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Military training areas as refuges for threatened dragonfly species: Effect of spatial isolation and military activity

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ABSTRACT

A long-term decline in habitat quality and freshwater species diversity has forced conservation managers to consider secondary habitats, such as military training areas (MTAs), that were previously overlooked but have conservation potential. Isolation from many negative anthropogenic influences combined with disturbances associated with military activities can benefit the diversity of terrestrial species. However, little is known about the conservation potential of freshwater habitats that are an integral part of MTAs. In this study, we used dragonflies and damselflies as valuable indicators of habitat quality to compare the diversity of freshwater sites inside and outside MTAs. We randomly selected 16 sites inside four extensive MTAs and 16 reference sites outside MTAs and examined the differences in traits of species occurring inside and outside the MTAs. We found that the diversity and conservation value of dragonfly communities inside MTAs was comparable to that in the most valuable freshwater habitats outside MTAs. Inside MTAs, species were primarily those associated with habitats in the late successional stages, while species associated with early successional stages were absent. Undoubtedly, the conservation potential of MTAs for freshwater invertebrates is in the long-term isolation from negative anthropogenic influences. Paradoxically, the main potential problem in protecting freshwater habitats inside MTAs is the cessation of military activity.

1. Introduction

Species richness is undergoing an unprecedented global decline (Thomas et al., 2004). This trend relates not only to rare species, but also to species that are still considered as common and, therefore, often overlooked (Inger et al., 2015). There is compelling evidence that freshwater diversity (estimated for North America) is diminishing as rapidly as species richness in some of the most stressed terrestrial ecosystems (Ricciardi and Rasmussen, 1999). Freshwater diversity is affected by anthropogenic influences, including habitat loss, habitat deterioration, water pollution, fragmentation of watercourses and flow regulation, the spread of exotic species, and climate change (Ricciardi and Rasmussen, 1999; Thomas et al., 2004), perhaps even more severely than the most affected terrestrial ecosystems (Dudgeon et al., 2006). However, comprehensive restoration of entire freshwater ecosystems is a lengthy process with uncertain success rates (Moreno-Mateos et al., 2012). Moreover, certain types of habitats are so deteriorated that their restoration is simply not possible, particularly as we lack basic information on how they functioned before they were affected by anthropogenic influences.

The long-term decline in habitat quality has lead conservation managers to consider habitats that have significant conservation potential but were previously overlooked. Typical examples of such areas include post-mining sites (Dolný and Harabiš, 2012; Tropek et al., 2010) and active and former military training areas (MTAs) (Cizek et al., 2013; Fincke et al., 2008; Lindenmayer et al., 2016; Quist et al., 2003; Zentelis and Lindenmayer, 2015). Some of these sites are larger than many national parks and protected areas, are often relatively isolated, and have experienced little or no urbanization (Cohn, 1996; Doležalová et al., 2012; Hüttl and Gerwin, 2005). Globally, the size of terrestrial MTAs is estimated to be at least 50 m ha, an area approximately equal to the size of France (Zentelis and Lindenmayer, 2015), although the actual figure may be closer to 200–250 m ha (Zentelis et al., 2017). Paradoxically, the restrictive regimes maintained in MTAs prevent many of the negative impacts on the environment that occur in the surrounding landscape. Also, many MTAs have been isolated for many decades, which enables an understanding of ecosystem function before the era of agricultural intensification in the second half of the 20th century (Reif et al., 2008). Military activities have created habitats (mainly early successional stages) that have gradually disappeared in

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the surrounding landscapes, such as dry, sandy grasslands, bare soil or temporary pools.

Warren et al. (2007) advocate the heterogeneous disturbance hypothesis, which suggests that biodiversity is higher where there are multiple kinds, frequencies, severities, periodicities, sizes, shapes, or durations of disturbances. Undoubtedly, a high diversity of disturbances is typical in MTAs, as the destructive nature of military activities and gunfire/fire often create disturbances that frequently produce heterogeneous landscapes and high habitat heterogeneity (Lindenmayer et al., 2016; Tews et al., 2004; Zentelis and Lindenmayer, 2015) (Tews et al., 2004). Such disturbances may positively influence diversity, as they can substitute natural processes that were retarded or eliminated by other anthropogenic activities. This can result in the formation of rich habitat mosaics, including the two extremes as well as the continua of disturbance and successional stages (Warren et al., 2007). Conversely, military activities may affect ecosystem processes so that the climactic successional state may not be easily predicted from the early successional stages (Suding et al., 2004). Therefore, general patterns of freshwater ecosystems cannot be derived from a knowledge of adjacent terrestrial ecosystems in MTAs.

In this study, we focus on the diversity of dragonflies and damselflies (odonates) occurring in active and former MTAs, where the most significant threats to European odonates, including intensive management, urbanization, agriculture, and intensive fish farming are absent (Kalkman et al., 2010). Dragonfly and damselfly assemblages reflect the changes in quality of both aquatic and adjacent terrestrial habitats and are, therefore, widely considered as good environmental indicators (Córdoba-Aguilar, 2008; Sahlén and Ekestubbe, 2001). Moreover, larvae and imagoes of odonates are exclusively predators and highly important in the freshwater food web (Corbet, 1999; Knight et al., 2005). Previous studies on the diversity of arthropods in MTAs have almost exclusively targeted insect groups (e.g. butterflies) that are closely associated with flowering plants (Cizek et al., 2013; Kim et al., 2015; Warren and Büttner, 2008). Although these studies documented the importance of appropriate disturbance regimes for disturbance-dependent endangered species, they did not address the diversity of aquatic species and their habitats. Odonates are similar to most invertebrates in that the most endangered species are those associated with habitats in early and late successional stages (Harabiš and Dolný, 2010; Kalkman et al., 2010). Although adult odonates are fully terrestrial insects, the larvae are closely associated with aquatic habitats (Corbet, 1999; Suhling et al., 2015); therefore their responses to anthropogenic changes in the environment may be different from that of terrestrial insects (Harabiš et al., 2013).

The current view on the conservation value of human-created habitats is overly restrictive, and given the number of freshwater invertebrates experiencing a global decline it is necessary to consider the conservation potential of novel habitats. Therefore, we focus not only on the biodiversity of freshwater habitats (ponds, bogs, and wetlands) inside and outside MTAs, but obtain more detailed knowledge of how specific disturbance regimes and isolation from agricultural intensification has selected on individual species and traits. We assumed that inside the MTAs there were abundantly represented species associated with early successional stages and species associated with oligotrophic freshwater habitats that were preserved from direct human intervention.

2. Methods

The study was conducted in four MTAs and their surrounding landscapes within the Czech Republic (Fig. 1). Two of the MTAs were still active and two were closed. Most were situated mainly on highland areas with similar climates, while the former Ralsko MTA was slightly drier and warmer (Table 1). Establishment of MTAs began in the early 1950s. Currently, an optimization process is in progress, which includes closure of several MTAs and the reducing in size of active MTAs.

Four study sites – freshwater habitats with an area 1000–205,000 m^2 – were selected inside each MTA. Study sites with different types of standing water were selected to represent a range of habitats and odonate species. Reference sites of a similar type and size as those inside the MTAs were selected within the 10-km surrounding landscape from the border of the MTA. Reference sites were randomly chosen ponds, wetlands, and extensive wetlands, artificial pools, and peat bogs (Appendix A). The majority of reference sites were national monuments.

2.1. Data sampling

Data sampling was conducted from late May to early September 2016. Each site was visited every 30 days (four visits per site in total) to capture seasonal changes in species composition. Sampling was conducted during sunny and calm (wind less than 25 km/h) weather conditions with a minimum air temperature of 20 °C. The order of visits to the sites in each region was conducted randomly between 10:00 and 16:00 to minimize the effect of "time of day" on abundance.

Each site was sampled for a fixed time of 30 min. We focused mainly on microhabitats where we expected to find dragonflies and damselflies, specifically, places with a high abundance of littoral and submerged vegetation. All individuals were captured using a standard butterfly net (50 cm in diameter) and were identified to species level, counted, and later released. Relative abundances of individual species were estimated in categories according to the abundance classification system of the British Dragonfly Society: 1, 2–5, 6–10, 11–20, 21–100, 101–500, 500 + (Smallshire and Beynon, 2010). Singletons, regionally absent species, and species developing strictly in flowing waters were not included in the analyses. Dragonflies were identified following Dijkstra and Lewington (2006). The nomenclature used followed van Tol (2006). In addition, environmental parameters were measured using pre-selected criteria (Table 2); water pH and ammonia concentration were measured twice a year using an absorption spectrophotometer.

Species traits

We analyzed the effect of environmental variables on individual life-history strategies. Species traits included: Body size = mean body length according to Dijkstra and Lewington (2006); relative dispersal ability according to Harabiš and Dolný (2011); larval life-history according to Corbet (1999); habitat breadth = number of habitat types classified according to IUCN Red list of threatened species (IUCN, 2006); tolerance to drying = permanency and tolerance to shading. All species traits are summarized in Table 2.

The conservation value of the species assemblages at individual sites was determined using the dragonfly biotic index site value (DBIsv). The DBI is comprised of three components: regional distribution, national red-list classification, and species sensitivity to habitat changes. Each index component ranged from 0 (min) to 3 (max). The total DBI value for each individual species was the sum of all three component values (Simaika and Samways, 2009). To control for different numbers of species among sites, we divided the total DBIs of all species by the total number of species per site. This method standardized the DBI score to give the DBI site value, which enabled the comparison of DBI among sites. Total DBI for individual species is shown in Appendix B.

2.2. Statistical analysis

A generalized linear mixed model (GLMM) with a Poisson distribution and log-link (model with species richness) and GLMM with a log-normal distribution (model with DBI site value) were used to test the effects of environmental factors (explanatory variables) on species richness and conservation value (DBI site value) (dependent variables). MTAs were included in both models as random effects. All linear

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