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Review

Habitat management alternatives for conservation forests in the temperate zone: Review, synthesis, and implications

Frank Götmark *

Department of Biological and Environmental Sciences, University of Gothenburg, Box 463, SE40530 Göteborg, Sweden

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ABSTRACT

Temperate forests with high values for biological conservation, including old-growth and mid-aged (>50 years) semi-natural forests, cover large areas. Many of the forests are protected, and the protected area is expected to increase. The protection efforts need to be supported by research about habitat management. I reviewed >2000 studies of such forests, selecting 150 studies dealing with trees, bushes and forest structure. Of these, 59% gave no recommendation for management; the forest was used as ecological baseline. Minimal intervention was recommended in 8% of the studies. In the remaining studies (33%), active management of many types was proposed. Based on the review and the literature, I suggest four habitat management alternatives: (1) *Minimal intervention*, the most common form of management, usually allows continued succession and disturbances in the forests. They should develop as old-growth and act as ecological baselines. (2) *Traditional management*, based on historical reference, is used to create other forest structures that favour biodiversity (e.g. red-listed taxa) related to past cultural landscapes. (3) *Non-traditional management* is an action to produce old-growth characteristics or specific forest composition, or to favour one or a few tree species which may or may not have been abundant in the past. (4) *Species management*, for threatened, indicator and other species, and rewilding, is based on one or a small set of species that is valuable or can shape the forest (rewilding may be included in alternative 1, but emphasizes large predators). Depending on forest size and objectives, combinations of these management types may be used. If the concept of ecological restoration is used, which assumes one "best" forest habitat, researchers risk overlooking the importance of evaluating all the alternatives 1–4. There is often not only one correct habitat option for conservation forests. Many more studies of the management alternatives are needed, particularly long-term experiments. In addition, management plans, decisions, and actions in practical management of conservation forests need to be studied, to clarify choices and present conditions.

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* Tel.: +46 317863650; fax: +46 31416729.
E-mail address: frank.gotmark@gu.se

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"There is thus surprisingly litte information about the effects of conservation activity." (Rackham, 2006, p. 512)

"...although science and history may inform management, the ultimate driver of policy is human values and perceptions." (Foster et al., 2003, p. 85)

"And those experts who make the strongest arguments, even if wrong, tend to be the most influential..." (Doak et al., 2008, p. 958).

1. Introduction

1.1. Background and aims

The area of protected forest is steadily growing (Chape et al., 2008; Schmitt et al., 2009). With new goals from Nagoya (UNEP, 2010), within 10–20 years some 15–20% of the temperate forest might be protected to secure biodiversity. To date, forest conservation research has been dominated by the efforts to protect forest (Schmitt et al., 2009), the design and improvement of reserve systems (Margules and Sarkar, 2007) and the modification of forestry to favour biodiversity (Lindenmayer and Franklin, 2003; Gustafsson et al., 2012). In the future, research about ecosystem and habitat management (Ausden, 2007; Hobbs and Cramer, 2008) will become increasingly important for forests with planned and existing protection.

Natural forests have been used for research on ecology and paleoecology (e.g. Peterken, 2001; Grenier et al., 2005; Faison et al., 2006). Simultaneously, there has been increased interest in re-instating traditional management methods in forests (Wallis de Vries, 1998; Egan and Howell, 2001; Ausden, 2007). In addition, the introduction of large herbivores and predators into areas where they are absent is one (debated) alternative (Soulé, 2003; Caro, 2007). But field experiments in forests to evaluate management alternatives are rare and the subject lacks a broad review. In systematic conservation planning (Margules and Pressey, 2000), "implement management action" and monitoring are the last two steps in the planning. Thus, habitat management generally comes after forest protection and reserve selection procedures, and the management largely remains to be developed (cf. Margules and Sarkar, 2007).

The percentage of protected area is generally higher for tropical forest types (9–26%) than for temperate forest types (6–13%, Schmitt et al., 2009%). Two of the four most disturbed (converted) biomes in the world are temperate ones (Hoekstra et al., 2005; see also Sanderson et al., 2002). Only 2–3% of the total area of large intact forest ecosystems (that potentially can maintain all or much of their biodiversity) occurred in the temperate broadleaf zone (Bryant et al., 1997; Potapov, 2008). Despite the threats in tropical and boreal zones, these areas retain a much higher total area of natural or semi-natural forest (Hoekstra et al., 2005; MEA, 2005).

Data on global forests also reveal other trends. During the period 1990–2000 forest cover decreased in the tropics, but increased in temperate and boreal zones (MEA, 2005, p. 597). In many temperate countries or regions, the forest area and standing volume have increased for many decades (Lindenmayer and Franklin, 2003; Nagaike et al., 2005; Tak et al., 2007; Lunt et al., 2010; Sitzia et al., 2010; Gowda et al., 2012), either through natural succession or reforestation. Forest regrows in old, marginal agricultural areas with conservation values, leading to discussions about alternative options in management (Foster, 2000; Sitzia et al., 2010).

Forests with conservation values in the temperate zone include old forest in national parks and reserves (e.g. Parviainen et al., 2000), abandoned land with naturally regenerating forests (Balandier et al., 2005; Nagaike et al., 2005; Lunt et al., 2006), and small forest sites with potentially high biodiversity values, such as woodland key habitats (Timonen et al., 2010), ancient woodlands (Kirby, 2003) and indigenous forest remnants (Dymond et al., 2007). Many mid- and late-successional forests derive from historical land uses such as woodland pasture, coppice woodland, savanna, or more recently abandoned fields and pastures (Foster and Aber, 2004; Lunt et al., 2006; Rackham, 2006; Szabo, 2010). Compared to boreal forests, temperate forests are richer in tree and shrub species (Latham and Ricklefs, 1993; Williams and Woinarski, 1997), creating more variation and more complex successional patterns (cf. Pollock and Payette, 2010).

Below I review literature about management in conservation forests. One hypothesis was that it might be appropriate to identify and classify alternative forms of habitat management. The terms and concepts used are defined in Table 1. Two concepts, succession and natural disturbances, form the background of many management decisions and are described in the next section. I then review the scientific literature, with a focus on forest structure and trees, the fundamental components often subjected to management. A synthesis with four suggested management alternatives follows, and finally the implications and future research needs.

My focus is conservation forests (Table 1) and biodiversity. Note that the management is influenced also by social and aesthetic values, not discussed here (in practice, these values may be more important than the alternatives reviewed here – see, e.g. Orians, 1986; Runte, 1987; Aagesen, 2000; Foster, 2000; Milton, 2002; Foster et al., 2003; Harmon and Putney, 2003; Fazey et al., 2005; Keiter, 2010; Nielsen, 2013; and discussion in Desjardins, 2006).

1.2. Two relevant concepts in forest ecology

The professional life of ecologists and managers (30–40 years) is much shorter than the development of a forest and the life span of most trees. Therefore, caution is needed in decisions. I argue that two concepts must be considered in combination; *natural disturbances* and *succession*. Ecologists often use or refer to these concepts in advice to managers.

Forests experience more or less dramatic natural disturbances that kill or fell dominant trees, create dead wood and more open stand conditions that initiate regeneration among herbs, shrubs and trees (Peterken, 2001; Kimmins, 2004; Gilliam, 2007; Stokland et al., 2012). In turn, herbivorous and saproxylic organisms, such as insects, are favoured (Grove, 2002; Bouget and Duelli, 2004). Disturbances create new niches for many species, but some shrubs and trees survive in the 'persistence niche' by sprouting (Bond and Midgley, 2001). Important disturbances are windstorms, fires, flooding, drought, extreme cold, tree damages caused by large mammals, fungi or insects, landslides, avalanches, earthquakes, vulcanic eruptions, and asteroid collisions (e.g., Pickett and White, 1985; Abrams, 1992; Attiwill, 1994; Pontailler et al., 1997; Allen et al., 1999; Lorimer and White, 2003; Gu et al., 2008).

Table 1
Definition of terms and concepts used in the text.

Conservation forest	Forest with ecological and social conservation values, protected or considered for protection, and not used for or little used for harvest[a]
Old-growth forest	Forest 100–150 years old or more, with a natural or semi-natural structure[b]
Temperate forest	Temperate broadleaf and mixed forest, and temperate coniferous forest[c]
Habitat management	Management of the habitats in conservation forests for ecological values (biodiversity), with four proposed alternatives in the synthesis, including minimal intervention[d]
Active management	Manipulation/treatment of habitats and/or species
Non-intervention	No influence or physical change of the habitat(s) by managers, and human visits forbidden[e]
Minimal intervention	Human influence and change of the habitats is minimized, to low level[f]
Restoration (Ecological restoration)	Management that seeks to reach a preferred state of forest structure related to e.g. history or ecological function, often contrasted with a degraded state[g]

[a] As a general rule, the forests should have trees more than 50 years old, but there are many exceptions that contain conservation values (e.g. a forest where all or most trees died naturally, or productive forests ca. 35–50 years old, with high diversity of trees or other species). Set-aside forests where the owners cannot or do not want to cut trees are included (e.g. Ask and Carlsson, 2000), but urban parks managed mainly for recreation excluded.
[b] References to alternative definitions and discussion: Kimmins (2004) and Lindenmayer (2009), see also Hunter and White (1997).
[c] Based on the global classification in Olson et al. (2001), including large areas in western and eastern North America, Europe and western Russia, eastern Asia, and parts of southern South America, Australia, and New Zealand (Röhrig and Ulrich, 1991; Nakashizuka and Iida, 1995; Kimmins, 2004; DellaSala, 2011; and TerraNorte RLC land cover map, see arc.iki.rssi.ru/eng/2011investig.htm). In some cases, I included studies that classified the forest as temperate (e.g. based on climate) even if it was located outside the temperate zones of Olson et al. (2001). Several such cases concerned forests at higher altitudes.
[d] Management in other contexts includes administrative functions such as leadership, planning, organization, and control of effectiveness, but these are not dealt with here (see Dearden and Rollins, 2009; Lertzman, 2009, and reviews in Lockwood et al., 2006; Chape et al., 2008).
[e] Non-intervention is difficult or almost impossible to achieve (Kareiva et al., 2007) and might be reserved for e.g. sacred sites (Pungetti et al., 2012).
[f] Minimal intervention is considered more realistic than non-intervention and the concept should facilitate discussions about management of conservation forests (see, e.g. White and Bratton, 1980, p. 252; Safriel, 1997; and Ausden, 2007, p. 25).
[g] See for instance Stanturf and Madsen, 2005; Prach et al., 2007; Roberts et al., 2009.

Some regions and landscapes seem to experience more natural disturbances than others. Few detailed studies have compared forests and regions in this respect (but see Peters, 1997). Two studies reviewed disturbances within large regions, with obvious differences among landscapes (Nakashizuka and Iida, 1995; Lorimer and White, 2003). Possibly, forests in eastern North America experience more natural disturbances than other temperate forests, due to hurricanes, tornados, and ice storms (but see Schelhaas et al., 2003).

Humans caused many of the historical and pre-historical fires in temperate forest landscapes (see Section 3.2) and thus it is difficult to separate natural and cultural fire regimes. Also, human-induced climate change may increase storm rates (Young et al., 2011). In western and northern Europe, storms are the major disturbance in semi-natural forests (e.g. Pontailler et al., 1997; Peterken, 2001; Schelhaas et al., 2003; Nilsson et al., 2004; Firm et al., 2008). Strong storms are also recorded in north-east Asia (Abe et al., 1995; Nakashizuka and Iida, 1995) and New Zealand (Martin and Ogden, 2006). Tree species differ in sensitivity to storms, and some stands are protected (Holeksa et al., 2009); therefore, depending on tree species and stand, disturbance intervals vary widely. We should not forget that humans cause most of the disturbances by cutting trees for wood production, and by harvesting directly after natural disturbances (Schelhaas et al., 2003; Lindenmayer et al., 2008). Cutting/felling disturbances vary much among temperate countries (Lindenmayer and Franklin, 2003; Stanturf and Madsen, 2005), and one should recognize cultural as well as natural disturbance regimes.

In forest conservation science, the study of natural disturbances has been an active field during the past 25 years. Succession, or directional change in forest communities over time, is an equally important process (Peterken, 2001; Kimmins, 2004) but it has received less attention during this period (for succession and restoration in more open habitats, see Prach et al., 2007). Forest succession is slow and less visible than disturbances, which are dramatic and attract attention. Herein lies a danger: when a branch of ecology such as the study of natural disturbances increases strongly in popularity, it might come to dominate management thinking, unless ecologists are trained to grasp complexity and long time scales.

Succession depends on and interacts with disturbances, and it produces patterns or stages in stand development, such as stand initiation, 'self-thinning' of larger trees, and old-growth (Oliver and Larsson, 1990; Kimmins, 2004). Trees such as *Quercus*, *Tilia*, *Pinus*, *Eucalyptus*, and *Nothofagus* can reach ages of 300–1000 years, so we need studies spanning long time periods to understand succession and disturbance. Unfortunately, there are few studies of very old forests – unique in this respect in the European lowlands are the stands la Tillaie and le Gros Fouteau in Fontainebleau (France), where no or little cutting has been done since 1372 (Koop, 1989; Pontailler et al., 1997; Mountford, 2002).

The present emphasis on natural disturbance regimes came from ecologists in the USA (see Sousa, 1984; Peterken, 2001; and references therein). Note that succession re-created forest on much of the agricultural land that was abandoned in the mid-western and eastern parts of the US (White and Mladenoff, 1994; Foster and Aber, 2004). In Sweden, large-scale increases in the area of early successional forest occurred about 500–600 AD, 1300–1400 AD, and 1900–2000 AD, in all cases due to decreased human land use (Lagerås, 2007). Disturbances to trees and forests may be easy to observe only when most of the forest has returned and has grown tall and old (Schelhaas et al., 2003).

Because we have few long-term forest studies, and even fewer long-term experiments (Turner et al., 2003), researchers use mathematical modelling to clarify ecological processes, mechanisms, and management (e.g. Loehle, 2000; Bugmann and Solomon, 2000; Choi et al., 2007; Didion et al., 2009). Long-term predictions from the models should be treated cautiously (Kimmins, 2004). Several studies underline the unpredictable nature of stand development and forest structure (Peterken and Jones, 1987, 1989; Williams, 2003; von Oheimb and Brunet, 2007; Hahn and Emborg, 2007; Doak et al., 2008).

Much work has been done on gap-phase dynamics, that is, when canopies in old-growth forests open up late in the successional sequence when trees die (review in Peterken, 2001). Other aspects of long-term forest succession remain unstudied, partly because there are few very old forests. For instance, Nock et al. (2008) quantified fascinating and predictable light changes at ground level below growing trees. The old idea of a single late-successional climax stage is often rejected, but the textbooks explain how the climax hypothesis was developed into e.g. *climax patterns*, in which the structure of old forests varies spatially (Kimmins, 2004; Krebs, 2009).

2. Review: scientific studies in temperate conservation forests

2.1. Objectives and methods

My focus was on research directly relevant to the practical management of conservation forests. Literature that fulfilled all of the following three criteria/categories was selected for the review: (1) empirical ecological studies published 1991–2010; (2) conservation forests in the temperate zone, as defined in Tables 1; and (3) studies of forest structure, trees and bushes. Trees are fundamental for management decisions in forest, since they may be cut or otherwise affected by e.g. animals and disturbances, in turn influencing canopy openness and forest structure.

I excluded studies from university-owned or university-leased experimental forests, set aside only for research. Ecologists studying such forests do not need to interact in the same way with managers and stakeholders, and these studies would have weaker link to practical management. I also excluded reviews, meta-analyses, and studies of sustainable forestry where production was also an important objective; examples of such excluded studies are Decocq et al. (2004) and Nitschke (2005). On the other hand, for example the comparison by Banner and Lepage (2008) of old-growth with second growth stands was included.

I asked the following questions: (1) For what purpose(s) did the ecologists study the forest? (2) What did they study and how did they design their studies? and (3) What recommendation(s), if any, were stated? I used the database ISI Web of Science to search for literature published 1991–2010. I made six literature searches 22 January–7 February 2011, using the following search terms (with "AND" between terms):

(1) protected area, management, forest (538 publications),
(2) temperate, forest, management, conservation (263),
(3) old-growth, temperate, management (120),
(4) restoration, forest, temperate, management (73),
(5) park, ecosystem management (127),
(6) traditional, forest, biodiversity (449).

Overall, 1500 listed publications of potential interest were checked, with the overlap between pairs of searches being less than ca. 10%. Only 17% (262) of the listed publications were from the first 10 years (1991–2000), and 83% from 2001 to 2010, showing the strong growth of this literature. The files are saved in Web of Science format and can be obtained online as Supplementary material (Table A1).

For a test of whether relevant articles published 1991–2010 were overlooked in the database search, I searched in my own literature collected during 15+ years from leading journals in forest science (e.g. *Forest Ecology and Management*, *Canadian Journal of Forest Research*), conservation science (e.g. *Biological Conservation*, *Conservation Biology*), and from many books and other scientific journals (e.g. *Nature*, *Science*).

Many studies listed in the Web of Science searches did not meet my criteria. In total, 84 publications were selected. From my own collection of literature, I selected 86 publications based on the same criteria. The overlap between the two searches was 20 publications, reducing the Web of Science search to 64 publications. Thus, it seems easy to miss many relevant papers in reviews that are based only on Internet databases, if the investigator has little prior experience of the subject and the literature. The 86 + 64 publications were pooled for the review ($n = 150$). The literature references, sorted and summarized, can be obtained online as Supplementary material (Table A2), and the 86 and 64 publications are kept separate there.

2.2. Results

Of the 150 publications, 46% were studies from broadleaf (angiosperm) forests, 46% from mixed broadleaf–coniferous forests, and 8% from coniferous forests. Studies from Europe (49%) and North America (38%) dominated; relatively few studies were from Australia/New Zeeland (6%), Eastern Asia (3.3%) and South America (2.6%). Obviously, there is a large geographical bias; for instance, large areas of temperate forest in Russia were not represented.

The purposes of the studies were (1) basic forest ecology only (38%), (2) combined basic forest ecology and active conservation management (32%), and (3) active management only or mainly (30%, $n = 150$), in North America often referred to as ecosystem management. From 1991, there has been increasing interest in active management: for the period 1991–2000, 45% of the studies addressed the purposes 2–3 above, and 2001–2010 69% of the studies did so, which means that 31% of them concerned basic ecology only in 2001–2010. Before 1990 in the US, the interest in active management seemed to be very low (see Nowacki and Trianosky, 1993).

Forest structural aspects (short time scale) was one main subject in the literature (38%, $n = 150$), another main focus was succession and stand/tree development (38%, e.g. studies of stands of different ages). Less commonly the empirical studies focused on (natural) disturbances (15%), paleoecology and history (7%) and climate/carbon (2%, $n = 150$). (Note that many articles on the subject of natural disturbances and conservation have been conceptual, not empirical.)

Most studies (74%, $n = 150$) were descriptive, often dealing with single forest sites; 16% were comparisons of forest types or states (e.g. younger vs. old-growth forests, burned vs. unburned forests, grazed vs. ungrazed); and 10 (7%) were experimental studies with treatment and control plots.

Nearly half (47%, $n = 150$) of the studies did not recommend any particular management for the conservation forests (Table 2). In 12% of the studies, alternative options were only briefly discussed, without any specific recommendation. Minimal intervention, or removal of negative (human) disturbances, was recommended in 8% of the studies. In the remaining studies (33%), active management was proposed (see Table 2).

I classified the active management suggested into four categories. The first and predominant category concerned desired tree and stand structure, including dead wood (D1-4 in Table 2). The second category was the use of fire to control vegetation/trees (D5) and the third category (D6-7) was related to keystone species, for example, the browsing pressure of herbivores was suggested to be controlled through large predators. The fourth category (D8-9) was based on former land use and historical baselines. Finally, D10 combined several alternatives. Based on these results and the literature (and own judgements) I outline and suggest four management alternatives for temperate conservation forests. The first and second category above can fall into several management alternatives (see below).

3. Synthesis: four major management alternatives

3.1. Minimal intervention

This is probably the most common approach to the management of conservation forests in the temperate zone (and elsewhere). Minimal intervention includes IUCN's categories Ib ("Wilderness area, protected area managed mainly for wilderness protection"), II ("National park, protected area managed mainly for ecosystem

Table 2
Specification of management of forest structure/woody vegetation in 150 empirical studies of conservation forests.

Recommended management	% of studies (n = 150)	No. of studies
A. Not specified	47	
B. Minimal intervention proposed (or "control/remove disturbances")	8	
C. Alternatives discussed, no proposal	12	
D. Active management, proposed	33 (n = 49)	
1. *Specification of tree and stand structure, including dead wood*		
(D1) Detailed specification of desired stand type		9
(D2) Favour a (given) tree species		11
(D3) Favour old-growth (thinning/openings/dead wood)		5
(D4) Create dead wood		3
2. *Use of fire to control vegetation/trees*		
(D5) Use fire, or fire may be used		5
3. *Control through keystone species*		
(D6) Control herbivore damages		1
(D7) Top-down control through large predators		2
4. *Use historical evidence as baseline*		
(D8) Grazing specification/mowing		4
(D9) Management based on historical baseline		2
5. *Combine several alternatives*		
(D10) Combine management alternatives, active ones or active + mimimal intervention		7
Sum		49

Note: Supplementary file available online (Table A2).

protection and recreation") and III ("Natural monument, protected area managed mainly for conservation of specific natural feature") (Chape et al., 2008). If scientific research is the main or only activity, IUCN's category Ia ("Strict nature reserve, protected area managed mainly for science") is applicable; also applicable is core area in Biosphere Reserves (Parviainen et al., 2000; Chape et al., 2008). Minimal intervention is referred to as spontaneous rewilding by Feldman (2010). Here I put rewilding under species management, as researchers describing rewilding strongly emphasize a few species (large mammals), see Section 3.4.

There are at least three ecological reasons for minimal intervention in conservation forests. First, old-growth forests are rare in many regions, and forests that exceed ages of about 250 years are extremely rare in the temperate zone. Several tree species can become much older than 250 years. Second, old-growth forests with their associated processes favour many taxa (Hunter, 1999; Moning and Müller, 2009; Landres, 2010; Paillet et al., 2010). Third, forests under minimal intervention serve as references for direct human impact, including forestry and other land use, and active management (Arcese and Sinclair, 1997).

Table 3
Biodiversity response to partial cutting (conservation thinning) of mixed oak-rich forest with initially closed canopy. Based on 25 sites, studied 2–5 years in southern Sweden, with cutting and undisturbed reference plots at each site, studied before and after treatment.

Positive effect, treatment vs. reference	No response/small difference, treatment vs. reference	Negative effect, treatment vs. reference
Effect of treatment (partial cutting/thinning)		
+Small oaks (<2 m tall)[a]	Ascomycetes (fungi) on fine dead wood (1–10 cm)[h]	– Basidiomycetes (fungi) on dead wood[h]
+Large oaks (>30 cm DBH)[b]		
+Forbs and grasses[c]	Fungi on downed oaks[i]	– Snails and slugs[k]
+Mosses on ground[d]	Fungus gnats (Mycetophilids)[j]	(– Red-listed fungi on dead wood)[h]
+Lichens on dead wood[e]	Mosses on dead wood[e]	
+Lichens on large oaks[f]	Red-listed saproxylic oak beetles[g]	(– Less dead wood, in long-term)[l]
+Saproxylic oak beetles[g]		
+Herbivorous beetles[g]		
+(Red-listed lichens on large oaks)[f]		

Plus and minus refer to increased and decreased species richness, respectively, for treatment relative to reference plots; for oak, plus refers to increased regeneration/growth. "Effect" means statistically significant, but parentheses indicate marginally significant effect. Based on surveys 2001–2009, after cutting in the winter of 2002/2003. References.
[a] Götmark (2007).
[b] Götmark (2009).
[c] Götmark et al. (2005).
[d] Paltto (2009).
[e] Paltto et al. (2008).
[f] Nordén et al. (2012).
[g] Franc and Götmark (2008).
[h] Nordén et al. (2008).
[i] Nordén and Götmark (2008).
[j] Økland et al. (2008).
[k] Rancka (2013).
[l] Not measured, only predicted (dead wood data from before cutting in Nordén et al. (2004)).

Minimal intervention areas set up for research and monitoring (other use limited, or prohibited) are not common; one example is the Russian system of Zapovednik (Shtilmark, 2003). Arcese and Sinclair (1997) argued "for managing a representative number of protected areas as ecological baseline controls to help in understanding the effects of humans worldwide" (see also Sinclair, 1998). They outlined four consequences for such areas: (1) no effort to maintain status quo, (2) minimal intervention with respect to natural processes, (3) monitoring within and outside the area, and (4) if active management must be used, it should only be carried out on part of the system. This fourth principle should, in my view, form the basis of experimental studies of the management alternatives: *when we have controls (references) with minimal intervention, combined with treatment (alternative, active management), we will faster gain reliable, useful knowledge for management*.

McKinney and Lockwood (1999) warned that biotic homogenization (replacement of local biotas with non-indigenous species, usually introduced by humans) can be a serious threat. In many forest reserves, managers attempt to eliminate or control exotic species considered as damaging to local forest biodiversity. Invasive, non-native species include many plants, e.g. shade-tolerant shrubs like *Rhamnus cathartica* in parts of the eastern US (Martin et al., 2009; Schulte et al., 2011), introduced conifers in south America (Pauchard et al., 2010), invertebrates such as slugs (Brunet and von Oheimb, 2008), and mammals (Coomes et al., 2003). Control of invasive and non-native species is under debate (Davis et al., 2011), but may occur under all management alternatives.

Long-term studies of minimal intervention are rare, but valuable: see Appendix A, Example Section 1 for such studies – selected to show approaches in different countries. Sinclair (1998) states that former "presence or absence of pre-historic humans is not relevant" to the objective of using minimal intervention as ecological baseline control in protected areas, which leads us to the next management alternative.

3.2. Traditional management

This is management based on historical, archeological, and paleoecological evidence, seeking to produce or maintain forest conditions that existed before modern agriculture and forestry converted the temperate landscapes. Traditional management is based on specific historic or pre-historic information on forest habitat types and former management (e.g. Clark, 1990; Rackham, 1998, 2006; Kirby and Watkins, 1998; Pykälä, 2000; Egan and Howell, 2001; Peterken, 2001 p. 318; Honnay et al., 2004; Parrotta and Agnoletti, 2007 and papers in the same issue). Before modern agriculture and forestry, much of the temperate forest had a mixture of habitat types and semi-open structure, and was used for traditional agriculture: slash-and-burn crop systems, coppice woodland, satoyama (Appendix A, Example Section 2), tree pollarding, woodland pastures, and savanna are examples (e.g., Norton, 2003; Takeuchi et al., 2003; Foster and Aber, 2004; Lagerås, 2007; Rackham, 2006; Bobrovskii, 2010).

Several components in traditional management have direct links to the modern concept of natural disturbance regimes (Pykälä, 2000). First, grazing and browsing domestic animals are potentially capable of keeping the forests semi-open (Bergmeier et al., 2010). In North America, the role and usefulness of domestic animals in ecosystems is often debated, which is rarely the case in Europe (reviews in Mitchell and Kirby, 1990; Wallis de Vries, 1998; see also Fried and Huntsinger, 1998). Second, manipulation of tree cover and trees (e.g. coppice, pollarding, forms of selective cutting) influences floristic and habitat conditions (Rackham, 2006). Third, periodical use of fire kills some trees and favours grass (crops or pasture). Although forest fires are an important part of natural disturbance regimes, studies of fire history seem to suggest that humans caused the majority of the historical and pre-historical forest fires (e.g. Bowman, 1998; Williams, 2003; McDadi and Hebda, 2008; Lorimer et al., 2009; Pausas and Keeley, 2009; Bjorkman and Vellend, 2010; Bobrovskii, 2010; Niklasson et al., 2010; Olsson et al., 2010). Therefore, use of fire can be traditional management, if specified as such. However, prescribed fire, recommended for some regions of the USA for instance, may also be non-traditional management (see Section 3.3). Prescribed fire is usually a form of fuel reduction treatment, related to the fire hazards in forests with high tree volume and dead wood levels (e.g. Franklin, 2003; Wuerthner, 2006).

Much temperate forest occurs in affluent countries, where agrotechnological change has meant that traditional forms of management have largely disappeared. Managed wooded hay meadows (Kull and Zobel, 1991; Myklestad and Saetersdal, 2003), low-intensity indigenous management (Trosper, 2007) and satoyamas (Takeuchi et al., 2003; Berglund, 2008), occur only in scattered, small habitat fragments. By contrast equivalent systems may still occur in other vegetation zones in less affluent countries (e.g. Berkes et al., 2000; Shahabuddin and Rao, 2010).

There are at least three ecological reasons for traditional management in conservation forests. First, many species that occur in these human-created habitats are threatened (red-listed) due to lack of suitable habitat, and may need active management (Ausden, 2007; Bjorkman and Vellend, 2010; Gärdenfors, 2010; Prevosto et al., 2011). Second, many second-growth temperate forests have more-or-less closed canopies (although this is not well quantified). Partial opening of such canopies will favour light-demanding species at ground level and regeneration of shade-intolerant herbs and trees, if grazing and browsing levels are controlled. Third, traditional management in conservation forests should increase heterogeneity of forest habitat types, and different forms of land use may be incorporated in management of an area or property (Lindbladh et al., 2007; see also Section 3.5).

Emulation of former land use on abandoned, presently tree-covered areas is a complex challenge (e.g. Rotherham, 2007). Initially, trees will be cut and probably mostly harvested, which might be controversial. For temperate forest, there are few relevant experimental or semi-experimental studies, but there may be many undescribed practical examples. Studies of grazing systems of a semi-traditional type (forms of low-intensity agriculture, that tend to disappear) show that preservation of intermediate tree cover or groves in pastures increases forage yield and biodiversity in the form of native species (Le Brocque et al., 2009; Sánchez-Jardón et al., 2010, and references therein). Such results are important for sustainable land use, landscape aesthetics, and ecotourism.

Paleoecology can reveal former vegetation types at site and landscape level, and thereby "can inform our understanding of the appropriate range" of variation (Bradshaw, 2005, p. 28). Molinari et al. (2005) studied vegetation changes in an old-growth *Picea* forest over 9000 years, suggesting that "re-introduction of a suite of deciduous tree species can be biologically justified". These trees disappeared partly due to humans; however, former humans have also had a positive influence (see Molinari et al., 2005). Studies like this one reveal conditions that existed from several hundred up to several thousand years ago, but a detailed reference far back in time that could guide current management may be difficult to obtain. The efforts may still be worthwhile however, especially if combined with research in history, archeology and ecology (e.g. dendrochronology). For studies of traditional management in different countries, see Appendix A, Example Section 2.

3.3. Non-traditional management

This is active management of conservation forests for development towards old-growth characteristics, desirable forest structure, or tree species that favour biodiversity (Coates and Burton, 1997; Singer and Lorimer, 1997; Peterken, 2001; Keeton, 2006; Ausden, 2007; Götmark, 2007, 2009; and papers in Stanturf and Madsen, 2005). Peterken (2001, p. 318) labels this alternative "designed management". Under this form of management, no historic or pre-historic state of the forest needs to be specified or acknowledged. Several of the authors consider combined conservation management and low-intensity silviculture (i.e. harvest at low levels, but cut trees may also be left as dead wood to improve conditions for saproxylic organisms, if there is shortage of dead wood).

There are at least three ecological reasons for non-traditional management in conservation forests. First, it is flexible and not bound by minimal intervention or historical reference. Managers may justify actions on the basis of many factors and concepts, such as threat, rarity of habitat type, and emerging concepts such as ecological integrity (Callicott et al., 1999; Dearden and Rollins, 2009, p. 85, 114) and functional diversity (Cadotte et al., 2011; Davis et al., 2011). Second, non-traditional management can create old-growth structure faster than is normally possible under continued succession in second-growth even-aged forests. For instance, crown release (cutting of certain canopy trees to improve growth in others) creates large trees faster and allows regeneration in gaps (Singer and Lorimer, 1997). Third, certain tree species such as oaks *Quercus* spp. that are important for associated wildlife (Ranius and Jansson, 2000; Abrams, 2003; Spector and Putz, 2006; Ohsawa, 2007) may be favoured by e.g. partial cutting or other conservation actions (Devine and Harrington, 2006; Götmark, 2007, 2009; Brudvig et al., 2011). Many actions that could favour forest biodiversity are possible, especially in mixed closed-canopy stands in the age span of about 50–100 years (somewhat younger stands/forests may also be used). In mid-aged closed-canopy stands, light is usually a limiting factor for herbs and other ground-living taxa, and they may be favoured by selective killing (e.g. girdling or felling) of canopy trees to produce dead wood and light. Introduction of beneficial species is dealt with in our next alternative (Section 3.4).

For studies of non-traditional management in different countries, see Appendix A, Example Section 3. The Swedish Oak Project may be the only well-replicated BACI (Before–After-Control-Impact) field experiment of non-traditional management in temperate forest. It started in 2000 and is planned to be long-term (Example Section 3). Results from this project, based on seven organism groups, are summarized in Table 3.

3.4. Species management

This is management of conservation forests mainly based upon one or a few species, or a certain (small) set of species, that may be threatened, keystone, umbrella, flagship or otherwise of high conservation value (Caro, 2010). I also consider rewilding as species management, as it emphasizes introduction and the regulatory role of a few large mammalian predators, and the role of large herbivores (megaherbivores) in large tracts of 'wild' land (Martin and Klein, 1984; Vera, 2000; Willers, 2002; Donlan et al., 2005; Caro, 2007; Soulé, 2003, 2010). To judge from Peterken (2001, e.g. p. 284) and own experiences (pers. obs.), forest reserves created for one, a few or a small set of species (except trees) are rare.

There are at least two ecological reasons for species management in conservation forests. First, if the extinction risk is high for a forest species that is judged as especially valuable and for which we have good knowledge, specific management action for that species and its habitats should be justified. This point should also include threatened species that are specialists with respect to (micro)habitat. Second, if a keystone species (low abundance in a community, but disproportionately strong influence on the ecosystem) can control overabundant species or improve the ecological function of a forest, it may be favoured, re-established or introduced (McLaren and Peterson, 1994; Soulé, 2003; Kauffman et al., 2010).

Species management has been successfully tested for highly endangered species, such as snakes (Pike et al., 2011). In Sweden, the white-backed woodpecker (*Dendrocopus leucotos*) is red-listed at the highest threat level, and several actors protect and actively manage forests to preserve this species, which is also an umbrella and indicator species (Roberge et al., 2008a,b) and a flagship species (attracts attention and funding). In north-western USA, the legally protected northern spotted owl (*Strix occidentalis caurina*) triggered a conservation plan for large forest areas (Thomas et al., 2006; Gosselin, 2009), with minimal intervention in this case.

Large herbivores might be keystones in keeping temperate forests semi-open, in turn favouring trees and shrubs such as *Quercus* and *Corylus* (Vera, 2000). However, Vera's forest model for the Holocene is debated, and he did not consider alternative explanations (e.g. interpretations of pollen diagrams, role of predators, fire, windstorms, flooding; see Svenning, 2002; Bradshaw, 2002, 2004; Mitchell, 2005; van Vuure, 2005; Faison et al., 2006; Rackham, 2006). Large predators can strongly influence forest ecosystems. In Yellowstone national park, elk (*Cervus elaphus*) numbers increased when wolves (*Canis lupus*) were exterminated in the early twentieth century, leading to reduced regeneration of browse-sensitive trees such as aspen (*Populus tremuloides*) and willow (*Salix* spp.). The re-introduction of wolves in 1995 was reported to reduce elk numbers and increase regeneration of trees (see Kauffman et al., 2010). One mechanism could be prey (elk) avoidance of habitats with high predation risk, such as open areas where trees may regenerate. Kauffman et al. (2010) analysed this mechanism with respect to aspen, finding no support for the idea that the top predator (wolf) influenced the trees in this way. However, the browsing pressure decreased as a whole in the forest, due to a 60% reduction of elk numbers, at least partly due to wolves.

Larger forests allow valuable studies of near-complete large mammal communities, as in the Białowieża national park (Jedrzejewska and Jedrzejewski, 1998) with populations of wolves, lynx (*Lynx lynx*), moose (*Alces alces*) and European bison (*Bison bonasus*). However, the predator populations were fairly small: the wolf was only protected in the Polish part of the forest, which had 10–20 wolves 1980–1993. The European bison was extinct in the wild, but re-introduced in Białowieża in the late 1950s, where there are now about 450 bison. Although no effects of inbreeding have been observed in the lowland line of bison (*B. b. bonasus*), the effective population size is only 23.5 and the average inbreeding level 50% (Tokarska et al., 2011). Plans are underway to introduce bison in parts of eastern Europe (Kuemmerle et al., 2010). Although large mammals attract much attention, Białowieża and Yellowstone are not protected and managed especially for large mammals, but as relatively wild large forests, important for many forest species, tourism, research, and other values (Wesolowski, 2005; Marris, 2008).

If large mammals were re-introduced in large early successional forests, for instance in abandoned Post-Soviet land (Kuemmerle et al., 2011a,b), rewilding and species management could be a main objective, at least initially. The situation in other temperate areas, especially in production landscapes with many small scattered conservation forests, is very different and rewilding projects are less likely (but see Fraser, 2009).

3.5. Combinations, and the role of forest size

Many protected temperate forests and other forests valuable for biodiversity contain several forest habitat types and also non-forest habitats. Almost all sites also have traces of, or effects of, earlier human land use. Traditional management may then enrich local biodiversity and visitor experiences. Importantly, the opportunity for combinations of the four management alternatives presented above should increase with the size of the conservation forest. Forests of about 1000 hectares can easily contain for example traditional and non-traditional management, or minimal intervention and traditional management. Larger forest-dominated national parks such as Yellowstone national park in the USA (8987 km^2), the temperate Zapovedniks Kavkazski and Sikhote-Alin in Russia (2825 and 3900 km^2, www.sevin.ru/natreserves/), and Białowieża Forest in Poland/Belarus (about 1000 km^2 protected area) are not common, but may be large enough for viable populations of large carnivores. Of the very Large Protected Areas (vLPAs, >25,000 km^2), only one of 63 identified global areas is located in the temperate zone, the Bernardo O'Higgins national park, 35,259 km^2 in southern Chile (based on Cantu-Salazar and Gaston, 2010). However, New Zealand's South Island has a larger contiguous protected area (>40,000 km^2) dominated by temperate forest (national parks and other land administered by the Department of Conservation; www.doc.govt.nz/about-doc/role/maps-and-statistics/).

While large forests offer many opportunities in protection and management, biodiversity-rich forests and protected forests in the temperate zone are usually small, in many cases just a few hectares. For instance, in Lithuania, Estonia, Latvia, Finland, Sweden and Norway there are in total 263,951 woodland key habitats, identified on the basis of biodiversity value, with a mean size ranging from 1 to 5 ha (Timonen et al., 2010). Even small forest sites can be of high value for biodiversity and conservation (Shafer, 1995; Turner and Corlett, 1996; Fischer and Lindenmayer, 2002; Götmark and Thorell, 2003; Rackham, 2006; Brudvig et al., 2009), and they may be 'stepping stones' for species affected by climate change. The choice of habitat management alternative(s) is and will be important for all sites, large as well as small.

Fig. 1 shows the management alternatives presented here along a time scale of 500 years, relevant for decisions (including research). The figure indicates that very old temperate forests (>400 years) are rare, at least in the European lowlands.

4. General discussion

4.1. The review and synthesis of the literature

I have described many approaches to habitat management and research in conservation forests, but I also show that it is possible to synthesise four major management alternatives. These may guide future research, and their usefulness can then be further tested. In the review, many studies concerned basic ecology. Although management was not directly addressed in these studies, the researchers actually used the minimal intervention alternative and their studies testify to its importance. My conclusions concern shrubs, trees and forest structure, fundamental components of any forest, but additional similar reviews of various forest- or tree-associated taxa are also needed (e.g. species in the soil and dead wood, and in the canopy). In a meta-analysis of studies in European managed (forestry) and unmanaged forests (conservation forests), Paillet et al. (2010) found that vascular plants were disfavoured in the unmanaged forests, birds responded in a heterogeneous way, while bryophytes, lichens, fungi, and beetles responded positively in unmanaged forests, and the older the forest, the stronger the recovery of biodiversity.

About one third of the studies proposed active management, mainly to favour certain trees or old-growth characteristics. Few recommended management based on a historical baseline, or rewilding (introduction of large predators), alternatives that were emphasized in Kirby and Watkins (1998) and in Soulé and Terborgh (1999); see also Fraser, 2009 for recent applications of rewilding. The traditional management alternative and habitat restoration have stimulated much research (e.g. Bjorkman and Vellend, 2010; Hall, 2010). Restoration and rewilding are useful in many forest-related situations (e.g., Holl and Aide, 2011), but I suggest that testing and evaluation of management alternatives is

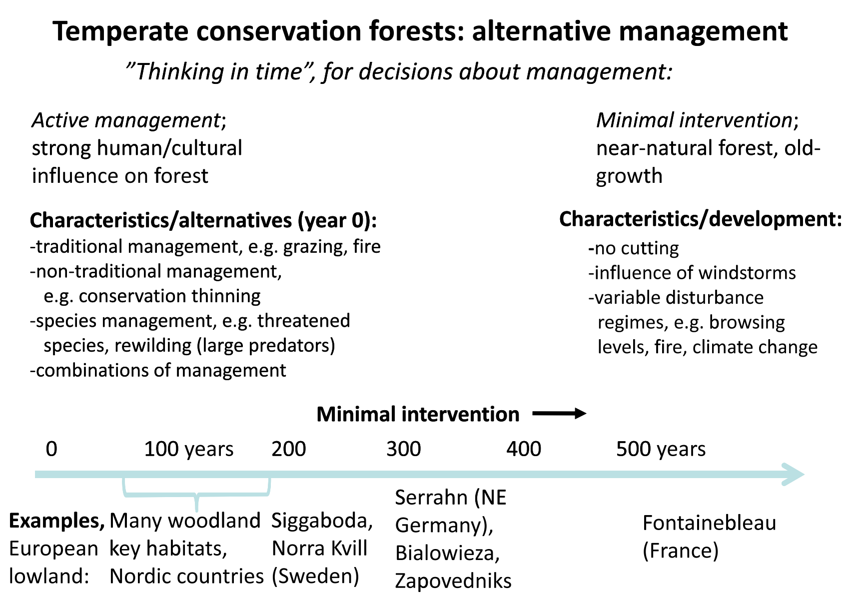


Fig. 1. Active management (several forms) and minimal intervention as alternatives in the management of temperate forests with conservation values. At year 0, the forest is assumed to contain above average or high conservation values. At this starting point, tree density and structure may vary, and the site subjected to any of the activities/decisions listed under "Characteristics". A time scale of 500 years is used to illustrate that such a period may be needed to obtain high quality old-growth forest, with some trees of this age. Below the time arrow are examples of minimal intervention among the conservation forests in the European lowlands, with the approximate age of the forest. These forests have had no or little direct human disturbance (e.g. cutting), but indirect effects such as human influence on ungulate densities, and changes in browsing pressure, are involved. Examples were found in published studies (this search only covered English scientific literature). Protected mountain forests are not included (e.g. Holeksa et al., 2009) or steep forested slopes, where there may be many more examples of long periods of minimal intervention. Sources: ages for woodland key habitats are subjectively estimated for southern Sweden (F.G., there are sometimes trees of higher age there, see Timonen et al., 2010), Siggaboda Nature Reserve (Bolte et al., 2010), Norra Kvill National Park (Niklasson and Drakenberg, 2001), Serrahn (von Oheimb et al., 2005), Białowieża National Park in Poland (Wesolowski, 2005), protected Zapovedniks (Shtilmark, 2003), and la Tillaie and le Gros Fouteau in the Fontainebleau Forest, France (Pontailler et al., 1997; Mountford, 2002).

appropriate for scientific research in conservation forests. There is no *a priori* reason why one of the four management alternatives would be better than the others, if the forest habitat is considered broadly. Testing of alternative hypotheses, or at least considering alternatives, is basic to good science (Platt, 1964; Gosselin, 2009). Moreover, research and field experiments often give surprising results and may not support common belief (Peterken, 1993; Doak et al., 2008; Gross, 2010).

4.2. Management of conservation forests and approaches in research

The science of biological conservation is growing rapidly, but the advice given to forest managers changes over time. Such changes, e.g. regarding management by fire, or absence of fire, and policies for large predators, were documented by Runte (1987). However, for minimal intervention in forests in particular the time scale for (strong) protection is important (Fig. 1), because otherwise changing climate, political conflicts, and changing ideas in management may affect a decision on minimal intervention as ecological baseline.

Much of ecology and conservation science consist of studies of popular and easily accessible species, but Caro (2007) identified limitations in using single species or one organism group as the sole basis for conservation decisions. Temperate conservation forests are very species-rich, with taxa that are not easy to study (e.g. fungi, insects; e.g. Blackwell, 2011; Ulyshen, 2011), but by studying many taxa we can learn about the communities that management alternatives favour (e.g., Table 3). The response of selected taxa should be studied by long-term field experiments (Tilman, 1987; Belovsky et al., 2004). Such work can be combined with monitoring of biodiversity (Nichols and Williams, 2006; Lengyel et al., 2008). Active management and minimal intervention can be evaluated for instance in IUCN category Ia protected areas or in biosphere reserves. A simple "50/50% rule" with treatment and minimal intervention in equal proportion by area should be useful for management research and for keeping some forest as ecological baseline, to assess human influence in the surrounding landscapes (Arcese and Sinclair, 1997; Nilsson et al., 2002; van Mantgem et al., 2009).

Learning by strong experiments has long been emphasized by researchers through the concept adaptive management (McDonald-Madden et al., 2010; see also McLain and Lee, 1996). Lindenmayer et al. (2008) stated that there "are very few applications of active adaptive management in forest management anywhere in the world, despite an extensive literature". The authors refer to managers who want, or must take decisions on the best management (Kirkpatrick and Kiernan, 2006; Cook et al., 2010), without research that cannot easily be funded. Soulé (2010) concludes that adaptive management belongs to "failed proposals" and "rational but idealistic approaches". In the UK, despite much ecological research, K. Kirby (pers. comm.) and R. Harmer (pers. comm.) were not aware of any management research in conservation forests that used treatment and controls, and measurements before and after treatment.

If researchers suggest strong experiments to study habitat management, they themselves need to show their power for funding agencies, authorities, and managers. Managers of protected areas seem to more often use experience-based than evidence-based information in their decisions (Cook et al., 2010, and references therein). To overcome knowledge gaps, researchers interested in management of conservation forests need to establish experiments and other studies together with authorities and managers.

In the Białowieża National Park in Poland, research produced as many as 5000 reports (Marris, 2008). Researchers in the US might use the LTER (Long-Term Ecological Research) sites set up in 1980, but there are few forests in this network (Turner et al., 2003). The US Forest Service has a network of 77 experimental forests and ranges for long-term studies of e.g. forestry, aspects of old-growth, and global warming (Lugo, 2006). The old Russian system of Zapovedniks combines a preservation mandate with a research mandate (Weiner, 1999; Danilina, 2001; Shtilmark, 2003; Spetich et al., 2009). Parts of some Zapovedniks are increasingly used for tourism, and the collecting of data in Zapovedniks can be characterised more as monitoring than research (L. Khanina and M. Bobrovskii, pers. comm., see also www.wild-russia.org/html/pubs.htm).

Another approach is to review past management decisions and policies. Researchers have rarely analysed management plans and actual measures in these forests (but see Rackham, 2006; Schulte et al., 2006, and 'category 4 research' in Underwood, 1995). This would be an important basis for evaluation of the habitat management alternatives, at national, regional and landscape level. In such studies, sites have to be contacted, as management plans in archives or on the Internet may not correspond to reality, or are not up-to-date. Parviainen et al. (2000) reviewed strict forest reserves in Europe; in 1999, nearly 30,000 km^2 of the European forest was strictly protected, about 1.7% of the total forest area (if the European region of Russia is included, the figure would be 47,000 km^2). Minimal intervention best describes these reserves; game (herbivore) control, fire control, and removal of exotic species often or sometimes took place there. 'Strict' reserve was interpreted very differently in different countries, but the "subjects, goals, methodologies and constraints for scientific research" were "strikingly similar throughout Europe" (Parviainen et al., 2000). Many of these reserves could function as ecological baseline controls, and coordinated through the European Union (in the Natura 2000 system).

Because there are so many conservation forests, studies of the actual management regimes require sampling of forests (units in statistical analysis) for further description and analyses. For examples of studies using stratified random sampling of forest reserves, see Götmark and Thorell, 2003; Thorell and Götmark, 2005.

The cultural variation in conservation management (Henderson, 1992) leads to debate (Locke and Dearden, 2005) and needs more study. For instance, in northern Europe (Fennoscandia), almost all conservation forests are open for visitors, while in continental Europe the public is not allowed to visit some types of forest reserves (pers. obs.). Such differences have consequences; for instance, visitors may spread exotic species into forests.

5. Conclusions and future research

Temperate conservation forests, including old-growth and protected forests, set-asides and mid-aged forests with low harvest demands, are of high cultural and scientific value. I propose four habitat management alternatives as a framework for future research and management decisions. Habitat management in the conservation forests varies from country to country, and is influenced by historical and cultural factors. However, science can influence how habitat management is realized and below I suggest five questions for future research. (1) How do species-rich taxa respond to different management alternatives, such as traditional management vs. minimal intervention, in conservation forests? – relatively young forests, in early successional stages, may be of special interest and long-term study would be very valuable. (2) To what extent are taxa of special interest (e.g. red-listed species) reduced or eliminated, or favoured or added, by one alternative compared to others? (3)

How does active management vs. minimal intervention change species composition of shrubs and trees, and regeneration of desirable woody plants? (4) How does active management change forest structure, including dead wood, light conditions and other factors, compared to minimal intervention? (5) How does active management for a single forest species (e.g. red-listed species, or keystone) influence this and other species – and could the species in the long run be favoured by disturbances and succession in the forest under minimal intervention? In addition, temperate forests seem to be more carbon-dense than tropical and boreal forests (Keith et al., 2009). The consequences of climate change and carbon balances for the habitat management alternatives need more study (for a general review, see Milad et al., 2012).

To link science and practical management, researchers should initiate long-term experiments together with agencies and managers of conservation forests. Moreover, we need research about the actual use of habitat management in conservation forests. Contemporary projects in ecological restoration are important in degraded or damaged ecosystems, but for many mid-aged and older conservation forests there is often not one management alternative that generally can be considered the correct one. The four alternatives described here all deserve more research, to better support nature conservation.

Appendix A.
Example Section 1 - Studies of minimal intervention

In Pennsylvania (USA), a forest was studied in 1929 and in 1978; reduction of smaller size classes of some tree species was the strongest effect there, and was suggested to be due to increased deer browsing (Whitney, 1984). An old-growth forest in Michigan (USA) was measured over periods of 16-32 years and like the former had not experienced any recent major disturbance. Competition among trees was analysed, with possible future dominance of hemlock (*Tsuga canadensis*) (Woods, 2000a). Further long-term studies (six decades) of other old-growth stands 100 km away also suggested that the forest type was not compositionally stable, even though there had been no major disturbances for 400 years. ''*Fagus*, *Tsuga*, and perhaps *Acer saccharum* would, in different parts of the stand, achieve near-total dominance in the absence of large-scale disturbance, but only after elapsed time of a millennium or more'' (Woods, 2000b). Two years after this publication, a strong windstorm hit part of the forest, causing tree death similar to the mortality over the previous decade, but differentially among the tree species (Woods, 2004).

In the UK, Peterken and Jones (1987, 1989) studied Lady Park Wood, a coppice with standards (scattered larger trees) abandoned 1902 and with free secondary succession over 75 years. The forest became strongly affected by deer grazing, elm disease, and especially drought. The authors concluded that "succession is seen as an unpredictable process without a definite outcome". Vessers udde in southern Sweden, a relatively rare type of reserve where humans are prohibited to enter, was studied repeatedly 1922-1992 (Kardell and Fiskesjö, 1999). The initial grazed oak wood pasture was reforested, the number of vascular plant species decreased from 78 to 26, and much dead wood from many woody species was produced (68 m^3/ha in 1992). Many species were then presumably using that dead wood. Many other interesting studies exist, e.g. on interactions among *Tilia*, *Quercus*, *Picea* and *Pinus* in an old-growth stand in Latvia 1912-2006 (Brūmelis et al., 2011). For a study of temperate forest in a South American National Park, see photograph with text.

Old fire scars on *Araucaria araucana*, (Pehuén, or ''Monkey Puzzle''), a tree endemic to NW Patagonia in South America. Forests in national parks under minimal intervention are valuable for studies of human influence inside the park (history) and in landscapes outside. Fire history in *Araucaria* forest was studied by dendrochronology in Lanín National Park, Argentina, and outside (Mundo et al. 2012). Fires were dated back to 1441, were relatively common during the 19th century and decreased after the park was established in 1937. Native people had probably set many of the early fires. Cutting and burning of forest for agriculture and livestock occurred about 1890-1920. In addition, the fires reflected changes in climate and weather conditions over long periods. Photograph: Ignacio Mundo, December 2007 in Ea. Nahuel Mapi (for scale, a backpack was place to the left of the tree with scar).

Example Section 2 - Studies of traditional management

One fascinating example of traditional management is the New Forest in the UK, a former royal hunting ground and a common that has been grazed and browsed by domestic animals and deer for about 900 years (Putman, 1986). In the 1980's it contained 10,000 ha of forest and 27,500 ha of open land used by 2500 deer, 3500 horses and 2000 cattle. This resulted in a strong grazing and browsing pressure. The trees in the New Forest originate from three periods (1650-1750, 1860-1910 and 1930-1945) when the number of animals and the grazing pressure on seedlings and saplings temporarily decreased (Peterken and Tubbs, 1965; Putman, 1986). It is a highly valued site with over 20 million visitors per year. Grant and Edwards (2008) suggest that "future conservation policies, and hence management strategies, must be flexible as to the species composition and structure of future woodlands" and that "managers must also focus on issues of public perception", given ''the wide range of users and their different values".

On islands in the archipelago off SW Finland, Kotiluoto (1998) compared (1) grazing, (2) thinning, and (3) thinning, mowing, and grazing combined for abandoned sites that had been invaded by shrubs and trees (data before-after treatment). Many common forb and grass species were recorded after the treatment, but very few species considered to be indicators of old meadow vegetation. For related studies of complex effects in restoration, see Jonsson (1995) and Mitlacher et al. (2002). Most studies in Europe and North America concern herbaceous plants, ignoring the majority of species that occur in forest and dead wood (Hambler 1995). Kotiluoto (1998) stated that the abandoned sites "develop into less species rich shrub and tree communities", a statement which thus should require more work. Creation of habitat variation for biodiversity at the landscape level seems to guide many restoration efforts, which is a simple but useful goal, depending on landscape type.

Austad and Skogen (1990) tested restoration by means of pollarding and traditional mowing in a deciduous woodland in western Norway, after more than 40 years of disuse and succession. Understory trees (mainly *Alnus*) were removed, *Ulmus* pollards were created and the field layer was mown once or twice per year. Pollarding was successful, and after expansion of tall, nitrophilic herbs (e.g. *Urtica* and *Rubus*), low and medium-sized forbs and grasses increased, and the average number of such species in plots nearly doubled. The test was considered successful, but the management was considered costly (Austad and Skogen, 1990), which is one reason why such work and research are rare.

In temperate areas of North America, prescribing fire to restore oak savanna and semi-open woodland may be the most common form of traditional management in woodland. Fire was formerly used to transform the forest habitat by Native Americans (Williams, 2003). Peterson and Reich (2001) studied oak savanna in Minnesota and found that frequent burning (at least three fires per decade) prevented development of a sapling layer and canopy ingrowth; one fire per decade produced stands with dense sapling thickets. In a 17-year study, annual low-intensity burning favoured more open forest and herbs (and the non-native *Alliaria petiolata*) compared to unburned forest (Bowles et al., 2007). Although fire and reduced incidence of fires have clear effects, the complex long-term changes in the deciduous forests in the USA seem to be caused by several factors, such as changes in climate, forest composition, browsing animals, and the extinction of the passenger pigeon, *Ectopistes migratorious* (McEwan et al., 2011, Buchanan and Hart, 2012).

For example from Japan and forest used for coppice, see photograph and text below.

Secondary succession in former traditionally managed coppice, part of old Satoyama landscape on the slope of Mount Zao, 40 km SW of Sendai in Japan, 600 m above sea level. This kind of forest still covers relatively large areas. Here it is dominated by *Quercus serrata* and *Q. crispula* (coppiced, multiple stems), but also *Fagus crenata* and Prunus can be seen on the picture. Other tree species in the area include *Acer palmatum* and *A. japonicum*. The forest was coppiced before 1950 and used for fuel, traditional craft, and for collecting fungi. The former Satoyama farming landscape, based on rice, fish, seafood, and wood (pasturing of minor importance) is restored locally in the Satoyama Initiative (Takeuchi et al., 2003, Takeuchi, 2010). For a comparison between Satoyamas and the Scandinavian traditional infields and outlands (based much on cattle, sheep, and pastures), see Berglund (2008). East Asian forests are rich in tree species, and probably also in other taxa. For conservation forests and habitat management, studies of minimal intervention (like stands of this type) and of traditional management (recreated coppice) are valuable for understanding the alternatives (see also Nagaike et al. 2005, Yamaura et al. 2012). Photograph: Björn E. Berglund, April 2005.

Example Section 3 - Studies of non-traditional management

The starting point in non-traditional management may be a dense or closed-canopy forest. For instance, after 100 years of secondary succession from arable land under minimal intervention, two UK stands had a shade flora; Harmer et al. (2001) suggested that if nature conservation is one of the objectives, open spaces and thinning would be required there (only vascular plants were discussed).

When larger trees are desirable in closed-canopy second-growth stands, crown release through partial cutting might hasten tree development. In northern Wisconsin, USA, percent increase in basal area growth of trees after thinning was linearly correlated with percent plot basal area removed and with percent crown perimeter release of individual trees, e.g. sugar maple *Acer saccharum* (Singer and Lorimer, 1997). The authors suggested that crown release also increases the diversity of vegetation layers (shrubs, small trees, large trees) and increases the number of canopy gaps, standing snags, and fallen logs. By combining field data with models, Keeton (2006) studied how to best achieve vertically differentiated canopies, elevated dead wood density, variable horizontal density (including gaps), and re-allocation to larger tree diameter classes (see also Choi et al., 2007). Bauhus et al. (2009) emphasized the need to complement forest reserves with silvicultural methods that retain or create a certain degree of 'old-growthness'. In addition, restoration cutting might cause complex changes, such as unexplained death of large trees (Fulé et al., 2007; see also Götmark, 2009).

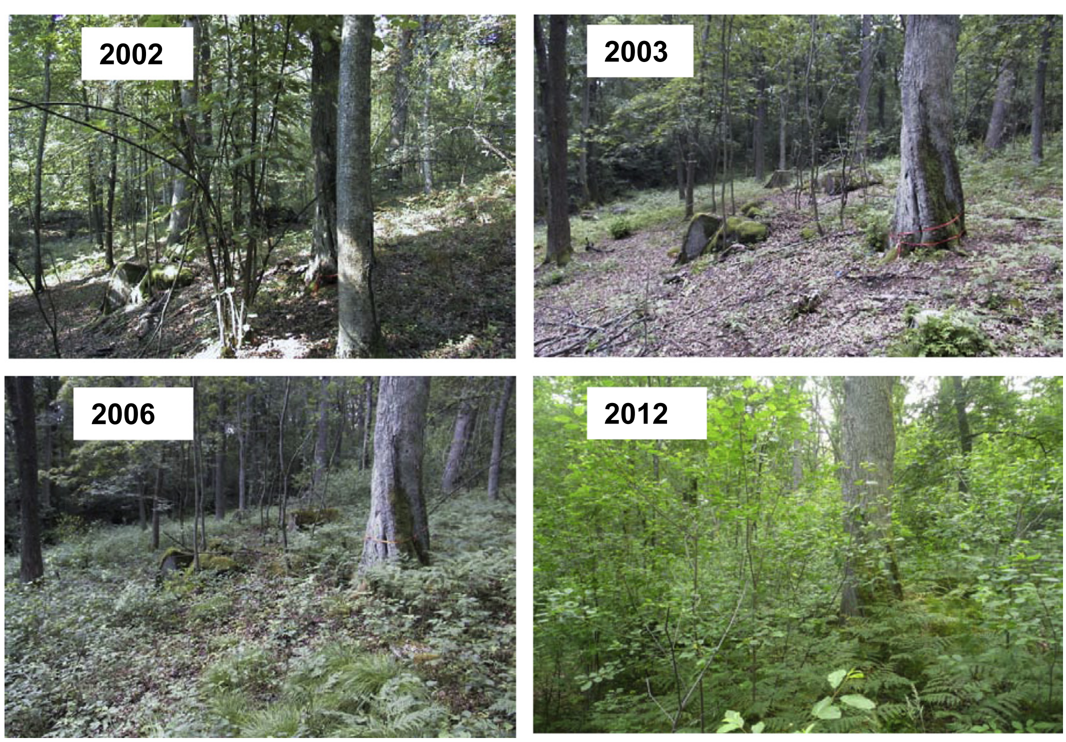
Another approach for second-growth stands is to favour legacy trees that contain red-listed or otherwise valuable associated species. Old hollow oaks *Quercus* spp., threatened by other invading trees (Paltto et al., 2011; Spector and Putz, 2006; Vera, 2000), is one example. Oak regeneration also requires that enough light reaches the oak seedlings and saplings, and conservation-oriented partial cutting (conservation thinning) is one alternative for closed-canopy oak-rich forests. This is tested in our Swedish Oak Project, a BACI (Before-After-Control-Impact) field experiment that began in 2000 and is planned to be long-term.

Our 25 study sites are small nature reserves and woodland key habitats (Timonen et al., 2010) with large oaks and many other trees, essentially closed canopies, and basal areas of 20-38 m^2/ha. About 60 years ago, canopy openness (% visible sky from the ground) was on average 50% and the sites have a history of agriculture (small fields and pasture woodland). The sites are spread over a large area and landscape factors are also analysed. Because the forests contain many valuable trees and structures other than oaks, active management is not self-evident. Instead, we test non-traditional management versus minimal intervention.

At each site, we use one plot (1 ha) for partial cutting, and one plot (1 ha) nearby for minimal intervention, studying these both before and after cutting in the winter 2002/03. We examine responses in vascular plants (herbs, shrubs and trees), bryophytes, lichens, saproxylic fungi, saproxylic and herbivorous beetles, fungus gnats (Mycetophilidae; Diptera) and snails and slugs (terrestrial molluscs). These taxa were chosen to represent both light-demanding and shade-tolerant or dessication-sensitive organisms. We do not study birds and mammals, which are generally well-known in Sweden, and would have required large study sites. The region and landscape is a mosaic of many small scattered conservation forests. We cut about 25-30% of the basal area at each site, harvesting mainly smaller, intermediate and some larger trees to create more open conditions, especially around larger oaks. Tops, branches, and two dead oaks were left in each plot, the rest was harvested (the project was funded for tests of careful biofuel cutting for biodiversity).

The short-term (1-6 years) effects of conservation thinning are mainly positive or neutral for biodiversity (Table 2, and references there). In several cases (e.g. Götmark et al., 2005; Nordén et al., 2012), responses in the taxa to cutting could not have been detected without our minimal intervention plots. In addition, species turnover was high also under minimal intervention (Götmark et al., 2005; Nordén et al., 2012; Paltto et al., 2008). After 8-10 years, conservation thinning seems to favour regeneration of shrubs (e.g. *Corylus*, *Rhamnus*, *Lonicera*) rather than trees such as oaks (Leonardsson and Götmark, unpubl.) – see photographs. Planting of oak seedlings is one management possibility (Jensen et al., 2012). While our results so far at least partly support non-traditional management, long-term data are needed to evaluate the management alternatives (Belovsky et al., 2004; Tilman, 1987), including unpredictable events (Doak et al., 2008). We suggest that at least 30% of this kind of forest in the region should be reserved for minimal intervention (Götmark, 2009).

A similar study of closed-canopy mixed-species forest with large oaks, and experimental restoration of oak savanna (with undisturbed reference plots), was started in 2002 in Iowa, USA. It illustrates the importance of restoring the large gaps characteristic of oak savanna, through cutting of non-savanna tree species, for promoting the growth of oak seedlings (Brudvig and Asbjornsen, 2009) and for the release of relict overstory oak trees from competition with non-savanna tree species (Brudvig et al., 2011). The focus of that project is thus traditional management.



Conservation thinning at Rya Åsar Nature Reserve, south-western Sweden. The photos show the plot for non-traditional management, with partial cutting in the winter of 2002/03, and subsequent development at fixed place for photo. In 2002, *Corylus avellana* and *Sorbus aucuparia* grew near the large *Quercus robur* (retained). Little change took place in the plot with minimal intervention (both plots 1 ha). Tilman (1987) concluded that experiments longer than the typical 3 years can change conclusion for several taxa, which should be clear here. Photographs: Frank Götmark.

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Appendix B. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foreco.2013.06.014.

References

Aagesen, D., 2000. Rights to land and resources in Argentina's Alerces National Park. Bull. Latin Am. Res. 19, 547–569.

Abrams, M.D., 1992. Fire and the development of oak forest. BioScience 42, 346–353.

Abrams, M.D., 2003. Where has all the white oak gone? BioScience 53, 927–939.

Abe, S., Masaki, T., Nakashizuka, T., 1995. Factors influencing sapling composition in canopy gaps of a temperate deciduous forest. Vegetatio 120, 21–32.

Allen, R.B., Bellingham, P.J., Wiser, S.K., 1999. Immediate damage by an earthquake to a temperate montane forest. Ecology 80, 708–714.

Arcese, P., Sinclair, A.R.E., 1997. The role of protected areas as ecological baselines. J. Wildl. Manage. 61, 587–602.

Ask, P., Carlsson, M., 2000. Nature conservation and timber production in areas with fragmented ownership patterns. For. Policy Econ. 1, 209–223.

Attiwill, P.M., 1994. The disturbance of forest ecosystems: the ecological basis for conservative management. For. Ecol. Manage. 63, 247–300.

Ausden, M., 2007. Habitat Management for Conservation. Oxford University Press, Oxford.

Austad, I., Skogen, A., 1990. Restoration of a deciduous woodland in Western Norway formerly used for fodder production: effects on tree canopy and field layer. Vegetatio 88, 1–20.

Balandier, P., Prevosto, B., Guitton, J.-L., 2005. Forest restoration in the French Massif Central. In: Stanturf, J.A., Madsen, P. (Eds.), Restoration of Boreal and Temperate Forests. CRC press, Boca Raton, pp. 355–367.

Banner, A., LePage, P., 2008. Long-term recovery of vegetation communities after harvesting in the coastal temperate rainforests of northern British Columbia. Can. J. For. Res. 38, 3098–3111.

Bauhus, J., Puettman, K., Messier, C., 2009. Silviculture for old-growth attributes. For. Ecol. Manage. 258, 525–537.

Belovsky, G.E. et al., 2004. Ten suggestions to strengthen the science of ecology. BioScience 54, 345–351.

Berglund, B.E., 2008. Satoyama, traditional farming landscape in Japan, compared to Scandinavia. Jpn. Rev. 20, 53–68.

Bergmeier, E., Petermann, J., Schröder, E., 2010. Geobotanical survey of wood-pasture habitats in Europe: diversity, threats and conservation. Biodiv. Conserv. 19, 2995–3014.

Berkes, F., Colding, J., Folke, C., 2000. Rediscovery of traditional ecological knowledge as adaptive management. Ecol. Appl. 10, 1251–1262.

Bjorkman, A.D., Vellend, M., 2010. Defining historical baselines for conservation: ecological changes since European settlement on Vancouver Island, Canada. Conserv. Biol. 24, 1559–1568.

Blackwell, M., 2011. The fungi: 1, 2, 3, . . ., 5.1 million species? Am. J. Bot. 98, 426–438.

Bobrovskii, M.V., 2010. Effect of historical land use on the structure of forest soils in European Russia. Eurasian Soil Sci. 43, 1458–1466.

Bolte, A., Hilbrig, L., Grundmann, B., Kampf, F., Brunet, J., Roloff, A., 2010. Climate change impacts on stand structure and competitive interactions in a southern Swedish spruce–beech forest. Eur. J. For. Res. 129, 261–276.

Bond, W.J., Midgley, J.J., 2001. Ecology of sprouting in woody plants: the persistence niche. Trends Ecol. Evol. 16, 45–51.

Bowles, M.L., Jacobs, K.A., Mengler, J.L., 2007. Long-term changes in an oak forest's woody understory and herb layer with repeated burning. J. Torrey Bot. Soc. 134, 223–237.

Bowman, D.M.J.S., 1998. The impact of Aboriginal landscape burning on the Australian biota. New Phytol. 140, 385–410.

Bouget, C., Duelli, P., 2004. The effects of windthrow on forest insect communities: a literature review. Biol. Conserv. 118, 281–299.

Bradshaw, R., 2002. (Book review of) Grazing ecology and forest history. For. Ecol. Manage. 165, 327–329.

Bradshaw, R., 2004. The Holocene structure of north-west European temperate forest induced from paleaoecological data. In: Honnay, O. et al. (Eds.), Forest Biodiversity: Lessons from History for Conservation. Elsevier, Amsterdam, pp. 11–25.

Bradshaw, R., 2005. What is a natural forest? In: Stanturf, J.A., Madsen, P. (Eds.), Restoration of Boreal and Temperate Forests. CRC press, Boca Raton, pp. 15–30.

Brudvig, L.A., Asbjornsen, H., 2009. Dynamics and determinants of *Quercus alba* seedling success following savanna encroachment and restoration. For. Ecol. Manage. 257, 876–884.

Brudvig, L.A., Blunck, H.M., Asbjornsen, H., Mateos-Remigio, V.S., Wagner, S.A., Randall, J.A., 2011. Influences of woody encroachment and restoration thinning on overstory savanna oak tree growth rates. For. Ecol. Manage. 262, 1409–1416.

Brudvig, L.A., Damschen, E.I., Tewksbury, J.J., Haddad, N.M., Levey, D.J., 2009. Landscape connectivity promotes plant biodiversity spillover into non-target habitats. Proc. Nat. Acad. Sci., PNAS 106, 9328–9332.

Brümelis, G. et al., 2011. Dynamics of natural hemiboreal woodland in the Moricsala Reserve, Latvia: the studies of K.R. Kupffer revisited. Scand. J. For. Res. 26 (Suppl. 10), 54–64.

Brunet, J., von Oheimb, G., 2008. Elm disease and hungry slugs: drastic vegetation changes in Dalby Söderskog, a south Swedish deciduous forest. Svensk Bot. Tidskr. 102, 27–37 (in Swedish, English summary).

Bryant, D., Nelson, D., Tangley, L., 1997. The Last Frontier Forests. World Resources Institute, Washington, DC.

Buchanan, M.L., Hart, J.L., 2012. Canopy disturbance history of old-growth *Quercus alba* sites in the eastern United States: examination of long-term trends and broad-scale patterns. For. Ecol. Manage. 267, 28–39.

Bugmann, H.K.M., Solomon, A.M., 2000. Explaining forest composition and biomass across multiple biogeographic regions. Ecol. Monogr. 10, 95–114.

Cadotte, M.W., Carscadden, K., Mirotchnick, N., 2011. Beyond species: functional diversity and the maintenance of ecological processes and services. J. Appl. Ecol. 48, 1079–1087.

Callicott, J.B., Crowder, L.B., Mumford, K., 1999. Current normative concept in conservation. Conserv. Biol. 13, 22–35.

Cantu-Salazar, L., Gaston, K.J., 2010. Very large protected areas and their contribution to terrestrial biological conservation. BioScience 60, 808–818.

Caro, T., 2007. The Pleistocene re-wilding gambit. Trends Ecol. Evol. 22, 281–283.

Caro, T., 2010. Conservation by Proxy. Indicator, Umbrella, Keystone, Flagship, and Other Surrogate Species. Island Press, Washington, DC.

Chape, S., Spalding, M., Jenkins, M.D., 2008. UNEP World Conservation Monitoring Centre, The world's Protected Areas. University of California Press, Berkeley.

Choi, J., Lorimer, C.G., Vanderwerker, J.M., 2007. A simulation of the development and restoration of old-growth structural features in northern hardwoods. For. Ecol. Manage. 249, 204–220.

Clark, R.L., 1990. Ecological history for environmental management. Proc. Ecol. Soc. Aust. 16, 1–21.

Coates, K.D., Burton, P.J., 1997. A gap-based approach for development of silvicultural systems to address ecosystem management objectives. For. Ecol. Manage. 99, 337–354.

Cook, C.N., Hockings, M., Carter, R.W., 2010. Conservation in the dark? The information used to support management decisions. Front. Ecol. Environ. 8, 181–186.

Coomes, D.A., Allen, R.B., Forsyth, D.M., Lee, W.G., 2003. Factors preventing the recovery of New Zealand forests following control of invasive deer. Conserv. Biol. 17, 450–459.

Danilina, N., 2001. The Zapovedniks of Russia. George Wright Forum 18, 48–55.

Davis, M. et al., 2011. Don't judge species on their origins. Nature 474, 153–154.

Dearden, P., Rollins, R. (Eds.), 2009. Parks and Protected Areas in Canada: Planning and Management. Oxford University Press, Oxford.

Decocq, G. et al., 2004. Plant diversity in a managed temperate deciduous forest: understorey response to two silvicultural systems. J. Appl. Ecol. 41, 1065–1079.

DellaSala, D.A. (Ed.), 2011. Temperate and Boreal Rainforests of the World: Ecology and Conservation. Island Press, Washington.

Devine, W.D., Harrington, C.A., 2006. Changes in Oregon white oak (Quercus garryana Dougl. Ex Hook.) following release from overtopping conifers. Trees 20, 747–756.

Desjardins, J.R., 2006. Environmental Ethics. Wadsworth, Boston.

Didion, M. et al., 2009. Potentials and limitations of using large-scale forest inventory data for evaluating forest succession models. Ecol. Model. 220, 133–147.

Doak, D.F. et al., 2008. Understanding and predicting ecological dynamics: are major surprises inevitable? Ecology 89, 952–961.

Donlan, J. et al., 2005. Re-wilding North America. Nature 436, 913–914.

Dymond, J.R., Ausseil, A.-G., Shephard, J.D., Janssen, H., 2007. A landscape approach for assessing the biodiversity value of indigenous forest remnants: case study of the Manawatu/Wanganui region of New Zealand. Ecol. Econ. 64, 82–91.

Egan, D., Howell, E.A., 2001. The Historical Ecology Handbook: A Restorationist's Guide to Reference Ecosystems. Island Press, Washington, DC.

Faison, E.K., Foster, D.R., Oswald, W.W., Hansen, B.C.S., Doughty, E., 2006. Early Holocene openlands in southern New England. Ecology 87, 2537–2547.

Fazey, I., Fischer, J., Lindenmayer, D.B., 2005. What do conservation biologists publish? Biol. Conserv. 124, 63–73.

Feldman, J., 2010. Spontaneous rewilding of the Apostle Islands. In: Hall, M. (Ed.), Restoration and History. Routledge, New York, pp. 34–45.

Firm, D., Nagel, T.A., Diaci, J., 2008. Disturbance history and dynamics of an old-growth mixed species mountain forest in the Slovenian Alps. For. Ecol. Manage. 257, 1893–1901.

Fischer, J., Lindenmayer, D.B., 2002. Small patches can be valuable for biodiversity conservation: two case studies on birds in southeastern Australia. Biol. Conserv. 106, 129–136.

Foster, D.R., 2000. Conservation lessons and challenges from ecological history. For. Hist. Today (fall), 2–11, <http://www.foresthistory.org/publications/FHT/fhtfall00.html>.

Foster, D.R. et al., 2003. The importance of land-use legacies to ecology and conservation. BioScience 53, 77–88.

Foster, D.R., Aber, J.D. (Eds.), 2004. Forests in Time. The Environmental Consequences of 1000 Years of Change in New England. Yale University Press, New Haven.

Franc, N., Götmark, F., 2008. Openness in management: hands-off vs management of conservation forests – the response of beetles to partial cutting. Biol. Conserv. 141, 2310–2321.

Franklin, J.F., 2003. Challenges to temperate forest stewardship – focusing on the future. In: Lindenmayer, D.B., Franklin, J.F. (Eds.), Towards Forest Sustainability. CSIRO Publishing, Collingwood, pp. 1–14.

Fraser, C., 2009. Rewilding the World. Metropolitan books, New York.

Fried, J.S., Huntsinger, L., 1998. Managing for naturalness at Mt. Diablo state park. Soc. Nat. Resour. 11, 505–516.

Fulé, P.Z., Roccaforte, J.P., Covington, W.W., 2007. Posttreatment tree mortality after forest ecological restoration, Arizona, United States. Environ. Manage. 40, 623–634.

Gärdenfors, U., 2010. The 2010 Red List of Swedish Species. Swedish Species Information Centre, SLU Uppsala.

Gilliam, F., 2007. The ecological significance of the herbaceous layer in temperate forest ecosystems. BioScience 57, 845–858.

Gosselin, F., 2009. Management on the basis of the best scientific data or integration of ecological research within management? Lessons learned from the Northern spotted owl saga on the connection between research and management in conservation biology. Biodiv. Conserv. 18, 777–793.

Götmark, F., 2007. Careful partial harvesting in conservation stands and retention of large oaks favour oak regeneration. Biol. Conserv. 140, 349–358.

Götmark, F., 2009. Experiments for alternative management of forest reserves: effects of partial cutting on stem growth and mortality of large oaks. Can. J. For. Res. 39, 1322–1330.
Götmark, F., Paltto, H., Nordén, B., Götmark, E., 2005. Evaluating partial cutting in broadleaved temperate forest under strong experimental control: short-term effects on herbaceous plants. For. Ecol. Manage. 214, 124–141.
Götmark, F., Thorell, M., 2003. Size of nature reserves: densities of large trees and dead wood indicate high value of small conservation forests in southern Sweden. Biodiv. Conserv. 12, 1271–1285.
Gowda, J.H., Kitzberger, T., Premoli, A.C., 2012. Landscape responses to a century of land use along the northern Patagonian forest-steppe transition. Plant Ecol. 213, 259–272.
Grant, M.J., Edwards, M.E., 2008. Conserving idealized landscapes: past history, public perception and future management in the New Forest (UK). Veg. Hist. Archaeobot. 17, 551–562.
Grenier, D.J., Bergeron, Y., Kneeshaw, D., 2005. Fire frequency for the transitional mixedwood forest of Timiskaming, Quebec, Canada. Can. J. For. Res. 35, 656–666.
Gross, M., 2010. Ignorance and Surprise. Science, Society and Ecological Design. MIT Press, Cambridge.
Grove, S.J., 2002. Saproxylic insect ecology and the sustainable management of forests. Ann. Rev. Ecol. Syst. 33, 1–23.
Gu, L. et al., 2008. The 2007 eastern USA spring freeze: increased cold damage in a warming world? BioScience 58, 253–262.
Gustafsson, L. et al., 2012. Retention forestry to maintain multifunctional forests: a world perspective. BioScience 62, 633–645.
Hahn, K., Emborg, J., 2007. Suserup Skov: structures and processes in a temperate, deciduous forest reserve. Ecol. Bull. 52, 1–195.
Hall, M. (Ed.), 2010. Restoration and History. The Search for a usable Environmental Past. Routledge, New York.
Hambler, C., 1995. Biodiversity conservation in Britain: science replacing tradition. Brit. Wildl. 6, 137–147, <http://www.britishwildlife.com/classicarticlesview.asp>.
Harmer, R., Peterken, G., Kerr, G., Poulton, P., 2001. Vegetation changes during 100 years of development of two secondary woodlands on abandoned arable land. Biol. Conserv. 101, 291–304.
Harmon, D., Putney, A.D. (Eds.), 2003. The Full Value of Parks: From Economics to the Intangible. Rowman & Littlefield, Lanham.
Henderson, N., 1992. Wilderness and the nature conservation ideal – Britain, Canada, and the United States contrasted. Ambio 21, 394–399.
Hobbs, R.J., Cramer, V.A., 2008. Restoration ecology: interventionist approaches for restoring and maintaining ecosystem function in the face of rapid environmental change. Ann. Rev. Environ. Resour. 33, 39–61.
Hoekstra, J.M., Boucher, T.M., Ricketts, T.H., Roberts, C., 2005. Confronting a biome crisis: global disparities of habitat loss and protection. Ecol. Lett. 8, 23–29.
Holeksa, J., Saniga, M., Szwagrzyk, J., Czemiak, M., Staszynska, K., Kapusta, P., 2009. A giant tree stand in the west Carpathians – an exception or a relic of formerly widespread mountain European forests? For. Ecol. Manage. 257, 1577–1585.
Holl, K.D., Aide, T.M., 2011. When and where to actively restore ecosystems? For. Ecol. Manage. 261, 1558–1563.
Honnay, O., Verheyen, K., Bossuyt, B., Hermy, M. (Eds.), 2004. Forest Biodiversity: Lessons from History for Conservation. CABI Publishing, Wallingford.
Hunter, M.L. (Ed.), 1999. Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press, Cambridge.
Hunter, M.L., White, A.S., 1997. Ecological thresholds and the definition of old-growth forest stands. Nat. Areas J. 17, 292–296.
Jedrzejewska, B., Jedrzejewski, W., 1998. Predation in Vertebrate Communities. The Białowieża Primeval Forest as a Case Study. Springer, Berlin.
Jensen, A.M., Götmark, F., Löf, M., 2012. Shrubs protect oak seedlings against ungulate browsing in temperate broadleaved forests of conservation interest: a field experiment. For. Ecol. Manage. 266, 187–193.
Jonsson, L., 1995. Effects of Restoration on Wooded Meadows in Southeastern Sweden. PhD Thesis, University of Lund, Sweden.
Kareiva, P., Watts, S., McDonald, R., Boucher, T., 2007. Domesticated nature: shaping landscapes and ecosystems for human welfare. Science 316, 1866–1869.
Kauffman, M.J., Brodie, J.F., Jules, E.S., 2010. Are wolves saving Yellowstone's aspen? A landscape-level test of a behaviorally mediated trophic cascade. Ecology 9, 2742–2755.
Kardell, L., Fiskesjö, A.-L., 1999. Vessers udde 1921–1992. Skog, vegetation och mark efter 70 års fridlysning. Rapport 83, Institutionen för skoglig landskapsvård, SLU Uppsala, 126p (in Swedish).
Keeton, W.S., 2006. Managing for late-successional/old-growth characteristics in northern hardwood-conifer forests. For. Ecol. Manage. 235, 129–142.
Keiter, R.B., 2010. The national park system: visions for tomorrow. Nat. Resour. J. 50, 71–110.
Keith, H., Mackey, B.G., Lindenmayer, D.B., 2009. Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests. Proc. Nat. Acad. Sci. PNAS 106, 11635–11640.
Kimmins, J.P., 2004. Forest Ecology. Macmillan & Collier, New York.
Kirby, K., 2003. Woodland conservation in privately-owned cultural landscapes: the English experience. Environ. Sci. Policy 6, 253–259.
Kirby, K.J., Watkins, C. (Eds.), 1998. The Ecological History of European Forests. CAB International.
Kirkpatrick, J., Kiernan, K., 2006. Natural heritage management. In: Lockwood, M., Worboys, G.L., Kothari, A. (Eds.), Managing Protected Areas: A Global Guide. Earthscan, London, pp. 421–447.
Koop, H., 1989. Forest Dynamics. Springer, Berlin.
Kotiluoto, R., 1998. Vegetation changes in restored semi-natural meadows in the Turku Archipelago of SW Finland. Plant Ecol. 136, 53–67.
Krebs, C., 2009. Ecology: The Experimental Analysis of Distribution and Abundance. Pearson International Edition.
Kuemmerle, T. et al., 2010. European bison habitat in the Carpathian Mountains. Biol. Conserv. 143, 908–916.
Kuemmerle, T. et al., 2011a. Post-Soviet farmland abandonment, forest recovery, and carbon sequestration in western Ukraine. Global Change Biol. 17, 1335–1349.
Kuemmerle, T. et al., 2011b. Cost-effectiveness of strategies to establish a European bison metapopulation in the Carpathians. J. Appl. Ecol. 48, 317–329.
Kull, K., Zobel, M., 1991. High species richness in an Estonian wooded meadow. J. Veg. Sci. 2, 711–714.
Lagerås, P., 2007. The Ecology of Expansion and Abandonment. National Heritage Board, Sweden.
Latham, R.E., Ricklefs, R.E., 1993. Continental comparisons of temperate-zone tree species diversity. In: Ricklefs, R.E., Schluter, D. (Eds.), Species Diversity in Ecological Communities. Univ. of Chicago Press, Chicago, pp. 294–314.
Landres, P., 2010. Let it be: a hands-off approach to preserving wilderness in protected areas. In: Cole, D.N., Yung, L. (Eds.), Beyond Naturalness. Island Press, Washington, DC, pp. 88–105.
Le Brocque, A.F., Goodhew, K.A., Zammit, C.A., 2009. Overstorey tree density and understorey regrowth effects on plant composition, stand structure and floristic richness in grazed temperate woodlands in eastern Australia. Agric. Ecosyst. Environ. 129, 17–27.
Lengyel, S. et al., 2008. Habitat monitoring in Europe: a description of current practices. Biodivers. Conserv. 17, 3327–3339.
Lertzman, K., 2009. The paradigm of management, management systems, and resource stewardship. J. Ethnobiol. 29, 339–358.
Lindbladh, M., Brunet, J., Hannon, G., Niklasson, M., Eliasson, P., Eriksson, G.R., Ekstrand, A., 2007. Forest history as a basis for ecosystem restoration – a multidisciplinary case study in a south Swedish temperate landscape. Restor. Ecol. 15, 284–295.
Lindenmayer, D.B., 2009. Old forest, new perspectives-Insights from the Mountain Ash forests of the Central Highlands of Victoria, south-eastern Australia. For. Ecol. Manage. 258, 357–365.
Lindenmayer, D.B., Franklin, J.F. (Eds.), 2003. Towards Forest Sustainability. CSIRO Publishing, Collingwood.
Lindenmayer, D.B., Burton, P.J., Franklin, J.F., 2008. Salvage Logging and Its Ecological Consequences. Island Press, Washington.
Locke, H., Dearden, P., 2005. Rethinking protected area categories and the new paradigm. Environ. Conserv. 32, 1–10.
Lockwood, M., Worboys, G.L., Kothari, A. (Eds.), 2006. Managing Protected Areas: A Global Guide. Earthscan, London.
Loehle, C., 2000. Strategy space and the disturbance spectrum: a life-history model for tree species coexistence. Am. Nat. 156, 14–33.
Lorimer, C.G., White, A.S., 2003. Scale and frequency of natural disturbances in the northeastern US: implications for early successional forest habitats and regional age distributions. For. Ecol. Manage. 185, 41–64.
Lorimer, C.G. et al., 2009. Presettlement and modern disturbance regimes in coast redwood forests: implications for the conservation of old-growth stands. For. Ecol. Manage. 258, 1038–1054.
Lugo, A.E., 2006. Long-term research at the USDA Forest Service's experimental forests and ranges. BioScience 56, 39–48.
Lunt, I.D., Jones, N., Spooner, P.G., Petrow, M., 2006. Effects of European colonization on indigenous ecosystems: post-settlement changes in tree stand structures in Eucalyptus–Callitris woodlands in central New South Wales, Australia. J. Biogeogr. 33, 1102–1115.
Lunt, I.D., Winsemius, L.M., McDonald, S.P., Morgan, J.W., Dehaan, R.L., 2010. How widespread is woody plant encroachment in temperate Australia? Changes in woody vegetation cover in lowland woodland and coastal ecosystems in Victoria from 1989 to 2005. J. Biogeogr. 37, 722–732.
Margules, C.R., Pressey, R.L., 2000. Systematic conservation planning. Nature 405, 243–253.
Margules, C.R., Sarkar, S., 2007. Systematic Conservation Planning. Cambridge University Press, Cambridge.
Marris, E., 2008. The heart of the wood. Nature 455, 277–280.
Martin, P.H., Canham, C.D., Marks, P.L., 2009. Why forests appear resistant to exotic plant invasions: intentional introductions, stand dynamics, and the role of shade tolerance. Front. Ecol. Environ. 7, 142–149.
Martin, P.S., Klein, R.G. (Eds.), 1984. Quarternary Extinctions: A Prehistoric Revolution. University of Arizona Press, Tucson.
Martin, T.J., Ogden, J., 2006. Wind damage and response in New Zealand forests: a review. New Zeal. J. Ecol. 30, 295–310.
McDadi, O., Hebda, R.J., 2008. Change in historic fire disturbance in a Garry oak (Quercus garryana) meadow and Douglas-fir (Pseudotsuga menziesii) mosaic, University of Victoria, British Columbia, Canada: a possible link with First Nations and Europeans. For. Ecol. Manage. 256, 1704–1710.
McDonald-Madden, E. et al., 2010. Monitoring does not always count. Trends Ecol. Evol. 25, 547–550.

McEwan, R.W., Dyer, J.M., Pederson, N., 2011. Multiple interacting ecosystem drivers: toward an encompassing hypothesis of oak forest dynamics across eastern North America. Ecography 34, 244–256.
McKinney, M.L., Lockwood, J.L., 1999. Biotic homogenization: a few winners replacing many losers in the next mass extinction. Trends Ecol. Evol. 14, 450–453.
McLain, R.J., Lee, R.G., 1996. Adaptive management: promises and pitfalls. Environ. Manage. 20, 437–448.
McLaren, B.E., Peterson, R.O., 1994. Wolves, moose, and tree rings on Isle Royale. Science 266, 1555–1558.
MEA (Millenium Ecosystem Assessment), 2005. Current State & Trends Assessment. <http://www.Milleniumassessment.org/en/Condition.aspx> (Chapter 21).
Milad, M., Schaich, H., Bürgi, M., Konold, W., 2012. Climate change and nature conservation in Central European forests: a review of consequences, concepts and challenges. For. Ecol. Manage. 261, 829–843.
Milton, K., 2002. Loving Nature: Towards an Ecology of Emotion. Routledge, New York.
Mitchell, F.J.G., Kirby, K.J., 1990. The impact of large herbivores on the conservation of semi-natural woods in the British Uplands. Forestry 63, 333–353.
Mitchell, F.J.G., 2005. How open were European primeval forests? Hypothesis testing using palaeoecological data. J. Ecol. 93, 168–177.
Mitlacher, K., Poschlod, P., Rosen, E., 2002. Restoration of wooded meadows – a comparative analysis along a chronosequence on Öland (Sweden). Appl. Veg. Sci. 5, 63–73.
Molinari, C., Bradshaw, R.H.W., Risbol, O., Lie, M., Ohlson, M., 2005. Long-term vegetational history of a Picea abies stand in south-eastern Norway: implications for the conservation of biological values. Biol. Conserv. 126, 155–165.
Mountford, E.P., 2002. Fallen dead wood levels in the near-natural beech forest at La Tillaie reserve, Fontainebleau, France. Forestry 75, 203–208.
Moning, C., Müller, J., 2009. Critical forest age thresholds for the diversity of lichens, molluscs and birds in beech (*Fagus sylvatica* L.) dominated forests. Ecol. Indicat. 9, 922–932.
Mundo, I., Kitzberger, T., Roig Junent, F.A., Villabla, R., 2012. Fire history in the Araucaria araucana forests of Argentina: human and climate influences. Int. J. Wildl. Fire 22, 194–226.
Myklestad, A., Saetersdal, M., 2003. Effects of reforestation and intensified land use on vascular plant species richness in traditionally managed hay meadows. Ann. Bot. Fenn. 40, 423–441.
Nagaike, T., Yoshida, T., Miguchi, H., Nakashizuka, T., Kamitani, T., 2005. Rehabilitation for species enrichment in abandoned coppice forests in Japan. In: Stanturf, J.A., Madsen, P. (Eds.), Restoration of Boreal and Temperate Forests. CRC press, Boca Raton, pp. 371–381.
Nakashizuka, T., Iida, S., 1995. Composition, dynamics and disturbance regime of temperate deciduous forests in Monsoon Asia. Vegetatio 121, 23–30.
Nichols, J.D., Williams, B.K., 2006. Monitoring for conservation. Trends Ecol. Evol. 21, 668–673.
Nielsen, A.B., 2013. Municipal woodland in Denmark: resources, governance and management. Scand. J. For. Res. 28, 49–63.
Niklasson, M., Drakenberg, B., 2001. A 600-year tree-ring fire history from Norra Kvills National Park, southern Sweden: implications for conservation strategies in the hemiboreal zone. Biol. Conserv. 101, 63–71.
Niklasson, M. et al., 2010. A 350-year tree-ring fire record from Białowieza Primeval Forest, Poland: implications for Central European lowland fire history. J. Ecol. 98, 1319–1329.
Nilsson, C., Stjernquist, I., Bärring, L., Schlyter, P., Jönsson, A.M., Samuelsson, H., 2004. Recorded storm damage in Swedish forests 1901–2000. For. Ecol. Manage. 199, 165–173.
Nilsson, S.G., Niklasson, M., Hedin, J., et al., 2002. Densities of large living and dead trees in old-growth temperate and boreal forests. For. Ecol. Manage. 161, 189–204.
Nitschke, C.R., 2005. Does forest harvesting emulate fire disturbance? A comparison of effects on selected attributes in coniferous-dominated headwater systems. For. Ecol. Manage. 214, 305–319.
Nock, C.A., Caspersen, J.P., Thomas, S.C., 2008. Large ontogenetic declines in intra-crown leaf area index in two temperate deciduous tree species. Ecology 89, 744–753.
Nordén, B., Götmark, F., 2008. Biobränsle från lövdominerad skog: uttagsnivå och relation till biologisk mångfald på död ved. Report contract 30382–1, Swedish Energy Agency, 14p (in Swedish).
Nordén, B., Götmark, F., Tönnberg, M., Ryberg, M., 2004. Dead wood in semi-natural temperate broadleaf woodland: contribution of coarse and fine dead wood, attached dead wood and stumps. For. Ecol. Manage. 194, 235–248.
Nordén, B., Götmark, F., Ryberg, M., Paltto, H., Allmer, J., 2008. Partial cutting reduces species richness of fungi on woody debris. Can. J. For. Res. 38, 1807–1816.
Nordén, B., Paltto, H., Claesson, C., Götmark, F., 2012. Partial cutting can enhance epiphyte conservation in temperate oak-rich forests. For. Ecol. Manage. 270, 35–44.
Norton, D., 2003. Sustainable forest management in New Zealand. In: Lindenmayer, D.B., Franklin, J.F. (Eds.), Towards Forest Sustainability. CSIRO Publishing, Collingwood, pp. 167–188.
Nowacki, G.J., Trianosky, P.A., 1993. Literature on old-growth forests of eastern North America. Nat. Areas J. 13, 87–107.
Økland, B., Götmark, F., Nordén, B., 2008. Oak woodland restoration: testing the effects on biodiversity of mycetophilids in southern Sweden. Biodiv. Conserv. 17, 2599–2616.
Ohsawa, M., 2007. The role of isolated old oak trees in maintaining beetle diversity within larch plantations in the central mountainous region of Japan. For. Ecol. Manage. 250, 215–226.
Oliver, C.D., Larsson, B.C., 1990. Forest Stand Dynamics. McGraw-Hill, New York.
Olson, D.M. et al., 2001. Terrestrial ecoregions of the World: a new map of life on Earth. BioScience 51, 1–6.
Olsson, F. et al., 2010. A continuous record of fire covering the last 10,500 calendar years from southern Sweden: the role of climate and human activities. Palaeogeogr. Palaeoclimat. Palaeoecol. 291, 128–141.
Orians, G.H., 1986. An ecological and evolutionary approach to landscape aesthetics. In: Penning-Rowsell, G.C., Lowentha, D. (Eds.), Landscape Meanings and Values. Allen & Unwin, London, pp. 3–25.
Paillet, Y. et al., 2010. Biodiversity differences between managed and unmanaged forests: meta-analysis of species richness in Europe. Conserv. Biol. 24, 101–112.
Paltto, H., Nordén, B., Götmark, F., 2008. Partial cutting as a conservation alternative for oak Quercus spp. forest – response of bryophytes and lichens on dead wood. For. Ecol. Manage. 256, 536–547.
Paltto, H., 2009. Mångfald av markmossor i ekrik lövskog – effekter av biobränsleuttag. Report contract 31733-1, Swedish Energy Agency, 8p (in Swedish).
Paltto, H., Nordberg, A., Nordén, B., Snäll, T., 2011. Development of oak wood pastures into secondary woodland reduces the richness of rare epiphytic lichens. PLoS ONE 6 (9), e2467.
Parrotta, J.A., Agnoletti, M., 2007. Traditional forest knowledge: challenges and opportunities. For. Ecol. Manage. 249, 1–4.
Parviainen, J., Bücking, W., Vandekerkhove, K., Schuck, A., Päivinen, R., 2000. Strict forest reserves in Europe: efforts to enhance biodiversity and research on forests left for free development in Europe (EU-COST-Action E4). Forestry 37, 107–118.
Pauchard, A. et al., 2010. Introduced conifer invasions in South America: an update. Front. Biogeogr. 2, 34–36.
Pausas, J.G., Keeley, J.E., 2009. A burning story: the role of fire in the history of life. BioScience 59, 593–601.
Peterken, G.F., 1993. Long-term studies in forest nature reserves. In: Broekmeyer, W., Vos, W., Koop, H. (Eds.), European Forest Reserves. Scientific Publishers, Wageningen, pp. 35–48, Pudoc.
Peterken, G.F., 2001. Natural Woodland: Ecology and Conservation in Northern Temperate Regions. University of Cambridge, UK.
Peterken, G.F., Jones, E.W., 1987. Forty years of change in Lady Park Wood: the old-growth stands. J. Ecol. 75, 401–429.
Peterken, G.F., Jones, E.W., 1989. Forty years of change in Lady Park Wood: the young-growth stands. J. Ecol. 77, 477–512.
Peterken, G.F., Tubbs, C.R., 1965. Woodland regeneration in the New Forest, Hampshire since 1650. J. Appl. Ecol. 2, 159–170.
Peters, R., 1997. Beech Forests. Geobotany 24. Kluwer.
Peterson, D.W., Reich, P.B., 2001. Prescribed fire in oak savanna: fire frequency effects on stand structure and dynamics. Ecol. Appl. 11, 914–927.
Pickett, S.T.A., White, P.S. (Eds.), 1985. The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, New York.
Pike, D.A., Webb, J.K., Shine, R., 2011. Chainsawing for conservation: ecologically informed tree removal for habitat management. Ecol. Manage. Restor. 12, 1–9.
Platt, J.R., 1964. Strong inference. Science 146, 347–353.
Pollock, S.L., Payette, S., 2010. Stability in the patterns of long-term development and growth of the Canadian spruce–moss forest. J. Biogeogr. 37, 1684–1697.
Pontailler, J.-Y., Faille, A., Lemée, G., 1997. Storms drive successional dynamics in natural forests: a case study in Fontainebleau forest (France). For. Ecol. Manage. 98, 1–15.
Potapov, P., 2008. Mapping the world's intact forest landscapes by remote sensing. Ecol. Soc. 13 (2), 51.
Prach, K., Marrs, R., Pysek, P., van Diggelen, R., 2007. Manipulation of succession. In: Walker, L.R., Walker, J., Hobbs, R.J. (Eds.), Linking Restoration and Ecological Succession. Springer, New York, pp. 121–149.
Prevosto, B. et al., 2011. Impacts of land abandonment on vegetation: successional pathways in European habitats. Folia Geobot. 46, 303–325.
Pungetti, G., Oviedo, G., Hooke, D. (Eds.), 2012. Sacred Species and Sites. Advances in Biocultural Conservation. Cambridge University Press, Cambridge.
Putman, R.J., 1986. Grazing in Temperate Ecosystems, Large Herbivores and the Ecology of the New Forest. Croom Helm, London.
Pykälä, J., 2000. Mitigating human effects on European biodiversity through traditional animal husbandry. Conserv. Biol. 14, 705–712.
Rackham, O., 1998. Implications of historical ecology for conservation. In: Sutherland, W. (Ed.), Conservation Science and Action. Blackwell, Oxford, pp. 152–174.
Rackham, O., 2006. Woodlands. The New Naturalist Library 100. HarperCollins, London.
Rancka, B. 2013. Conservation thinning in mixed oak forest: negative but mild effect on land molluscs. MSc Thesis, Dept of Biology and Environmental Sciences, Univ. of Gothenburg, Sweden, 33 p.
Ranius, T., Jansson, N., 2000. The influence of forest regrowth, original canopy cover and tree size on saproxylic beetles associated with old oaks. Biol. Conserv. 95, 85–94.
Roberge, J.M., Angelstam, P., Villard, M.-A., 2008a. Specialised woodpeckers and naturalness in hemiboreal forests – deriving quantitative targets for conservation planning. Biol. Conserv. 141, 997–1012, error in 141, 1728–1729.

Roberge, J.M., Mikusinski, G., Svensson, S., 2008b. The white-backed woodpecker: umbrella species for forest conservation planning? Biodiv. Conserv. 17, 2479–2494.
Roberts, L., Stone, R., Sugden, A., 2009. The rise of restoration ecology (also Special Section). Science 325, 555–576.
Röhrig, E., Ulrich, B. (Eds.), 1991. Temperate Deciduous Forests. Ecosystems of the World 7. Elsevier, Amsterdam.
Rotherham, I.D., 2007. The implications of perceptions and cultural knowledge loss for the management of wooded landscapes: a UK case-study. For. Ecol. Manage. 249, 100–115.
Runte, A., 1987. National Parks: The American Experience. University of Nebraska Press, Lincoln.
Safriel, U.N., 1997. The Carmel fire and its conservation repercussions. Int. J. Wildl. Fire 7, 277–284.
Sánchez-Jardón, L., Acosta, B., del Pozo, A., Casado, M.A., Ovalle, C., Elizalde, H.F., Hepp, C., de Miguel, J.M., 2010. Grassland productivity and diversity on a tree cover gradient in Nothofagus pumilio in NW Patagonia. Agric. Ecosyst. Environ. 137, 213–218.
Sanderson, E.W., Jaiteh, M., Levy, M.A., Redford, K.H., Wannebo, A.V., Woolmer, G., 2002. The human footprint and the last of the wild. BioScience 52, 891–904.
Schelhaas, M.-J., Nabuurs, G.-J., Schuck, A., 2003. Natural disturbances in the European forests in the 19th and 20th centuries. Global Change Biol. 9, 1620–1633.
Schmitt, C.B. et al., 2009. Global analysis of the protection status of the world's forests. Biol. Conserv. 142, 2122–2130.
Schulte, L.A., Mitchell, R.J., Hunter Jr., M.L., Franklin, J.F., McIntyre, R.K., Palik, B.J., 2006. Evaluating the conceptual tools for forest biodiversity conservation and their implementation in the U.S. For. Ecol. Manage. 232, 1–11.
Schulte, L.A., Mottl, E.C., Palik, B.J., 2011. The association of two invasive shrubs, common buckthorn (Rhamnus cathartica) and Tartarian honeysuckle (Lonicera tatarica), with oak communities in the midwestern United States. Can. J. For. Res. 41, 1981–1992.
Shafer, C.L., 1995. Values and shortcomings of small reserves. BioScience 45, 80–88.
Shahabuddin, G., Rao, M., 2010. Do community-conserved areas effectively conserve biological diversity? Global insights and the Indian context. Biol. Conserv. 143, 2926–2936.
Shtilmark, F., 2003. History of the Russian Zapovedniks 1895–1995. Russian Nature Press, Edinburgh.
Sinclair, A.R.E., 1998. Natural regulation of ecosystems in protected areas as ecological baselines. Wildl. Soc. Bull. 26, 399–409.
Singer, M.T., Lorimer, C.G., 1997. Crown release as a potential old-growth restoration approach in northern hardwoods. Can. J. For. Res. 27, 1222–1232.
Sitzia, T., Semenzato, P., Trentanovi, G., 2010. Natural reforestation is changing spatial patterns of rural mountain and hill landscapes: a global overview. For. Ecol. Manage. 259, 1354–1362.
Soulé, M.E., 2003. The role of large mammals in US forests. In: Lindenmayer, D.B., Franklin, J.F. (Eds.), Towards Forest Sustainability. CSIRO Publishing, Collingwood, pp. 1–14.
Soulé, M.E., 2010. Conservation relevance of ecological cascades. In: Terborgh, J., Estes, J.A. (Eds.), Trophic Cascades: Predators, Prey, and the Changing Dynamics of Nature. Island Press, Washington, pp. 337–352.
Soulé, M.E., Terborgh, J. (Eds.), 1999. Continental Conservation. The Scientific Foundations of Regional Reserve Networks. Island Press, Washington, DC.
Sousa, W.P., 1984. The role of disturbance in natural communities. Ann. Rev. Ecol. Syst. 15, 353–391.
Spector, T., Putz, F.E., 2006. Crown retreat of open-grown southern live oaks (*Quercus virginiana*) due to canopy encroachment in Florida, USA. For. Ecol. Manage. 228, 168–176.
Spetich, M.A., Kvashnina, A.E., Nukhimovskya, Y.D., Rhodes Jr., O.E., 2009. History, administration, goal, value, and long-term data of Russia's strictly protected scientific nature reserves. Nat. Areas J. 29, 71–78.
Stanturf, J.A., Madsen, P. (Eds.), 2005. Restoration of Boreal and Temperate Forests. CRC press, Boca Raton.
Stokland, J.N., Siitonen, J., Jonsson, B.G., 2012. Biodiversity in Dead Wood. Cambridge University Press, Cambridge.
Svenning, J.C., 2002. A review of natural vegetation openness in north-western Europe. Biol. Conserv. 104, 133–148.
Szabo, P., 2010. Driving forces of stability and change in woodland structure: a case-study from the Czech lowlands. For. Ecol. Manage. 259, 650–656.
Tak, K., Chun, Y., Wood, P.M., 2007. The South Korean Forest Dilemma. Int. Forestry Rev. 9, 547–548.
Takeuchi, K., Brown, R.D., Washitani, I., Tsunekawa, A., Yokohari, M. (Eds.), 2003. Satoyama: The Traditional Rural Landscape of Japan. SpringerTokyo, Tokyo.
Thomas, J.W. et al., 2006. The Northwest Forest Plan: origins, components, implementation, experience, and suggestions for change. Conserv. Biol. 20, 277–287.
Tilman, D., 1987. Ecological experimentation: strengths and conceptual problems. In: Likens, G.E. (Ed.), Long-Term Studies in Ecology. Springer-Verlag, New York, pp. 136–157.
Timonen, J. et al., 2010. Woodland key habitats in northern Europe: concepts, inventory and protection. Scand. J. For. Res. 25, 309–324.
Thorell, M., Götmark, F., 2005. Reinforcement capacity of potential buffer zones: forest structure and conservation values around forest reserves in southern Sweden. For. Ecol. Manage. 212, 333–345.
Tokarska, M., Pertoldi, C., Kowalczyk, R., Perzanowski, K., 2011. Genetic status of the European bison *Bison bonasus* after extinction in the wild and subsequent recovery. Mammal Rev. 41, 151–162.
Trosper, R.L., 2007. Indigenous influence on forest management on the Menominee Indian Reservation. For. Ecol. Manage. 249, 134–139.
Turner, I.M., Corlett, R.T., 1996. The conservation value of small, isolated fragments of lowland tropical rain forest. Trends Ecol. Evol. 11, 330–333.
Turner, M.G. et al., 2003. Disturbance dynamics and ecological response: the contribution of long-term ecological research. BioScience 53, 46–56.
Ulyshen, M.D., 2011. Arthropod vertical stratification in temperate deciduous forests: implications for conservation-oriented management. For. Ecol. Manage. 261, 1479–1489.
Underwood, A.J., 1995. Ecological research and (and research into) environmental management. Ecol. Appl. 5, 232–247.
UNEP, 2010. Convention on Biological Diversity, UNEP/CBD/COP/DEC/X/2. Nagoya, Japan, October 2010.
van Mantgem, P.J. et al., 2009. Widespread increase of tree mortality rates in the Western United States. Science 323, 521–524.
van Vuure, C., 2005. Retracing the Aurochs – History, Morphology and Ecology of an Extinct Wild Ox. Pensoft Publishers.
Vera, F.W.M., 2000. Grazing Ecology and Forest History. CABI Publishing, Oxford, UK.
von Oheimb, G., Brunet, J., 2007. Dalby Söderskog revisited: long-term vegetation changes in a south Swedish deciduous forest. Acta Oecol. 31, 229–242.
von Oheimb, G., Westphal, C., Tempel, H., Härdtle, W., 2005. Structural pattern of a near- natural beech forest (*Fagus sylvatica*) (Serrahn, North-east Germany). For. Ecol. Manage. 212, 253–263.
Wallis de Vries, M.F., 1998. Large herbivores as key factors for nature conservation. In: WallisDeVries, M.F., Bakker, J.P., Van Wieren, S. (Eds.), Grazing and Conservation Management. Kluwer, Dordrecht, pp. 1–20.
Wesolowski, T., 2005. Virtual conservation: how the European Union is turning a blind eye to its vanishing primeval forests. Conserv. Biol. 19, 1349–1358.
White, M.A., Mladenoff, D.J., 1994. Old-growth forest landscape transitions from pre-european settlement to present. Landsc. Ecol. 9, 191–205.
White, P.S., Bratton, S.P., 1980. After preservation: philosophical and practical problems of change. Biol. Conserv. 18, 241–255.
Whitney, G.G., 1984. Fifty years of change in the arboreal vegetation of heart's content, an old-growth hemlock-white pine-northern hardwood stand. Ecology 65, 403–408.
Weiner, D.R., 1999. A Little Corner of Freedom. Russian Nature Protection from Stalin to Gorbachev. University of California Press, Berkeley.
Williams, J.E., Woinarski, J.C.Z. (Eds.), 1997. Eucalypt Ecology. Cambridge University Press, Cambridge.
Williams, M., 2003. Deforesting the Earth. University of Chicago Press, Chicago.
Willers, B., 2002. Pleistocene diversity as a biological "baseline" (Review of Flannery, T., The Eternal Frontier). Conserv. Biol. 16, 564–565.
Woods, K.D., 2000a. Dynamics of late-successional hemlock–hardwood forests over three decades. Ecology 81, 110–126.
Woods, K.D., 2000b. Long-term change and spatial pattern in a late-successional hemlock–northern hardwood forest. J. Ecol. 88, 267–282.
Woods, K.D., 2004. Intermediate disturbance in a late-successional hemlock-northern hardwood forest. J. Ecol. 92, 464–476.
Wuerthner, G. (Ed.), 2006. The Wildfire Reader. A Century of Failed Forest Policy. Island Press, Washington.
Yamaura, Y., Oka, H., Taki, H., Ozaki, K., Tanaka, H., 2012. Sustainable management of planted landscapes: lessons from Japan. Biodiv. Conserv. 21, 3107–3129.
Young, I.R., Zieger, S., Babanin, A.V., 2011. Global trends in wind speed and wave height. Science 332, 451–455.