Introduction

Disturbance Dynamics in Boreal Forests: Defining the Ecological Basis of Restoration and Management of Biodiversity

Timo Kuuluvainen

Disturbance is any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, and substrate availability or the physical environment.

Pickett and White (1985)

1 Introduction

Knowledge of forest disturbance and successional processes, population dynamics of forest-dwelling species, and the interaction between these two, is a prerequisite for developing ecologically more sustainable forest management strategies. To address these issues, a conference entitled "Disturbance dynamics in boreal forests: restoration and management of biodiversity" was held in Kuhmo, eastern Finland, on 21–25 August 2000. The conference was the third one with the general theme of disturbance dynamics in boreal forests (Engelmark et al. 1993, Bergeron et al. 1998). During the one-week conference 108 talks and 64 posters were presented, representing both basic ecological research on disturbance dynamics and applications of this knowledge to the restoration and management of biodiversity in different parts of the circumboreal forest (Karjalainen and Kuuluvainen 2000, Burton and Kuuluvainen 2001). Twenty-six of these presentations appear as scientific papers on the following pages.

2 Disturbances, Heterogeneity, and Biodiversity

Forest ecosystems are highly variable in structure, function, and species diversity. This heterogeneity of habitats and species in space and time is called *biodiversity* (Kouki 1994). Disturbances are important for biodiversity because they largely determine the characteristics of the habitat mosaic, which, in turn, affect the population dynamics of forest-dwelling species.

All forest ecosystems are characterized by disturbances (Pickett and White 1985, Attiwill 1994). In natural boreal forests, disturbances are caused by such factors as fires, storms, insects, pathogens, floods, and animals including the moose and beaver (Esseen et al. 1997, Engelmark 1999). The occurrence of these disturbances and the time interval between them, i.e. the length of relatively uninterrupted successional development, contribute to the structural heterogeneity and overall biodiversity of the forest ecosystem (Pickett and White 1985, Kuuluvainen 1994, Pickett et al.

Timo Kuuluvainen, Department of Forest Ecology, P.O. Box 27, FIN-00014 University of Helsinki, Finland.
E-mail: Timo.Kuuluvainen@helsinki.fi

Fig. 1. The structure and species composition of natural boreal forests are developed through an intricate interplay between disturbance and successional processes that operate at different spatial scales over long periods. Historical materials can be a useful information source of natural disturbance dynamics and variability of the boreal forest. Old boreal forest photographed in 1903 in the Orivesi district, southern Finland (photograph by Brutus Lesche). Archives of the Department of Forest Ecology, University of Helsinki.

1997, Bergeron et al. 1998, see Fig. 1).

However, human actions are at an accelerating rate replacing natural disturbances in the boreal forest (Esseen et al. 1997). In many regions, forest management has become the main driving force affecting forest dynamics. While human simplification and modification of forest structure to meet management goals, such as production of timber, have often been successful in creating resource flow stability, this has happened at the expense of biological diversity (Kouki 1994, Esseen et al. 1997, Linder and Östlund 1999, Siitonen 2001).

Dead wood provides a good example of the close connection between disturbances and biodiversity. In natural boreal forests, recurring disturbances, from small-scale gap perturbations to stand-replacing catastrophic events, kill trees and create dead wood (Jonsson and Kruys 2001). Dead trees are important for biodiversity because of the large number of species dependent on dead wood (saproxylic species). In Finland, the number of saproxylic species is estimated at 4000–5000, which makes up 20–25% of all forest-dwelling species (Siitonen 2001). In southern Finland, the average amount of coarse woody debris is 60–90 m^3/ha in natural forests but only 2–10 m^3/ha in managed forests (Siitonen 2001). This means that at the landscape level the average amount of coarse woody debris has been reduced by 90–98%. General species area models suggest that in the long run such a decline in habitat availability could lead to a loss of over 50% of the original saproxylic species in managed forests (Siitonen 2001).

The characteristics of the living tree community, determined by disturbance and successional processes, similarly contribute to species diversity. The amount and diversity of epiphytic lichens, for instance, depend on the composition and structure of the tree community (Esseen et al. 1996, Kuusinen 1996). A high epiphyte biomass, typical of old-growth forests, provides habitats for a diverse community of invertebrates, which, in turn, are an important food source for canopy-favoring passerine birds (Pettersson et al. 1995, Esseen et al. 1996). These examples serve to demonstrate the intimate links between disturbances, successions, structural variability, and biodiversity in boreal forest ecosystems.

3 Changing Perceptions of Forest Disturbances

It was not until the 1970s that ecologists started to recognize the importance of disturbances in forest ecosystems. The earlier "balance-of-nature" paradigm of ecological thinking emphasized stability, homogeneity, and predictability of successional development (Clements 1916, Cajander 1926). Although there were individual researchers who realized the importance of disturbances (e.g. Sernander 1938), the predominant attitude was that disturbances, such as fires, storms, and insect outbreaks, were exceptional events that did not really belong to the normal state of forests. Consequently, a need was perceived to protect forests against such disturbances, not only in managed forests but also in reserves. This view clearly overemphasized the role of succession and its assumed endpoint, the so-called climax, while the role of disturbances was underestimated.

The "balance-of-nature" view of forests is, in a way, congruent with the optimality model of timber management, emphasizing maximum timber production through homogeneous stand and age-class structure, and avoidance of losses due to natural disturbances ("damages"). However, it has become evident that this model of forest management often leads to reduction in biodiversity, options for production of ecosystem services other than timber, and possibly, the ability of ecosystems to adapt to environmental changes (Kouki 1994, Christensen et al. 1996, Esseen et al. 1997, Linder and Östlund 1999, Siitonen 2001). These concerns have been further amplified by the increased awareness of the important role of natural disturbances in forest ecosystems. First, it is perceived that disturbances are a necessary renewing and creative force that maintains variability and biodiversity in forest ecosystems (Pickett and White 1985, Holling 1992, Attiwill 1994). This view sharply contrasts with the old equilibrium paradigm, according to which disturbances are merely something harmful and unnatural in forest ecosystems. Second, it is now acknowledged that ecologically sustainable forest management must be based on the recognition that forest ecosystems are capable of maintaining their function, diversity, and ecological resilience under specific, constantly variable, natural disturbance regimes (Franklin 1989, Attiwill 1994, Kouki 1994, Hunter 1999, Landres et al. 1999).

Concerns about the ecological consequences of forest management combined with a better grasp of the important role of natural disturbances in forest ecosystems leads to the conclusion that to maintain native biodiversity we must apply management methods that create habitat availability sufficiently similar to that produced by natural disturbances (Attiwill 1994). From the forest ecosystem point of view, humans are just another disturbance factor in the boreal forest, comparable to fires, storms, and insect outbreaks.

4 Natural Disturbance Dynamics – a Paradigm for Ecological Restoration and Sustainable Management

The idea of using natural disturbances dynamics as a template for ecological restoration and management is straightforward and appealing but at the same time challenging to apply for at least three reasons. First, to develop rigorous management applications, we need comprehensive scientific knowledge on natural disturbance dynamics and its effects on biodiversity. This is a major research challenge because of the complexity of the phenomenon, the large spatial and temporal scales involved, and the inherent natural variability of forests (Landres et al. 1999). In some areas, no large naturally dynamic forest areas are left to be used as reference areas (e.g. Kuuluvainen 2002, Quine et al. 2002). In addition, climatic change may have variable and unpredictable effects on disturbance dynamics of the boreal forest in the future (Flannigan et al. 1998, Dale et al. 2001). Second, developing practical yet scientifically based management methods has not proven to be an easy task, although promising progress has been made. Third, the existing conceptual models combined with established management protocols may restrict the ability of managers and organizations to adopt new forest management methods.

Reliable scientific understanding of disturbance dynamics in different parts of the boreal zone is needed, since knowledge of disturbance ecology in one part of the boreal zone is often not directly applicable to another area (e.g. Canada versus Scandinavia). Although knowledge of disturbance ecology in boreal forests has increased significantly during recent years, much remains to be discovered. For example, large catastrophic disturbances were considered to be the most important type of disturbance throughout the boreal forest. However, ecologists have found that in many areas small-scale disturbances that occur continuously can actually be more influential than infrequent catastrophic disturbances (Bergeron et al. 1998, Rouvinen et al. 2002). In fact, dichotomies such as small- versus large-scale disturbances, or small versus large cycles, are misleading simplifications because disturbance dynamics is inherently a hierarchical multiscale phenomenon.

Forest structures created by natural disturbances are complex and can not be easily reproduced by management (Franklin et al. 2002). Inadequate understanding of the ecological consequences of natural disturbance dynamics, or overly simplistic application of this knowledge, may lead to forest structures that lie far beyond their natural range of variability. This can be the case, for instance, if only mean disturbance interval is imitated in regeneration cutting without giving sufficient consideration to the variability in extent, repeatability, and severity of disturbances (e.g. Pennanen 2002). This emphasizes the need for managers to have a comprehensive understanding of disturbance dynamics and successional processes of natural forests both at stand and landscape levels (Franklin et al. 2002). Furthermore, in many cases, an approach where knowledge of natural forest disturbance dynamics and population dynamics of species is combined is needed to develop methods of restoration and management of biodiversity (Burton and Kuuluvainen 2001).

Recently, several approaches have been suggested for developing strategies for more sustainable forest management based on natural disturbances or natural variability of forests (Haila et al. 1994, Coates and Burton 1997, Kohm and Franklin 1997, Angelstam 1998, Hunter 1999, Lähde et al. 1999, Bergeron et al. 2002, Franklin et al. 2002, Harvey et al. 2002, Seymour et al. 2002).

5 Disturbance Dynamics as a Conceptual Model for Ecologically Sustainable Forest Management

Natural disturbances, such as fires, storms, and insect outbreaks, have traditionally been foresters' worst enemies. The mental leap to start using these harmful events as models of silviculture and management is a substantial one and should not be underestimated. In addition, communication of disturbance dynamics is difficult because of the complexity and inherent variability of the phenomenon. The spatial and temporal scales involved are often outside ordinary human perspective. This poses challenges for researchers to transfer their knowledge to managers and other interest groups. Linking of ecological scales related to natural disturbances and human psychometric scales is needed to report what are the ecological consequences of chosen management policies (Rykiel 1998). Scientific knowledge as such is insufficient.

However, considering human actions in the forest in the framework of disturbance ecology may provide us with a new conceptual model to utilize forests on a more sustainable basis. The advantage of the disturbance dynamics approach arises from forest management basically being a scheduling of disturbances of different intensity, such as timber harvesting and silvicultural operations, in space and time to meet certain production targets. Another advantage is that it encourages managers to adopt a dynamic long-term perspective on management and to explicitly consider the hierarchical nature of forest ecosystems and disturbance dynamics (Harvey et al. 2002). This approach emphasizes that biodiversity conservation and forestry cannot be considered separately. Every management action has an effect on the habitat characteristics of the forest, meaning that forest management and biodiversity conservation are inherently connected. A fundamental reason for this connection is that in most cases both forestry and biodiversity depend on the availability of the same resource, trees (Siitonen 2001). Accordingly, forest management often has to serve the twin goals of timber production and maintenance of biodiversity.

In conclusion, increased understanding of natural disturbance dynamics and its ecological role makes it feasible to develop restoration and forest management strategies that aim at ensuring the maintenance of native biodiversity (Hunter 1999, Bergeron et al. 2002, Harvey et al. 2002). The natural disturbance dynamics approach can potentially function as a conceptual "communication interface" between ecologists and forest managers, when combining biodiversity and timber production goals in forest management.

6 Remarks on the Conference Location

The geographical location of the conference site in Kuhmo, close to the Finnish-Russian border in eastern Fennoscandia, is interesting from the viewpoint of the topic of the conference. On the Finnish side, during recent decades, intensive forestry has strongly shaped the structure of forests and only fragments of the original boreal forest have been left unmanaged. On the other side of the border, in Russian Karelia, relatively large areas of mostly natural forest still prevail. This large-scale "ecological experiment" has provided interesting possibilities for research and for demonstrating the differences in structure and biodiversity between natural and managed forests in Fennoscandia. To protect the ecological uniqueness of the forests along the Finnish-Russian border, the idea of forming a Green Belt of protected areas has been presented. These last large unmanaged forests are important not only for protection of biodiversity but also for providing templates of natural variability for future forest management in Scandinavia and northwestern Russia. Because of these reasons the Friendship Park Research Center in Kuhmo has been and continues to be an important facility for boreal forest research in eastern Fennoscandia.

The theme of the conference is also closely linked with practical problems of developing methods of sustainable forest management. On the Russian side, despite protection plans, commercial pressures exist to utilize the valuable natural forest areas. The key question is how these forests should be managed to maintain their ecological integrity and biological diversity. In this respect, the situation in Russia is similar to that in Canada, where natural forests are being logged. By contrast, in the intensively managed forests of Finland, and in many parts of Scandinavia, the problem focuses more on how to restore the biological diversity of impoverished forest ecosystems.

Finally, it is noteworthy that the large forested region of Viena Karelia, located northeast of Kuhmo, has given birth to one of the treasures of world literature, the Kalevala epic. Kalevala is the Finnish national epic compiled by Elias Lönnrot (1802–1884) from ancient oral poetry. The Vienansalo wilderness area, examined from the ecological perspective in some papers of this volume, is located in the very heart of the former Kalevala poem singing area. Although the poem singing tradition has mostly vanished, the forest of the Kalevala can still be seen in many parts of the magnificent Vienansalo wilderness. In essence, the Kalevala epic reminds us of the intimate relationship between forest and human culture in the boreal zone.

It is the sincere wish of the organizers that the research results and ideas that were presented in the conference, and those that appear in the following papers, will give answers, provide tools, and inspire creative thinking for successful restoration and management of biodiversity within the circumboreal forest.

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