

POLICY PERSPECTIVE

Natural Versus National Boundaries: The Importance of Considering Biogeographical Patterns in Forest Conservation Policy

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Abstract

Applying biogeographical insights to the regulation of production forestry and the determination of forest reserve strategies is expected to increase the effectiveness of biodiversity conservation actions. Here, we assess the extent to which such applications take place. By using Sweden as a case study, we demonstrate fundamental differences among biogeographical regions in natural patterns and processes, past land-use, and anthropogenic impacts that need to be better incorporated into strategic conservation planning and decisions. Furthermore, assessment of specific forestry regulations and biogeographical variation in a number of other countries/provinces embracing boreal and temperate biomes also indicate that natural boundaries are insufficiently considered in forest management policies. We suggest that a substantial potential exists to better align conservation priorities with biogeographical characteristics. To illustrate the application of such an approach, we present a decision support model on how forest conservation policies that rest on natural boundaries and ecological processes can be developed.

Introduction

Conversion and degradation of the Earth's forest ecosystems is a significant contributor to currently elevated rates of species extinction (Secretariat of the Convention on Biological Diversity 2010). Two-thirds of the world's remaining forests have now lost their primary status, and during the last decade alone over 40 million ha were degraded or cleared (FAO 2010). Stemming the global biodiversity crisis requires substantial improvements in the designation and sustainable management of protected and production forests alike, which in-turn needs more effective forest conservation policies. Policies are unlikely to be effective if they do not account for the range of forest ecosystems a nation or a region con-

tains. Nevertheless, a recent cross-national comparative study of specific environmental forest policies embracing 20 countries and also numerous states and provinces (McDermott *et al.* 2010) indicates that many countries have at least some forest practice policies that are unlikely to capture or account for variation in natural forest conditions.

The term "conservation biogeography" has been coined to stress the need to apply biogeographical principles, theories and analyses to problems regarding biodiversity conservation (Ladle & Whittaker 2011). One focus hitherto has been the identification of limited and threatened areas of utmost importance to species diversity, e.g., hotspots (Myers *et al.* 2000) and key ecoregions (Olson *et al.* 2001), especially at the global level. Analyses

of how spatial variation in ecological conditions needs to be taken into account when developing environmental policies within nations are also at the core of this science branch (Ladle & Whittaker 2011). Here, we focus on how biogeographical patterns and associated ecological processes should preferably direct forest conservation strategies, with boreal and temperate forests in target. We present two cases: first we provide an assessment of biogeography, natural processes, forest conservation policy, and production forestry operations for a single country, Sweden, a nation that extends over 14 degrees of latitude, with forests belonging to boreal and temperate biomes. We assess whether divergent circumstances between biomes within this country likely require specific conservation policy interventions to rectify forest ecosystem degradation and associated species loss. Second, we compile information on clear-cut size limits and number of ecoregions in a selection of boreal countries/provinces to analyze how well forest management policies appear to align with biogeographical variation. We end by presenting a decision support model for adjusting forest conservation policies to natural boundaries. Our conclusions and recommendations are likely relevant for forest-dominated and biogeographically diverse nations and regions around the globe.

Sweden as a case study: boreal and temperate biomes require different policies

Biomes, forestry, and conservation in Sweden

Sweden encompasses boreal and temperate biomes, and is separated by a hemiboreal transition zone (Figure 1). Forestry is an important industrial activity with wood used for pulp and timber, and increasingly also for bioenergy. Forests cover 65% of the land-area and >90% of the productive forest land of 23 million ha is used for forestry, with the majority consisting of even-aged stands dominated by the indigenous tree species Norway spruce *Picea abies* (L.) H. Karst and Scots pine *Pinus sylvestris* L. (Swedish Forest Agency 2013). Intensive approaches to forestry have been conducted for more than 50 years, and have caused substantial declines in biodiversity, manifested in a large number of forest-dependent red-listed species (Gärdenfors 2010). Establishment of protected areas has been the traditional instrument for conservation; approximately 4% of productive forest land is formally protected (2% beneath the mountain region), and an additional ca. 5% is set aside by forest owners as part of forest certification requirements (Swedish Forest Agency 2013). However, during the last two decades, retention actions, i.e., sav-

ing trees and tree patches at the time of harvest, have been applied to substantial areas of production forests in Sweden.

A central target for Sweden's biodiversity is that "Species habitats and ecosystems and their functions and processes must be safeguarded. Species must be able to survive long-term in viable populations with sufficient genetic variation" (Regeringskansliet & Miljödepartementet 2012). Certification has rapidly increased for 20 years, resulting in >70% of the productive forest land certified according to FSC (Forest Stewardship Council) and/or PEFC (Programme for the Endorsement of Forest certification).

Swedish national policies do not consistently adhere to natural boundaries

The conditions influencing biodiversity and its conservation clearly differ between Sweden's boreal and temperate zones. For instance, there are more tree species and productivity is higher in the south than in the north, while the proportion of protected forests is higher in the north (Figure 1). The biomes also diverge with regards to natural processes, types and intensity of former agricultural land-use, and the degree of impact from industrial forestry (Table 1). Examples of disconnects between natural boundaries and national policies include the Forestry Act and FSC and PEFC certification standards that do not adjust retention approaches to biome-specific conditions, despite the potential ineffectiveness of retaining tree species and habitat types irrespective of their importance to the regional flora and fauna. Furthermore, the loss of broadleaf trees species has disproportionately occurred in the south, driven in part by extensive conversion to spruce plantations (Gustafsson & Ahlén 1996) but current forest policies are not built to rectify more than a minor proportion of these historical losses. In addition, current policies assume that lower levels of atmospheric nitrogen deposition in the boreal zone translate into an increased opportunity for nitrogen forest fertilization in this region, although a relatively small addition of fertilizer to boreal forest stands can have a disproportionately large and adverse effect on forest floor vegetation (Hedwall *et al.* 2013).

Standardized clear-cut size limits indicate mismatches between policy and biogeographical variation

Clearcutting is widely used as a harvesting method in boreal and temperate regions (Kimmins 1992). It is reasonable that policies regarding clearcut sizes should correspond to natural disturbance dynamics, which is a strong

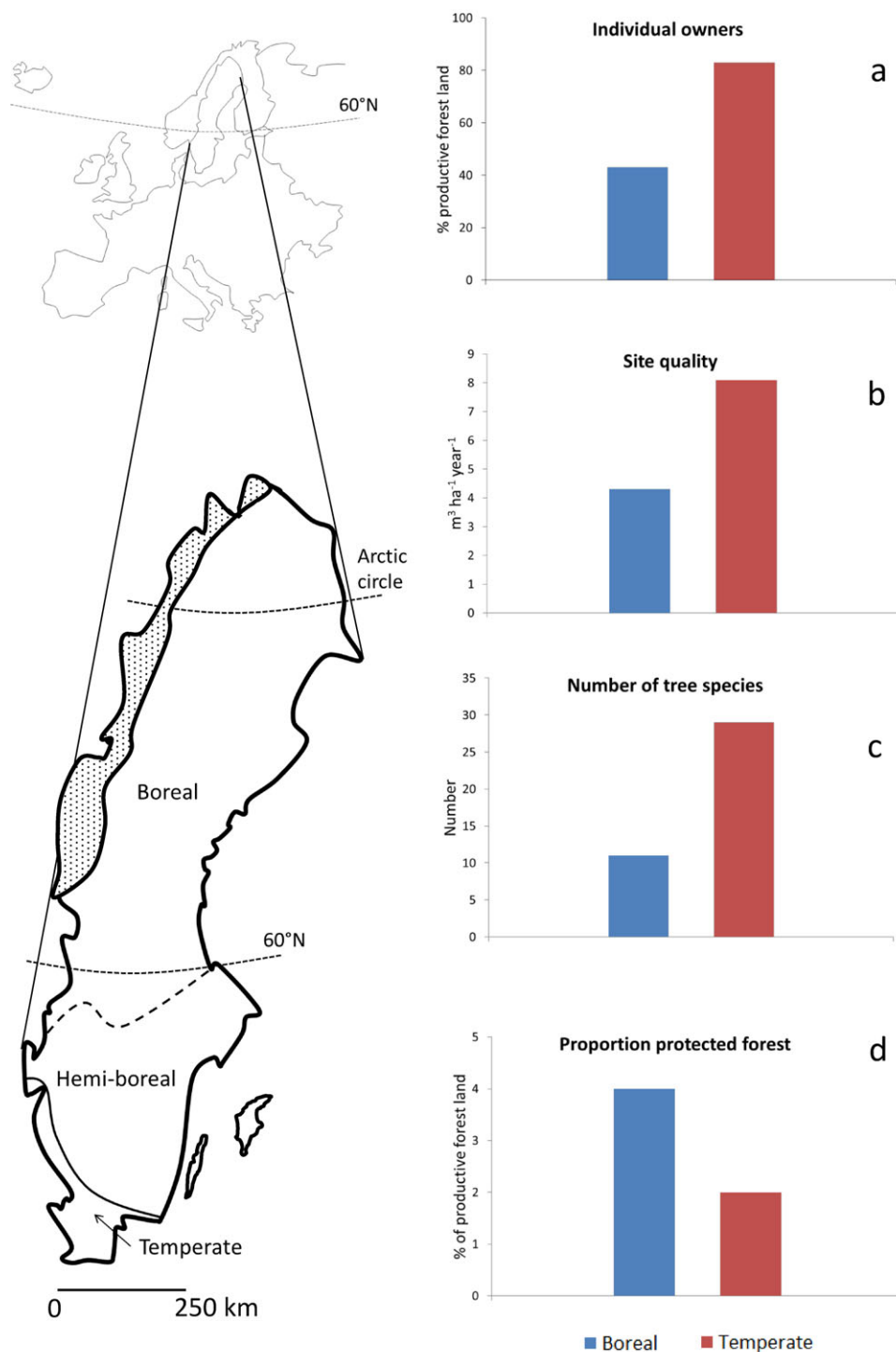


Figure 1 Examples of differences in land tenure, forest conditions, biodiversity, and conservation efforts between the boreal and temperate biomes of Sweden (excluding the hemiboreal transition zone), which require recognition in environmental policies. For more differences, see Table 1. Individual owners are single owners, estates, and small companies with an average amount of forest land of ca. 50 ha. Site quality is the potential annual increase in tree volume per hectare, and provides an estimate of productivity (average per biome). Sources: (a), (b), and (d) (Swedish Forest Agency 2013), (c) (Mossberg *et al.* 1992).

Table 1 Examples of factors of importance to biodiversity conservation that differ between the boreal and temperate biomes of Sweden. For more biome-specific conditions, borders and additional differences, see Figures 1

Factors important to biodiversity conservation	Boreal	Temperate
Natural patterns and processes associated with biomes		
Disturbance dynamics	Larger-scale disturbance processes Fire more important	Smaller scale gap-phase dynamics Wind more important
Forest-age composition at landscape level	Varied	Old forests dominate
Main tree species	Coniferous-dominated. Norway spruce <i>Picea abies</i> , Scots pine <i>Pinus sylvestris</i> , birch <i>Betula</i> spp., aspen <i>Populus tremula</i>	Broadleaved-dominated: Oak <i>Quercus robur</i> , <i>Quercus petraea</i> , beech <i>Fagus sylvatica</i> , ash <i>Fraxinus excelsior</i> , lime <i>Tilia cordata</i> , alder <i>Alnus glutinosa</i>
Past land-use		
Agricultural use of current forest land	Low-impact farming near settlements, partly from slash and burn	Long and substantial impact via cattle grazing, mowing, and coppice
Anthropogenic impact		
Proportion remaining intact forest	Low	Very low
Eutrophication (due to nitrogen fertilization and deposition)	Low	High

driver of ecosystem processes and thus of fundamental importance to biodiversity (Kuuluvainen & Grenfell 2012). Smaller clear-cut limits may be more suited to areas with single-tree or tree-group mortality due to wind-fall, insects, or pathogens like in the temperate biome (Nagel *et al.* 2013) while larger sizes should be more adequate to regions where fires may result in much larger disturbances, as in the boreal biome (Kneeshaw *et al.* 2011). An analysis of seven countries and provinces traversing boreal and temperate biomes reveals that none has >3 clearcut size limits although ecoregion variation often is large (Figure 2). For instance, Russia has only one limit referring to biogeographical variation (250 ha for hardwood pioneer species in the Far East) although this country embraces 15 ecoregions. Although not all of a state's forested ecoregions can be assumed to require distinct forest management policies, we see the lack of correspondence in this example as reflecting a general pattern of low recognition of natural boundaries.

The road ahead: policies that rest on natural boundaries and ecological processes

Potential for biogeographical approaches within and across nations

Our assessment of circumstances in Sweden as well as of regulations on clear-cut sizes in a number of boreal and temperate states indicate that there is a large potential to

better adjust to biogeographical variation. Improvement of policies may also be important among nations. For instance, a common forest strategy was recently adopted by the European Commission but lacked acknowledgment of the extensive gradients in biodiversity, natural disturbances, soils, water, and climate on this continent (European Commission 2013). Admittedly, there are also good examples of regional approaches in large nations with extensive biogeographical gradients, like subdivision into regional Forest Stewardship Council (FSC) for Canada.

Inadequate accounting of biogeographical considerations in forest policy is unlikely to be limited to the boreal and temperate biomes. Further research is thus needed to assess the extent of this problem in the biogeographically and biologically diverse tropical and subtropical regions. For instance in a mega-diverse country like Brazil it will be crucial to acknowledge biome differentiation in forest policies, like the Forest Code, and in programs for protected areas, like the National System of Conservation Units (SNUC; Silva 2005).

The importance of socioeconomic context

Socioeconomic context substantially contributes to conservation success. For example, land-ownership needs to be considered when developing biome-targeted forest conservation policies. In Sweden, the proportion of forest owners with small land-holdings is considerably higher in the temperate zone than in the boreal zone

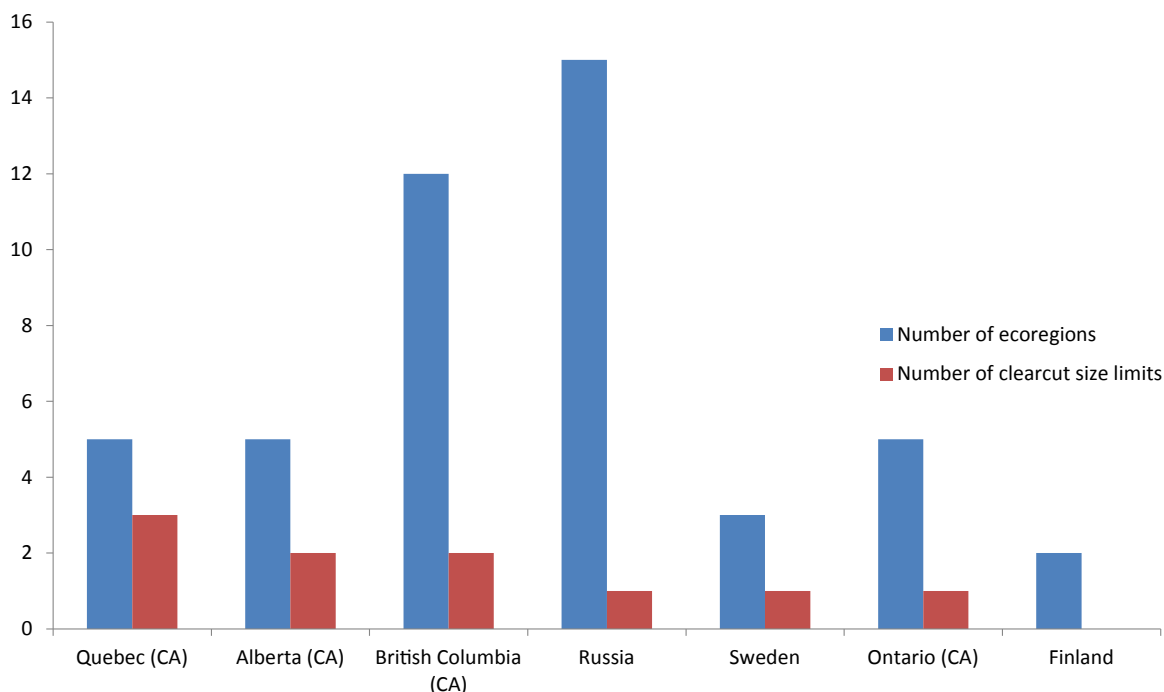


Figure 2 Clear-cut size limits and number of forest ecoregions (to indicate biogeographical variation) in a selection of countries/provinces that belong to both the boreal biome and the temperate biome and in which clear-cutting takes place. Countries/provinces are ordered according to number of clearcut-size limits. CA = Canada. Sources: Clear-cut limits: McDermott *et al.* (2010), ecoregions: Olson *et al.* (2001). The biome classification of Olson *et al.* (2001) differs slightly from the one presented in Figure 1. For more details, see Supporting Information Table S1.

(Figure 1), with associated implications for conservation. It restricts the implementation of landscape-level planning in the south since cooperation among multiple owners is often problematic. Swedish laws and regulations nevertheless apply equally to all types of landowners. In many other countries, differences in whether forests are owned publicly or privately may complicate the alignment of environmental forest policy to biogeographical boundaries. For example, in many countries, like the United States, environmental forest policies are relatively weak for privately owned forest lands, while restrictions are stronger on publicly owned forest lands which also have larger exposure to public scrutiny (McDermott *et al.* 2010). If forest ownership patterns associated with weaker national restrictions, overlap with forest regions requiring tighter forest regulation, then ineffective or degrading outcomes for forested environments can be exacerbated.

Historical development may affect conservation

Biogeography-based conservation interventions may also be necessary to maintain traditional land-uses that over centuries or millennia produced ecosystems hosting a

flora and fauna that today is rare and threatened (Götmark 2013). Landscapes shaped by ancient agricultural practices are found worldwide and are of global significance for biodiversity (Secretariat of the Convention on Biological Diversity 2010). The degree to which ecosystems are shaped by former land-uses often differs depending on the biomes or other biogeographical units considered. For instance, traditional agricultural practices have been comparatively limited in the boreal zone of Sweden. In contrast, during pre-industrial times in the temperate zone extensive cattle-grazing and hay-making created semi-open landscapes with old and large trees, providing habitats of substantial value to biodiversity (Table 1).

A decision-support model for how biogeographical differentiation can be integrated into conservation strategies and policies

To provide a pathway for integrating natural boundaries and biogeographical characteristics into conservation strategies and policies we have developed a decision support model (Figure 3). The context of application

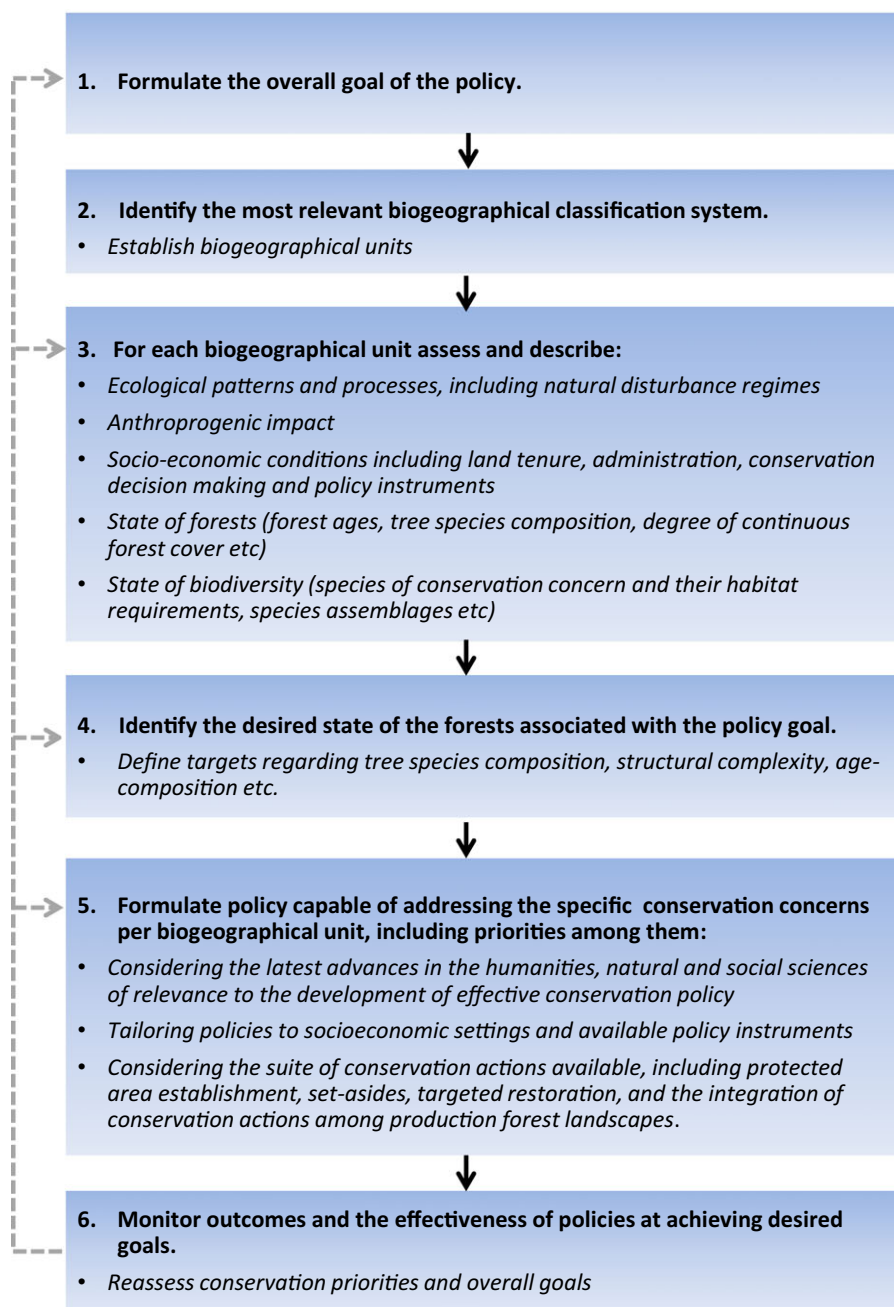


Figure 3 Decision support model for conservation policies that takes biogeography-specific conditions into account. Note that for this process to be most effective consultation with stake-holders will be necessary, and also repeated evaluations of policy outcomes and reassessment of key goals in light of knowledge advancements (dashed arrows). The biogeographical units used (step 2) may also require re-evaluation, especially with respect to changing climatic conditions.

suits both the formulation of new conservation policies as well as the identification of gaps in existing policies. *The first step* is to formulate the overall goal for the conservation policy. For the Swedish example the goal is preserving biodiversity, but goal setting may also relate

to increasing resilience, sustaining ecosystem services or other biodiversity-related values. Step one is to some extent value based, i.e., formulations of goals and desired states need to acknowledge societal perceptions on non-monetary values associated with forests. Key questions

for biodiversity conservation (as for the Swedish case) include: Should prioritizations be based on representativity, e.g., ensuring that the whole array of habitats is preserved rather than focusing on preserving rare habitats? To what extent should the aim be to emulate natural forest conditions versus the preservation of ancient cultural landscapes (see above)? To what extent and under what conditions should novel ecosystems (*sensu* Hobbs *et al.* 2009) be accepted or even encouraged, considering that they are unavoidable under climate change?

The second step is to identify existing biomes or other significant classifications, relevant to the geographical area in question. Numerous classification systems are available and it will be important to consider not only those most relevant to the set goals, but also to consider those applied by neighboring nations, to facilitate transnational approaches. *The third step* is to make a thorough analysis of conditions relevant to biodiversity (or other identified goal) for each biogeographical unit, corresponding to Figure 1 and Table 1, as per the Swedish example. This includes analysis of forest dynamics, natural forest composition, past land-use and how human impacts have affected and transformed the natural biota. Furthermore, this step includes biodiversity patterns: geographical distribution of species of conservation concern as well as their habitat requirements. Socioeconomic conditions are also essential considerations, since prerequisites for successful implementation and the application of different policy instruments may vary between biogeographic regions. *The fourth step* is to define desired states for the forests, like tree-species composition, stand age-distribution, and targets for structures of importance to biodiversity, like dead wood and old trees.

The fifth step is the formulation of the policy. Knowledge of land-tenure and available policy instruments and their acceptance is important, with the status of protected areas as a key consideration. In addition, the potential for integrated conservation actions within production forestry requires assessment. The degree to which the active restoration of degraded forest habitats is needed and how this may differ between biomes and forest habitats also needs to be decided. All of these considerations should be made for each biogeographical unit, and prioritizations regarding different conservation measures within and between units will be the core outcome of this approach. For this process to be effective *a sixth and final step* is needed; repeated evaluations of policy outcomes as well as reassessment of key goals in light of knowledge advancements. Without following such a process, akin to those advocated in adaptive management frameworks (Rist *et al.* 2013), even attempts considering biogeographical differences can result in undesirable outcomes for biodiversity.

Conclusions

A stronger emphasis on biogeographical boundaries will very likely lead to more effective forest conservation actions. To provide for such a development, we have suggested an approach for biogeographic analysis to support policy processes, mainly based on biome-specific characteristics. In due time, it will also be crucial to target smaller biogeographical units, and fine-tune resultant policies. Transition zones between biomes, in our case the hemiboreal, also need further attention since their intermediate position will most likely support comparatively rich biodiversity. Our analysis indicates a substantial need to better align environmental forest policies with the biogeographically distinct requirements of biodiversity conservation.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Table S1. Prescriptions regarding clearcut size and forest area (McDermott *et al.* 2010) for a selection of countries and provinces in the northern hemisphere that belong to the boreal biome as well as the temperate biome.

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