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Erasing a European biodiversity hot-spot: Open woodlands, veteran trees and mature forests succumb to forestry intensification, succession, and logging in a UNESCO Biosphere Reserve

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ABSTRACT

Open woodlands are among the biologically richest habitats of the temperate zone. Although open woodlands were much more common in the past and covered large areas of Europe, their original cover and magnitude of their loss remain mostly unknown. Here, we quantify the loss of open woodlands and assess the potential for their restoration in an internationally protected biodiversity hot-spot, floodplain woodlands of lower Thaya and March rivers of Dolní Morava UNESCO Biosphere Reserve in Czech Republic. Aerial photographs from years 1938 and 2009 were used to analyse changes in forest canopy closure across an area of 146 km^2 and separately for 270 ha of nature reserves found in the area. Forestry maps and aerial photographs were used to analyse changes in forest age structure. Between 1938 and 2009, expansion of closed-canopy forest reduced open woodlands cover from 41% to 5.7% of total wooded area, or 68.5% to 14.1% in the state reserves respectively. Logging has led to a decrease in mature forest cover from 45% to 26% between 1990 and 2009. State reserves prevented logging, but not open woodlands loss. The magnitude of open woodlands loss parallels that of tropical habitats, but has gone unabated by nature conservation. Opportunities to restore open woodlands and conserve associated biodiversity in the internationally protected (e.g. UNESCO, Natura 2000), mostly state-owned, woodlands are being compromised by rapid logging. Our results also point to the low efficiency of international conservation measures in post-communist members of European Union.

Introduction

Open woodlands are among the most diverse temperate habitats, sustaining species associated with forest and open habitats as well as its own unique biota (Eggers et al. 2010; Mabry et al. 2010; Chytrý et al. 2012). Together with their indispensable element–veteran trees – (Hall & Bunce 2011), open woodlands are key features sustaining biodiversity in many Holarctic landscapes (Rackham 1998; Bengtsson et al. 2000). Many of the most endangered and protected species, including numerous plants, fungi, and animals, depend on open-woodland habitats from the Mediterranean to Northern Europe (e.g. Bengtsson et al. 2000; Ranius & Jansson 2000; Spitzer et al. 2008; Vodka et al. 2009; Hédl et al. 2010; Bugalho et al. 2011; Norden et al. 2012). Open woodlands thus deserve special attention of the conservation community across Europe.

Forestry and agricultural intensification have brought extensive changes to European landscapes, causing severe alteration and fragmentation of numerous habitats (Stoate et al. 2001). In woodlands, intensification resulted in removal of old trees, homogenisation of spatial and age structure, and ultimately in canopy closure. The organisms depending on open woodlands and open-grown and/or veteran trees were affected especially severely (Bengtsson et al. 2000). In North America, where fire dynamics and large herds of wild ungulates have locally survived until recent times, open woodlands are considered a high conservation priority, and their decline has been well documented (Anderson et al. 1999; Jenkins & Parker 2000; Bai et al. 2005). In Europe, open woodlands have been maintained mostly by human activities such as pastures, wood extraction and fires for most of recorded history, and were thus viewed by conservationists as human altered, damaged biotopes. Increasing canopy closure in originally open woodlands has been often perceived as forest "renaturalisation" rather than a threat to its biodiversity (Bengtsson

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et al. 2000; Vrška et al. 2006). Except for a few countries in Western Europe, where effort to conserve open woodlands, or parklands increases steadily (e.g. Rackham 1998; Rotherham 2013), open woodlands remained a "Cinderella habitat" in most of the continent. Their disappearance went nearly unnoticed, and despite that the problem is apparently widespread (Bércesné Mocskonyi 2011; Brunet et al. 2012; Rotherham 2013), its magnitude remains largely unknown.

Although the biota of open woodlands and veteran trees still partly survives e.g. in parks, game-reserves, or old-growth forests (e.g. Spitzer et al. 2008; Hédl et al. 2010), the above changes in land use have most likely created a large extinction debt (Tilman et al. 1994; Sebek et al. 2013). Restoration of open woodlands and safeguarding the continuous presence of veteran trees at key areas are thus necessary to prevent further losses (Ranius & Jansson 2000). Such efforts might be thwarted by an emphasis on timber production rather than biodiversity conservation on the side of the forestry profession, and/or a lack of understanding on the side of nature conservationists. In many EU countries, the "hands-off" approach or the "strict reserve concept" in lack of natural disturbance factors and/or economic interests often dominate forest management in protected areas, without paying much attention to biodiversity (e.g. Vrška et al. 2006; Wesołowski 2005).

Using 146 km^2 of an internationally protected biodiversity hotspot, and a key refuge of biota associated with open and mature woodlands and veteran trees in Central Europe as an example, we (i) quantified the changes in open woodlands cover over the past 70 years using aerial photographs from 1938 and 2009; (ii) analysed the changes of forest-age structure in the last two decades for assessing the potential for restoration of open-woodlands and conservation of their biodiversity; and (iii) compared the changes in the cover of open-woodlands and the age structure between commercial forests and nature reserves in order to assess the efficiency of conservation measures.

Methods

Study area

The study covered 14,630 ha of Pannonian, alluvial woodlands and meadows along the lower Morava (March) and Dyje (Thaya) rivers (Fig. 1). It is a biodiversity hot-spot for numerous taxa associated with open woodlands, veteran trees, and wetlands (e.g. Vicherek et al. 2000; Rozkošný & Vaňhara 1995–1996). The terrain is flat (149–184 m a.s.l.), the mean annual temperature and precipitation is 9.6 °C and 500 mm. The prevailing trees are pedunculate oak (*Quercus robur*), narrowleaf ash (*Fraxinus angustifolia*), hornbeam (*Carpinus betulus*), and field maple (*Acer campestre*).

The main traditional managements such as woodland pasture, coppicing with standards, and pollarding were abandoned 150–60 years ago in favour of growing planted forests with 90–150 year rotation (Vrška et al. 2006; Altman et al. 2013; Sebek et al. 2013).

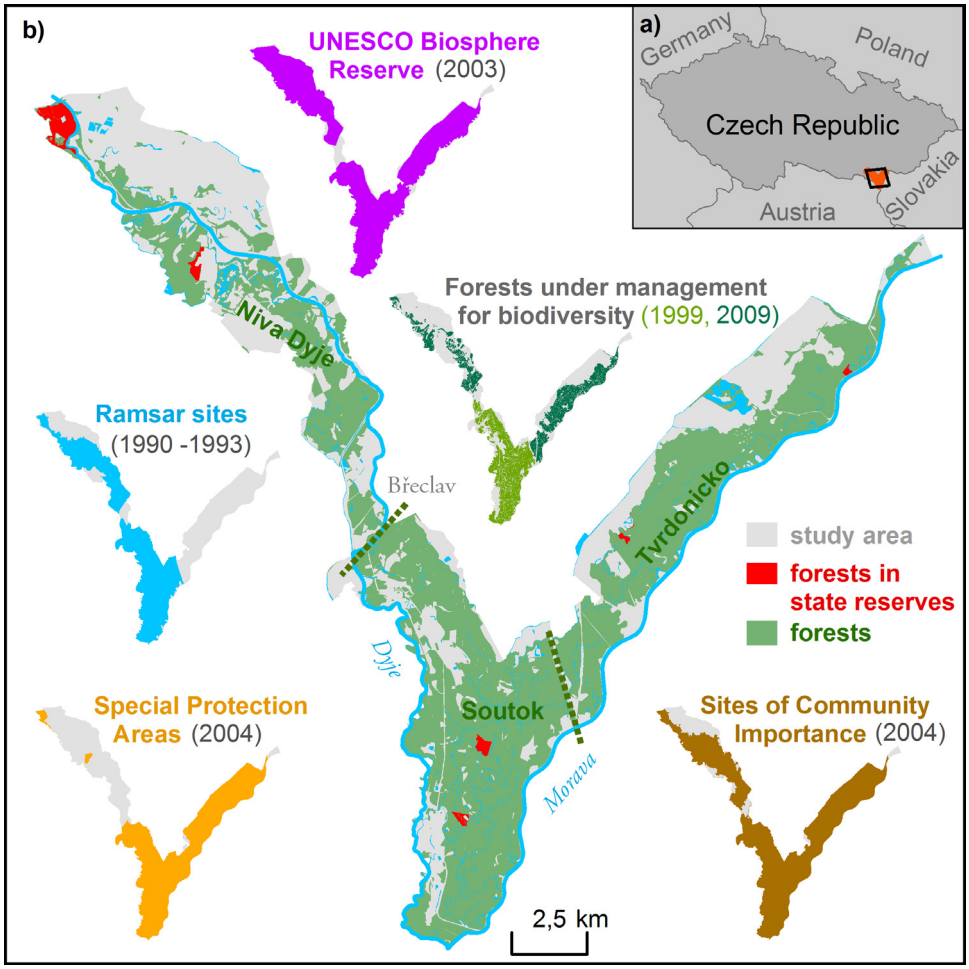

Fig. 1. Floodplain woodlands along lower Dyje and Morava rivers in SE Czech Republic accumulated multiple international and national conservation statuses and recognitions. Position of study area (a), its cover of woodlands (green), forest management units (dark green) and woodlands in nature reserves (red) (b). The smaller maps indicate overlap of numerous international (c–f) and national (g) conservation designations and years of their declaration. *Compare with logging rate in* Fig. 4. (for interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Today, the area comprises a mosaic of commercial oak/ash plantations, with a prevailing rotation period of 140/110 years, managed using ≤2 ha clear-cuts; and fragments of open and formerly open woodlands and meadows with old (>150 years) trees, mainly oaks. The area has been divided into three parts (Niva Dyje, Tvrdonicko and Soutok, *see* Fig. 1), corresponding with forestry management units. Their management does not differ in principles, one unit thus may serve as example of what is likely to happen in the others. Forest management in the target area follows a plan prepared for a 10-year period valid from 2010–2019.

Owing to its high biodiversity and nature conservation value, the area has gained international and national recognition (Fig. 1). It is included into the Lower Morava UNESCO Biosphere Reserve; and parts of the area have been declared the Floodplains of the Morava-Dyje-Danube Confluence Trilateral Ramsar Site, and Lednice fishponds Ramsar site; Site of Community Importance (SCI) Soutok–Podluží, SCI Niva Dyje and Special Protection Areas (SPA) Soutok-Tvrdonicko, SPA Lednice fishponds and SPA Pálava. The "target species" for the Natura 2000 sites (SCIs & SPAs) include such mature and open-woodland and veteran-tree specialists as the hermit beetle (*Osmoderma barnabita*), the great capricorn beetle (*Cerambyx cerdo*), the stag beetle (*Lucanus cervus*), the collared flycatcher (*Ficedula albicollis*), or middle spotted woodpecker (*Dendrocopos medius*) (Ranius & Jansson 2000; Buse et al. 2007; Walankiewicz et al. 2007; Harvey et al. 2011). In 1999, the forests in the Soutok management unit were declared as "forest under special management aimed at biodiversity conservation", a forest category recognised by law in the Czech Republic. The rest of the forests in the study area gained this status in 2009. The forests have been certified under the Programme for Endorsement of Forest Certification Scheme (PEFC) since 2009. There are six nature reserves containing woodlands or wooded meadows in the target area: Křivé jezero (declared 1973); Ranšpurk (1949); Cahnov-Soutok (1949); Skariny (1956); Pastvisko u Lednice (1990); and, Stibůrkovská jezera (1994). The last two reserves are wetlands containing only fragments of woodlands, mostly non-existent in 1938. The reserves' total area is 269.05 ha, their wooded areas had been mostly unmanaged since their year of establishment, or even longer. Attempts to declare a larger protected area recognised under local laws (IUCN protected area category V.) started in the 1980s, with the last attempt in 2010; they have never been successful and were recently abandoned by the Ministry of Environment.

Outside the six nature reserves, conservation measures currently applied include retention of 100 trees per 10 ha of logged area (since 2007), avoidance of disturbances to raptor/stork nests by forestry activities (since 2004), and postponement of felling of 1003 ha of stands for 10 years (from 2009 to 2019). The retention trees are believed to play an important role in the conservation of veteran-tree associated biodiversity; their survival rate and hence effect are, however, unknown. Unknown also is the fate of the stands with postponed felling after 2019; or even earlier, as the forestry company has already suggested their logging.

Analyses

To quantify changes in woodland spatial structure, aerial photographs from the years 1938 and 2009 were used. The scanned aerial photos in 1200 DPI resolution were obtained from the Military Geographic and Hydrometeorologic Office, Dobruska, and transformed into a national coordinate system (S-JTSK) with ground resolution 0.5 m. Using visual photo interpretation, the information on land use/land cover categories (*following* Miklín & Smolková 2011), has been transferred into geo-databases. Seven land cover categories of woodlands were differentiated based on tree density and canopy structure:

(i) Closed forest – homogenously looking closed-canopy stands, mostly even-aged, either planted forest or outcomes of long succession history with a lack of disturbances
(ii) Structured forest – structured canopy indicating varied tree height and age, ground not visible among trees
(iii) Semi-open forest – distance among tree crowns up to 10 m; ground visible
(iv) Open forest – average distance among trees 11–40 m
(v) Clear-cut
(vi) Wooded meadow – grasslands with trees >40 m apart

Solitary trees were counted in the main areas of their occurrence. Categories (ii), (iii), (iv) and (vi) allow sunshine to penetrate the canopy and at least partly reach the ground, and allow for survival of veteran, open-grown trees; they were thus considered suitable for at least parts of open woodlands biota. The categories (i, v) were considered unsuitable to biota of open woodlands. After stump-grinding and mechanical-site preparation, the clearings resemble a ploughed arable field; they will turn into closed-canopy stands when tree saplings reach ~2 m height.

Forest age structure was obtained from forestry maps with information on tree age-class distribution for each stand (stand area 1–10 ha) for the year 1999. The maps were available at the WMS map service (FMI, 2011) for 7112.6 ha of state owned forests, thus covering 83.3% of woodlands in the study area, including woodlands in nature reserves. To bring the map up to date, the age of each stand was increased by one decade; clearings logged between 2000 and 2009 were identified using aerial photographs from the 2009 vegetation season, and their area was subtracted from each age class. This method missed logging performed in late 2009 and 2010 and thus probably underestimated the cleared area by ~10%.

To demonstrate recent changes in age structure, forest stands were grouped as follows: (i) young (clearings and stands <50 years old); (ii) medium age (50–100 years); and, (iii) mature (>100 years), and their cover was compared between 1990 and 2009. The grouping followed age structure obtained for the year 2009. For the year 1990 the age of all stands in 2009 was lowered by 20 years; and all clearings and stands <20 years old were classified as mature. This method possibly overestimated mature stand cover in 1990 due to the shorter rotation age of poplars and willows (40 and 30 years) (Lesprojekt 2000). The overestimation is, however, likely to be minimal due to a low (~5%) representation of these trees in the area (Hrib 2004).

Results

Woodland spatial structure

Of the ~8500 ha of woodlands in the target area, open woodlands and closed forest covered a similar share, 40.1% and 50.8% in 1938. Open woodlands, however, declined to 5.7% in 2009, whereas closed forest increased to 79.4% (Fig. 2). All categories of open woodlands experienced marked decline during the study period due to expansion of closed forest; only some wooded meadows turned to non-wooded grasslands. The quality of remaining open-woodlands has also decreased as the number of solitary trees decreased from 362 to 213 across the main areas of present open woodlands (mostly wooded meadows) (Table 1).

Nature reserves contained 192 ha of woodlands, i.e. 2.3% of all woodlands in the target area. The protection status did not prevent the marked expansion of closed forests at the cost of open woodlands. Between 1938 and 2009, open woodlands cover decreased from 68.5% to 14.1%, and closed forest increased from 21% to the level encountered outside reserves (Table 1).

Table 1
Loss of open woodlands, and expansion of closed forest, characterises the changes in canopy density of woodlands in floodplains of the lower Dyje and Morava rivers in the SE Czech Republic between 1938 and 2009. The total and relative covers of clearings and woodland categories, according to their canopy density for the whole target area, and separately for territory of the present-day existing state of nature reserves are given.

	1938 total		1938 reserves		2009 total		2009 reserves		1938–2009 change*	
	%	ha	%	ha	%	ha	%	ha	Total %	Reserves %
Open woodlands total	***40.1***	**3392**	***68.5***	**119**	***5.8***	**490**	***14.1***	**27**	***14.5***	***22.7***
Structured forest	*16.5*	1395	*37.1*	64	*0.5*	41	*0.0*	0	*2.9*	*0.0*
Semi-open forest	*6.6*	557	*11.7*	20	*2.7*	226	*8.1*	16	*40.6*	*80.0*
Open forest	*13.4*	1135	*14.9*	26	*0.5*	45	*3.4*	6	*4.0*	*23.1*
Wooded meadow	*3.6*	305	*4.9*	8	*2.1*	178	*2.6*	5	*58.4*	*62.5*
Closed forest	***50.8***	**4290**	***21.0***	**36**	***79.4***	**6780**	***81.4***	**156**	***158.0***	***433.3***
Clearings	***9.1***	**770**	***10.5***	**18**	***14.9***	**1268**	***4.6***	**9**	***164.7***	***50.0***
Total wooded area		**8451**		**173**		**8539**		**192**	***101.0***	***110.9***

Bold: main categories; Regular: subcategories; Italics: relative numbers (percentage).
* cover in 2009 as % of 1938 cover.

Forest age structure

Rapid changes in forest age structure occurred in the target area during the last two decades. Mature stands (>100 years) covered half of the area in 1990, but only a quarter in 2009. They were replaced by young stands (<50 years old) whose cover increased from a quarter to a half within the last two decades (Fig. 3). The logging rate apparently peaked between 1999 and 2009, as the stands 0–10 years old constituted the largest share (15.6%) of forest area. They were followed by stands 11–20 years old (10.8%), and stands 71–80 years old (10.3%). In the Tvrdonicko management unit, for example, 29.6%, 43.6% and 52.8% (cumulative) of all forests have been logged during the last two, three and four decades. During the last decade, the logging rate in the two remaining management units surpassed that of Tvrdonicko (Fig. 4).

In the reserves, the age structure was much more stable as young/medium-age/mature stands covered 42.9/18.9/79.1 ha in 1990 and 51.9/21.3/67.6 ha in 2009. The largest share was constituted by stands >160 years old (27.4%); followed by stands 41–50 years old, covering 18.1%; and 81–90 years old, covering 10.9%.

Discussion

Analysis of spatial forest structure revealed the rapid decrease in cover of open woodlands in one of the most important hot-spots of open woodlands biodiversity in Central Europe over the last 70 years. The disappearance rate of open woodlands in the target area thus parallels or exceeds that of tropical forest habitats (e.g. DeFries et al. 2005). Our earliest data originate in 1938, while forest pasture had terminated in the study area ca 70 years earlier in 1870s (Vrška et al. 2006). We thus observed only part of the changes brought by forestry intensification, and the original cover of open woodlands must have been much larger. The decrease in area of open woodlands was accompanied by deterioration of the quality of the remaining open-woodland habitats, as indicated by a decrease in the number of solitary trees. In situ tree inventory showed that the habitat quality will deteriorate further. At sites where hundreds of veteran trees are present today, very few will remain in coming decades due to the lack of younger solitary trees and the poor health state of the remaining ones (Čížek & Hauck 2008). Similarly, infilling of formerly open woodlands has a detrimental effect on old, open grown trees that are lower than forest trees, unable to

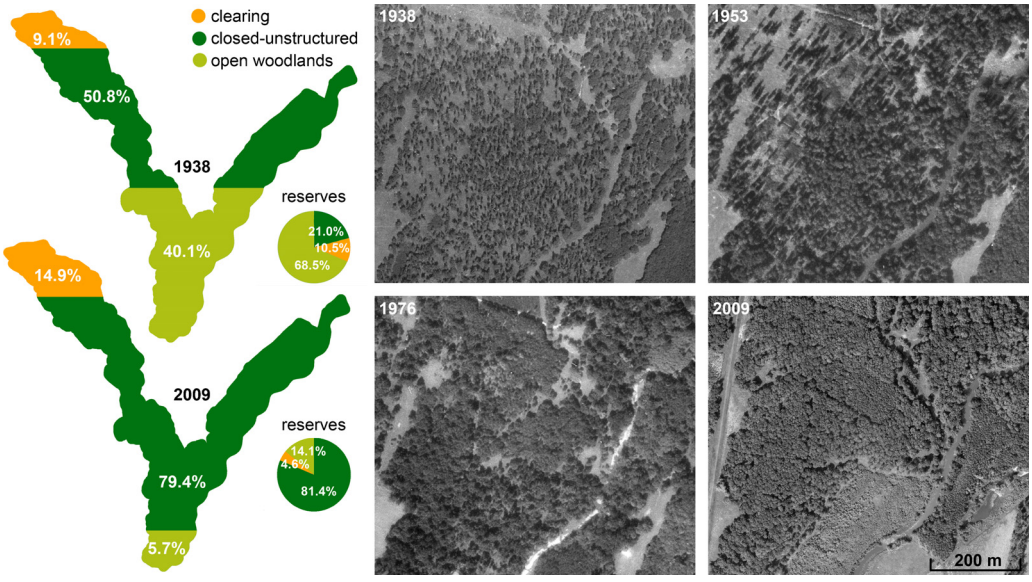

Fig. 2. Loss of open woodlands in floodplains of lower Dyje and Morava rivers in SE Czech Republic between 1938 and 2009. Relative cover of open woodlands (light green), closed canopy woodlands (dark green) and clearings (orange) as revealed by analysis of aerial photographs is given for the whole target area (blind maps) and for reserves (circles) (left). Example of gradual increase in canopy closure of 50 ha of an oak woodland over the past seventy years. Open forest prevailed in 1938, then semi-open forest and structured forest covered most of the area depicted in 1953 and 1976, while closed-canopy forest prevailed in 2009 (right).

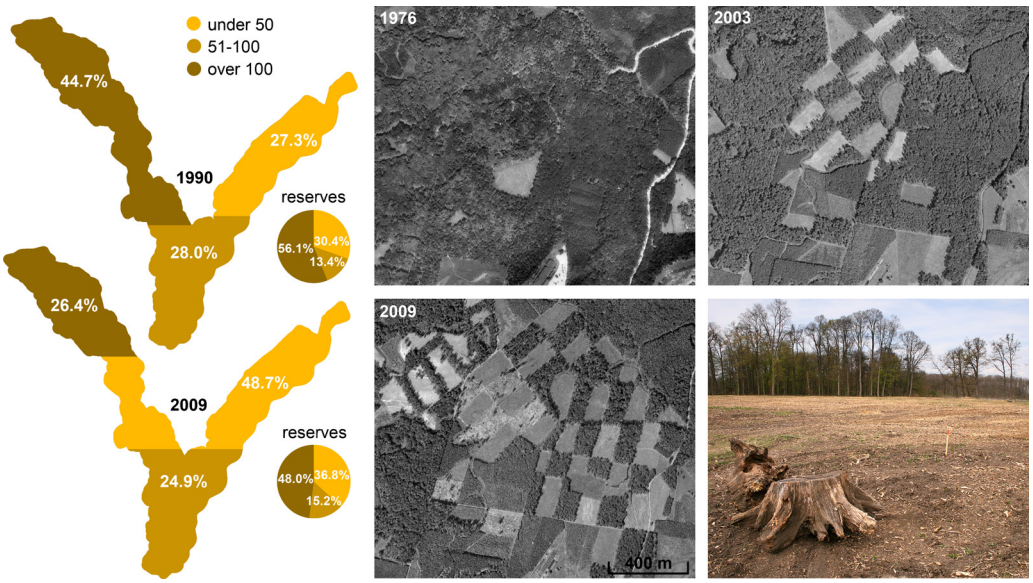

Fig. 3. Logging caused the decrease of mature forest cover in the floodplain woodlands of the Lower Morava UNESCO Biosphere Reserve between 1990 and 2009. The relative cover of mature (dark brown), medium (light brown) and young forest stands (yellow) is given for the whole target area (blind maps) and for reserves (circles) (left). The course of logging in 240 ha of the Biosphere Reserve since its declaration in 2003, with an example of clearing after stump grinding mechanical site preparation (right). For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.

compete with them (for the fate of large, veteran oaks in reserves of the area see Vrška et al. 2006).

The impact of the above changes on the biota of open woodlands is likely to be detrimental. Large continuous areas of suitable habitats were fragmented into small, isolated patches, thus fragmenting the populations of many associated organisms. Such shrinkage of habitat, magnified by the decrease in its quality, must have created an enormous extinction debt (cf. Hanski & Ovaskainen 2002). Observed local extinctions of such open woodland specialists including for example the roller (*Coracias garrulus*), hoppoe (*Upupa epops*), Woodland Brown (*Lopinga achine*) and Scarce Fritillary (*Euphydrias maturna*) (Beneš et al. 2002; Konvička et al. 2008; Hudec & Šťastný, 2005) further highlight the necessity to restore open woodlands in order to prevent further losses (Ranius & Jansson 2000).

Despite all the losses, the area under study still represents a Central European hot-spot of biota associated with open woodlands and veteran trees; the current cover of open woodlands ranks highly among woodland areas of the region. Although generally unsuitable to organisms of open woodlands, closed-canopy forests prior to first clearcut do retain some key habitat features, such as giant veteran trees, for a rather long time (Ranius & Jansson 2000), while numerous plants survive in sterile form or in the soil seed bank (Brown & Oosterhuis 1981). Old planted oak forests at about their harvest age (140 years) also host many species associated with veteran trees, and use of management techniques such as partial cutting, or selective harvest, coppicing and wood pasture would thus relatively easily change the current course of habitat deterioration and restore a state more favourable to open-woodlands biota (Mabry et al. 2010).

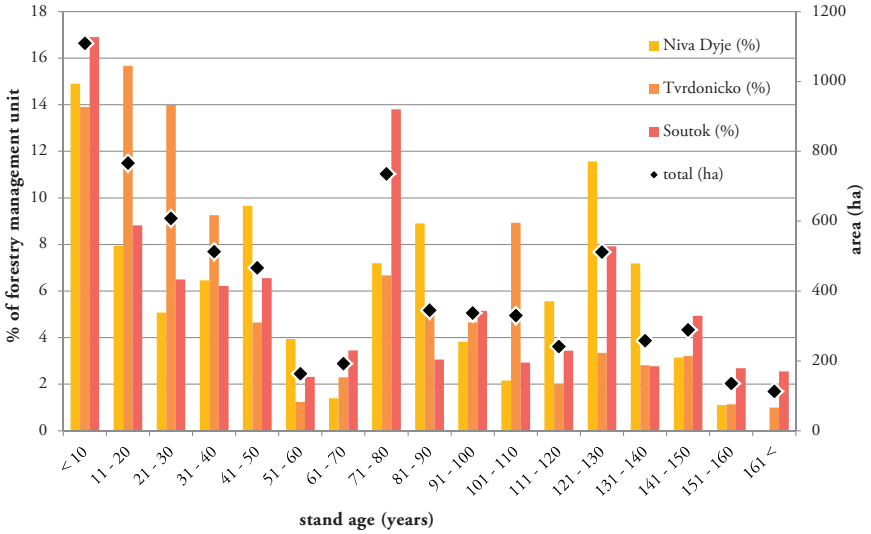

Fig. 4. Distribution of stand age-classes in floodplain woodlands along the lower Dyje and Morava rivers in SE Czech Republic in 2009 mirrors logging rates in the past decades. The relative cover of a given age class per management unit (columns) and the entire area (black diamonds). Note that stands <20 years old are the two most common classes, the result of rapid logging in the past two decades. These are followed by stands 70–80 years old, bearing witness to the increased energy needs during and after World War II.

Forest age structure

Analysis of the forest age structure in one of the largest existing internationally protected tracks of Pannonian floodplain oak woodlands revealed rapid decrease in mature forest cover over the last 20 years. The existence of mature planted stands would allow for rapid restoration of open woodland with old trees, thus bridging the gap in existence of open woodlands with veteran trees as rapidly as possible. Rapid decrease in mature forest cover thus arguably threatens the prospects for effective restoration of open woodlands and conservation of their biodiversity in the target area.

Despite the fact that the rotation age of the main timber species is 140 and 110 years, more than a quarter of all forests of the area have been logged during the last 20 years. The two most commonly represented forest age classes show that the logging rate was highest in the last two decades. This is followed by the age class bearing witness to the increased timber demands during and after World War II. The rapid logging in the Tvrdonicko management unit spans the late communist times; i.e. the 1980s. It indicates that the current high logging rate is rather a heritage of the communist past than the result of recent socio-economic changes in Central/Eastern Europe (Pullin et al. 2009). Yet not everything can be blamed on the heritage of the past. The forestry company actively seeks options to increase their harvest. For example, the status of ~900 ha of oak stands as a certified source of acorns for forest planting has been revoked since 2000, thus allowing for their earlier harvest. The logging eased neither after the UNESCO Biosphere Reserve declaration in 2003, nor after the adoption of EU legislation in 2004. This means that the current intensity of logging within the UNESCO Biosphere Reserve and Natura 2000 sites surpasses that practiced during war and post-war times. It, however, lasts for decades, and slows down only when nothing to log remains, as the situation in Tvrdonicko management unit demonstrates. At the Soutok management unit, some 50 ha a year were logged during the past decade; this year, the forestry company requested logging 88 ha, including stands with postponed felling.

Although the logging rate partly results from the uneven age structure and is technically legal according to local laws, it poses a great threat to local biodiversity, and is extremely unlikely to meet the conservation criteria of UNESCO Biosphere Reserves or the Natura 2000 sites. Most of the logged parcels are clear-cuts, often immediately adjoining one another. This way, large tracts (up to hundreds of hectares) without trees >50 years old were gradually formed, creating effective migration barriers to less mobile species. Often, remnants of forests retaining habitat continuity (former coppices and coppices with standards) are clear-cut and replaced by even aged plantations. Moreover, the clearings are subject to stump grinding and mechanical site preparation, which allows the invasive *Aster lanceolatus* to become most common plant on prepared sites, and prevents most open woodland specialists from being able to exploit clearings (e.g. most saproxylics organisms including stag beetle) (Ols et al. 2013). Forestry intensification and logging threatens forests of high conservation value elsewhere in the European Union, including the renowned Bialowezha forest in Poland (Wesołowski 2005), and national parks in Slovakia (Falťan et al. 2011), Czech Republic (Svoboda et al. 2010) and Romania (Knorn et al. 2012), indicating the problem is widespread in the region.

Biodiversity conservation between "natural processes" and economic interests

State reserves represent a negligible portion (2.3%) of the wooded area. They are thus insufficient to facilitate the survival of local biodiversity. Despite the rare accumulation of numerous local and international conservation statuses and recognitions, and despite numerous attempts to declare more reserves, economical interests prevented enlargement of an area off limits to logging and intensive forestry. Virtually all forests in the area are accessible to logging despite international protection. This is mostly due to fact that under national laws, the Natura 2000 sites guarantee only weak protection status, while Ramsar sites and UNESCO Biosphere Reserves lack any legal recognition. Further, the floodplain of Lower Morava Biosphere Reserve lacks zonation and any working management plan.

Due to rapid canopy closure allowed by conservation focusing on "natural processes", the reserves would, however, fail to serve as refuges to biota of open woodlands (*see* Supplementary Figure 5), regardless of their area. Available evidence suggests that open woodlands covered the area since the end of the last ice-age (Opravil 1983). They were probably sustained by wild herbivores and/or fires (Vera 2000) that were later replaced by traditional management (i.e. pasture, copicing and pollarding). Exclusion of such disturbance factors has created closed-canopy forests that may have never existed to such extent in the area. The canopy closure leads to rapid exclusion of oak (Janík et al., 2008) and inevitably results in a decrease of biodiversity (e.g. Vodka & Cizek 2013). On the other hand, the reserves prevented logging thus leaving more space for habitat restoration than commercial stands. Substantial enlargement of reserves accompanied by their active conservation management is therefore urgently needed.

Supplementary material related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jnc.2013.08.002.

Using the study area as an example, we presented one of the first quantifications of the loss of open woodlands in temperate Europe and assessed prospects for their restoration. We conclude that: (i) the disappearance rate of open woodlands in Europe is probably similar to that of many tropical habitats; (ii) this disappearance has gone unabated even in nature reserves; (iii) conservation practice has yet to recognise the importance of open woodlands for the conservation of biodiversity and adopt measures to support one of the most endangered habitats in Europe; (iv) the recent changes in woodland age structure caused by logging are compromising chances for future habitat restoration at the study area; and, (v) there are indications of complacency in post-communist countries with regard to biodiversity conservation.

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