler in the flow of exhaust gases (Haynes, 2009). The other components (such as bottom ash, boiler slag and the flue gas desulphurisation materials) constitute about 25–30% (Haynes, 2009).

Much is known about the negative impacts of flying ash on human health and the environment (Borm, 1997; Adriano et al., 2002), and consequently, rapid reclamation of fly ash deposits is recommended and routinely practiced (Haynes, 2009). On the other hand, the evidence is accumulating that various post-industrial barrens, such as quarries, gravel pits, spoil heaps and brownfields, often harbour biotic communities of high conservation value, providing refuges for many species vanishing from human-affected landscapes (Benes et al., 2003; Lundholm and Richardson, 2010; Tropek et al., 2010; Heneberg et al., 2013; Lenda et al., 2012). From this point of view, the fly ash deposits, hitherto unexplored, may therefore deserve attention. The few published systematic surveys of biota colonising these sites have been restricted to plants (Ash et al., 1994; Kovar, 2004), lichens (Kovar, 2004) and fungi (Kubatova et al., 2002). These studies found minimum biodiversity with practically no species of conservation value, presumably due to hostile substrate chemistry. No study published so far has targeted insects, which represent the bulk of terrestrial biodiversity, and for which the physical and spatial microhabitats structure may be more decisive than the chemical composition of the substrate (e.g., Dennis et al., 2006).

Fly ash deposits share many important features with inland drift sand dunes, a highly endangered habitat in continental Europe. The shared features include finely grained and mechanically unstable substrate prone to desiccation (Andreotti et al., 2009; Haynes, 2009; Fanta and Siepel, 2010), and a resulting microclimate with wide fluctuations of daily and annual temperatures, as well as steep gradients of moisture and nutrients (Riksen et al., 2006; Exeler et al., 2009; Fanta and Siepel, 2010). Specialists of

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drift sands (psammophilous species herein) must withstand frequent disturbances and considerable stress. In many psammophilous species, the specialisation for large areas of the bare sands is so pronounced that they do not occur in any other natural habitat (Riksen et al., 2006; Exeler et al., 2009; Fanta and Siepel, 2010). Based on their shared features, we hypothesised that fly ash deposits should attract the specialised arthropods of drift sands.

Drift sands have suffered one of the highest rates of habitat loss among European environments (Hoekstra et al., 2005; Riksen et al., 2006; Fanta and Siepel, 2010). In the form of inland (continental) dunes, they had been widespread in many areas of Central Europe until the late 19th century. Abhorred as wastelands, they were often the first sites targeted for agricultural improvement, afforestation and building development (Fanta and Siepel, 2010; Riksen et al., 2006). Loss of these habitats accelerated with the decline of grazing, followed by succession, and with increased environmental eutrophication by atmospheric nitrogen deposition, the latter particularly harmful for specialists of low competition – high stress environments (Exeler et al., 2009; Benes et al., 2002). As a result, psammophilous insects are rapidly disappearing from much of Europe. For example, all the psammophilous butterflies of the Czech Republic died out in the late 20th century (Benes et al., 2002) and psammophilous species from other insect groups have been affected by similar losses across Europe (cf. Glowacinski and Nowacki, 2004; Farkac et al., 2005; Dicks et al., 2010).

Bees and wasps (Hymenoptera: Aculeata, except for ants) represent a conspicuous and species-rich insect group containing important pollinators, predators and parasitoids. They rank among the most severely declining insects (Dicks et al., 2010; New, 2012), with more than 30% of 1238 species recorded from the Czech Republic classified as regionally extinct or critically endangered (Straka, 2005a,b,c; Fig. 1). A large proportion of aculeate hymenopterans utilise sandy substrates for nest building (New, 2012). In the Czech Republic, a country that represents well the conditions in temperate Europe, 101 species are strict specialists of drift sands, restricted to this biotope (Macek et al., 2010), and from this number, 67% are regionally extinct or critically endangered (Fig. 1). The proportion is more than twice as high than the proportion of extinct and critically endangered species in the complete bee and wasp Czech fauna (32.7%), illustrating the high level of threat faced by inland drift sand specialists in Central Europe.

Here, we bring the survey of bees and wasps colonising two fly ash deposits aiming to answer the following questions: (1) Do ash deposits offer a surrogate habitat for vanishing psammophilous species? (2) Do the main microhabitat type within the deposits differ in their conservation potential for those species? (3) Do fly ash deposits have potential to supplement natural sand dunes in the studied region? Besides species richness, we evaluated the conservation potential of the studied habitats using specialisation and national red-list status of individual bee and wasp species (cf., Feest, 2006; Tropek et al., 2010) To the best of our knowledge, this paper represents a pioneering survey of any arthropod group in this so far neglected type of post-industrial barrens.

2. Methods

We surveyed two localities of fly ash deposits in the Polabí region, Northern Czech Republic, Central Europe (Fig. 2). This lowland with a relatively mildly warm temperate climate (sensu Quitt, 1971; average temperature 8–9 °C, annual precipitation 550–700 mm) was the historical granary of the country. Continental drift sand habitats, once relatively common in this region, have disappeared almost entirely due to afforestation and/or succession during the last century. The Chvaletice ash deposit, (50°1′ N, 15°27′ E; 250 m alt.) had sedimented ash from the Chvaletice Power Station since the late 1970s, while the Bukovina ash deposit (50°7′ N, 15°50′ E; 250 m a.s.l.) had sedimented ash from the Opatovice nad Labem Power Station since the 1960s. At the beginning of 2000s, the establishment of desulphurisation in both power stations changed the ash deposition technology, terminating the sedimentation. Major parts of the ash sedimentation lagoons were drained and the exposed fly ash was left to spontaneous succession. At present, both localities are being technically reclaimed by covering with fertile topsoil and conversion to species-poor mesophilous grassland and/or forest plantation (cf. Tropek et al., 2012). In 2009, however, the unreclaimed ash surfaces still covered ca 20 ha in the Chvaletice ash deposit and 10 ha in the Bukovina ash deposit.

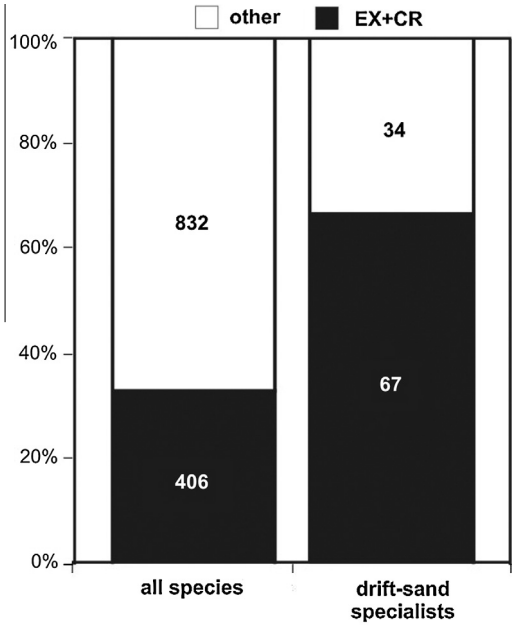

Fig. 1. The drift sand specialists are the most endangered guild of bees and wasps: proportions of regionally extinct (EX) and critically endangered (CR) species from complete fauna and from strict drift sand specialists in the Czech Republic.

At both localities, insects were sampled in three spontaneously developed habitats: (i) plots with *barren dry* strongly desiccative and thus loose substrate (herbaceous cover <10%); (ii) plots in vicinity of water lagoons and/or in large depressions with *barren humid* and thus presumably more compact substrate (herbaceous cover <10%); and (iii) and plots *overgrown* by *Calamagrostis epigejos* and other grasses (herbaceous cover >80%). All the three habitat types and their transitions create the overwhelming majority of both studied deposits. We hypothesised that these distinct habitats were host to different bee and wasp species because of a totally different offer of microhabitats for their nesting. Three replicates of each habitat were selected within each locality to be as equally (in sense to avoid two neighbouring plots of the same habitat type) distributed as possible, with at least several tens of metres between any neighbouring plots. In each replicate, we established one 3 m × 3 m plot where 9 yellow pan traps (15 cm in diameter) filled by water with a small amount of detergent were exposed in a regular grid. Four exposure times (1–3 May, 13–15 June, 1–3 July, 30 July–1 August, all 2009), all under optimal weather (>25 °C, clear skies, not windy), covered the key emergence periods of the studied insect group. All collected bees and wasps (Hymenoptera: Aculeata, except for ants) were identified to species. Their threat status, distribution and life history, including their psammophilous specialisation, follow national red lists (Straka, 2005a,b,c) and catalogue (Macek et al., 2010).