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Biologia **70**/1: 113—120, 2015
Section Zoology
DOI: 10.1515/biolog-2015-0009

Effect of reintroduced manual mowing on biodiversity in abandoned fen meadows

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Abstract: Wetlands have recently become of high environmental interest. The restoration effects on habitats like fens are one of the main topics of recent restoration ecology, especially due to their interconnection with other ecosystems. We studied the manual mowing effect on abandoned fen using the response of three study taxa: diurnal butterflies, flower-visiting beetles and vascular plants. Our results showed that butterflies seems to be quickly-responding indicator taxon for evaluation and that restored management had a positive effect on both species richness and composition of this insect group. The results indicated that the manual mowing effect could be rapid. In comparison with the surrounding landscape, we found that: (i) the manually mowed site was most similar to strictly protected area, (ii) some species of high conservation value could reach higher abundance in restored than protected site, and (iii) manual mowing could bring a new type of habitat (i.e., spatial heterogeneity) compared to the other management types (abandonment, conservation and agri-environmental mowing). The main implication seems to be optimistic for practice: The manual mowing of long-term abandoned fen is leading to the creation of habitat with high conservation value in a relatively short time.

Key words: agri-environmental schemes; diurnal butterflies; Lepidoptera; flower-visiting beetles; Coleoptera; nature conservation; multi-taxa approach; vascular plants

Introduction

Human influence in the landscape is still rising and often leads to a call for the restoration of former ecosystems and reintroduction of traditional management techniques (Hobbs & Harris 2001). Furthermore, Roberts et al. (2009) argued that our planet's future may depend on the maturation of the discipline known as restoration ecology. Former predictions indicated that ecosystems will take centuries to recover from human disturbances (Jones & Schmitz 2009). However, the main goal is not necessarily to restore or mitigate the impacts of human activities to an ecosystem to a pristine, pre-human ideal (Roberts et al. 2009), especially in the light of recent knowledge that many types of damaged ecosystems are able to go through rapid recovery (Jones & Schmitz 2009). It may be still questionable what types of ecosystems are more or less restorable (Moreno-Mateos et al. 2012), what kind of changes in communities of organisms are caused by reintroduction of traditional management techniques and how effective restoration or similar activities could be (Hobbs & Harris 2001; Jones & Schmitz 2009).

Restoration and traditional management techniques appear to be more ecosystem friendly than present prevailing farming methods. Agricultural intensification and abandonment of less-productive and less-accessible land have led to the declines of taxa associated with fens and similar areas (Prach 1993). Policies regarding these areas as threatened fauna and flora habitats assume that a restored ecosystem may replace losses in structure and function in relatively short time frames (Zedler & Callaway 1999). Zedler (2000) argued that the restoration of wetlands takes more than water, e.g. because hydrological regimes of wetlands are highly complex and the wetland restoration is mainly driven by the mitigation of damage to them by agricultural intensification. Nearly the same situation is with more or less humid grasslands (Jones & Schmitz 2009). The drainage of these sites has eliminated highly valued ecosystem functions, leading to regulations that require compensation (Zedler 2000).

Recent studies have dealt with the recovery of communities of species that prefer humid or wet grasslands (Zimmermann et al. 2005; Billeter et al. 2007; Hedberg & Kotowski 2010; Valkó et al. 2012). Several methods and techniques were used in management amendments, like tree or shrub removal, hay or species reintroduction, sowing of ingenuous propagules or sod cutting (Wynhoff 1998; Mouquet et al. 2005; Lepš et al. 2007; Klimkowska et al. 2010; Sundberg 2012). Probably the easiest and softest method of restoration of formerly intensively-managed grasslands is diversification of mowing regimes (Grill et al. 2008; Cizek et al. 2012), which can also be applied after the more radical methods.

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Hand mowing was the most traditional way of producing hay and management of grasslands. Mowing of meadows (using invention of scythes) is known from Iron Age (1,000 B.C. –0; e.g., Horák et al. 2012). Presently, this management type appears to be obsolete way of producing hay. On the other hand, this management type has been evaluated only rarely (Valkó et al. 2012) and it would be useful to know the differences between hand- and machine-mowing effects, in order to understand what had been lost due to modernisation (Humbert et al. 2009).

Several taxa or individual species associated with fens and grasslands appear to be decreasing their abundances due to abandonment of traditional management types (Konvicka et al. 2008). Butterflies, beetles and plants belong to well-studied taxa and their responses to disparate environmental factors often indicate the actual condition of the studied environment (Benes et al. 2002; Valkó et al. 2012). The arthropod-plant interaction in grassland habitats is very high. Larvae of butterflies and beetles mostly forage on the tissues of plant species and the presence and abundance of adults well reflects larval activity as in other insect taxa (Steffan-Dewenter & Tscharntke 1997).

Our questions regarding the manual mowing effect on wetland communities were: Are there differences in effects of reintroduced manual mowing for butterflies, beetles and plants? Is manual mowing in an abandoned fen able to create a species rich habitat compared to surrounding landscape? And, if yes, is only a species rich habitat created or is another fragment of disparate habitat mosaic established?

Material and methods

Study area and its history

Wetlands of Sruby (49.9877 N; 16.1946 E) are part of the former large area between the riparian corridor of the meandered Loucna River and forested lower ridge, which is a part of the eastern-Bohemian forests (Czech Republic) between the cities of Chocen and Hradec Kralove (Faltysová et al. 2002). Most parts of the Sruby rural environment are comprised of former forests, which were deforested at the beginning of the 14th century, when the first permanent settlement was established here (Sedlacek 1908). As most of the area was on low-productive hydromorphic (i.e., gley) soils with high moisture, the main source for living was forestry and pasture combined with the establishment of several ponds in the beginning of the 16th century (Láska 1936). Growing wealth and contemporary trends in land use during the period after World War I (1914–1918) (Václavík 1869) led to drainage of most of the rural environment of Sruby (Láska 1936). Most parts of the study area were then used as arable land, alternating with temporary grasslands (D. Kurkova, pers. commun.). Nature monument Vstavacova louka was established in 1989 in response to agricultural intensification and the use of heavy duty technologies (Faltysová et al. 2002). Unmanaged drainage after the Velvet Revolution in 1989 caused the rising level of soil moisture of arable land and the worsening of crop farming, which led to the establishment of secondary fen vegetation. Southern part of the study area was abandoned in 1992 (J. Matousek, pers. commun.).

Recently the non-forested part of the study area consisted of (i) agri-environmental machine-mowed wet meadows (agri-environmental thereinafter), (ii) strictly protected fen meadows (conservation thereinafter), and (iii) abandoned fen (abandonment thereinafter), (iv) which was partly manually mowed and hay was carried away in 2010 and 2011 (manual mowing thereinafter).

Study taxa, design and methods

Vascular plants (thereinafter plants) were counted in percentage cover scale between the first (2010) and second manual mowing in the beginning of June 2011 within 32 plots of 1 × 1 m. Each pair of 16 plots was distributed approximately in two lines with the distance of 5 m going through particular treatment (manual mowing and abandonment) and at regular distances of 20 m to the next pair. The distance to the edges was > 10 m. The distance between plots in each pair was 20 m for inner pairs and 30 m for outer pairs.

Diurnal butterflies and burnet moths (Lepidoptera, thereinafter butterflies) and flower-visiting beetles (Coleoptera, thereinafter beetles) were studied using a time-limited (16 min) survey method. Each treatment consisted of eight survey walks in the same location as plots for the sampling of plants. The edges as transition zones were omitted approximately the same as in plants. All butterflies and beetles were recorded during nine visits from the beginning of May to the middle of September 2011, reflecting their phenological activity in the conditions of eastern Bohemia (Horak et al. 2013). All visits were only during fine weather conditions (sunny, no wind, temperature ≥ 20 °C) and during 10–11 AM or 2–3 PM.

For the analysis of total species richness of each study taxa and comparisons among treatments, we used sample-based species rarefactions (Mao Tau function) with 95% confidence intervals (Colwell 2006) and the Chao estimator (Chao 1984). Analyses were computed in EstimateS 8.2 (Colwell 2006). The number of randomisations was set at 1,000.

We focused on predictors which were testable only within a limited spatial scale, because the study was conducted in a limited grassland landscape surrounded by forests and crop fields. Un-replicated treatments were the only option for our study (Oksanen 2001). We controlled this problem using randomised techniques for species richness data (Gotelli & Colwell 2001) and a set of coordinates (x, y, xy, x^2, y^2) as spatial co-predictors for the multivariate analysis of species composition (Horak 2013) in comparison with traditional statistical methods as it is recommended by Oksanen (2001). Namely, the comparison of species richness of study taxa in study treatments was computed using paired *t*-test for dependent variables with normal distribution in Statistica 7.

Another aim was investigated using an analysis focused at identifying species composition and response to each treatment, which was carried out using multivariate statistical methods provided by CANOCO for Windows version 4.5 (ter Braak and Šmilauer 2002). Redundancy analysis (RDA), a constrained linear ordination method, was used to solve our task with 9,999 unrestricted permutations under the full model. The resulting ordination diagram was created in CanoDraw 4.14 (ter Braak & Šmilauer 2002). In this case we used data from the time of the peak activity of wetland butterflies (i.e. four summer visits). As a traditional statistical method for comparison, we used ANOVA

Table 1. Check-list of butterflies in Wetlands of Sruby.

Family	Species	No. of individuals
Hesperidae	*Carterocephalus palaemon* (Pallas, 1771)	4
Hesperidae	*Thymelicus sylvestris* (Poda, 1761)	16
Lycaenidae	*Lycaena dispar* (Haworth, 1802)	10
Lycaenidae	*Lycaena phlaeas* (L., 1761)	5
Lycaenidae	*Lycaena tityrus* (Poda, 1761)	3
Lycaenidae	*Phengaris nausithous* (Bergsträsser, 1779)	16
Lycaenidae	*Phengaris teleius* (Bergsträsser, 1779)	8
Lycaenidae	*Polyommatus amandus* (Schneider, 1792)	1
Lycaenidae	*Polyommatus icarus* (Rottemburg, 1775)	64
Lycaenidae	*Thecla betulae* (L., 1758)	1
Nymphalidae	*Aglais urticae* (L., 1758)	3
Nymphalidae	*Aphantopus hyperantus* (L., 1758)	39
Nymphalidae	*Araschnia levana* (L., 1758)	17
Nymphalidae	*Argynnis adippe* (Denis & Schiffermüller, 1775)	1
Nymphalidae	*Argynnis aglaja* (L., 1758)	2
Nymphalidae	*Argynnis paphia* (L., 1758)	3
Nymphalidae	*Boloria dia* (L., 1767)	1
Nymphalidae	*Coenonympha pamphilus* (L., 1758)	115
Nymphalidae	*Inachis io* (L., 1758)	14
Nymphalidae	*Issoria lathonia* (L., 1758)	1
Nymphalidae	*Maniola jurtina* (L., 1758)	115
Nymphalidae	*Melanargia galathea* (L., 1758)	18
Nymphalidae	*Pararge aegeria* (L., 1758)	2
Nymphalidae	*Vanessa atalanta* (L., 1758)	3
Nymphalidae	*Vanessa cardui* (L., 1758)	1
Pieridae	*Colias hyale* (L., 1758)	6
Pieridae	*Gonepteryx rhamni* (L., 1758)	53
Pieridae	*Leptidea reali* Reissinger, 1989	8
Pieridae	*Pieris brassicae* (L., 1758)	34
Pieridae	*Pieris napi* (L., 1758)	157
Pieridae	*Pieris rapae* (L., 1758)	21
Zygaenidae	*Zygaena filipendulae* (L., 1758)	36
Zygaenidae	*Zygaena loti* (Denis & Schiffermüller, 1775)	1
Zygaenidae	*Zygaena viciae* (Denis & Schiffermüller, 1775)	2

Table 2. Check-list of beetles in Wetlands of Sruby.

Family	Species	No. of individuals
Buprestidae	*Anthaxia nitidula* (L., 1758)	1
Cantharidae	*Rhagonycha fulva* (Scopoli, 1763)	167
Cerambycidae	*Pseudovadonia livida* (F., 1776)	2
Cetoniidae	*Cetonia aurata* (L., 1758)	13
Cetoniidae	*Oxythyrea funesta* (Poda, 1761)	37
Cetoniidae	*Protaetia marmorata* (F., 1792)	1
Cetoniidae	*Valgus hemipterus* (L., 1758)	1
Chrysomelidae	*Clytra quadripunctata* (L., 1758)	1
Coccinelidae	*Coccinella septempunctata* L., 1758	31
Coccinelidae	*Harmonia axyridis* (Pallas, 1773)	7
Curculionidae	*Larinus turbinatus* Gyllenhal, 1835	3
Melyridae	*Malachius bipustulatus* (L., 1758)	1
Oedemeridae	*Oedemera femorata* (Scopoli, 1763)	5
Oedemeridae	*Oedemera virescens* (L., 1767)	1

for dependent variables with normal distribution in Statistica 7.

Results

In total, we recorded 34 species of butterflies (Table 1), 14 beetle species (Table 2) and 90 species of plants (Table 3).

Species rarefactions

With respect to differences between manual mowing and abandonment we observed 29 species of butterflies, 14 beetle species and 90 species of plants.

Rarefactions were made separately for each taxonomic group (Fig. 1). They did not reach their asymptotes. However, the Chao estimator approached the total number of species in the case of butterflies and plants (Figs 1A, B). This suggested that most of the

Table 3. Check-list of plants in Wetlands of Sruby.

Family	Species	No. of samples
Apiaceae	*Aegopodium podagraria*	6
Apiaceae	*Angelica sylvestris*	12
Apiaceae	*Chaerophyllum bulbosum*	1
Apiaceae	*Chaerophyllum temulum*	2
Apiaceae	*Heracleum sphondylium*	1
Apiaceae	*Pastinaca sativa*	6
Apiaceae	*Peucedanum palustre*	12
Asteraceae	*Achillea millefolium* agg.	19
Asteraceae	*Centaurea jacea*	6
Asteraceae	*Cirsium arvense*	26
Asteraceae	*Cirsium canum*	23
Asteraceae	*Cirsium oleraceum*	3
Asteraceae	*Eupatorium cannabinum*	3
Asteraceae	*Leontodon hispidus*	1
Asteraceae	*Leucanthemum vulgare* agg.	1
Asteraceae	*Tanacetum vulgare*	1
Asteraceae	*Taraxacum* sect. *Ruderalia*	7
Boraginaceae	*Symphytum officinale*	19
Brassicaceae	*Cardamine* sp.1	1
Cannabidaceae	*Humulus lupulus*	2
Caryophyllaceae	*Lychnis flos-cuculi*	6
Caryophyllaceae	*Myosoton aquaticum*	1
Caryophyllaceae	*Stellaria graminea*	9
Caryophyllaceae	*Stellaria media*	1
Colchicaceae	*Colchicum autumnale*	3
Cyperaceae	*Carex acuta*	3
Cyperaceae	*Carex acutiformis*	1
Cyperaceae	*Carex hirta*	14
Cyperaceae	*Carex ovalis*	1
Cyperaceae	*Carex pallescens*	1
Cyperaceae	*Carex vesicaria*	3
Cyperaceae	*Carex vulpina*	2
Cyperaceae	*Juncus conglomeratus*	4
Cyperaceae	*Juncus effusus*	3
Equisetaceae	*Equisetum arvense*	3
Fabaceae	*Lathyrus pratensis*	15
Fabaceae	*Lotus corniculatus*	1
Fabaceae	*Trifolium pratense*	1
Fabaceae	*Vicia cracca*	8
Fabaceae	*Vicia cracca*	1
Fagaceae	*Quercus robur*	2
Hypericaceae	*Hypericum maculatum*	4
Lamiaceae	*Galeopsis* sp.1	2
Lamiaceae	*Glechoma hederacea*	7
Lamiaceae	*Mentha* sp.1	2
Lythraceae	*Lythrum salicaria*	8
Malvaceae	*Tilia cordata*	1
Orobanchaceae	*Melampyrum nemorosum*	2
Plantaginaceae	*Veronica chamaedrys*	5
Plantaginaceae	*Veronica serpyllifolia*	1
Poaceae	*Agrostis capillaris*	1
Poaceae	*Agrostis stolonifera*	8
Poaceae	*Alopecurus pratensis*	23
Poaceae	*Arrhenatherum elatius*	6
Poaceae	*Calamagrostis canescens*	2
Poaceae	*Calamagrostis epigejos*	17
Poaceae	*Dactylis glomerata*	1
Poaceae	*Deschampsia cespitosa*	12
Poaceae	*Elymus caninus*	3
Poaceae	*Elytrigia repens*	6
Poaceae	*Festuca pratensis*	3
Poaceae	*Holcus lanatus*	7
Poaceae	*Molinia caerulea*	1
Poaceae	*Phalaris arundinacea*	1
Poaceae	*Phleum pratense*	1
Poaceae	*Poa palustris*	10
Poaceae	*Poa pratensis*	18
Poaceae	*Trisetum flavescens*	1
Polygonaceae	*Persicaria amphibia*	2
Polygonaceae	*Rumex acetosa*	3

Table 3. (continued)

Family	Species	No. of samples
Primulaceae	*Lysimachia nummularia*	10
Primulaceae	*Lysimachia vulgaris*	3
Ranunculaceae	*Anemone nemorosa*	1
Ranunculaceae	*Ranunculus acris*	2
Ranunculaceae	*Ranunculus auricomus*	6
Ranunculaceae	*Ranunculus repens*	19
Ranunculaceae	*Thalictrum lucidum*	1
Rosaceae	*Alchemilla* sp.1	3
Rosaceae	*Potentilla anserina*	8
Rosaceae	*Potentilla erecta*	1
Rosaceae	*Potentilla reptans*	3
Rosaceae	*Rubus* sp.1	1
Rosaceae	*Sanguisorba officinalis*	15
Rubiaceae	*Galium album*	4
Rubiaceae	*Galium aparine*	5
Salicaceae	*Salix* sp.1	2
Scrophulariaceae	*Scrophularia nodosa*	1
Urticaceae	*Urtica dioica*	3
Valerianaceae	*Valeriana* sp.1	1
Violaceae	*Viola* sp.1	4

species of butterflies and plants were represented in the analysis.

Beetles were thus excluded from subsequent analyses as unsuitable taxa.

Species richness and manual mowing effect

The paired *t*-test showed that the species richness of butterflies was significantly higher on manually mowed than abandoned sites ($t = 4.46$; $P < 0.01$) and the same result was derived from rarefactions (Fig. 2A). Plants showed a non-significant response ($t = 1.03$; $P =$ n.s.) and an almost opposite pattern in species rarefactions (Fig. 2B).

As analyses on plants showed potentially biased results (Oksanen 2001), thus we excluded plants from further analyses.

Effect of manual mowing and surrounding habitats on species richness and composition of butterflies

During this study, we recorded 28 species of butterflies. Our results showed that the design using four management types was significant ($F = 6.98$; $P < 0.01$) explaining 36.66% of adjusted variance.

The rarefactions showed that there was only a slight difference in the species richness of butterflies between conservation and manually mowed sites, while abandoned site showed the lowest species richness (Fig. 3).

The results of redundancy analysis of butterfly data (first canonical axis: $R^2 = 19.80\%$; $F = 5.93$; $P < 0.01$; all canonical axes: $R^2 = 24.39\%$; $F = 2.57$; $P < 0.01$) showed that some species assemblages were associated with disparate management type – majority of wetland preferring species of conservation interest (*Lycaena dispar*, *Phengaris nausithous* and *P. telejus*) were presented only in conservation and manually mowed sites and only generalist species showed an association with agri-environmental type of management. Figure 3 also shows that conservation and manually mowed sites were quite similar in species composition, while there were only a few species that were more distributed in abandoned fen.

Discussion

Butterflies

Our comparisons of three taxa showed that there were differences among them and that, in our case, butterflies seem to be a quickly-responding indicator taxa for the evaluation of manual mowing effects compared to beetles and plants. Butterflies are more mobile and can therefore potentially respond more quickly to the mowing effect than plants. This also indicated that without any hydrological restoration (Moreno-Mateos et al. 2012; Zedler & Callaway 1999), or any introduction of species (Lepš et al. 2007; Klimkowska et al. 2010) in a site that has been drained and abandoned for a long time, mowing might increase butterfly species abundance, but not restore the plant community (Hedberg & Kotowski 2010). The main reason for plants might be relatively short time compared to butterflies (Valkó et al. 2012).

Beetles

Flower-visiting beetles were not suitable group for our aims, even though they have been occasionally used for the evaluation of disparate management activities (Noordijk et al. 2009). The most probable reason was that they were relatively species poor and nearly half of them were singletons and thus probable tourists (Novotny and Basset 2000), while only four species reached a reasonable abundance. We also did not observe beetle species associated with humid habitats, probably caused by the study group of flower-visiting beetles, which seems to be more generalis-

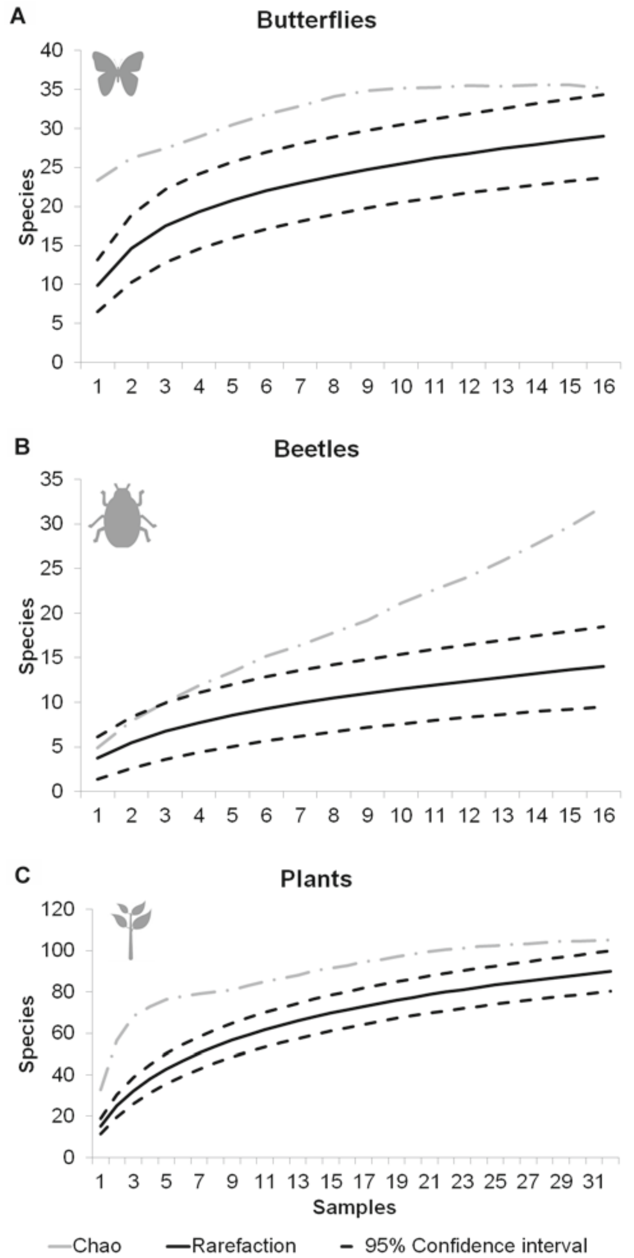

Fig. 1. Rarefactions and Chao estimators of total species richness of observed (A) butterflies, (B) beetles, and (C) plants. Complete data for species from all samples of manual mowing and abandonment design are included. The solid lines show the sample-based rarefaction, the two surrounding dashed lines 95% confidence intervals and the upper grey dash-and-dotted lines are the Chao estimators of the total number of species. Note that the x and y axes are not to the same scale for (A), (B) and (C).

tic than other specialised groups (Rainio & Niemela 2003).

Plants

Vascular plants as sedentary organisms have a tendency to lower dispersal ability, which most probably limited them in potential quick responses to the management activities in our study (but see Nathan 2006). Sedentary behaviour may cause their higher persistence in the exploited landscape, but they probably need a longer time for the response, e.g., restoration of their propagules (Prach 1993). The same reason could influence relatively low number of species that prefer habitats influenced by water (e.g., wetland specialists). Moreover, specialized species could vanish before the manual mowing was reintroduced. The next reason for non-response of the plant community to the management could be the fact that no hydrological restoration was conducted (Zedler & Callaway 1999). As our results showed, the response of plants to the restoration effect tended to be spatially biased (Oksanen 2001). The response of wetland specialised species of plants was nearly the same as the total species assemblage, although there was no significant trend in their response.

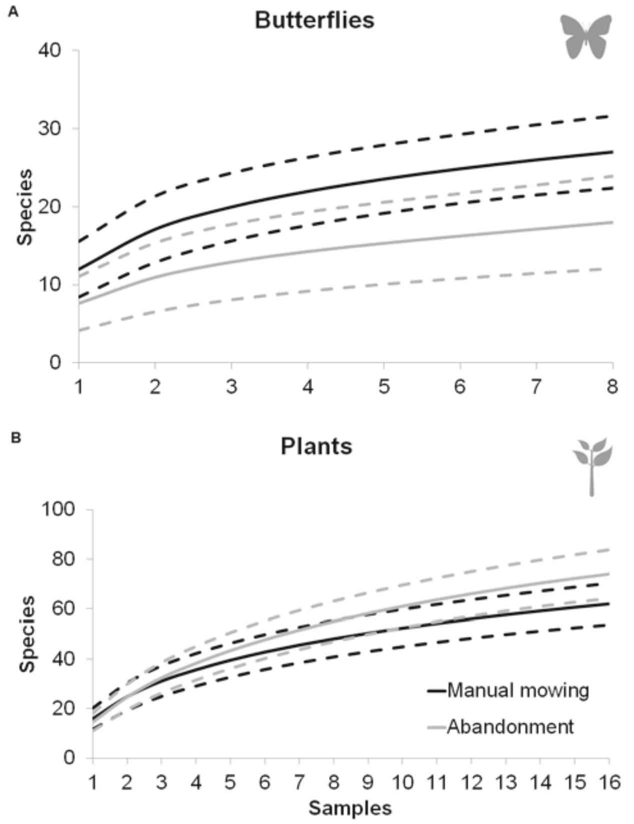

Fig. 2. Results of species rarefactions comparing the effect of manual mowing and abandonment on the species richness of (A) butterflies and (B) plants. The solid lines (black for manual mowing and grey for abandonment) show the sample-based species rarefactions and the two surrounding dashed lines are 95% confidence intervals. Note that the scales on x and y axes are not the same for Figs B and C.

Synthesis

Funds for restoration and conservation activities are limited in rural agricultural landscapes, especially in those which are not a part of protected areas. Thus, recent limited and short-time funding called for rapid assessment and suitable indicator organisms. In our study, butterflies were the suitable group for both response to the manual mowing effect and comparisons with the surrounding landscape. From the point of view of this study group, manual mowing of abandoned fen brought

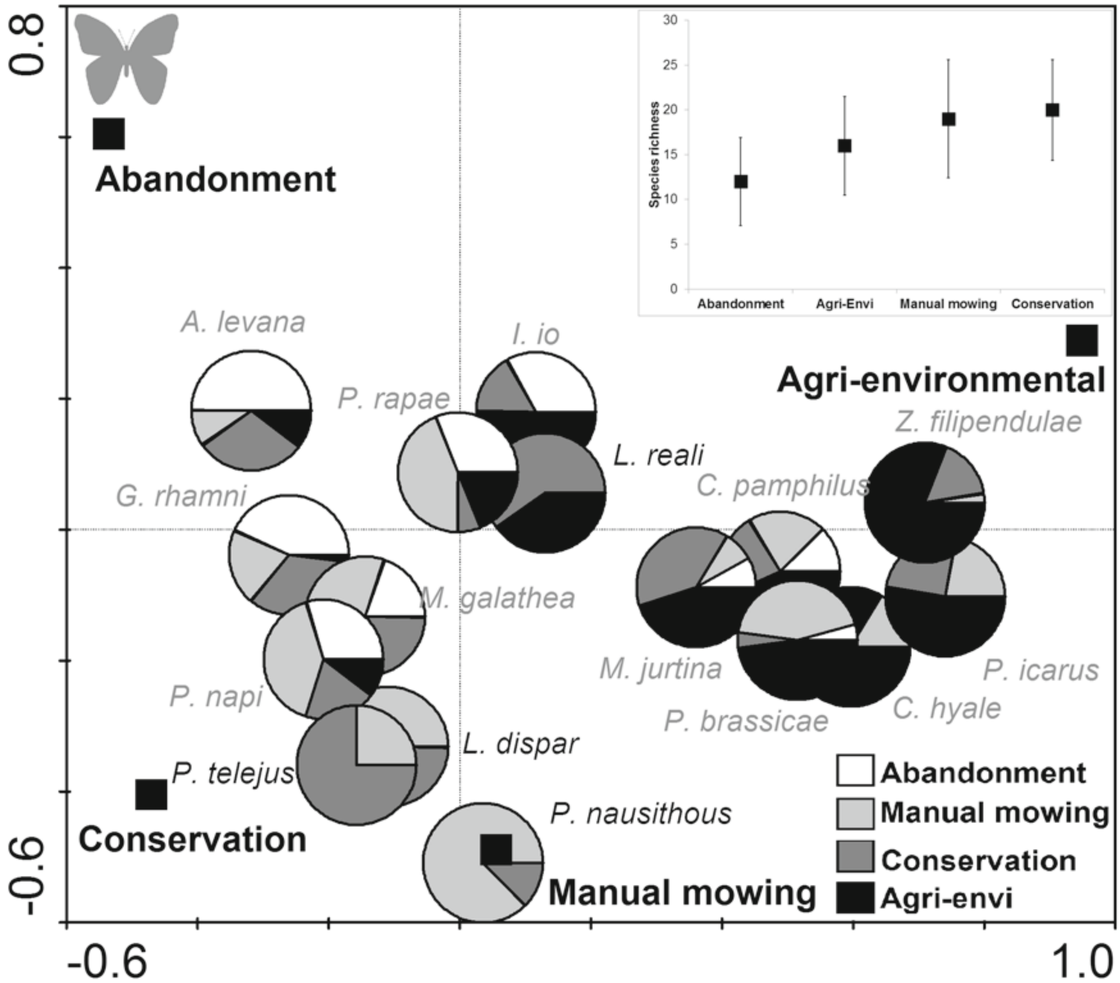

Fig. 3. Abundance based pie symbols species-environmental plot visualising distribution of species with different response to the type of management. Note that only species with more than five occurrences are shown. Species with black labels (*Leptidea reali*, *Lycaena dispar*, *Phengaris nausithous* and *P. telejus*) are wetland specialists. Result of final values of species rarefactions with 95% confidence intervals comparing the effect of abandonment, manual mowing, conservation and agri-environmental mowing on the species richness of butterflies is in the upper right corner.

a species rich habitat, which also promoted endangered species dependent on wetlands (e.g., *Phengaris* Blues). In comparison with the surrounding landscape, butterflies were able to rapidly restore their populations or recolonise the restored fen, and their species richness was (quite surprisingly) high, as in the long-term preserved site. This was probably caused by environmentally-friendly manual mowing with biomass removal (Cizek et al. 2012). The highly similar and species rich fauna of restored sites compared with preserved sites indicates that the recolonisation of formerly abandoned sites is the most probable driver, even in highly endangered and sedentary *Phengaris* Blues (Fric et al. 2007) associated with wetlands (Wynhoff 1998).

Conclusion

The most interesting information derived from our study is that, in similar cases, the manual mowing effect is able to create a type of habitat that is, from a species composition point of view, of conservation interest, and secondly the effect of some species groups (i.e., butterflies) could be relatively rapid.

Acknowledgements

We would like to thank the non-governmental organisation Lesák, o.s. (www.lesak.eu) for logistics and the creation of different management activities, D. Kurková, J. Stratílek, J. Matoušek and J. Šimek for historical information, L. Bourdon for English proof reading and two reviewers for suggestions. This research was partly supported by the Grant CIGA no. 20144302.

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Received November 29, 2013
Accepted December 10, 2014