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The importance of the gravel excavation industry for the conservation of grassland butterflies

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ABSTRACT

Conservation biology often relies on the protection of (semi)natural habitat remnants. However, the ever increasing human population is taking over natural resources and habitats. Here, contrary to most other studies, we ask how human-associated severe changes in the environment can be used to enrich local biodiversity. We tested if industrial activity (gravel excavation) leads to the creation of habitats that support grassland butterflies and how these areas add to the richness of local species when compared to typical semi-natural habitats (grasslands). We also identified key factors affecting the richness, abundance, diversity and commonness of butterfly species to provide practical recommendations. Species richness, diversity index and the occurrence of rare species were higher in gravel-pit shores than in grasslands. The richness of butterfly species and their abundance were positively affected by the richness of plant species, shrub density and age of the gravel-pit but negatively by the cover of water reservoirs in the surrounding area and the isolation of gravel-pits from grasslands. Butterfly diversity was positively influenced by the richness of plant species and proximity of human settlement but negatively by area of the shore and isolation. Our study is the first one to show the high value of gravel-pits for the conservation of butterflies. We recommend the inclusion of gravel-pits in a system of ecological networks and management of their surroundings to improve the colonization rate of rare species. We suggests that directing interest to the possible positive effects of industrial development on biodiversity may support conservation efforts.

1. Introduction

Populations of many insects across Europe have declined rapidly (Thomas et al., 2004; Biesmeijer et al., 2006; Warren and Bourn, 2011). Many factors are responsible for this phenomenon, especially the intensification of agriculture (Van Swaay et al., 2010; Dover et al., 2011), habitat fragmentation (Van Swaay et al., 2010), urbanization (Clark et al., 2007), pollution (Mulder et al., 2005), invasive alien species (Moroń et al., 2009) and climate change (Settele et al., 2008). Great effort has been made to work out the specific actions and programs to stop this dramatic loss of species diversity with the emphasis put on the conservation of remaining (semi)natural habitats and increasing connectivity among them (Öckinger and Smith, 2006; Brückmann et al., 2010; Loss et al., 2011). Also, agri-environmental schemes in the European Union are being carried out in the hope that many insects inhabiting agricultural landscape will survive (Batáry et al., 2010). However, this attitude towards the conservation of species diversity faces many practical problems (Warren and Bourn, 2011). The creation and management of semi-natural habitats, the design of ecological corridors or stepping stones are costly and, hence, may be limited only to the local scale. The alternative or supplementary solution for the above problem is to look for the unrecognized advantages to biodiversity that are brought by human activity usually regarded as damaging to the environment. Man-made habitats, often associated with industrial or settlement development, may have high conservation value (Prach, 2003; Tropek and Konvicka, 2008; Lundholm and Richardson, 2010; Berg et al., 2011). Moreover, studies in such new habitats give an insight into the functioning of the ecosystem and the formation of animal and plant assemblages (Prach, 2003; Santoul et al., 2004). It has been shown that limestone quarries (Benes et al., 2003; Jukes et al., 2010; Tropek et al., 2010), road verges (Munguira and Thomas, 1992; Thomas et al., 2002; Saarinen et al., 2005), former open-surface coal mines (Holl, 2006) and landfills (Davis, 1989) may be refuges for rare plants and

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butterflies. The above mentioned studies suggest that the habitats created by industrial activity may significantly contribute to the conservation of species diversity and/or mitigate the negative results of human activity. In Europe, gravel-pits have become more and more common features in the landscape (Santoul et al., 2004; Skórka et al., 2006; Skórka, 2007). The excavation of aggregate (gravel, sand) has increased greatly because companies building roads and human settlements have created a huge market (Stryszewski, 2006; Galos, 2009). For example, in Poland the annual excavation of gravel and sand doubled between 2000 and 2006 (Stryszewski, 2006; Smakowska-Filipek and Smakowski, 2008). The results of this mining activity are various waterbodies with shores covered by diverse vegetation (Skórka et al., 2006; Bzdon, 2008). It is already recognized that gravel-pits are important habitats for some waterbirds (Santoul et al., 2004; Skórka et al., 2006). Shores of gravel-pits are wide (often up to 50 m) and are covered by many flowering plant species (Bzdon, 2008). The latter suggests that gravel-pit shores may be an important habitat for many butterfly species. To our knowledge, the value of gravel-pits for butterflies has not been studied to date. Therefore, in this study we explored the value of this habitat for butterflies by comparing their number, abundance, diversity and commonness of species with those found in a typical habitat of butterflies: extensively managed or recently abandoned meadows (Kruess and Tscharntke, 2002; Skórka et al., 2007; Dover et al., 2011). Further, we identified local- and landscape-level factors affecting the richness, abundance, diversity and commonness of butterfly species on gravel-pit shores to provide recommendations helpful in the management of this habitat for these insects.

2. Material and methods

2.1. Study area

The study was conducted in 2006 in 50 gravel-pits located in two provinces (Małopolska, Podkarpacie – total area 30,000 km^2) of southern Poland (Fig. 1 and Supplementary file). Gravel-pits were selected at random from our database of 209 gravel-pit complexes (total area 5000 ha) in Małopolska and Podkarpacie (Skórka et al., 2006; Skórka, unpublished). The mean ± SE size and age of the selected gravel-pits were 19.3 ha ± 3.2 ha (range: 1.1–89.0 ha) and 11.2 years ± 1.1 years (range: 3–34 years), respectively. The bedrock in the study sites is mainly composed of boulder clay, sand and glacial accumulation gravel (Zawiejska and Wyżga, 2010). Shores of the gravel-pits were covered by diverse vegetation, mostly dry grasslands and margin communities (class: *Festuco-Brometea; Trifolio-Geranietea sanguinei*), xeric sand grasslands (*Koelerio glaucae-Corynephoretea canescentis*), fresh and moderately moist meadows (*Molinio-Arrhenatheretea*), mesophilous communities of tall perennials (*Artemisietalia vulgaris* and *Convolvuletalia sepium*) and perennial ruderal communities (*Agropyretea intermedio-repentis*). Most numerous plant genera were: *Carex* (six species), *Trifolium* (7), *Vicia* (8) and *Veronica* (6). The intensiveness of gravel excavation was differentiated between gravel-pits. Most of them were extensively exploited and their relatively large fragments were abandoned after the aggregate extraction. Fourteen gravel-pits were intensively exploited (over 50% of area were in the exploitation) and ten were recently abandoned gravel-pits.

2.2. Butterfly surveys

We established 50 transects (200 m long, 5 m wide), where the butterflies were counted with the Pollard method (Pollard and Yates, 1993). The location of the transect was established by the random generation of geographical coordinates at the selected gravel-pits. The transects were parallel to the shoreline and located in the middle of the shore. We defined shore as a land created during excavation of gravel that lies between water surface and other land use type (e.g. arable field, grassland, forest, see also: Supplementary file). In our sample of gravel-pits the mean width of the shore was 16 m ± 2 m (range: 5–58 m). Mean area of the shore ± SE was 4.7 ha ± 0.6 ha (range: 0.9–18.3 ha). We made seven surveys in each transect between the end of April and the end of August 2006. The surveys were done during favourable weather conditions (temperature of at least 18 °C, wind 3 or less on the Beaufort scale, cloud cover not greater than 25%). The total number of butterfly species (species richness), the total number of individuals (abundance) and Simpson's index of diversity were calculated for each transect. We used the Simpson's index because it is easily interpretable as the probability that two randomly selected individuals are of the same species (Simpson, 1949). Moreover, it is commonly used and is one of the least biased indices regardless of the abundance distribution model used and when sample size is small (Mouillot and Lepretre, 1999).

The number of occupied grid squares from the Polish Butterfly Atlas (Buszko, 1997) (http://motyle.info/forum/portal2.php?show=rozmieszczenie) based on field work done in 1986–1995 were used to provide a commonness (non-rarity) value for each species (Rosin et al., in press). A mean commonness score (C_s), weighted by species abundance, was then calculated for each transect. The formulae is as follow:

$$C_s = \frac{\sum_i^t (Ng \times Nind)}{Ntot}$$

where *Ng* is number of occupied grid squares by a given species in Poland derived from Polish Butterfly Atlas (Buszko, 1997), *Nind* is a number of individuals of a given species recorded during all counts in a given transect, *Ntot* is total number of individuals of all $(i,\ldots,t)$ species recorded during all counts in a given transect.

For our recorded species this score could, hypothetically, range from nine (if only *Colias erate* was recorded in a transect) to 873 for *Pieris napi* only. In our transects the score (averaged across all species recorded in a given transect) varied from 356 to 693.

To compare the number of species, abundance, diversity index and commonness of butterflies found at gravel-pit shores with those in grasslands we established a further 50 transects on extensively managed grassland or recently abandoned ones (<5 years). We chose grasslands in the vicinity of the studied gravel-pits (mean ± SE distance to the gravel-pits was 247 ± 12 m, range: 50–410 m) to keep such factors as the habitat patch size, bedrock and landscape composition similar to the transects on the shores. We chose extensively managed grasslands and recently abandoned grasslands because our earlier study showed that they are one of the most important and widespread butterfly habitats, covering about 11% of the study area (Skórka et al., 2007; Lenda and Skórka, 2010). The structure of agriculture in southern Poland is that fields and grasslands are usually small and elongated thus, are a little bit similar to the gravel-pit shores as far as shape is concerned. The mean ± SE grassland size was 6.1 ± 0.7 ha (range: 0.9–18.3 ha) and did not differ from the mean size of shore area (bootstrapped $t = 1.67$, $P = 0.096$). These grasslands were mown once a year in autumn or once every 2 or 3 years. Ten grasslands had not been managed for 4–5 years. No fertilizer was used in all meadows but two, where small amount of nitrogen and calcium (exact quantities not known) was applied occasionally in some years.

2.3. Variables measured in transects

The following environmental variables potentially affecting butterfly populations were determined in transects at gravel-pits: