iForest Biogeosciences and Forestry

Research Article
doi: 10.3832/ifor1867-009
vol. 9, pp. 560-568

IUFRO division 8.02 - Mendel University Brno (Czech Republic) 2015
"Coppice forests: past, present and future"
Editors: Tomas Vrska, Renzo Motta, Alex Mosseler

Integrating conservation objectives into forest management: coppice management and forest habitats in Natura 2000 sites

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Most forest habitats, as defined and listed for their nature conservation importance in the Habitats Directive of the European Union and in the Bern Convention, result from centuries of human intervention. This paper explores the scope for, and the attitudes towards coppicing in Natura 2000 sites in some of the EU28 countries where coppice was historically one of the most important traditional silvicultural systems. A questionnaire survey was circulated to experts involved with Natura 2000 sites and case studies were conducted in Belgium, the Czech Republic, Estonia, Germany, Italy and the United Kingdom, to investigate attitudes to coppice silviculture within the framework of Natura 2000 site management plans. A list of forest habitat types capable of being managed as coppices was compiled and populated with sites at national and regional levels. At the regional level, management plans for the relevant forest habitat types in Natura 2000 sites were critically scrutinised together with other statutory, administrative or contractual measures. The results show that approaches to integrate coppice management into conservation plans differ widely. Examples of disparities are given and the possible causes discussed. A case is made for coppicing to be continued, where appropriate, as an important strategy in site management plans that aim to conserve habitats and improve forest biodiversity.

Keywords: Habitats Directive, Natura 2000, Forest Habitat Types, Coppice, Biodiversity, Landscape

Introduction

Abandonment of coppice management is a complex phenomenon due to the collapse of small roundwood and fuelwood markets throughout Europe following the second world war, the marginalisation of rural and mountain areas, the inaccessibility of many of the sites, and the cost of carrying out uneconomic harvesting operations for conservation. However, current policies at the European Union (EU) level (*e.g.*, EU Renewable Energy Directive 2009/28/EC, Framework Program for the Forestry Sector – Horizon 2020, EU 995/2010 Timber Regulation) seem to cast new perspectives for this old silvicultural system.

This system, admittedly, does not conflict with the aims of conservation policies in Europe. Management of Natura 2000 sites, *i.e.*, Sites of Community Importance (SCIs) or Special Areas of Conservation (SACs), is advocated, though not legally prescribed, by the Habitats Directive of the EU (Council Directive 92/43/EEC) in order to "maintain and restore, at a favourable conservation status, natural habitats and species of wild fauna and flora of Community interest". The Habitats Directive defines "favourable conservation status" as the "sum of the influences acting on a natural habitat and its typical species that may affect its long-term natural distribution, structure and functions as well as the long-term survival of its typical species within the [European] territory". However, particularly for forest habitat types, the Interpretation Manual of European Union Habitats gives no specific reference to their vertical (single or multi-storey) or horizontal structure (European Commission 2013b). The "Natura 2000 and forests" guide (European Commission

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Received: Sep 08, 2015 - Accepted: Mar 21, 2016

Citation: Mairota P, Buckley P, Suchomel C, Heinsoo K, Verheyen K, Hédl R, Terzuolo PG, Sindaco R, Carpanelli A (2016). Integrating conservation objectives into forest management: coppice management and forest habitats in Natura 2000 sites. iForest 9: 560-568. – doi: 10.3832/ifor1867-009 [online 2016-05-12]

Communicated by: Tomas Vrska

2003) recommends that "traditional management systems that have created valuable ecosystems, such as coppice, on appropriate sites should be supported when economically feasible". Similarly, the Habitats Directive states that "Measures taken [...] shall take account of economic, social and cultural requirements and regional and local characteristics" and with the approach of integrating different forest functions, which is typical of the European culture of managing forests. Moreover, the Natura 2000 network includes sites intended to protect secondary habitats and successional stages, in which traditional management activities, even if nowadays uneconomic, may well be necessary to achieve the conservation objectives (Loidi & Fernández-González 2012, European Commission 2013a).

Nevertheless, non-intervention or conversion to high forest seem to be the most common approaches to forest management in protected areas. Therefore, this study investigates attitudes to coppicing in a representative sample of EU Member States within SCI/SAC site management plans (SMPs), and examines the case for reconsidering coppicing among the options to improve and conserve habitats, and to enhance biodiversity.

Methods

Countries participating in the survey included Belgium (BE), the Czech Republic (CZ), Estonia (EE), Germany (DE), Italy (IT) and the United Kingdom (UK), encompassing a range of EU Biogeographical Regions, different amounts of forest cover, centralized to devolved countries, and both small and large regions. Where a government has delegated responsibility for managing Natura 2000 sites to regional authorities or statutory conservation bodies, the relevant NUTS (European Commission 2015) administrative level has been used.

Tab. 1 - Standardised data collection framework. Main sources for data collection: EUNIS database or regional official websites, Natura 2000 Barometer; EE: EELIS, Keskkonnaagentuur - Keskkonnaregister; UK: Joint Nature Conservation Committee; BE: Trading Economics; CZ: Czech National Forestry Inventory, Nature Conservation Agency of the Czech Republic; DE: German National Forest Inventory (2012); IT: National Forest Inventory INFC (2005). All databases are available through public web sites (see Box S1 in Supplementary material).

Data ID	Data description
1	General aspects
1.1	Compiler's name
1.2	Country of study
	Total area
	Total forest area
1.3	No. of terrestrial SCIs/SACs
	Area of terrestrial SCIs/SACs
1.4	No. of terrestrial SCIs/SACs including forest habitats types with potential for coppice
1.5	No. of forest habitats types with potential for coppice
	No. of sites with SMPs under Habitats Directive
1.6	Notes
2	General occurrence in all available management plans for study regions
2.1	Compiler's name
2.2	Country of study
2.3	Study region
2.4	No. of SCIs/SACs in study region including forest habitats types with potentials for coppice
2.5	No. of available SMPs for study region
2.6	N. of SMPs containing the word "coppice" or similar terms
2.7	No. of SMPs mentioning former coppicing/pollarding
2.8	Notes
3	Analysis of individual management plans
3.1	Site code NUTS2/NUTS3
3.2	Site name
3.3	List of FHT_WPC
3.4	No. pages
3.5	Count of term "coppice" or similar terms
3.6	Own chapter about coppice in table of content YES/NO
3.7	Current coppice management
3.8	Coppice related aims for species YES/NO
3.9	Coppice related aims for species comments
3.10	Coppice related aims for habitats YES/NO
3.11	Coppice related aims for habitats comment
3.12	Main management recommendations for active coppices
3.13	Notes

The study was in two parts: (a) a questionnaire and (b) six case studies. The questionnaire was sent to experts in countries directly involved in national or regional SCI/SAC administration. Fifteen open-ended questions (Tab. S1 in Supplementary material) were designed to gather information about both the conservation status and the current management of forest habitats present within the designated sites. The focus was on the following topics:

- to understand how each country deals with coppices in SCIs/SACs;
- to identify the forest habitat types listed in Annex I of the Habitats Directive with the capacity to coppice successfully, *i.e.*, forest habitat types dominated by angiosperm trees, able to respond to cutting by forming secondary shoots and using reserves from the stool or belowground plant parts (Del Tredici 2001, Clarke et al. 2010 - FHT_WPC), and those which are or have been historically coppiced (FHT_C);
- to verify the distribution and conservation status of FHT_C forests across countries and Natura 2000 sites;
- to determine the extent to which the Habitats Directive is being implemented in SMPs, and the administrative authority for managing Natura 2000 sites.

The questionnaire was conducted at the national level for most selected countries, but to illustrate important differences in regional administration, four representative territorial regions at a lower level were selected in Italy: IT-C1 Piemonte; IT-D4 Friuli Venezia Giulia; IT-E2 Umbria and IT-F4 Puglia (NUTS2). For Belgium, due to resource limitations, only BE-1 Flemish region, or Flanders (NUTS1), was considered.

Guidelines for the compilation of SMPs were issued by the European Commission (2000) and for a range of forest habitat types (European Commission 2003). SMPs are usually publicly available on official websites. Case studies to scrutinise Natura 2000 SMPs for their similarities and differences in relation to coppice were carried out at national (EE) and sub-national levels: IT-E2 Umbria and ITF-4 Puglia (NUTS2), UK-J, South East England and UK-L Wales (NUTS1), and DE-B Rhineland-Palatinate (NUTS1). The number of SMPs examined varied between case studies according to their frequency and representativeness.

For both the questionnaire and the case studies, data collection included (Tab. 1):

- collation of national territorial statistics from EU or national level databases, *e.g.*, country forest area, number of terrestrial SCIs/SACs (for web links see Box S1 in Supplementary material);
- compilation of a list of Habitats Directive Annex I forest habitat types with potential for coppice;
- compilation of a country level list of SCIs/SACs, where these forest habitat types may also occur, using the European nature information system (EUNIS) data-

base. Additionally for the case studies, their designation, total site surface area, habitat type surface area within site, number of protected habitat types and species were taken from the EUNIS database. Descriptions of SCIs/SACs and individual SMPs were collected at either national or regional levels from official websites.

The 172 SMPs examined represented 51% of those available (Fig. 1). When there were obvious generic similarities within a region, only a sample of these were examined. For example, 99 SMPs were available for IT-E2 Umbria, but as these were fairly similar in both structure and content, only 15 SMPs (15.3%) were scrutinised.

Results

General description of countries

Most European Biogeographical Regions were represented in the countries and regions surveyed: Alpine (IT, DE), Atlantic (UK, BE, DE), Boreal (EE), Continental (DE, CZ, IT), Pannonian (CZ) and Mediterranean (IT). The land areas of the selected countries vary significantly with BE, CZ and EE having considerably less than the UK, DE and IT (Fig. 2). EE is the most forested country and the UK the least, while IT, CZ, DE, and BE are intermediate. The four IT NUTS2 also have different proportions of forest, IT-E2 Umbria and IT-D4 Friuli Venezia Giulia having above the national average forest cover (46.1% and 45.4%, respectively), while IT-C1 Piemonte is closer to the national average (37%) and IT-F4 Puglia is the least forested region in the country (9.2%).

For this group of countries the terrestrial component of the Natura 2000 network accounts for an average 14.6% of the country area (Fig. 2). Of this, an average of 73.9% is protected under the Habitats Directive (*i.e.*, consists of SCI/SAC sites only). The percentage cover in terrestrial SCIs/SACs of different countries seems to be consistent with the total percentage of forest cover, suggesting a tendency to designate forest areas as SCIs/SACs where there is the opportunity.

Compliance with the Habitats Directive recommendation to compile SMPs for all SCI/SAC sites differs widely within the EU28, *e.g.*, 90% of Swedish Natura 2000 sites are covered, whereas Slovakia, Bulgaria, Ireland and Poland have none, and there is no data for Greece and Croatia (European Environmental Agency 2015).

Forest habitat types with potential for coppice

Based on the re-sprouting potential of the dominant trees, 53 (68%) of the 78 Annex I forest habitat types in the Habitats Directive have potential for coppice (Tab. 2). The majority (55%) fall into the 9100 "Forests of Temperate Europe" category, followed by 9200 "Mediterranean deciduous forests" (23%), 9300 "Mediterranean sclerophyllous forests" (17%) and 9000 "Forests of Boreal Europe" (6%).

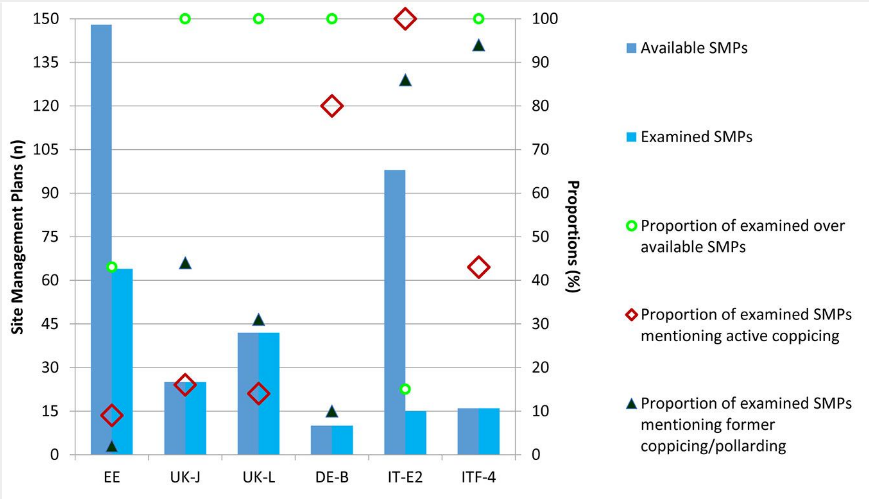

Fig. 1 - Synopsis of numbers of individual Site Management Plans examined, showing the proportion mentioning active or historic coppicing.

Questionnaires

In all the examined countries coppicing is allowed by law (question 1), although in CZ it has to be authorised on a case-by-case basis and under specific restrictions.

From the list of forest habitat types with potential for coppice, 32 types (60%) were present in the responding countries (question 2). For 31 of these, coppicing was, or had formerly been, a common regeneration method (Tab. 2). Their distribution by broad Annex I forest categories is the same as the initial list (Fig. S1 in Supplementary material). Italy emerges as the richest country in terms of the number of forest habitat types and the most heterogeneous, followed by EE, DE, CZ, UK, and BE (Fig. S2 in Supplementary material).

The same category can be differently managed in different countries, *e.g.*, 9130 (*Asperulo-Fagetum* beech forests) is widespread but coppiced rarely in CZ, and represents an atypical kind of coppice only in

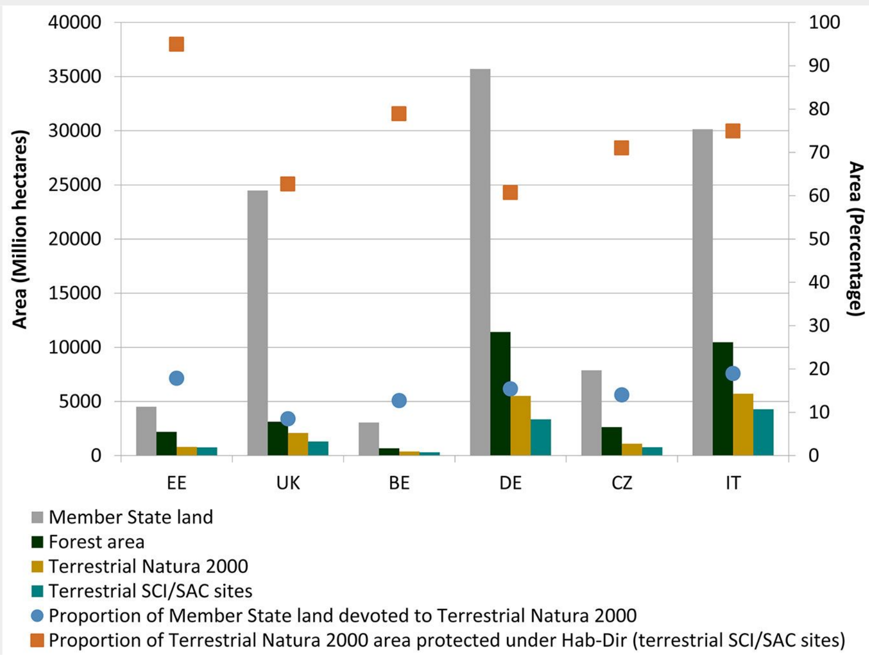

Fig. 2 - Country area, forest area, terrestrial Natura 2000. Proportion of each Member State land area devoted to Terrestrial Natura 2000 sites in the study countries. The proportion of SCI/SAC area within Natura 2000 sites is also shown. Sources for data: EUNIS Database; EE: EELIS, Keskkonnaagentuur Keskkonnaregister; BE: Trading Economics; UK: Joint Nature Conservation Committee; DE: German National Forest Inventory 2012; IT: National Forest Inventory 2005 (see Box S1 in Supplementary Material for the links to web sites).

Tab. 2 - Initial list of forest habitat types of community interest with potential for coppice within EU28 (A), list of forest habitat types present in one or more of the surveyed countries (B), countries where the habitat is or has been managed as coppice (C). Source: List derived from the EUNIS Database (http://eunis.eea.europa.eu/habitats). The codes and the names of the forest habitat types correspond to those of the Annex I the EU Council Directive 92/43/EEC. (*): priority habitat types.

(A) Habitat type code and name	(B) Presence	(C) Coppiced
9020* Fennoscandian hemiboreal natural old broadleaved deciduous forests (*Quercus, Tilia, Acer, Fraxinus or Ulmus*) rich in epiphytes	Yes	EE
9070 Fennoscandian wooded pastures	Yes	EE
9080 Fennoscandian deciduous swamp woods	Yes	EE
9110 *Luzulo-Fagetum* beech forests	Yes	IT,BE,CZ
9120 Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the shrublayer (*Quercion robori-petraeae* or *Ilici-Fagenion*)	Yes	BE,UK
9130 *Asperulo-Fagetum* beech forests	Yes	IT,BE,CZ,DE,UK
9140 MedioEuropean subalpine beech woods with Acer and *Rumex arifolius*	Yes	IT
9150 MedioEuropean limestone beech forests of the *Cephalanthero-Fagion*	Yes	IT,CZ
9160 SubAtlantic and medio-European oak or oak-hornbeam forests of the *Carpinion betuli*	Yes	IT,BE,CZ,DE,UK
9170 *Galio-Carpinetum* oakhornbeam forests	Yes	CZ,DE
9180* *Tilio-Acerion* forests of slopes, screes and ravines	Yes	IT,CZ,DE,UK
9190 Old acidophilous oak woods with *Quercus robur* on sandy plains	Yes	BE,DE,UK
91A0 Old sessile oak woods with *Ilex* and *Blechnum* in the British Isles	Yes	UK
91B0 Thermophilous *Fraxinus angustifolia* woods	No	-
91C0 Caledonian forest	No	-
91D0* Bog woodland	Yes	UK
91E0* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*	Yes	IT,BE,CZ,DE,UK
91F0 Riparian mixed forests of *Quercus robur, Ulmus laevis* and *Ulmus minor, Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)	Yes	IT,CZ,DE
91G0 Pannonic woods with *Quercus petraea* and *Carpinus betulus*	Yes	CZ,DE
91H0* Pannonian woods with *Quercus pubescens*	Yes	CZ
91I0 Euro-Siberian steppic woods with *Quercus* spp.	Yes	CZ
91K0 Illyrian *Fagus sylvatica* forests (*Aremonio-Fagion*)	Yes	IT
91L0 Illyrian oakhornbeam forests (*Erythronio-carpinion*)	Yes	IT
91M0 PannonianBalkanic turkey oak -sessile oak forests	Yes	IT
91N0 Pannonic inland sand dune thicket (*Junipero-Populetum albae*)	No	-
91Q0 Western Carpathian calcicolous *Pinus sylvestris* forests	No	-
91S0 Western Pontic beech forests	No	-
91V0 Dacian Beech forests (*Symphyto-Fagion*)	No	-
91W0 Moesian beech forests	No	-
91X0 Dobrogean beech forests	No	-
91Y0 Dacian oak and hornbeam forests	No	-
91Z0 Moesian silver lime woods	No	-
9210* Apeninne beech forests with *Taxus* and *Ilex*	Yes	IT
9220 Apennine beech forests with *Abies alba* and beech forests with *Abies nebrodensis*	Yes	IT
9230 GalicioPortuguese oak woods with *Quercus robur* and *Quercus pyrenaica*	No	-
9240 *Quercus faginea* and *Quercus canariensis* Iberian woods	No	-
9250 *Quercus trojana* woods	Yes	IT
9260 *Castanea sativa* woods	Yes	IT
9270 Hellenic beech forests with *Abies borisii-regis*	No	-
9280 *Quercus frainetto* woods	Yes	IT
92A0 *Salix alba* and *Populus alba* galleries	Yes	IT
92B0 Riparian formations on intermittent Mediterranean water courses with *Rhododendron ponticum, Salix* and others	No	-
92C0 *Platanus orientalis* and *Liquidambar orientalis* woods (*Platanion orientalis*)	No	-
92D0 Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*)	No	-
9310 Aegean *Quercus brachyphylla* woods	No	-
9320 *Olea* and *Ceratonia* forests	No	-
9330 *Quercus suber* forests	No	-
9340 *Quercus ilex* and *Quercus rotundifolia* forests	Yes	IT
9350 *Quercus macrolepis* forests	Yes	IT
9360 Macaronesian laurel forests (*Laurus, Ocotea*)	No	-
9380 Forests of *Ilex aquifolium*	Yes	IT
9390 Scrub and low forest vegetation with *Quercus alnifolia*	Yes	-
93A0 Woodlands with *Quercus infectoria (Anagyro foetidae-Quercetum infectoriae)*	Yes	-

the north of Germany, where also 9140 (Medio-European subalpine beech woods with *Acer* and *Rumex arifolius*) is rare and not coppiced; 9150 (Medio-European limestone beech forests of the *Cephalanthero-Fagion*) is very rare in the BE region of Flanders, yet probably coppiced in CZ and DE, mostly derived from 9130 in historical times.

Question 3 explored the conservation status (*e.g.*, "favourable", "unfavourable recovering", "unfavourable declining", "not assessed" and "unknown") for each FHT_C as reported and defined by the EEA database. The great majority of habitats were classified as unfavourable or inadequate (U1) or unfavourable or bad (U2), with only a few favourable listings (FV) in Alpine, Pannonian, Continental and Mediterranean Biogeographical Regions (Fig. S3 in Supplementary material).

The questionnaires (question 4) confirmed the low compliance of this group of countries in developing SMPs reported by the European Environmental Agency (2015). However, in Italy there are surrogates for the missing SMPs, namely the "regional conservation measures", for all habitat types belonging to the same Biogeographical Region (IT-D4 Friuli Venezia Giulia), or for macro-environmental categories (IT-C1 Piemonte and IT-F4 Puglia). In the two northern Italian regions more SMPs are in preparation (50 in IT-C1 Piemonte, and 56 in IT-D4 Friuli Venezia Giulia). It was confirmed (question 5) that existing SMPs are publicly available and that the EU Guidelines (European Commission 2000) in some countries (BE, CZ, DE, EE, IT) are strengthened by national and even regional guidelines (question 13). As for the habitat descriptions (question 14), some countries (BE, DE, EE, IT, UK) have issued national or regional (DE) interpretation manuals in addition to the Interpretation Manual of European Habitats (European Commission 2013b).

Generally, SMPs in all the countries surveyed took particular account of species listed in the Annexes to the Habitats Directive (question 6). Apart from a very few examples (UK, DE, IT-C1 Piemonte), these SMPs did not cite species which are favoured by active coppice management (question 7), and focused exclusively on Annex II species, relatively few of which are specifically adapted to coppicing (question 8).

Although the ecological requirements for rare "coppice species", such as the hazel grouse (*Bonasa bonasia*) from DE, and the stag beetle (*Lucanus cervus*) from IT Piemonte, are made explicit and listed in the habitat descriptions, neither of the latter species is restricted to coppice habitats (question 9).

Active coppice management was reported for most countries, but only for research purposes in CZ, and none in EE (question 10 - Vild et al. 2013, Müllerová et al. 2015). In the past decade EU LIFE projects to restore coppicing have been carried out in DE. In the UK, conservation coppicing is targeted at rare, rather than Annex II species, *e.g.*, specialist butterflies (Chequered skipper, *Carterocephalus palaemon* and Pearl-bordered fritillary, *Bolaria euphrosyne*), birds (*e.g.*, nightingale, *Luscinia megarhynchos*) and dormouse (*Muscardinus avellanarius*).

In EE and many other countries, non-intervention is the default management strategy for protected areas. No special management prescriptions for coppices within Natura 2000 sites (question 11) were given for BE, DE, CZ and UK, but in some IT regions (*e.g.*, IT-D4 Friuli Venezia Giulia) such prescriptions were applied in all protected sites. Elsewhere coppicing rules tended to be strict, specifying coupe size, rotation length, number of standards and standard age category, sporadic tree species release and canopy cover.

The UK and CZ were the only countries where SMPs were compiled by the same body that designates Natura 2000 sites (question 12). In all the other countries, external consultants of varied professional types were engaged on a public tender basis including conservation experts (only in the UK), biologists (DE, EE, IT), forestry consultants (BE, DE, EE, IT), agronomists (BE, DE, IT), or landscape managers and historians (EE) and urban planners (IT - question 15).

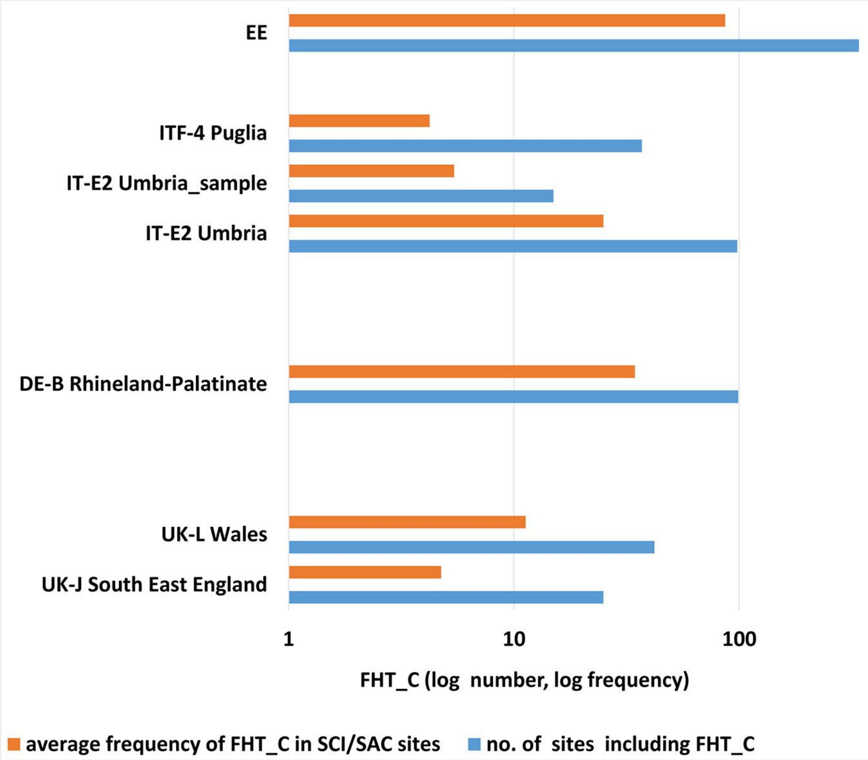

Fig. 3 - Number of FHT_C present in SCI/SAC sites by study units and their frequency.

Case studies

Sample units obviously differed in terms of the total number of SCI/SAC sites containing FHT_C and in the average frequency of any FHT_Cs within these sites (Fig. 3). A relatively high value indicated that by and large in all sites the same FHT_C could be found (*e.g.*, in DE and EE). Values lower than this average indicate that sites are more dissimilar from one another in terms of the FHT_C they contain (*e.g.*, IT and UK).

However, sample units were more similar in terms of the average number of all habitat types within each site and by the relative richness of FHT_C (Fig. 4). On average,

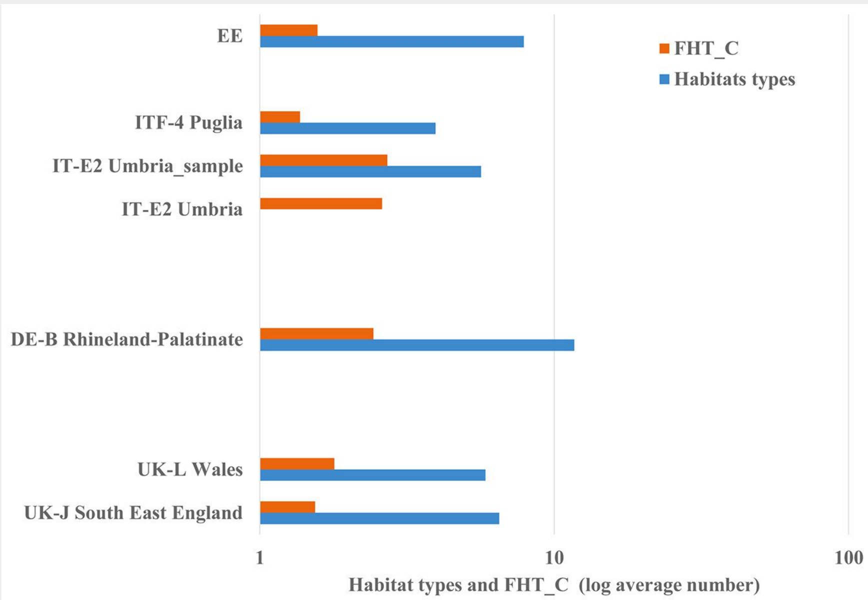

Fig. 4 - Average number of habitat types and of FHT_C present in SCI/SAC sites by study units.

FHT_C accounted for as much as 48% of all habitat types present in each site in IT-E2 Umbria, but only 20% in EE. This result is particularly interesting considering the relatively high agreement between amount of FHT_C relative to the number of habitat types present in each site and the number of species protected on average in the same sites (*e.g.*, 74 in IT-E2 Umbria but 5 in EE).

The proportions of SMPs mentioning coppice or former coppicing/pollarding (Fig. 1) varied between regions, with respectively 100% and 86% in IT-E2 Umbria, 43% and 94% in ITF-4 Puglia, 14% and 31% in UK-L Wales, 16% and 44% in UK-J, South East England, 80% and 10% in DE-B Rhineland-Palatinate and 9% and 2% in EE.

The analysis of individual management plans allowed a more detailed consideration of management perspectives in relation to coppice in SCI/SAC sites and Annex I forest habitats. These are summarised in the following sub-sections for each case study.

United Kingdom

The four conservation agencies in the UK responsible for designating SACs are Natural England, Natural Resources Wales, Scottish Natural Resources and the Northern Ireland Environment Agency. Natural England publishes Site Improvement Plans for each SAC, but these do not cover any ongoing routine management or maintenance, so any current coppicing or pollarding work is unknown. Like Scottish Natural Heritage and Northern Ireland Environment Agency, they publish very brief citations describing the site and its qualifying habitats. Rather than specifically proposing a silvicultural system, they cite such generic objectives as:

- the removal or eradication of non-native species;
- the control of grazing within the woodlands, to ensure adequate regeneration;
- the promotion of a good woodland structure and a mix of tree ages; and
- maintaining the extent of the woodland habitat and minimising disturbance.

SMPs in this sense tended to be ideal "visions" of management, rather than actual prescriptions for active operations. The general impression was that non-intervention or minimal interventions could be applied at most sites: there was rarely a specific recommendation for coppice management. Over 70% of SAC woodland area in Wales was allocated to this minimal intervention category, although much was located in gorges, in steep valleys or on wetland where active management would be physically limited by the terrain or too costly to maintain. Interestingly, site management plans here stressed that "favourable conservation status" was a wider objective, *i.e.*, not necessarily applying to the individual sites themselves, but emphasising what an individual site can contribute to the whole. The repeated emphasis on maintaining a high forest structure in both Wales and Scotland was probably a tacit recognition of the Atlantic influence on woodland types in western Britain, where the protection of rare bryophytes and lichens, hole-nesting and canopy-feeding birds, accumulation of deadwood for saproxylic invertebrates and natural tree regeneration were regarded as greater priorities than successional habitats like coppice.

Germany

Availability of German management plans differed in each NUTS1 region. In NUTS1 Rhineland-Palatinate, these were only available for 10 SAC sites out of 97 with FHT_WPC.

Coppicing in Germany was more likely to occur in habitats dominated by oaks. Indication of the term "oak coppice" was found only in some management plans. Other forest habitat types, such as 9130 (*Asperulo-Fagetum*) was managed as coppice in a very limited area in northern Germany. Authorship of the SMPs seemed to heavily influence management intentions, as similar passages and prescription, often with identical sentences, suggested a common writer. In Rhineland-Palatinate there were only two management plans where coppice management played a role (one plan covering three sites and one for a single site). Management prescriptions differed among sites with regard to the provision of habitat for particular species. For example, to support the habitat of the hazel grouse (*Bonasa bonasia*) small clear cuts were also suggested.

At one site in forest habitat type (9170 *Galio-Carpinetum* oak-hornbeam forest), two different forms of management were advocated: (a) small clearcuts (producing a patchy coppice structure) and (b) thinning for conversion to high forest (tending veteran oaks with deadwood). As in the case of SMP for DE5613301 Lahnhänge, this might be explained by the need of creating heterogeneous forest structural conditions to meet the contrasting habitat requirements of protected species such as hazel grouse, Middle spotted woodpecker (*Dendrocopos medius*) and Stag beetle (*Lucanus cervus*). Over-aged coppice in Germany has reached a point where it could be developed in many different directions: reactivated coppice, coppice with standards, conversion to high forests, or spontaneous development. Every solution has a different aim and will support different species.

Italy

Regione Umbria is the regional authority responsible for managing SCIs/SACs in IT-E2 Umbria, with SMPs compiled by external consultants who are most probably foresters, consistent with the strong forestry tradition of this region. SMPs were in two parts, a short description of the site, also reiterating information provided by the Natura 2000 Standard forms, and a second part consisting of regulations detailing prescriptions and constraints for the site.

Coppicing was not deemed relevant to the conservation of species or groups of species, yet it was not considered incompatible with conservation objectives for the site. A number of plans recommended conversion to high forest for specific forest habitat types (91L0 Illyrian oak-hornbeam forests, 91M0 Pannonian-Balkanic turkey oak-sessile oak forests, 9210* Apennines beech forests with *Taxus* and *Ilex*, 92A0 *Salix alba* and *Populus alba* galleries, 9340 *Quercus ilex* and *Quercus rotundifolia* forests, 9260 *Castanea sativa* woods) or even non-intervention (*e.g.*, 91L0 forests), and a few encouraged the development of a forest landscape mosaic, alternating coppices, high forests and non-intervention forests.

Where socio-economic considerations tended to support or even dictate an active coppice silviculture, constraints were set regarding cut size and contiguity, length of rotation, releasing certain tree species and retaining isolated trees according to regional forest regulations in force. The principles of Sustainable Forest Management (SFM) were encouraged in coppice management, such as the retention of standards in groups (Grohmann et al. 2002, Grohmann 2005) rather than the usual even distribution of these trees across the stand. This mode of standards selection is reputed to be effective in improving the stability of retained trees, the growth of stools, the diversity of tree species and other biodiversity, the marking and extraction operations, and soil protection (Piussi & Alberti 2015).

In IT-F4 Puglia, the regional authority responsible for the management of SCIs/SACs also used external consultants, most often urban planners, supported by naturalists rather than foresters, to compile SMPs, consistent with the poor forestry tradition of this region and the large size of sites, including complex anthropogenic landscapes. No schedule was provided for the specialist flora and fauna, other than a generic indication of their relative priority. As before, regulations constrain a number of activities including coppicing, which was considered irrelevant, or even injurious, to the conservation of species or groups of species. Conversion to high forest or non-intervention was generally advocated. High forests were assumed to increase species diversity, particularly of forest trees (the aim of a mixed species forest was often advocated), and to improve the forest structure. The objective was to promote natural stand regeneration and increase coarse woody debris, on the assumption that this would enhance biodiversity.

Where socio-economics was locally important, similar constraints applied to cut size and contiguity, longer rotation intervals, retention of heavy standards with a given number of ageing/decaying trees.

The main difference between the prescriptions for active coppicing in SMPs in IT-E2 Umbria and IT-F4 Puglia are that in Umbria these are intended to sustain coppice management, whereas in Puglia they tend to dismiss this system.

Estonia

The authority in charge of all SACs in Estonia is the Estonian Environmental Board (*Keskkonnaamet*). More than half of these sites had an up-to-date SMP, whereas in older SACs these were implemented more than five years ago. The authors of the plans were botanists, ecologists and foresters from the regional administrations or from Estonian universities. Typical plans consisted of a state-of-the-art description accompanied by maps, general management instructions for each habitat type and detailed guidelines of how to improve the habitat for site-specific endangered species.

The layout of the SMPs followed a common pattern: in most general sections there was a list of forbidden activities, including clear-cutting of large areas and the cultivation of energy forests. Any economic management could be carried out only in the buffer zones, whilst in the inner protected areas only spontaneous development of the forest was allowed. The only exceptions here concerned decreasing the conifer ratio to protect the specific broadleaf forest type, and a one-time cutting back of clearings for open-land birds or for providing firewood on isolated islands.

In many SACs, further management involved raising the water table (especially in 91D0* Bog woodland) and leaving dead wood on site. Both of these activities were designed to develop habitats for different species, but significantly they also decreased the probability of any active utilisation of the site by humans. The one exception among the categories examined was habitat 9070 Fennoscandian wooded pastures, that requires constant human activity and coppicing. However, once again management prescriptions were for one-time only harvests, after which the sprouting of trees was to be suppressed by periodical grazing or mowing.

Discussion

Although EU member states should harmonise Natura 2000 Directives with national interests, as expected, variations in attitudes towards coppice management in SCIs/SACs are observed when non-legally binding recommendations (including traditional forest management, hence coppice where appropriate) from nature protection directives are not incorporated into national and regional legislation frameworks. Where national authorities had delegated this responsibility to regional authorities, the resulting variations in the implementation of Natura 2000 legislation were more marked. Accordingly, progress in formulating SMPs ranged widely between the EU countries.

Large differences in forest cover between the surveyed countries appeared to influence geographical patterns of SCIs and SACs; countries with greater forest cover had more designated sites and larger countries were able to accommodate more of them. A fifth to almost a half of all the SCIs/SACs surveyed contained habitat types associated with coppice management. With a few exceptions (*e.g.*, DE) many of the forest areas in SMPs were officially listed as active or historic coppices, but very few SMPs specifically mentioned coppices or ongoing coppice management. Generally, however, the current conservation status of forest habitats within Natura 2000 sites was poor, not necessarily because they had been coppiced in the past or were no longer being managed/coppiced, but possibly because the habitat was/is being degraded in some way, or populations of Annex II species were declining. The designation of SCIs/SACs within NUTS regions, at levels 1, 2 or 3 lead to widely different attitudes and policies with regard to forest management, and in the level of detail given in SMPs. Where the smaller NUTS units were consolidated under one authority, as in NUTS1 in the UK and NUTS2 in Italy, the SMPs tended to be much more homogeneous and uniform.

According to the hierarchical planning approach proposed by Baskent & Keles (2005), SMPs should represent the first level of cascade planning, but they were mainly descriptive and aspirational rather than definitive, probably because of the extreme complexity involved in implementing the many contrasting objectives of a SMP (Winkel et al. 2015). Consequently, SMPs seemed to be generally ineffective in setting integrated, landscape-level objectives and second-level targets such as tactical forest management plans.

As SMPs were written by various types of professional bodies in different countries, cultural attitudes towards nature conservation, forests and silvicultural management, and the site's historical socio-economic context, also influenced their implementation. The Habitats Directive aim of "maintaining and restoring sites at favourable conservation status" may therefore be interpreted differently according to these widely-varying professional and educational backgrounds.

Species which might benefit from coppice management (Spitzer et al. 2008, Buckley & Mills 2015) were generally underemphasised in SMPs, possibly because those cited in Annex II of the Habitats Directive are mostly rarities or endemics, or are likely to occur in open habitats as in forests. Some of the listed species could use coppice habitats, open forests or forest edges, but equally many others required deep shade, closed canopies, dead wood and veteran trees. However, it could be argued that the Directive also protects the habitat *per se* with its suite of characteristics and the relatively frequent species associated with the mosaic of age classes created by coppice woods or coppice-with-standards. The biodiversity associated with these systems could be regarded as important as protecting some rare elements of biodiversity.

Although coppicing in SMPs was not advocated widely, there was often some acknowledgment of former copping. With a few exceptions, there was a tendency to consider that conversion to high forest, or even non-intervention, was more desirable than coppicing. Justification was rarely given but, especially in plans written by foresters, one motive was expressed that high forest is more likely to return some financial return (but see Motta et al. 2015). Some SMP compilers clearly felt that non-intervention promoted spontaneous vegetation dynamics and silvo-genetic processes, and would return the site to a more "natural" state. Again, the perception could be that this would promote old-growth forest, a condition regarded as the ultimate expression of the ecosystem maturity.

A decision in SMPs for non-intervention or to convert a coppice to high forest would appear to depend on whether the aim was to enhance biodiversity in a generic sense, or to focus on one particular habitat type for its specific biodiversity, such as the bryophyte-rich Atlantic oakwoods in the UK (Sanderson 2008). High forest might not be appropriate to encourage the biodiversity assets typically associated with a particular habitat type by the Habitats Directive, particularly so where poor site conditions and legacies are likely to determine rather unpredictable vegetation dynamic paths (Foster et al. 2003). Recent studies (Chiarucci et al. 2010, Loidi & Fernández-González 2012) warned against the difficulties of literally adhering to the concept of potential natural vegetation for conservation purposes. In addition, Garadnai et al. (2010) in their forest patch scale study, corroborated by other studies (Bartha et al. 2008), have shown that actively managed beech coppices host a wider pool of vascular plants than abandoned coppices. This is consistent with the findings of Tellini Florenzano et al. (2012) who showed that, although richness in forest bird species is positively related to stand age for both coppice and young growth, the forest specialists did not seem to be negatively influenced by the amount of open spaces.

According to the Convention on Biological Diversity, old-growth forest conditions can indeed occur in both ancient and secondary forests. However, such conditions take place at the forest stand scale and are relatively transitory within the stand dynamic, as they correspond to just one of the possible later stages of stand development, as described by different classification schemes (Bormann & Likens 1979, Leibundgut 1981, Oliver & Larson 1990, Carey

& Curtis 1996, Spies & Franklin 1996, Franklin et al. 2002). Besides leading to a convergence in forest structure, the high forest strategy, much as coppice abandonment, might lead to a dominance, at the landscape level, of senescent woodlands and the loss of the earlier successional stages of forest ecosystems. Heterogeneity of forest stand development stages, including coppice woodlands, at different ecosystem organisation levels, has been advocated for many years in connection with the maintenance of high levels of beta-diversity (Hunter 1990, Buckley 1992, Fuller & Warren 1993, Mairota et al. 2006, Chiarucci et al. 2008, Garadnai et al. 2010, Kopecký et al. 2013, Buckley & Mills 2015).

Concluding remarks

Socio-economic and especially cultural factors affected SMP strategies and attitudes towards coppicing. Active coppicing had virtually ceased or was expected to cease in many SCIs/SACs, partly owing to the absence of ready markets for coppice products, to which managers have responded to by advocating conversion and non-intervention as the most feasible conservation strategies. Yet, demand for wood for energy is expected to increase in the period to 2020 (Mantau et al. 2010, UNECE-FAO 2011), in response to the EU Renewable Energy Directive 2009/28/EC. Therefore, a balanced forest management (combining coppice, high forest and non-intervention, as most appropriate to specific forest habitats and site conditions) at the stand/landscape level could revitalise local economies. This would ensure compliance with the Framework Program for the Forestry Sector - Horizon 2020 and improve transparency of woodfuel flows in agreement with the EU 995/2010 Timber Regulation, while being beneficial to achieve a specific habitat conservation status (as defined by the Habitats Directive and described by the European Commission's Interpretation manual). There are no studies to demonstrate conclusively that high forest or "wilderness" (European Commission 2013a) approaches alone best achieve "favourable conservation status" or indeed the specific biodiversity aims for the majority of forest habitats in SCI/SACs. In some forest types this may be true, although a number of studies now indicate that active coppice management can improve forest biodiversity at both a local and landscape level.

Acknowledgements

This study was carried out as a task of the Working Group 4 "Services, protection, nature conservation" of the FPS COST Action FP1301 "Innovative management and multifunctional utilization of traditional coppice forests - an answer to future ecological, economic and social challenges in the European forestry sector" (EuroCoppice). We thank two anonymous reviewers and Jenny J. Mills for their critical comments, which greatly improved the original manuscript. Authors order follows a modified Sequence Determines Credit criterion (Tscharntke et al. 2007): whole credit to 1st and 2nd authors, half credit to 3rd author, one third credit to 4th author, credit equally divided by the number of authors for 5th -9th authors.

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Supplementary Material

Box S1 - Links to public databases.

Tab. S1 - Questionnaire.

Tab. S2 - Explanation of abbreviations used in the text.

Fig. S1 - Comparison of the distribution of all forest habitat types, forest habitat types with potential for coppice (FHT_WPC), and forest habitat types currently or formerly coppiced (FHT_C), by broad Annex I forest categories.

Fig. S2 - Distribution of forest habitat types by Annex I broad forest categories among the examined countries.

Fig. S3 - Number of forest habitat types currently or formerly coppiced (FHT_C) by conservation status in different biogeographical regions represented by the questionnaire.

Link: Mairota_1867@suppl001.pdf